BS EN 16602-70-61:2022



BSI Standards Publication

Space product assurance — High-reliability soldering for surface mount, mixed technology and hand-mounted electrical connections

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National foreword

This British Standard is the UK implementation of EN 16602-70-61:2022. It supersedes BS EN 16602-70-08:2015, BS EN 16602-70-07:2014 and BS EN 16602-70-38:2019, which are withdrawn.

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Space product assurance - High-reliability soldering for surface mount, mixed technology and hand-mounted electrical connections

Assurance produit des projets spatiaux - Soudure haute fiabilité pour les connexions électriques à montage en surface, à technologie combinée et montées à la main

Raumfahrtproduktsicherung - Hochzuverlässige Montage von Oberflächen-Befestigungen und Durchgangslochverbindungen

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European Foreword

This document (EN 16602-70-61:2022) has been prepared by Technical Committee CEN/CLC/JTC 5 “Space”, the secretariat of which is held by DIN (Germany).

This document (EN 16602-70-61:2022) originates from ECSS-Q-ST-70-61C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2023, and conflicting national standards shall be withdrawn at the latest by May 2023.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 16602-70-38:2019; EN 16602-70-07:2014; EN 16602-70-08:2015.

This new ECSS Standard (ECSS-Q-ST-70-61C) was created by merging and updating the content of the following three standards:

- ECSS-Q-ST-70-07C “Verification and approval of automatic machine wave soldering”
- ECSS-Q-ST-70-08C “Manual soldering of high-reliability electrical connections”
- ECSS-Q-ST-70-38C Rev.1 “High-reliability soldering for surface-mount and mixed technology”

The intention of this completely new standard was to optimize the structure of the document, following the chronological order of assembly processes and introducing criterion for new technologies that were not covered by the three standards now superseded by this new standard.

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and will therefore have precedence over any EN covering the same scope but with a wider do-main of applicability (e.g. : aerospace).

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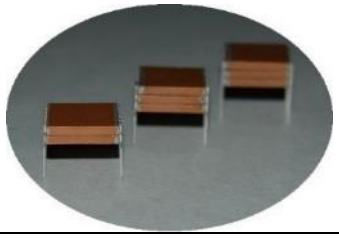
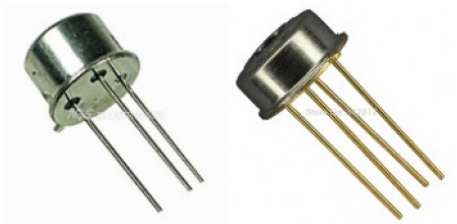
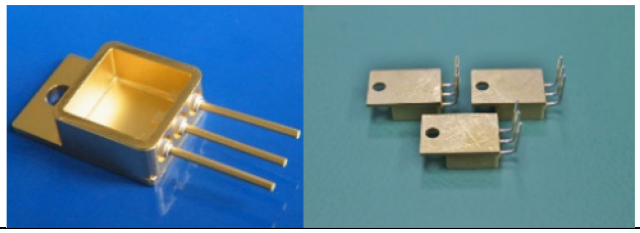
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Introduction

This document defines the technical requirements and quality assurance provisions for the manufacture and verification of high-reliability electronic circuits of surface mount, through hole, solderless assemblies, and soldering of harness and wire interconnection, for space applications, launchers, and associated equipment.

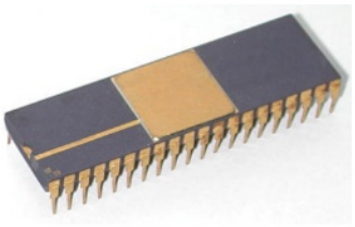
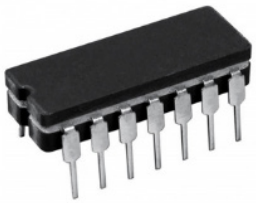
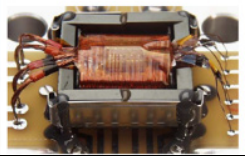
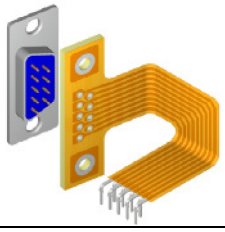
In the following table, principal types of through hole components and SMDs, including examples, can be gathered in the following families.

NOTE In the text of this document the term "component" is used instead of "device".

THROUGH HOLE COMPONENTS (non exhaustive list)	
Radial component resistors capacitors fuses diodes	
Axial component Capacitors resistors diodes	
Stacked capacitors CH capacitors CNC capacitors	
TO Metal Can package TO-39	
TO Metal tab package TO254	

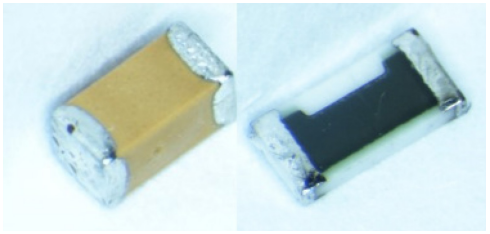
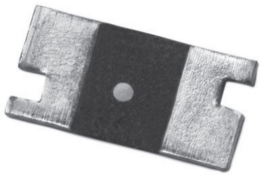
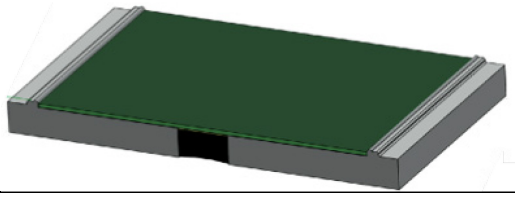
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THROUGH HOLE COMPONENTS (non exhaustive list)	
Dual in Line Package (DIL or DIP) Side brazed DIP and DIL	 
Connectors	 
Leaded magnetics transformers with straight pins	  
Sculptured flex	

