Proposal:

Qualification Temperature Profile of electronic devices for Leadfree Reflow Soldering.

IPC B-10a and JEDEC JC-14.1 Joint Working Group
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Proposed by the German automotive electronic OEMs:

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BOSCH Continental TEMIC HELLA SIEMENS VDO Automotive

IPC/JEDEC J-STD-020B(C):
Moisture / Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices

Part 1: **Proposal for changes of tables and figures of the IPC/JEDEC J-STD-020B due to requirements of the manufacturing process of electronic control units.**

Part 2: **Explanation and arguments for these requirements.**

Part 1:

We propose changes regarding the following tables and figures:

J-STD-020B: Table 4-1 Package Peak Reflow Temperatures

Table 4-1 Package Peak Reflow Temperatures

Reflow Conditions	Pkg. Thickness ≥2.5 mm or Pkg. Volume ≥350 mm³	Pkg. Thickness <2.5 mm and Pkg. Volume <350 mm³
SnPb Eutectic	Convection 225 +0/-5°C	Convection 240 +0/-5°C
Pb Free	Convection 245 +0/-5°C	Convection 250 +0/-5°C

J-STD-020B: Table 5-2: Classification Reflow profile (Pb-free Assembly)

Table 5-2 Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly		Pb-Free Assembly	
	Large Body	Small Body	Large Body	Small Body
Average ramp-up rate (T_L to Tp)	3°C/second max.		3°C/second max.	
Preheat – Temperature Min (Ts_{min}) – Temperature Max (Ts_{max}) – Time (min to max) (ts)	100°C 150°C 60-120 seconds		150°C 200°C 60-180 seconds	
Tsmax to T_L – Ramp-up Rate			3°C/second max	
Time maintained above: – Temperature (T_L) – Time (t_L)	183°C 60-150 seconds		217°C 60-150 seconds	
Peak Temperature (Tp)	225 +0/-5°C	240 +0/-5°C	245 +0/-5°C	250 +0/-5°C
Time within 5°C of actual Peak Temperature (tp)	10-30 seconds	10-30 seconds	10-30 seconds	20-40 seconds
Ramp-down Rate	6°C/second max.		6°C/second max.	
Time 25°C to Peak Temperature	6 minutes max.		8 minutes max.	

Note: All temperatures refer to topside of the package, measured on the package body surface.

