TECHtips
Electronics Manufacturing Insights from ACI Technologies, Inc.

Thermal Profiling for Reflow

Reflow temperature profiling is the most important aspect of proper control of the solder reflow process. It may appear to some to be a magical art practiced by a select experienced few, who are able to divine the proper settings for a reflow oven by reading graphs as if they were tea leaves. This does not have to be true. This article outlines a systematic method by which engineers and technicians can implement a successful reflow process from scratch.

The most basic type of profile is a ramp-to-peak (RTP) profile as shown in Figure 1. This type of profile is one where the rate of temperature increase over time is virtually constant for the entire heated portion of the profile. An RTP profile type is very common and is the easiest type to implement. There are three critical parameters for all solder materials on an RTP profile: peak temperature, rate of temperature increase over time (slope), and time above liquidus.

The peak temperature is exactly what it appears to be: the highest temperature experienced during the reflow process. The slope is the rate of temperature increase over time during the reflow process. The time above liquidus parameter is the time spent above the temperature at which the solder alloy is fully melted. These parameters will vary based on the alloy (especially peak temperature and time above liquidus) and the flux formulation (especially slope). The primary source for these parameters is the manufacturer's data sheet for the solder paste that is used. In many cases, these specifications will provide an acceptable range. In some cases, only a minimum or maximum requirement is provided. This article will use a fictional solder paste that provides the following requirements: peak temperature of 240-255°C, profile slope of 0.8-1.0°C/second, and a time above liquidus of 30-60 seconds.

The first step of developing a reflow profile is to set the conveyor speed. This is the most important parameter to set correctly as any change during process development will invalidate all of the work accomplished to that point. The conveyor speed can be calculated as long as all the necessary information is available. The technician must know (or measure) the heated length of the oven and determine the required peak temperature and profile slope.

The next step is to calculate the time needed to reach the peak temperature by determining the difference between the peak temperature and room temperature and dividing that result by the slope. In our hypothetical example, the time to peak is (247.5 - 25) / 0.9 = 247.2 seconds. Notice that the midpoint was used for each

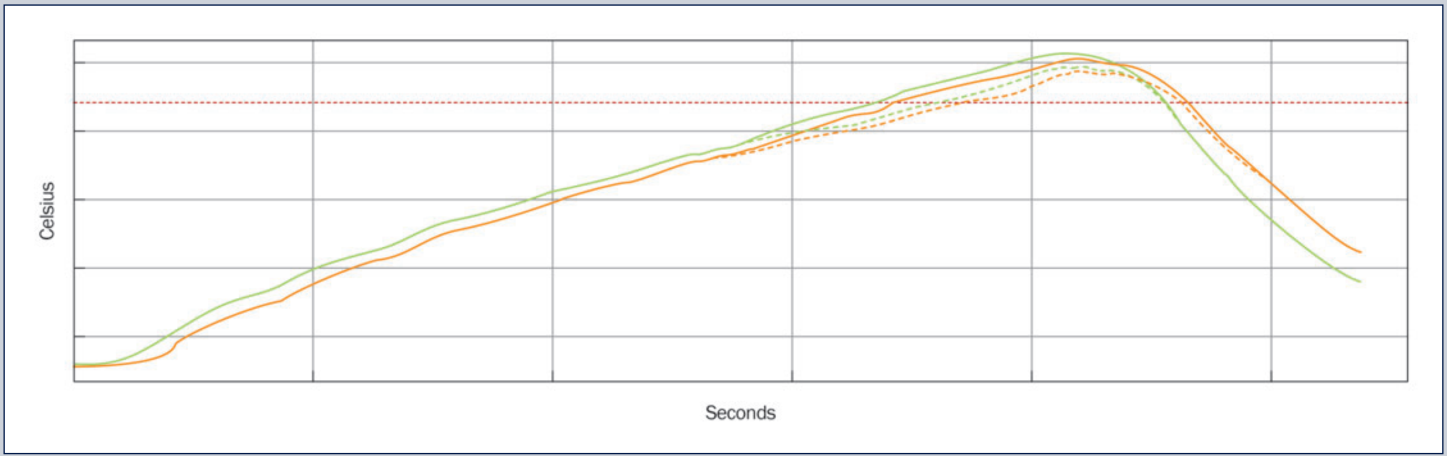

Figure 1: Ramp-to-peak profile.

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range? This ensures that our calculated conveyor speed is near the center of the acceptable range.

Once the time to peak has been determined, the conveyor speed is calculated by dividing the heated length of the oven by the time to peak. Our hypothetical oven has 84 inches of heated length, resulting in a conveyor speed of 84 / 247.2 = 0.34 inches/second or approximately 20 inches/minute. The precision of the conveyor speed setting is not critical since the center of the range was used for peak temperature and profile slope, so rounding the value is acceptable. Once this value is determined, it will remain unchanged for the balance of the profile development.

The next task is to determine the goal temperature for the assembly at the end of each oven zone. In order to calculate the goal temperature at the zone exit, the technician must know the number of heated zones in the oven, the peak temperature desired, and the exit temperature of the previous zone. The calculation begins by determining the desired temperature rise for each zone, which is calculated by dividing the difference between the peak temperature and room temperature by the number of heated zones. In our example the oven has seven heated zones, so the calculation is (247.5 - 25) / 7 = 31.8 or approximately 32°C per zone.

The goal temperature for zone 1 is then calculated by adding the previous zone exit temperature (room temperature for zone 1) and the temperature rise per zone. For our example, this becomes 25 + 32 = 57°C. This is the temperature the assembly should reach by the end of the first zone, but the oven should be set to a higher value. There will be a difference between the oven set point and the temperature of the assembly during the reflow process. A good starting point is approximately 20°C higher, so the oven's first zone should be set to 80°C. The subsequent zones can remain at their default value (typically room temperature) for now. Once the first zone has reached operating temperature, a measurement can be taken by passing an assembly with thermocouples and a data logger through the oven. After each pass, the assembly's temperature is compared to the goal and the oven set point is adjusted, as necessary, until the assembly exits the first zone at approximately 57°C. This process is repeated for each zone in sequence.

It is important to ensure that the slope of the profile curve remains constant throughout the zone. A profile that flattens at the end of any zone indicates the assembly is nearly reaching temperature equilibrium in that zone. This can be due to a high convection rate which should be reduced, if possible. If the oven does not have adjustable convection rates, the conveyor speed will need to be increased. If the conveyor speed is changed, the expected slope needs to be recalculated to ensure it is within specification. This is accomplished in the same manner as the determination of the conveyor speed, except the conveyor speed is now a known value, and the expected slope is the unknown value. If the conveyor speed is changed, the entire zone setting process should start again from zone 1.

The final two (or three) zones, typically, are where reflow occurs and is where the profile should exceed the liquidus point of the solder. The entire time the profile spends over the liquidus point of the solder is counted towards the time above liquidus parameter. This includes the time after the peak temperature (which will occur at the end of the last heated zone). The peak temperature and time above liquidus are typically adjusted by modifying the temperatures of the last two or three zones. This is accomplished through trial and error. However, by following the system described in this article the trial and error portion of developing a profile is limited to minor changes in a limited number of zones at the end of the process.

ACI Technologies can provide assistance developing reflow processes; call the Helpline at 610.362.1320, email helpline@aciusa.org, or visit https://www.aciusa.org/helpline.html.

ACI Technologies, Inc.