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Pressure Sensor Surface Mount (SMT) Guidelines

A Technical Note

1.0 INTRODUCTION

The purpose of this Technical Note is to assist the end-user with pressure sensor (subsequently referred to as "sensor") surface mount application. Process debug and final disposition of the surface mount process is the responsibility of the end user.

2.0 Printed Circuit Board (PCB) Considerations [1]

The PCB surface finish and material should be considered for lead-free application due to the higher reflow temperature and lead-free solder compatibility.

2.1 PCB Surface Finish

Selection of a suitable surface finish depends on the end-user's PCB design requirements, assembly process, handling/storage, and cost. The most common surface finishes compatible with a lead-free SMT process are:

- Organic Solderability Preservatives (OSP)
- Electroless Ni/Immersion Au (ENIG)
- Immersion Ag
- Immersion Au

2.2 PCB Materials

Due to the higher reflow temperature requirement of lead-free solder paste, a PCB laminate material with a $T_g \geq 170°C$ is recommended.

2.3 PCB Preparation Before Solder Paste Printing

Bake PCBs at elevated temperatures within eight hours of use. This step reduces excessive moisture from the PCB. (Moisture in the PCB, under solder resist layers, trapped within layers, etc., can lead to excessive solder defects.) A bake time of four hours minimum at 65°C [149°F] is generally adequate.

3.0 Solder Paste Printing Process

3.1 Solder Paste and Flux Materials

3.11 SnAgCu Lead-Free Solder Alloy

Typical lead-free SnAgCu solder has a melting temperature of 217°C to 221°C [423°F to 430°F] for solder reflow applications. This alloy is widely accepted in the semiconductor industry due to its low cost, relatively low melting temperature, and good thermal fatigue resistance. The reliability of SnAgCu solder alloys (see Table 1) and their physical properties are almost as effective as the current lead-containing solders.

Table 1. SnAgCu Family of Lead-Free Solder Alloys

Metal	Proportion
Sn	95.5% to 96.5%
Ag	3.0% to 4.0%
Cu	0.5% to 0.7%

3.12 Flux Considerations

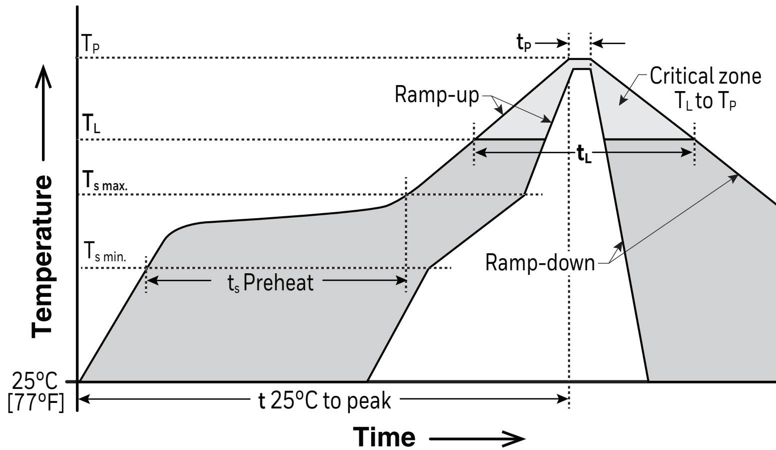
- "No-clean" flux must be used for soldering.
- If PCB assembly cleaning is performed, water soluble (WS) flux can be used. Ensure the component cavities (top side port and bottom side gage vent hole, if any) are protected by adhesive tape made with Dupont™ Kapton® polyimide film, a vinyl cap or other means prior to the cleaning process. This step prevents contamination and the introduction of foreign materials. Honeywell is not responsible for potential and foreign material contamination found in the device cavities due improper cleaning processes.

