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*The Institute for  
Interconnecting  
and Packaging  
Electronic Circuits*

# IPC-D-325A

## Documentation Requirements for Printed Boards, Assemblies and Support Drawings

### IPC-D-325A

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

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### Standards Should:

- Show relationship to DFM & DFE
- Minimize time to market
- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feed back system on use and problems for future improvement

### Standards Should Not:

- Inhibit innovation
- Increase time-to-market
- Keep people out
- Increase cycle time
- Tell you how to make something
- Contain anything that cannot be defended with data

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*THE INSTITUTE FOR  
INTERCONNECTING  
AND PACKAGING  
ELECTRONIC CIRCUITS*

**IPC-D-325A**

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Developed by the IPC-D-325 Task Group of the Documentation and Information Committee of the Institute for Interconnecting and Packaging Electronic Circuits

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

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# Table of Contents

|                                                                          |    |                                                         |    |
|--------------------------------------------------------------------------|----|---------------------------------------------------------|----|
| <b>1.0 SCOPE</b> .....                                                   | 1  | <b>5.0 SAMPLE FIGURES AND EXAMPLES</b> .....            | 31 |
| 1.1 Purpose .....                                                        | 1  | <b>6.0 MASTER DRAWING NOTES AND CHECK LIST</b> .....    | 52 |
| 1.2 Classification .....                                                 | 1  | 6.1 Examples of Typical Notes:.....                     | 52 |
| 1.3 Interpretation “shall” .....                                         | 3  | 6.2 Master Drawing Check List.....                      | 53 |
| 1.4 Documentation Media .....                                            | 3  | <b>7.0 DESIGN OUTPUTS</b> .....                         | 54 |
| 1.5 Artwork – Generation .....                                           | 3  | 7.1 Design Verification.....                            | 54 |
| 1.6 Presentation .....                                                   | 3  | 7.2 Final Documentation Package .....                   | 54 |
| 1.7 Conflict – Military Application .....                                | 4  | 7.3 CAD System Outputs.....                             | 54 |
| 1.8 Order of Precedence.....                                             | 4  | 7.4 Data Transfer .....                                 | 54 |
| <b>2.0 APPLICABLE DOCUMENTS</b> .....                                    | 4  | 7.5 Readme File.....                                    | 54 |
| 2.1 Institute for Interconnecting and Packaging Electronic Circuits..... | 4  | <b>8.0 PRINTED BOARD ASSEMBLY DRAWINGS</b> .....        | 54 |
| 2.2 Department of Defense .....                                          | 4  | 8.1 Assembly Drawing Definition .....                   | 55 |
| 2.3 Other Documents.....                                                 | 5  | 8.2 Dash / Group Numbers .....                          | 56 |
| <b>3.0 REQUIREMENTS</b> .....                                            | 5  | 8.3 Printed Board Assembly Drawing Requirements .....   | 56 |
| 3.1 Terms and Definitions .....                                          | 5  | 8.4 Special Assembly Drawing Notes .....                | 56 |
| 3.2 Drawing Sizes and Format .....                                       | 5  | 8.5 Parts List (PL) Definition .....                    | 56 |
| 3.3 Title Block.....                                                     | 5  | 8.6 Separate Parts List.....                            | 56 |
| 3.4 Titles and Subtitles.....                                            | 5  | 8.7 Integral Parts List.....                            | 56 |
| 3.5 Sign-off Column.....                                                 | 5  | 8.8 Item (Find) Number .....                            | 57 |
| 3.6 Multiple Sheets.....                                                 | 5  | 8.9 Electrical Component Cross Reference Listing.....   | 57 |
| 3.7 Master Drawing Number/Bare Board Part Number .....                   | 5  | 8.10 Revision Level Control (RLC) Chart (Optional)..... | 57 |
| 3.8 Preliminary Release.....                                             | 5  | 8.11 Spare Component Locations Chart (Optional).....    | 57 |
| 3.9 Initial Release.....                                                 | 6  | 8.12 Cover Sheets (Optional).....                       | 57 |
| 3.10 Master Drawing Revision Level/Bare Board Revision Level .....       | 6  | 8.13 Parts Information.....                             | 59 |
| 3.11 Approvals Block.....                                                | 10 | 8.14 Non-Standard Part Information.....                 | 59 |
| 3.12 Revision Letters.....                                               | 11 | 8.15 Manufacturing Tools Chart (Optional) .....         | 59 |
| 3.13 Temporary Revision (Optional) .....                                 | 12 | 8.16 Electrostatic Sensitive Devices (ESD) .....        | 59 |
| 3.14 Updated and/or Redrawn Drawings .....                               | 12 | 8.17 Quality Conformance Coupons.....                   | 71 |
| 3.15 Contract Number .....                                               | 12 | <b>9.0 PRINTED BOARD SUPPORT DRAWINGS</b> .....         | 71 |
| 3.16 Application Block (Optional) .....                                  | 12 | 9.1 Fixtures .....                                      | 71 |
| 3.17 Commercial and Government Entity (Cage Code).....                   | 12 | <b>10.0 SCHEMATIC/LOGIC DIAGRAMS</b> .....              | 76 |
| 3.18 Distribution Key (Optional).....                                    | 12 | 10.1 Scope .....                                        | 76 |
| 3.19 Material Block (Optional).....                                      | 12 | 10.2 Definition Schematic Diagram.....                  | 76 |
| 3.20 Configuration Control .....                                         | 12 | 10.3 Reference Standards.....                           | 76 |
| 3.21 Numbering of Notes.....                                             | 13 | 10.4 Format.....                                        | 76 |
| <b>4.0 DOCUMENTATION PACKAGE</b> .....                                   | 13 | 10.5 Line Styles and Lettering.....                     | 76 |
| 4.1 Documentation and Electronic Data.....                               | 13 | 10.6 Graphic Symbols and Cell Libraries .....           | 76 |
| 4.2 Master Drawing.....                                                  | 13 | 10.7 Abbreviations and Acronyms .....                   | 76 |
| 4.3 Marking .....                                                        | 18 | 10.8 Layout.....                                        | 76 |
| 4.4 Grid Systems .....                                                   | 23 |                                                         |    |

|                   |                              |    |             |                                                                                                            |    |
|-------------------|------------------------------|----|-------------|------------------------------------------------------------------------------------------------------------|----|
| 10.9              | Connecting Lines.....        | 76 | Figure 4-3  | Electrostatic Discharge Symbol .....                                                                       | 18 |
| 10.10             | Junctions .....              | 76 | Figure 4-4  | Board Cross Section - Six Layer Construction .....                                                         | 20 |
| 10.11             | Terminals .....              | 77 | Figure 4-4A | Example of Typical Cross-Section<br>Detail, mm [in] .....                                                  | 21 |
| 10.12             | Wire Leads .....             | 77 | Figure 4-4B | Symmetrical Multilayer Printed Board<br>Cross-Section Illustrating Constraining-Core<br>Construction ..... | 21 |
| 10.13             | Interrupted Paths .....      | 77 | Figure 4-5  | Artwork Configuration Control Chart,<br>Double-Sided Board .....                                           | 22 |
| 10.14             | Mechanical Linkages.....     | 77 | Figure 4-6  | Artwork Configuration Control Chart,<br>6 Layer Board .....                                                | 22 |
| 10.15             | Connectors .....             | 77 | Figure 4-7  | Typical Hole Schedule.....                                                                                 | 23 |
| 10.16             | Numerical Values .....       | 77 | Figure 4-8  | Drill Pattern Viewed from Primary Side, Layer 1,<br>Scale 1/1.....                                         | 25 |
| 10.17             | Multi-Element Symbols .....  | 78 | Figure 4-9  | Printed Board Profile (Board Outline<br>Dimensioning), Example 1.....                                      | 26 |
| 10.18             | Functions .....              | 78 | Figure 4-9A | Printed Board Profile (Board Outline<br>Dimensioning), Example 2.....                                      | 27 |
| 10.19             | Reference Designations.....  | 78 | Figure 4-10 | Example of Quality Conformance Coupons per<br>IPC-D-275, 7.0.....                                          | 28 |
| 10.20             | Type Designations.....       | 78 | Figure 4-11 | Advantages of Positional Tolerance Over Bilateral<br>Tolerance, mm [in] .....                              | 28 |
| 10.21             | Unused Pins.....             | 79 | Figure 4-12 | Example of Location of a Pattern of Tooling<br>Mounting Holes, mm [in].....                                | 29 |
| 10.22             | Spares.....                  | 79 | Figure 4-13 | Example of Location of a Pattern of<br>Plated-Through Holes, mm [in] .....                                 | 29 |
| 10.23             | Gnd and Power Table.....     | 79 | Figure 4-14 | Example of Location of a Conductor Pattern Using<br>Fiducials, mm [in] .....                               | 30 |
| 10.24             | Notes on Schematics.....     | 79 | Figure 4-15 | Example of Printed Board Profile Location and<br>Tolerance, mm [in] .....                                  | 30 |
| 10.25             | Schematic/Logic Diagram..... | 79 | Figure 4-16 | Example of a Printed Board Drawing Utilizing<br>Geometric Dimensioning and<br>Tolerancing, mm [in] .....   | 31 |
| 10.26             | Final Schematic/Logic.....   | 79 | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 1 of 5 .....                                                   | 32 |
| <b>Appendix A</b> | .....                        | 80 | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 2 of 5 .....                                                   | 33 |
| <b>Appendix B</b> | .....                        | 82 | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 3 of 5. ....                                                   | 34 |

### Tables

|           |                                                            |    |
|-----------|------------------------------------------------------------|----|
| Table 3-1 | .....                                                      | 6  |
| Table 4-1 | Typical Master Drawing Documentation<br>Requirements ..... | 14 |
| Table 4-2 | Typical Master Drawing Detail Requirements .....           | 15 |
| Table 4-3 | Drill Size Recommendations.....                            | 24 |
| Table A-1 | Geometric Characteristic Symbols<br>and Modifiers.....     | 82 |
| Table A-2 | Abbreviations.....                                         | 82 |

### Figures

|            |                                                                                     |    |             |                                                                                                          |    |
|------------|-------------------------------------------------------------------------------------|----|-------------|----------------------------------------------------------------------------------------------------------|----|
| Figure 3-1 | Artwork Configuration Control (Option I) .....                                      | 7  | Figure 4-15 | Example of Printed Board Profile Location and<br>Tolerance, mm [in] .....                                | 30 |
| Figure 3-2 | Artwork Configuration Control (Option II).....                                      | 8  | Figure 4-16 | Example of a Printed Board Drawing Utilizing<br>Geometric Dimensioning and<br>Tolerancing, mm [in] ..... | 31 |
| Figure 3-3 | Artwork Configuration Control (Option III).....                                     | 9  | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 1 of 5 .....                                                 | 32 |
| Figure 3-4 | Title Block .....                                                                   | 10 | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 2 of 5 .....                                                 | 33 |
| Figure 3-5 | Continuation Sheet and Rev.....                                                     | 11 | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 3 of 5. ....                                                 | 34 |
| Figure 3-6 | Sign-off Column & Revision Status of Sheets.....                                    | 11 | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 4 of 5 .....                                                 | 35 |
| Figure 3-7 | Temporary Revision - Optional.....                                                  | 12 | Figure 5-1  | Typical Multilayer Master Drawing,<br>Sheet 5 of 5 .....                                                 | 36 |
| Figure 4-1 | Graphical Representation Illustrating Artwork -<br>Master Drawing Relationship..... | 16 |             |                                                                                                          |    |
| Figure 4-2 | Printed Wiring Board - Viewing .....                                                | 17 |             |                                                                                                          |    |

