

Workmanship requirements for soldered electronic assemblies —

Part 1: General

The European Standard EN 61192-1:2003 has the status of a
British Standard

ICS 31.190

National foreword

This British Standard is the official English language version of EN 61192-1:2003. It is identical with IEC 61192-1:2003.

The UK participation in its preparation was entrusted to Technical Committee EPL/501, Electronic assembly technology, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 75 and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 26 June 2003

© BSI 26 June 2003

ISBN 0 580 42112 0

Workmanship requirements for soldered electronic assemblies
Part 1: General
(IEC 61192-1:2003)

Exigences relatives à la qualité
d'exécution des assemblages
électroniques brasés
Partie 1: Généralités
(CEI 61192-1:2003)

Anforderungen an die Ausführungsqualität
von Lötbaugruppen
Teil 1: Allgemeines
(IEC 61192-1:2003)

This European Standard was approved by CENELEC on 2003-03-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 91/345/FDIS, future edition 1 of IEC 61192-1, prepared by IEC TC 91, Electronics assembly technology, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61192-1 on 2003-03-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2003-12-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2006-03-01

This standard should be used in conjunction with the following parts of EN 61192, under the general title *Workmanship requirements for soldered electronic assemblies*:

Part 2: Surface-mount assemblies

Part 3: Through-hole mount assemblies

Part 4: Terminal assemblies

Annexes designated "normative" are part of the body of the standard.

In this standard, annex ZA is normative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61192-1:2003 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-2-58	NOTE	Harmonized as EN 60068-2-58:1999 (not modified).
IEC 60326	NOTE	Related but not equivalent to EN 123600:1996, EN 123700:1996 and EN 123800:1996.
IEC 61188-5-1	NOTE	Harmonized as EN 61188-5-1:2002 (not modified).
IEC 61189-2	NOTE	Harmonized as EN 61189-2:1997 (not modified).
IEC 61190-1-2	NOTE	Harmonized as EN 61190-1-2:2002 (not modified).
IEC 61190-1-3	NOTE	Harmonized as EN 61190-1-3:2002 (not modified).
ISO 9001	NOTE	Harmonized as EN ISO 9001:2000 (not modified).
ISO 9453	NOTE	Harmonized as EN ISO 29453:1993 (not modified).

CONTENTS

INTRODUCTION	6
1 Scope and object	7
2 Normative references	7
3 Terms and definitions	8
4 General requirements	8
4.1 Order of precedence	8
4.2 Process control	11
4.3 Facilities	12
4.4 Process identification	13
5 Pre-process activities	15
5.1 Design checks	15
5.2 Specification and procurement of components	17
5.3 Specification and procurement of printed boards	17
5.4 Specification and procurement of process materials	18
5.5 Inspection plan, inspection facilities and handling	19
5.6 Storage and kitting of components, boards and materials	20
5.7 Handling during assembly, packaging and shipping	21
5.8 Electrical testing	21
6 Component preparation	22
6.1 Lead and termination solderability	22
6.2 Lead forming	24
6.3 Lead flattening	25
6.4 Lead cropping	25
6.5 Lead coplanarity	26
6.6 Thermal shock during re-tinning	26
6.7 Moisture and gas traps	26
7 Mounting structure and printed board preparation	26
7.1 Surface preparation	26
7.2 Temporary masking requirements	26
7.3 Gold on printed board surface-mount lands	27
7.4 Printed board condition	27
8 Surface-mount solder paste deposition	27
8.1 Description of process	27
8.2 Storage and handling of solder paste	28
8.3 Screen (off-contact) printing	29
8.4 Stencil (in-contact) printing	30
8.5 Syringe dispensing	31
8.6 Transfer deposition of solder preforms	31
9 Non-conductive adhesive deposition and curing	32
9.1 Stencil printing	32
9.2 Syringe dispensing	32
9.3 Pin transfer printing	33
9.4 Adhesive curing	33

10	Surface-mounted component placement	34
10.1	Leadless discrete components with metallized terminations.....	34
10.2	Leadless circular cylinder components, for example, metal electrode leadless faces (MELFs)	34
10.3	Leaded discrete small component packages	34
10.4	Leaded integrated circuit packages	36
10.5	Leaded 'fine-pitch' integrated circuit packages	37
10.6	Modified leaded through-hole packages	37
10.7	Leadless chip carrier packages.....	37
10.8	Placement equipment	37
11	Through-hole component insertion	39
11.1	General	39
11.2	Axial lead components (two leads).....	40
11.3	Radial lead components (two leads).....	40
11.4	Radial lead components (three or more leads)	41
11.5	Multilead integrated circuit packages	41
11.6	Pin grid array (PGA) components.....	42
11.7	Surface-mount packages modified for insertion.....	42
11.8	Large components	42
11.9	Insertion methods and equipment	42
11.10	Cutting and clinching leads	43
12	Placement of terminals and press-fit pins	44
12.1	Attachment of terminals to printed boards	44
12.2	Soldering wires and component leads to terminals	44
13	Reflow soldering	45
13.1	Infrared reflow soldering in pass-through equipment.....	46
13.2	Convection reflow soldering in pass-through equipment	47
13.3	Mixed infrared and convection reflow soldering in pass-through equipment.....	47
13.4	Vapour phase reflow soldering	47
13.5	Laser scan reflow soldering	48
13.6	Thermode (hot bar) reflow soldering	49
13.7	Hot gas multijet reflow soldering	49
13.8	Focused infrared multi-point reflow soldering	50
14	Immersion soldering	50
14.1	General requirements	51
14.2	Wave soldering.....	52
14.3	Drag soldering	53
14.4	Hot dip soldering	53
15	Individual point soldering	53
15.1	Manual soldering with an iron.....	53
15.2	Hot gas pencil reflow soldering	55
16	Cleanliness/cleaning	56
16.1	Use of 'no clean' fluxes	57
16.2	Cleaning materials.....	57
16.3	Cleaning processes	57
16.4	Cleanliness assessment	58