3.2 Solder Paste Reflow Profile [2]

- Ensure the solder reflow profile follows both the solder paste manufacturer's recommendation and the general JEDEC/

IPC standard J-STD-20 guidelines. Figure 1 shows the J-STD-20 specification's range of temperature profiles. The component peak temperature guidelines are given in Table 2. Note all specified temperatures in Figure 1 and Table 2 refer to the temperatures measured on the top surface of the sensor package.

Figure 1. JEDEC J-STD-20 Recommended Lead-Free Reflow Profile [2]



PROFILE PARAMETER	LEAD-FREE ASSEMBLY
Ramp-up rate ($T_{s\ max.}$ to T_p)	3°C/s max.
Preheat temperature ($T_{s\ min.}$ to $T_{s\ max.}$)	150°C to 200°C [302°F to 392°F]
Preheat time (t_s)	60 s to 180 s
Time above T_L, 217°C [423°F] (t_L)	60 s to 150 s
Peak temperature (Tp)	See Table 2.
Time within 5°C of peak temperature (tp)	20 s to 40 s
Ramp down rate	6°C/s max.
Time 25°C [77°F] to peak temperature	8 minutes max.

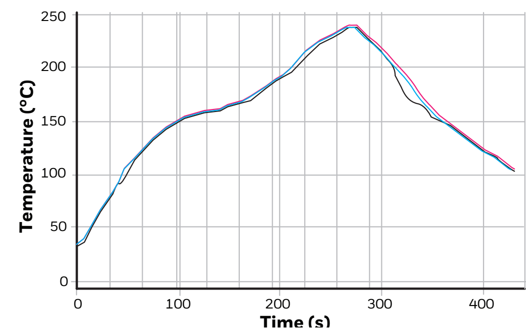
Table 2. Maximum Peak Reflow Temperatures of Lead-Free Packages

PACKAGE THICKNESS[1]	VOLUME (<350 mm^3)
<1,6 mm [0.063 in]	260°C [500°F]
<1,6 mm to 2,5 mm [0.063 in to 0.098 in]	260°C [500°F]
>2,5 mm [0.098 in]	250°C [482°F]

[1]Excludes external terminals/leads and BGA balls. Integrated heat sinks are not excluded.

- Ensure the peak reflow temperatures do not exceed the maximum temperatures specified in Table 2. This step prevents thermal damage to the sensor package. All lead-free packages are qualified for up to three times reflow at peak temperatures in accordance with Table 2.
- Figure 2 shows a generic, lead-free reflow profile.

Figure 2. Generic Lead-Free Reflow Profile



3.3 Solder Paste Storage

Typical solder paste storage temperature is 0°C to 10°C [32°F to 50°F]. Store the cartridges tip down to prevent air pocket formation. Remove the solder paste from cold storage at a minimum of eight hours before use. Do not use forced heating methods to bring the solder paste up to temperature.

3.4 Solder Paste Shelf LIfe

Solder paste shelf life is typically six months when stored tightly sealed in its original packaging and at a temperature of 0°C to 10°C [32°F to 50°F]. Use air shipment to minimize the time the container is exposed to higher temperatures.

3.5 Solder Paste Stencil Design [1]

Solder paste application is the first step of the SMT process and stencil selection is very critical. Optimal stencil specifications are:

- Material: Stainless steel foil
- Type: Laser cut
- Foil thickness: 0,27 mm [0.005 in]
- Stencil aperture reduction: 10%

Ensure the stencil aperture geometry is optimized to reduce solder balls. Figure 3 shows two geometries that help control and mitigate the risk of SMT defects due to solder balls.

