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Reflow Soldering – The Basics

By

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Reflow soldering is a thermal process which is designed to melt a solder paste (a mixture of solder alloy powder with a solder flux to form a tacky paste) which has been placed on the exposed conductive pads of a circuit board and the contacts or leads of an electronic device to form a solder joint.

SMT components can be as small as 0.005" x 0.010" (0.13mm x 0.26mm) and as large as 6 square inches (4000 square mm). The components are so small, and require such precision when placing them on the circuit boards, that equipment called pick and place machines must be used to pick up and place them on the circuit boards.

Figure 1. Circuit board with solder paste applied to pads

Figure 2. Typical SMT components (shown much larger than actual size)

Reflow soldering is the most popular way of melting solder to form good solder joints and can be used to process anywhere from dozens to many thousands of solder joints, all at the same time as the circuit boards progress through a reflow oven, typically on a conveyor belt or side chain conveyor.

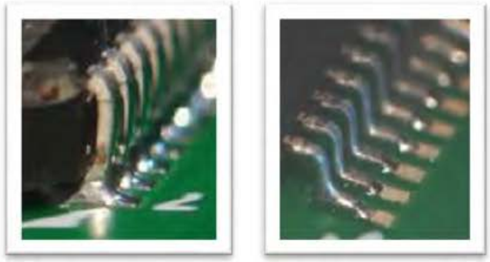

Figure 3. Components after reflow soldered to circuit board pads

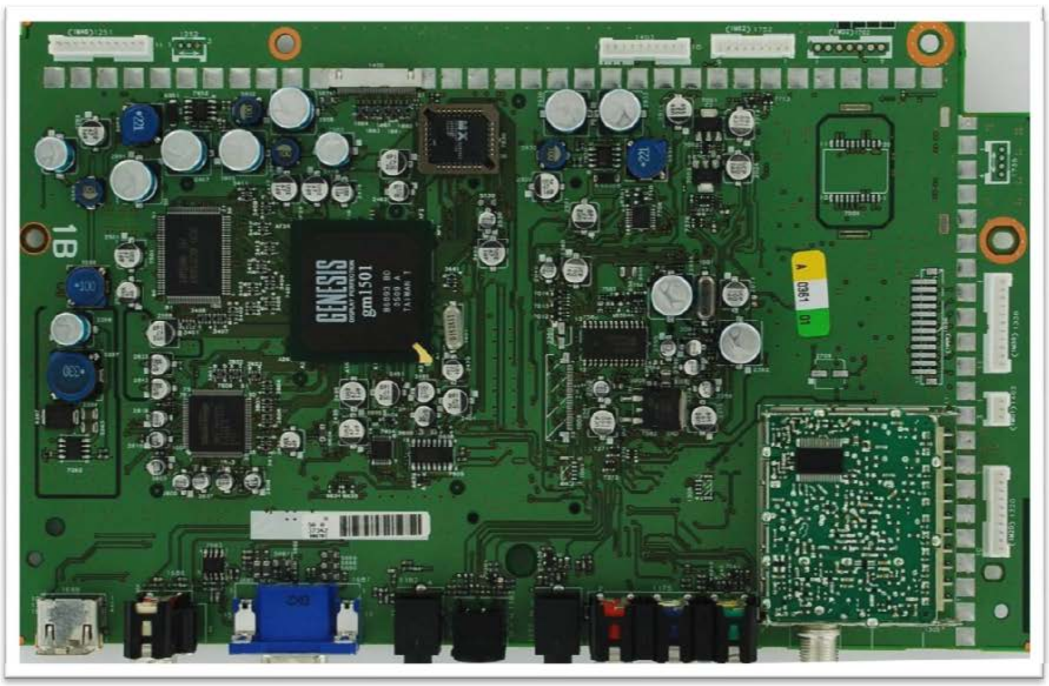

Figure 4. A circuit board assembly with hundreds of SMT components and thousands of solder joints

A typical reflow soldering thermal process can be divided into four basic phases: ramp, soak, spike, and cooling. Each phase of the reflow process is designed to apply, hold or remove heat from the solder joint being formed. How much and how fast depends on the solder alloy, the flux type and the limits of the components. *Together, the four phases of the reflow process are called the "thermal profile" for that circuit board assembly.*