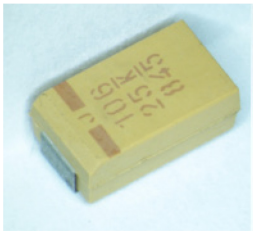
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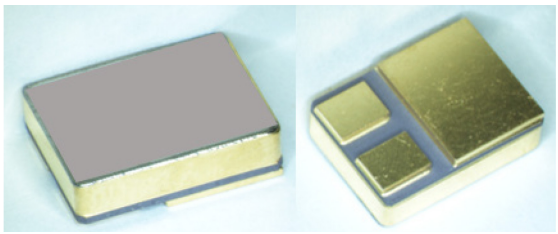
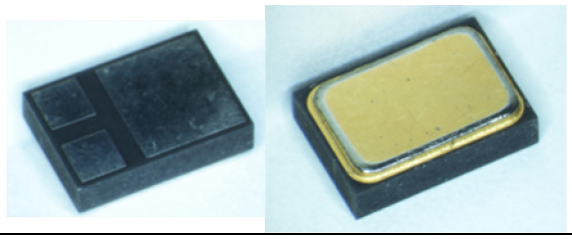
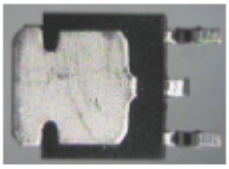
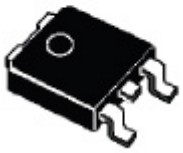
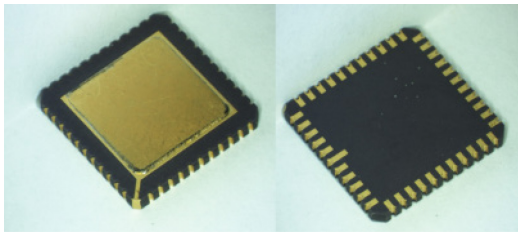
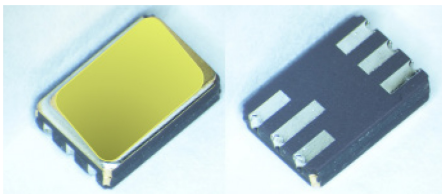
SMT COMPONENTS (non exhaustive list)	
Rectangular and square end-capped or end-metallized component with rectangular body, leadless chip (see 10.4.2) ceramic end capped chip resistors and capacitors.	
ceramic resistors arrays	
metallic terminations fuses, thermistors CSM 2512	
metallic termination resistor SMS 2512	
Cylindrical and square end-capped components with cylindrical or oval body, leadless chip (see 10.4.3) MELF for cylindrical end capped: • Diodes in MELF, minimelf or micromelf	

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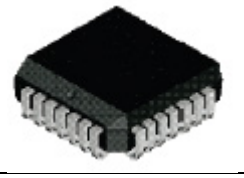
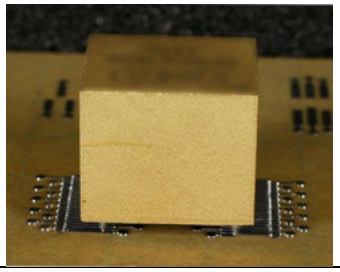
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SMT COMPONENTS (non exhaustive list)	
• Resistors in MELF, minimelf or micromelf	
Square end capped: • D- 5 family for square end capped with cylindrical or oval bodies	
Bottom terminated chip component (see 10.4.4) **This type of component has either metallised terminations on the bottom side or extended terminals from the bottom side.** Chip inductors	 
Component with inward formed L-shaped leads (see 10.4.5) moulded tantalum chip capacitors. SMD moulded shunt	  

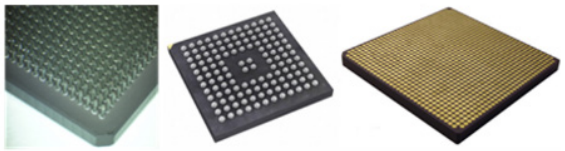
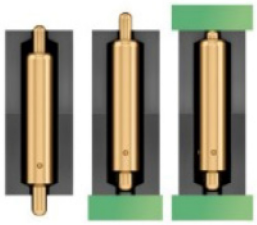
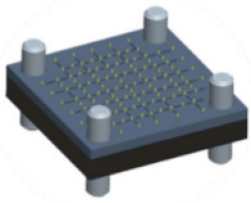
Documents
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SMT COMPONENTS (non exhaustive list)	
Leadless component with plane termination (see 10.4.6) - With metal plane termination: SMD0.5, SMD1, SMD2, SMD0.2*(TO276 JEDEC family denomination) - With non-metal plane termination: SMD0.2* ***Package exists in two versions**	 
Leaded component with plane termination (see 10.4.7) Diode PAcKage (DPAK or TO252)	  DPAK
Leadless castellated ceramic chip carrier component (see 10.4.8) The main component of this type is leadless ceramic chip carrier (LCCC) LCC6	 
No lead QFN (see 10.4.9) quad flat pack no leads	

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SMT COMPONENTS (non exhaustive list)	
Flat pack and gull-wing leaded component (see 10.4.10) small-outline transistor (SOT), small-outline package (SO), flat pack and quad flat pack (QFP) and SMD connectors with stress-relief (MHD). transformers Components with both flat rectangular and round leads are included in this group. The components can be delivered either with pre-formed leads or with straight leads which will be then in-house preformed by the user.	 
"J" leaded component (see 10.4.11) ceramic leaded chip carriers (CLCC) and plastic leaded chip carriers (PLCC).	
Components with ribbon terminals without stress relief (flat lug leads) (see 10.4.12) This package has flat leads extending from the sides	
Stacked modules components with leads protruding vertically from bottom (see 10.4.13)	

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SMT COMPONENTS (non exhaustive list)	
Area array components (AAD) (see 10.4.14) Components connected via an array of solder columns (Column Grid Array - CGA), solder balls (Ball Grid Array - BGA) or directly to the board (Land Grid Array - LGA). The columns and balls consist of various types of solder with wide-ranging properties.	 CGA BGA LGA
Solderless connection (see 10.7) solderless connectors solderless interposers for LGA or connectors	 

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1
Scope

This Standard defines the technical requirements and quality assurance provisions for the manufacture and verification of high-reliability electronic circuits of surface mount, through hole, solderless assemblies and soldering of harness and wire interconnection.

The Standard defines workmanship requirements, the acceptance and rejection criteria for high-reliability assemblies intended to withstand ground testing conditions including LTS (long term storage) and the environment imposed by space flight and launchers.

The mounting and supporting of components, terminals and conductors specified in this standard applies only to assemblies designed to continuously operate over the mission within the temperature limits of -55 °C to +85 °C at solder joint level.

Requirements related to printed circuit boards are contained in ECSS-Q-ST-70-60 and ECSS-Q-ST-70-12.

This standard does not cover lead-free soldering and associated requirements.

This Standard does not cover the qualification and acceptance of the EQM and FM equipment with high-reliability electronic circuits of surface mount, through hole and solderless assemblies.

This Standard does not cover verification of thermal properties for component assembly.

This Standard does not cover pressfit connectors due to the possible damage in the PCB that is not evaluated within this test requirement.

The qualification and acceptance tests of equipment manufactured in accordance with this Standard are covered by ECSS-E-ST-10-03.

This standard may be tailored for the specific characteristics and constraints of a space project, in accordance with ECSS-S-ST-00.

