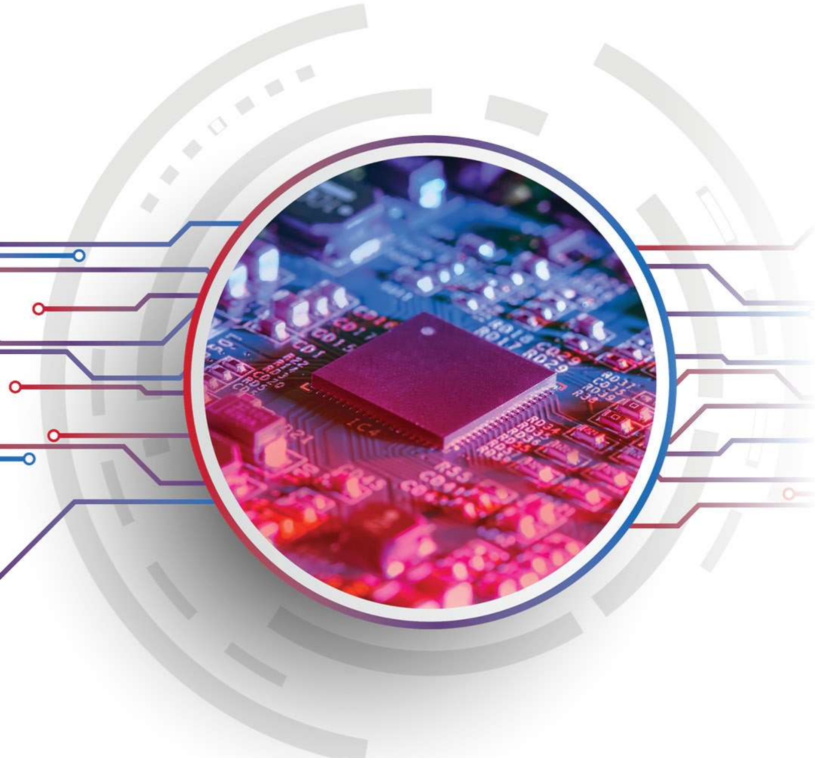
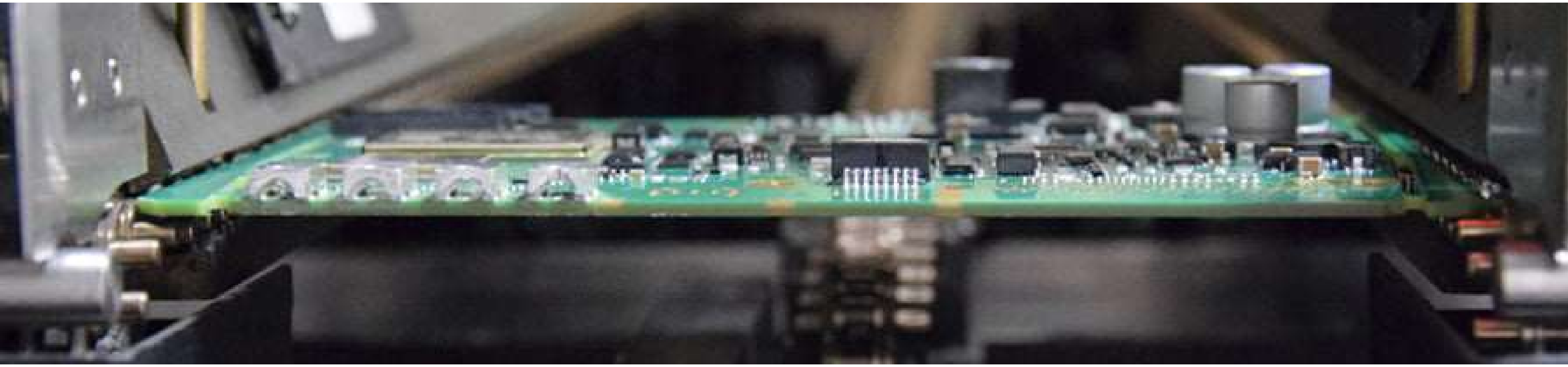


