



IPC-HDBK-001F

# Handbook and Guide to Supplement J-STD-001

Developed by the IPC-HDBK-001 Task Group (5-22F) of the Assembly and Joining Committee (5-00) of IPC

**Supersedes:**

IPC-HDBK-001E - February 2012  
IPC-HDBK-001 w/Amendments  
1 & 2 - October 2005  
IPC-HDBK-001 w/Amendment 1 -  
December 2000  
IPC-HDBK-001 - March 1998

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

Contact:

IPC

# Table of Contents

<b>Δ0.1 GENERAL</b> .....	1	2.2 IPC .....	8
Δ0.1.1 Scope .....	1	2.3 Electrostatic Discharge Association .....	9
Δ0.1.2 Purpose .....	1		
<b>Δ0.2 FORMAT (Using This Handbook)</b> .....	1	<b>3 MATERIAL, COMPONENTS, AND EQUIPMENT REQUIREMENTS</b> .....	
<b>1 GENERAL</b> .....	2	3.1 Materials .....	9
1.1 Scope .....	2	3.2 Solder .....	9
1.2 Purpose .....	2	3.2.1 Solder – Lead Free .....	12
1.3 Classification .....	2	3.2.2 Solder Purity Maintenance .....	18
1.4 Measurement Units and Applications .....	3	3.3 Flux .....	20
1.4.1 Verification of Dimensions .....	3	3.3.1 Flux Application .....	23
1.5 Definition of Requirements .....	3	3.4 Solder Paste .....	23
1.5.1 Hardware Defects and Process Indicators .....	4	Δ3.4.1 Solder Powder .....	24
1.5.2 Material and Process Nonconformance .....	4	Δ3.4.2 Particle Shape Effects .....	24
1.6 General Requirements .....	4	Δ3.4.3 Solder Particle Size Effects .....	24
1.7 Order of Precedence .....	4	Δ3.4.4 Oxide Content in Solder Paste .....	24
1.7.1 Conflict .....	4	Δ3.4.5 Metals Content .....	24
1.7.2 Clause References .....	4	Δ3.4.6 Paste Viscosity .....	25
1.7.3 Appendices .....	5	Δ3.4.7 Determination of Correct Paste Volume .....	25
1.8 Terms and Definitions .....	5	3.5 Solder Preforms .....	26
1.8.1 Disposition .....	5	3.6 Adhesives .....	26
1.8.2 Electrical Clearance .....	5	3.7 Chemical Strippers .....	26
1.8.3 FOD (Foreign Object Debris) .....	5	3.8 Components .....	27
1.8.4 High Voltage .....	5	3.8.1 Component and Seal Damage .....	27
1.8.5 Manufacturer (Assembler) .....	5	3.8.2 Coating Meniscus .....	27
1.8.6 Objective Evidence .....	5	3.9 Soldering Tools and Equipment .....	27
1.8.7 Process Control .....	5		
1.8.8 Proficiency .....	6	<b>4 GENERAL SOLDERING AND ASSEMBLY REQUIREMENTS</b> .....	28
1.8.9 Solder Destination Side .....	6	4.1 Electrostatic Discharge (ESD) .....	28
1.8.10 Solder Source Side .....	6	4.2 Facilities .....	29
1.8.11 Supplier .....	6	4.2.1 Environmental Controls .....	29
1.8.12 User .....	6	4.2.2 Temperature and Humidity .....	29
1.8.13 Wire Overlap .....	6	4.2.3 Lighting .....	29
1.8.14 Wire Overlap .....	6	4.2.4 Field Assembly Operations .....	29
1.9 Requirements Flowdown .....	6	4.3 Solderability .....	29
1.10 Personnel Proficiency .....	7	4.4 Solderability Maintenance .....	30
1.11 Acceptance Requirements .....	7	4.5 Removal of Component Surface Finishes .....	30
1.11.1 General Assembly Requirements .....	7	4.5.1 Gold Removal .....	30
1.11.2 Miscellaneous Requirements .....	7	4.5.2 Other Metallic Surface Finishes Removal .....	31
1.11.3 Health and Safety .....	7	4.6 Thermal Protection .....	31
1.11.3.1 Health and Safety .....	7	4.7 Rework of Nonsolderable Parts .....	32
1.11.3.2 Procedures for Specialized Technologies .....	7	4.8 Preprocessing Cleanliness Requirements .....	32
<b>2 APPLICABLE DOCUMENTS</b> .....	8	4.9 General Part Mounting Requirements .....	32
2.1 EIA .....	8	4.9.1 General Requirements .....	32