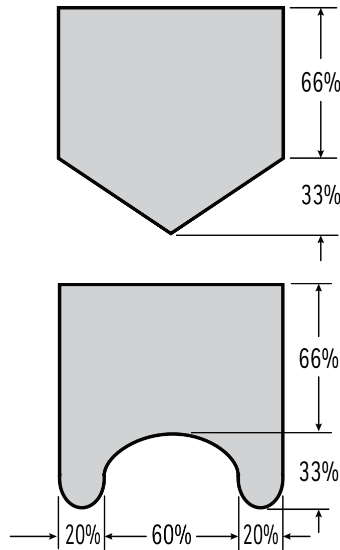
Figure 3. Recommended Stencil Aperture Geometries

Home Plate

- Inside corners are cut back to limit paste volume
- Printed at 1:1 with pad or at 10% reduction

Radiused Inverted Home Plate (RIHP)

- Corners are rounded to reduce tightness and protrusions

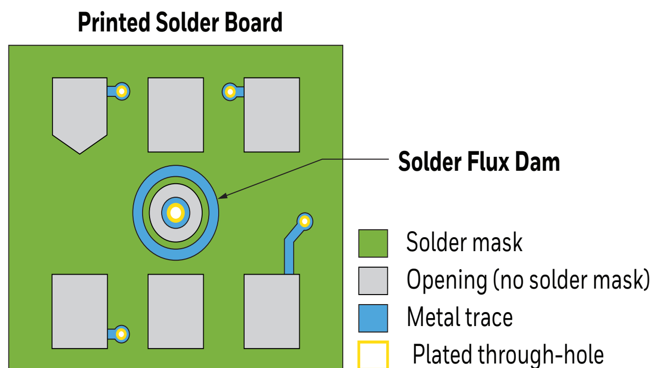


3.6 Solder Flux Dam

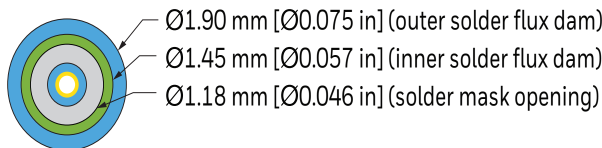
When mounting a sensor to a PCB assembly, consider using a solder flux dam to mitigate the risk of no-clean solder flux migration into the underside of the piezoresistive sense element. The basic feature geometry is shown in Figure 4.

- The solder flux dam shown in Figure 4 is for a 0.30 mm [0.012 in] diameter plated through-hole. If a different hole diameter is desired, use the dimensions given in Figure 4 to proportion the hole diameter.
- The recommended diameter for a gage sensor vent hole is 1,57 mm [0.062 in]. Ensure the vent hole lines up directly below the sensor's gage hole and that it remains open and unobstructed.

Figure 4. Solder Flux Dam Geometry (Shown with 0.30 mm Diameter Plated Through-Hole)



Solder Flux Dam Dimensions



3.7 Solder Paste Mask Considerations

- Ensure the solder mask is pulled away from the solder pad perimeter. The solder mask opening around the PCB pads can be as large as the spacing between the pads.
- Consult with the chosen PCB supplier about processing capabilities. Minimum solder mask width strongly depends on the PCB manufacturer's capabilities and the end-user's design guidelines.
- Do not place PCB vias and traces the near the package corners without using a solder mask. This step avoids potential shorting between exposed package PCB assembly features.

3.8 Squeegee Types for Use with Solder Paste

Paste solder volume is dependent on the squeegee type. For paste solder application, consider the following two types:

- Stainless steel
- Nylon

3.9 Solder Paste Printing

- Follow the solder paste manufacturer's recommended guidelines to accommodate paste-specific characteristics.
- Conduct post-print inspection and solder paste volume measurement. This step is critical in ensuring good print quality and uniform paste deposition.

3.10 Sensor Assembly Mounting to PCB Considerations

3.10.1 SMT Component Pick-and-Place

Current industry standard, automated pick-and-place equipment should be able to support most lead-free solders.

- Ensure the pick-and-place machine is equipped with an optical recognition system (such as a vision system) for centering sensor pads and PCB assembly pads during the pick-and-place process.
- Conduct a placement accuracy study to calculate compensations required to ensure pad-to-pad alignment.
- Other considerations are:
  - Pick up non-ported cover style sensors by the sides of the sensor cover.

- Pick up ported cover style sensors by the port.
- Do not subject ported style cover sensors to pick-and-place vacuum. Ensure the port is vented to atmosphere at all times.

