Reflow Profiling

The Benefits of Implementing a Ramp-to-Spike Profile

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Introduction

The issue of reflow profiling has been and continues to be a hot topic. Questions ranging from Why Profile? to How To Profile? to How Can I Better Profile? continue to proliferate. However, the pains often associated with profiling can be reduced greatly if certain guidelines are followed and if there is a strong understanding of the variables that can be encountered during the reflow process. This paper shall discuss the appropriate guidelines and troubleshooting methods for reflow profiling, and in particular shall focus upon the advantages of newer-style reflow ovens and the benefits of implementing the linear ramp-to-spike profile.

Delta (Δ) T

Many older-style ovens were prone to heating different parts of an assembly at varying rates, often depending upon the color and texture of the parts and substrates being reflowed. Thus, some areas of an assembly heated could reach much higher temperatures than other areas. This variation of temperature is referred to as the ΔT (Delta T) of an assembly. The result of a large ΔT is that, unless eliminated, certain areas of an assembly may receive excessive heat, while other areas may receive insufficient heat. This could cause a variety of solder defects, ranging from solder balling to non-wetting to damaged devices to voiding to charred residues.

Reflow Ovens: New and Improved

Most newer-style reflow ovens, known as the *forced convection* type, provide heat by blowing warmed air on and around assemblies. One of the advantages of this type of oven is that these are able to provide heat to an assembly gradually and uniformly, exclusive of part color or texture. Although the absorption of this heat may vary slightly due to the varying thickness and component population of an assembly, newer style ovens generally provide heat in such a manner so that the ΔT is not significant. In addition, the maximum temperature and temperature rate of a given profile can be controlled strictly with these ovens. That is, these ovens offer greater zone to zone stability, which provides the operators of these ovens with a more controlled reflow process.

Soaking: Why and When

The sole intention of the soak zone is to reduce/eliminate a large ΔT. The intended result of the soak is to bring the temperature of all parts of the assembly to equilibrium before the assembly reaches the reflow temperature of the solder so that all parts of the assembly will be reflowed simultaneously. *However, because assemblies reflowed in a more efficient oven often are at a virtual equilibrium of temperature throughout the profile, the soak zone can become an unnecessary step.* Therefore, because the soak zone is unneeded, the profile may be altered into a linear (RTS) profile.

It is important to note that the soak zone generally is *not* needed to activate the flux chemistry of solder paste. This is a common misconception in the industry, and it bears correcting. Most solder paste chemistries used today will demonstrate adequate wetting activity when processed in a linear RTS profile. In fact, as is discussed later in this paper, using the RTS profile generally will *improve* wetting.

Ramp-Soak-Spike[1]

The RSS profile may be used with RMA or no clean chemistries, but generally is not recommended for use with water soluble chemistries, as the soak zone of the RSS profile may break down the activators of the paste prematurely and result in less-than-adequate wetting. As stated above, the sole purpose of using the RSS profile is to eliminate or reduce a large ΔT.

[1] All profiles pertain to the Sn63/Pb37 alloy, which has a eutectic melting point of 183°C

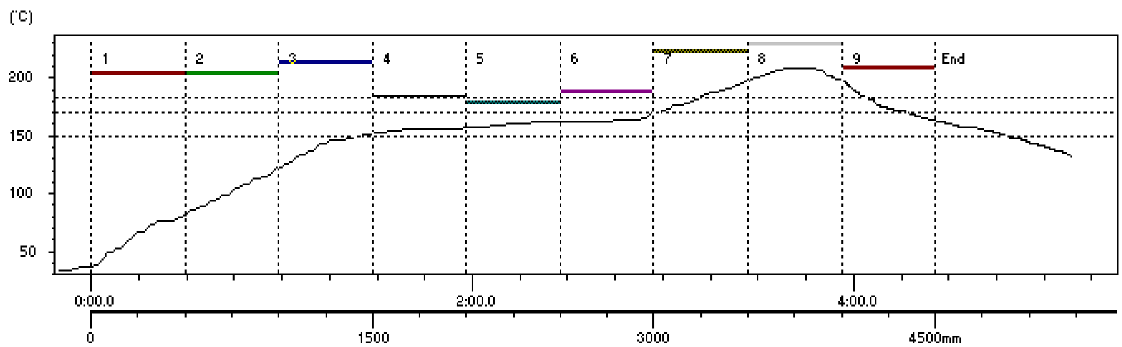

figure 1

As seen in figure 1, the RSS profile begins with a steep ramp up to approximately 150°C within a target time of 90 seconds at a maximum rate of rise of 2-3°C/second. Following the ramp area, the profile soaks the PCB assembly between 150-170°C within a target time of 90 seconds; the assembly should achieve thermal equilibrium by the completion of the soak zone. After the soak, the assembly will enter the spike area, where the assembly will be reflowed above 183°C for a target time of 60 seconds, plus/minus 15 seconds

The entire profile should last between 3½ to 4 minutes from 45°C to a peak temperature of 215°C ± 5°C. The cool down rate of the profile should be controlled within 4°C/second. In general, a faster cool down rate will result in a finer grain structure and a stronger and shinier solder joint. However, exceeding 4°C/second could result in thermal shock to the assembly.