4.9.2	Lead Deformation Limits .....	32	5.4.6	Pierced or Perforated Terminals .....	56
4.10	Hole Obstruction .....	32	5.4.7	Cup and Hollow Cylindrical Terminals – Placement .....	56
4.11	Metal-Cased Component Isolation .....	33	5.5	Soldering to Terminals .....	57
4.12	Adhesive Coverage Limits .....	33	5.5.1	Bifurcated Terminals .....	57
4.13	Mounting of Parts on Parts (Stacking of Components) .....	33	5.5.2	Slotted Terminal .....	57
4.14	Connectors and Contact Areas .....	34	5.5.3	Cup and Hollow Cylindrical Terminals – Soldering .....	57
4.15	Handling of Parts .....	34	5.6	Jumper Wires (See Figure 5-19) .....	58
4.15.1	Preheating .....	34	5.6.1	Insulation .....	59
4.15.2	Controlled Cooling .....	34	5.6.2	Wire Routing .....	59
4.15.3	Drying/Degassing .....	35	5.6.3	Wire Staking .....	59
4.15.4	Holding Devices and Materials .....	35	5.6.4	Land .....	60
4.16	Machine (Nonreflow) Soldering .....	35	5.6.5	Supported Holes .....	60
4.16.1	Machine Controls .....	35	5.6.6	SMT .....	60
4.16.2	Solder Bath .....	36			
4.17	Reflow Soldering .....	37	<b>6</b>	<b>THROUGH-HOLE MOUNTING AND TERMINATIONS .....</b>	<b>63</b>
4.17.1	Intrusive Soldering (Paste-in-Hole) .....	46	6.1	Through-Hole Terminations – General .....	63
4.17.2	Selective Soldering .....	46	6.1.1	Lead Forming .....	65
4.18	Solder Connection .....	47	6.1.2	Termination Requirements .....	67
4.18.1	Exposed Surfaces .....	47	6.1.3	Lead Trimming .....	68
4.18.2	Solder Connection Anomalies .....	48	6.1.4	Interfacial Connections .....	68
4.18.3	Partially Visible or Hidden Solder Connections .....	49	6.1.5	Solder Meniscus in Solder .....	69
4.19	Heat Shrinkable Soldering Devices .....	49	6.2	Supported Holes .....	69
			6.2.1	Solder Application .....	69
<b>5</b>	<b>WIRES AND TERMINAL CONNECTIONS .....</b>	<b>49</b>	6.2.2	Through-Hole Component Lead Soldering .....	69
5.1	Wire and Cable Preparation .....	49	6.3	Unsupported Holes .....	69
5.1.1	Insulation Damage .....	50	6.3.1	Lead Termination Requirements for Unsupported Holes .....	69
5.1.2	Strand Damage .....	50			
5.1.3	Tinning of Stranded Wire .....	51	<b>7</b>	<b>SURFACE MOUNTING OF COMPONENTS .....</b>	<b>70</b>
5.2	Solder Terminals .....	51	7.1	Surface Mount Device Lead .....	70
5.3	Bifurcated, Turret and Slotted Terminal Installation .....	51	7.1.1	Plastic Components .....	70
5.3.1	Shank Damage .....	51	7.1.2	Forming .....	70
5.3.2	Flange Damage .....	52	7.1.3	Unintentional Bending .....	70
5.3.3	Flared Flange Angles .....	52	7.1.4	Flat Pack Parallelism .....	70
5.3.4	Terminal Mounting – Mechanical .....	52	7.1.5	Surface Mount Device Lead Bends .....	71
5.3.5	Terminal Mounting – Electrical .....	52	7.1.6	Flattened Leads .....	71
5.3.6	Terminal Mounting – Soldering .....	53	7.1.7	Parts Not Configured for Surface Mounting .....	71
5.4	Mounting to Terminals .....	53	7.2	Leaded Component Body Clearance .....	71
5.4.1	General Requirements .....	53	7.2.1	Axial-Leaded Components .....	71
5.4.2	Turret and Straight Pin Terminals .....	54	7.3	Parts Configured for Butt/I Lead Mounting .....	71
5.4.3	Bifurcated Terminals .....	54	7.4	Hold Down of Surface Mount Leads/Components .....	72
5.4.4	Slotted Terminals .....	55	7.5	Soldering Requirements .....	72
5.4.5	Hook Terminals .....	55	7.5.1	Misaligned Components .....	72

