www.singhamarpreet.com

SMT – Understanding Reflow Profile

Zenaca Consulting
Amarpreet Singh

Revision 0
Dec 23, 2023

Agenda

- Purpose
- Reflow oven – Major OEM
- Components of reflow oven
- Reflow profile
- Common defects

Purpose

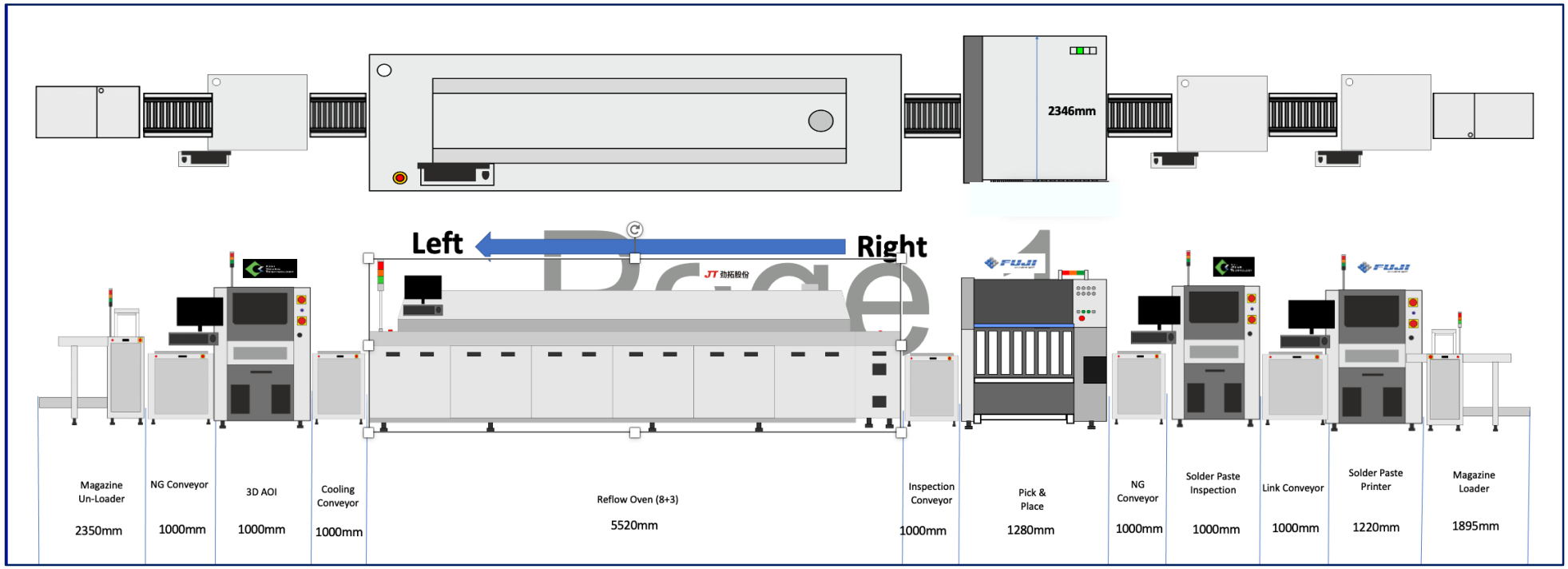
“ The purpose of this document is to provide a comprehensive overview of the “Reflow Soldering Process “in the context of printed circuit board assembly (PCBA).”

SMT Line Details

- Reflow soldering is a critical step in the Printed Circuit Board Assembly (PCBA) process. It is the method of soldering SMT components onto a PCB.

- During the reflow soldering process, the solder paste undergoes a controlled heating and cooling cycle to create reliable and strong solder joints between the components and the PCB.

SMT Equipment Details



- A reference line with Fuji Pick n place machine.