# An Understanding on SMT REFLOW

01.8.2021

MacDermid Alpha
ELECTRONICS SOLUTIONS

# Reflow

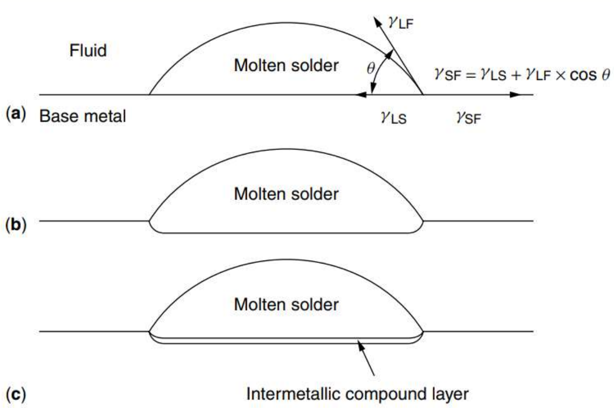


# Soldering theory

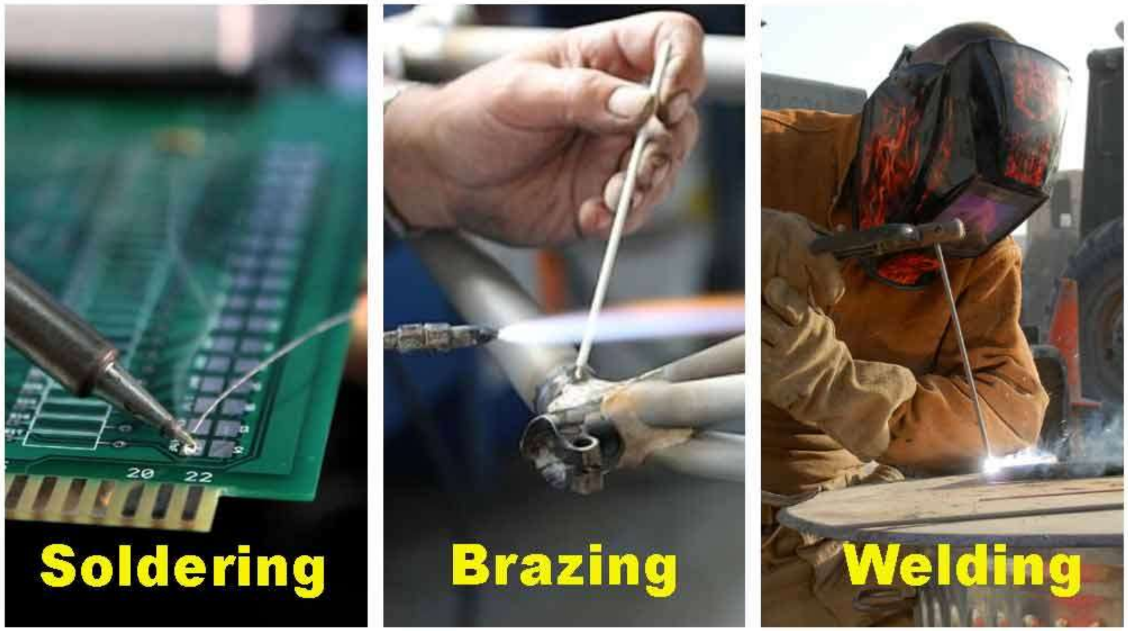
The soldering process can be depicted below and can be roughly divided into three stages:

(1) Spreading (2) base metal dissolution and (3) formation of an intermetallic

Solder wetting process involves (a) liquid solder spreading over base metal, with contact angle θ dictated by balance of interfacial tension forces, (b) base metal dissolving in liquid solder, (c) base metal reacting with liquid solder to form intermetallic compound layer




In this relation, γSF stands for the interfacial tension between the base metal substrate and the fluid, γLS is the interfacial tension between substrate and the liquid solder, γLF is the interfacial tension between liquid solder and the fluid, and θ represents the contact angle between liquid solder and the substrate.


Soldering
Brazing
Welding

## Comparison of Welding, Soldering and Brazing.

| S.No. | Welding | Soldering | Brazing |
|---|---|---|---|
| 1 | These are the strongest joints that can bear the load. The strength of the welded joint can exceed the strength of the base metal. | These are the weakest joint of the three. Not to bear the weight. Generally, use to make electrical contacts. | These are stronger than soldering but also weaker than welding. It can be used to bear some load. |
| 2 | The temperature of the desired welding zone is upto 3800°C. | Temperature required upto 450°C. | It may go up to 600°C in brazing. |
| 3 | The workpiece needs to be heated to their melting point to join. | Workpieces do not need to be heated. | The workpiece is heated but below the melting point. |
| 4 | The mechanical properties of the base metal may vary in the joint space due to heating and cooling. | There is no change in mechanical properties after joining. | The mechanical properties of the joint may change, but it is almost negligible. |
| 5 | Involving heat consumption, high-level skills are required. | The costs involved and the skill requirement is very low. | The costs involved and the skills needed are between the two others. |
| 6 | Heat treatment is usually required to eliminate the unwanted effects of welding. | No heat treatment is required. | No heat treatment is required after brazing. |
| 7 | Since it is performed at high temperature, it is not necessary to preheat the work before welding. | Preheating the workpiece before soldering is good for making good quality joints. | Preheating is beneficial for forming a solid joint because brazing is done at relatively low temperatures. |

# What is Reflow Soldering

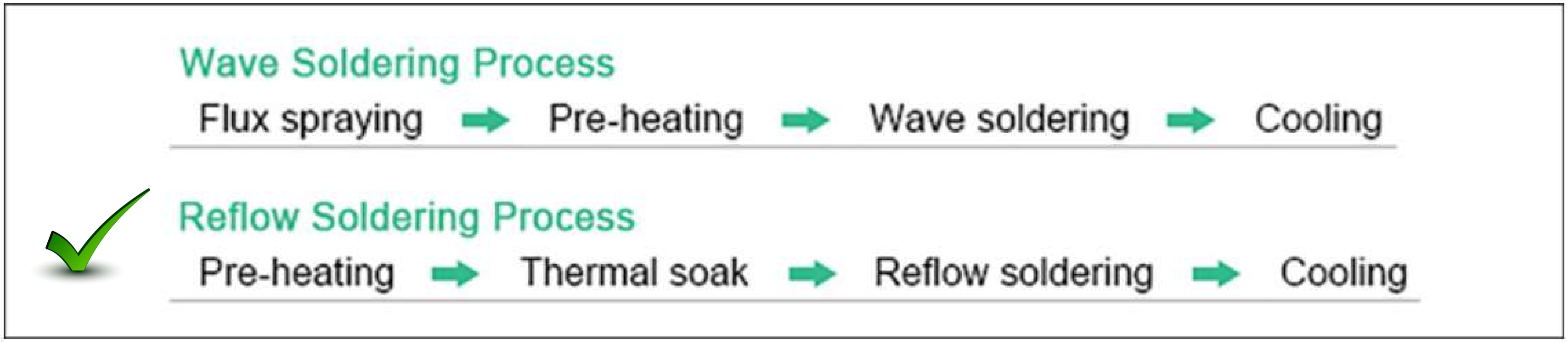
Reflow soldering is the most widely accepted method of joining surface mount components to printed circuit boards (PCBs). The aim of the process is to form acceptable solder joints by first pre-heating the components/PCB/solder paste and then melting the solder without causing damage by overheating.