|             |                                                                                               |    |             |                                                                                              |    |
|-------------|-----------------------------------------------------------------------------------------------|----|-------------|----------------------------------------------------------------------------------------------|----|
| Figure 5-2  | Typical SMT Printed Board, Panelized and Routed for Break-Apart Use (Refer to IPC-D-322)..... | 37 | Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 5 of 8 .....                                    | 64 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 1 of 14.....                  | 38 | Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 6 of 8 .....                                    | 65 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 2 of 14.....                  | 39 | Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 7 of 8 .....                                    | 66 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 3 of 14.....                  | 40 | Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 8 of 8 .....                                    | 67 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 4 of 14.....                  | 41 | Figure 8-3  | Typical Through-Hole Printed Wiring Assembly Drawing, Sheet 1 of 2 .....                     | 68 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 5 of 14.....                  | 42 | Figure 8-3  | Typical Through-Hole Printed Wiring Assembly Drawing, Sheet 2 of 2 .....                     | 69 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 6 of 14.....                  | 43 | Figure 8-4  | Typical SMT Assembly with Components on Two Sides.....                                       | 70 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 7 of 14.....                  | 44 | Figure 8-5  | Electrostatic Discharge Symbol .....                                                         | 71 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 8 of 14.....                  | 45 | Figure 9-1  | Typical Backing Plate Assembly Used to Support Printed Board During Press-Fit Operation..... | 72 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 9 of 14.....                  | 46 | Figure 9-2  | Typical Printed Board Assembly Latch Mechanism.....                                          | 72 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 10 of 14.....                 | 47 | Figure 9-3  | Printed Board Assembly Illustrating Typical Front Panel and Ejector Mechanism.....           | 72 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 11 of 14.....                 | 48 | Figure 9-4  | Typical Heatsink Assembly .....                                                              | 73 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 12 of 14.....                 | 49 | Figure 9-5  | Typical Stiffener Assembly.....                                                              | 74 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 13 of 14.....                 | 50 | Figure 9-6  | Typical Heatsink Bracket .....                                                               | 75 |
| Figure 5-3  | Typical Multilayer Master Drawing with External Heatsink, Sheet 14 of 14.....                 | 51 | Figure 10-1 | Connecting Line Junctions .....                                                              | 77 |
| Figure 7-1  | Typical Readme.txt File.....                                                                  | 55 | Figure 10-2 | Switch/Relay Terminals.....                                                                  | 77 |
| Figure 8-1  | Typical Printed Wiring Assembly Drawing.....                                                  | 58 | Figure 10-3 | Wire Leaded Components .....                                                                 | 77 |
| Figure 8-1A | Typical PWB Assembly Marking Nomenclature....                                                 | 59 | Figure 10-4 | Interrupted Paths.....                                                                       | 77 |
| Figure 8-1B | Typical PWB Assembly Marking Nomenclature....                                                 | 59 | Figure 10-6 | Connectors .....                                                                             | 78 |
| Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 1 of 8 .....                                     | 60 | Figure 10-5 | Switches/Relays .....                                                                        | 78 |
| Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 2 of 8 .....                                     | 61 | Figure 10-7 | Semiconductors.....                                                                          | 78 |
| Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 3 of 8 .....                                     | 62 | Figure 10-8 | Unused Pins .....                                                                            | 79 |
| Figure 8-2  | Typical Parts List for a PWB Assembly, Sheet 4 of 8 .....                                     | 63 | Figure A-1  | Feature control frame incorporating datum references.....                                    | 82 |
|             |                                                                                               |    | Figure A-2  | Feature control frame .....                                                                  | 82 |
|             |                                                                                               |    | Figure A-3  | Order of precedence of datum references.....                                                 | 82 |

# Documentation Requirements for Printed Boards, Assemblies and Support Drawings

## 1.0 SCOPE

This standard establishes requirements and other considerations for the documentation of printed boards and printed board assemblies.

**1.1 Purpose** The purpose of this standard is to establish the general requirements for the preparation of drawings necessary to fully describe end product printed boards, printed board assemblies and related support drawings. Special emphasis is given to the technical requirements necessary to fully describe the fabrication and assembly of various types of printed boards. Regardless of material, construction, layer count, special fabrication requirements, or end product usage, the documentation package may include, but not be limited to the following:

- Master Drawing Requirements
- Specifications
- Board Definition
- Artwork/Phototooling
- Soldermask Requirements
- Master Pattern Drawing
- Production Master
- Assembly Drawing and Parts List
- Electrical Test Requirements
- Final Schematic/Logic Diagram
- Related Support Drawings
- Artwork Plot Data
- Excellon Drill Data

Refer to IPC-D-275, "Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies," regarding all subjects pertaining directly to design.

This standard may be used for both commercial and military applications. Printed boards and printed board assemblies intended for military usage **shall** be fabricated and/or assembled by a manufacturer that has been qualified to the appropriate military specification, unless otherwise agreed to contractually.

Documentation intended for military electronic equipment **shall** be so noted.

**1.1.1 Organization of Information** This standard is organized into various sections in order to provide information for the documentation of rigid printed boards and printed board assemblies.

The major sections and their specific emphasis are:

- Section 1 – Scope, Purpose and Classification
- Section 2 – Applicable Documents
- Section 3 – Documentation Requirements
- Section 4 – Documentation Package
- Section 5 – Sample Figures and Examples
- Section 6 – Master Drawing Notes and Check List
- Section 7 – Design Outputs
- Section 8 – Printed Board Assembly Drawings (Including Figures & Examples)
- Section 9 – Printed Board Support Drawings
- Section 10– Schematic / Logic Diagrams

**1.2 Classification** This standard recognizes that rigid printed boards and printed board assemblies are subject to classifications by intended end item use. Classification of producibility is related to complexity of the design and the precision required to produce the particular printed board or printed board assembly.

Any producibility level or producibility design characteristic may be applied to any end-product equipment category. Therefore, a high-reliability product designated as class "3" (see 1.2.2), could require level "A" design complexity (preferred producibility) for many of the attributes of the printed board or printed board assembly (see 1.2.3).

**1.2.1 Board Types** This standard provides design information for different board types. Board types are classified:

- 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

**1.2.2 Performance Classes** Three general end-product classes have been established to reflect progressive increases in sophistication, functional performance requirements and testing/inspection frequency. It should be recognized that there may be an overlap of equipment between classes.



The printed board user is responsible for determining the class in which his board product belongs.

#### *Class 1 — General Electronic Products*

Includes consumer products, some computer and computer peripherals, as well as general military hardware suitable for applications where cosmetic imperfections are not important and the major requirement is function of the completed printed board or printed board assembly.

#### *Class 2 — Dedicated Service Electronic Products*

Includes communications equipment, sophisticated business machines, instruments and military equipment where high performance and extended life is required, and for which uninterrupted service is desired but is not critical. Certain cosmetic imperfections are allowed.

#### *Class 3 — High Reliability Electronic Products*

Includes the equipment for commercial and military products where continued performance or performance on demand is critical. Equipment downtime cannot be tolerated, and must function when required such as for life support items, or critical weapons systems. Printed boards and printed board assemblies in this class are suitable for applications where high levels of assurance are required and service is essential.

**1.2.3 Producibility Level** When appropriate, this standard will provide three levels of design complexity: Levels A, B, and C. Included are special features, tolerances, measurements, assembly, testing of completion, and verification of the manufacturing process. Higher levels of design complexity often result in a reduction of the producibility level and, therefore, increased fabrication costs. These levels are:

Level A — General Design Complexity-Preferred

Level B — Moderate Design Complexity-Standard

Level C — High Design Complexity-Reduced Producibility

The producibility levels are not to be interpreted as a design requirement, but a method of communicating the degree of difficulty of a feature between design and fabrication/assembly facilities. The use of one level for a specific feature does not mean that other features must be of the same level. Selection should always be based on the minimum need, while recognizing that the precision, performance, conductive pattern density, assembly and testing requirements determine the design producibility level. The numbers listed within the numerous tables are to be used as a guide in determining what the level of producibility will be for any feature. The specific requirement for any feature that must be controlled on the end item **shall** be specified on the master drawing of the printed board or the printed board assembly drawing.

**1.2.4 Documentation Classification** This standard provides three classes for documentation requirements to reflect progressive increases in sophistication of the drawing package. The three classes of documentation are:

Class A — Minimal Documentation

Class B — Moderate Documentation

Class C — Full Documentation

Selection of class should be based on the minimum need, recognizing that less sophisticated classes require more coordination and communication between user and vendor. Requirements for documentation **shall** be specified in the contract order used to procure documentation, equipment or both.

**Note:** Classification of documentation requirements should not be confused with the classification of end item use, as referenced in other IPC standards and specifications which refer to: Class 1) consumer products; Class 2) general industrial; and Class 3) high reliability equipment. The need to apply documentation practices to a particular class of equipment should depend on the complexity of the interface required to produce the printed board; therefore, any documentation class may be applied to any of the end product equipment categories (classes) as required; examples: Class 2B would be industrial equipment supported by moderate documentation.

There are three classes of documentation requirements. These requirements reflect the differences in sophistication and completeness of the documentation packages. The three classes are defined as follows:

#### *Class A — Minimal Documentation*

This class of documentation is identified as minimal and consists of layout and artwork only. Class A documentation is usually used for internal use and requires a good deal of coordination between the user and manufacturer of the board. Information may be incomplete in some instances and relies heavily on in-house agreed to manufacturing processes, such as standard material, standard plating processes, standard tolerances, etc.

Documentation is suitable for the application, where the only requirement is that the manufacturer can produce a functional product from information supplied. It may include, as a minimum, the designer's layout or check plot containing manufacturing notes/instructions and single image artwork master.

#### *Class B — Moderate Documentation*

Class B documentation package consists of complete board definition, without any description of the manufacturing allowances that have been incorporated into the design. Contractual drawing requirements may apply. Quality conformance coupons may be defined by the design; their position in relationship to the board or the manufactured panel is optional.

The Class B documentation package requires sufficient clarity such that the information may be reviewed by a board manufacturer, in order to establish product producibility using the artwork or other tooling supplied. Since Class B documentation is manufacturer sensitive, responsibility for various aspects of the manufacturing cycle **shall** be agreed to between user and fabricator.

Class B documentation is specifically prepared to convey maximum information to the manufacturer and includes: a master drawing, all manufacturing notes and a single or multiple image artwork master. Performance specifications may be referenced, and contractual drawing requirements may be applied.

#### *Class C — Full Documentation*

Class C is a fully documented procurement package. Documentation is to the extent that the information is self-sufficient and may be sent to multiple vendors, with each producing the identical product. This documentation package requires that the full manufacturing allowances are disclosed and documented. Quality conformance coupons are mandatory, as required by the design, with the location illustrated on the master drawing and artwork establishing the relationship between coupons and the board.

Class C documentation includes a formal master drawing and may include a single/multiple image production master, magnetic tape, NC instructions, reference to material requirements, dielectric constant, glass style resin content, etc.; electrical test data, performance testing and sampling plan call outs. In addition, contractual drawing requirements may apply.

**1.3 Interpretation “shall”** the emphatic form of the verb, is used throughout this standard whenever a requirement is intended to express a provision that is mandatory. Deviation from a “**shall**” requirement may be considered if sufficient data is supplied to justify the exception.

The words “should” and “may” are used whenever it is necessary to express nonmandatory provisions.

“Will” is used to express a declaration of purpose.

To assist the reader, the word “**shall**” is presented in bold characters.

**1.4 Documentation Media** Two methods for developing documentation are defined in this standard.

The media are:

- Hard Copy Method
- Automated Data Method

**1.4.1 Hard Copy Documentation** Hard copy documentation may make reference to automated data for defining conductor routing paths, or hole location data. References

**shall** be by note indicating the number assigned and type of storage media containing the data.

**1.4.2 Automated Data** Automated data may make reference to material, performance or testing requirements that exist in hard copy format. References **shall** be contained in the automated data comment records. Automated data may be used to produce hard copy master drawings; however, all automated data must be complete and in user processable format.

The storage media **shall** contain a label describing the exact format, files and revisions contained within the tape or diskette. This will allow the user to immediately process all data without confusion and delay.

When automated data is requested, the media (or electronic transfer) **shall** be agreed to between user and vendor.

The preferred method for generation of CAD data is IPC-D-35X series. Refer to IPC-D-350: This standard specifies record formats used to describe printed board products with detail sufficient for tooling, manufacturing, and testing requirements. The records are also useful when the manufacturing cycle includes computer aided processes and numerically controlled machines.

Other formats however, i.e., Gerber plot data, Excellon N.C. drill, profile data, or test data may be requested. Refer to 4.3.4.

**1.5 Artwork – Generation** Most printed boards are now designed using a CAD (Computer Aided Design) System, with the ultimate objective being to generate precision artwork. This is accomplished by producing plot files which are used to drive a precision photo-plotter. The precision photo plotter is used to create the precision plotted artwork (dimensionally stable films). The plotted films may be used for the following purposes:

- Production master (used to fabricate boards). The material may be either film or glass plates, as required.
- Master pattern drawing, part of the drawing package and usually a reproduction of the original artwork (see options #1 and #2, described in 4.2.3).

**1.6 Presentation** All dimensions and tolerances in this standard are expressed in metric units with millimeters being the main form of dimensional expression. Inches may be shown in brackets as appropriate and are not always a direct conversion depending on the round-off concept or the required precision. Users are cautioned to employ a single dimensioning system, and not intermix millimeters and inches. Reference information is shown in parentheses ( ). Dimensioning should be in accordance with IPC-D-300.



**1.7 Conflict – Military Application** In the event of any conflict, the following order or precedence **shall** prevail:

1. The procurement contract.
2. The approved master drawing or assembly drawing (supplemented by an approved deviation list, if applicable).
3. This standard.
4. Other applicable documents.

**1.8 Order of Precedence** In the event of any conflict in the development of new designs, the following order or precedence **shall** prevail:

1. The procurement contract.
2. An approved master drawing or assembly drawing (supplemented by an approved deviation list, if applicable).
3. This standard.
4. Other applicable documents.

