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TECHNICAL SPECIFICATION

Process management for avionics – Aerospace and defence electronic systems containing lead-free solder –
Part 22: Technical guidelines

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PROCESS MANAGEMENT FOR AVIONICS – AEROSPACE AND DEFENCE ELECTRONIC SYSTEMS CONTAINING LEAD-FREE SOLDER –

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FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 62647-22, which is a technical specification, has been prepared by IEC technical committee 107: Process management for avionics.

The text of this technical specification is based on the following document: IEC/PAS 62647-22[1].

This technical specification cancels and replaces IEC/PAS 62647-22, published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Coherence with IEC/TS 62647-1 and IEC/TS 62647-2 definitions.

b) Reference to IEC 62647 documents when already published.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
107/205/DTS	107/218/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62647 series, published under the general title *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

[1] IEC/PAS 62647-22, which served as a basis for the present document, has been derived from GEIA-HB-0005-2.

INTRODUCTION

0.1 General

The global transition to lead-free (Pb-free) electronics impacts the aerospace, defence, and high performance (ADHP) industry and other industries having high reliability applications in various ways.

0.2 Transition to Pb-free

In addition to the perceived need to replace the tin-lead solders used as an interconnect medium in electronic and electrical systems, the following variations to established practice will need to be considered:

- components and printed circuit boards (PCBs)/printed wiring boards (PWBs) will need to be able to withstand higher manufacturing process temperatures;
- printed circuit boards (PCBs)/printed wiring boards (PWBs) will need to have robust solderable lead-free (Pb-free) surface finishes;
- manufacturing and inspection techniques are needed that yield repeatable reliability characteristics;
- at least initially, Pb-free alloys used within the equipment should be restricted to those that are compatible with tin-lead soldering systems;
- a maintenance strategy should be developed that will facilitate the support repair of new and existing equipment throughout a long life time which can be higher than 20 years.

This document will establish guidelines for the use of Pb-free solder and mixed tin-lead/lead-free alloy systems while maintaining the high reliability standards required for aerospace electronic and electrical systems. Currently the largest volume of lead (Pb) in many of these electronic systems is in the tin-lead eutectic (Sn-37Pb) and near eutectic alloys (Sn-36Pb-2Ag, Sn-40Pb) used in printed circuit board/printed wiring board assemblies, wiring harnesses and electrical systems. High-lead solder alloys are not specifically addressed in this document; however, many of the methodologies outlined herein are applicable for their evaluation.

A good deal of the information desired for inclusion in this technical guidelines document does not exist. A large number of lead-free (Pb-free) investigative studies for aerospace and high reliability electronic and electrical systems are either in progress or in the initiation stage. The long durations associated with reliability testing necessitates a phased release of information. The information contained herein reflects the best information available at the time of document issuance. It is not the goal of this document to provide technical guidance without an understanding of why that guidance has technical validity or without concurrence of the technical community in cases where sufficient data is lacking or conflicting. The document will be updated as new data becomes available.

Further complicating matters is the fact that no single alloy across the supply base will be replacing the heritage tin-lead eutectic alloy and that it is not likely that qualification of one alloy covers qualification for all other alloys. Given the usual requirement for long, high performance electronic service lives, any lead-free (Pb-free) alloy will need to have predictable performance when mixed with heritage tin-lead alloys. Lead-free (Pb-free) alloys containing elements such as bismuth (Bi) or indium (In) that can form alloys having melting points within the equipment’s operating temperature range will need to be considered very carefully before use. Although lead-free (Pb-free) solder alloys are still undergoing some adjustments, it appears that the Sn-Ag-Cu family of alloys will be used for surface mount assembly and either Sn-Ag-Cu, Sn-Cu or Sn-Cu-Ni (Sn-Cu stabilized with nickel) alloys will be dominant in wave solder applications. In addition, some applications are using the Sn-Ag alloy family [1] [2] [3].[2]

The majority of the lead-free (Pb-free) solder alloys being considered have higher melting temperatures than tin-lead eutectic solder. In order to make use of the lead-free (Pb-free) solders, changes to the molding compound, die attach and printed circuit board (PCB)/printed wiring board (PWB) insulation systems are being introduced to accommodate the 30 °C to 40 °C higher (54 °F to 72 °F higher) processing temperature. Thus, not only is the lead-free (Pb-free) transition changing the solder alloy, but a significant portion of the electronic packaging materials are changing as well. The higher melting point, greater creep resistance and higher strength of the lead-free (Pb-free) alloys have driven a significant amount of study into the thermal cycling and mechanical vibration/shock assessments of these new alloys.

The consumer electronics industry has invested considerable resources to ensure that lead-free (Pb-free) solder will perform adequately for their products. Creep resistance of lead-free (Pb-free) alloys can vary considerably from heritage tin-lead solders. The creep/stress relaxation performance of the solder depends on the stress level, temperature and time for a specific solder material and joint composition. Therefore, one needs to establish what the acceleration factor is between a particular test condition and application. The interpretation of the results of a head-to-head testing needs to be assessed in terms of the anticipated service conditions with respect to these acceleration factors. Thermal preconditioning prior to thermal cycling should be considered in the lead-free (Pb-free) solder assessment plan particularly as it relates to changes in solder microstructure. Modeling/analysis is needed to properly compare the tin-lead and lead-free (Pb-free) alloy performance and correct for the stress relaxation differences obtained for the various piece parts and thermal cycling conditions.