Documents
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2
Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system - Glossary of terms
EN 16601-40	ECSS-M-ST-40	Space project management - Configuration and information management
EN 16602-10-09	ECSS-Q-ST-10-09	Space product assurance - Nonconformance control system
EN 16602-20	ECSS-Q-ST-20	Space product assurance - Quality assurance
EN 16602-60	ECSS-Q-ST-60	Space product assurance - Electrical, electronic and electromechanical (EEE) components
EN 16602-60-05	ECSS-Q-ST-60-05	Space product assurance - Generic requirements for hybrids
EN 16602-60-13	ECSS-Q-ST-60-13	Space product assurance - Commercial electrical, electronic and electromechanical (EEE) components
EN 16602-70	ECSS-Q-ST-70	Space product assurance - Materials, mechanical parts and processes
EN 16602-70-01	ECSS-Q-ST-70-01	Space product assurance - Cleanliness and contamination control
EN 16602-70-02	ECSS-Q-ST-70-02	Space product assurance - Thermal vacuum outgassing test for the screening of space materials
EN 16602-70-12	ECSS-Q-ST-70-12	Space product assurance - Design rules for printed circuit boards
EN 16602-70-28	ECSS-Q-ST-70-28	Space product assurance - Repair and modification of printed circuit board assemblies for space use
EN 16602-70-60	ECSS-Q-ST-70-60	Space product assurance -Qualification and procurement of printed circuit boards
EN 16602-70-71	ECSS-Q-ST-70-71	Space product assurance -Materials processes and their data selection
	EN 61340-5-1:2016	Electrostatics - Part 5-1: Protection of electronic devices from electrostatic phenomena - General requirements

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	ESA-STR-258	ESA-Approved Skills Training Schools - Electronic Assembly Techniques
	ESCC 23500 (September 2013)	Requirements for lead materials and finishes for components for space application
	IPC J-STD-001H (September 2020)	Requirements for Soldered Electrical and Electronic Assemblies
	IPC J-STD-004B-AM1 (November 2011)	Requirements for Soldering Fluxes
	IPC J -STD-033D (January 2018)	Handling, Packing, Shipping and Use of Moisture, Reflow, and Process Sensitive Devices
	IPC-TM-650 (Latest edition)	Test methods manual
	ISO 9454-1:2016	Soft soldering fluxes — Classification and requirements — Part 1: Classification, labelling and packaging
	ISO 14644-1:2015	Cleanrooms and controlled environments — Part 1: Classification of air cleanliness by particle concentration
	MIL-STD-883 K Method 2009 (April 2016)	Test Method Standard, Microcircuits

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3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms from other standards

a. For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

b. For the purpose of this Standard, the terms and definitions from ECSS-Q-ST-60 apply, in particular for the following term(s):

   1. commercial component

c. For the purpose of this Standard, the terms and definitions from ECSS-Q-ST-70-28 apply, in particular for the following term(s):

   1. repair
   2. rework

3.2 Terms specific to the present standard

3.2.1 Approval Authority

entity that reviews and accepts the verification programme, evaluating the test results and grants the final approval

3.2.2 assembly sensitive component

component prone to have cracks in solder joint exceeding 75 % of acceptance criteria of solder cracks or showing nonconformance outside the component manufacturer limit, due to assembly.

NOTE 1 The ESA list of assembly sensitive components is regularly updated and published on ESCIES for information, see www.escies.org, Technologies - ESA SMT Verification. ESA-TECMSP-MO-018961.

NOTE 2 Each company maintains its own list of assembly sensitive components in the PID.

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3.2.3 bifurcated terminal

terminal containing a slot or split in which wires or leads are placed before soldering

NOTE The term "**split terminal**" is synonymous.

3.2.4 blister

delamination in form of localized swelling and separation between any of the layers of a laminated base material in a printed circuit board

3.2.5 bonding

application process of adhesive underneath a package for mechanical or thermal purpose

3.2.6 bridging

build-up of solder or conformal coating between components, component leads or base substrate forming an elevated path

3.2.7 clinched lead

conductor or component lead which passes through a printed circuit board and is then bent to contact the printed circuit board pad

NOTE The clinched portion is not forced to lie flat on the pad and some innate spring back is desirable before this form of termination is soldered.

3.2.8 cold flow

tendency of a solid material to move slowly or deform permanently under the influence of persistent mechanical stresses.

NOTE For example, for PTFE (Teflon) insulation sleeves under pressure.

3.2.9 cold solder joint

joint in which the solder has a blocky, wrinkled or piled-up appearance and shows signs of improper flow or wetting action

NOTE It can appear either shiny or dull, but not granular. The joint normally has abrupt lines of demarcation rather than a smooth, continuing fillet between the solder and the surfaces being joined. These lines are caused by either insufficient application of heat or the failure of an area of the surfaces being joined to reach soldering temperature.

3.2.10 conformal coating

thin polymeric film applied on a populated PCB that conforms to the shape of the surface it covers.

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3.2.11 co-planarity

difference between maximum and minimum termination height when component rests on flat surface

3.2.12 collective assembled components

set of components that are soldered to PCB in one operation

NOTE For example, vapour phase soldered components, in contrast to manually soldered where each component is soldered individually.

3.2.13 critical zone

area in the solder joint in which the existence and magnitude of cracks is subject to acceptance or rejection

3.2.14 dewetting

condition in a soldered area in which the liquid solder has not adhered intimately, characterized by an abrupt boundary between solder and conductor, or solder and terminal/termination area

NOTE This is often seen as a dull surface with islands of thicker shiny solder.

3.2.15 disturbed solder joint

unsatisfactory connection resulting from relative motion between the conductor and termination during solidification of the solder

3.2.16 dynamic wave soldering machine

system that achieves wave soldering and which consists of stations for fluxing, preheating, and soldering by means of a conveyor

3.2.17 electrical clearance

spacing between separate electrical conductors of a printed circuit board assembly

3.2.18 exposed pad

exposed metallization on the bottom of a package

NOTE The exposed pad can have both electrical or thermal purpose and is often plated with same material and finish as the edge terminations, for soldering purposes. Exposed pad can be thermally bonded, soldered or left unconnected if not needed for the intended application.

3.2.19 fillet

smooth concave build-up of material between two surfaces

NOTE Example: A fillet of solder between a component lead and a solder pad or terminal, or a fillet of

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conformal coating material between a component and printed circuit board.

3.2.20 flux

material which, during soldering, removes the oxide film, protects the surface from oxidation, and permits the solder to wet the surfaces to be joined

3.2.21 glass meniscus

glass fillet of a lead seal which occurs where an external lead leaves the package body

3.2.22 modal survey

characterization of the dynamic properties of systems in the frequency domain

NOTE A typical example is testing structures under vibrational excitation

3.2.23 outsourcing

act of subcontracting work to another company in compliance with customer PID

3.2.24 pin in paste

process where a through hole component is mounted and soldered in the surface mounting process

3.2.25 pits

small holes or sharp depressions in the surface of solder

NOTE This can be caused by flux blow-out due to entrapment or overheating.

3.2.26 potting compound

compound, usually electrically non-conductive, used to encapsulate or as a filler between components, conductors, or assemblies

3.2.27 pressfit connector

solderless termination technology where each contact is pressed into a plated hole of a printed circuit board creating a mechanical and electrical joint

3.2.28 reprocessing

preparatory operation done on a component prior to assembly

NOTE Degolding, pretinning, lead forming, and cutting are examples of reprocessing.