## 2.0 APPLICABLE DOCUMENTS

The following documents form a part of this standard to the extent specified herein. The revision of the document in effect at the time of solicitation **shall** take precedence.

### 2.1 Institute for Interconnecting and Packaging Electronic Circuits<sup>1</sup>

**IPC-A-22** UL Recognition Test Coupon

**IPC-T-50** Terms and Definitions for Interconnecting and Packaging Electronic Circuits

**IPC-D-275** Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies

**IPC-RB-276** Qualifications and Performance Specifications for Rigid Printed Boards.

**IPC-D-300** Printed Board Dimensions and Tolerances

**IPC-D-310** Guidelines for Phototool Generation and Measurement Techniques

**IPC-D-322** Guidelines for Selecting Printed Wiring Board Sizes.

**IPC-MC-324** Performance Specification for Metal Core Boards

**IPC-D-350** Printed Board Description in Digital Form

**IPC-D-351** Printed Board Drawings in Digital Form

**IPC-D-352** Electronic Design Data Description for Printed Boards in Digital Form

**IPC-D-354** Library Format Description for Printed Boards in Digital Form

**IPC-D-355** Printed Board Automated Assembly Description in Digital Form

**IPC-D-356** Bare Board Electrical Test Information in Digital Form

**IPC-A-600** Acceptability of Printed Boards

**IPC-A-610** Acceptability of Printed Board Assemblies

**IPC-TM-650** Test Methods Manual

2.1.1 Microsectioning

2.4.22 Bow and Twist

2.6.8 Temperature Cycling, Printed Wiring Board

**IPC-ET-652** Guidelines for Electrical Testing of Printed Wiring Boards

**IPC-SM-782** Surface Mount Design and Land Pattern Standard

**IPC-SM-840** Qualification and Performance of Permanent Polymer Coating (Solder Mask) for Printed Boards

### 2.2 Department of Defense<sup>2</sup>

#### 2.2.1 Military<sup>2</sup>

**MIL-STD-12** Abbreviations for Use on Drawings

**MIL-STD-100** Engineering Drawing Practices

**MIL-STD-130** Ident Marking of U.S. Military Property

**MIL-STD-1686** Electrostatic Discharge Control Program for Protection of Electric Equipment

**MIL-S-13949** Plastic Sheet, Laminated, Copper-Clad (for Printed Wiring)

**MIL-I-43553** Epoxy Base Ink, Type II

**MIL-G-45204** Gold Plating (Electrodeposited)

**MIL-I-46058** Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)

**MIL-HDBK-263** Electrostatic Discharge Control Handbook

#### 2.2.2 Federal<sup>2</sup>

**QQ-A-250** Aluminum and Aluminum Alloy Plate Sheet

**QQ-N-290** Nickel Plating (Electrodeposited)

1. Application for copies should be addressed to IPC, 2215 Sanders Road, Northbrook, IL 60062-6135

2. Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094; (215) 697-2667.

## QQ-S-571 Solder; Tin Alloy; Lead-Tin Alloy; and Lead Alloy

### 2.3 Other Documents

#### 2.3.1 American Society for Testing Materials (ASTM)<sup>3</sup>

**ASTM B-152** Copper Sheet, Strip Plate and Rolled Bar

#### 2.3.2 Electronic Industries Association (EIA)<sup>4</sup>

**JEDEC Publication 95** Registered and Standard Outlines for Solid State Products

#### 2.3.3 Underwriters Laboratories (UL)<sup>5</sup>

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

**UL 796** Printed Wiring Boards

#### 2.3.4 American National Standards Institute (ANSI)<sup>6</sup>

**ANSI-Y14.1** Drawing Sheet Size and Format

**ANSI-Y14.5** Dimensioning and Tolerancing

**ANSI-Y15** Electrical and Electronic Diagrams

**ANSI-Y15A** Interconnection Diagrams

**ANSI-Y15B** Supplement to ANSI Y14.15, 1966 and ANSI Y14.15a, 1970

**ANSI-Y32.1** Logic Diagram Standards

**ANSI-Y32.10** Graphic Symbols for Power Diagrams

**ANSI-Y32.2** Graphic Symbols for Electrical and Electronic Diagrams

**ANSI-Y32.16** Reference Designations

**ANSI/IEEE STD.91** Graphic Symbols for Logic Functions

**ANSI/IEEE STD.991** Logic Circuit Diagrams

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

### 3.0 REQUIREMENTS

Documentation prepared in accordance with this document **shall** meet or exceed all requirements as specified.

**3.1 Terms and Definitions** Definitions applicable to this standard **shall** conform to IPC-T-50.

**3.2 Drawing Sizes and Format** The drawing sizes and format used to prepare the master drawing **shall** be in accordance with ANSI-Y14.1. Wherever possible, standard

drawing sizes A, B, C, or D **shall** be used.

Drawing sizes E and F are not recommended. A preference is given to D size multiple sheet drawings.

When continuation sheets of the drawing are used for conductor pattern definition, they need not be prepared on standard drawing formats. Standard sheet sizes **shall** be used, with a standard continuation sheet title block located in the lower right corner of each sheet.

**3.3 Title Block** The title block **shall** contain the appropriate title of the document, the scale, the drawing number, the cage code number of the facility preparing the master drawing, if applicable, plus the appropriate approval block. On continuation sheets without revision blocks, the title block **shall** contain provisions for recording the revision (Figures 3-4 and 3-5).

**3.4 Titles and Subtitles** Titles and subtitles **shall** always be shown in uppercase letters. The names of items used as titles for drawings **shall** be brief, descriptive and of uniform definition. Titles will be comprised of a basic noun or noun phrase and **shall** include sufficient modifiers to differentiate like items in the same major assembly.

**3.5 Sign-off Column** The sign-off column, often referred to as the revision column, includes space for the following: revision, description of change, date and approval (engineer's signature) and, as an option, a zone location of the change (Figure 3-6).

Whenever engineering drawings are revised utilizing a computer or CAD equipment, signatures may be entered electronically and printed/plotted, provided that security measures are in place to safeguard signature entry; i.e., use of unique passwords.

**3.6 Multiple Sheets** When a master drawing is created using multiple sheets, the first sheet of the master drawing **shall** contain the revision status block. The purpose of the revision status block is to record the revision status of each sheet contained within the drawing. (See revision status of sheets, Figure 3-6.)

**3.7 Master Drawing Number/Bare Board Part Number** The number assigned to the master drawing describing the printed board and the part number of the "Bare Board" **shall** be the same number.

**3.8 Preliminary Release** Quite often it becomes necessary to release printed boards and associated documentation in a preliminary or prototype state. Since it is desirable

3. American Society for Testing Materials, 1916 Race Street, Philadelphia, PA 19103.

4. Application for copies should be addressed to EIA, 2001 Pennsylvania Avenue, N.W., Washington, D.C. 20006-18136).

5. Application for copies should be addressed to UL, 333 Pingston Avenue, Northbrook, IL 60062.

6. Application for copies should be addressed to ANSI, 11 W. 42nd Street, 13th Floor, New York, NY 10036-8002.

to maintain revision level control during this stage, either of the following methods are suggested (Table 3-1).

**Method #1** This method starts out with Proto Release #1 using Revision “+A” for the first release; Proto Release #2 uses Revision “+B” for the second release; Proto Release #3 uses Revision “+C” for the third release, etc.

**Method #2** This method is very similar to method number #1, except this method starts out with Proto Release #1 using Revision 1 for the first release; Proto Release #2 uses Revision 2 for the second release; Proto Release #3 uses Revision 3 for the third release, etc.

Either of the above methods will continue until such time that the board is released for production. At that time, all revisions will either be removed or raised to revision dash (—), to signify the initial production release.

**3.9 Initial Release** Initial release of a drawing does not constitute need for a revision letter and is given a dash (—) revision. The initial release is considered the first production release. A master drawing released at revision dash (—) indicates that the document has had no revisions. The first production change for any released master **shall** be Revision “A”, with subsequent and sequential letters being

used for additional revisions; i.e., Revision “B”, Revision “C”, etc., in accordance with Table 3-1 and Figure 3-6.

**Table 3-1**

| Revision Sequence     |                      |           |
|-----------------------|----------------------|-----------|
| Proto Release         | Preliminary Revision |           |
|                       | Method #1            | Method #2 |
| Proto Release #1      | +A                   | 1         |
| Proto Release #2      | +B                   | 2         |
| Proto Release #3      | +C                   | 3         |
| Proto Release #4      | +D                   | 4         |
| Initial Release       | —                    | —         |
| Production Changes    |                      |           |
| Engineering Change #1 | A                    | A         |
| Engineering Change #2 | B                    | B         |
| Engineering Change #3 | C                    | C         |

**3.10 Master Drawing Revision Level/Bare Board Revision Level** The revision level of the master drawing and the revision level of the “Bare Board” (part) **shall** always be the same revision. The “Bare Board” **shall** be marked with this revision. Items which become an integral part of the finished board (and illustrated in the following charts); i.e., silk screen artwork, solder mask artwork, solder paste stencil artwork, metal core artwork, laminated heat sinks, etc., also require revision level control. There are three generally accepted approaches to master drawing revision level control. Any of the following three Options are acceptable.

|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        |          |            |
|---------------------------------|-----------|-------|---|---|---|---|---|---|--------|--------|--------|--------|--------|----------|------------|
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | REV COL. |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | -        | INIT. REL. |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | -1       |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | A        |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | B        |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | B1       |            |
| B1                              | B         | REV   | B | B | B | B | B | B | B      | B      | B      | B      | B      | B        | B          |
| B                               | B         | REV   | B | B | B | B | B | B | B      | B      | B      | B      | B      | B        | B          |
| A                               | A         | REV   | A | A | A | A | A | A | A      | A      | A      | A      | A      | A        | A          |
| -1                              | -         | REV   | - | - | - | - | - | - | -      | -      | -      | -      | -      | -        | -          |
| -                               | -         | REV   | - | - | - | - | - | - | -      | -      | -      | -      | -      | -        | -          |
| DWG<br>REV                      | BD<br>REV | LAYER | 1 | 2 | 3 | 4 | 5 | 6 | TOP SS | BOT SS | TOP SM | BOT SM | TOP SP | BOT SP   |            |
| MASTER DRAWING REVISION CONTROL |           |       |   |   |   |   |   |   |        |        |        |        |        |          |            |

Figure 3-1 Artwork Configuration Control (Option I)

**Option I (Preferred)** Illustrating same revision level for the drawing, board and all artwork layers.

### 3.10.1 Master Drawing Revision Level – Option I

**(Preferred)** Whenever changes are made to the master drawing that does not affect tooling, form, fit or function of the “Bare Board”, the master drawing may have a numerical suffix added to the revision (ex.: -1, A1, A2, A3, etc.),

thus modifying the drawing revision without affecting the “Bare Board” revision status. This indicates that only a drawing change has been made. Option I requires that, whenever changes are made which do affect tooling, form, fit, or function, all artwork revisions must be raised to the next higher revision. Thus, all artwork revisions and the master drawing revision **shall** always be at the same revision (Option I, Figure 3-1).

|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        |          |            |
|---------------------------------|-----------|-------|---|---|---|---|---|---|--------|--------|--------|--------|--------|----------|------------|
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | REV COL. |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | -        | INIT. REL. |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | -1       |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | A        |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | B        |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | B1       |            |
| B1                              | B         | REV   | B | A | A | A | - | B | A      | A      | B      | -      | -      | -        |            |
| B                               | B         | REV   | B | A | A | A | - | B | A      | A      | B      | -      | -      | -        |            |
| A                               | A         | REV   | A | A | - | - | - | A | A      | -      | -      | -      | -      | -        |            |
| -1                              | -         | REV   | - | - | - | - | - | - | -      | -      | -      | -      | -      | -        |            |
| -                               | -         | REV   | - | - | - | - | - | - | -      | -      | -      | -      | -      | -        |            |
| DWG<br>REV                      | BD<br>REV | LAYER | 1 | 2 | 3 | 4 | 5 | 6 | TOP SS | BOT SS | TOP SM | BOT SM | TOP SP | BOT SP   |            |
| MASTER DRAWING REVISION CONTROL |           |       |   |   |   |   |   |   |        |        |        |        |        |          |            |

Figure 3-2 Artwork Configuration Control (Option II)

**Option II (Permissible)** Illustrating same revision level for the drawing and board but unique revisions for each artwork layer.

**3.10.2 Master Drawing Revision Level – Option II (Permissible)** This method is very similar to option I with the following exception: each artwork layer may receive a unique revision. Whenever changes are made to the master drawing that does not affect tooling, form, fit or function of the “Bare Board”, the master drawing may have a numerical suffix added to the revision (ex.: -1, A1, A2, A3, etc.); thereby modifying the drawing revision without affecting the “Bare Board” revision.