J-STD-020B: Figure 5-1 Classification Reflow Profile

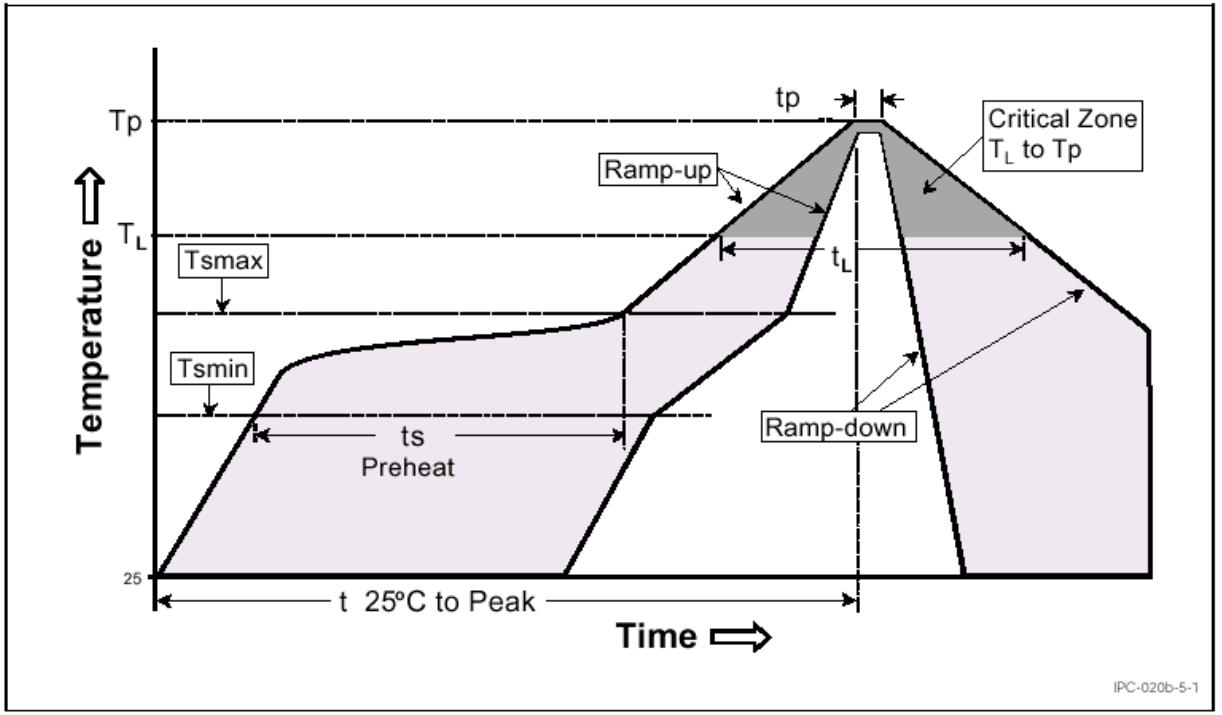

Figure 5-1 Classification Reflow Profile

The following tables and figures represent the requirements of a serial production of automotive electronic control units.

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Proposal for table 4-1 (Package Peak Reflow Temperatures):

small devices 260 - 0 °C	h<1,8 mm **or** V<350 mm³	thin **or** small volume	eg. SOT, QFN, SO28, LQFP
large devices 250 - 0 °C	1,8≤h<2,5 mm **and** 350 mm³≤V<2000 mm³	medium thickness **and** large volume	eg. BGA (24x24mm), PQFP80, SO44XL
	h≥2,5 mm **and** 350 mm³≤V<1000 mm³	thick **and** medium volume	eg. SOP20, PLCC28, MO188, TO263
very large devices 245 - 0 °C	h≥2,5 mm **and** V≥1000 mm³	thick and large volume	eg. PQFP160, PLCC44, PLCC52

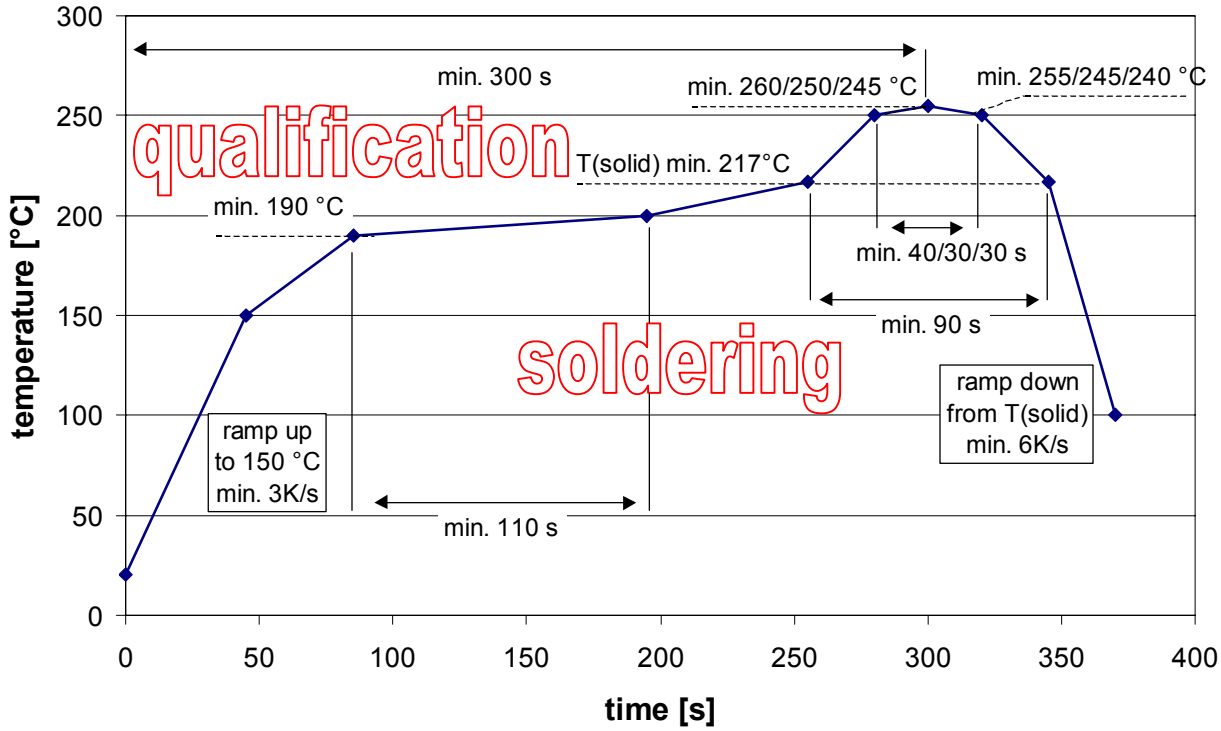
- still volume and thickness classification (no heat capacity or thermal conductivity criteria are used)
- volume excludes external terminals and nonintegral heatsinks
- measurement of temperature on top of package
- 3 classes of packages
- logic operator “or” instead of “and” at 260 °C class