The equipment used for the above process is known as Reflow Oven

# Factors Influencing Reflow

- **Materials:**
  - PCB (Type, Laminate, Thickness of Cu, Surface Finish type & thickness, Solder mask registration / accuracy)
  - Solder paste (Particles - size, oxides-free, alloy, flux type, volume, print quality)
  - Components – Termination surface quality , thickness, accuracy of placement, co-planarity
- **Equipment:**
  - Type of Oven, Number of Zones, Lowest Delta T across the Oven
- **Process Variables:**
  - Paste print quality, Time, Temperature, Rate of increase of temperature, Conveyor speed,

# Soldering Process




- The components are temporarily attached to the contact pads before the soldering commences.
- This includes two steps.

  - In the first step, solder paste is precisely applied to each pad via a solder paste stencil.

  - In the second step, we use to pick and place machines for placing the components on the pads.
- Actual reflow soldering doesn't start until the completion of these preparations.
- The actual soldering process has four steps which we are about to discuss.

**1. Pre-heating**

Pre-heating is very important if you want to create reliable joints in a professional grade PCB assembly. It has two major purposes during reflow soldering.

- It allows PCB assembly to warm up and easily reach the required temperature and achieve the necessary thermal profiling.
- Pre-heating pushes out volatile solvent within the solder paste and helps in completely expelling them. If we don't perform it correctly then it will affect the soldering quality.

**2. Thermal Soak**

Reflow soldering also depends on the flux which is present in the solder paste. Hence, the temperature must rise significantly so that the flux may activate. Otherwise, the flux won't play an active role in the reflow soldering process.

**3. Reflow Soldering**

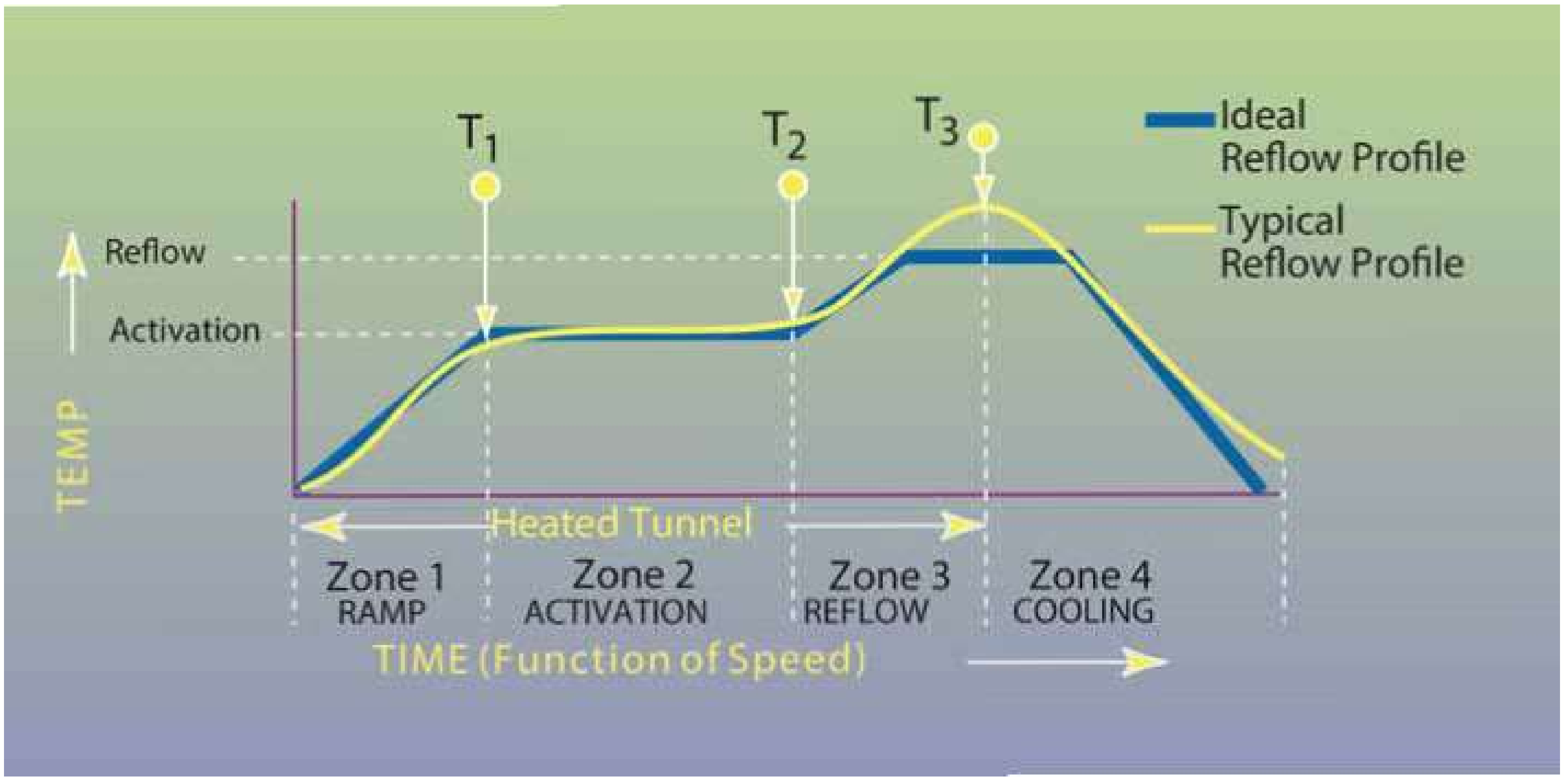
- This step involves the peak temperature of the whole process.
- Peak temperature allows the melting and reflowing of the solder paste.
- Temperature control is very important in the reflow soldering process.
- If the temperature is very low then it can stop the solder paste from reflowing while if the temperature is very high then it may damage the board or SMT components.