Option II requires that, whenever changes are made which do affect tooling, form, fit or function, only artwork layers affected by the change need be raised to the next higher revision. The revision level of the master drawing must be equal to (and the same as) the revision of the highest artwork revision (Option II, Figure 3-2).

|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        |          |            |
|---------------------------------|-----------|-------|---|---|---|---|---|---|--------|--------|--------|--------|--------|----------|------------|
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | REV COL. |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | -        | INIT. REL. |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | A        |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | B        |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | C        |            |
|                                 |           |       |   |   |   |   |   |   |        |        |        |        |        | D        |            |
| D                               | D         | REV   | D | D | D | D | D | D | D      | D      | D      | D      | D      | D        | D          |
| C                               | C         | REV   | C | C | C | C | C | C | C      | C      | C      | C      | C      | C        | C          |
| B                               | B         | REV   | B | B | B | B | B | B | B      | B      | B      | B      | B      | B        | B          |
| A                               | A         | REV   | A | A | A | A | A | A | A      | A      | A      | A      | A      | A        | A          |
| -                               | -         | REV   | - | - | - | - | - | - | -      | -      | -      | -      | -      | -        | -          |
| DWG<br>REV                      | BD<br>REV | LAYER | 1 | 2 | 3 | 4 | 5 | 6 | TOP SS | BOT SS | TOP SM | BOT SM | TOP SP | BOT SP   |            |
| MASTER DRAWING REVISION CONTROL |           |       |   |   |   |   |   |   |        |        |        |        |        |          |            |

Figure 3-3 Artwork Configuration Control (Option III)

**Option III (Permissible)** Illustrating same revision level for the drawing, board and all artwork layers.

**3.10.3 Master Drawing Revision Level - Option III (Permissible)** Whenever changes are made, regardless of the reason, the revisions of all artwork layers and the master drawing revision level **shall** be raised to the next higher revision level.

Thus, all artwork revisions and the master drawing revision **shall** always be at the same revision. Note: Option III does not use the numerical suffix numbering scheme (Option II, Figure 3-3).

BOARD PART NO. →

DRAWING NO. →

DRAWING REV →

CONTRACT NO. →

DISTRIBUTION KEY (OPTIONAL) →

PART NO. 991856-1

UNLESS OTHERWISE SPECIFIED DIMENSIONS AND TOLERANCES ARE IN INCHES AND APPLY TO THE FINISHED PART

TOLERANCE ON:

|                       |                        |                  |
|-----------------------|------------------------|------------------|
| 2 PLACE DEC<br>± .03" | 3 PLACE DEC<br>± .010" | ANGLES<br>± 1/2° |
|-----------------------|------------------------|------------------|

MAIL →

2 →

3 →

4 →

3 →

2 →

1 →

APPLICATION BLOCK (OPTIONAL)

MATERIAL BLOCK (OPTIONAL)

TITLE

SUB-TITLE

APPROVAL BLOCKS

CAGE CODE

DRAWING REV (OPTIONAL)

DRAWING NO.

formation, inc.

FORMING, INC.  
121 WHITTENDALE DRIVE  
MOORESTOWN, N.J. 08057

DTFA01-936-00039

PRINTED WIRING BOARD  
RKM CONTROLLER

991856

56776

991856

1 OF 5

Figure 3-4 Title Block

**3.11 Approvals Block** All signatures may include but not be limited to (Figure 3-4):

- Draftsman's signature and date
- Designer's signature and date
- Checker's signature and date
- QA signature and date
- Project engineer's signature and date.

The diagram shows a drawing title block with the following fields and callouts:

- APPROVAL BLOCKS (OPTIONAL)**: Points to the 'DRAWN' and 'ISSUED' fields.
- CAGE CODE**: Points to the 'CAGE CODE' field containing '56776'.
- DRAWING NO.**: Points to the 'DWG. NO.' field containing '991856'.
- DRAWING REV (OPTIONAL)**: Points to the 'REV.' field containing 'T'.

The title block also includes a 'SIZE' field with 'D', a 'SCALE' field with '1/1', and a 'SHEET' field with '2 OF 5'.

**Figure 3-5 Continuation Sheet and Rev**

The diagram shows a drawing title block with the following components and labels:

- DRAWING NUMBER:** Points to the field containing '991778'.
- DRAWING REVISION:** Points to the field containing 'SM 1'.
- REVISIONS:** Points to the table containing revision details.
- DRAWING REVISION:** Points to the 'REV' column header in the revisions table.
- ENGINEERING APPROVAL BLOCK:** Points to the table containing approval details.
- REVISION STATUS OF SHEETS:** Points to the 'REV STATUS OF SHEETS' table.

**REV STATUS OF SHEETS Table:**

| REV STATUS OF SHEETS | REV | B | B | B | B | B |   |   |   |    |  |
|----------------------|-----|---|---|---|---|---|---|---|---|----|--|
| SHEET                | 1   | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |  |
|                      |     |   |   |   |   |   |   |   |   |    |  |

**REVISIONS Table:**

| ZONE | REV | DESCRIPTION     | DATE     | APPROVED  |
|------|-----|-----------------|----------|-----------|
|      | -   | INITIAL RELEASE | 12/12/90 | E. MALITZ |
|      | A   | SEE ECP 910425  | 4/11/91  | J. LAING  |
|      | B   | SEE ECP 910508  | 5/9/91   | J. LAING  |

**ENGINEERING APPROVAL BLOCK Table:**

| DATE | APPROVED |
|------|----------|
|      |          |

**Figure 3-6 Sign-off Column & Revision Status of Sheets**

**3.12 Revision Letters** The first engineering change, considered the first production change, **shall** be assigned the letter “A”. Subsequent changes **shall** follow in sequence: “B”, “C”, “D”, etc. Uppercase letters **shall** be used in

alphabetical sequence. The letters “I”, “O”, “Q”, “S”, “X”, and “Z” **shall** be omitted. When revisions are numerous enough to exhaust the alphabet, the revision following “Y” **shall** be “AA”, and the next “AB”, then

|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |                                                                                                                      |  |  |  |  |  |  |  |  |  |
|----------------------|--|--|--|--|--|--|--|--|--|----------------------|--|--|--|--|--|--|--|--|--|----------------------------------------------------------------------------------------------------------------------|--|--|--|--|--|--|--|--|--|
| 3                    |  |  |  |  |  |  |  |  |  | Dwg. No 991799       |  |  |  |  |  |  |  |  |  | 1                                                                                                                    |  |  |  |  |  |  |  |  |  |
| REV STATUS OF SHEETS |  |  |  |  |  |  |  |  |  | REV                  |  |  |  |  |  |  |  |  |  | REVISIONS                                                                                                            |  |  |  |  |  |  |  |  |  |
| SHEET                |  |  |  |  |  |  |  |  |  | 1 2 3 4 5 6 7 8 9 10 |  |  |  |  |  |  |  |  |  | ZONE REV DESCRIPTION DATE APPROVED                                                                                   |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | -                                                                                                                    |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | INITIAL RELEASE                                                                                                      |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | 12/21/90 E. MALITZ                                                                                                   |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | TEMPORARY REV OF THIS BOARD IS REV A. THIS DWG WILL BE REVISED AND REDRAWN WHEN ARTWORK IS REPLOTTED. PER ECP 910223 |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | 2/18/91 T.C. WANG                                                                                                    |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | TEMPORARY REV OF THIS BOARD IS REV B. THIS DWG WILL BE REVISED AND REDRAWN WHEN ARTWORK IS REPLOTTED. PER ECP 910312 |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | 3/14/91 T.C. WANG                                                                                                    |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | B ARTWORK REPLOTTED AND RELEASED FOR PRODUCTION AT REV B PER ECP 910312                                              |  |  |  |  |  |  |  |  |  |
|                      |  |  |  |  |  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  | 4/19/91 T.C. WANG                                                                                                    |  |  |  |  |  |  |  |  |  |

Figure 3-7 Temporary Revision – Optional

“AC”, etc. Should “AA” to “AY” be exhausted, the next sequence **shall** be “BA”, “BB”, etc.

**3.13 Temporary Revision (Optional)** Occasionally, it may be desirable to update documentation without replottting artwork. This usually occurs when existing boards are updated by rework (cut lines and added wires). The revision of the reworked boards is changed by remarking the boards with the next higher revision letter. The sign-off column (revision column) of the master drawing is updated by adding the following notation:

“Temporary rev. of this board is rev. A (or the next higher rev.). This drawing will be revised and redrawn when artwork is replotted”. Per ECP #XXXXXX or ECO #XXXXXX.

This scheme may be repeated, if necessary. This procedure allows the drawing to be updated and released and at the same time maintain revision level control. Another advantage is that the artwork may be replotted at some latter date or when convenient, without writing another Engineering Change Proposal (ECP) or Engineering Change Notice (ECN). The drawing will, however, need to be redrawn (or replotted) and reissued (Figure 3-7).

**3.14 Updated and/or Redrawn Drawings** When a drawing is redrawn or replotted on a new format, the original names and dates must be maintained; however, only the latest revision requires the engineer’s signature and date. When historical files are maintained, only the latest revision need be recorded on the drawing.

**3.15 Contract Number** The contract number or purchase order number, when applicable, **shall** be entered in the appropriate contract number block (Figure 3-4).

**3.16 Application Block (Optional)** The application block is divided into two parts: “Next Assembly” and “used on”. The drawing number of each next higher assembly is entered in the next higher assembly block. The project name, model number or other designation assigned to the program or equipment, is entered in the “used on” block. The application block may be expanded to accommodate additional information (Figure 3-4).

### 3.17 Commercial and Government Entity (Cage Code)

The cage code **shall** always be the cage code of the design activity whose drawing number is assigned to the drawing and **shall** be entered on the drawing in the appropriate block (Figure 3-4).

**3.18 Distribution Key (Optional)** Quite often, distribution of drawings is controlled by assigning a specific “key” which controls distribution of drawings to specific recipients. This key may be placed in a small block located in the lower right-hand corner and directly above the title block (Figure 3-4).

**3.19 Material Block (Optional)** The material block may have numbers (enclosed inside of a square or flag) corresponding to the appropriate note(s) which specifies material requirements (Figure 3-4).

**3.20 Configuration Control** The master drawing **shall** document the following information: The number of artwork layers, applicable drawing numbers assigned to the layers, individual file numbers (when applicable) and revision levels of the individual layers. Additionally, include other artwork file numbers and their revisions; i.e., solder mask artwork, silk screen artwork and solder paste stencil artwork, when applicable. Test data and revision including file numbers; numerical control data and revision including

file numbers; laminated heat sinks and revision; copper-invar-copper constraining core revision **shall** be listed and controlled (4.3.6).

**3.20.1 PWB Updates** Once Drawings have been created and released, and as subsequent design changes are incorporated, the designer must remain fully cognizant of the impact and ripple effect to other associated Drawings and documentation. Especially important is the “mandatory requirement and obligation” of updating all associated drawing revisions. A Printed Wiring Board requiring a change **shall** be updated by raising the revisions of the following: the master drawing, including revisions of all cognizant artwork; the “bare board marking revision”; solder paste stencil artwork; metal core artwork; laminated heat sinks, etc. An update to a PWB is permissible, provided the following criteria is met: the change **shall** not affect form (shape), fit (dimensional size) and function (electrical characteristics). Refer to 3.10 through 3.10.3.

General Rule: The updated PWB must be a direct replacement for the previous revision board. Quite often, the previous revision PWB must be reworked and made equal to the new revision board.

**3.20.2 Re-identified Board (Re-ident)** Whenever a printed board requires a change which does affect the form, fit or function, the board must be re-identified and given a new identity.

This obviously will require the designer to create new documentation for the new (re-identified) board. The reason is that the new board is physically or functionally different than the old board and is not a direct replacement for the old board. The revisions in this situation must be treated the same as an initial release; therefore, the documentation, artwork and board revisions are assigned a dash (—) revision.

**3.21 Numbering of Notes** All notes **shall** be numbered. Those notes which are referenced elsewhere on the drawing, **shall** be enclosed in a square or flag. The corresponding reference number(s) delineated elsewhere on the drawing **shall** also be enclosed in a square or flag.

#### 4.0 DOCUMENTATION PACKAGE

Information contained in this section outlines requirements to be considered when developing the documentation package needed to fully describe the construction and performance of printed boards.

**4.1 Documentation and Electronic Data** The printed board documentation package generally consists of the master drawing, master pattern drawing or reproductions of the artwork masters (film or paper), printed board assembly drawing, parts list, numerical control (NC) data for drilling,

profile routing data, library data, test data (bare board and functional), component placement data, and artwork plot data.

**Note:** Electronic data may be supplied, in lieu of reproductions (as noted above), prepared in accordance with IPC-D-350 format (preferred), or other standard industry formats. Information may be supplied on magnetic media (magnetic tape or diskettes) or, when convenient, data may be transmitted over transmission lines (7.4 and 7.5).