Ramp-to-Spike

The RTS profile may be used with any chemistry or alloy, and is preferred for use with water soluble solder pastes and difficult-to-solder alloys and parts. If for any reason a large ΔT exists on the assembly, such as with processes using fixturization or those using an inefficient reflow oven, the RTS may not be the appropriate choice of profile.

The RTS profile has several advantages over the RSS profile. The RTS profile generally will result in brighter and shinier joints and fewer problems concerning solderability, since the solder paste reflowed in a RTS profile will still contain its flux vehicle throughout the entirety of the preheat stage. This also will promote better wetting, and thus the RTS should be used on difficult-to-wet alloys and parts. Because the ramp rate of the RTS profile is so controlled, there is much less concern of solder defects or thermal shock to the assembly resulting from too high a ramp rate. In addition, the RTS profile is more economical due to the reduced heating energy used in the first half of the oven. Furthermore, troubleshooting the RTS tends to be a relatively simple process, and operators with experience troubleshooting the RSS profile should have no difficulty in adjusting the RTS profile in order to achieve optimum profiling results.

Setting Up the RTS Profile

As seen in figure 2, the RTS profile is simply a gradual linear ramp from ambient to peak temperature. The ramp zone of the RTS profile serves as the preheat zone for the assembly, wherein the flux is activated, the volatiles are driven off, the assembly is prepared for reflow, and thermal shock is prevented. The typical ramp rate for a RSS profile is 0.6-1.8°C/second. The first 90 seconds of the ramp should be kept as linear as possible.

A simple rule of thumb for the ramp rate of the RTS profile is that 2/3 of the profile should be below 150°C. After this temperature, the activation systems of most solder pastes begin to break down quickly. Therefore, keeping the front end of the profile cool will preserve the life of the activator longer, resulting in better wetting and shinier solder joints.

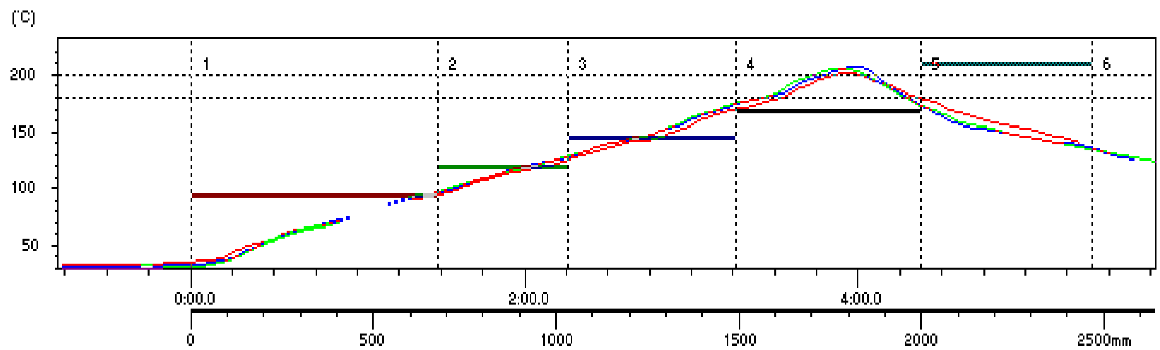

figure 2

The spike zone of the RTS profile is the stage where the assembly reaches the reflow temperature of the solder. After reaching 150°C, the peak temperature should be reached as quickly as possible. The peak temperature should be controlled at 215°C ± 5°C, with time above liquidus (183°C) at 60 seconds ± 15 seconds. This time above liquidus will reduce flux entrapment and voiding and will increase pull strength. As with the RSS profile, the RTS profile length should be a maximum of 3½ - 4 minutes from ambient to peak temperature, and the cool down rate should be controlled within 4°C/second.

Certain board coatings may require an increase in the profile peak temperature. If soldering to gold over nickel coated pads, a peak temperature of at least 220°C should be met; this will prevent post-reflow thermal reliability issues, as tin and gold form a secondary eutectic at 217°C. If soldering to pads coated with an organic surface protectant (OSP), peak temperatures up to 225°C may be required to penetrate the coating completely. These profile peak temperature adjustments are necessary if using either the RTS or RSS profile.

