Table of Contents

1 **GENERAL** 1
1.1 Scope 1
1.2 Purpose 1
1.3 Classification 1
1.4 Measurement Units and Applications 1
1.4.1 Verification of Dimensions 1
1.5 Definition of Requirements 1
1.5.1 Hardware Defects and Process Indicators 2
1.5.2 Material and Process Nonconformance 2
1.6 General Requirements 2
1.7 Order of Precedence 3
1.7.1 Conflict 3
1.7.2 Clause References 3
1.7.3 Appendices 3
1.8 Terms and Definitions 3
1.8.1 Diameter 3
1.8.2 Disposition 3
1.8.3 Electrical Clearance 3
1.8.4 FOD (Foreign Object Debris) 3
1.8.5 High Voltage 3
1.8.6 Manufacturer (Assembler) 3
1.8.7 Objective Evidence 4
1.8.8 Process Control 4
1.8.9 Proficiency 4
1.8.10 Solder Destination Side 4
1.8.11 Solder Source Side 4
1.8.12 Supplier 4
1.8.13 User 4
1.8.14 Wire Overwrap 4
1.8.15 Wire Overlap 4
1.9 Requirements Flowdown 4
1.10 Personnel Proficiency 5
1.11 Acceptance Requirements 5
1.12 General Assembly Requirements 5
1.13 Miscellaneous Requirements 5
1.13.1 Health and Safety 5
1.13.2 Procedures for Specialized Technologies 5

2 **APPLICABLE DOCUMENTS** 6
2.1 IPC 6
2.2 JEDEC 7
2.3 Joint Industry Standards 7
2.4 ASTM 7
2.5 Electrostatic Discharge Association 7
2.6 International Electrotechnical Commission 7
2.7 SAE International 7
2.8 Military Standards 7

3 **MATERIALS, COMPONENTS AND EQUIPMENT REQUIREMENTS** 8
3.1 Materials 8
3.2 Solder 8
3.2.1 Solder – Lead Free 8
3.2.2 Solder Purity Maintenance 8
3.3 Flux 9
3.3.1 Flux Application 9
3.4 Solder Paste 9
3.5 Solder Preforms 9
3.6 Adhesives 9
3.7 Chemical Strippers 9
3.8 Components 9
3.8.1 Component and Seal Damage 9
3.8.2 Coating Meniscus 10
3.9 Tools and Equipment 10

4 **GENERAL SOLDERING AND ASSEMBLY REQUIREMENTS** 10
4.1 Electrostatic Discharge (ESD) 10
4.2 Facilities 10
4.2.1 Environmental Controls 10
4.2.2 Temperature and Humidity 10
4.2.3 Lighting 10
4.2.4 Field Assembly Operations 10
4.3 Solderability 10
4.4 Solderability Maintenance 10
4.5 Removal of Component Surface Finishes 11
4.5.1 Gold Removal 11
4.5.2 Other Metallic Surface Finishes Removal 11
4.6 Thermal Protection 11
4.7 Rework of Nonsolderable Parts 11
4.8 Preprocessing Cleanliness Requirements 11
4.9 General Part Mounting Requirements 11
4.9.1 General Requirements 12
4.9.2 Lead Deformation Limits 12
4.10 Hole Obstruction 12
4.11 Metal-Cased Component Isolation 12
4.12 Adhesive Coverage Limits 12
4.13 Mounting of Parts on Parts (Stacking of Components) 12

4.14 Connectors and Contact Areas 12
4.15 Handling of Parts 12
4.15.1 Preheating 12
4.15.2 Controlled Cooling 12
4.15.3 Drying/Degassing 12
4.15.4 Holding Devices and Materials 12
4.16 Machine (Nonreflow) Soldering 13
4.16.1 Machine Controls 13
4.16.2 Solder Bath 13
4.17 Reflow Soldering 13
4.17.1 Intrusive Soldering (Paste-in-Hole) 13
4.18 Solder Connection 13
4.18.1 Exposed Surfaces 14
4.18.2 Solder Connection Anomalies 14
4.18.3 Partially Visible or Hidden Solder Connections 14
4.19 Heat Shrinkable Soldering Devices 14