17	Electrical test.....	59
17.1	In-circuit test	60
17.2	Functional test.....	60
17.3	Test probes and probe lands.....	60
18	Rework and repair	60
18.1	General	60
18.2	Unmarked components	61
18.3	Pre-heating printed boards and sensitive components	61
18.4	Re-use of removed components.....	61
18.5	Selection of rework tools and equipment	62
18.6	Surface-mounted component realignment	64
18.7	Adding solder to existing joints.....	64
18.8	Removing excess solder	65
18.9	Component removal.....	65
18.10	Component replacement.....	65
18.11	Repair of assemblies returned from the field	66
19	Conformal coatings, including solder resist	66
19.1	General	66
19.2	Conformal protective coating	66
19.3	Solder mask coating	69
20	Packaging and shipping	70
20.1	Materials	70
20.2	Mechanical protection.....	71
20.3	Marking/labelling	71
20.4	Handling	71
21	Training	71
21.1	Training of designers, engineers and senior line management.....	71
21.2	Training production line personnel	71
Annex ZA (normative) Normative references to international publications with their corresponding European publications		73
Bibliography		75
Figure 1 – SM single-sided surface-mount assembly, reflow only		13
Figure 2 – SM single-sided assembly, immersion only		13
Figure 3 – Mixed technology assembly, double-sided: reflow and immersion, flow or wave solder		14
Figure 4 – Mixed technology assembly, double-sided reflow and manual.....		14
Figure 5 – Mixed technology assembly, double-sided, immersion only.....		14
Figure 6 – Typical passive surface-mounted component package styles		35
Figure 7 – Typical semiconductor surface-mounted component package styles.....		36
Figure 8 – Typical axial-lead components		39
Figure 9 – Typical radial dual-lead components		39
Figure 10 – Radial lead component with shaped lead stand-off		39
Figure 11 – Typical radial lead transistor, with spacer		40
Figure 12 – Typical multilead integrated circuit package types		41
Figure 13 – Typical pin grid array package.....		42
Figure 14 – Examples of anchored terminals		44
Figure 15 – Types of wire attachment		45

Table 1 – Recommended rework equipment for common component types..... 67

Table 2 – Limits of conformal coating defects (percentage of one side of board area)..... 67

INTRODUCTION

This part of IEC 61192 covers general workmanship requirements for the manufacture of soldered electronic assemblies that can enable the requirements of IEC 61191-1 and its related sectional standards to be met.

The requirements for surface-mount assemblies as well as through-hole mount assemblies and terminal assemblies are given in IEC 61192-2, IEC 61192-3 and IEC 61192-4, which are separate but related standards.

WORKMANSHIP REQUIREMENTS FOR SOLDERED ELECTRONIC ASSEMBLIES –

Part 1: General

1 Scope and object

This part of IEC 61192 specifies general requirements for workmanship in soldered electronic assemblies on printed boards and on similar laminates attached to the surface(s) of organic substrates.

This standard does not include hybrid circuits in which the conductor metallization is deposited directly on a ceramic substrate or onto a ceramic-coated metal substrate. It includes multichip modules assembled on organic substrates but excludes them when they are assembled on inorganic substrate surfaces such as ceramic or silicon.

The purpose of this standards is:

- a) to define requirements and guidelines for good workmanship and practice in the preparation, soldering, inspection and testing of electronic and electrical assemblies;
- b) to enable achievement of high yields and high product quality through process control in production;
- c) to enable the suppliers and users of electronic assemblies to specify good manufacturing practice as part of a contract.

2 Normative references

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

IEC 60194, *Printed board design, manufacture and assembly – Terms and definitions*

IEC 61188-1-1, *Printed boards and printed board assemblies – Design and use – Part 1-1: Generic requirements – Flatness considerations for electronic assemblies*

IEC 61188-5-2, *Printed boards and printed board assemblies – Design and use – Part 5-2: Attachment (land/joint) considerations – Discrete components*¹⁾

IEC 61189-3, *Test methods for electrical materials, interconnection structures and assemblies – Part 3: Test methods for interconnection structures (printed boards)*

IEC 61190-1-1, *Attachment materials for electronic assembly – Part 1-1: Requirements for soldering fluxes for high-quality interconnections in electronics assembly*

¹⁾ To be published.

IEC 61191-1, *Printed board assemblies – Part 1: Generic specification – Requirements for soldered electrical and electronic assemblies using surface mount and related assembly technologies*

IEC 61191-2, *Printed board assemblies – Part 2: Sectional specification – Requirements for surface mount soldered assemblies*

IEC 61191-3, *Printed board assemblies – Part 3: Sectional specification – Requirements for through-hole soldered assemblies*

IEC 61191-4, *Printed board assemblies – Part 4: Sectional specification – Requirements for terminal soldered assemblies*

IEC 61192-2, *Workmanship requirements for soldered electronic assemblies – Part 2: Surface-mount assemblies*

IEC 61192-3, *Workmanship requirements for soldered electronic assemblies – Part 3: Through-hole mount assemblies*

IEC 61192-4, *Workmanship requirements for soldered electronic assemblies – Part 4: Terminal assemblies*

IEC 61249-8 (all parts), *Materials for interconnection structures – Part 8: Sectional specification set for non-conductive films and coatings*

IEC 61340-5-1, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC 61340-5-2, *Electrostatics – Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide*

IEC 61760-2, *Surface mounting technology – Part 2: Transportation and storage conditions of surface mounting devices (SMD) – Application guide*

ISO 9002, *Quality systems – Model for quality assurance in production, installation and servicing*

3 Terms and definitions

For the purposes of this part of IEC 61192, the definitions in IEC 60194 and the following apply.