For instance, BGAs have a lot of solder balls that melt during the reflow soldering. If we don't achieve the optimal soldering temperature than these balls may melt unevenly and BGAs may suffer from rework.

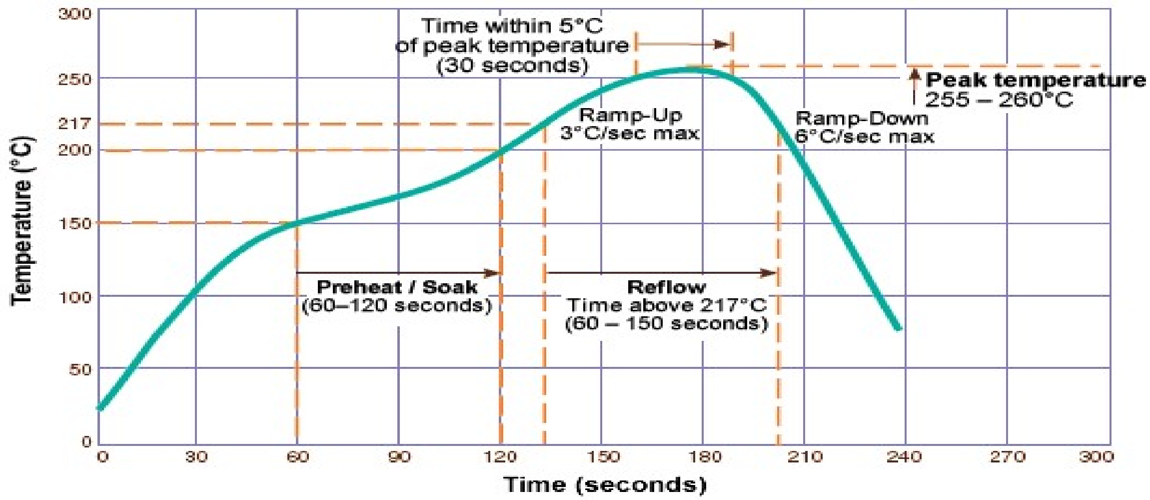
**4. Cooling**

When we achieve the peak temperature, the temperature curve will start falling. Cooling leads to solidification of the solder paste and parts are permanently fixed to their contact pads on the board.

# A temperature vs time graph is called Reflow profile



# Reflow Profile




- **Preheat –** Solvent will begin to evaporate at 2-3 degrees/sec rise rate, More rate will damage the component from thermal shock or crack, solder paste may spatter, Low rate may reduce the evaporation of flux volatiles.

- **Thermal Soak-** Removes the solder paste volatiles and activate the flux, Too high or too low rate lead to balling or solder spattering , The thermal equilibrium of the entire assembly should take place.

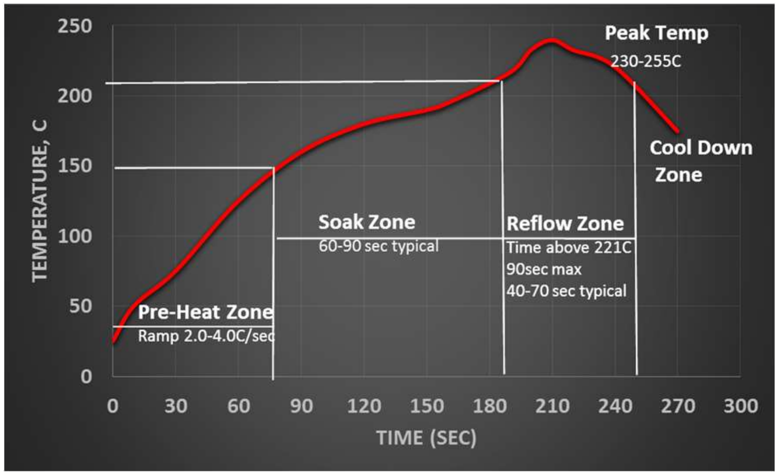
- **Reflow zone –** Also called TAL (time above liquidious ) or the melting point of solder , More time may damage the components , too little tie may have cold joints or dull joints .

