2.3. Protecting the Quality & Reliability of Passive (and Active) Components: the J-STD-075 PSL Classification & Labeling

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ABSTRACT

While typically not the most expensive of a PCBA BoM (Bill of Materials), passive components are often the most numerous. Passive components also characterize by a wide variability in form factors and features.

In the early days of the RoHS directive implementation and transition to Pb-free soldering, it was shown that several passive component types could barely withstand higher Pb-free processing temperatures and could be damaged during the soldering stages.

This evolution evidenced temperature sensitivities of components such as aluminum, film and tantalum capacitors, inductors and transformers, fuses, crystals/oscillators, connectors…

About twenty years after the RoHS directive enforcement, progresses in materials and processes have been made to improve passive component resistance to Pb-free soldering temperatures but they still have processing limitations to a large extent.

In addition, contrarily to active components, lots of passive component types are not molded or resin encapsulated and turn out to be more exposed to PCBA cleaning compatibility issues.

These passive component sensitivities that induce PCBA processing limitations or adaptations are not new: they are captured since 2008 in the ECIA/IPC/JEDEC J-STD-075 joint international standard that defines a PSL (Process Sensitivity Level) classification and labeling system. More than fifteen years later, it must be admitted that the awareness regarding this standard remains very limited within passive component manufacturers with only few punctual examples of actual implementations and consideration. Despite all the quality and reliability issues this daily causes to high-end hardware electronics even when deploying extensive efforts upstream…

This paper will show the impacts PCBA processes can have on passive components and highlight the J-STD-075 standard requirements. Finally, the need to manage component sensitivities using J-STD-075 PSL classification will be underlined as a call to action for passive component manufacturers.

SENSITIVITY TO MOISTURE IN REFLOW: THE MSL CLASSIFICATION & LABELING

The sensitivity of electronic components to moisture and risks of damages during reflow caused by humidity absorption are well known and have been extensively characterized for a long time.

This dates back to the move from hermetic to non-hermetic plastic components back in the 80-90's that evidenced the hygroscopic nature of the plastic packages could have deleterious effects on SMT components after reflow exposure. Through this technology change, it has been seen that the rapid temperature rise during reflow soldering causes expansion of the moisture absorbed within plastic components which can generate package integrity defects such as cracks or delaminations, the so-called popcorn effect – see Fig.1.

To manage these moisture sensitivities, IPC/JEDEC joint industry standards have been created to define:

- a MSL (Moisture Sensitivity Level) classification and labeling system for components: J-STD-020 standard
- the related handling, baking and packing requirements: J-STD-033 standard

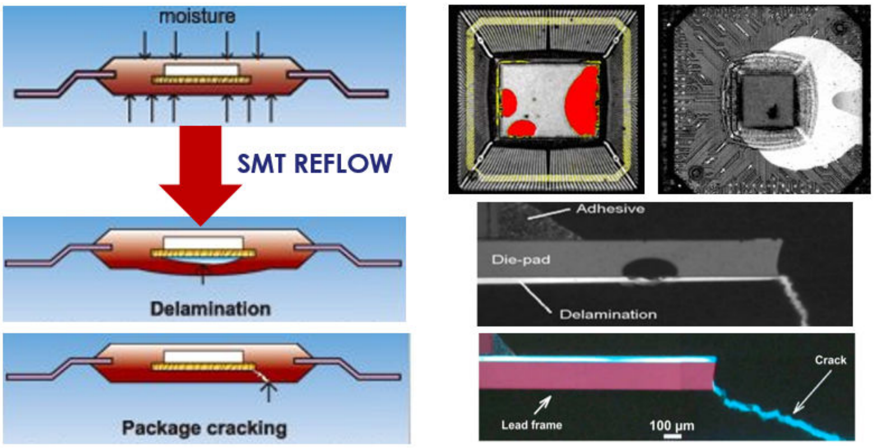

Fig.1. Sensitivity to Moisture in Reflow: Illustration of the popcorn effect in SMT plastic package components.

The IPC/JEDEC J-STD-020 standard (reference [1]) has been introduced in 1996 followed by the IPC/JEDEC J-STD-033 (reference [2]) in 1999, more than 25 years ago.
Both are kind of universal standards of reference, well established within the whole electronics industry and daily used by any component manufacturers and board-assemblers worldwide. These two international standards are currently in revisions –F (J-STD-020) and –D (J-STD-033) and regularly maintained on a 5-year cycle basis.