**4.1.1 Computer Aided Design (CAD Output)** All CAD system output data **shall** meet the requirements of IPC-D-35X series format and/or other industry acceptable standard formats.

**4.1.2 Documentation Requirements** All documentation **shall** meet the requirements of this specification. When required by contract, documentation for Class 3 military assemblies **shall** also meet the requirements of DOD-STD-100.

**4.2 Master Drawing** The master drawing **shall** be prepared in accordance with the requirements of this specification.

During the design review, the class (1, 2, or 3) of documentation **shall** be considered, as shown in Table 4-1.

Typical master drawing documentation requirements are shown in Table 4-2.

The master drawing describes all details needed to fabricate the printed board and may include the following:

- Design Requirements
- Board Details Including Construction
- Materials and Process Specification
- Conductor Definition
- Minimum Spacing Requirements
- Artwork Configuration Control Chart
- Fabrication Allowances
- Solder Mask Requirements
- Marking Requirements (Traceability)
- Silk Screen Requirements
- Bow and Twist Requirements
- Test Coupon Requirements
- Electrical Test Requirements
- Performance Requirements
- Master Pattern Drawing
- Computer Aided Design (CAD) Reference Data

Table 4-1 Typical Master Drawing Documentation Requirements

| Class 1                                                                                                                                                                                                                                  | Class 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Class 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The engineering printed board layout or check plot <b>shall</b> serve as the master drawing and be supplemented with manufacturing instructions and other pertinent notes to provide the necessary information to manufacture the board. | The master drawing <b>shall</b> describe the physical board details, if etchback is required, the location of traceability markings, and provide separate views of each conductor layer of the printed board. Any and all pattern features not controlled by hole size and locations <b>shall</b> be adequately dimensioned either specifically, by notes, or by reference to a grid system used in the design of the boards. The plating and coating thickness <b>shall</b> be specified. Quality conformance test circuitry may also be included on the master drawing, when required. The information in Table 4-2 may be used as a guide. | The master drawing <b>shall</b> describe the board in accordance with Table 4-2. Quality conformance test circuitry in accordance with the design standard <b>shall</b> be included. Test circuitry <b>shall</b> reflect the design of the boards and all manufacturing processes, such as drilling, plating, etching, fusing, ground/voltage planes, separate fabricated layers, permanent coatings (solder mask) etc. The master drawing <b>shall</b> also indicate the process allowances that were used in the design or artwork preparation of the printed board. The master pattern drawing, part of the master drawing set, may be supplied using one of the following methods: reproductions of the layer image(s) reproduced using photographic techniques or pen plotted; or supplied as electronic data. Any and all pattern features not controlled by hole sizes and locations <b>shall</b> be adequately dimensioned either specifically, by note, or by reference to a grid system used in the design of the boards. |

- Numerical Control Reference Data
- A graphical representation illustrating the Artwork to Master Drawing relationship is illustrated in Figure 4-1. The purpose of this diagram is to illustrate the correlation between the original photoplotted Artwork, Master Drawing, Master Pattern Drawing and Production Master (4.2, 4.2.1, 4.2.2, and 4.2.3).

#### 4.2.1 Artwork Master (Original Photoplot Master)

Original precision artwork is usually generated by photoplotting, using a vector or laser photoplotter. Refer to IPC-D-310.

The artwork **shall** contain as a minimum, the following information:

- Board part number and revision.
- Layer number (Figure 4-2).
- For composite printed boards, a complete set of quality conformance coupons is required for the top board, the bottom board and the composite board.
- Three registration targets (or moires) **shall** be located on grid and on each layer of artwork. Each additional layer or artwork **shall** have registration targets located at the same points which, **shall** register with each other, layer to layer.
- Marking or silkscreen artwork (when required) **shall** have a minimum of two alignment targets to coincide with the center line or features located on the board surface to be marked.
- Component pedestal artwork (when required) **shall** have

a minimum of two alignment targets to coincide with the center line of features located on the board surface.

G. Special tooling artwork: During the formal design review and prior to layout, special tooling requirements which can be generated during design should be considered (IPC-D-275, 3.2.7).

**4.2.2 Production Master** When specified in the contract or purchase order, a production master film of each layer **shall** be provided as part of the drawing set. When a production master is not provided as part of the drawing set, the fabricator **shall** have responsibility for creating the production master film set, the accuracy of which **shall** meet the requirements of the master drawing.

Quite often, the fabricator is supplied with data from which he must produce the production master film set. These precision films are created by photoplotting. The data is often electronically transmitted or supplied on magnetic media; i.e., mag tape or diskettes.

When production masters are supplied as a supplement to the engineering documentation package, they **shall** be supplied as readily usable 1:1 precision masters. Production masters may be single or multiple image artwork.

**4.2.3 Master Pattern Drawing** The master pattern drawing (Figure 4-1), part of the master drawing set, may be supplied using one of the following options:

**Option #1:** A reproduction of the original artwork or data base prepared on a drawing format. The master pattern layer image(s) may be reproduced using photographic techniques or pen plotted, when practical. All layers of artwork

Table 4-2 Typical Master Drawing Detail Requirements

| Characteristics          | Requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A. Board Details         | <ol style="list-style-type: none"> <li>1. The type, size and shape of the printed board and all tolerance conditions thereof.</li> <li>2. Dielectric separation between layers.</li> <li>3. Bow and twist allowances.</li> <li>4. Overall board thickness requirements including tolerances.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| B. Materials             | <ol style="list-style-type: none"> <li>1. Type class and grade of material, including color if applicable.</li> <li>2. Plating and coating material(s) type and thickness(es).</li> <li>3. Marking inks or paint and permanency.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| C. Hole Details          | <ol style="list-style-type: none"> <li>1. The size, location and tolerances for all holes.</li> <li>2. The plating requirements for all holes.</li> <li>3. The hole cleaning requirements including if etchback is required or permitted.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| D. Conductor Definition  | <ol style="list-style-type: none"> <li>1. Shape and arrangement of both conductor and non-conductor patterns on each layer of the printed board. (Paper or film copies of the production master(s) or copies of artwork may be used to define these patterns.)</li> <li>2. Electronic data may be supplied, in lieu of reproductions (as noted above), refer to Table 4-1, Figure 4-1, and 4.2.3.</li> <li>3. Conductor width and spacing on the finished printed board.</li> <li>4. Dimensions and tolerances for critical pattern features which may affect circuit performance.</li> <li>5. Conductor layer identification starting with the primary side, the next conductive layer <b>shall</b> be Layer 2. (For assemblies with components on both sides the most complex or densely populated side <b>shall</b> be Layer 1.)</li> </ol> |
| E. Marking               | <ol style="list-style-type: none"> <li>1. Printed board identification marking.</li> <li>2. Layer identification - revision (optional).</li> <li>3. Size, shape and location of reference designation and legend marking, if required.</li> <li>4. Traceability marking and/or date code and serial number (when required).</li> <li>5. Location and size requirements for fabricator's I.D., UL, ESD marking and cage code.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                        |
| F. Processing Conditions | <ol style="list-style-type: none"> <li>1. Processing allowances that were used in the design of the printed board, including but not limited to: <ol style="list-style-type: none"> <li>a. Conductor width allowance</li> <li>b. Conductor spacing allowance</li> <li>c. Land/hole fabrication allowance</li> <li>d. Solder mask or cover layer registration allowance</li> </ol> </li> <li>2. Applicable processing specifications.</li> <li>3. Location of quality conformance coupons or circuitry.</li> </ol>                                                                                                                                                                                                                                                                                                                              |
| G. Design Concepts       | <ol style="list-style-type: none"> <li>1. Maximum rated voltage (maximum voltage between two non-connected adjacent conductors with the greatest potential difference).</li> <li>2. Identification of testing and test point locations (when applicable).</li> <li>3. Modular grid system(s) used: <ol style="list-style-type: none"> <li>a. Metric grid - 2.0, 1.0, 0.5 or multiples of 0.1 mm</li> <li>b. Inch based grid - 0.100, 0.050, 0.025 or multiples of 0.005 inches</li> </ol> </li> </ol>                                                                                                                                                                                                                                                                                                                                          |
| H. Documentation         | <ol style="list-style-type: none"> <li>1. Terms used on the master drawing <b>shall</b> conform to this standard and IPC-T-50.</li> <li>2. Notes either included on the first sheet(s) or location of notes specified on the first sheet(s)</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

including solder masks(s), silk screen(s), laminated heat sinks and solder paste stencil(s), when applicable, **shall** be illustrated; more than one artwork layer may be arranged on one drawing sheet.

**Option #2:** Electronic data may be supplied, in lieu of reproductions (as noted above), prepared in accordance with IPC-D-350 Format (preferred), or other standard industry formats.

**4.2.4 Notes, Placement** The placement of notes on the master drawing **shall** be on the first sheet and located in the upper left-hand corner. The width of the note column should not exceed a width of 6 to 8 inches. Notes which apply to a multiple sheet drawing should always begin on the first sheet. Notes should always be:

- Clear and concise
- Written in the present tense
- Carefully composed to convey one message: capable of only one interpretation

**4.2.5 Board Construction / Cross Sectional View** The master drawing **shall** have a cross sectional view showing the construction and lay-up of the board. The cross sectional view may be drawn as an exploded view and should include: The core thicknesses and tolerances; prepreg and tolerances; constraining core and construction, (when required) including thickness and tolerance; individual layer locations; solder mask information (top and bottom, when required); silk screen information (top and bottom, when required); primary and secondary (top and bottom),

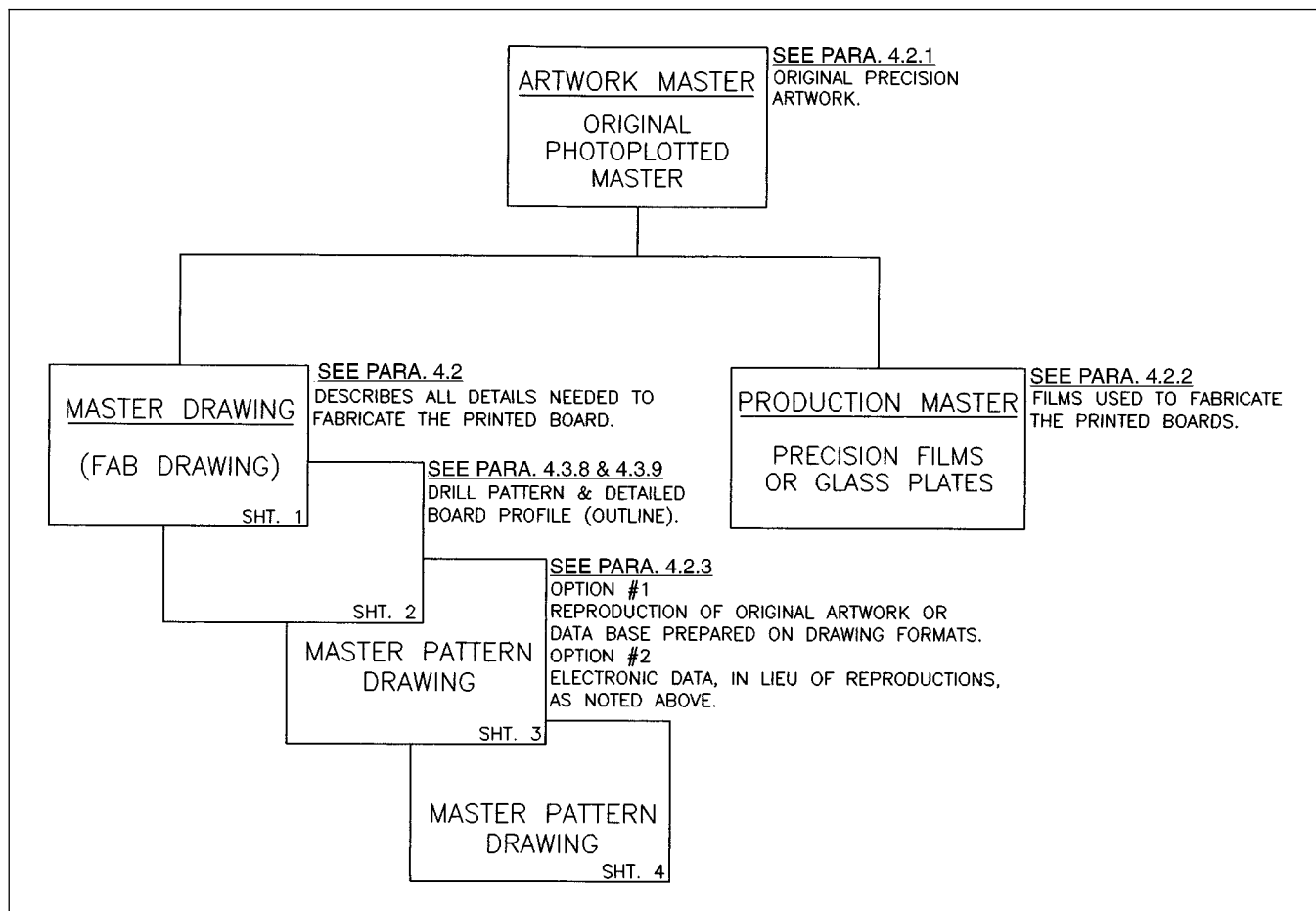


Figure 4-1 Graphical Representation Illustrating Artwork - Master Drawing Relationship

identification plus an overall dimension including tolerance. Refer to Figures 4-4, 4-4a and 4-4b for typical examples.