While there is much data on near eutectic SAC (e.g., SAC305 and SAC405) Pb-free thermal cycling, there is less information regarding lead-free (Pb-free) vibration and shock performance. Fortunately, the vibration and shock performance data can be obtained relatively quickly. During vibration/shock testing, the near eutectic SAC Pb-free solder behaves more rigidly than the Sn-Pb solder transferring greater loads to the interfaces between the solder alloy and the substrate interfaces. The increased amount of tin in Pb-free alloys increases the intermetallic thickness when copper substrates are used. In addition, when nickel or electroless nickel (nickel – phosphorous) substrates are used, the increased copper in the SAC alloy can result in the formation of intermetallics on the nickel interface, which are less robust than Sn-Cu or Sn-Ni intermetallics that are typical of tin-lead solder joints. Mechanical test results to-date suggest that a robust assessment of lead-free (Pb-free) alloy assembly in vibration and shock environments will need to include thermal aging for interface and microstructural stabilization prior to any dynamic mechanical testing. Alloys other than SAC should be assessed to determine their vibration and shock performance characteristics.

2 Numbers in square brackets refer to the Bibliography.

PROCESS MANAGEMENT FOR AVIONICS – AEROSPACE AND DEFENCE ELECTRONIC SYSTEMS CONTAINING LEAD-FREE SOLDER –

Part 22: Technical guidelines

1 Scope

This part of IEC 62647 is intended for use as technical guidance by aerospace, defence, and high performance (ADHP) electronic applications and systems suppliers, e.g., original equipment manufacturers (OEMs) and system maintenance facilities, in developing and implementing designs and processes to ensure the continued performance, quality, reliability, safety, airworthiness, configuration control, affordability, maintainability, and supportability of high performance aerospace systems (subsequently referred to as ADHP) both during and after the transition to Pb-free electronics.

The guidelines may be used by the OEMs and maintenance facilities to implement the methodologies they use to ensure the performance, reliability, airworthiness, safety, and certifiability of their products, in accordance with IEC/TS 62647-1:2012.

This document also contains lessons learned from previous experience with Pb-free aerospace electronic systems. The lessons learned give specific references to solder alloys and other materials, and their expected applicability to various operating environmental conditions. The lessons learned are intended for guidance only; they are not guarantees of success in any given application.

This document may be used by other high-performance and high-reliability industries, at their discretion.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC/TS 62647-1:2012, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 1: Preparation for a lead-free control plan*

IEC/TS 62647-2, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 2: Mitigation of deleterious effects of tin*

IEC/TS 62647-3:–, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 3: Performance testing for systems containing lead-free solder and finishes*[3]

GEIA-HB-0005-4, *Guidelines for Performing Reliability Assessment for Lead Free Assemblies used in Aerospace and High-Performance Electronic Applications*

IPC/JEDEC JP002, *Current Tin Whiskers Theory and Mitigation Practices Guideline*

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[3] Under consideration.

IPC-1066, *Marking, Symbols and Labels for Identification of Lead-Free and Other Reportable Materials in Lead-Free Assemblies, Components and Devices*

IPC-9701, *Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
alloy composition
whole ingredients of an alloy whose weight is defined in percent

Note 1 to entry: For instance 63Sn-37Pb corresponds to a mixture of 63 % by weight of tin (Sn) and 37 % by weight of lead (Pb).

3.1.2
alloy 42
nickel-iron controlled-expansion alloy containing 42 % nickel that is often used as a lead-frame material in electronic packages

3.1.3
assemblies
electronic items that require electrical attachments, including soldering of wires or component terminations

EXAMPLE Circuit cards and wire harnesses.

[SOURCE: IEC/TS 62647-1:2012, 3.1]

3.1.4
CAF
conductive anodic filament
copper conductive filament form between two adjacent conductors or plated vias in a printed circuit board (PCB)/printed wiring board (PWB)

Note 1 to entry: See IPC-TM-650, method 2.6.25.

3.1.5
critical
state of an item or function, which if defective, will result in the system's inability to retain operational capability, meet primary objective, or affect safety

[SOURCE: IEC/TS 62647-1:2012, 3.2]

3.1.6
creep
time-dependent strain occurring under stress

3.1.7
CSAM
C-mode scanning acoustic microscopy
method for evaluating electronic packages for internal delamination using high frequency sound waves

3.1.8
CTE
coefficient of thermal expansion
degree of expansion of a material divided by the change in temperature

Note 1 to entry: PCB/PWB CTE (x-y axis) is measured in the direction in the plane of the piece part mounting surface and is used to quantify the stresses in the solder joint arising from the differences in CTE between the piece parts and the PCB/PWB during thermal cycling. CTE (z axis) is measured in the “thickness” direction and is typically used to quantify plated through hole stress.

