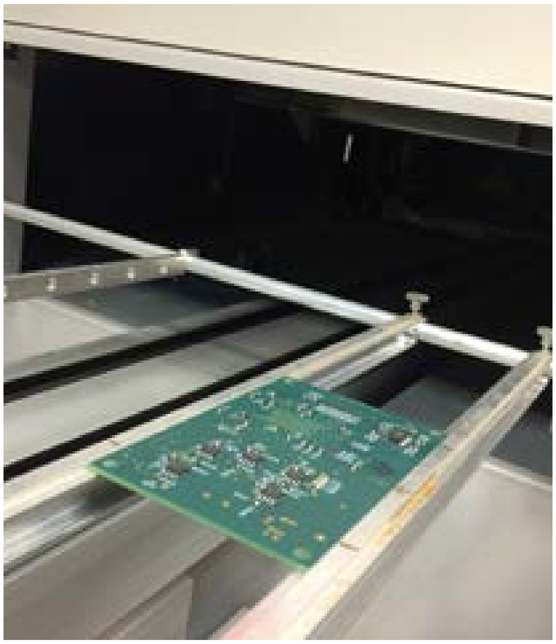
WHEN TO REQUEST A CUSTOM REFLOW PROFILE

The solder paste composition primarily defines the time/temperature graph or thermal profile of a reflow process. Therefore, as long as a specific solder paste is in use, the thermal profile remains relatively the same. For instance, the industry uses two types of standard reflow profiles—one for PCBs using leaded solder, and the other for PCBs using lead-free solder. However, it may be necessary to limit the temperature excursion on the higher side to protect SMD components on the PCB from damage, and on the lower side to obtain reliable soldering.



For an oven to achieve the required reflow profile suitable for a specific solder paste, it may be necessary to tweak its controls based on the PCB assembly being soldered. Major factors causing the variations are:

- Thermal conductivity of components on the PCB
- Specific temperature thresholds of the components on the PCB
- Density of components on the PCB
- Physical area of the assembly
- Thickness of the PCB
- Thermal mass of the assembly
- Load capacity of the oven

Therefore, if the PCB assembly has unique characteristics, such as extraordinary board thickness, special material, many components, special components, heavy copper, and/or similar, it may be necessary to go for a custom reflow profile.

COMMON SOLDERING GUIDELINES

In general, the melting temperature of solder far exceeds the maximum operating temperature of any SMD device. To avoid damaging the assembly, essentially, the soldering must be completed in as small a time as possible, so that the SMD devices face the reflow temperature for only a minimum period. The industry follows a few thumb rules as a general guideline:

- Thermal conductivity of components on the PCB
- Specific temperature thresholds of the components on the PCB
- Density of components on the PCB
- Physical area of the assembly
- Thickness of the PCB
- Thermal mass of the assembly
- Load capacity of the oven

Therefore, if the PCB assembly has unique characteristics, such as extraordinary board thickness, special material, many components, special components, heavy copper, and/or similar, it may be necessary to go for a custom reflow profile.

TYPICAL REFLOW SOLDERING

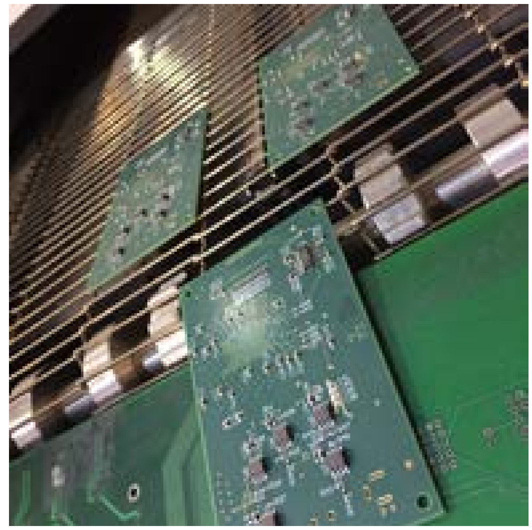
The above guidelines lead to two types of standard reflow solder profiles for the oven, subject to whether the solder paste under use is leaded or lead-free. The major differences between the two are:

SOLDER PASTE TYPE	MELTING TEMPERATURE (CELSIUS)	MINIMUM PEAK REFLOW TEMPERATURE (CELSIUS)
SAC (Lead-Free)	217	235
SnPb (with Lead)	183	215

The melting temperature is the most important step in the reflow soldering process, as at this temperature the solder paste deposits on the PCB assembly melt and form the solder joints. This happens as the assembly boards ride a conveyor to pass through the oven, which exposes them to a temperature profile that varies in time. According to the guideline above, a typical reflow solder profile will have three phases:

1. **PREHEAT PHASE:** the PCB assembly warms up to a temperature lower than the melting point of the solder paste.
2. **REFLOW PHASE:** the PCB assembly heats up to a peak temperature well above the melting point of the solder paste but remains below the temperature at which the board and components may be damaged.
3. **COOLING PHASE:** The PCB assembly cools down under control and the soldered joints solidify before the assembly exits the oven.

The reflow phase has a lower and an upper limit for the peak temperature. Measured at the solder joint, the lower limit of the peak temperature must be high enough to make reliable solder joints. The solder paste characteristics determine this temperature, and the past supplier should provide the details.



Measured at the top of the component body, the upper limit for the peak temperature must be lower than that used for MSL assessment of SMDs and the temperature beyond which the PCB starts to degrade.

When exposed to the profile temperatures, certain areas on the PCB assembly will become hotter than others. That means the assembly will have hot spots and cold spots, where the areas will be the hottest and the coolest respectively.

Areas on the PCB with only a few components, or the smallest components, and with little copper will be the hot areas, while cold spots on board will be the sections with a high density of large components, as these absorb a lot of heat. Areas on the board with large lands of copper will also allow the local temperature to remain low. The location of hot and cold spots will also depend on the dimensions of the board and its orientation when passing through the oven.

It is necessary to keep the temperature of the hot spots on a PCB assembly lower than the upper limit of the peak temperature. In the same way, the temperature of the cold spots must be higher than the lower limit of the peak temperature.

THE TIME FACTOR

How long the PCB assembly remains in any individual phase within the oven is of considerable importance. The temperature profile is really a temperature/time graph, representing the component body temperature, measured at its top.

In the preheat phase, the maximum temperature is lower than the melting point of the solder paste. Temperature at hot spots will shoot up rapidly and remain there until the board has passed through. However, it is essential that small solder paste deposits not remain at the intermediate temperature for long, as their activator or flux may evaporate. The cold spots on the board warm up slowly, and therefore, solder paste deposits in cold spots retain their activator better.

The conveyor speed in the oven should allow both the hot and the cold spots to reach roughly the same temperature by the time the PCB assembly reaches the end of the preheat phase.

In the reflow phase, the solder melts to form soldered joints. The solder paste characteristics determine the minimum peak temperature that all solder joints in both the hot and cold spots must reach to form a reliable joint. To prevent component or board damage, no region may exceed a maximum peak temperature. Even if the hot and cold spots enter the reflow phase at the same temperature, the hot spots will reach the highest peak temperature faster than the cold spots can. However, for reliable soldering, both the hot and the cold spots must be within the allowed range of the peak temperature. To achieve this may require a tweaking of the conveyor belt speed and the oven temperature settings.

It is also necessary to limit the peak temperature to below that which could damage the components or the board. Moisture sensitivity of the components determines their maximum peak temperature tolerance, while for PCBs it depends on their Tg characteristic. When using SnPb (with lead) solder paste, the typical peak temperature must be above 215 degrees celsius, and above 235 degrees celsius for lead-free SAC solder. However, it the industry recommendation is to not exceed a temperature of 260 degrees celsius. This leaves only a small process window for lead-free soldering, necessitating a tighter process control.