3.1

new design

design that has not previously been assembled by the manufacturer

4 General requirements

4.1 Order of precedence

Unless the user specifies compliance with all of the requirements (or with specific items) in this standard, for example, as part of a supply contract, the relevant mandatory clauses and subclauses herein may be interpreted as guidance.

Line drawings in this standard are intended to assist in interpretation of the written requirements. The written requirements take precedence.

4.1.1 Conflict

When the user elects to specify compliance with all or some of the mandatory requirements of this standard,

- a) in the event of conflict between the text of this standard and the applicable documents cited herein, refer to IEC 61191-1 for the relevant priorities and to IEC 61191-2, IEC 61191-3 and IEC 61191-4 for technical requirements. However, nothing in this standard supersedes applicable laws and regulations.
- b) in the event of conflict between the requirements of this standard and the applicable user assembly drawing(s) and specifications, the latter shall govern. When the conflict is between the requirements of this standard and drawing(s) or specification(s) that have not been approved by the user, the latter shall be submitted to the user for approval. Upon such approval, the acceptance (or changes) shall be documented for example, by official revision note or equivalent on the drawing(s) or specification(s) which shall then govern.
- c) where the applicable user documentation requirements are less stringent than the applicable mandatory items in IEC 61191-1, IEC 61191-2, IEC 61191-3, IEC 61191-4, or in this standard, neither the supplier or the user shall claim compliance with this or any of the standard listed in this clause, without identifying the specific clauses and related requirement relaxations in each and every such claim.

4.1.2 Interpretation of requirements

When the user elects to specify compliance with the mandatory requirements of this standard,

- a) unless otherwise specified by the user, the word "shall", signifies that the requirement is mandatory. Deviation from any "shall", requirement requires written acceptance by the user, for example, via assembly drawing, specification or contract provision.
- b) the words "should", and "may", reflect recommendations and guidance respectively and are used whenever it is intended to express non-mandatory provisions.

4.1.3 Classification

The introduction of product classification permits the user to select performance requirements according to end-use application.

This standard recognizes that electronic and electrical assemblies are subject to classification by intended end-item use. Subclause 4.3 of IEC 61191-1 identifies three general end-product levels that have been established to reflect differences in producibility, complexity, functional performance requirements and verification (inspection/test) frequency. It should be recognized that there may be overlaps of equipment between levels.

The user of the assemblies is responsible for determining the level to which the product belongs. The contract shall specify the level required and indicate any exceptions or additional requirements to the parameter, where appropriate. The three levels are:

Level A – general electronic products, includes consumer products, some computer and computer peripherals and hardware suitable for applications where the major requirement is function of the completed assembly;

Level B – dedicated service electronic products, includes communications equipment, sophisticated business machines and instruments where high performance and extended life is required, and for which uninterrupted service is desired but not mandatory (typically the end-use environment would not cause failures);

Level C – high-performance electronic products, includes all equipment where continued performance or performance-on-demand is mandatory. (Equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support systems and other critical systems.)

The status of product for each level is subdivided into the following three workmanship conditions.

- a) **Target** – represents a standard of practice and workmanship that shall be the goal for all normal operations. (This is a pass category.)
- b) **Acceptable** – represents a minimum condition that can be supplied to a user or, where appropriate, the next manufacturing centre without correction or rework; when the incidence of deviations within this standard increases to a significant proportion of production (as set by pre-determined process control limits), it should represent cause for concern and call for corrective action. (This is a pass category.)
- c) **Non-conforming** – represents an incident that demands correction by appropriate rework (or scrapping) and is to be formally reported as a defect for quality and process control purposes; it is deemed likely to render the process unacceptable or the product subsequently unreliable. (This is a fail category.)

The first occurrence of non-conformance implies that all other conditions preceding the non-conformance are acceptable. For example, if a non-conforming condition is stated as "10 % or more of the surface is dewetted", this implies that if 9 % of the surface is dewetted, this is acceptable for that defect in the applicable level.

Non-conformance in level A automatically implies non-conformance in level B and level C. Non conformance in level B implies non-conformance in level C.

The manufacturer shall dispose of the non-conforming product based on design, service and user requirements (rework, repair, use as is, or scrap).

Actual measurement of specific material quantity, component placement, component position, or solder fillet dimensions may be carried out for referee purposes.

The inspector should not select the level for the part under inspection. Documentation that specifies the applicable level for the inspection should be provided to the inspector.

Acceptance and/or rejection workmanship decisions shall be based on applicable documentation such as the contract, the relevant specification or referenced documents. In some cases, inset tolerances may be applied to minimize the risk of subsequent process deviations or defects.

4.2 Process control

4.2.1 Defects and process deviation indicators (PDIs)

Table 2 in IEC 61191-1, Table 1 in IEC 61191-2, Table 2 in IEC 61191-3 and Table 3 in IEC 61191-4 list typical defects that are unacceptable and require disposition, for example, rework, repair. The manufacturer is responsible for identifying other areas of risk and treating those additional concerns. Such items should be documented on the assembly drawing. Other than the unacceptable defects listed, anomalies and variances from within 'acceptable' limits are considered as process deviation indicators and shall be monitored when their occurrence is observed. Disposition of process deviations revealed by PDIs is not required.

4.2.2 Process control and process improvement requirements

IEC 61191-1 requires the use of process control methodologies in the implementation and evaluation of processes used to produce electrical and electronic assemblies. Subject to agreement by the user, the manufacturer/assembler may be exempt from performing specific quality conformance evaluations and inspections detailed in this standard provided objective evidence of a comprehensive and current process improvement plan is available.

The means of control of design, of materials and component quality, and of machine operation control shall be demonstrated.