3.2.29 shield

metallic sheath surrounding one or more wires, cables, cable assemblies, or a combination of wires and cables that is used to prevent or reduce the transmission of electromagnetic energy to or from the enclosed conductors

NOTE The shield also includes an insulating jacket that can cover the metallic sheath.

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3.2.30 solder balls

numerous spheres of solder having not melted in with the joint form and being scattered around the joint area normally attached by flux residues

NOTE Can be caused by incorrect preheating or poor-quality solder.

3.2.31 solder-cup terminal

hollow, cylindrical terminal closed at one end to accommodate one or more conductors

3.2.32 solder icicle

conical peak or sharp point of solder usually formed by the premature cooling and solidification of solder upon removal of the heat sources

3.2.33 solder pad

conductive surface on a printed circuit board to which terminations are soldered to form electrical connections

3.2.34 solder stand-off

thickness of solder between the underside of the component termination and the solder pad

3.2.35 split terminal

see "**bifurcated terminal**" 3.2.3

3.2.36 staking

application process of adhesive on the outside of a package for mechanical purpose

3.2.37 stress relief

method or means to minimize stresses to the soldered termination or component

NOTE Generally, in the form of a bend or service loop in a component lead, solid or stranded wire to provide relief from stress between terminations, as that caused, for instance by movement or thermal expansion.

3.2.38 stud termination

upright conductor termination through a printed circuit board

3.2.39 technology samples

samples of boards assembled with representative technology

3.2.40 thermal shunt

element with good heat-dissipation characteristics used to conduct heat away from an article being soldered

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3.2.41 turret terminal

round post-type grooved stud around which conductors are fastened before soldering

3.2.42 underfill

material deposited between a component and substrate

3.2.43 verification board

substrate assembled with components subjected to a verification programme

3.2.44 wicking

flow of molten solder or cleaning solution by capillary action

NOTE Occurs when joining stranded wire; solder is drawn within the strands, but normally not visible on outer surface of strands. Wicking can also occur within the stress relief bend of a component lead.

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
AAD	area array device NOTE: also known as "area array component"
AOI	automatic optical inspection
AWG	American wire gauge
AXI	automatic X-ray inspection
BGA	ball grid array
CBGA	ceramic ball grid array
CCGA	ceramic column grid array
CGA	column grid array
CLCC	ceramic leadless chip carrier
CTE	coefficient of thermal expansion
DCL	declared component list
DIL	dual in line
DIP	dual in line package
DPAK	diode package
DRD	document requirement definition
EDX	Energy dispersive X-ray
ETFE	ethylene tetrafluoroethylene

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Abbreviation	Meaning
EPA	ESD protected area
ESD	electrostatic discharge
FEP	fluorinated ethylene propylene
FM	flight model or flight hardware
FP	flat pack package
IST	interconnect stress testing
JEDEC	Joint Electron Device Engineering Council
LCCC	leadless ceramic chip carrier
MELF	metal electrode face bonded NOTE: MELF includes the terms "minimelf" and "micromelf"
MIP	mandatory inspection point
MPCB	Materials, Mechanical Parts and Processes Control Board
MRR	manufacturing readiness review
MSL	moisture sensitivity level
NCR	Nonconformance report
PCB	printed circuit board
PLCC	plastic leaded chip carrier
PID	process identification document
PSD	power spectral density
PTFE	polytetrafluoroethylene
PTH	plated though hole
QFN	quad flat pack no leads
QFP	quad flat pack
R_g	resistance to ground
R_s	surface resistance
r.m.s.	root-mean-square
SEM	scanning electronic microscope
SIR	surface insulation resistance
SMD	surface mounted device NOTE: In the text of this document the term “component” is used instead of “device”
SMT	surface-mount technology
SO	small outline
SOD	small outline diode
SOT	small outline transistor
SOP	small outline package

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Abbreviation	Meaning
TO	transistor outline
TRB	test review board
TRR	test readiness review
TSOP	thin small outline package
RF	radio frequency

3.4 Nomenclature

The following nomenclature apply throughout this document:

a. The word “shall” is used in this document to express requirements. All the requirements are expressed with the word “shall”.

b. The word “should” is used in this document to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, all the recommendations in this standard are either converted into requirements or tailored out.

c. The words “may” and “need not” are used in this document to express positive and negative permissions respectively. All the positive permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.

d. The word “can” is used in this document to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have a completely different meaning: “may” is normative (permission) and “can” is descriptive.

e. The present and past tense are used in this document to express statement of fact, and therefore they imply descriptive text.

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4 Principles of reliable soldered connections

The following are the general principles to provide reliable soldered connections:

- Reliable soldered connections are the result of proper design, control of tools, materials, processes work environments and workmanship performed in accordance to verified and approved procedures, inspection control and precautions.
- The basic design concepts to provide reliable connections and to avoid solder joint failure are as follows:
  - Stress relief is an inherent part of the design which reduces detrimental thermal and mechanical stresses on the solder connections.
  - Where adequate stress relief is not possible materials are so selected that the mismatch of thermal expansion coefficients is a minimum at the constraint points in the component mounting configuration.
- The assembled substrates are designed to allow easy inspection, rework, and repair.
- The electrical and mechanical integrity of components and assemblies are retained after exposure to processes employed during manufacture and assembly, as handling, baking, fluxing, soldering, cleaning depanelization, electrical test and PCB integration.
- Soldering to gold using tin-lead alloy can cause failure.

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5
Preparatory conditions

5.1 Facility cleanliness

a. Personnel facilities shall be separated from the soldering areas.

NOTE Example: Washrooms, eating areas, smoking facilities.

b. Furniture shall be arranged to allow thorough cleaning of the floor and workbench.

c. Areas used for soldering shall be kept free from contaminants.

NOTE Loose material such as dirt, dust, solder particles, oil or clipped wires can contaminate soldered connections.

d. Working areas shall be kept free from any tools or equipment not used for the current task.

e. Working surfaces shall be covered with an easily cleaned hard top or have a replaceable surface of clean, non-corrosive, silicone-free ESD compatible paper.

f. Tools used during soldering operations shall be free of visible contaminant.

g. Excess lubricants shall be removed from tools before soldering starts.

5.2 Environmental conditions

a. The clean room shall be compliant to the requirements of clause 5.3.1 of ECSS-Q-ST-70-01.

b. The soldering area shall have as minimum a cleanliness level of ISO Class 8.2 in accordance with ISO 14644-1 (2015).

NOTE Particle concentrations for ISO Class 8.2 are not mentioned in the ISO Standard and can only be calculated with the formula in Annex E of ISO 14644-1 (2015). See Table 5-1.