Reflow Oven - Major OEM

1. BTU International
2. Electrovert
3. Heller industries
4. Rehm thermal systems
5. SEHO Systems
6. ERSA GmbH
7. SMT Max
8. JT
9. JTU
10. Tamura

** In addition to this list, there will be additional OEM's supplying SMT reflow ovens.*

Components of Reflow Oven

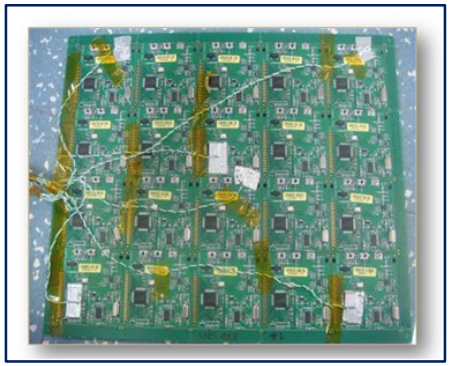
1. Heating Zone: Heating zones in a reflow oven are responsible for gradually raising the temperature of the printed circuit board (PCB) assembly during the reflow soldering process. The purpose is to bring the solder paste to its melting point, allowing it to form reliable solder joints between the components and the PCB.

- *Conveyor System*: The PCB assembly is transported through the heating zones on a conveyor belt. The conveyor speed is adjustable, allowing for precise control over the time the PCB spends in each heating zone.

- *Infrared (IR) or Convection Heating*: Heating zones typically use either infrared radiation or convection heating (hot air) to transfer heat to the PCB assembly. Infrared heating is efficient for rapid and targeted heating, while convection heating provides uniform temperature distribution.

Components of Reflow Oven

- *Temperature Profile*: The reflow oven is programmed with a specific temperature profile that dictates the heating ramp-up, dwell time, and cooling phases. Multiple heating zones allow for precise control of the temperature profile based on the requirements of the solder paste and components.



Profile Board

Thermal Profiler

The temperatures are measured using a thermal profiler. An actual PCBA is converted as a profile board and thermocouples are attached to the various locations of the PCBA for measuring the temperature on various components of the PCBA.

Components of Reflow Oven

2. Cooling Zone: The cooling zone in a reflow oven is designed to gradually cool down the PCB assembly after the reflow process. The controlled cooling prevents thermal shock and ensures that the solder joints solidify without defects.

- *Forced Air Cooling* : Fans or forced air systems are commonly used to facilitate the cooling process. The controlled airflow helps in dissipating heat from the PCB assembly. For high end application N2 (Nitrogen) environment is created in cooling zone for creating high reliable solder joints.

- *Temperature Reduction* : The temperature in the cooling zone is gradually reduced to avoid abrupt changes that could lead to stress on the solder joints or components.

Components of Reflow Oven

3. Control System: The control system in a reflow oven plays a pivotal role in regulating and monitoring various parameters to ensure optimal soldering conditions.

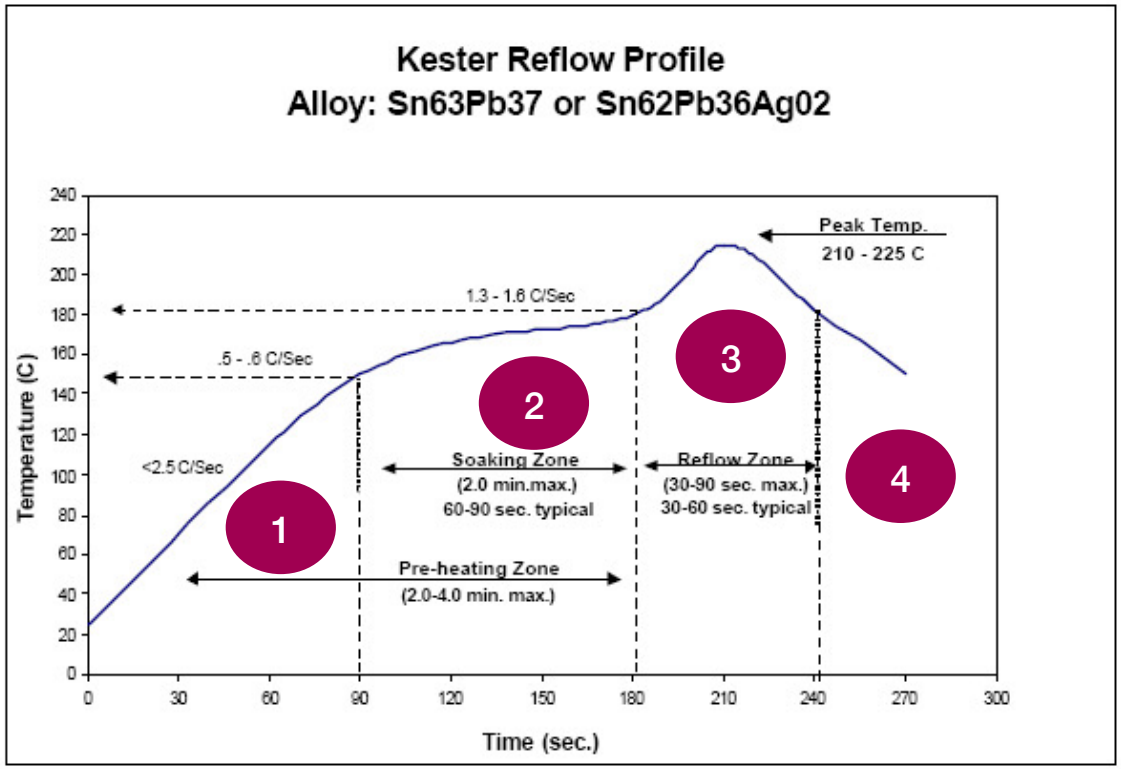
- *Temperature Control* : It provides precise control of temperature profiles in each heating zone. Closed-loop temperature control systems maintain setpoints with high accuracy.
- *Conveyor Speed Control* : The conveyor speed is adjustable to control the time the PCB spends in each zone, adhering to the specified reflow profile.
- *User Interface:* User-friendly interfaces enable operators to input reflow profiles, monitor the production process, and adjust as needed.