Process improvement plans do not necessarily require statistical process control methods provided evidence demonstrating alternative data collection, feedback and corrective action procedures and methods is available.

4.2.3 Requirements flowdown

The applicable requirements of this standard shall be imposed by each manufacturer or supplier on all applicable subcontracts and purchase orders. The manufacturer or supplier shall not impose or allow any variation from these requirements on subcontracts or purchase orders other than those that have been approved by the user.

Unless otherwise specified, the requirements of this document are not imposed on the procurement of off-the-shelf (catalogue) items. However, the manufacturers of these items may comply as deemed appropriate.

4.2.4 Designs

4.2.4.1 New designs

Refer to clause 3 and 5.1.

4.2.4.2 Existing designs

The requirements of this standard should not constitute the sole cause for redesign of a currently approved design. However, when existing designs undergo changes that impact hardware configuration, the design shall be reviewed and user-approved changes made that allow for maximum practical compliance.

4.2.5 Personnel proficiency

The following requirements shall be:

- a) prior to commencing work, all instructors, operators and inspection personnel shall be proficient in the tasks to be performed;
- b) objective evidence that proficiency shall be maintained and be available for review and shall include records of training to the applicable job functions being performed, testing to the requirements in this standard, and results of periodic reviews of proficiency.

NOTE For further information, refer to ISO 9001 and ISO 9002. Details of relevant training categories are given in clause 21.

4.2.6 Electrostatic discharge (ESD)

The ESD control programme shall be in accordance with IEC 61340-5-1 and IEC 61340-5-2. Documented procedures, electrostatic discharge control for the protection of ESD-sensitive electrical and electronic parts, components, assemblies and equipment shall be maintained during, but not limited to

- a) receipt and test of incoming items;
- b) board, component, and part storage and kitting;
- c) manufacturing and rework;
- d) inspection and test cycles
- e) storage, packing and shipping of completed products;
- f) transport and installation.

Failure analysis ESD procedures shall be documented and be available for review.

4.3 Facilities

4.3.1 Workplace cleanliness

The workplace shall meet the following requirements:

- a) cleanliness and ambient environments in all work areas shall be maintained at levels that prevent contamination or deterioration of soldering tools, materials and surfaces to be soldered;
- b) eating, drinking and use of tobacco products and drugs shall be prohibited in the work areas.

4.3.2 Environmental controls

The soldering facility should be enclosed, temperature and humidity controlled and maintained at a positive pressure.

For operator comfort and solderability maintenance, the temperature should be maintained between 18 °C and 30 °C and the relative humidity (RH) should not exceed 70 %. For process control, the need for closer temperature and humidity limits may apply, for example, in solder paste and adhesive deposition.

When relative humidity decreases to 30 % or lower, the manufacturer shall verify that electrostatic discharge control is adequate and that sufficient moisture is present for flux performance and solder paste application.

4.3.3 Lighting

Illumination at the working surface of manual soldering and inspection surfaces shall be 1 000 lm/m² minimum.

4.3.4 Field conditions

In field operations where the controlled environment conditions required by this standard cannot be effectively achieved, special precautions shall be taken to maximize the quality of solder connections and to minimize the effects of uncontrolled environment on the operation being carried out on the hardware.

4.3.5 Clean rooms

The assembly of electronic products may necessitate the use of clean rooms to ensure compliance with the requirements of this standard in production. If required, the class of clean room shall be agreed between the user and manufacturer/assembler.

4.3.6 Equipment maintenance

Machines incident to all the assembly, soldering and testing processes shall be maintained to assure capability and efficiency commensurate with the design parameters established by their manufacturers. Maintenance procedures and schedules shall be documented to assist reproducible processing.

4.4 Process identification

4.4.1 Construction formats and process sequences

Examples of five basic construction formats applicable to this specification are shown in figures 1 through 5, together with typical associated process sequences.

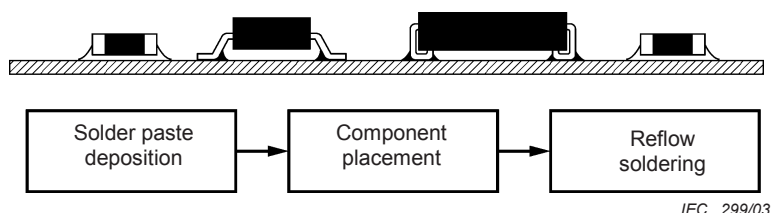


Figure 1 – SM single-sided surface-mount assembly, reflow soldering only

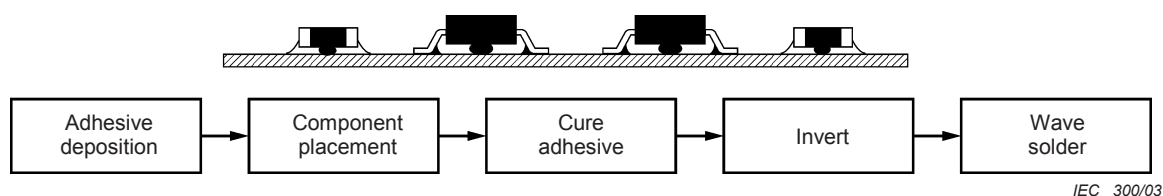


Figure 2 – SM single-sided assembly, immersion only

NOTE Where manual insertion and soldering of leaded components is required after a mass immersion flow or wave soldering operation, it may be necessary to cover the related plated through-holes with a peelable resist mask to prevent them being filled with solder. Refer to clause 19.