7.5.2	Unspecified and Special Requirements .....	72	9.1.3	Haloing .....	88
7.5.3	Bottom Only Chip Component Terminations .....	73	9.1.4	Edge Delamination .....	88
7.5.4	Rectangular or Square End Chip Components – 1, 3 or 5 Side Termination .....	73	9.1.5	Land/Conductor Separation .....	88
7.5.5	Cylindrical End Cap Terminations .....	73	9.1.6	Land/Conductor Reduction in Size .....	89
7.5.6	Castellated Terminations .....	73	9.1.7	Flexible Circuitry Delamination .....	89
7.5.7	Flat Gull Wing Leads .....	73	9.1.8	Flexible Circuitry Damage .....	89
7.5.8	Round or Flattened (Coined) Gull Wing Leads .....	74	9.1.9	Burns .....	89
7.5.9	J Lead Terminations .....	74	9.1.10	Non-Soldered Edge Contacts .....	89
7.5.10	Butt/I Terminations .....	74	9.1.11	Measles .....	89
7.5.11	Flat Lug Leads .....	74	9.1.12	Crazing .....	89
7.5.12	Tall Profile Components Having Bottom Only Terminations .....	74	9.2	Marking .....	90
7.5.13	Inward Formed L-Shaped Ribbon Leads .....	74	9.3	Bow and Twist (Warpage) .....	90
7.5.14	Surface Mount Area Array Packages .....	74	9.4	Depanelization .....	90
7.5.15	Bottom Termination Components (BTC) .....	75			
7.5.16	Components with Bottom Thermal Plane Terminations (D-Pak) .....	75	<b>10 COATING, ENCAPSULATION AND STAKING (ADHESIVE) .....</b>	<b>90</b>	
7.5.17	Flattened Post Connections .....	75	Δ10.0.1	Conformal Coating General .....	90
7.5.18	P-Style Terminations .....	75	Δ10.0.2	Conformal Coating Adhesion .....	91
7.6	Specialized SMT Terminations .....	75	Δ10.0.3	Substrate Preparation .....	92
<b>8 CLEANING PROCESS REQUIREMENTS .....</b>	<b>75</b>		10.1	Conformal Coatings – Materials .....	94
Δ8.0.1	Process Residues and Their Impact on Product Reliability .....	76	Δ10.1.1	Acrylic (AR) .....	96
Δ8.0.2	Historical Perspective on Cleaning and Cleaning Processes .....	76	Δ10.1.2	Epoxy (ER) .....	96
Δ8.0.3	Magnification and Visual Inspection for Cleanliness .....	77	Δ10.1.3	Silicone (SR) .....	96
Δ8.0.4	J-STD-001F Section 8 Demystified .....	78	Δ10.1.4	Polyurethane (UR) .....	96
8.1	Cleanliness Exemptions .....	78	Δ10.1.5	Paraxylylene (XY) .....	96
8.2	Ultrasonic Cleaning .....	79	Δ10.1.6	Two-Part Systems (Acrylic/Polyurethane and Other Combinations) .....	97
8.3	Post Solder Cleanliness .....	79	Δ10.1.7	Other Types of Conformal Coatings .....	97
8.3.1	Foreign Object Debris (FOD) .....	79	10.2	Conformal Coating – Masking .....	97
8.3.2	Flux Residue and Other Ionic or Organic Contaminants .....	79	10.3	Conformal Coating – Application .....	98
8.3.3	Post Soldering Cleanliness Designator .....	80	10.3.1	Conformal Coating on Components .....	99
8.3.4	Cleaning Option .....	80	10.3.2	Thickness .....	99
8.3.5	Tests for Cleanliness .....	80	10.3.3	Uniformity .....	99
8.3.6	Testing .....	80	10.3.4	Transparency .....	100
Δ8.4	Frequently Asked Questions on Cleanliness .....	83	10.3.5	Bubbles and Voids .....	100
<b>PCB REQUIREMENTS .....</b>	<b>88</b>		10.3.6	Delamination .....	100
9.1	Printed Circuit Board Damage .....	88	10.3.7	Foreign Objects Debris .....	100
9.1.1	Blistering/Delamination .....	88	10.3.8	Other Visual Conditions .....	100
9.1.2	Weave Exposure/Cut Fibers .....	88	10.3.9	Inspection .....	100
			10.3.10	Rework or Touchup of Conformal Coating .....	101
			10.4	Encapsulation .....	102
			10.4.1	Application .....	102
			10.4.2	Performance Requirements .....	102
			10.4.3	Rework of Encapsulant Material .....	102
			10.4.4	Encapsulant Inspection .....	103
			10.5	Staking .....	103