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Table 5-1: Particle concentrations classes 8 till 9 according to ISO 14644-1 (2015)

Particle sizes				
ISO class	**0,5 µm**	**1 µm**	**5 µm**	**Comment**
ISO-class 8	3 520 000	832 000	29 300	From Table 1 of ISO
ISO-class 8.1	4 430 000	1 050 000	36 800	Calculation acc ISO Annex E equation
ISO-class 8.2	5 570 000	1 320 000	46 400	Calculation acc ISO Annex E equation
ISO-class 8.5	11 100 000	2 630 000	92 500	From Annex E in ISO
ISO-class 9	35 200 000	8 320 000	293 000	From Table 1 of ISO

c. Areas used for assembly or cleaning of components and areas where toxic or volatile vapours are generated or released shall include a local air extraction system.

d. The room temperature of the facility shall be maintained at (22 ±3) °C.

e. The relative humidity at room temperature of the facility shall be maintained at (55 ±10) %.

f. The soldering area shall not be exposed to draughts.

g. Air shall be supplied to the room through a filtering system that provides a positive pressure difference with respect to adjacent rooms.

5.3 Lighting requirements

a. Lighting intensity shall be a minimum of 1080 lux on the work surface.

NOTE In selecting a light source, the colour temperature of the light is an important consideration. Light ranges from 3000 K-5000 K enable users to distinguish various printed circuit assembly features and contaminants with increased clarity.

b. At least 90 % of the work area shall be without shadows or severe reflections.

5.4 Precautions against static discharges

5.4.1 Overview

Electronic components are particularly sensitive to electrostatic charging and discharging. To protect these components, it is necessary to define measures with regard to their handling, transport and storage.

The ESD control programme helps reducing to a minimum level the ESD-related damage to components. Main topics of the programme are:

- ESD coordinator,

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- Training,
- Product qualification,
- Compliance verification,
- Grounding/bonding systems,
- Personnel grounding,
- EPA requirements,
- Packaging systems,
- Marking.

The controls referenced in this document have been selected from document "ANSI/ESD S20.20-2014 2.0 SCOPE". The goal is to prevent damage of the isolated conductors and of the ESD sensitive devices (ESDS) which are susceptible to discharges that are greater than or equal to 100 V (Human Body Model) or 200 V (Charged Device Model).

5.4.2 General

a. An ESD Control Programme in accordance with EN 61340-5-1 (2016) shall be developed and implemented by the supplier.

NOTE IEC TR 61340-5-2 guideline can be used for editing the ESD Control Programme.

b. The process for the selection of new components shall include their ESD sensitivity.

c. Electrostatic sensitive components shall be handled, prepared, mounted, soldered, and cleaned in an ESD protected area compatible with ESD class of the components.

NOTE Electrostatic sensitive components are classified in different categories. For some, additional ESD conditions to the nominal are needed.

5.4.3 ESD Protected Area

a. ESD sensitive devices shall be assembled in an EPA.

b. As a minimum, a dissipative mat, a wrist strap and common grounding facility for both shall be in place in the EPA.

c. EPA areas shall be visibly marked as such.

d. ESD rules and regulations shall apply as specified in EN 61340-5-1 (2016).

e. If the measured electrostatic field or surface potential exceeds the stated limits, ionization or other charge mitigating techniques shall be used.

f. Relative Humidity shall be controlled in the EPA in accordance with requirement 5.2e.

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5.4.4 Precautions against ESD during manufacturing

a. Delimited EPA and corresponding ESD control items shall be in compliance with Table 5-2.

b. Ionized air in presence of high voltage or RF shall be used in compliance with components manufacturer recommendations.

NOTE Static charges on isolated components or tooling can be dissipated using ionised air.

c. A wrist strap shall be worn by the operator.

d. Powered equipment at the workstation shall be grounded.

e. The normal value of the resistance between the tip of the soldering system and the ground of the ESD protected area shall not exceed 5 Ω.

NOTE The measurement is generally performed at soldering temperature.

f. A ground-fault circuit interrupter shall be installed.

g. Protective clothing shall be made from static dissipative material.

h. Gloves and finger cots shall be made from static dissipative material.

i. Tools, such as mounting aids, consumables, masking tape, shall be conductive or static dissipative.

j. Paperwork accompanying ESD sensitive components shall be contained in static dissipative bags or envelopes.

NOTE Example of accompanying paperwork are traveller logs, drawings, and instructions.

k. Paperwork shall not come into contact with ESD sensitive components.

Table 5-2: EPA requirements summary

ESD Control item		Limits values * (unit: Ω)
Working surfaces, storage, racks and trolleys	Dissipative top surface	$R_s < 1 \times 10^9$
	ESD protected to ground	$R_g < 1 \times 10^9$
Flooring	ESD protected to ground	$R_g < 1 \times 10^9$
Ionization		Decay (1000 V to 100 V) in less than 20 s Offset voltage ± 35V
Seating	ESD protected to ground	$R_g < 1 \times 10^9$
Wrist strap system	ESD protected to ground	$R_g < 35 \times 10^6$
* Values are taken from Tables 2 and 3 of EN 61340-5-1:2016.		

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5.4.5 Protective packaging and ESD protection

a. All ESD-sensitive items shall be contained within ESD-protective containers for movement between and within ESD-protected areas.

b. ESD protective packaging shall display ESD warning signs.

c. If the packaging is not ESD safe, it shall be labelled accordingly.

NOTE The objective of ESD protection is to prevent ESD to the item contained within, to allow for dissipation of charge, and to prevent charging of the ESD item by an external electrostatic field.

d. A container providing mechanical and ESD protection shall be used, whenever the ESD-sensitive electronic assembly is transported within a manufacturing plant or during shipment to external destinations.

NOTE This can be achieved by a container with:

- an outer shell that provides adequate mechanical protection for the contents,
- foam or bubble wrap shock absorbing liners that have static shielding covers,
- shielding package for the ESD sensitive contents.

e. All static-shielding bags shall be metallized.

f. Bags, film, bubble wrap or foam of Pink-Polyethylene shall not be used near any ESD-sensitive item or within an ESD protected area.

NOTE Pink-polyethylene provides little protection against ESD events and voltage fields and is a contaminants source.

g. Shipping popcorn, foam liners and polystyrene foam shall not be used near ESD-sensitive items unless shielding overwrap protects them.

h. Electrostatic sensitive components shall be kept in appropriate ESD protected packaging.

NOTE For example, kept in shielded bags.

i. Containers for ESD sensitive components shall be labelled as such.

5.5 Equipment and tools

5.5.1 General

a. Equipment and tools shall be inspected to meet requirements from respective clauses 5.5.2 to 5.5.19.

b. All tools and inspection equipment shall be maintained and calibrated, and their results recorded in accordance with clause 17.

c. Equipment shall not generate, induce, or transmit electrostatic charges to components being placed.