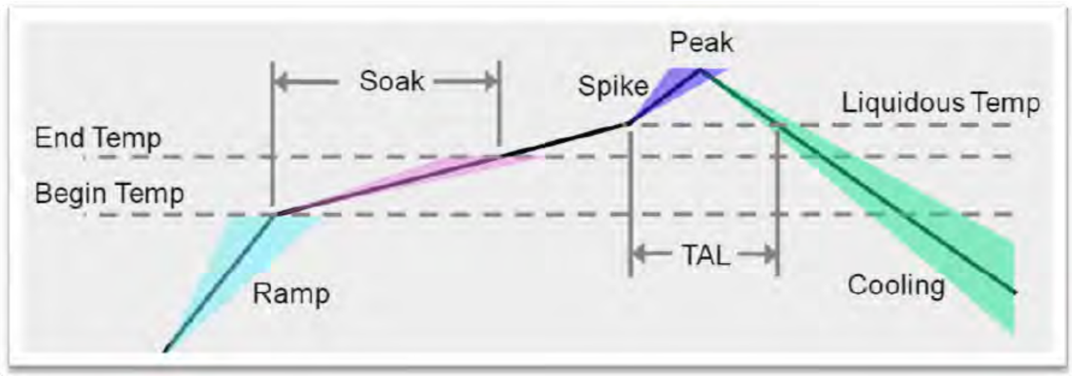

Figure 5. A thermal profile made up of all four thermal profile phases

Let's discuss each of these phases and their purpose:

Ramp phase

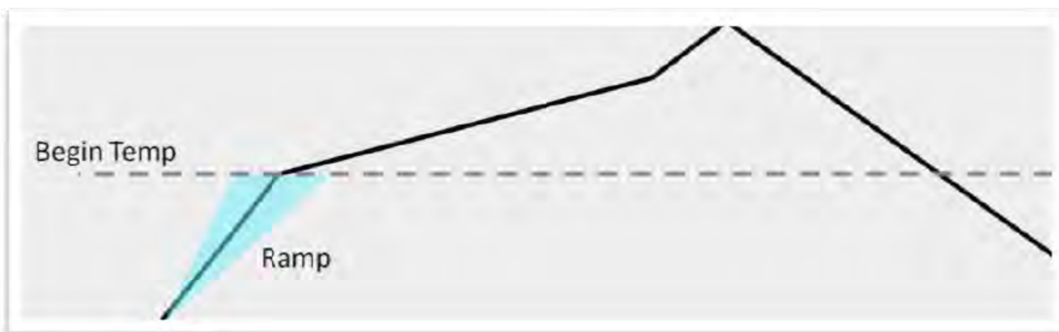

Figure 6. Ramp phase of the thermal profile

The ramp phase, sometimes called preheat, is where the circuit board is heated from room temperature to a point where the solder flux can begin to melt, chemically cleaning the surfaces of the pads and component conductors for good solder wetting. The rate at which the temperature rises must be controlled so as not to heat the components too quickly or you could damage the components from thermal shock. *Typical ramp rates or slope is usually somewhere between 1.0 °C and 3.0 °C per second.*

Also, the ramp phase is where solvents in the solder paste begin to evaporate. If the rate is too fast, the evaporating solvents can cause the paste to splatter, sending bits of it all over the surface of the circuit board.

Soak phase

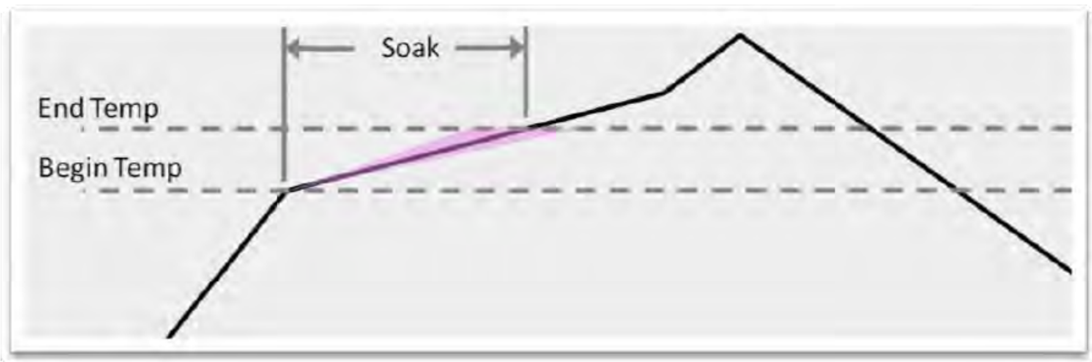

Figure 7. Soak phase of a thermal profile

The soak phase is typically 60 to 120 second long and is designed to allow the solder paste solvents to evaporate and give the flux enough time to fully clean the pads and component conductors of metal oxides, which naturally form over time. If the soak time is too short, the solder flux may not be able to complete the job. Too much soak time and the flux may be spent and new oxides can reform. Also, if the soak temperature is too low, fluxes may not fully activate. Conversely, if the soak temperature is too high, you may melt the solder prematurely.