10.5.1	Staking – Application .....	103	Figure 3-10	Lead-Free Solder Alloy Attack of Wave Solder Equipment .....	16
10.5.2	Staking – Adhesive .....	103	Figure 3-11	Copper Erosion Due to Lead-Free Soldering Processes .....	17
10.5.3	Staking – Inspection .....	103	Figure 3-12	Coating Meniscus on a Lead .....	27
<b>11</b>	<b>WITNESS (TORQUE/ANTI-TAMPERING) STRIPE</b> .....	103	Figure 4-1	Thermal Shunt .....	32
<b>12</b>	<b>PRODUCT ASSURANCE</b> .....	104	Figure 4-2	Component Bridging .....	33
12.1	Hardware Defects Requiring Disposition .....	104	Figure 5-1	Compound Wire Stripper .....	49
12.2	Inspection Methodology .....	104	Figure 5-2	Stripped Wire .....	50
12.2.1	Process Verification Inspection .....	104	Figure 5-3	Antiwicking Tool .....	51
12.2.2	Visual Inspection .....	104	Figure 5-4	Flange Damage .....	52
12.2.3	Sampling Inspection .....	105	Figure 5-5	Flare Angles .....	52
12.3	Process Control Requirements .....	105	Figure 5-6	Terminal Mounting – Mechanical .....	52
12.3.1	Opportunities Determination .....	106	Figure 5-7	Terminal Mounting .....	52
12.4	Statistical Process Control .....	106	Figure 5-8	Stress Relief .....	53
<b>13</b>	<b>REWORK AND REPAIR</b> .....	106	Figure 5-9	Wire Wrap .....	53
13.1	Rework .....	106	Figure 5-10	Wire Wrap Around Terminal Post .....	53
13.2	Repair .....	106	Figure 5-11	Continuous Runs .....	54
13.3	Post Rework/Repair Cleaning .....	106	Figure 5-12	Wire and Lead Wrap Around .....	54
<b>APPENDIX GUIDE</b> .....	107	Figure 5-13	Side Route Connections and Wrap on Bifurcated Terminal .....	55	
<b>APPENDIX A</b>	<b>Guidelines for Soldering Tools and Equipment</b> .....	108	Figure 5-14	Bottom Route Terminal Connection .....	55
<b>APPENDIX B</b>	<b>Minimum Electrical Clearance – Electrical Conductor Spacing</b> .....	110	Figure 5-15	Top Route Terminal Connection .....	55
<b>APPENDIX C</b>	<b>J-STD-001 Guidance on Objective Evidence of Material Compatibility</b> .....	111	Figure 5-16	Hook Terminal Connections .....	56
<b>APPENDIX D</b>	<b>Cross Reference Listing by Revision</b> .....	111	Figure 5-17	Immersed or Perforated Terminal Wire Placement .....	56
<b>ACRONYM INDEX</b> .....	119	Figure 5-18	Solder Height .....	57	
		Figure 5-19	Jumper Wires .....	62	
		Figure 6-1	Component Lead Stress Relief Examples .....	63	
		Figure 6-2	Side Mounting .....	63	
		Figure 6-3	Vertical Mounting of Freestanding Components .....	64	
		Figure 6-4	Mounting of Components with Dual Non-Axial Leads .....	64	
		Figure 6-5	Typical Configuration of Components with Dual Non-Axial Leads .....	64	
		Figure 6-6	End Mounting .....	64	
		Figure 6-7	Mounting with Feet on Standoffs .....	65	
		Figure 6-8	Non-Resilient Footed Standoffs .....	65	
		Figure 6-9	Lead Forming Forces .....	66	
		Figure 6-10	Lead Bends .....	67	
		Figure 6-11	Through-Hole Mounting Methods .....	67	
		Figure 6-12	Via Fill .....	69	
		Figure 7-1	Surface Mount Device Lead Forming .....	70	
		Figure 7-2	DIP Lead Forming .....	70	
		Figure 7-3	Surface Mounted and Butt/I Mounted DIPS .....	71	
		Figure 8-1	Burned PCB .....	76	
		Figure 8-2	Dendrites .....	76	
		Figure 8-3	Solder Mask Surface Appearance .....	77	