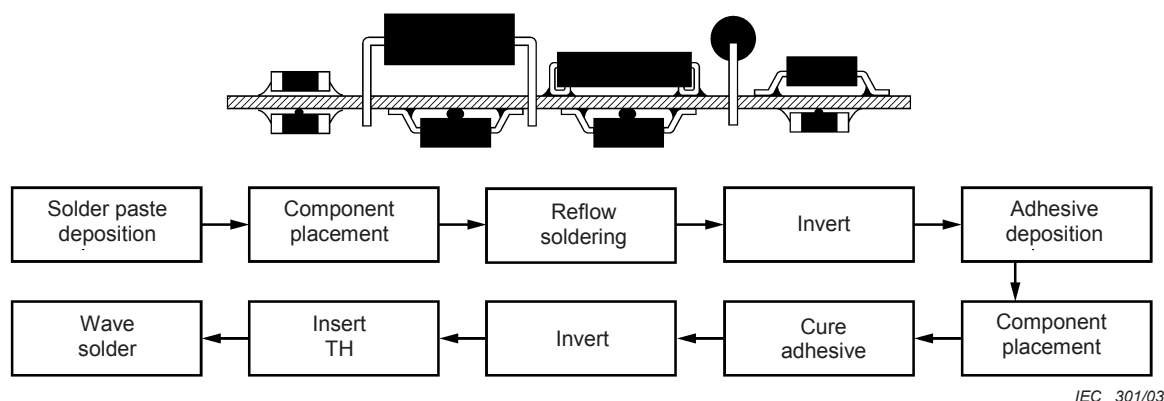


Figure 3 – Mixed technology assembly, double-sided: reflow and immersion, flow or wave solder

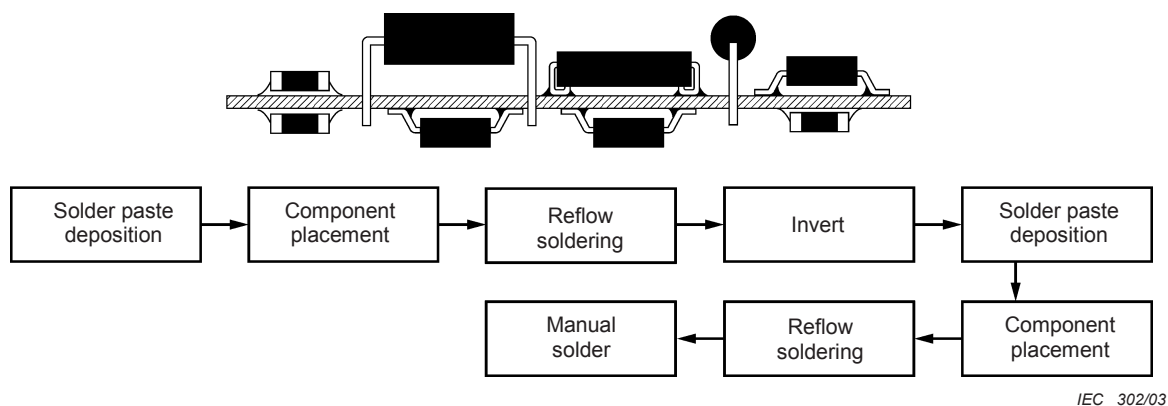


Figure 4 – Mixed technology assembly, double-sided reflow soldering and manual

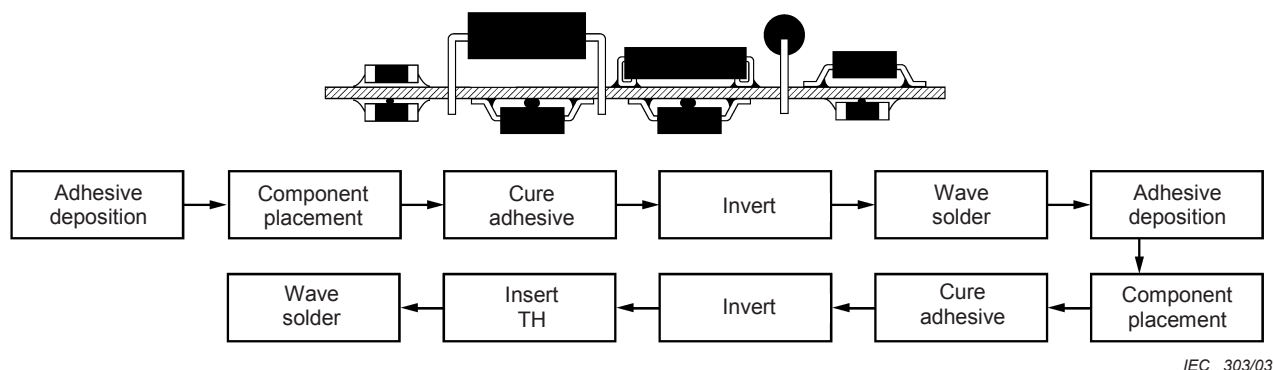


Figure 5 – Mixed technology assembly, double-sided, immersion only

4.4.2 Labelling/serialization

As a minimum, individual assemblies shall be labelled or marked in a manner that permits both the manufacturer's and the user's specified level of traceability to be achieved. For level C products, all items forming part of an assembly shall be traceable to individual goods inwards delivery notes.

4.4.3 Configuration control

To reduce risk of error in production, the issue numbers for all drawings and other data on individual products, and their modification or change notes, should be controlled for both the products and related machine control software, by a single authority within the assembler's plant.

4.4.4 Work-in-progress status

All assemblies, including those in each stage of manufacture and those returned for rework or from the user for repair, shall carry a means of identifying their status, for example, awaiting visual inspection, failed first in-circuit test, awaiting rework.

For level C products, this identification shall include the recording of each failure to pass successive inspections and tests (as well as recording the passing of them). Preferably the indicators (for example, coloured paint marks along the edge of the board or marked tags) should be easily visible to the human eye without having to apply magnification.

4.4.5 Personal safety

The assembler shall ensure that all relevant personal safety information relating to purchased equipment operation and the handling of purchased materials, components and substrates is obtained from suppliers and passed on to those who need it.