5 WIRES AND TERMINAL CONNECTIONS 15
5.1 Wire and Cable Preparation 15
5.1.1 Insulation Damage 15
5.1.2 Strand Damage 15
5.1.3 Tinning of Stranded Wire – Forming 16
5.2 Solder Terminals 16
5.3 Bifurcated, Turret and Slotted Terminal Installation 16
5.3.1 Shank Damage 16
5.3.2 Flange Damage 16
5.3.3 Flared Flange Angles 16
5.3.4 Terminal Mounting – Mechanical 17
5.3.5 Terminal Mounting – Electrical 17
5.3.6 Terminal Mounting – Soldering 17
5.4 Mounting to Terminals 17
5.4.1 General Requirements 17
5.4.2 Turret and Straight Pin Terminals 19
5.4.3 Bifurcated Terminals 19
5.4.4 Slotted Terminals 21
5.4.5 Hook Terminals 21
5.4.6 Pierced or Perforated Terminals 21
5.4.7 Cup and Hollow Cylindrical Terminals – Placement 22
5.5 Soldering to Terminals 22
5.5.1 Bifurcated Terminals 22
5.5.2 Slotted Terminal 22
5.5.3 Cup and Hollow Cylindrical Terminals – Soldering 22
5.6 Jumper Wires 22
5.6.1 Insulation 23
5.6.2 Wire Routing 23
5.6.3 Wire Staking 23
5.6.4 Unpopulated Land or Via – Lap Soldered 23
5.6.5 Supported Holes 23
5.6.6 SMT 23

6 THROUGH-HOLE MOUNTING AND TERMINATIONS 24
6.1 Through-Hole Terminations – General 24
6.1.1 Lead Forming 25
6.1.2 Termination Requirements 25
6.1.3 Lead Trimming 26
6.1.4 Interfacial Connections 26
6.1.5 Coating Meniscus In Solder 26
6.2 Supported Holes 27
6.2.1 Solder Application 27
6.2.2 Through-Hole Component Lead Soldering 27
6.3 Unsupported Holes 27
6.3.1 Lead Termination Requirements for Unsupported Holes 27

7 SURFACE MOUNTING OF COMPONENTS 28
7.1 Surface Mount Device Lead 28
7.1.1 Plastic Components 28
7.1.2 Forming 28
7.1.3 Unintentional Bending 29
7.1.4 Flat Pack Parallelism 29
7.1.5 Surface Mount Device Lead Bends 29
7.1.6 Flattened Leads 29
7.1.7 Parts Not Configured for Surface Mounting ... 29
7.2 Leaded Component Body Clearance 29
7.2.1 Axial-Leaded Components 29
7.3 Parts Configured for Butt/I Lead Mounting 29
7.4 Installation of Surface Mount Components 29
7.5 Soldering Requirements 29
7.5.1 Misaligned Components 30
7.5.2 Unspecified and Special Requirements 30
7.5.3 Bottom Only Chip Component Terminations 31
7.5.4 Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) 32
7.5.5 Cylindrical End Cap Terminations 33
7.5.6 Castellated Terminations 34
7.5.7 Flat Gull Wing Leads 35
7.5.8 Round or Flattened (Coined) Gull Wing Leads 36
7.5.9 J Lead Terminations 37

7.5.10 Butt/I Terminations 38
7.5.11 Flat Lug Leads and Flat Unformed Leads 40
7.5.12 Tall Profile Components Having Bottom Only Terminations 42
7.5.13 Inward Formed L-Shaped Ribbon Leads 43
7.5.14 Surface Mount Area Array Packages 44
7.5.15 Bottom Termination Components (BTC) 47
7.5.16 Components with Bottom Thermal Plane Terminations (D-Pak) 48
7.5.17 Flattened Post Connections 49
7.5.18 P-Style Terminations 50
7.6 Specialized SMT Terminations 50

8 CLEANING PROCESS REQUIREMENTS 51

8.1 Cleanliness Exemptions 51
8.2 Ultrasonic Cleaning 51
8.3 Post-Solder Cleanliness 51
8.3.1 Foreign Object Debris (FOD) 51
8.3.2 Flux Residues and Other Ionic or Organic Contaminants 51
8.3.3 Post-Soldering Cleanliness Designator 51
8.3.4 Cleaning Option 51
8.3.5 Test for Cleanliness 51
8.3.6 Testing 52

9 PCB REQUIREMENTS 53

9.1 Printed Circuit Board Damage 53
9.1.1 Blistering/Delamination 53
9.1.2 Weave Exposure/Cut Fibers 53
9.1.3 Haloing 53
9.1.4 Edge Delamination 53
9.1.5 Land/Conductor Separation 53
9.1.6 Land/Conductor Reduction in Size 53
9.1.7 Flexible Circuitry Delamination 53
9.1.8 Flexible Circuitry Damage 53
9.1.9 Burns 53
9.1.10 Non-Soldered Edge Contacts 53
9.1.11 Measles 53
9.1.12 Crazing 54
9.2 Marking 54
9.3 Bow and Twist (Warpage) 54
9.4 Depanelization 54