**4.2.6 Viewing** The layout or board design should always be viewed from the primary side of the board. When generating phototools, viewing should also be from the primary side and coincident with the board design (IPC-D-310). Unless otherwise specified, conductor layers **shall** be numbered consecutively, starting with the primary (component) side as layer 1, as shown in Figure 4-2. For those assemblies having components located on both sides, consider the side with greatest number of components as the primary side. When viewing the board from the primary side, any legend on the bottom layer (secondary side) will normally be mirror imaged. When board types 4, 5, and 6 are constructed as two separate printed boards and laminated to a substrate, the layers of each of the paired boards are to be numbered as illustrated in Figure 4-2.

**4.2.7 Accuracy and Scale** The accuracy and scale of the design layout or check plot must show sufficient detail to eliminate inaccuracies in interpretation during the artwork generation process. Obviously, when CAD equipment is

used during design, inaccuracies and ambiguities are usually minimal. Whenever practical, the design layout should be drawn or plotted at a 1:1 scale.

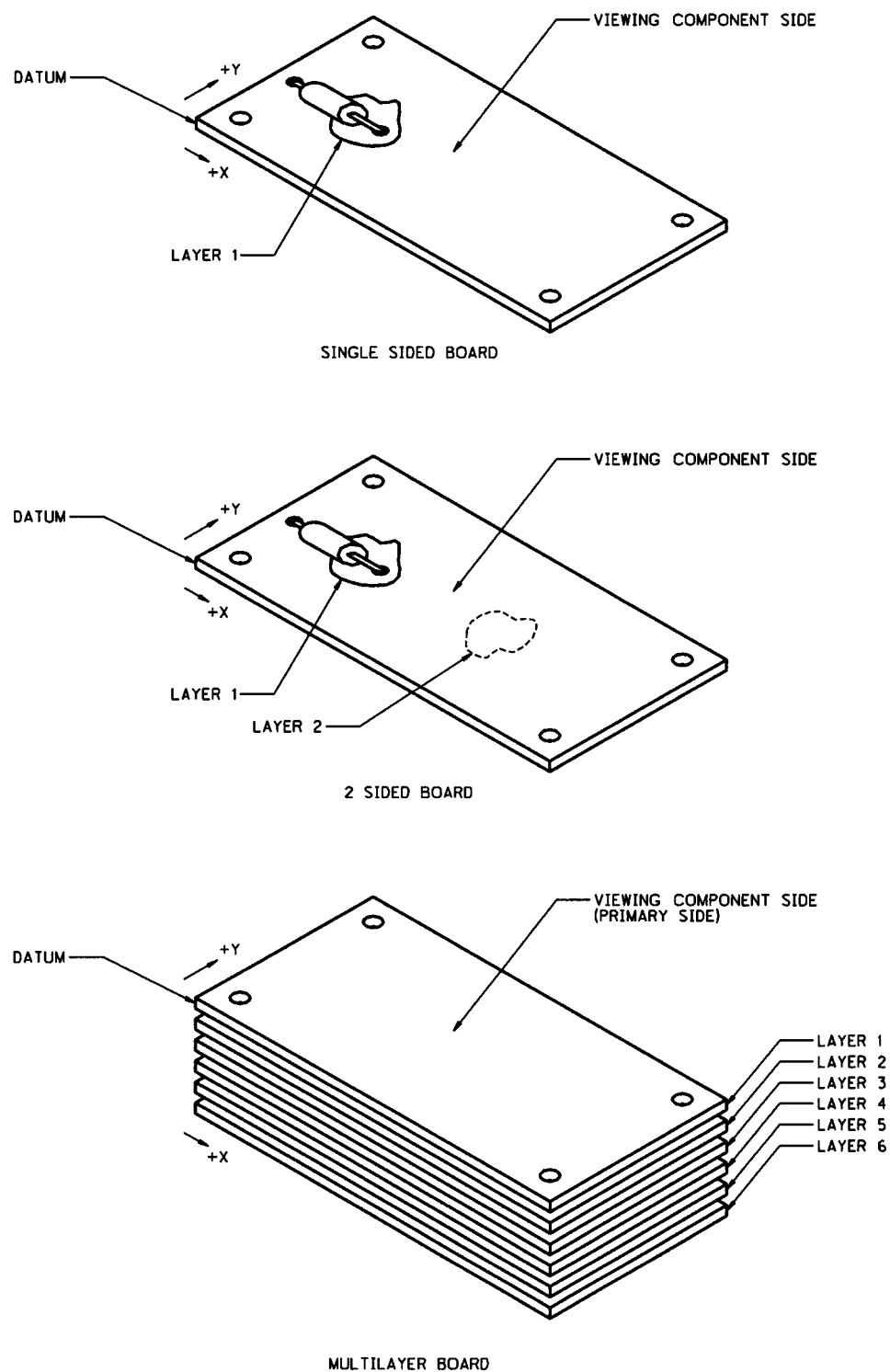
#### 4.2.8 Multilayer Boards with Blind and/or Buried Vias

The location of blind and/or buried vias **shall** be identified for each layer pair and should be illustrated on the drawing. When controlled depth drilling is used to create blind vias (usually filled with solder), the drill depth from top or bottom must be included in the separate drill list data. Blind and/or buried vias may be illustrated on the drawing using the artwork and/or may be imbedded in the electronic data. Quite often, a cross-sectional view is used to illustrate the following: The corresponding layer pairs, blind vias, buried vias and through-holes.

Separate drill files are needed for each of the following:

- blind or controlled depth drill files (top or bottom)
- blind hole drill files associated with layer pairs
- buried hole drill files associated with layer pairs
- through-hole drill file ° °

**4.2.9 Constraining Core Printed Boards** When creating documentation illustrating constraining core printed boards



NOTE: FOR THOSE PRINTED BOARD ASSEMBLIES THAT HAVE COMPONENTS ON BOTH SIDES, EITHER SIDE MAY BE DESIGNATED AS THE PRIMARY SIDE AND IS USED TO DEFINE LAYER 1.

Figure 4-2 Printed Wiring Board - Viewing

(Figure 4-4b), the following parameters **shall** be considered: Substrate drawings, illustrating constraining core construction, must use the same coordinate zero feature location as the printed board(s). The following information should be included: clearance holes required for the top-to-bottom plated through-hole interconnects, profile dimensioning, thickness(es), materials used, processing requirements and coupon clearance holes. The coupon **shall** be designed in accordance with IPC-D-275, Section 7.0. Holes which connect with the inner planes should be identified on the drawing as reference information.

When separate printed boards are laminated to a substrate, the designer must consider the documentation requirements needed to fully illustrate each board. Separate drawings may be developed for each board, or a single composite drawing may be used.

The location of blind and buried vias **shall** be identified for each layer pair and should be illustrated on the drawing. When controlled depth drilling is used to create blind vias, the drill depth from top or bottom must be included in the separate drill list data. Blind and/or buried vias may be illustrated on the drawing using the artwork and/or may be imbedded in the electronic data. Quite often, a cross sectional view is used to illustrate the following: The constraining core, the corresponding layer pairs, blind vias, buried vias and through-holes.

Separate drill files are needed for each of the following:

- blind or controlled depth drill files (top or bottom)
- blind hole drill files associated with layer pairs
- buried hole drill files associated with layer pairs
- through-hole drill file

### 4.3 Marking

**4.3.1 Marking and Legends** When specified on the master drawing, boards and assemblies **shall** be marked by appropriate inks, labels, etched characters, or other permanent methods. Marking should be used to provide reference designators, part or serial numbers, revision level, orientation or polarization symbols, bar codes, electrostatic discharge (ESD) symbol, etc. Markings should not be located under components or in locations which will be hidden after final assembly or installation. Avoid locating markings on conductive surfaces (whenever possible). Markings should not be placed on surfaces covered with melting metals. Markings should always be legible and of contrasting color.

Whenever practical, fixed format information such as part number, revision level, layer number, and orientation symbols should be incorporated in the artwork master and be considered during printed board layout and design. Coupons should include this same information. Variable format

information, such as serial numbers, fabricator information, date codes, etc., should be placed in an appropriate area utilizing permanent nonconductive, non-nutrient and high contrast inks, labels, laser scribes, or other means, with sufficient durability to survive assembly and cleaning. If a conductive marking ink is used, it **shall** be permanent and appropriately isolated by spacing or coating from the balance of the circuitry.

Markings **shall** be of sufficient size, clarity, and location to allow legibility during processing, inspection, storage, installation, and field repair of a board or assembly. Usually, a minimum character height of 1.5 mm [0.060 in] with a line width of 0.3 mm [0.012 in] is adequate. Every attempt should be made to provide enough space for the marking. It is recommended that space be reserved, when component placement is determined, per IPC-D-275, 4.1.1. Avoid the use of marking inks in close proximity to surfaces which are to be soldered; resin systems used in these inks may impair solderability.

The master drawing **shall** specifically indicate the location for the date code, fabricator's I.D. and UL marking, fabricator's cage code, ESD symbol and all other required traceability markings; i.e., serial number marking.

**4.3.2 Electrostatic Discharge (ESD) Marking** ESD, military or Underwriters Laboratories requirements may include special marking considerations which **shall** become a part of the master drawing. When electrostatic (ESD) sensitive components are used on a printed wiring board assembly, the (ESD) symbol may be marked or screened, using a permanent ink or label, able to withstand assembly processing or etched in copper and may be part of the artwork (Figure 4-3).

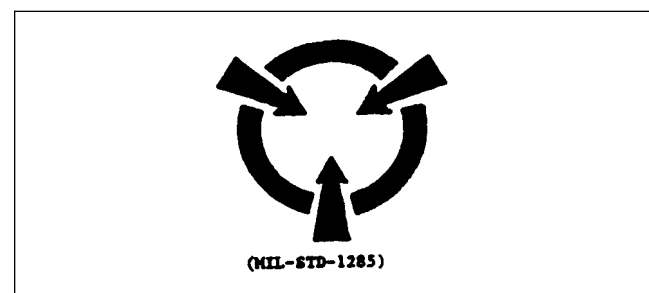


Figure 4-3 Electrostatic Discharge Symbol

Refer to 8.16 through 8.16.3 on printed board assembly documentation for additional information pertaining to electrostatic discharge (ESD) requirements.

**4.3.3 Manual Layout** Manual layouts should be completed with appropriate notations, marking requirements, and revision level definition. It is necessary to structure this information such that there can be no misunderstanding by anyone viewing the layout. Notes are especially important

during the engineering review cycle, the digitizing effort, and whenever the document is to be used by someone other than the originator.

**4.3.4 Computer Aided Design (CAD) Systems** When computer aided design (CAD) systems are used in the design process, software is used to accomplish some of the tasks which were formerly done manually. These tasks include defining components and the foot prints, automated placement of components, definition of layers, automated routing of conductors, design rules checking, and generation of check plots, etc.

Automated systems, such as CAD equipment, computer aided engineering (CAE) equipment, computer aided manufacturing (CAM) equipment, test equipment, photoplotters, automated assembly equipment (auto insertion and/or pick and place equipment, automated optical inspection (AOI) equipment, must communicate with each other. It is recommended that standard industry formats be used when communicating this data between systems.

The IPC-D-35X series of documents and record formats have been developed to serve as a standard format used to facilitate the interchange or electronic transfer of "Printed Board Description in Digital Form," between CAD systems and other facilities.

Electronic transfer and/or delivery of computer generated data (as part of the documentation package) should meet the requirements of IPC-D-35X series of standards. Archived data should be in accordance with IPC-D-350, IPC-D-351, IPC-D-352, IPC-D-353, IPC-D-355, IPC-D-356, etc.

When using computer aided design (CAD) equipment, the database should include, in complete detail, all information needed to produce the printed board. This information should include all notes, board details including construction and lay-up, materials and process specifications, hole details, conductor definition, minimum spacing requirements, fabrication allowances, solder mask requirements, marking requirements, silk screen requirements, bow and twist requirements, test coupon requirements, electrical test requirements, performance requirements, numerical control reference data, etc.

The use of check plots is important in helping to verify that the data base matches the requirements of design.

**4.3.5 Artwork Measurements** Generation of artwork and measurement techniques **shall** be in accordance with the requirements of IPC-D-310.