5 Pre-process activities

5.1 Design checks

This task applies to each individual board design and includes the following checking activities necessary to assure satisfactory mechanized equipment performance and manual workmanship. The list of checks is not intended to be exhaustive and does not include all reliability aspects.

5.1.1 Design checks for all assembly types

- a) Check that the board design conforms to applicable layout component clearance and orientation rules for the intended soldering and assembly processes and permits specified post-assembly component positional and relevant solder joint contour requirements given in the IEC 61191 series to be met.
- b) Check that, when the board is to be wave- or drag-soldered and supports components needing preheating to within 100 °C (or less) of the solder bath temperature (for example, leadless multilayer ceramic capacitors), sufficient space free of components has been allowed for a supporting carrier to prevent sagging.
- c) Check that all land layouts and associated tracks give thermal isolation from connected large thermal masses so that manual soldering and rework can be carried out with minimum time-temperature combination.
- d) Check that the printed board and its specified dimensions, flatness, coatings and resists and the specified components are suitable for use through the intended processes and process equipment without degradation of reliability of the assembly (in case of doubt, seek the supplier's written confirmation.).
- e) Check that the distribution of copper layers and earth-plane design are balanced to achieve the best possible board flatness after soldering. Wherever practicable, large copper areas (for example, earthplanes, power planes) should be cross-hatched to reduce delamination risks.

- f) Check that there is sufficient clearance around each component to permit the use of the appropriate manufacturer's recommended rework tool and method (see 18.5).
- g) Check that all 'in-circuit' or other test probes can contact the board without touching any solder joint, component lead or body and that the requirements of the appropriate sectional specification are met (see 17.3).
- h) Check that the available in-circuit test equipment has sufficient nodes to meet the test requirement on the basis of checking all required components – preferably in one pass through the equipment.
- i) Check that, within the constraints of available knowledge, legal safety requirements and relevant national or international safety standard specifications, the proposed design will be reasonably safe when used in the manner and environment for which it has been designed.

A hazard and risk analysis is helpful in assessing this issue and is mandatory in some applications. Where necessary, appropriate warnings to users should be made available.

5.1.2 Design checks for surface-mounted assemblies

- a) The design checks stated in 5.1.1 apply.
- b) Check that the layout enables the planned solder paste or adhesive deposition equipment to perform at acceptable speed and quality.
- c) When mass reflow soldering is intended, check that land patterns for small 2, 3 and 4 termination/lead components have balanced thermal mass and balanced surface tension effects to avoid unwanted movement during soldering.
- d) Check that the layout allows sufficient clearance for surface-mount component placement, pre- and post-soldering visual inspection of component bodies and solder joints and electrical probe testing of the assembly during in-circuit and/or functional test.
- e) Check that solder joints to surface-mounted components are sufficiently spaced away from break lines when individual circuits are separated (break-out) from a step and repeat array panel.
- f) Check that test probe pads are spaced to allow use of robust, reliable test probes, for example, not less than 2,5 mm apart (ensure that the requirements of 17 are met).
- g) Ensure that the designed test circuitry and supporting test jig(s) will not harm the assembly function or structure. Check for excessive voltages and check that mechanical forces from test probes do not distort boards after soldering, even those that are bowed, twisted or dished.
- h) Where leadless multilayer ceramic capacitors are used, check that sufficient land length is available to meet the requirements of IEC 61191-2 (see IEC 61188-5-2).
- i) When optical alignment is intended on printing or automatic component placement machines, check that the fiducial marks used on the board are suitable for the machines involved, for example, as to their size, shape, surface finish, contrast.

5.1.3 Design checks for mixed technology assemblies involving auto-placement and auto-insertion

- a) The design checks stated in 5.1.1 and 5.1.2 apply.
- b) Check that sufficient clearance is available around surface-mounted components to avoid damaging them during subsequent through-hole insertion and crop and clinch operations.

5.2 Specification and procurement of components

To assist in assuring that components supplied are 'fit for purpose' and enable rework to be kept to a minimum, the following workmanship requirement should be implemented.

5.2.1 Product processes and applications

The procuring authority should, in advance of contract placement and purchase, advise the assembler of the application field of the product and its related environmental and mechanical test specifications. The assembler should pass on this information to suppliers and also inform them of the intended assembly process and the relevant time-temperature cycles and cleaning methods to be seen by the components – including rework of solder joints and any subsequent soldering operation required for populating both faces.

5.2.2 Component package style

The assembler should ensure that the components are specified to arrive in the package style for which the board layout has been designed (see examples in Figures 6 and 7) and that they will be presented in a packaging format that the appropriate sequencing/insertion or placement equipment can handle satisfactorily, for example, in tapes, reels, tubes, trays, bulk feed magazines.

5.2.3 Component transit packaging

To optimize the maintenance of solderability, the transit packaging of solderable components should be specified as maintaining a low relative humidity and protection against atmospheric contamination in transit and in any intermediary storage, for example, on a distributor's premises. Contact between termination materials/lead surfaces and soft plastic materials such as polyethylene, cling film and transit or storage of reels, tubes or magazines packed unsealed in hygroscopic box materials such as cardboard, should be avoided wherever practicable.

In particular, packaging for ceramic and other small components should not permit jostling and abrasion of loose components, one against another.

5.2.4 Date of manufacture and solderable coating thickness

Where necessary, the assembler should ascertain the date of manufacture of components and the guaranteed minimum solderable coating thickness and method of applying it. This information will assist in determining their suitability for high post-soldering yield.

The recommended minimum solder coating thickness on any one lead is 6 μm for components to be used within 12 months of manufacture and 8 μm for any longer time. Coatings other than solder may require different minimum thickness.