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d. Any machine or part of machine, in particular the conveyor, shall be grounded to avoid electrostatic discharge.

e. Machines and equipment used to solder surface mount components shall either be a type incorporating dynamic single or dual solder wave or be of the solder reflow type.

f. The supplier shall verify, based on the available documentation, that the equipment do not impose any processing parameters that are in contradiction to the processing parameters given by the individual component data sheets.

NOTE Examples of processing parameters include maximum temperature to avoid internal melting, thermal shocks, thermal damages, removal of marking ink, degradation of encapsulating plastic.

g. Temperature and time profiles for assembly shall be identified by the supplier and approved by the Approval Authority.

h. The supplier shall identify changes and implement a verification programme in compliance with the requirements from clause 13.

i. The supplier shall demonstrate the reproducibility of their processes.

5.5.2 Brushes

a. Medium-stiff natural- or synthetic bristle, ESD-safe, brushes shall be used for cleaning.

NOTE 1 Special care has to be taken not to damage any surface or adjacent materials.

NOTE 2 Brushes with wooden handle can be used.

b. Brushes shall be cleaned in a solvent in accordance with clause 6.4.

c. Brushes shall not be damaged by the solvents used for PCB cleaning.

d. Wire brushes shall not be used.

5.5.3 Cutters and pliers

a. Cutting edge profiles and cutter usage shall be in accordance with Figure 5-1.

b. The cutter used for trimming conductor wire and component leads shall shear sharply, producing a clean, flat, smooth-cut surface along the entire cutting edge.

NOTE 1 These measures minimize the transmission of mechanical and shock loads to delicate components.

NOTE 2 Smooth, long-nose pliers or tweezers can be used for attaching or removing conductor wires and component leads.

c. No twisting action shall occur during the cutting operation.

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d. Cutting edges shall be checked for damage and maintained in a sharp condition.

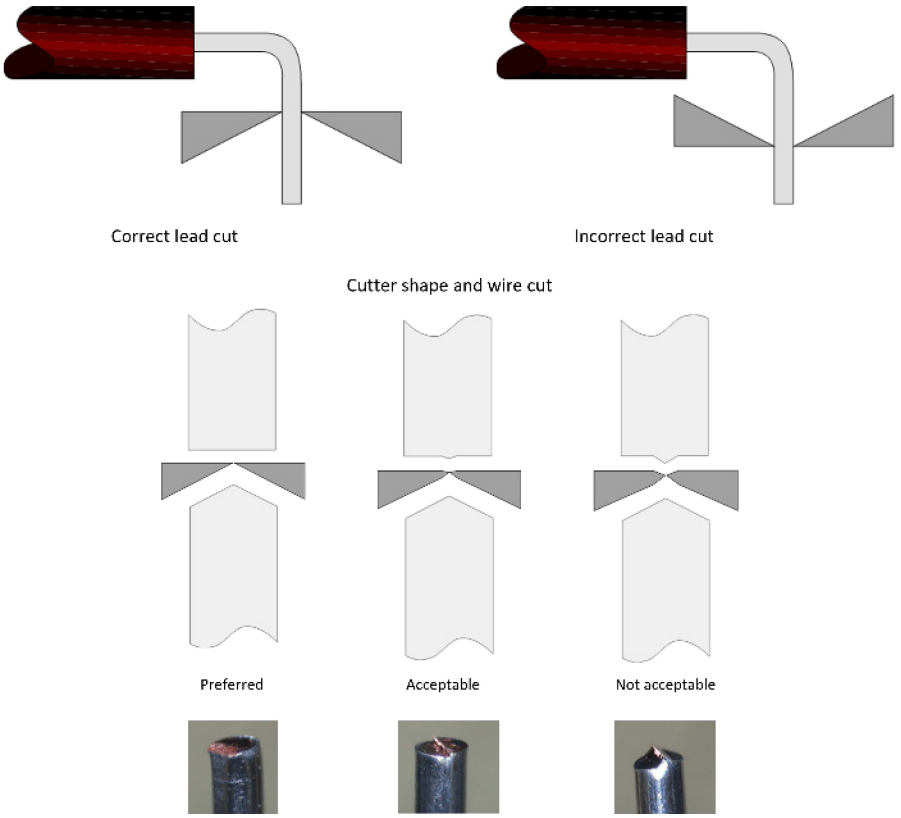


Figure 5-1: Profile of correct cutters for trimming leads

5.5.4 Bending tools

a. Component leads shall be bent or shaped using tools, including automatic bending tools, which do not nick or damage the leads or insulation.

b. Components shall not be damaged by the bending process specified in clause 8.2.7.

NOTE It is good practice to use bending tools with polished finish.

c. Bending tools shall have no sharp edges in contact with the component leads.

d. A maximum reduction of 10 % of initial section of the lead may be acceptable provided that it is representative of the verified configuration.

5.5.5 Clinching tools

a. Clinching tools shall not damage the surfaces of printed-circuit conductors, components or component leads.

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5.5.6 Insulation strippers

5.5.6.1 Thermal strippers

a. The temperature of the stripper shall not burn, blister, or cause excessive melting of the insulation.

NOTE 1 Thermal insulation strippers can be used for wire insulation types susceptible to damage by mechanical strippers.

NOTE 2 It is good practice to apply thermal strippers for use with AWG 22 and smaller wire sizes where there is a possibility of the wire stretching if a mechanical stripper is used.

NOTE 3 Local air extraction units can be used during thermal stripping.

5.5.6.2 Precision mechanical cutting-type strippers

a. Mechanical strippers shall be of the following types:

1. Automatic power-driven strippers with precision, factory-set, cutting, and stripping dies and wire guards, or
2. Precision-type hand strippers with accurately machined and factory-pre-set cutting heads.

NOTE Figure 5-2 shows an example of acceptable mechanical strippers.

b. Stripping tools or machines shall fit the size of the wire conductor.

NOTE It is good practice to mask off the die openings for wire sizes not in use.

c. The conductor shall not be twisted, ringed, nicked, cut, or scratched by the process.