### Figures

Figure 3-1	Phase Diagram for Eutectic Solder .....	11
Figure 3-2	Eutectic Solder Microstructure .....	11
Figure 3-3	Eutectic Solder Microstructure .....	11
Figure 3-4	Solder Wire Core Flux Comparison .....	13
Figure 3-5	Solder Alloy Fracture Toughness Testing Results .....	14
Figure 3-6	Solder Alloy Drop Shock Testing Results .....	14
Figure 3-7	Lead-Free Solder Alloy/Component Surface Finish Incompatibility Example .....	15
Figure 3-8	left: Non-Uniform Solder Joint Microstructure, right: Incomplete Solder Joint Reflow (Head-on-Pillow) .....	16
Figure 3-9	Component Degradation Due to Lead-Free Soldering Process Incompatibility .....	16

Figure 8-4	White Residue .....	78	Table 4-1	Baking Times and Temperatures (Bare/ Unpopulated PCB) .....	35
Figure 8-5	Frosted Solder Appearance .....	78	Table 4-2	Common Screen Parameters .....	39
Figure 8-6	Average Tin Whisker Density .....	87	Table 4-3	Common Screening Problems and Solutions ...	39
Figure 8-7	Average Tin Whisker Density .....	88	Table 4-4	Physical Properties of Vapor Phase Reflow Fluids .....	41
Figure 10-1	Cure Windows of Primer Cure .....	93	Table 4-5	Advantages and Disadvantages of Vapor Phase Soldering .....	41
Figure 10-2	Conditions that Influence the Extent of Primer Cure .....	93	Table 4-6	Thermal Data for Electronic Materials .....	42
Figure 10-3	Influence of Temperature and Humidity .....	94	Table 4-7	Problems and Solutions in Vapor Phase Soldering .....	43
Figure 10-4	Conformal Coating Family Trees .....	95	Table 4-8	IR Radiation .....	44
<b>Tables</b>					
Table 1-1	Metric Prefixes .....	3	Table 4-9	Advantage and Disadvantages of IR Soldering .....	44
Table 1-2	Conversion Formulae .....	3	Table 4-10	Characteristics of Infrared Sources for SMT Soldering .....	44
Table 3-1	Common Physical Property Values for Eutectic or Near Eutectic Tin/Lead Solder .....	12	Table 5-1	Allowable Strand Damage .....	50
Table 3-2	Lead-Free Solder Alloys .....	13	Table 5-2	Hook Terminal Wire Placement .....	56
Table 3-3	Lead-Free Solder Alloys and Their Melting Temperatures .....	13	Table 5-3	Pierced or Perforated Terminal Wire Placement .....	56
Table 3-4	Levels of Allowable Solder Impurities for Sn60Pb40 and Sn63Pb37 Solders (Weight %) .....	18	Table 6-1	Component to Land Clearance .....	63
Table 3-5	Test Requirements for Flux Classifications (from J-STD-004B w/Amendment 1) .....	22	Table 6-2	Components with Spacers .....	65
Table 3-6	Flux Identification System (from J-STD-004B w/Amendment 1) .....	22	Table 6-3	Lead Bend Radius .....	66
Table 3-7	Mesh Size vs. Particle Size for Solder Powders Used in Solder Paste .....	24	Table 6-4	Protrusion of Leads in Supported Holes .....	68
Table 3-8	Recommended Viscosities of Solder Pastes ....	25	Table 6-5	Protrusion of Leads in Unsupported Holes .....	68
Table 3-9	Effects of Parameters on Viscosity .....	25	Table 8-1	Equivalency Values from MIL-STD-2000 .....	82
			Table 8-2	Flux Identification .....	84
			Table 10-1	Preferred Conformal Coating Removal Methods .....	102