Component manufacturers routinely define MSL ratings as prescribed by the J-STD-020 standard, board-assemblers are used to accommodating the component exposure to humidity in their facilities through floor life tracking, storage in dry cabinets or baking as defined in J-STD-033.

It is worth noting that the J-STD-020 was originally entitled "*Moisture/Reflow Sensitivity Classification for* ***Nonhermetic Solid State Surface Mount Devices***" thus covering only active electronic components, not passive explicitly.
Passive components have been added to the J-STD-020 scope from the revision –E introduced in 2014 as witnessed by the title change to "*Moisture/Reflow Sensitivity Classification for* ***Nonhermetic Surface Mount Devices***".

This means that SMT passive components shall use the same MSL classification protocol as active devices summarized below:
- Initial electrical test, visual inspection and acoustic microscopy
- Component preconditioning: Dry baking + moisture soak (conditions function of the targeted MSL)
- SMT reflow exposure: 3 reflow cycles, J-STD-020 reflow profile requirements
- Post-reflow electrical test, visual inspection and acoustic microscopy

One major difference between active and passive components rely in the failure criteria after reflow exposure: While acceptable delaminations and other package integrity defects are pretty accurately described for active devices, they are not defined for passive components due to their large variability in constructions and form factors.

The 9.2.4 section pertaining to Non-IC Devices in the active J-STD-020F states the following: "*Currently J-STD-020 does not provide failure criteria for non-IC devices. Any party choosing to use the procedure within this standard to determine the MSL rating for a non-IC package is responsible for defining the appropriate failure criteria to ensure the long term reliability of the device.*"

MSL ratings of SMT passive components are therefore required to be determined using the same protocol as active devices but without any supporting failure criteria from the J-STD-020 standard.

The two following examples show how MSL ratings can be misleading for passive components.

MnO_2 tantalum capacitors: The questionable MSL1 rating

Globally, SMT polymer tantalum capacitors are MSL3 rated, conditioned in Dry Packs and managed as MSL3 active components in board-assembly manufacturing.
By contrast, MnO_2 tantalum capacitors are regarded as non-sensitive to humidity by component manufacturers, thus MSL1 rated and typically not conditioned in Dry Packs.

Both polymer and MnO_2 tantalum capacitors include a plastic molding and other constituents that do absorb moisture.

The MSL1 rating remains highly subjective without knowing the test conditions and failure criteria used which are typically not publicly available or communicated by the manufacturers.
Assessments performed in [3] and [4] showed that MnO_2 exposed to a MSL1 moisture preconditioning could easily generate cracks after SMT reflow and strongly affect the propensity of catastrophic failures after first power-on.

Thales experienced such kind of failures and moisture-induced post-reflow cracks of MnO_2 tantalum capacitors (see Fig.2), which has also been reported by other high-reliability users like in [5].

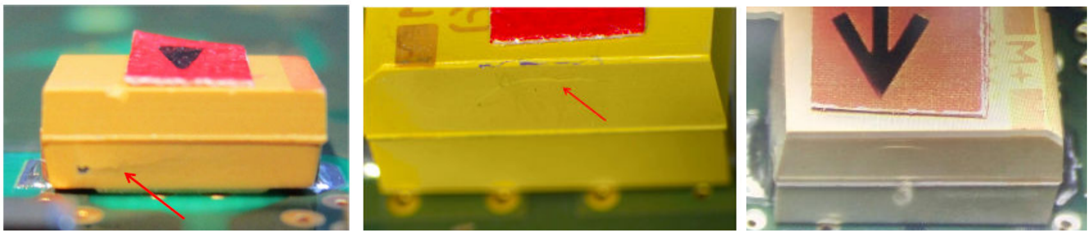

Fig.2. Soldered MnO_2 tantalum capacitors with moisture-induced cracks.

Handling MnO_2 tantalum capacitors as MSL3 components can be a workaround to mitigate the failure risks but this has a cost impact and is not easy to consistently manage in a manufacturing production context.

The best approach would definitely be to standardize the test conditions and failure criteria for tantalum capacitors and have the MSL ratings defined against a common basis.

Polymer resettable fuses: The unverified MSL1 rating

Resettable fuses are passive components used as protection against overcurrent faults in electronic circuit designs. They typically include a polymer that can change from a crystalline into an amorphous state depending on the component heating temperature.

In this case, a MSL assessment/verification was performed on such polymer resettable fuse with a MSL1 rating.
The parts were submitted to a MSL1/260°C preconditioning and controlled after 1 and 3 reflow cycles.
Internal delaminations were found after just 1 reflow cycle and resistance measurements were out of specification after the 3 reflow cycles required by the J-STD-020 MSL protocol – see Fig.3.