- **Ramp Down –** The Rate at which assembly shall be cooled down.

# Reflow Profile

**Preheating Zone:**
- Components are heating up (gradually without thermally shocking them).
- Solvent evaporation (starts)
- The activation system is starting to clean the powder surfaces and pads.

**Soak Zone:**
- Temperature of the entire assembly to equilibrium before reaching the reflow.
- Solvent continue to evaporate.
- Temperature range at which the flux begins to remove oxides.




**Reflow Zone:**
- Alloy melts and allow solder to wet and form the proper fillet.

**Cooling Zone:**
- Solidification of the solder joint
- Cooling of the assembly (faster cooling will result in finer grain and higher fatigue resistance). Cooling rate will affect Joint strength and appearance.

# Heating technologies

Regardless of the technology used for heating boards, the primary objective is to control the thermal profile to prevent undesirable conditions – such as:

1) Tombstoning (a condition that causes the component to stand up)

2) Delamination of the substrate (a partial separation of the layers of circuit board material, similar to blisters) &

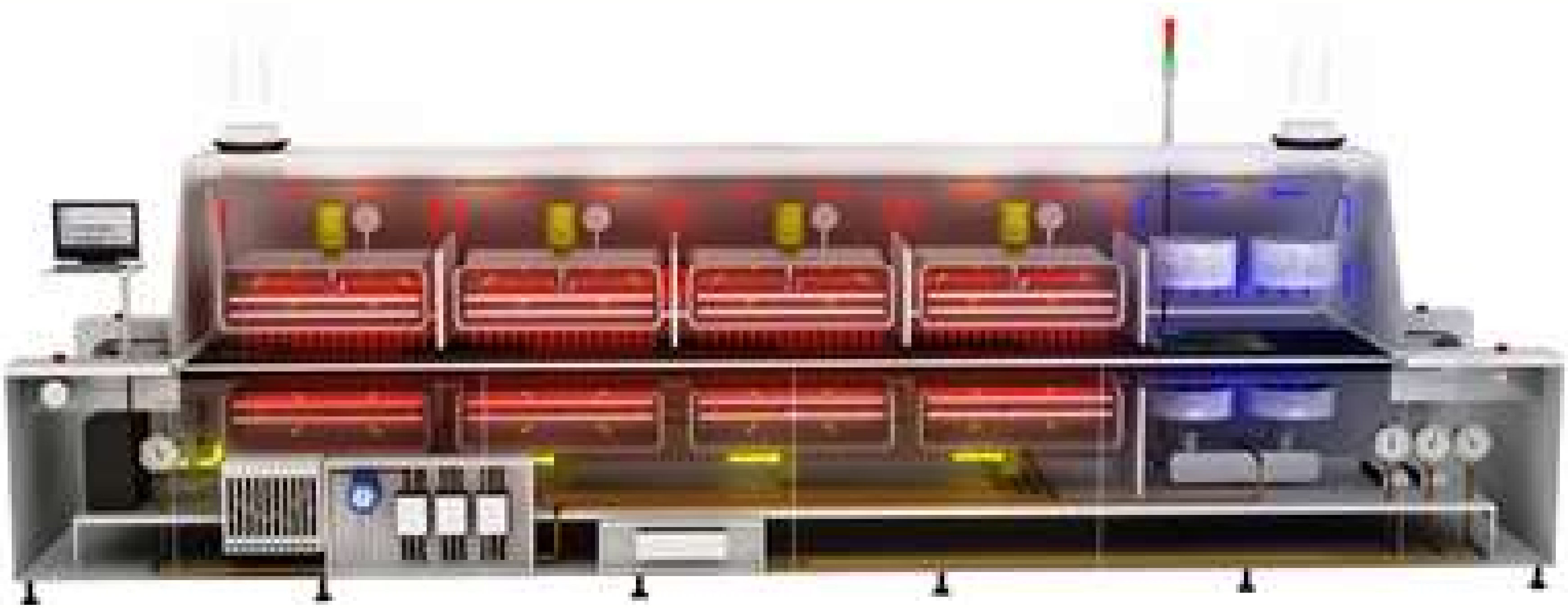
3) Poor adhesion/contact caused by over-heating and under-heating.

Typically, there are three main methods used for reflow oven heating. They are:

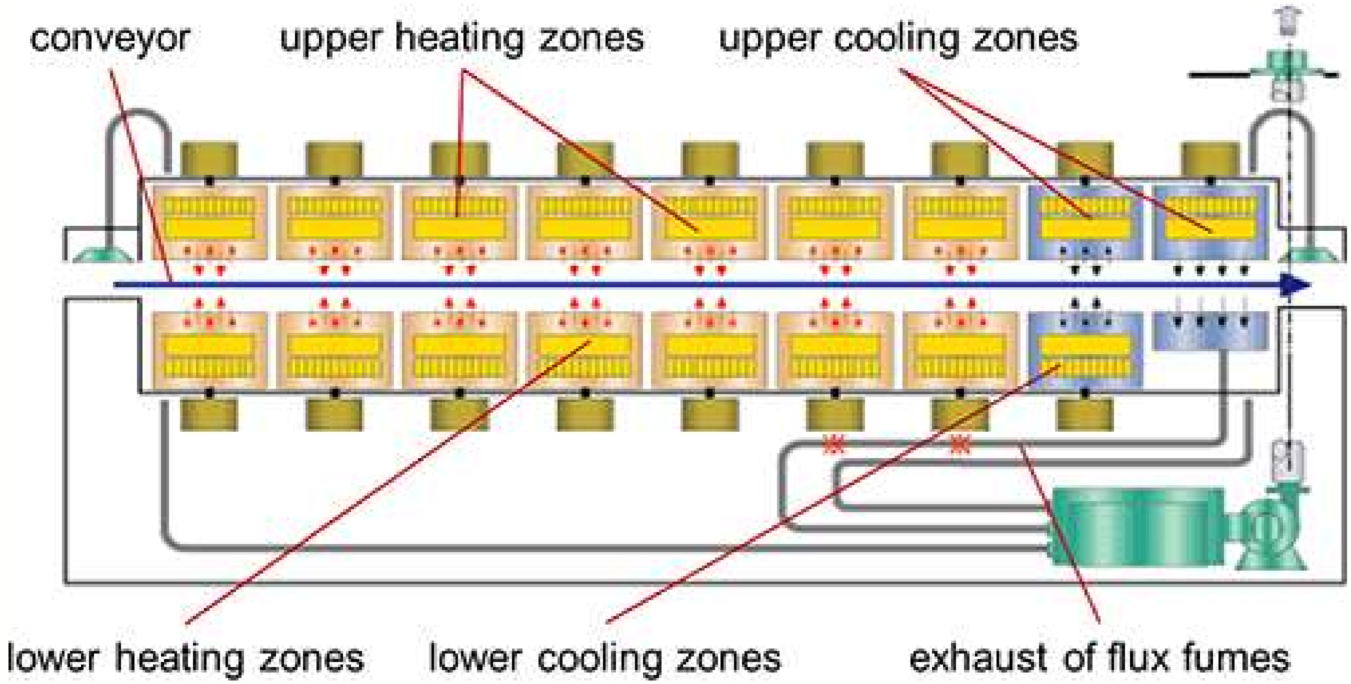
1. Vapor phase
2. Infrared
3. Convection

# Reflow Oven

# Inside a Reflow Oven



# Reflow Oven

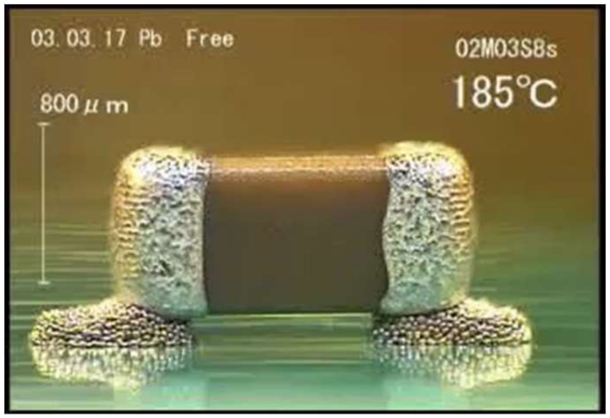

conveyor
upper heating zones
upper cooling zones
lower heating zones
lower cooling zones
exhaust of flux fumes