3.10.2 Gage Sensor Vent Hole (applies to gage sensors only)

- Ensure the gage hole on the bottom remains open and unobstructed. The recommended vent hole diameter is 1,57 mm [0.062 in] in the PCB assembly to accommodate proper atmospheric venting of the application.
- Ensure the vent hole lines up directly below the sensor's gage hole and remain open and unobstructed.

3.10.3 Adhesive Use

- Use of adhesives to secure the sensor is not recommended; however, where necessary, may be applied providing the gage vent hole (if applicable) at the underside of the package does not become blocked.
- If adhesives are used, ensure they are ionically-clean, taking into account the maximum ionic content as shown in the following guidelines:
  - Cl < 50 ppm
  - K < 50 ppm
  - Na < 20 ppm

4.0 SMT Solder Reflow Process

Solder reflow process optimization is critical in ensuring successful, lead-free assembly and achieving a high yield and long-term solder joint reliability. Ensure the development of an optimized thermal profile includes the following:

- Solder paste characteristics
- PCB size
- Component density
- Larger/smaller component mix
- Component peak temperature requirements

4.1 Temperature Profiling

- Perform temperature profiling on all new PCB designs by attaching thermocouples to the PCB assembly solder joints, on the top surface of the larger components, as well as at multiple locations on the PCBs. This step ensures that all components are heated to a temperature above the minimum reflow temperatures and the smaller components do not exceed the maximum temperature limit.
- Ensure the solder reflow profile follows the solder paste manufacturer's recommendation and the general JEDEC/IPC J-STD-20 standard guidelines.

4.2 Reflow Oven Considerations

For lead-free assembly, ensure the reflow oven is equipped with multiple heating zones and a gaseous nitrogen atmosphere. Ovens with multiple heating zones offer greater flexibility to optimize the reflow profile.

A gaseous nitrogen atmosphere has been shown to improve wettability and to reduce the temperature gradient across the PCB assembly. This type of atmosphere can also enhance the appearance of the solder joints by reducing the oxidation effects, as well as enhancing wetting with lead-free solders. The vast majority of assemblers seek a solder paste that can be reflowed in air, so many lead-free solder paste chemistries are being developed with this in mind.

4.3 Sensor Soldering Methods Not Recommended

- Hand soldering is not recommended due to the excessive amount of energy lead-free soldering requires compared to solder alloys that contain lead. The heat transfer to the solder joint is very critical and must not be attempted with a soldering iron.
- IR reflow is not recommended due to potential damage from radiation heat transfer.

4.4 Sensor Reflow Considerations

- For optimum performance, ensure the sensor is reflow soldered only once. Sensor performance may degrade if it is subjected to more than one de-soldering and subsequent re-soldering to the PCB assembly.
- Ensure the sensor is positioned with the port oriented upward, NOT downward.
- Ensure the sensor port is covered while being mounted to the PCB assembly.

4.5 Post Reflow Visual Inspection Considerations

Lead-free solder joints are not as shiny as Sn/Pb solder joints. In addition, the solder fillet profile is generally not as great as with the Sn/Pb solder joints.

- Train quality inspectors to distinguish the quality of lead-free solder joints after reflow.
- Implement IPC-610 (Acceptability of Electronic Assemblies) and train/certify operators to follow this standard.

5.0 PCB Assembly Handling Considerations

Packaging stresses associated with sensor assembly to a next level PCB assembly should be covered in the final assembly design. Ensure the following precautions are taken:

- Use keep out areas at the end-of-line test probe locations. Avoid probe location around or directly on the opposite side of the sensor. Test probes in the wrong locations may affect sensor output.
- Survey all end-of-line test systems to understand the maximum microstrain exerted on the sensor/PCB assembly. It is recommended that strain on each assembly is $\leq$ 500 µstrain.
- Sensor orientation sensitivity is addressed.
- Do not screw down or heat stake the PCB assembly near the sensor. Ensure screw and heat staking locations do not exert excessive force in, around, or directly on the opposite side of the sensor. Excessive screw or heat staking force can affect sensor output.
- Do not use ultrasonic cleaning. The frequencies used may damage wire bond interconnections.
- Survey singulation processes like PCB assembly depaneling/sawing with a sensor to understand the maximum strain exerted on the sensor/PCB assembly. It is recommended that strain on each assembly is $\leq$ 500 µstrain.