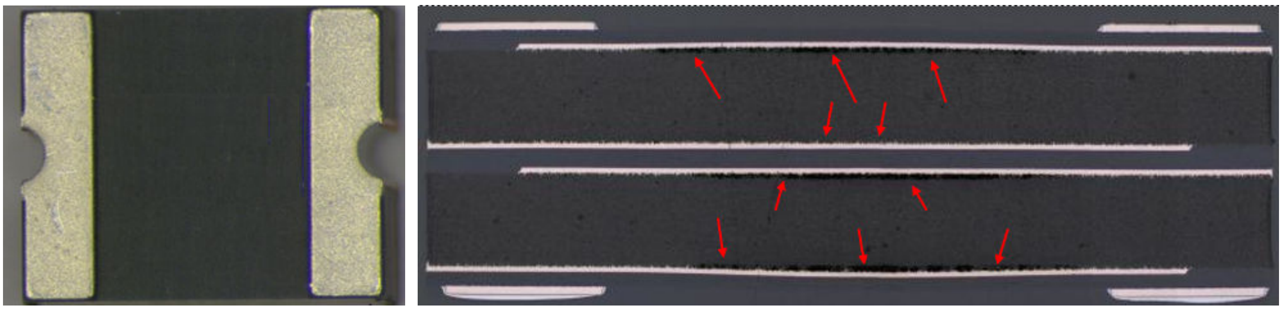

Fig.3. Internal delaminations of polymer resettable fuses after MSL1 assessment/verification.

Exchanges with the manufacturer allowed to confirm the findings and, worst, to evidence that the MSL test protocol in place relied only on electrical tests performed after 1 single reflow cycle, without any additional inspection or physical analysis.
This experiment clearly highlighted a manufacturer misinterpretation/misuse of the J-STD-020 for the determination of the MSL rating of passive components, which unfortunately is far from being an isolated case…

SENSITIVITY TO SOLDERING, CLEANING AND OTHER PCBA PROCESSES: THE PSL CLASSIFICATION & LABELING

Sensitivity to soldering

With the advent of the RoHS directive in 2006, the electronics industry transitioned to Pb-free soldering processes with reflow temperatures higher of about 40°C compared to Tin-Lead reflow.

This major evolution turned out to have a strong impact on MSL ratings: the first MSL reclassifications in regards to higher temperature Pb-free SAC305 reflow profiles yielded a typical drop of two MSL levels compared to Tin-Lead soldering. As a response, the industry has developed and implemented more thermally robust plastic IC packaging materials and manufacturing processes, e.g.:

- Molding compounds, die-attach adhesives, PCB laminate materials…
- Adhesion promotion treatments

Newly developed materials and processes allowed to recover the MSL Pb-free gap for active devices but soldering resistance was much more challenging and critical to ensure for passive components.
Quoting reference [6] from 2008: "*Many non-semiconductor commodities had barely been able to support the SnPb assembly profiles. It was not well known in the industry just how little thermal safety margin existed on many such passive components".*

The temperature sensitive components pointed at this time included the following types:

- Capacitors: aluminium, film, tantalum and double carbon layer capacitors
- Inductors and transformers with insulated wire type coil
- Crystals, oscillators, resonators
- Fuses
- Non solid-state relays
- LEDs
- Connectors

Most of these components have reduced Pb-free soldering process window and induce PCBA manufacturing limitations. To facilitate their identification within BOMs (Bill-of-Materials) prior to board manufacturing and be able to properly set-up PCBA processes, the EIA/IPC/JEDEC J-STD-075 (reference [7]) was created in 2008.

Originally entitled "*Classification of* ***Non-IC Electronic Components*** *for Assembly Processes*", J-STD-075 extends the MSL concept from the J-STD-020 standard through the definition of PSL (Process Sensitivity Levels) ratings and related classification and labeling requirements specifically for passive components.

The revision -A issued in 2018 extended the scope to active components as reflected in the title change to "*Classification of* ***Passive and Solid State Components*** *for Assembly Processes*".

J-STD-075 defines PSL ratings in regards to soldering in reflow for SMT and wave soldering for through-hole components as well as cleaning and other PCBA manufacturing processes.

As per J-STD-075, SMT passive components shall withstand 3 reflow cycles with a peak temperature and reflow profile parameters consistent with J-STD-020 (see *Fig.4*), else they shall be classified and labelled with a PSL rating.