Components of Reflow Oven

- *Data Logging and Monitoring* : Advanced reflow ovens feature data logging capabilities, allowing manufacturers to track and analyse temperature profiles for quality control. Real-time monitoring of key parameters ensures immediate detection of any deviations from the desired profile.

- *Integration with SMT Line:* The control system is often integrated with the broader SMT assembly line, allowing for seamless coordination with other equipment. The ovens communicate with the MES system too to track the progress of each PCBA on the line and related parameters.

Anatomy Of Reflow Profile

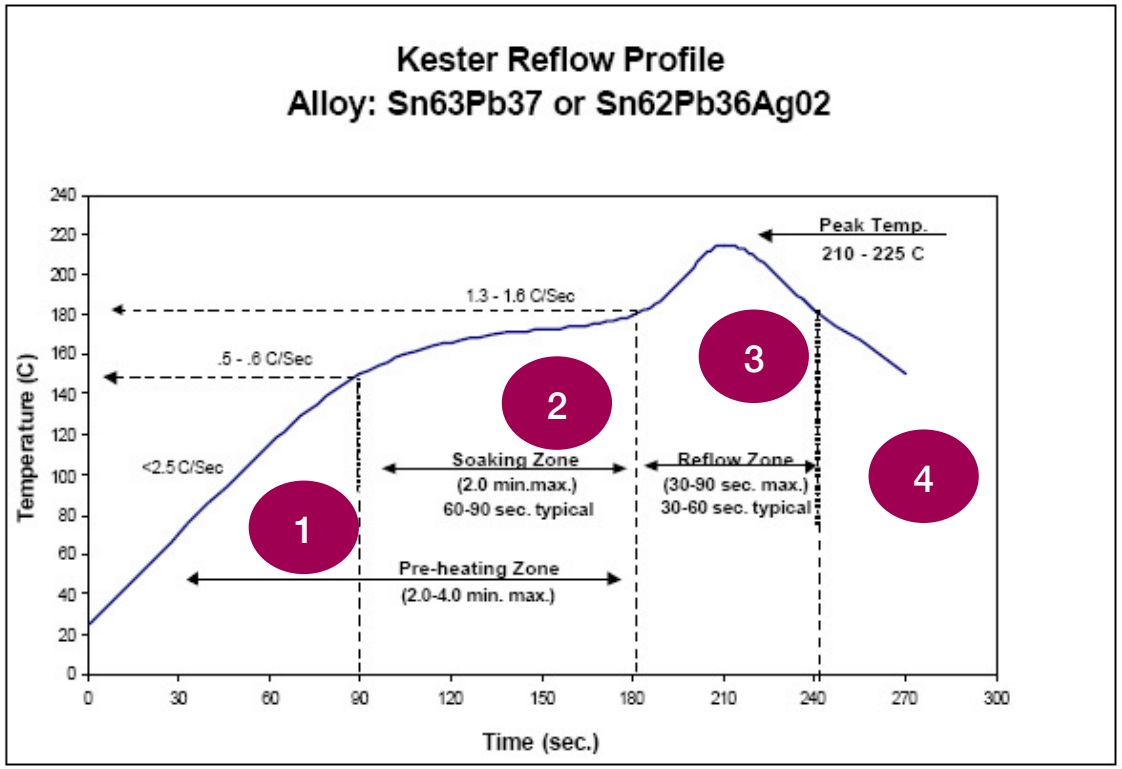


Picture Credit - https://electronics.stackexchange.com/

1. Pre-Heat : Conveyor carries the PCB assembly into the preheat zone. The purpose of this zone is to remove moisture and prepare components for soldering.

2. Soak: PCB moves through the soak zone. This zone activate the flux and promote proper wetting of solder paste.

Anatomy Of Reflow Profile



3. Reflow: PCB enters the reflow zone where solder paste melts and wicks around the component and to the PCB pad.

4. Cooling: PCB proceeds through the cooling zone. This zone cool the assembly, solidifying the solder joints.

1. Pre-Heat

- In this zone board temperature increases from room temperature to 150ºC.
- While the board is heating, the solvent is evaporating from the deposited solder paste.
- Both the board and components begins warming up.
- The board temperature is ramped up at a rate in the range of 1.5ºC to 2.5ºC per second, resulting in an overall time in preheating zone of about 50-90 seconds.

2. Soak

- Ensures that the entire board, including components of various masses, is at nearly equal temperature prior to solder melting.
- The component of different masses must be at same temperature or very close to same temperature.
- In the soak zone, the activated flux also prevents the solderable surfaces from re-oxidizing.
- The amount of soak time required for a given assembly depends on the thermal variation across the board and how quickly the oven’s convention can overcome those differences.