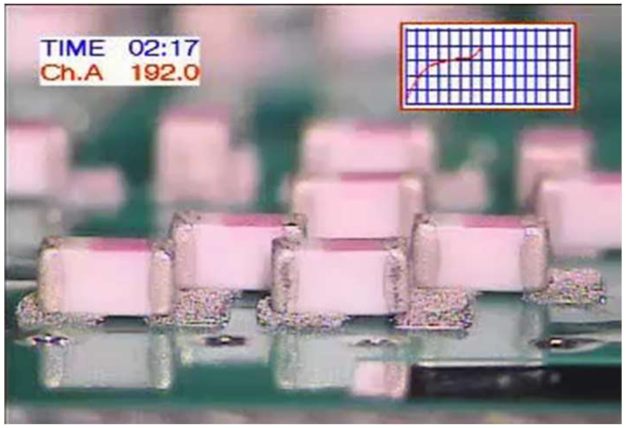
# Equipment Video

https://youtu.be/Zw53kxy7yL0

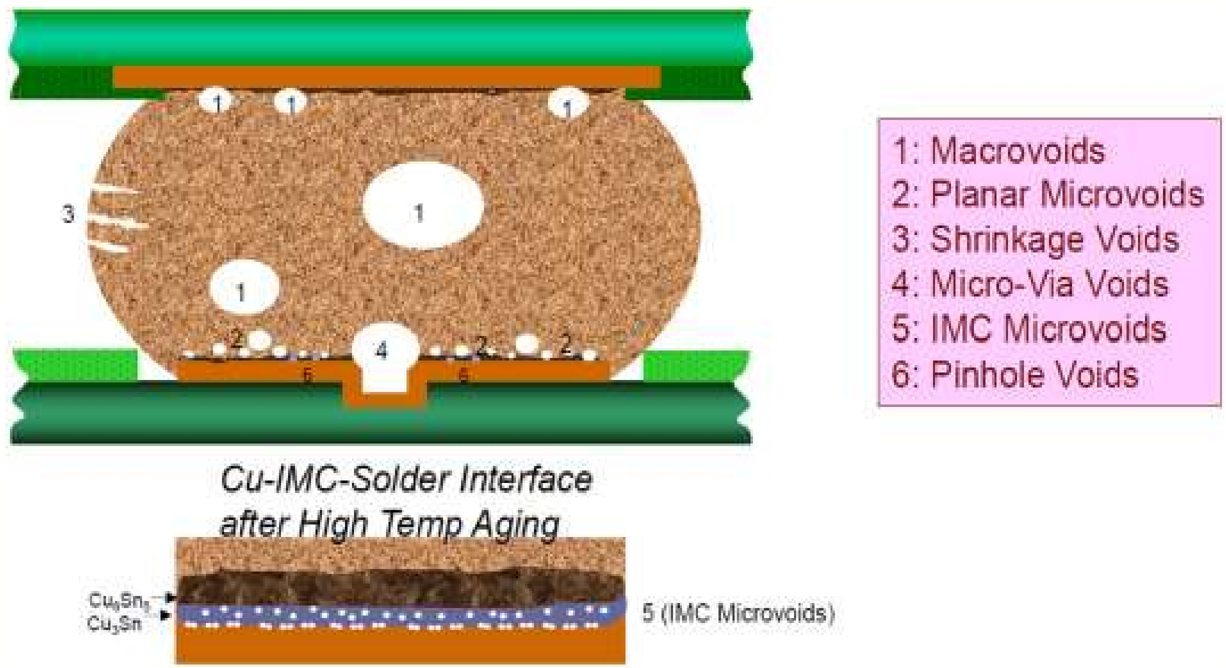
https://youtu.be/xn_oN8ZMaMk

# Some Common Issues

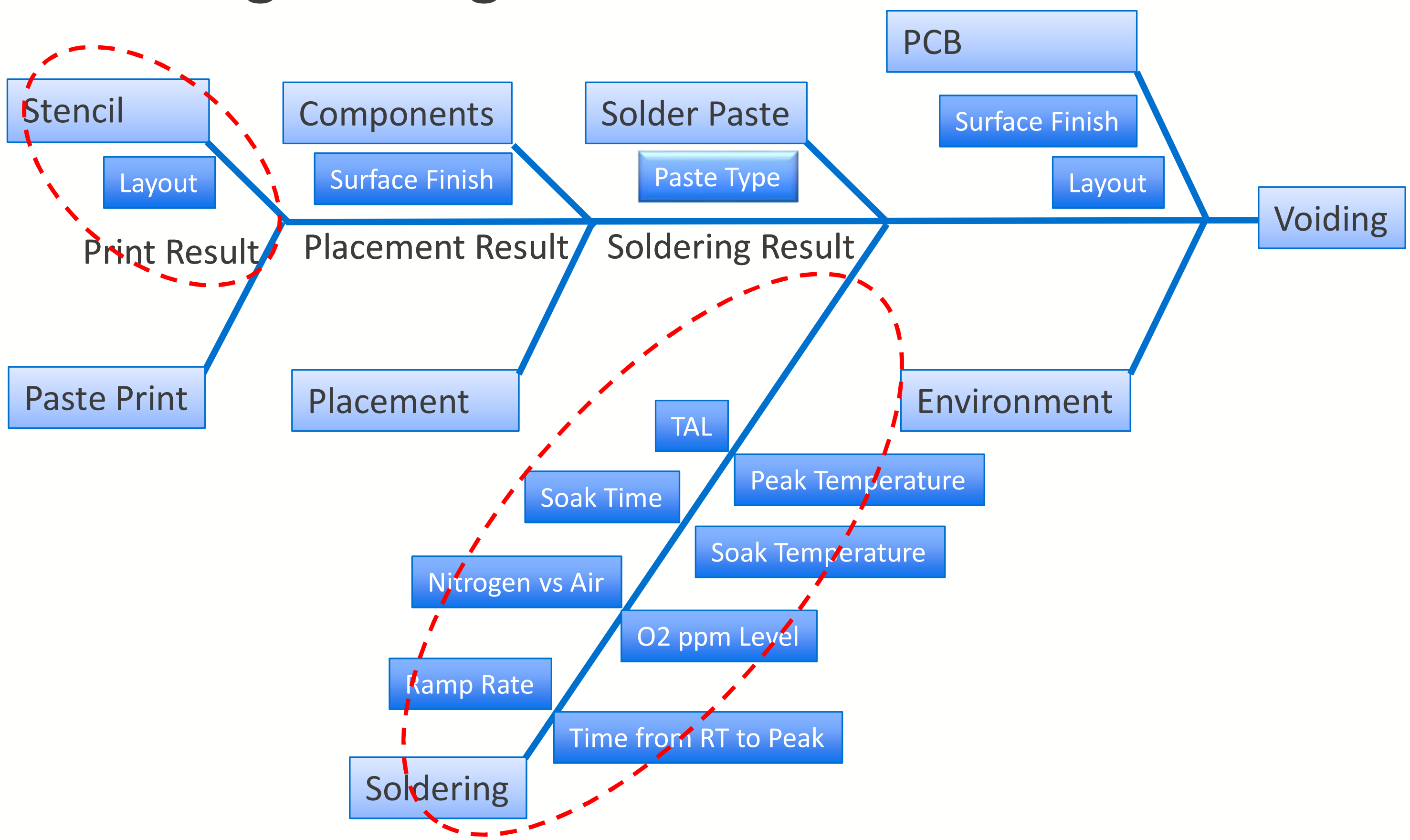



# Influence of Reflow Profile to a Solder Joint Quality & Reliability



# Factors Influencing Voiding



# Reflow Profile Zones Influencing  Voiding

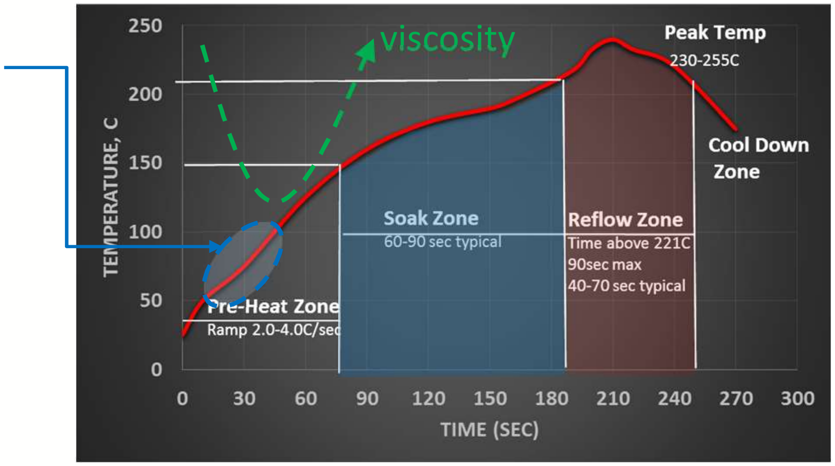
- Softening point of solids in flux (solder paste viscosity drops)
- Solvent evaporation (g1) (viscosity increases).
- Solvent reacts with active ingredients

R-COOH + R'OH->R-COOR' +$H_2O$(g2)

- Activators start to react with Metal Oxides and any contamination on the surfaces to be soldered.

MO+2R-COOH ->M$(R\text{-}COO)_2$+$H_2O$ (g3)

- Flux spreads over the substrate (prevent re-oxidation)



# Reflow Profile Parameters

| Preheat | Rate is too high | Rate is too low |
|---|---|---|
| | • Flux/solder paste spatter (rapidly boiling). Premature paste activation and depletion of activators.<br>• Dull, grainy solder due to no activation/carrier left for the reflow zone.<br>• Popcorning of moisture sensitive components | • Flux spreads everywhere carrying fines with it which causes solder balls |
| **Soak** | **Too Long** | **Too Short** |
| **Time** | • Premature paste activation and depletion of activators. | • High voiding due to insufficient carrier evaporation.<br>• Poor wetting or non-wetting |
| | **Too high** | **Too Low** |
| **Temperature** | • Dull grainy solder joints.<br>• Poor flux quality or low flux quantity (residue darkens and appears to have excessive surface cracks).<br>• Poor wetting or de-wetting | • Dull, grainy, un-reflowed solder.<br>• Flux entrapment – voiding<br>• Higher than normal flux quantity and typically good flux quality.<br>• Non-wetting - poor solder flow |

# Reflow Profile Parameters

| Reflow | Too Long | Too Short |
| --- | --- | --- |
