Design for Manufacturing (DFM): Verifying Component Selection

Abstract
Due to the recent industry-wide move to RoHS compliance, it has become more important to verify component selection from design through prototype phases for compatibility to the manufacturing process. RoHS compliant means that the component does not contain six hazardous substances: lead, mercury, cadmium, hexavalent chromium, PBB, & PBDE. It does not mean that these parts are compatible with the manufacturing process. RoHS manufacturing requires higher soldering temperatures than Tin-Lead to ensure reliable connections between the board & components. The issue is that these elevated temperatures can damage some RoHS components. Unfortunately, verification cannot always be fully accomplished by a diligent review of the manufacturer's component specifications. Frequently, issues are uncovered when prototypes are built. These concerns may impact reliability or only be cosmetic in nature; however, either can affect the marketability of the product.

It is important to define and understand both the product requirement and the process requirement to design a valid component verification process.

Some of the factors to consider beyond the initial electrical performance of the component are:

- Ability to withstand heat
- Changes to the electrical characteristics of the component due to heat or repeated heat cycles
- Potential cosmetic changes to the component due to exposure to heat or heat cycles (melted housing)
- Relationship of the component lead finish to wetting characteristics
- The relationship of likely component placement to process and the other components on the assembly
- Compatibility to process chemistry (e.g. no-clean versus aqueous flux)
- Compatibility to mechanical and thermal stress in manufacturing cycle and use
- Ability to rework component
- Lead finish specification
- Cooling rates

Certain issues will be of greater or lesser concern depending upon the product requirements. For example, a product sold at the board-level is always more sensitive to cosmetic issues than one sold packaged in an enclosure. In cases where a product is being designed to a specific customer requirement, it is vital to understand what omissions in the specification may exist and may become an issue once the design is complete and submitted for approval.

If we examine how some common components are specified (or not specified) it will become clear that by simply relying on the manufacturer's specification, there may not be enough information to properly verify a particular component.

Figures 1 and 2 show the recommended reflow profiles for a chip resistor. These are examples of relatively well-specified parts. In many cases, the manufacturer will simply say the peak reflow temperature is X, and may or may not add that it can withstand that temperature for a given period of time. In each case, the manufacturer has expressed the peak temperature and duration above a certain temperature. In Figure 1 we see that the part can dwell between 60-90 seconds above 220 degrees centigrade. In figure 2 we see that the part can dwell above 230 degrees centigrade for 30-40 seconds. Figure 1 specifies a ramp rate to pre-heat; Figure 2 does not specify a ramp rate at all. Figure 1 specifies a minimum time between 190 centigrade and

220 degrees centigrade; Figure 2 makes no mention of this dwell prior to liquid state. Figure 1 specifies the ramp-down rate at 6 degrees centigrade per second; Figure 2 does not specify ramp down rate.

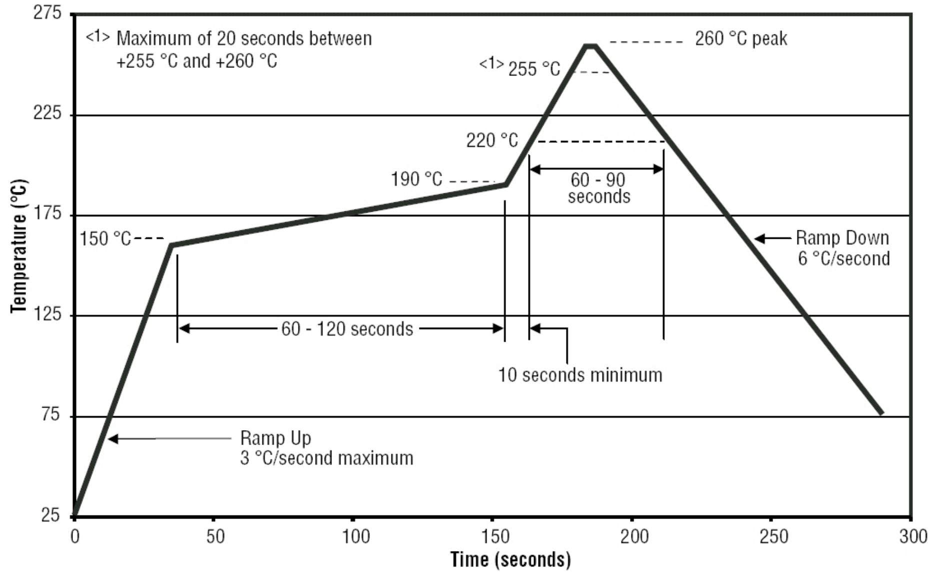


Figure 1

■ Recommended Soldering Conditions

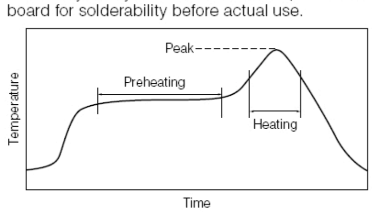
Recommendations and precautions are described below.