6.0 Diagnostic Tools and Troubleshooting

Table 3 provides several diagnostic tools that may be used for process debug and final disposition of the surface mount process.

Table 3. Soldering Diagnostic Tools

Name	Purpose
X-ray analysis	• Ensures proper solder spread under the sensor to the boundary of the pad • Addresses solder voiding
Solder joint micro-sectioning	• Provides a method to inspect solder joint quality during process optimization; it is less suitable to production inspection due to process limitations
In-process 3D solder paste analysis	• Monitors solder volume during the solder application process; 3D solder paste analysis real-time feedback can be attained using currently available equipment
Solder strength shear testing	• Determines solder volume; Analysis tools are available to provide feedback

See Appendix A for the following troubleshooting guidelines:

- Table A1: Solder Paste Printing Process
- Table A2: Solder Reflow Process
- Table A3: Component Pick and Place Process

APPENDIX A. TROUBLESHOOTING GUIDELINES

Table A1. Solder Paste Printing Process Troubleshooting Guide

PROBLEM	PREVENTION	REMEDY
Excess solder paste	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup	• Use an Xbar-R chart to track solder paste height • Ensure a reflow oven thermal profile is part of the oven certification program • Reduce screen printer print gap • Reduce squeegee speed and/or force • Reduce stencil aperture by 10% • Investigate a different stencil aperture geometry such as the home plate design (See Section 3.5)
Solder balls	• Conduct operator training • Conduct stencil buy-off before production • Ensure proper solder paste storage temperature • Ensure proper solder paste thawing time • Ensure solder paste FIFO (First In/First Out) use • Perform first article solder paste height inspection after setup	• Conduct 100% visual inspection • Measure solder paste height • Use an Xbar-R chart to track solder paste height • Reduce stencil aperture by 10% • Investigate a different stencil aperture geometry such as the home plate design (See Section 3.5)
Damaged stencil apertures	• Conduct operator training • Conduct stencil buy-off before production • Implement a periodic squeegee replacement program • Perform first article solder paste height inspection after setup	• Conduct 100% visual inspection • Measure solder paste height • Use an Xbar-R chart to track solder paste height • Conduct stencil inspection at shift change
Pad- to-pad offset	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Readjust stencil position and pad registration • Check stencil tension • Conduct stencil inspection at shift change • Clean stencil every four hours
Solder smear	• Conduct operator training • Conduct stencil buy-off before production • Implement a periodic squeegee replacement program • Perform first article solder paste height inspection after setup	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Readjust stencil position and pad registration • Check stencil tension • Check stencil for excessive wear • Check squeegee for wear • Conduct stencil inspection at shift change • Clean stencil every four hours

Table A1. Solder Paste Printing Process Troubleshooting Guide (continued)

PROBLEM	PREVENTION	REMEDY
Small areas of solder smaller than aperture/pad	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup • Implement periodic squeegee replacement program • Ensure stencil printer has real time squeegee pressure and speed control and feedback	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Clean stencil every four hours • Add fresh solder paste to stencil • Adjust squeegee print speed
Large areas of solder greater than aperture/pad	• Conduct operator training • Conduct stencil buy-off before production • First article solder paste height inspection after setup • Periodic squeegee replacement program	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Reduce squeegee pressure • Ensure stencil printer has real time squeegee pressure feedback • Clean stencil every four hours • Inspect PCB for contamination • Inspect stencil at end of shift
Paste volume high/ solder deposition height too high	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Reduce squeegee speed • Reduce squeegee pressure • Reduce printer print gap • Clean stencil every four hours • Inspect stencil at end of shift
Solder slump	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup • Ensure proper solder paste storage temperature • Ensure proper solder paste thawing time • Ensure solder paste FIFO use • Follow solder paste technical data sheet	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Adjust squeegee speed • Reduce squeegee pressure • Ensure solder stencil printer has real time squeegee pressure and speed control and feedback
Excess solder paste	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup • Ensure proper solder space storage temperature • Ensure proper solder paste thawing time • Ensure solder paste FIFO use	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Conduct stencil inspection at shift change • Reduce stencil aperture size • Reduce stencil thickness