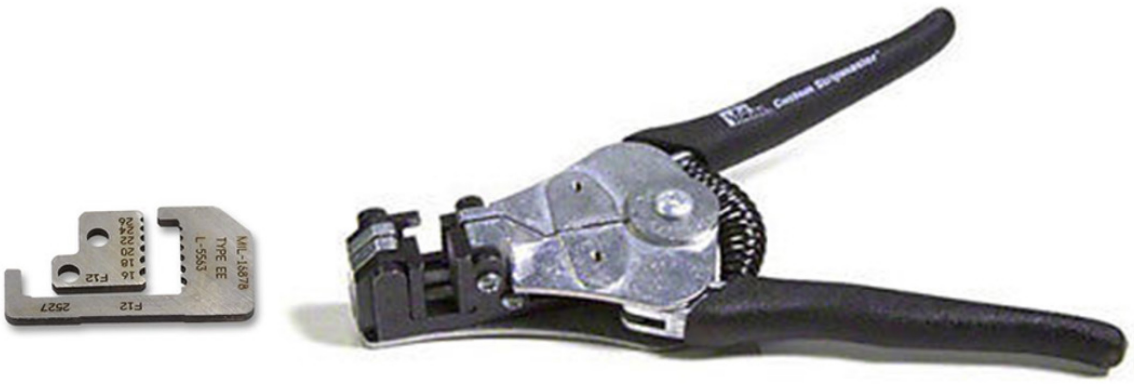


Figure 5-2: Example of suitable mechanical strippers

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5.5.6.3 Enamel stripping for wires

a. The enamel shall be removed by chemical or thermal means.

b. The enamel may be removed by mechanical means provided that visual inspection using a minimum magnification of x40 is carried out to confirm absence of damage of the conductor.

c. When stripping the ends of enamel wires the complete removal of the enamel shall be verified by visual inspection.

d. Chemical stripping materials shall be completely neutralised and be cleaned such that there are no residues from the stripping, neutralizing, or cleaning steps.

e. The enamel shall not be visually contaminated by the stripping process.

5.5.6.4 Verification of stripping tools

a. Thermal and mechanical stripping tools shall be verified by removal of insulation at the start of each production batch.

5.5.7 Hot air blower

a. Hot air blower shall be used for shrinking of sleeves

b. Hot air blower may be used for removal of some adhesives

c. Hot air blower shall be able to maintain and control a defined temperature.

d. Temperature of the hot air blower shall be set at a temperature in compliance with the materials and not degrade surrounding assembly or materials.

NOTE it is good practice to have a thermocouple around to ensure absence of degradation.

e. Hot air blower shall meet requirement 5.5.1d against ESD.

5.5.8 Soldering tools

5.5.8.1 General

a. The leads shall not be damaged during preparation and assembly.

5.5.8.2 Holding tools

a. Holding tools used as soldering aids shall not be wetted by the solder during the assembly.

5.5.8.3 Thermal shunts

a. A thermal shunt shall be able to act as heat sink to protect thermally sensitive components.

NOTE 1 An effective clamp-type thermal shunt can be constructed by inserting small copper bars into the jaws of an alligator clip.

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NOTE 2 Shunts can be held in place by friction, spring tension or any other means that does not damage the finish or insulation.

5.5.8.4 Anti-wicking tools

a. The conductor gauge sizes of the anti-wicking tools shall be marked on the tool.

NOTE Anti-wicking tools can be used for pretinning the stranded wires.

5.5.8.5 Soldering irons

a. The size and shape of the soldering iron and tip shall not damage adjacent areas or connections during soldering operations.

b. Temperature-controlled soldering irons shall be used.

c. Temperature of the solder tip shall be verified once a week and after each solder tip change.

d. Selected temperature of the solder tip shall remain within +/-10°C.

e. Resistance between the soldering tip and the workstation grounding point shall be compliant with IPC- J/STD/001H Sept 2020.

f. AC and DC current leakage from heated tip to ground shall not create deleterious effects on equipment or components.

g. Tip transient voltages generated by the soldering equipment shall not exceed 2 V peak under a minimum loading impedance of 100 kΩ.

h. A soldering iron holder shall be used.

NOTE It is good practice to use a cage-type holder that leaves the soldering-iron tip unsupported when a temperature-controlled soldering iron is used.

5.5.9 Baking and curing ovens

a. An oven for baking and curing shall be able to heat and maintain the temperature of a printed circuit board or assembly within ±10 °C.

NOTE 1 It is good practice to take into account the size and number of objects to be heated, when selecting capacity and size of the oven.

NOTE 2 A vacuum oven can be used for drying operation.

b. An oven used for silicone shall not be used to bake out PCBs.

c. An oven used for silicone shall not be used to cure adhesives other than silicone.

d. The oven shall be equipped with an independent automatic shutdown system to protect from overheating.

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5.5.10 Solder deposition equipment

a. Equipment used to deposit solder pastes shall be of a screening, stencilling, dispensing, roller coating, dotting or jet printing type.

b. Solder deposit equipment shall deposit reproducible amount of solder paste.

NOTE The use of Solder Paste Inspection (SPI) equipment helps to ensure reproducible volume of deposited solder paste.

c. Equipment shall apply pastes of a viscosity and quantity such that the positioned component is retained on the board before and during soldering operations, ensuring self-centring and solder fillet formation.

d. Equipment used to apply solder preforms shall align the preform with the land or component lead and termination.

e. Solder paste deposition procedures and associated acceptance criteria shall be controlled and documented.

5.5.11 Automatic component placement equipment

a. Automatic or computer-controlled equipment used for component placement shall be of the coordinate-driven pick-and-place type or of the robotic type.

b. The placement equipment used shall be of a type that:

1. prevents component or board damages,
2. indexes components with respect to the circuit and
3. aligns the component terminations with the board terminal areas.

5.5.12 Dynamic wave-solder machines

a. Dynamic soldering machines shall be of automatic type and of a design offering the following:

1. Controlling the flux application.
2. Controlling preheating to drive off volatile solvents and to avoid thermal shock damage to the PCB and component packages.
3. Maintaining the solder temperature at the printed circuit board assembly to within ±5°C of the established bath temperature throughout the duration of any continuous soldering run when measured 3,0 mm below the surface of the wave.
4. Having a wave system that limits shadowing and allows solder fillet formation.
5. Having carriers made from a material that cannot contaminate, degrade or damage the printed circuit board or substrate nor transmit vibration or shock stress from the conveyors to a degree permitting physical, functional or electrostatic damage to components, board or substrate during transport through preheating, soldering and cooling stages.

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6. Showing an extraction system, either integral or separate, conforming to the requirements of clause 5.2.

NOTE to item 4: It is good practice to use nitrogen atmosphere.

b. The following wave soldering machine parameters shall be controlled:

1. the amount of flux and its coverage,
2. the preheat temperature and duration to avoid damage to the PCB and to the component packages,
3. the solder temperature so that the solder in the wave making contact with the board is 235 °C to 275 °C.

c. The supplier shall provide evidence that:

1. the conveyor speed does not vary by more than ±5 %, and
2. the height of the solder wave remains to a constant pre-selected value across the width of the wave.

5.5.13 Selective wave solder equipment

a. Selective wave soldering machines shall be of automatic type and of a design offering the following:

1. A holding mechanism for the board to be soldered, which can fixate the board during the process, without degrading or damaging the PCB or the mounted components.
2. Nozzle, through which a local solder wave applies solder selectively per component or termination, from the solder side of the PCB to the component leads to be soldered.
3. Automatic relative movement between nozzle and PCB both in-plane and out-of-plane direction.
4. Controllable flux application.
5. Maintain the preheating temperature to within ±5 °C during soldering to avoid thermal shock damage to the PCB and to component packages.
6. Maintaining the wave solder temperature to within ±5 °C of the established soldering temperature throughout the process.
7. Showing an extraction system, either integral or separate, conforming to the requirements of clause 5.2.