5.3 Specification and procurement of printed boards

To assist in assuring that substrates/printed boards supplied are 'fit for purpose' and enable rework to be kept to a minimum, the following workmanship requirements should be implemented.

5.3.1 Specifying printed boards

In addition to dimensional and accuracy data for board size, conductor tracks, pads, lands and holes, as a minimum the specification should define the required base materials, conductor thickness as delivered (particularly for fine tracks), solder coating type and thickness range, and applicable optical recognition mark shapes, sizes, positions, and surface finish; resist type, thickness and alignment accuracy; applicable protective surface finishes, break-out dimensional requirements (for example, lug widths and positions, slots, scribe lines) and the required bare board flatness. Refer to IEC 61188-1-1.

5.3.2 Notifying assemblers and their suppliers

Before procurement, the end-user should advise the manufacturer of the application or classification level of the product and its related environmental and mechanical test specifications. The manufacturer should pass this information on to suppliers and also inform them of the intended assembly process and the relevant time-temperature cycles and cleaning methods to be seen by the substrate or board, including rework of solder joints and any subsequent soldering process required for populating both faces.

5.3.3 Suitability for high assembly yield

To assist in assuring that substrates/boards arrive in a suitable condition for giving high-yield in placement and soldering operations,

- a) the manufacturer should ensure that the land surface finish and solderability specifications applied by suppliers to their products are suitable for the applicable method(s) of placement and soldering;
- b) the method of applying the solderable coating, the solder coating flatness and thickness range (if the finish is solder), and for optical sensing, the optical characteristics of the surface, are relevant parameters;
- c) the useful storage life of anti-oxidant and pre-flux coatings should not be exceeded (refer to 7.4 d));
- d) the transit packaging materials and the maximum stack quantity should be agreed with the supplier and specified as part of the contract. (Hygroscopic materials or those having significant free sodium, chlorine or sulphur ion content (for example, shrink film, cling film) should not be allowed in contact with solderable surfaces.)

5.4 Specification and procurement of process materials

5.4.1 Solder pastes and adhesives

To assist in assuring that these materials arrive in a suitable condition for giving high yield in reflow soldering operations, for each individual container the specification should require the supplier to state the date of manufacture of the paste or adhesive and the country of manufacture. The supplier should be required to provide the key to interpreting this data.

To minimize the exposure to air of solder paste intended for printing and hence reduce the risk of solder balling, procurement should preferably be based on a paste container size that is used up within 36 h of opening and having a re-sealable lid.

Dispensing syringes, though sealed in light-proof material for transit and storage, should preferably be transparent so that any signs of separation between the paste carrier and the solder particles can be seen.

5.4.2 Solder ingots for immersion soldering

Refer to ISO 9453.

5.4.3 Cleaning materials

Normally, cleaning materials are specified by their manufacturer's reference data. Containers should be specified in sizes that can be handled safely by available personnel or local lifting and transit equipment (for example, trolleys). Containers holding flammable, toxic or otherwise harmful materials shall be marked with appropriate standard hazard labels.

Discarded (used) cleaning materials shall be placed in safe containers that are easily distinguished from those holding unused materials and marked as above. Their disposal should be organized at the same time as purchase.

Local legal environmental and safety requirements for the management of flammable, toxic and environmentally harmful materials shall be complied with.

5.4.4 Stencils and screens

These are very sensitive to mechanical damage and the procurement specification should identify the exact method of packaging and the materials used for this purpose. Packaging materials in contact with the stencil or screen should not shed particles that may block small apertures. The parameters measured and methods used for goods inwards checks should also be specified.

5.4.5 Fluxes

Fluxes should be specified as meeting the relevant requirements, for example, those given in IEC 61190-1-1 or the user specification.

5.4.6 Temporary solder masks

Temporary solder masks shall be specified as to their suitability to adhere to the board materials, as well as to the integrity, adhesion and flexibility of the adhesive through the intended soldering time-temperature profile. Any contaminant left after their removal shall be specified as harmless and shall not deteriorate the solderability of surfaces requiring subsequent soldering or impair cleaning processes (if used). Refer to 19.3.

5.5 Inspection plan, inspection facilities and handling

5.5.1 Inspection plan

Sampling and confidence levels shall be matched to the supplier's quality history, the requirements of the assembly processes and the product classification level. A documented inspection plan in accordance with ISO 9002 shall be available for review.

5.5.2 Incoming goods inspection facilities

The manufacturer or assembler shall provide suitable handling capability at goods inwards inspection that minimizes the risk of mechanical damage, chemical or other contamination and electrostatic damage to inspected items that are required for use in subsequent production.

Inspection facilities for incoming items shall also include:

- a) sufficient lighting for visual inspection, i.e., greater than 1 000 lm/m² at bench-top level;
- b) adequate visual magnification;
- c) electrical test equipment for boards and components that fulfils the specified goods inwards test strategy requirements;
 - mechanical measuring equipment and jigs of sufficient accuracy to assure that the dimensions and form of incoming items meet the specified requirements;
 - access to board and component solderability test equipment capable of assessing whether the products are suitable for gaining high post-soldering yield and minimal rework in production.