10 COATING, ENCAPSULATION AND STAKING (ADHESIVE) 54

10.1 Conformal Coating – Materials 54
10.2 Conformal Coating – Masking 54
10.3 Conformal Coating – Application 54
10.3.1 Conformal Coating on Components 55
10.3.2 Thickness 55
10.3.3 Uniformity 55
10.3.4 Transparency 55
10.3.5 Bubbles and Voids 55
10.3.6 Delamination 55
10.3.7 Foreign Objects Debris 55
10.3.8 Other Visual Conditions 55
10.3.9 Inspection 56
10.3.10 Rework or Touchup of Conformal Coating 56
10.4 Encapsulation 56
10.4.1 Application 56
10.4.2 Performance Requirements 56
10.4.3 Rework of Encapsulant Material 56
10.4.4 Encapsulant Inspection 56
10.5 Staking 56
10.5.1 Staking – Application 56
10.5.2 Staking – Adhesive 58
10.5.3 Staking (Inspection) 58

11 WITNESS (TORQUE/ANTI-TAMPERING) STRIPE 58

12 PRODUCT ASSURANCE 58

12.1 Inspection Methodology 58
12.1.1 Process Verification Inspection 58
12.1.2 Visual Inspection 59
12.2 Process Control Requirements 60
12.2.1 Opportunities Determination 60
12.3 Statistical Process Control 60

13 REWORK AND REPAIR 61

13.1 Rework 61
13.2 Repair 61
13.3 Post Rework/Repair Cleaning 61

APPENDIX A Guidelines for Soldering Tools and Equipment 62

APPENDIX B Minimum Electrical Clearance – Electrical Conductor Spacing 64

APPENDIX C J-STD-001 Guidance on Objective Evidence of Material Compatibility 66

Figures

Figure 1-1 Overwrap 4
Figure 1-2 Overlap 4
Figure 4-1 Hole Obstruction 12
Figure 4-2 Acceptable Wetting Angles 13
Figure 5-1 Insulation Thickness 15

Figure 5-2 Flange Damage ... 16
Figure 5-3 Flare Angles ... 16
Figure 5-4 Terminal Mounting – Mechanical ... 17
Figure 5-5 Terminal Mounting – Electrical ... 17
Figure 5-6 Insulation Clearance Measurement ... 17
Figure 5-7 Service Loop for Lead Wiring ... 18
Figure 5-8 Cup and Hollow Cylindrical Terminal – Solder Height ... 18
Figure 5-9 Wires on Intermediate Turret Terminal ... 18
Figure 5-10 Wire and Lead Placement ... 19
Figure 5-11 Bifurcated Terminal Side Route Placement with Wrap ... 19
Figure 5-12 Bifurcated Terminal Side Route Placement – Straight Though and Staked ... 20
Figure 5-13 Bifurcated Terminal Top and Bottom Route Connection ... 20
Figure 5-14 Slotted Terminal ... 21
Figure 5-15 Hook Terminal Wire Placement ... 21
Figure 5-16 Acceptable Pierced or Perforated Terminal Wire Placement ... 22
Figure 5-17 Solder Depression ... 22
Figure 5-18 Cup and Hollow Cylindrical Terminals – Vertical Fill of Solder ... 22
Figure 6-1 Component Lead Stress Relief Examples ... 24
Figure 6-2 Lead Bends ... 25
Figure 6-3 Lead Trimming ... 26
Figure 6-4 Vertical Fill Example ... 26
Figure 7-1 Surface Mount Device Lead Forming ... 28
Figure 7-2 Surface Mount Device Lead Forming ... 28
Figure 7-3 Bottom Only Terminations ... 31
Figure 7-4 Rectangular or Square End Chip Components ... 32
Figure 7-5 Cylindrical End Cap Terminations ... 33
Figure 7-6 Castellated Terminations ... 34
Figure 7-7 Flat Gull Wing Leads ... 35
Figure 7-8 Round or Flattened (Coined) Gull Wing Leads ... 36
Figure 7-9 J Leads ... 37
Figure 7-10 Butt/I Terminations for Modified Through-Hole Leads ... 38
Figure 7-11 Butt/I Terminations for Solder Charged Leads ... 39
Figure 7-12A Flat Lug Leads ... 41
Figure 7-12B Flat Unformed Leads ... 41
Figure 7-13 Tall Profile Components Having Bottom Only Terminations ... 42
Figure 7-14 Inward Formed L-Shaped Ribbon Lead ... 43
Figure 7-15 BGA Solder Ball Clearance ... 45
Figure 7-16 Bottom Termination Component ... 47
Figure 7-17 Bottom Thermal Plane Termination ... 48
Figure 7-18 Flattened Post Termination ... 49
Figure 7-19 P-Style Termination ... 50
Figure 10-1 Radial Leaded Components whose height is greater than or equal to their length or diameter – Individual Rectangular Shaped Component ... 57
Figure 10-2 Radial Leaded Components whose height is greater than or equal to their length or diameter – Individual Cylindrically Shaped Component ... 57