Spike phase

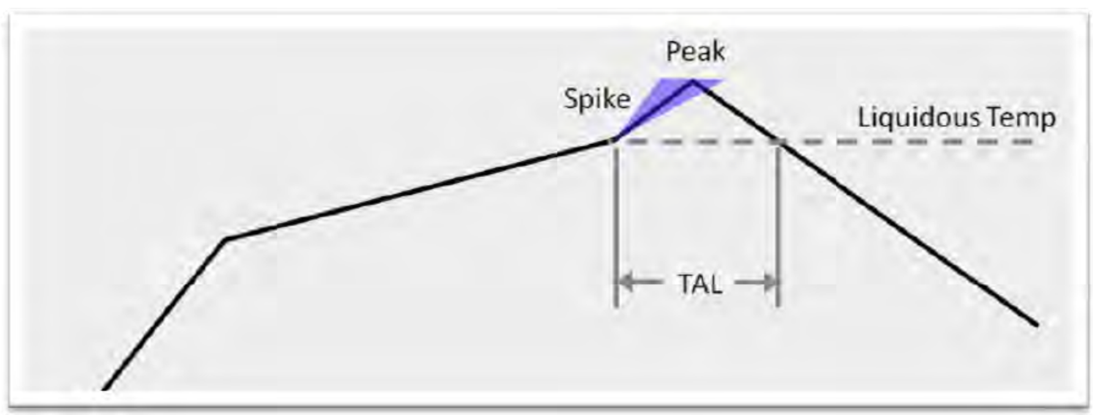

Figure 8. Spike phase of a thermal profile

The spike phase, sometimes called the reflow or time above liquidus (TAL) phase, is where the solder is finally melted. The temperature of this phase must be higher than the liquidus temperature (or melting point) of the solder, typically 10 °C to 20 °C above the liquidus temperature, but not so hot as to damage the components. *A common guideline is to subtract*

5 °C from the maximum temperature that the most sensitive component can withstand and let that be the peak temperature limit. Also, too much time above liquidus or too high temperatures (beyond 260 °C) will foster the growth of intermetallic compound in the solder joint. On the other end, too low a temperature may prevent the paste from reflowing completely. It is recommended that TAL be as short as possible; however, many pastes specify a minimum TAL of 30 to 60 seconds. Too little time above liquidus may trap solvents and flux, creating the potential for cold or dull solder joints.

Cooling phase

Figure 9. Cooling phase of a thermal profile

The cooling phase is for gradually cooling the solder joint alloy back to a solid and the circuit board down close to room temperature. A fast cooling rate will reduce the amount of intermetallic formed; however it must not be too fast, or thermal shock to the components may occur. The maximum allowable rate (slope) for a component applies whether you are heating it up or cooling it down.

Reflow ovens

Reflow ovens (or furnaces) are nothing more than a big long toaster with a conveyor belt. However, it's not easy to make a "toaster" which can produce a consistent thermal environment across the entire width and length of its conveyor, adequately handle a wide range of product loads, and deal with the evaporating flux solvents as they are heated.

Figure 10. Typical reflow ovens

This is typically done by providing several heating zones along the length of the conveyor which are independently controlled and thermally isolated from each other so they can be set at different temperature settings or “zone set points.” The heated zones are followed by several cooling zones. There may be as few as 4 heating zones to as many as 16, and from 1 to 6 cooling zones. How many zones depends mostly on how fast you want to run the conveyor (the more zones the faster) and how much money you have to spend. The zone set points in the oven are then set to meet the needs of the four thermal profile phases. The more zones you have, the more flexible your oven will be at meeting the needs of a specific thermal profile.

Reflow ovens are controlled by PCs with customized software and hardware interfaces to operate the many heaters and cooling systems. In addition, the PC controller monitors and controls the conveyor speed, and in many cases the rates of the fans which move the hot air through the oven zones. This forced air heating method, or convection heating, is the most common heat transfer method used in reflow solder processes. Other heating methods used to reflow solder include IR (infrared) or radiant heating , vapor phase, and conductive heating, which can help to meet special soldering needs. All heating methods have one thing in common; the need to melt solder without destroying the components being soldered to the circuit board, which translates to the need for a good thermal profile, and how to implement it.

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Austen Bio:

Paul Austen is a thirty-year veteran Senior Project Engineer with ECD, in Milwaukie, OR, USA, and holds a degree in Electrical Engineering from the University of Portland. Paul can be reached at paul.austen@ecd.com.