Proposal for table 5-2 (Classification Reflow Profiles) only Pb-free:

Profile Features	Small Devices	Large Devices	Very Large Devices
preheat			
ramp-up rate to 150 °C	min. 3 K/s (average value over 10 s)		
time from 190°C to 200°C	min. 110 s		
peak			
ramp-up rate from 200°C to T_{peak}	0,5 K/s - 3 K/s (average value over 10 s)		
time above $T_{solidus}$ (min. 217 °C)	min. 90 s		
peak temperature T_{peak}	260 (- 0) °C	250 (- 0) °C	245 (- 0) °C
time above T_{peak} - 5 K	min. 40 s	min. 30 s	min. 30 s
cooling			
ramp-down rate from $T_{solidus}$ (min. 217 °C)	min. 6 K/s (average value over 10 s)		
general			
time 25 °C to T_{peak}	min. 300 s		

- Qualification profile with min. values for temperatures, times and ramps.
- Device qualification temperature profile at the supplier has to stay above these values, while the soldering profile at the manufacturers has to stay below these values.

Proposal for figure 5-1 (Classification Reflow Profile):



- This is a **qualification profile** with minimum values for temperatures, times, ramp up and ramp down rates.
- The shown graph represents the limiting line between suppliers and manufacturers.

Why do we propose a temperature reflow profile with only one temperature versus time line?

- clear interface between device suppliers and manufacturers
- qualification has to be performed above the line, soldering of the devices has to be performed below the line
- profile represents the absolute necessary requirements for components during a reflow process on electronics manufacturers side
- the requirements are based on real measurements on product boards

Part 2:

Explanation and Argumentation of the peak temperatures and other characteristics of the Pb-free reflow qualification profile.