5.6 Storage and kitting of components, boards and materials

5.6.1 Storage

- a) All components, boards and process materials shall be stored under the manufacturer's recommended storage conditions and for no longer than the recommended shelf life (IEC 61760-2). Where these data are not available, the assembler should assume that boards and components require constant low humidity (<50 % relative humidity), stable temperature (for example, at +15 °C to +20 °C), and be stored away from polluting atmospheres. Boards should be stored lying flat.
- b) To preserve lead coplanarity and solderability, whenever practicable, components should be stored using tape-and-reel, tubes, trays or magazines until used, components should remain in their sealed transit packaging and housed in non-hygroscopic boxes. When breaking of the packaging seal is unavoidable, components should preferably be either stored in constant dry conditions, for example, at <40 % RH at room temperature for plastic-encapsulated integrated circuits, or repackaged in thick, re-sealable polypropylene bags with a dry desiccant.
- c) Tape-and-reel, tubes, trays and magazines should not be regarded as providing a satisfactory component storage atmosphere if they are exposed to humidity or temperature levels outside the manufacturer's recommended storage conditions. Small components in hygroscopic paper-based tapes should not be stored for long periods.
- d) Cardboard boxes are hygroscopic and therefore not recommended for use in storing solderable items unless they are retained in a temperature and humidity-controlled environment.
- e) In many instances solder pastes and/or adhesives can, with advantage to shelf life, be stored in a refrigerator, but the manufacturer should be contacted prior to so doing.
- f) Print screens and stencils should be kept scrupulously clean and, to minimize risk of damage, stored vertically (on edge) in cupboards. The risk of mechanical damage is reduced if they can be stored near the equipment that is used to clean them, rather than in a store remote from the production line.
- g) Cleaning materials shall be stored in accordance with their manufacturer's recommendations and relevant health and safety legislation shall be complied with. Bulk storage in a separate, specially designed building away from the production area is normal practice. Flammable or toxic materials required for immediate use in production shall be stored suitably in marked containers that are of a minimum practicable size. Fire extinguishers of the correct type should accompany flammable liquid containers while they are in transit into and out of stores and be available at the point of use in production.

5.6.2 Kitting

- a) Preferably, component, board, paste and adhesive stocks should be rotated and issued on a 'date of manufacture' earliest date code in/earliest date code out (EDI/EDO) basis rather than on 'date of receipt' first in, first out (FI/FO) into stores.
- b) When kitting components and boards for production batches, the assembler shall take appropriate steps to preserve the cleanliness of all solderable surfaces and precautions against damage from electrostatic discharge.
- c) For level C product manufacture, partially used tape and reels, tubes, trays and magazines at the end of a production or batch run should be returned to stores and storage conditions relevant for similar incoming goods applied.

5.7 Handling during assembly, packaging and shipping

The manufacturer or assembler shall provide at all stages suitable handling capability that minimizes the risk of mechanical damage, chemical or other contamination and electrostatic damage to all susceptible items.

- a) Solderable surfaces should not be handled with bare hands or fingers.
- b) If hand creams or lotions are used by personnel handling assemblies, they shall be of a type specially formulated for use in assembly areas; those containing silicones should be avoided.
- c) Assemblies awaiting inter-process movement or transit packaging should be stacked in racks made of conductive material that keep them well separated to avoid inter-assembly contact and risk of damage.
- d) Devices, materials and techniques used to retain parts and components to the printed board through preheat, fluxing, soldering and cooling stages shall be adequate to maintain component positioning and shall permit solder flow through plated through-holes and/or onto terminal areas. They shall not contaminate, damage or degrade any item.
- e) All personnel handling assemblies in production and packaging and shipping areas shall have received sufficient training to enable them to meet the requirements of the relevant specification. ESD precautions shall be strictly observed at all times.

5.8 Electrical testing

5.8.1 Incoming items

- a) Unless agreed in writing between the supplier and the manufacturer or assembler, the latter should perform electrical tests on incoming boards and components when the supplier cannot perform the required tests and their performance is critical to correct functioning of the equipment.
- b) For multilead through-hole and surface-mounted integrated circuits, particular care is needed during testing to avoid disturbing the leads in a manner that may affect their alignment with holes or land patterns on the board. For surface-mounting, protecting lead coplanarity and solderability is essential.

5.8.2 In-circuit test

The objective in production is to obtain a post-soldering yield that is high enough to avoid the need for rework prior to in-circuit testing.

As applied to surface-mount and mixed technology assemblies, in practice the instant diagnostic capability provided by in-circuit testing means that it is more often a soldering defect analyser than a component and interconnection test. Its value also lies in the fact that, for many circuit assemblies, a functional test at room temperature is often incapable of detecting incorrect individual component parameter values.

For these reasons, in-circuit testing (or equivalent) should always be on the basis of checking all components on the board. In some cases it may not be practical to fully exercise complex semiconductor components, but short circuits, open circuits and the presence or absence of connections should always be detectable.

5.8.3 Functional test

If no in-circuit testing is carried out, functional testing at room temperature may not reveal component parametric errors. This risk can be reduced if functional testing is carried out while the circuit is subjected to combined voltage and temperature (or other worst-case) extremes,

5.8.3.1 Boundary scan

Where the additional board surface area and finance for suitable software are available, boundary scan functional test methods can provide a suitable alternative to an in-circuit test.

5.8.4 Checking electrical/electronic test equipment

Provision should be made for routine calibration of test equipment. All equipment used to assess assembled board performance against user specifications shall be subjected to daily checks, for example, using a known "good", (golden) circuit or other methods. For equipment measuring primary parameters, for example, resistance, capacitance and inductance, verification linked to a national standard should be available.

6 Component preparation

6.1 Lead and termination solderability

Prior to acceptance of parts for storage or use, the manufacturer or assembler should ensure that they have been solderability tested using a sampling plan and conform to the requirements of the applicable solderability specifications.

To assist in maximizing the solderability of component terminations/leads, the assembler should assure, for solder-coated leads, that the guaranteed minimum solder coating thickness and the date and method of applying and, if appropriate, finishing it are suitable for the intended soldering process. Procedures should be in place to minimize degradation of solderability during storage, kitting and handling in production.

Mass reflow post-soldering results are more sensitive to component solderability than for mass immersion (for example, wave) soldering methods. For ceramic leadless components, where the contamination level in a solder bath is important (for example, due to high volume throughput) the use of nickel-barrier types with solder coating may be preferred.