NOTE to item 2: It is good practice to use local flow of nitrogen around the solder nozzle.

b. The following selective wave soldering machine parameters shall be controlled:

1. the amount of flux and its coverage,
2. the preheat temperature,
3. the solder temperature so that the solder in the selective wave making contact with the board is maximum 300 °C,
4. the nozzle speed so that the soldering time per lead does not exceed 10 s.

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5.5.14 Reflow process equipment

5.5.14.1 Condensation (vapour phase) reflow machines

a. Condensation reflow machines shall:

1. not transmit a movement or vibration into the assemblies being soldered that result in misalignment of components or disturbed solder joints,
2. be capable of preheating an assembly with solder paste to the temperature recommended by the solder paste manufacturer prior to soldering,
3. use a reflow fluid whose boiling point is a minimum of 17 °C above the melting point of the solder being used,
4. maintain the preselected temperature to within ±5 °C in the reflow zone during soldering,
5. include an extraction system that conforms to clause 5.2.

NOTE to item 3: For boards with high thermal mass or for mixed terminations finish on components, it is a good practice to select a higher peak temperature and to use a delta of 30°C for a good wettability.

b. Reflow process parameters for condensation reflow machines shall be controlled and documented according to clause 5.5.14.5.

5.5.14.2 Local hot gas reflow machines

a. Local hot gas reflow machines shall:

1. not transmit movement or vibration to the assemblies being soldered which result in misalignment of components or disturbed solder joints,
2. preheat an assembly with solder paste to the temperature recommended by the solder paste manufacturer prior to soldering,
3. heat the area of the assembly to be soldered using focused or unfocussed energy, to a preselected temperature that is a minimum of 30°C above the melting point of the solder being used as measured at laminate or substrate surface,
4. prevent the reflow of adjacent components and components localized on the opposite side,
5. prevent excessive temperature that can degrade surrounding materials such as adhesive, underfill,
6. Not to be above maximum allowed component temperature,
7. maintain the preselected reflow temperature within ±5°C as measured at the substrate surface.

b. Reflow process parameters for local hot gas reflow machines shall be controlled and documented according to clause 5.5.14.5.

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5.5.14.3 Forced convection and infrared reflow systems

a. Forced convection and infrared reflow machines shall be of design such that the system:

1. provides a controlled temperature profile and does not transmit movement or vibration into the assembly being soldered,
2. preheats an assembly with solder paste to the temperature recommended by the solder paste manufacturer prior to soldering,
3. heats the area of the assembly to be soldered using focused or unfocussed energy, to a preselected temperature that is a minimum of 30°C above the melting point of the solder being used as measured at laminate or substrate surface,
4. maintains the preselected temperature to within ±5 °C in the reflow zone during soldering,
5. not transmit movement or vibration to the assemblies being soldered which result in misalignment of components or disturbed solder joints.

b. Reflow process parameters for forced convection and infrared reflow systems shall be controlled and documented according to clause 5.5.14.5.

5.5.14.4 Other equipment for reflow soldering

a. Other solder reflow systems may be approved for use by the Approval Authority under the condition that they meet the requirements of either clause 5.5.14.1, 5.5.14.2 or 5.5.14.3.

5.5.14.5 Reflow process control parameters

a. The following reflow process parameters shall be controlled and documented:

1. preheat temperature to avoid damage to the PCB, to the component packages and to reduce the solder dwell time,
2. solder reflow parameters and cooling parameters to stay inside the solder paste requirements,
3. reflow temperature to be maintained within ±5 °C of the verified soldering temperature throughout the process,
4. peak temperature is within the range of 200°C minimum and 235°C maximum, tolerances of point 3 included when measured at PCB level.
5. capability to heat the soldering elements as PCB, components and to retain the present temperature within ±5 °C, and
6. conveyor speed not to vary by more than ±5 %.

NOTE 1 to item 3 and 4: It is good practice to use nitrogen if forced convection oven is used.

NOTE 2 to item 1 and 6: It is good practice to apply a preheating rate of 2 °C ±0,5 °C/mn.

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5.5.15 Depanelization tool

a. To prevent any damage on assembled PCB during depanelization, tools shall be able to meet following requirements:
   1. support PCBs to avoid bending and damage from vibration during process,
   2. guide cutting tool to avoid damage on PCB,
   3. use a local protection to avoid contamination,
   4. be a reproducible depanelization process.

5.5.16 Cleanliness testing equipment

a. Cleanliness testing equipment shall be able to:
   1. test the cleanliness of bare and assembled printed circuit boards,
   2. be sensitive enough to fulfil requirement 11.1.4e.2,
   3. meet the requirements of IPC-TM-650 Method 2.3.25.

5.5.17 Optical microscope

a. Optical microscope used for visual inspection shall provide optical magnification from 4x to 40x.

b. Optical microscope used for failure analysis shall provide, in addition to requirement 5.5.17a, an optical magnification from 50x to 500x.

5.5.18 Automatic Optical Inspection (AOI) equipment

a. AOI shall not replace final visual inspection.

NOTE AOI is an aid for inspection.

b. AOI equipment should be capable of detecting the following defects:
   1. Missing component
   2. Wrong type of component
   3. Wrong polarization
   4. Component upside down
   5. Misplacement
   6. Tombstoning or component placed on its edge
   7. Solder bridging
   8. Lack of solder
   9. Shape of solder joint when using a 3D AOI equipment.

5.5.19 X-ray inspection equipment

a. X-ray equipment shall be equipped with the following:

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1. X-ray tube with an acceleration voltage that permitted to provide the required resolution,
2. X-ray tube with micro-focus technology,
3. a digital detector with high resolution, and
4. a system with variable expansion factor.

NOTE X-ray equipment not intended for electronic assemblies or not properly set up can damage sensitive components.

b. X-ray equipment shall be calibrated to evaluate the total dose received by the components during the inspection.

NOTE To minimize the dose given to the component, it is good practice to:

- Record the total dose received.
- Use off-line image analysis as much as possible.
- Use filters, optimizing the direction of the X-ray beam and masking sensitive areas.

c. The resolution of the X-ray equipment shall be able to detect solder balls having a diameter of 0,03 mm.

d. The sensitivity shall be demonstrated by means of actual 0,03 mm diameter solder balls, stuck to adhesive tape, attached to the multilayer board assembly being inspected.

e. AXI (Automatic X-ray inspection) shall not replace final visual inspection.

NOTE AXI can be used for inline inspection.

f. AXI equipment should be capable of detecting the following defects:

1. Missing component
2. Component upside down
3. Misplacement
4. Tombstoning or component placed on its edge
5. Solder bridging
6. Lack of solder.

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