External parameters and conditions:

- reflow soldering equipment: only 4 of 7 reflow furnace suppliers are able to fulfill the shown requirements for the T-profile.
- Transportation speed: realistic production line speed (850 mm/min)
- Coldest solder joint on board: **min. 20 sec @ T = 230 °C**
  this corresponds to: **ca. 1 s @ T = 233 °C**

Temperature measurement with testboard:

- PCB represents typical boards in serial production.
- a defined thermal mass on PCB represents the **coldest solder joint** on serial boards (result of measurements with serial boards).
- Temperature measurement on different packages (always in the middle on top of the package)

Temperature tolerances of reflow furnaces and measuring errors:

General furnaces tolerances:

• State of furnace loading (full or without PCBs):	**± 0,5 K**
• Long term stability (5s tolerance):	**± 2,5 K**

Transverse temperature profile of furnaces:

• in general (according to furnace suppliers):	± 2,0 K
• only positive tolerance will be considered	**+ 2,0 K**

negative tolerance is taken into account in design of thermal mass (coldest solder joint) on test board

Tolerances of test board:

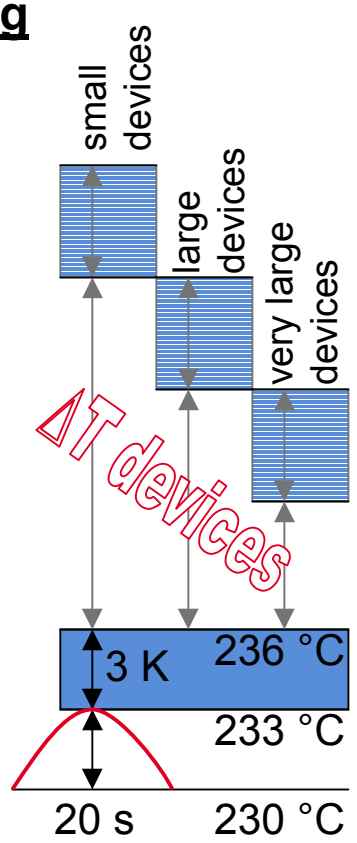
• thermocouples (NiCrNi) with evaluation unit:	± 1,0 K
• assembly of thermocouples:	± 0,5 K
• **Total tolerances of test board:**	**± 1,5 K**

Tolerances: Consequences for temperature profiling

The addition of measurement errors and furnace tolerances give a total tolerance. The coldest solder joint has to reach the temperature (233 °C + tolerance) to ensure that the coldest solder joint always see the necessary temperature of 233 °C (20 s @ 230 °C).

Using Gauss' error propagation theorem the independent tolerances can be added:

loading of the oven:	0,5 K
long term stability of the furnace:	2,5 K
test board:	1,5 K
total lower tolerance:	**3,0 K**



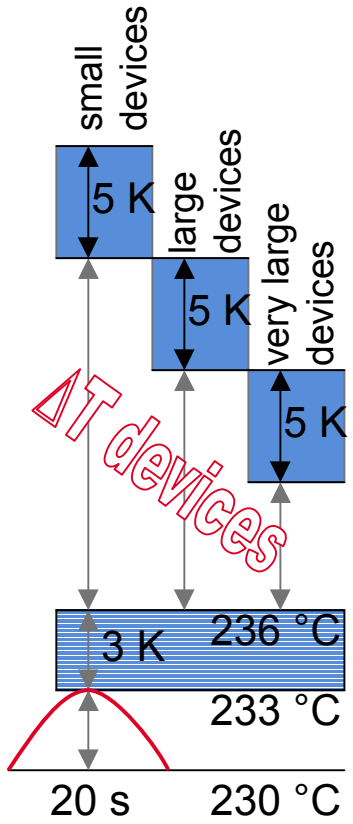
These 3,0 K have to be added to the 233 °C.
Therefore the coldest solder joint has to be profiled at 236 °C.