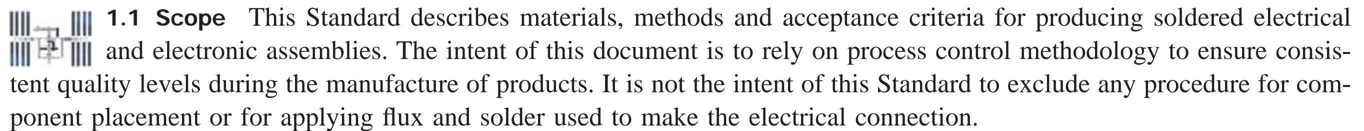
Tables

Table 1-1 Design, Fabrication and Acceptability Specifications ... 3
Table 3-1 Maximum Limits of Solder Bath Contaminant ... 8
Table 4-1 Solder Anomalies ... 14
Table 5-1 Allowable Strand Damage ... 15
Table 5-2 Terminal Mounting Minimum Soldering Requirements ... 17
Table 5-3 Turret and Straight Pin Wire Placement ... 19
Table 5-4 AWG 30 and Smaller Wire Wrap Requirements ... 19
Table 5-5 Bifurcated Terminal Wire Placement – Side Route with Wrap ... 20
Table 5-6 Bifurcated Terminal Side Route Straight-Through Staking Requirements ... 20
Table 5-7 Bifurcated Terminal Wire Placement – Bottom Route ... 20
Table 5-8 Hook Terminal Wire Placement ... 21
Table 5-9 Pierced or Perforated Terminal Wire Placement ... 21
Table 5-10 Solder Requirements Lead/Wire to Post ... 22
Table 6-1 Component to Land Clearance ... 24
Table 6-2 Components with Spacers ... 24
Table 6-3 Lead Bend Radius ... 25
Table 6-4 Protrusion of Leads in Supported Holes ... 25
Table 6-5 Protrusion of Leads in Unsupported Holes ... 25
Table 6-6 Supported Holes with Component Leads, Minimum Acceptable Conditions ... 26
Table 6-7 Unsupported Holes with Component Leads, Minimum Acceptable Conditions ... 27
Table 7-1 SMT Lead Forming Minimum Lead Length (L) ... 28
Table 7-2 Surface Mount Components ... 30
Table 7-3 Dimensional Criteria – Bottom Only Chip Component Terminations ... 31
Table 7-4 Dimensional Criteria – Rectangular or Square End Chip Components – 1, 2, 3 or 5 Side Termination(s) ... 32
Table 7-5 Dimensional Criteria – Cylindrical End Cap Terminations ... 33
Table 7-6 Dimensional Criteria – Castellated Terminations ... 34
Table 7-7 Dimensional Criteria – Flat Gull Wing Leads ... 35
Table 7-8 Dimensional Criteria – Round or Flattened (Coined) Gull Wing Leads ... 36