Troubleshooting the RTS Profile

In effect, the same rules are applied to troubleshooting both the RSS and the RTS profiles: Adjust the temperature and/or time at temperature of the profile as needed to achieve optimum results. Often this requires trial and error, with slight increases and/or decreases of temperature made and then the results of these changes being observed. Following is a summary of common reflow problems that may be encountered with the RTS reflow profile and the remedies by which to resolve them.

Solder Balling

Solder Balling is recognized by numerous tiny solder balls trapped along the peripheral edge of the flux residue after reflow. In a RTS profile, this most often is the result of too slow a ramp rate, wherein metal oxidation occurs as a result of the flux vehicle being burned off far ahead of reflow, resulting in solder balling. This problem normally can be corrected by slightly increasing the ramp rate of the profile. Solder balling may also be a result of too rapid a ramp rate. This however, is unlikely with the RTS profile, due to the relatively slow and steady ramp.

Solder Beading (Satellites)

Often confused with solder balling, solder beading is a defect recognized by one or a few larger balls, generally located around chip caps and resistors. Although this normally is the result of an excessive paste deposit during printing, it sometimes can be resolved with a profile adjustment. As with solder balling, solder beading which occurs during the RTS profile is normally a result of too slow a ramp rate. In this case, the slow ramp rate causes capillary action to draw the unreflowed paste away from the pad on which it was deposited to a place under the component. The paste reflows there forming a bead of solder that comes out to the side of the component. As with balling, the solution to solder beading occurring during the RTS profile is to raise the ramp rate until the problem is resolved.

Poor Wetting

Poor wetting often is the result of time and temperature ratios. The activators contained in solder pastes consist of organic acids, which degrade with time and temperature. If a profile is too long, the wetting of the joint can be compromised. Because paste activators normally survive longer with the RTS profile, poor wetting with this profile is less likely than with RSS. If poor wetting is experienced with the RTS profile steps should be taken to ensure that the first 2/3 of the profile occur below 150°C. This will extend the paste activators life and will result in improved wetting.

Solder Deficients

Solder deficients are often the result of uneven heating or an excessive heating ramp, which causes component leads to get too hot, which will result in the solder wicking up the leads. The leads will appear thicker after the profile and the pads will have an insufficient amount of solder on them. Reducing the ramp rate or otherwise ensuring the even heating of the assembly will help to prevent this defect.

Tombstoning

Tombstoning normally is the result of non-equal wetting forces, which causes a component to stand on end after reflow. In general, the slower the heating, and more stable a board is, the less this will occur. Reducing the ramp rate as it passes through 183°C will help to remedy this defect.

Voiding

Voiding is a defect found commonly with an X-ray or cross-section inspection of a solder joint. Voiding is recognized by the appearance of tiny "bubbles" in the joint. These may be air or flux entrapment. Voiding is generally caused by one of three profile errors: insufficient peak temperature, insufficient time at temperature, or excess temperature during the ramp stage. As the ramp rate of the RTS profile is so controlled, voiding normally is the result of the first and/or second error, which generally results in non-volatized flux entrapment in the joint. To correct voiding in this case, a profile should be taken at the point where the voiding is occurring and adjusted appropriately until the problem is resolved.

Dull & Grainy Joints

A relatively common reflow defect is dull and grainy joints. This may be a defect of only aesthetics, or it could be the sign of a weak joint. To correct this defect in the RTS profile, the two zones before the spike zone each should be reduced by 5°C; the peak temperature then should be raised by 5°C. If this is not successful, then the temperature should continue to be adjusted slightly in this manner until the desired results are achieved. These adjustments will prolong the life of the activator of the paste, thus reducing the paste's exposure to oxidation and improving the wetting ability of the paste.

Charred Residue

Charred residues, although not necessarily a defect of functionality, may be experienced using the RTS profile. To correct this, the temperature and/or time of the spike zone may have to be reduced. If a recommended RTS profile is being followed, this normally is a simple matter of a slight temperature (5°C) decrease.

Conclusion

The RTS profile is not a cure-all for every reflow profile related soldering issue. Nor can the RTS profile be used with all ovens or all assemblies. However, the implementation of the RTS profile can reduce energy costs, increase efficiency, reduce solder defects, improve wetting, and simplify the reflow process in general. This is not to state that the RSS profile has become obsolete, or that the RTS profile never can be used with an older-style oven. However, engineers should be cognizant of the fact that there may be a better reflow profile style available for the processes.