Table A1. Solder Paste Printing Process Troubleshooting Guide (continued)

PROBLEM	PREVENTION	REMEDY
Excessive squeegee pressure, debris on PCB, damaged aperture, warped stencil	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup • Implement periodic squeegee replacement program	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Reduce squeegee pressure • Ensure stencil printer has real time squeegee pressure feedback • Clean stencil every four hours • Inspect PCB for contamination • Inspect stencil at end of shift
Large variation in solder height	• Conduct operator training • Conduct stencil buy-off before production • Perform first article solder paste height inspection after setup	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Inspect stencil at end of shift • Measure solder paste height • Use an Xbar-R chart to track solder paste height • Adjust screen printer separation speed • Adjust squeegee speed • Ensure screen printer has real time squeegee pressure and speed control and feedback
Low solder volume/ low solder height	• Conduct operator training • Conduct stencil buy-off before production • Conduct first article solder paste height inspection after setup • Implement periodic printer squeegee replacement program	• Conduct 100% visual inspection • Supervision conducts first piece inspection and process sign-off • Inspect stencil at end of shift • Measure solder paste height • Use an Xbar-R chart to track solder paste height • Adjust screen printer separation speed • Adjust squeegee speed • Increase stencil thickness • Ensure screen printer has real time squeegee pressure and speed control and feedback
Ionic/Non-Ionic Contamination	• Conduct operator training • Follow operator Instructions • Ensure proper use of personal protective equipment • Follow PCB specification for: - manufacturing - shipping - handling - cleanliness	• Ensure the non-ionic cleanliness requirements of the PCB surface material is 10 $\mu g/cm^2$ as measured per IPC-TM-650 2.3.38 (Test Methods Manual: Surface Organic Contaminant Detection Test) • Ensure the ionic cleanliness requirements are specified as <2.5 $\mu g/in^2$ NaCl per IPC TM-650 2.3.28 (Test Methods Manual: Ionic Analysis of Circuit Boards, Ion Chromatography Method) in the manufacturing specification
Solder Flux not Activated	• Conduct operator training • Follow operator instructions • Follow solder manufacturer technical datasheet	• Ensure a reflow oven thermal profile is included in the oven certification program • Ensure oven thermal profile is above 150°C [302°F] for one to two minutes to completely activate solder flux
Component Open Circuit	• Conduct operator training • Follow operator instructions • Ensure proper use of personal protective equipment • Follow ANSI/ESD S20.20 (Electrostatic Discharge Certification)	• Supervision conducts first piece inspection and process sign-off • Implement a formal ESD management program to provide constant ESD monitoring and prevention; program should include process surveys of ESD throughout the manufacturing environment