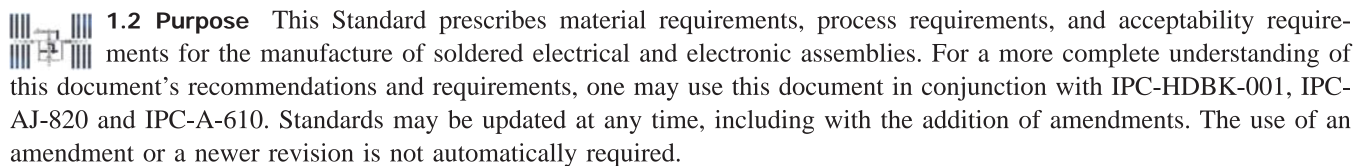
Table 7-9 Dimensional Criteria – J Leads 37
Table 7-10 Dimensional Criteria – Butt/I Connections 38
Table 7-11 Dimensional Criteria – Butt/I Terminations – Solder Charged Terminations 39
Table 7-12A Dimensional Criteria – Power Dissipating Flat Lug Leads 40
Table 7-12B Dimensional Criteria – Flat Unformed Leads, e.g., flexible circuitry termination 40
Table 7-13 Dimensional Criteria – Tall Profile Components Having Bottom Only Terminations 42
Table 7-14 Dimensional Criteria – Inward Formed L-Shaped Ribbon Leads 43
Table 7-15 Dimensional Criteria – Ball Grid Array Components with Collapsing Balls 45
Table 7-16 Ball Grid Array Components with Noncollapsing Balls 46
Table 7-17 Column Grid Array 46
Table 7-18 Dimensional Criteria – BTC 47
Table 7-19 Dimensional Criteria – Bottom Thermal Plane Terminations 48
Table 7-20 Dimensional Criteria Flattened Post Connections 49
Table 7-21 Dimensional Criteria – P-Style Terminations 50
Table 8-1 Designation of Surfaces to be Cleaned 51
Table 8-2 Cleanliness Testing Designators 51
Table 10-1 Coating Thickness 55
Table 12-1 Magnification Aid Applications for Solder Connections 59
Table 12-2 Magnification Aid Applications for Wires and Wire Connections 59
Table 12-3 Magnification Aid Applications – Other 59

Requirements for Soldered Electrical and Electronic Assemblies

1 GENERAL



1.1 Scope This Standard describes materials, methods and acceptance criteria for producing soldered electrical and electronic assemblies. The intent of this document is to rely on process control methodology to ensure consistent quality levels during the manufacture of products. It is not the intent of this Standard to exclude any procedure for component placement or for applying flux and solder used to make the electrical connection.



1.2 Purpose This Standard prescribes material requirements, process requirements, and acceptability requirements for the manufacture of soldered electrical and electronic assemblies. For a more complete understanding of this document's recommendations and requirements, one may use this document in conjunction with IPC-HDBK-001, IPC-AJ-820 and IPC-A-610. Standards may be updated at any time, including with the addition of amendments. The use of an amendment or a newer revision is not automatically required.

1.3 Classification This Standard recognizes that electrical and electronic assemblies are subject to classifications by intended end-item use. Three general end-product classes have been established to reflect differences in manufacturability, complexity, functional performance requirements, and verification (inspection/test) frequency. It should be recognized that there may be overlaps of equipment between classes.

The User, see 1.8.13, is responsible for defining the product class. The product class should be stated in the procurement documentation package.

CLASS 1 General Electronic Products
Includes products suitable for applications where the major requirement is function of the completed assembly.

CLASS 2 Dedicated Service Electronic Products
Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically the end-use environment would not cause failures.

CLASS 3 High Performance/Harsh Environment Electronic Products
Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

1.4 Measurement Units and Applications This Standard uses International System of Units (SI) units per ASTM SI10, IEEE/ASTM SI 10, Section 3 [Imperial English equivalent units are in brackets for convenience]. The SI units used in this Standard are millimeters (mm) [in] for dimensions and dimensional tolerances, Celsius (°C) [°F] for temperature and temperature tolerances, grams (g) [oz] for weight, and lumens (lm) [footcandles] for illuminance.

Note: This Standard uses other SI prefixes (ASTM SI10, Section 3.2) to eliminate leading zeroes (for example, 0.0012 mm becomes 1.2 µm) or as alternative to powers-of-ten (3.6×10^3 mm becomes 3.6 m).

1.4.1 Verification of Dimensions Actual measurement of specific part mounting and solder fillet dimensions and determination of percentages are not required except for referee purposes. For determining conformance to the specifications in this Standard, round all observed or calculated values "to the nearest unit" in the last right-hand digit used in expressing the specification limit, in accordance with the rounding method of ASTM Practice E29. For example, specifications of 2.5 mm max, 2.50 mm max, or 2.500 mm max, round the measured value to the nearest 0.1 mm, 0.01 mm, or 0.001 mm, respectively, and then compare to the specification number cited.

1.5 Definition of Requirements The words **shall** or **shall not** are used in the text of this document wherever there is a requirement for materials, preparation, process control or acceptance of a soldered connection.