3. Reflow

- In the reflow solder zone, the temperature is elevated to the melting point of the solder paste applied on the PCB pads.
- The molten solder acts as a bridge between the component leads and the PCB pads.
- Components may slightly shift during the reflow process, however these components aligned themselves based on the surface tension of the molten solder.
- The duration and temperature settings in this zone are critical for achieving the desired solder joint quality and preventing soldering issues.

4. Cooling

- The cooling zone is designed to gradually reduce the temperature of the PCB assembly after it has passed through the reflow solder zone.
- This controlled cooling helps prevent thermal shock to the components and ensures that the solder joints solidify without defects. It also helps preventing warpage and thermal stress on the PCB and the components.
- The cooling zone contributes to overall component reliability by preventing thermal shock and stress, which can impact the functionality and lifespan of electronic components.

Reflow Profile - Optimisation

Zone	Too Little Time(Fast Ramp)	Too Much Time (Slow Ramp)
Pre-Heat	Solder spattering Tombstone (If no soaking) High delta T (Difference in temperature across various components) Component pop corn or cracking	Mid chip solder balls Tombstone (If no soak) Flux is consumed even before solder metal reach liquids state
Soak	High delta T Tombstone Heavy flux residue	Charred flux residue, difficult to probe during ICT Poor wetting Random solder balls Mid chip solder balls Solder bridging
Reflow	Grainy solder joints Poor IMC (Inter metallic contact) Low fillet wetting height Intermittent open soldering joints Poor wetting	De-wetting Charred flux residue PCBA Warpage or delamination Component damage
Cooling	Thermal shock to components Intermittent open solder Fine soldering cosmetics	Poor cosmetics (Dull solder) Rough solder surface Fillet cracking (Even more in lead free soldering) Component displaced or disturbed solder joints