3.1.9
customer
entity or organization that (a) integrates a piece part, soldered assembly, unit, or system into a higher control level system, (b) operates the higher control level system, or (c) certifies the system for use

EXAMPLE This may include end item users, integrators, regulatory agencies, operators, original equipment manufacturers (OEMs), and subcontractors.

[SOURCE: IEC/TS 62647-1:2012, 3.5]

3.1.10
dicy cure
use of dicyandiamide (dicy), as a curing agent for epoxy resins

3.1.11
EM
electromigration of the PCB/PWB metallization

Note 1 to entry: Resistance to electromigration testing is typically performed between electrically biased conductors at elevated humidity and temperature.

3.1.12
eutectic
mixture of two or more metals at a composition that has the lowest melting point, and where the phases simultaneously crystallize from molten solution at this temperature

Note 1 to entry: A non-eutectic mixture will exhibit a pasty range during cooling where both liquid and solid phases are present prior to reaching the mixture’s solidus temperature.

3.1.13
FR4
flame retardant laminate made from woven glass fiber material impregnated with epoxy resin

3.1.14
Fick’s law
classic diffusive mass transport model where the mass diffusion is proportional to the concentration gradient in the material

3.1.15
fillet lifting
separation that occurs between a solder fillet and a PCB/PWB pad where the solder fillet has the appearance that it has lifted off the PCB/PWB pad

Note 1 to entry: The fillet lifting is caused by the formation of a low melting point phase (often a ternary alloy) or liquid phase in an alloy having a large pasty range. The thin layer of liquid present adjacent to the PCB/PWB pad results in a layer that allows the solidified solder above it to pull off the PCB/PWB pad [38] [73].

3.1.16
high performance
continued performance or performance on demand where an application (product, equipment, electronics, system, program) down time cannot be tolerated in an end-use environment which can be uncommonly harsh, and the application must function when required

EXAMPLE: Examples of high performance applications are life support or other critical systems.

[SOURCE: IEC/TS 62647-1:2012, 3.7]

3.1.17
incubation period
<tin pest formation> time required at cold temperature to initially form the brittle gray (α) tin phase from the ductile white (β) tin phase

3.1.18
inoculation
<tin pest formation> practice of facilitating the white (β) tin to gray (α) tin phase transformation by using seed particles of the gray tin phase on the white tin to reduce the nucleation barrier energy associated with the transformation

3.1.19
ICP-MS
inductively coupled plasma mass spectrometry
type of mass spectrometry used for analysis and capable of detecting metals and non-metals

3.1.20
Kirkendall void formation
void induced in a diffusion couple between two metals that have different interdiffusion coefficients

3.1.21
lead-free
Pb-free
less than 0,1 % by weight of lead (Pb) in accordance with reduction of hazardous substances (RoHS) guidelines

[SOURCE: IEC/TS 62647-1:2012, 3.8]

3.1.22
MSL
moisture sensitivity level
moisture sensitivity level rating of a plastic encapsulated electronic device as it relates to soldering

3.1.23
PCB
printed circuit board
PWB
printed wiring board
substrate using conductive pathways, tracks or signal traces etched from copper sheets laminated, and allowing to connect electrically a set of electronic components to realize a circuit card

[SOURCE: IEC/TS 62647-21:2013, 3.1.10]

3.1.24
peritectic
in a peritectic reaction, solid phase and liquid phase react on cooling to produce a new solid phase

3.1.25
piece part
electronic component that is not normally disassembled without destruction and is normally attached to a printed wiring board to perform an electrical function

[SOURCE: IEC/TS 62647-1:2012, 3.14]

3.1.26
PTH
plated through hole
plated through hole used on printed circuit boards (PCBs)/printed wiring boards (PWBs) for interconnecting between layers and for component attachment

Note 1 to entry: Plating of metal the wall of the hole allows electrical connection between internal and/or external conductive patterns on different layers.

3.1.27
repair
act of restoring the functional capability of a defective article in a manner that precludes compliance of the article with applicable drawings or specifications

[SOURCE: IEC/TS 62647-1:2012, 3.17]

3.1.28
rework
action taken to return a unit (SRU/LRU/system) to a state meeting all requirements of the engineering drawing, including both functionality and physical configuration by making repairs

Note 1 to entry: Also used to define the act of reprocessing non-complying articles, through the use of original or equivalent processing in a manner that assures full compliance of the article with applicable drawings or specifications.

[SOURCE: IEC/TS 62647-1:2012, 3.16]

3.1.29
SAC
family of Pb-free alloys containing tin, silver and copper used in surface mount technology or sometimes in wave solder processes

Note 1 to entry: The alloys typically have a composition near the eutectic (95,6Sn-3,5Ag-0,9Cu).

3.1.30
SAC-L
low silver content SAC alloys that are not eutectic compositions

Note 1 to entry: These alloys have increasingly been used for BGA package interconnects.

3.1.31
SIR
surface insulation resistance
method of electrical resistance measurement used to quantify the deleterious effects of fabrication, process or handling residues and performed on PCB/PWB

Note 1 to entry: These electrical resistance measurements are often performed after periods of humidity exposure.