Table 15-2 Base Profile for Reflow Solder Process

Reflow Profile Feature	Values Required for R0 Rating
Preheat Soak Temperature Min (Ts_{min}) Temperature Max (Ts_{max}) Time (Ts_{min} to Ts_{max}) (ts)*	 150 °C 200 °C 120 seconds*
Ramp-up rate (25 °C to Tp)	3 °C/second*
Liquidus temperature (T_L) Time maintained above Liquidus temperature (t_L)*	217 °C 150 seconds*
Peak package body temperature (Tp)	For users Tp must not exceed the Classification temp in Table 15-1 For suppliers Tp must equal or exceed the Classification temp in Table 15-1
Time (tp)* within 5 °C of the specified classification Temperature (Tc), see Figure 15.1	30 seconds*
Ramp-down Rate (Tp to 25 °C)	6 °C/second*
Time 25 °C to Peak Temperature (maximum)	8 minutes
* tolerance for ts, t_L, tp, ramp up, and ramp down are defined as a supplier minimum and a user maximum	

Peak temperature and reflow soldering conditions consistent with J-STD-020

Table 15-1 Reflow Process – Target Classification Temperatures

Package Thickness	Volume mm3 <350	Volume mm3 350 - 2000	Volume mm3 >2000
< 1.6 mm	260 °C	260 °C	260 °C
1.6 mm - 2.5 mm	260 °C	250 °C	245 °C
> 2.5 mm	250 °C	245 °C	245 °C

Fig.4. J-STD-075/J-STD-020 base reflow conditions for PSL rating determination (3 reflow cycles).

Similarly, though-hole passive components shall withstand 2 wave soldering passes with the defined J-STD-075 base profile parameters (see *Fig.5*), else they shall be classified and labelled with a PSL rating.

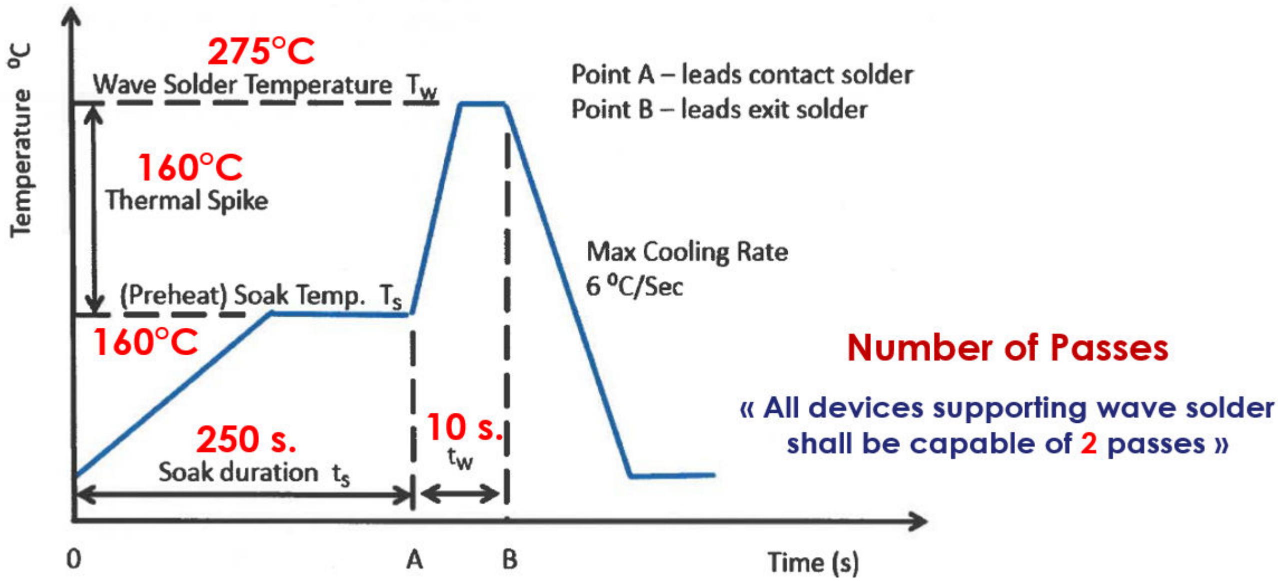

Fig.5. J-STD-075 base wave soldering conditions for PSL rating determination (2 passes).

Numerous passive components fail to meet the J-STD-075 base soldering conditions and should have a PSL rating, e.g. SMT/through-hole aluminium and film capacitors.

Unfortunately, J-STD-075 turns out to be very little applied by passive component manufacturers currently.