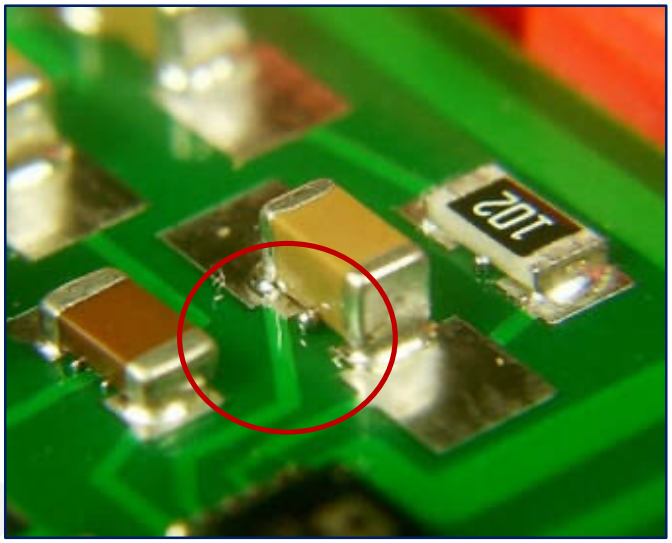
Reflow Attribute Balance

Attribute	*Too Little Time(Fast Ramp)*	*Too Much Time (Slow Ramp)*
Mid chip solder balls	Better	Worse
Random solder balls	Better	Worse
Tombstone	Worse	Better
Solder Void	Worse	Better
Solder spattering	Worse	Better
Solder cosmetics	Better	Worse

* The reflow profile needs to be designed and optimized for each PCBA.

Common Defects

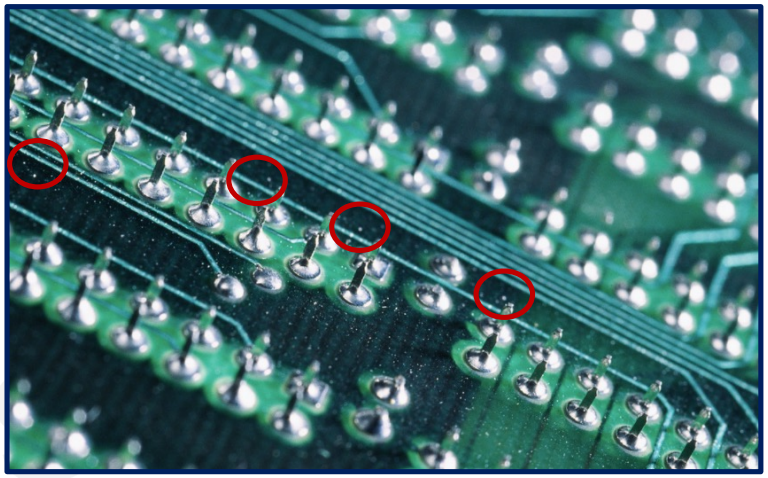
Mid Chip Solder Balls



- Potential Contributors
  - Size and shape of paste deposit
  - Pad finish
  - Reflow profile
  - Solder mask relief
  - Placement pressure
- How is it formed ?
  - There is too much of solder volume on the pad that gets squeezed out during the chip placement on the PCB
  - The paste which is squeezed out and sitting on the solder mask, gets converted into a solder balls.
- Possible Solutions
  - Stencil design improvement
  - Pad design improvement
  - Improve reflow profile

Random Solder Balls

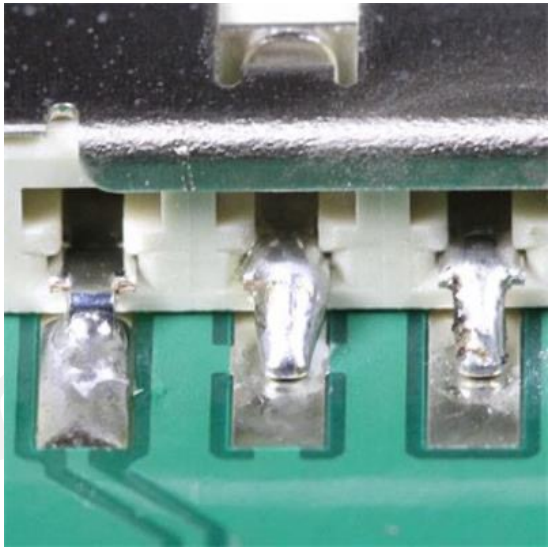
- Potential Contributors
  - Excess solder paste deposition
  - Reflow profile parameters
  - Inaccurate component placement
  - Inadequate cleaning of stencil, dried or blocked apertures
  - Component contamination
- Possible Solutions
  - Optimum stencil design
  - Store and handle solder paster as per supplier recommendations
  - Reflow profile optimisation
  - Accurate pick and placement of components
  - Select solder paste with low voiding characteristics



* For high reliability and critical boards, it is always recommended to implement machine cleaning and ensuring 100% removal of solder balls from the PCBA.