| TAL | • Dull grainy solder joints.<br>• Poor flux quality or low flux quantity (residue darkens and appears to have excessive surface cracks).<br>• Poor wetting or de-wetting<br>• Thicker IMC Layers | • Dull, grainy, un-reflowed solder<br>• Non-wetting - poor solder flow<br>• Higher than normal flux quantity and typically good flux quality<br>• Brittle solder joints due to poor IMC formation Flux entrapment - voiding |
| | **Too high** | **Too Low** |
| Peak Temperature | • Dull grainy solder joints.<br>• Potential dewetting.<br>• Amber or burnt flux residue with potential cracking. | • Dull grainy solder joints due to insufficient solder reflow.<br>• Poor wetting or non-wetting.<br>• Higher flux amount. Flux entrapment / voiding.<br>• Brittle solder joints, insufficient IMC |
| **Cooling Rate** | **Too Fast** | **Too Slow** |
| | • Potential component damage due to thermal shock.<br>• Residue cracking.<br>• Fine grain structure will result in better reliability performance. | • Larger grain structure. Lower fatigue resistant solder.<br>• Thicker IMC layer will lower reliability performance |

# Reflow Profile Parameters

| Profile Length | Too long | Too short |
|---|---|---|
| | • Poor solderability. Non-wetting or de-wetting.<br>• Dull grainy solder joints.<br>• Amber or burnt flux residue with potential cracking. | • Poor or no solderability, non-wetting.<br>• Dull grainy solder joints.<br>• Excessive flux quantity. High Voiding.<br>• Brittle solder joints, insufficient IMC |

# Profile Setting for Reliable & Repeatable Process

- An understanding on materials involved
- Such as PCB ( Board thickness, # of Layers,  Copper thickness / Surface area)
- Reflow Pallets ( Materials / Design )
- Each SMD's max heat bearing capability
- Solder Paste ( Alloy, Melting Point, Chemistry (flux), Powder Type)
- Efficiency of the Oven (Delta T)
- Assembly Complexity
- An understanding on Post Reflow processes & many more

**9840072555**