TYPICAL REFLOW SOLDER PROFILE

Achieving a suitable reflow profile for the solder paste composition presently under use depends on several specifics mainly, the type of oven the industry is using—infrared (IR) or vapor phase (VP)—and the heat transfer methods in the oven, typically a combination of radiation, conduction, convection, and condensation. The industry majorly uses the IR reflow oven, and thermal profiling is a critical function in printed circuit board assembly.

Apart from the physical construction and characteristics of the oven influencing the transfer of heat, the PCB assembly itself also adds to the challenge—primarily the layout, component size, package styles, and thermal mass of the devices—influencing the thermal issues along with different maximum temperatures the components can tolerate, presence of thermally sensitive components on the board, and the multitudinous formulations of solder and flux available.

Soldering profiles without adequately taking all the above into account could result in oven settings that produce failed components, unacceptable solder joints, and overall low reliability of the product. To mitigate such disasters, the industry takes recourse to the process of thermal profiling—effectively mapping the thermal effects of the reflow process on the solder, components, and the PCB that make up the assembly.

GENERATING CUSTOM REFLOW PROFILES

Initially, engineers would use a thermal profiler, an instrument for generating custom reflow profiles. These measured the minimum and maximum temperatures and slopes in the oven and on the PCB through thermocouples attached to various points on the PCB and beneath components, as the assembly traveled through the oven.

The process measured the difference in temperatures in the various locations. The engineer then used this information to minimize the thermal exposure that most heat-sensitive components faced, while ensuring higher thermal mass components had a proper reflow. These initial devices had software that provided only time/temperature graphs, and not data fully representing the thermal process. That meant engineers had to tweak the oven settings to achieve the required temperature profile—most did so using experience and intuition, but mainly through trial and error sessions—resulting in reduction of the available oven time during initial production.

Increasing complexity of the PCB assembly using mixed technologies/materials and special component packages such as the BGA, served to highlight the shortcomings of the above method. This led to a significant improvement not only in the hardware of the thermal profiler, but also in the software they use.

The initial thermal profile the modern software generates allows the engineer to input data such as the board thickness, component sizes, solder type, and thermocouple location. More expensive software may also allow including the maximum temperature components on bard can withstand, ramp rate of the oven, the solder paste characteristics, oven temperature settings, and conveyor speed limits. The engineer then places thermocouples on locations on the assembly he considers as thermal extremes, and runs the PCB assembly through the oven using the initial profile offered by the software.

The first run of the PCB assembly through the oven generates data that the engineer then uploads to the software to allow it to make an intelligent prediction. The engineer can now review the suggested profile changes to fine-tune it to adapt it to specific capabilities of a particular oven and production processes and factors the software may not be aware of, such as soldering BGAs with lead-free solder paste. It is critical for the software to have the ability to predict and generate a custom profile for each product. More capable software with predictive algorithms provide highly accurate thermal profiles, freeing the engineer from the earlier sequence of trial and error.

Modern reflow ovens often run under computerized control with software governing its numerous functions allowing the user to operate the system free of errors. Such systems help with any mass soldering process such as reflow, while evaluating the parameters in real-time. The temperature sensors use wireless data transmission, making it easy and convenient when generating custom reflow profiles.

Advanced Assembly processes multiple designs daily and has multiple process, manufacturing, and reflow engineers available to evaluate and to ensure the proper reflow profile is used for specialty designs. Advanced Assembly uses three profiles for most designs: one for leaded, one for lead-free, and one for mixed composite designs (leaded paste with lead-free BGAs).

CONCLUSION

The availability of advanced profile evaluators offers engineers several capabilities for generating custom reflow profiles. These include the ability to evaluate temperature at any moment, review the maximum temperatures and gradients, solder wetting times, and conveyor speeds. With the added ability to generate automatic reports and an overlay functions to allow comparison of the current profile with saved reference profiles, generating custom profiles for PCB assemblies is no longer a difficult or time-consuming task.

NEXT STEP: FREE CONSULTATION

Receive a free 15-minute, pre-production assembly consultation. Talk with our engineering team for PCB assembly questions such as how design elements affect manufacturability. Email ENG@aapcb.com to schedule your consultation via phone or email.