Poor Wetting

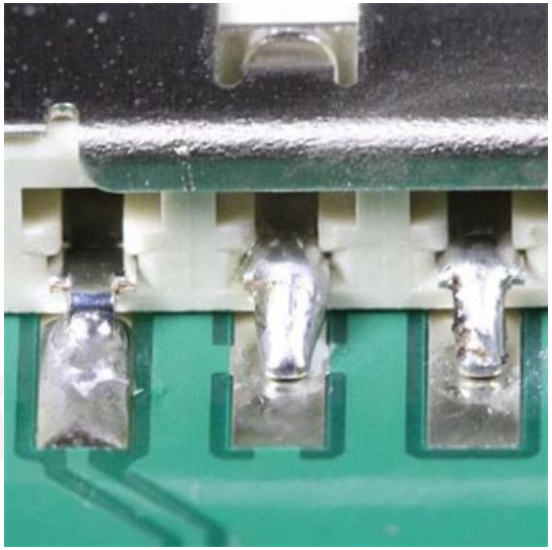
- It occurs when flux activity is reduced and can no longer remove the oxides from the board and component surfaces effectively.
- When this happens, the solder conglomerates and draws back from a wetted surface.
- Long soak temperatures can contribute to non wetting or poor wetting. Even oxidation of the PCB pads or component leads can result in poor wetting.



* It is always recommended minimum handling of the PCBA with bare hands, as this could also results in poor wetting of the solder joints due to contamination.

Poor Wetting

- It occurs when flux activity is reduced and can no longer remove the oxides from the board and component surfaces effectively.
- When this happens, the solder conglomerates and draws back from a wetted surface.
- Long soak temperatures can contribute to non wetting or poor wetting. Even oxidation of the PCB pads or component leads can result in poor wetting.



* It is always recommended minimum handling of the PCBA with bare hands, as this could also results in poor wetting of the solder joints due to contamination.

Tombstone

- *Definition* – Components on the PCB are exposed to heat, and tombstoning occurs when one end of a component is heated more quickly or to a higher temperature than the other end.

Uneven heating can be due to imbalances in thermal mass or differences in heat dissipation between the two ends of the component.

- *Possible Causes* –
  - Aperture design/ solder paste volume.
  - Pad shape / size
  - Uneven heating
  - Component placement accuracy
  - Difference in thermal mass on both terminals of the component

- *How to prevent it* –
  - ✓ Revaluate and Optimize the Reflow Profile
  - ✓ Stencil Design and Printing Optimization
  - ✓ Improve Component Placement Accuracy

In some cases, a combination of these fixes and additional process adjustments may be necessary to effectively eliminate tombstoning

Solder Voids

- *Definition* – Solder voids refer to the presence of small pockets or gaps within the solder joints of a printed circuit board assembly (PCBA). These voids are typically filled with gas, such as trapped air or volatiles released during the soldering process.
- *Possible Causes* –
  - Solder paste contamination
  - Contamination on PCBA pads or component leads
  - Metallisation of surface finish on PCBA and component
  - Reflow profile, low soak time
  - Pad geometry or component orientation might lead to solder voids (Air trapped in solder)
- *Mitigation Actions*–
  - Ensure components and PCB pads are free of moisture and contamination
  - Extended pre-heat time time above liquidous
  - Selection of chemistry, which is designed for higher soaks times and TAL.

Key to Successful Reflow Process

- Passionate process engineers, well trained by Industry experts on reflow profiling. Reflow profile is a mix or art and science as every product has different behaviour in reflow oven considering the design, components, solder paste etc.
- Operator training and certification system in place. No deviations from the defined processes.
- Process validation and continuous improvement culture. Zero defect quality mindset.
- Machine maintenance (TPM, Preventive) and calibration as per machine supplier guidelines.

Do you have more questions on topic ?

Please reach me at

Email : amar@singhamarpreet.com

Contact : +91 96866 83783

www.singhamarpreet.com

Thank You