As a result, lots of temperature sensitive components are not properly detected upstream and escape to board-assembly without the required care, which creates quality or reliability issues and increase the risks of field failures.

Sensitivity to cleaning

Active components in regular plastic molded packages are typically immune or resistant to PCBA cleaning processes, but passive components often use constructions that are more likely to be damaged by high pressure jet or immersion cleaning processes.
Also alkaline cleaning agents can chemically degrade polymers or corrode some metals from passive components.

A sample of four experienced cases are presented hereafter.

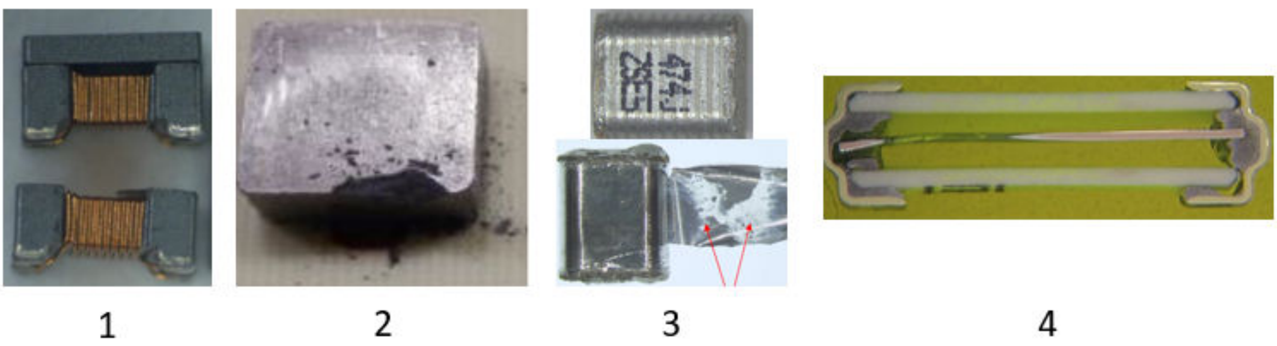

Fig.6. Examples of passive components sensitive or intolerant to cleaning.

(1): SMT common choke inductor

This ceramic inductor includes a ferrite slab glued on top of the coil winding. The cleaning chemistry is susceptible to degrade the adhesive and lift-off the ferrite slab which results in functional failures.

(2): SMT pressed-powder molded inductor

Pressed-powder molded inductors use a material that can be degraded under extended cleaning. Some components use a protective coating but this is not a general case.

(3): SMT naked film capacitor

Naked film capacitors use a wound aluminium foil that is unprotected and likely to corrode when exposed to cleaning agents.

(4): SMT wire-in-air fuse

Wire-in-air fuses consist in a ceramic cavity that includes a thin silver or copper wire and two end-cap terminations that do not ensure a perfect sealing. Ingress of the cleaning agent inside the fuse will corrode the internal metallic wire.

Other types of components are also known to be sensitive to cleaning, e.g. sensors with open constructions, switches, relays…

Passive component intolerances are difficult to capture and mostly discovered though hard lesson experiences at board-level. This reinforces the importance of having component manufacturers use PSL ratings to declare cleaning sensitivities and facilitate the prevention of manufacturing issues.

Contrarily to soldering sensitivity, the J-STD-075 standard does not specify any base conditions or test protocol to address cleaning sensitivity given the large variety of cleaning processes and chemistries used.

Sensitivity to other PCBA processes

In addition to soldering and cleaning sensitivities, the J-STD-075 standard includes additional PSL ratings for components exhibiting limitations in regards to other PCBA processes like vacuum picking or X-ray inspection (for active components).

Like for PCBA cleaning, there is no defined base conditions or requirements but component manufacturers are expected to report and label components with known process sensitivities using PSL ratings.

SUMMARY AND CONCLUSIONS

Expensive active components usually get more attention during BOM analyses before PCBA manufacturing, but there are actually many more quality and reliability risk opportunities within passive components that are mostly overlooked … Due to their higher count first but also because they are globally less robust in regards to PCBA manufacturing processes and require special processing care.

The J-STD-020 and J-STD-075 standards defining MSL/PSL classifications and labeling constitute excellent protections for the quality and reliability of passive components across the supply-chain.

Although implemented a long time ago and supported by all key ECIA, IPC and JEDEC organizations, awareness and usage by component manufacturers remain far too limited. This paper is a call to action for passive component manufacturers at a time when digital continuity between design and manufacturing processes is targeted.

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