The appropriate artwork tolerances and processing allowances **shall** be incorporated into the production of the phototool. Single-image masters, as well as multiple image masters may be provided as part of the documentation

and/or data package. Artwork may be produced on film or photographic glass plate media as required.

IPC-D-310 specifies the dimensional changes resulting due to changes in temperature and humidity on each of these products.

**Note:** Modern laser photoplotters have the ability to produce precision artwork within exceptional limits. Typical precision laser plotting accuracy exceeds:

|                          |            |
|--------------------------|------------|
| • Image Tolerance:       | +/-0.0005" |
| • Line Width Tolerance:  | +/-0.0005" |
| • Feature Repeatability: | +/-0.0003" |
| • Accuracy (Overall):    | +/-0.001"  |

Quality conformance coupons should be incorporated into the artwork. Coupons may be added by the design group or the board fabricator.

**4.3.6 Artwork Configuration Control Chart** It is suggested that the master drawing have an artwork configuration control chart (refer to Figures 4-5 and 4-6). The purpose of this chart is to organize, identify and control the revision levels of: the individual artwork layers; solder mask artwork and revision levels; silk screen artwork and revision levels; solder paste stencil artwork and revision levels; N.C. board drill data and revision levels; N.C. drill data and revisions for backing plate, and/or internal and external heat sinks (when applicable); N.C. routing data and revision level (when applicable); bare board test data and revision level; plus drawing number(s) assigned to the individual artwork layers and data files.

The column identified with "Rev. Level" summarizes the revision(s) of each individual corresponding artwork layer and data file(s).

The column identified with CU. WT. oz. identifies the copper weight specified for each individual layer. The last column, identified with "Nom. Finished Line Width," specifies the nominal finished line (conductor) width for each corresponding artwork layer.

**Note:** Occasionally, more than one line (conductor) width may be used on one layer. In those cases, a double entry may appear in the column titled "NOM. Finished Line Width"; Example: 0.007" / 0.010"; ground planes and voltage planes do not require an entry in this column.

A backing plate is a tool used with press-fit connectors (Figure 9-1.)

**4.3.7 Hole Schedule** It is suggested that the master drawing **shall** have a chart titled "Hole Schedule" (Figure 4-7).

The purpose of the hole schedule is to identify, by use of symbols, the various hole diameters used on the board. Diameters specified for plated holes are considered finished diameter(s) after all required platings and treatments (such as solder fusion).

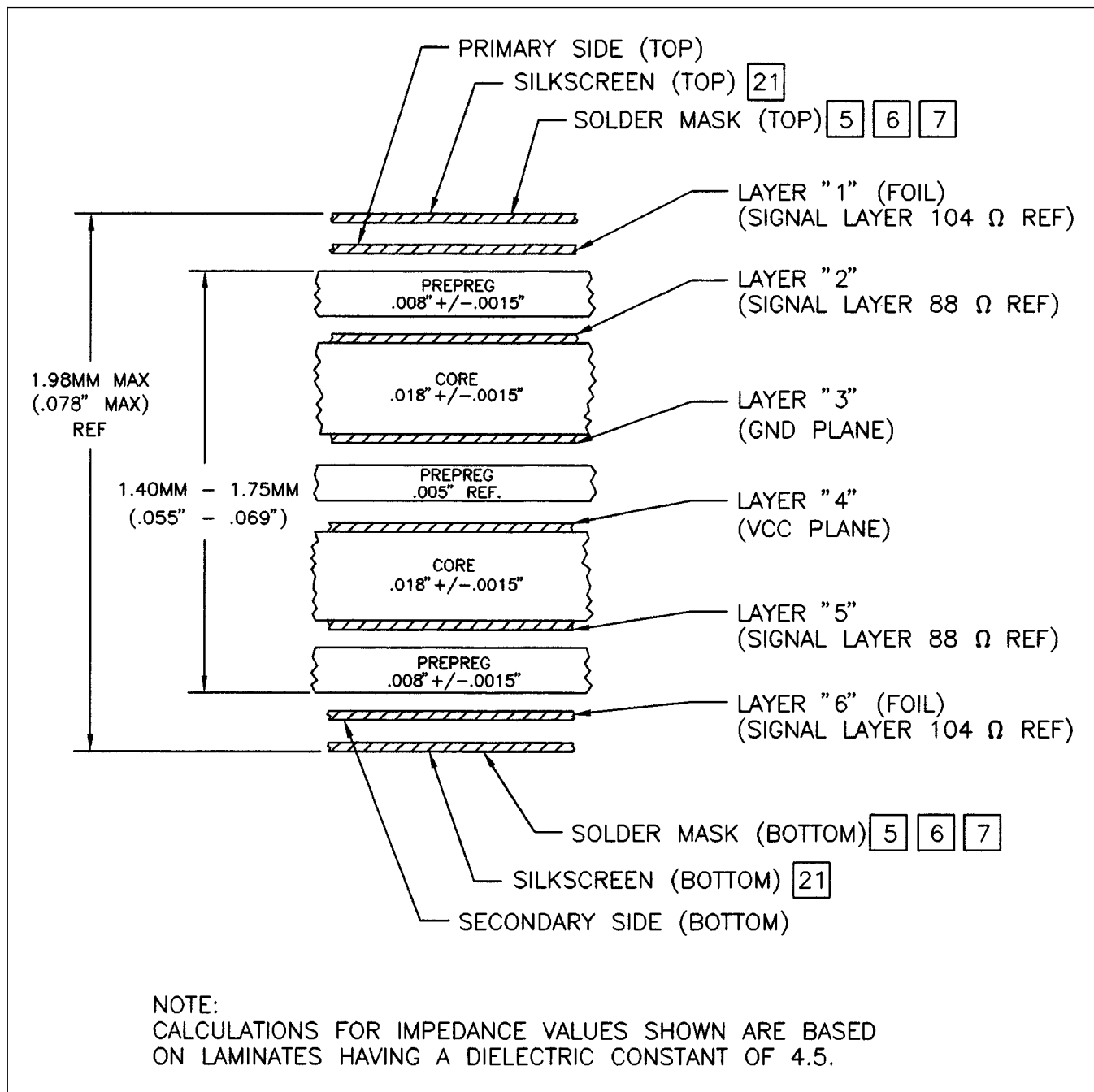


Figure 4-4 Board Cross Section - Six Layer Construction

Each unique hole diameter **shall** be assigned a separate drill legend symbol and code letter (optional) for reference. The drill legend **shall** also correspond with the plotted "Drill Pattern" illustrating all drill locations. Special and critical hole locations; i.e., holes used in conjunction with datums, tooling holes, mounting holes, stiffener holes, etc., may be dimensioned on the drill pattern (part of the master drawing). Locations and identity of all other holes (not dimensioned) may be illustrated with use of symbols. These holes must correspond with the symbols assigned in the drill legend column.

Every drilled hole must be identified (by symbol) and must contain the following information in the hole schedule: diameter, tolerance, plating requirements, (plated or non-plated). Additional information may identify tooling holes, tented holes or plugged holes. Another method of expressing the hole diameter tolerance is to show both the upper and lower diameter limits, refer to IPC-D-300.

**4.3.8 Drill Pattern** The drill pattern may be included as part of the master drawing (Figure 4-8). It may be a pen

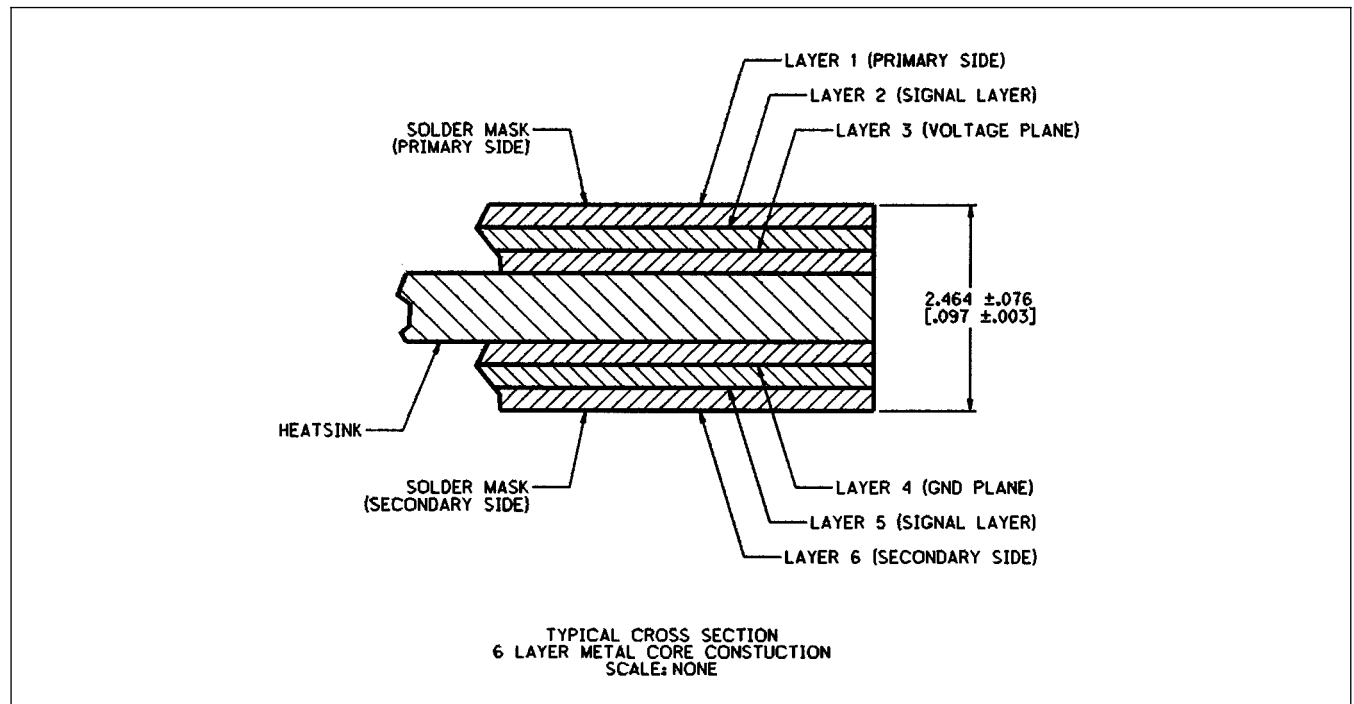


Figure 4-4A Example of Typical Cross-Section Detail, mm [in]

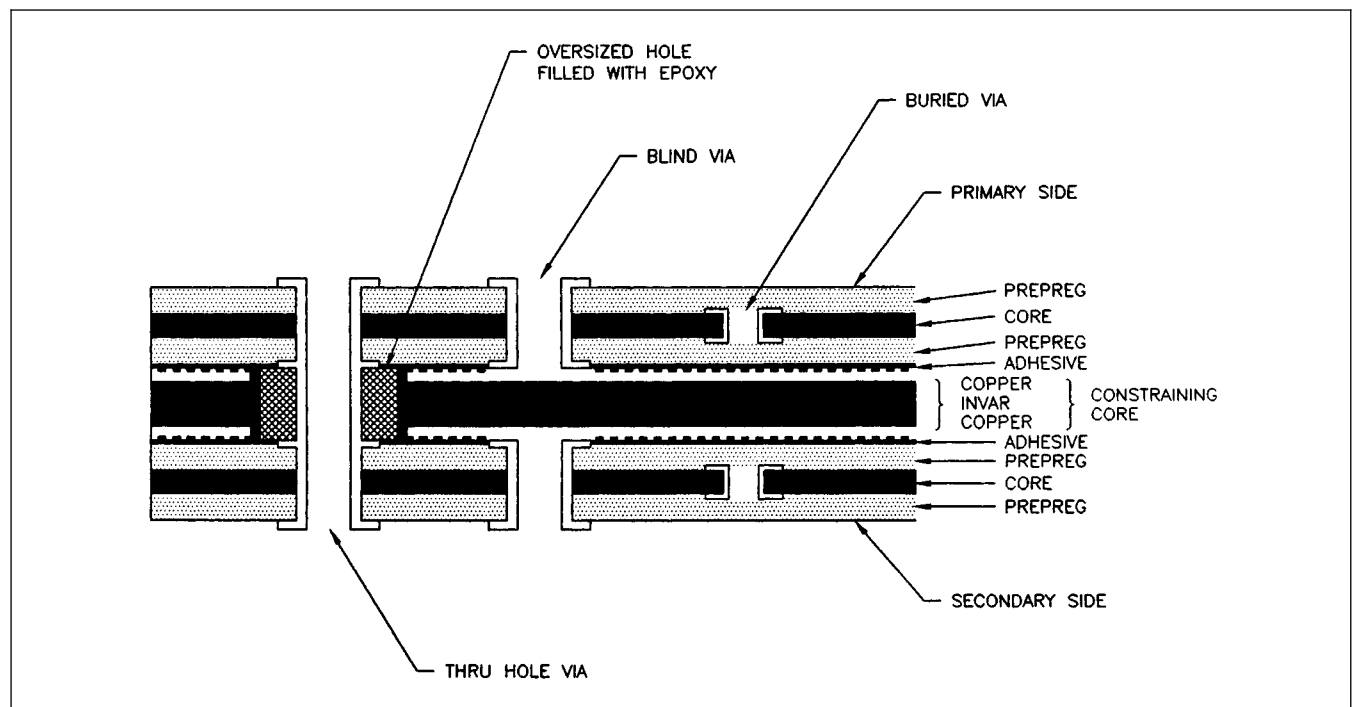


Figure 4-4B Symmetrical Multilayer Printed Board Cross-Section Illustrating Constraining-Core Construction

plot, a photoplot or photographic composite copy illustrating all drill locations. The drill pattern is produced at 1:1 scale, where symbols may be used to represent each unique hole diameter.