# Handbook and Guide to Supplement J-STD-001

## Δ 0.1 GENERAL

**Δ 0.1.1 Scope** This Handbook is a companion reference to the J-STD-001 *Requirements for Soldered Electrical and Electronic Assemblies* (Standard) and is intended to provide supporting information.

Additional detailed information can be found in documents referenced within the Standard (and this Handbook). Users are encouraged to reference those documents to better understand the applicable subject areas.

Although this Handbook uses mandatory terminology (e.g., **shall**, **must**, etc.), nothing within this Handbook is considered mandatory unless this document is specified as a mandatory requirement in the contract documentation.

The intent of this Handbook is to capture “how and why” information and give more background on the specification limits and how they were derived. In addition, other supporting information is provided to give a broader understanding of the process considerations needed for the production of acceptable hardware. The target user of this Handbook is a Process or Manufacturing Engineer.

**NOTE:** The revision of this Handbook (“F”) was revised in an attempt to align with the base document/Standard (J-STD-001 also rev “F”). Please check for the latest revision or for any amendment(s) that may include changes that could alter explanations for how and why, or more detailed discussions on criteria.

**Δ 0.1.2 Purpose** The Handbook describes materials, methods, and verification criteria that, when applied as recommended or required, will produce quality soldered electrical and electronic assemblies. The intent of the Handbook is to explain the “how-to,” the “why,” and fundamentals for these processes, in addition to implementing control over processes rather than depending on end-item inspection to determine product quality.

The J-STD-001 and the IPC-HDBK-001 do not exclude any acceptable process used to make the electrical connections, as long as the methods used will produce completed solder joints conforming to the acceptability requirements of the Standard.

## Δ 0.2 FORMAT (Using This Handbook)

This Handbook provides guidance on the J-STD-001F requirements. The section and paragraph numbers in this Handbook refer and correspond to the section and paragraph numbers in J-STD-001F. However, the information provided in this Handbook is applicable to Users of any previous version of J-STD-001.

Although this document will not provide discussion on each of the differences between J-STD-001F and J-STD-001FS, it may provide information on certain topics addressed in J-STD-001FS, i.e., lead-free mitigation, that may need to be considered in a general soldering process. This information will be included in the applicable section of this Handbook and not highlighted in any manner.

A cross reference listing, provided as Appendix D to this Handbook, will assist Users with identifying related paragraphs in previous revisions of J-STD-001. This cross reference listing includes identification of the associated Space Applications Electronic Hardware Addendum paragraphs for revisions E (ES) and D (DS).

Information concerning the appendices in J-STD-001 is either addressed in the body of this Handbook or covered more thoroughly in another document. An appendices guide is included at the end of Section 13 that links the topics discussed in the appendices of J-STD-001 to the appropriate supplemental information.

Where used verbatim, text that is directly quoted from a standard is italicized. In this Handbook, the word “Standard” refers specifically to J-STD-001 Revision F.

**NOTE:** References in the text of this Handbook (not text quoted from a Standard) referring only to Sections, Tables, and Figures in this Handbook will be annotated accordingly (see Example 1). If the reference is to a Section, Table, or Figure in the Standard, it will be followed by “of the Standard” (see Example 2).

**Example 1:** For more information on lead trimming, see 5.2.0.5.

**Example 2:** For more information on surface mount components, see Table 7-2 of the Standard.