● Recommended soldering conditions for reflow

· Reflow soldering shall be performed a maximum of two times.

· Please contact us for additional information when used in conditions other than those specified.

· Please measure the temperature of the terminals and study every kind of solder and printed circuit board for solderability before actual use.



For soldering (Example : Sn/Pb)

	Temperature	Time
Preheating	140 °C to 160 °C	60 s to 120 s
Main heating	Above 200 °C	30 s to 40 s
Peak	235 ± 5 °C	max. 10 s

For lead-free soldering (Example : Sn/Ag/Cu)

	Temperature	Time
Preheating	150 °C to 180 °C	60 s to 120 s
Main heating	Above 230 °C	30 s to 40 s
Peak	max. 260 °C	max. 10 s

● Recommended soldering conditions for flow

	For soldering		For lead-free soldering	
	Temperature	Time	Temperature	Time
Preheating	140 °C to 180 °C	60 s to 120 s	150 °C to 180 °C	60 s to 120 s
Soldering	245 ± 5 °C	20 s to 30 s	max. 260 °C	max. 10 s

Figure 2

These differences are at some level minor, but there are reasons behind them that are not readily apparent. Please also observe that in Figure 2 the note that states the maximum number of reflow cycles implies that in the case of a double-sided assembly, rework to side one after the second heat cycle of side two would require installation of a new component. There is also the note that says “Please measure the temperature of the terminals and study every kind of solder and printed circuit board for solderability before actual use” – that doesn’t seem to be practical, real-world advice.

From this cursory view of the specification for a very common component from two of the largest suppliers of these devices, we have seen that there are variations in the specification. If each of these differences were crucial to the ability of the device to function, it would make the task of component selection overwhelming and incredibly costly. Bear in mind that these variations are between two of the exact same very common component. If we were to develop a complete matrix for all the component types and follow the instruction in the note in Figure 2 for all of them, it would add little value to the product and bring development to a screeching halt.

It is then vital to discriminate what are the key values and why are they there. It is also important to understand that there are four competing elements in every design when soldering is taking place and there have to be reasonable compromises made to achieve a viable result.

The four competing elements are:

- Electrical function
- Component requirement
- Solder requirement
- Equipment

Obviously electrical function will always trump the other elements. After that, each of the other elements may take precedence over the others, depending on the circumstances. For example, an assembly that has small chip resistors may have to dwell at an elevated temperature to accommodate out-gassing and void reduction, or simply because there are high pin-count BGAs in the center of the assembly. In either of these cases, a certain number of the chip components with pure tin finish may become discolored, particularly if there is organic contamination present. We can see from Table 1 that tin will turn a predictable shade based on peak temperature. This Table is also useful in determining what the peak temperature the component was exposed to during processing.

TABLE 1
Tin Tempering

Temperature ºF	Temperature ºC	Colors
430	221.11	Very Pale Yellow
440	226.67	Light Yellow
450	232.22	Pale Straw Yellow
460	237.78	Straw Yellow
470	243.33	Deep Straw Yellow
480	248.89	Dark Yellow
490	254.44	Yellow Brown
500	260.00	Brown Yellow
510	265.56	Spotted Red Brown

The color shift of tin from tempering is an excellent example of a condition that is acceptable objectively and yet may be wholly unacceptable subjectively due to lack of experience, education and training. It also highlights the fact that RoHS processing has many more qualifications that need to be understood to avoid problems that were not at issue with conventional SN63 processing.

Summary

When qualifying any component for a RoHS design or conversion, it is important to document in the item master record what processes the component can withstand and how many heat cycles it can endure. A low ESR capacitor in an 1812 package may indeed be RoHS compliant but only be RoHS process compatible to certain processes. The equipment used to process the design must also be taken into account. Re-flow ovens that were well suited for lead processing may limit the options available for RoHS processing. Through-hole component selection and thermal relief is much more critical with RoHS processing than it was with SN63.

It is critical to qualify each component or family of components to a defined process or set of processes to avoid quality and reliability issues.