**Note:** Electronic data may be supplied in lieu of, and/or in addition to, the drill pattern described above, prepared in

accordance with IPC-D-350 format (preferred) or other standard industry formats.

Since a grid system is used to locate most holes, each hole location need not be individually dimensioned. Holes located off grid **shall** be individually dimensioned on the profile (board outline) drawing or on the drill pattern, whichever is more convenient.

| ARTWORK                                | DWG. NO. | REV LEVEL | Cu WT. OZ. | NOM. FINISHED LINE WIDTH |
|----------------------------------------|----------|-----------|------------|--------------------------|
| GERBER PLOT DATA:                      |          |           |            |                          |
| PRIMARY SIDE (HORIZ) SIGNAL LAYER "1"  | 991779   | B         | 1          | .007"                    |
| SECONDARY SIDE (VERT) SIGNAL LAYER "2" | 991779   | B         | 1          | .007"                    |
| SOLDER MASK (TOP)                      | 991779   | B         |            |                          |
| SOLDER MASK (BOTTOM)                   | 991779   | B         |            |                          |
| SILKSCREEN (TOP)                       | 991779   | B         |            |                          |
| SILKSCREEN (BOTTOM)                    | 991779   | B         |            |                          |
| N.C. DRILL DATA – P.C. BOARD           | 991779   | B         |            |                          |
| N.C. DRILL DATA – BACKING PLATE        | 991779   | A         |            |                          |
| BARE BOARD TEST DATA IPC-D-356 FORMAT  | 991779   | B         |            |                          |

Figure 4-5 Artwork Configuration Control Chart, Double-Sided Board

| ARTWORK                                     | DWG. NO. | REV LEVEL | Cu WT. OZ. | NOM. FINISHED LINE WIDTH |
|---------------------------------------------|----------|-----------|------------|--------------------------|
| GERBER PLOT DATA:                           |          |           |            |                          |
| PRIMARY SIDE (HORIZ) SIGNAL LAYER "1"       | 991793   | A         | 1/2        | .007"                    |
| INNER SIGNAL LAYER (VERT) SIGNAL LAYER "2"  | 991793   | A         | 1          | .007"                    |
| GROUND PLANE LAYER "3"                      | 991793   | A         | 1          | –                        |
| VCC PLANE (+5 VOLTS) LAYER "4"              | 991793   | A         | 1          | –                        |
| INNER SIGNAL LAYER (HORIZ) SIGNAL LAYER "5" | 991793   | A         | 1          | .007"                    |
| SECONDARY SIDE (VERT) SIGNAL LAYER "6"      | 991793   | A         | 1/2        | .007"                    |
| SOLDER MASK (TOP)                           | 991793   | A         |            |                          |
| SOLDER MASK (BOTTOM)                        | 991793   | A         |            |                          |
| SILKSCREEN (TOP)                            | 991793   | A         |            |                          |
| SOLDER PASTE SCREEN (TOP)                   | 991793   | A         |            |                          |
| N.C. DRILL DATA – PC BOARD                  | 991793   | A         |            |                          |
| BARE BOARD TEST DATA IPC-D-356 FORMAT       | 991793   | A         |            |                          |

Figure 4-6 Artwork Configuration Control Chart, 6 Layer Board

The drill pattern quite often serves as a template and is used as a tool when checking and inspecting the printed board drilling. The drill pattern **shall** be viewed from the primary side. Since the drill pattern is usually less cluttered than an artwork layer, marking information; i.e., date code, fabricator's I.D. and UL marking, plus fabricator's Cage Code may be shown in this view.

The drill pattern (viewed from the primary side) **shall** include quality conformance test coupons. The test coupon drill pattern illustrating all drill locations are produced at a 1:1 scale, and may use the same symbology as the printed board, to represent each unique hole diameter.

| CODE | DRILL LEGEND                                                                      | HOLE SCHEDULE |                 |                            |
|------|-----------------------------------------------------------------------------------|---------------|-----------------|----------------------------|
| A    |  | 3.25–3.38     | (.128"–.133")   | NON-PLATED                 |
| B    |  | 4.98–5.13     | (.196"–.202")   | NON-PLATED                 |
| C    |  | 3.56–3.57     | (.1403"–.1407") | NON-PLATED (TOOLING HOLES) |
| D    |  | 3.56–3.57     | (.1403"–.1407") | NON-PLATED (TOOLING SLOT)  |
| E    |  | 3.96–4.22     | (.156"–.166")   | PLATING REQ'D              |
| F    |  | 8.51–8.76     | (.335"–.345")   | PLATING REQ'D              |
| G    |  | 0.86–1.02     | (.034"–.040")   | PLATING REQ'D              |
| H    |  | 0.94–1.09     | (.037"–.043")   | PLATING REQ'D              |
| J    |  | 0.58–0.74     | (.023"–.029")   | PLATING REQ'D (TENTED)     |
| K    |  | 0.58–0.74     | (.023"–.029")   | PLATING REQ'D              |
| L    |  | 1.85–2.01     | (.073"–.079")   | PLATING REQ'D              |
| M    |  | 3.56–3.63     | (.140"–.143")   | NON-PLATED                 |
| N    |  | 1.55–1.70     | (.061"–.067")   | NON-PLATED                 |
| P    |  | 1.24–1.4      | (.049"–.055")   | PLATING REQ'D              |
| R    |  | 1.07–1.22     | (.042"–.048")   | PLATING REQ'D              |
| S    |  | 2.34–2.49     | (.092"–.098")   | NON-PLATED                 |
| T    |  | 1.30–1.45     | (.051"–.057")   | PLATING REQ'D              |

VALUES ARE IN MILLIMETERS AND INCHES.  
VALUES IN PARENTHESIS ARE INCH EQUIVALENTS.

Figure 4-7 Typical Hole Schedule

#### 4.3.8.1 Drill Size Recommendations for Printed Boards

The following table shows recommended drill sizes in standard 0.05 mm [0.002 in] increments. 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 the table is the maximum board thicknesses to which the various drill sizes should be applied. These dimensions are maximums. Thinner boards may be used to accommodate all drills shown within a drill set category.

Although the table shows over 124 various drill sizes, designers are encouraged to limit the number of drill selections to approximately 10 drill sizes per 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.

Table 4-3 is a suggested guideline based on the availability of existing manufactured drills.

**4.3.9 Profile (Board Outline) Dimensioning** The methods for dimensioning the profile (board outline) **shall** be in accordance with IPC-D-300. The methods for depicting feature size, position and location, form and associated tol-

erances **shall** be in accordance with IPC-D-300 (Figures 4-9 and 4-9A).

The board thickness **shall** be dimensioned in an end view or depicted in the board construction cross-sectional view (Figures 4-4 and 4-4A).

**4.4 Grid Systems** Grid systems are used to locate components, plated-through and non-plated holes, conductor patterns, surface mount land patterns, and other features of the printed board and its assembly; therefore, they need not be individually dimensioned.

When printed board features fall off grid, they **shall** be individually dimensioned and tolerated on the master drawing. These dimensions may appear either on the profile (board outline) view or on the drill pattern whichever is more convenient. Pin #1 should always be placed on grid. Grid systems **shall** be located with respect to a minimum of two datum points.

The grid increment **shall** be specified on the master drawing (or may be embedded in the CAD system data base). The selection of the grid increment is based on the component terminal location for through-hole components, or component center point for surface mount components. Typical grid increments are multiples of 0.13 mm [0.005 in] for through-hole components, and 0.05 mm [0.002 in] for surface mount components.

**Table 4-3 Drill Size Recommendations  
Related to Maximum Board Thickness**

| Drill Size [mm] |      |      |      | Maximum Board Thickness [mm] |
|-----------------|------|------|------|------------------------------|
| 0.10            | 0.15 | 0.20 | 0.25 | ≤1.0 (≤0.25)                 |
| 0.30            | 0.35 | 0.40 | 0.45 | ≤1.6                         |
| 0.50            | 0.55 | 0.60 | 0.65 | ≤3.2                         |
| 0.70            | 0.75 | 0.80 | 0.85 |                              |
| 0.90            | 0.95 | 1.00 | 1.05 | ≤4.8                         |
| 1.10            | 1.15 | 1.20 | 1.25 |                              |
| 1.30            | 1.35 | 1.40 | 1.45 | ≤6.4                         |
| 1.50            | 1.55 | 1.60 | 1.65 |                              |
| 1.70            | 1.75 | 1.80 | 1.85 |                              |
| 1.90            | 1.95 | 2.00 | 2.05 |                              |
| 2.10            | 2.15 | 2.20 | 2.25 |                              |
| 2.30            | 2.35 | 2.40 | 2.45 |                              |
| 2.50            | 2.55 | 2.60 | 2.65 |                              |
| 2.70            | 2.75 | 2.80 | 2.85 |                              |
| 2.90            | 2.95 | 3.00 | 3.05 |                              |
| 3.10            | 3.15 | 3.20 | 3.25 |                              |
| 3.30            | 3.35 | 3.40 | 3.45 |                              |
| 3.50            | 3.55 | 3.60 | 3.65 |                              |
| 3.70            | 3.75 | 3.80 | 3.85 |                              |
| 3.90            | 3.95 | 4.00 | 4.05 |                              |
| 4.10            | 4.15 | 4.20 | 4.25 |                              |
| 4.30            | 4.35 | 4.40 | 4.45 |                              |
| 4.50            | 4.55 | 4.60 | 4.65 |                              |
| 4.70            | 4.75 | 4.80 | 4.85 |                              |
| 4.90            | 4.95 | 5.00 | 5.05 |                              |
| 5.10            | 5.15 | 5.20 | 5.25 |                              |
| 5.30            | 5.35 | 5.40 | 5.45 |                              |
| 5.50            | 5.55 | 5.60 | 5.65 |                              |
| 5.70            | 5.75 | 5.80 | 5.85 |                              |
| 5.90            | 5.95 | 6.00 | 6.05 |                              |
| 6.10            | 6.15 | 6.20 | 6.25 |                              |

**4.4.1 Datums** The master drawing **shall** include the relationships and acceptable tolerances between all datum features as established in accordance with IPC-D-300.

A minimum of two holes located on grid **shall** be dimensioned and toleranced with respect to a datum reference

frame. This positions the grid with respect to the board and, at the same time, establishes the grid “0-0 point of origin”.

Electrical test data, tooling and numerical control data should always be generated from the same “0-0 point of origin”.

**4.4.2 Dimensions and Tolerances** The values of printed board dimensions and tolerances **shall** be in accordance with IPC-D-300. The dimensioning and tolerancing convention used on the master drawing **shall** be in accordance with IPC-D-300.

Historically, printed board designs have used bilateral tolerances for size and position, which is acceptable per ANSI Y14.5 with some exceptions with regards to datum references; however, the use of geometric dimensioning and tolerancing (GDT) has many advantages over size and bilateral tolerancing:

- It allows at least 57% more tolerance area with true positioning than with bilateral tolerancing (Figure 4-11).
- It provides maximum producibility while assuring the mechanical function of the printed board.
- It allows “bonus” or extra tolerances when the maximum/least material concept is used.
- It ensures that design requirements, as they relate to actual function, are specifically stated and carried out, especially when automated assembly techniques are to be used.
- It ensures interchangeability of mating parts.
- It provides uniformity and convenience in drawing delineation and interpretation, thus reducing controversy and guesswork.

**4.4.3 Datum Features** Datum features indicate the origin of a dimensional relationship between a toleranced feature and a designated feature or features on the printed board. Datum features are chosen to position the printed board in relation to a set of three mutually perpendicular planes (Figures 4-12 through 4-16). There are some cases where a single datum reference is sufficient, for example a printed board profile or a datum hole position.

Typically, printed board drawings are oriented with the component side or the designated Layer 1 facing up. This orientation establishes the backside of the printed board as the first (primary) of the three required datum planes. The other two datum planes (secondary and tertiary) are typically established minimum material conditions using holes and/or etched features on the printed board. The choice of features to be used for datums depends on what design elements are intended to be controlled. Board edge or feature edge datums should not be used primarily because they are