Table A2. Solder Reflow Process Troubleshooting Guide

PROBLEM	PREVENTION	REMEDY
Cold Solder Joint	• Conduct operator training • Follow operator instructions • Follow solder manufacturer's technical datasheet	• Supervision conducts first piece inspection and process sign-off • Ensure a reflow oven thermal profile is included in the oven certification program • Ensure solder exceeds liquidous temperature of 217°C to 221°C [423°F to 430°F]
Short Circuit	• Conduct operator training • Follow operator instructions • Follow solder manufacturer's technical datasheet	• Supervision conducts first piece inspection and process sign-off • Conduct In Circuit Testing (ICT) • Use an Xbar-R chart to track solder paste height • Ensure a reflow oven thermal profile is included in the oven certification program • Reduce stencil aperture by 10% • Investigate a different stencil aperture geometry such as the home plate design (see Section 3.5)
Ionic/Non-Ionic Contamination	• Conduct operator training • Follow operator instructions • Ensure proper use of personal protective equipment • Follow PCB specification for: - manufacturing - shipping - handling - cleanliness	• Ensure the non-ionic cleanliness requirements of the PCB surface material is 10 µg/cm^2 as measured per IPC-TM-650 (2.3.38) • Ensure the ionic cleanliness requirements are specified as <2.5 µg/in^2 NaCl per IPC TM-650 2.3.28 in the manufacturing specification • Review PCB specification for: - shipping - handling - cleanliness
Component Tombstone	• Conduct operator training • Follow operator instructions • Follow solder manufacturer technical datasheet	• Ensure a reflow oven thermal profile is included in the oven certification program • Slow down the oven profile ramp rate to reduce uneven thermal gradients • Conduct post reflow automated optical inspection
Component Billboard	• Conduct operator training • Follow operator instructions • Follow solder manufacturer technical datasheet	• Ensure a reflow oven thermal profile is included in the oven certification program • Adjust component placement position • Conduct post reflow automated optical inspection
Solder Flux not Activated Causing Short Circuit	• Conduct operator training • Follow operator instructions • Follow solder manufacturer technical datasheet	• Ensure a reflow oven thermal profile is included in the oven certification program • Ensure oven profile is above 150°C [302°F] for one to two minutes to completely activate solder flux
Component Open Circuit ESD	• Conduct operator training • Follow operator instructions • Ensure proper use of personal protective equipment • Follow ANSI/ESD S20.20 (Electrostatic Discharge Certification)	• First piece inspection and process sign-off by supervision • Conduct In Circuit Testing (ICT) • Implement a formal ESD management program to provide constant ESD monitoring and prevention; program should include process surveys of ESD throughout the manufacturing environment

Table A3. Component Pick and Place Process Troubleshooting Guide

PROBLEM	PREVENTION	REMEDY
Misplaced Components	• Conduct operator training • Follow operator instructions • Ensure proper use of personal protective equipment	• Supervision conducts first piece inspection and process sign-off • Ensure pick-and-place machine is equipped with visual inspection to detect mis-picked components • Ensure pick-and-place machine aborts after three pick attempts
Component Polarity Placed Incorrectly	• Conduct operator training • Follow operator instructions • Ensure proper use of personal protective equipment • Ensure component polarity is controlled in tape and reel	• Supervision conducts first piece inspection and process sign-off • Ensure pick-and-place machine is equipped with visual inspection to detect mis-picked components • Ensure pick-and-place machine aborts after three pick attempts
Wrong Component Value	• Conduct operator training • Follow operator instructions • Ensure proper use of personal protective equipment • Ensure MRP (Material Requirements Planning) system/BOM (Bill of Materials) is linked with bar code reader on reel, and bar code on reel feeder	• Supervision conducts BOM walk, first piece inspection, and process sign-off • Ensure pick-and-place machine has programming aspects that dedicate feeders and components
Missing Component	• Conduct operator training • Follow operator instructions • Ensure proper use of personal protective equipment • Clean vacuum tip periodically	• Supervision conducts first piece inspection and process sign-off • Implement a formal ESD management program to provide constant monitoring and prevention of electrostatic discharge; program should include process surveys of ESD throughout the manufacturing environment

References:

[1] Shea, Chrys. "Stencil Design for Lead-Free SMT Assembly," Available: www.practicalcomponents.com. [Accessed Sept. 29, 2017].

[2] JEDEC Solid State Technology Association, "Joint IPC Standard for Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices," J-STD-020E, 2014. Available: www.jedec.org, www.jedec.org/system/files/docs/J-STD-020E.pdf. [Accessed Oct. 3, 2017].

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