Tolerances: Consequences for the heat resistance of electronic devices

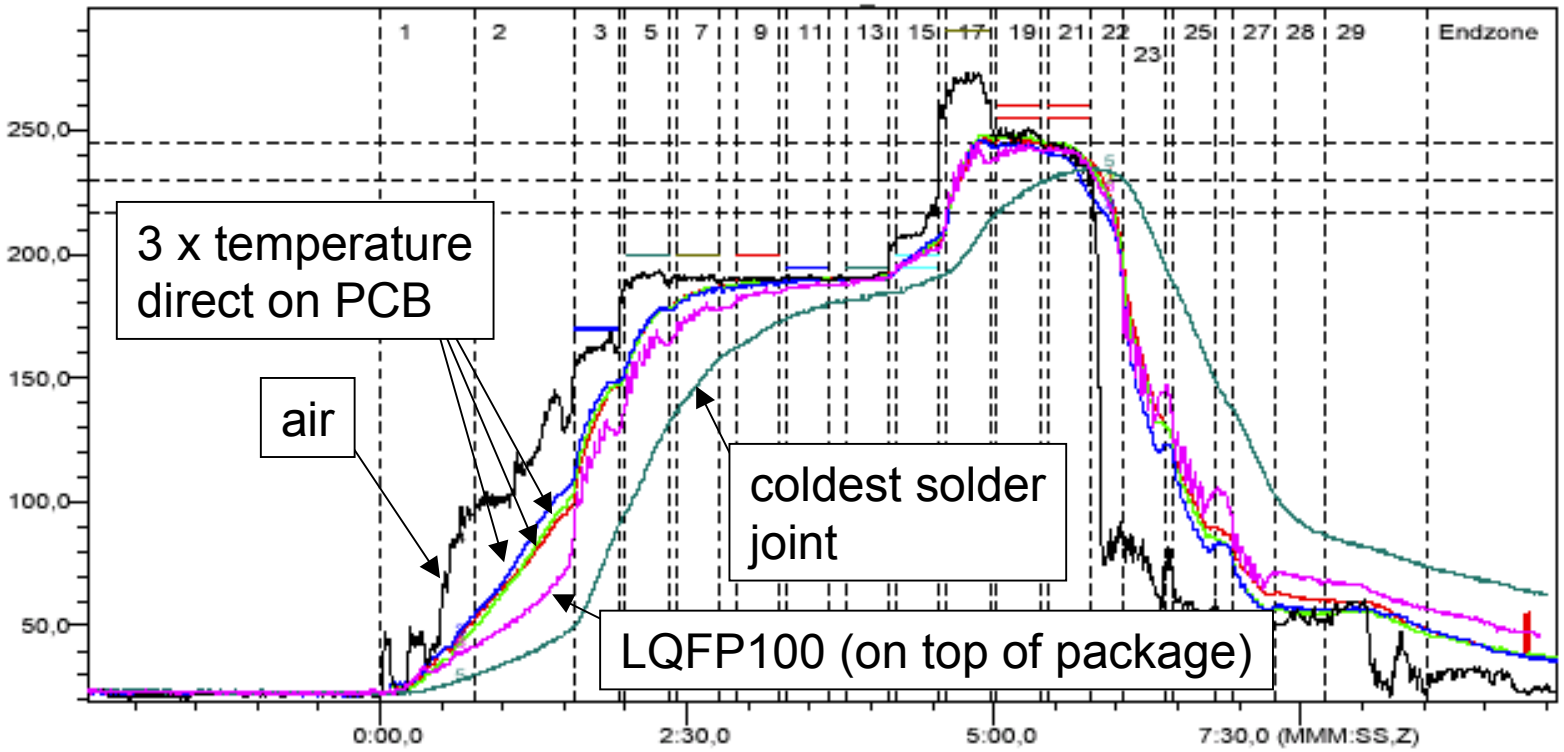
The total furnace and board tolerance together with the transverse temperature profile have to be added on top of the measured temperature values.

Board and furnace tolerance (see last slide):	3,0 K
Transverse temperature tolerance:	2,0 K
total upper tolerance	**5,0 K**

Due to the thickness and volume of the devices the temperatures on top of the packages reach different values (ΔT devices). The 5,0 K have to be added to these values to ensure that the devices withstand the possible temperatures in the reflow furnace.



Typical reflow profile with one test board:



v (transport) = 850 mm/min
ΔT (devices) = 13 K

List of temperatures of typical molded packages (measurement on top of packages):

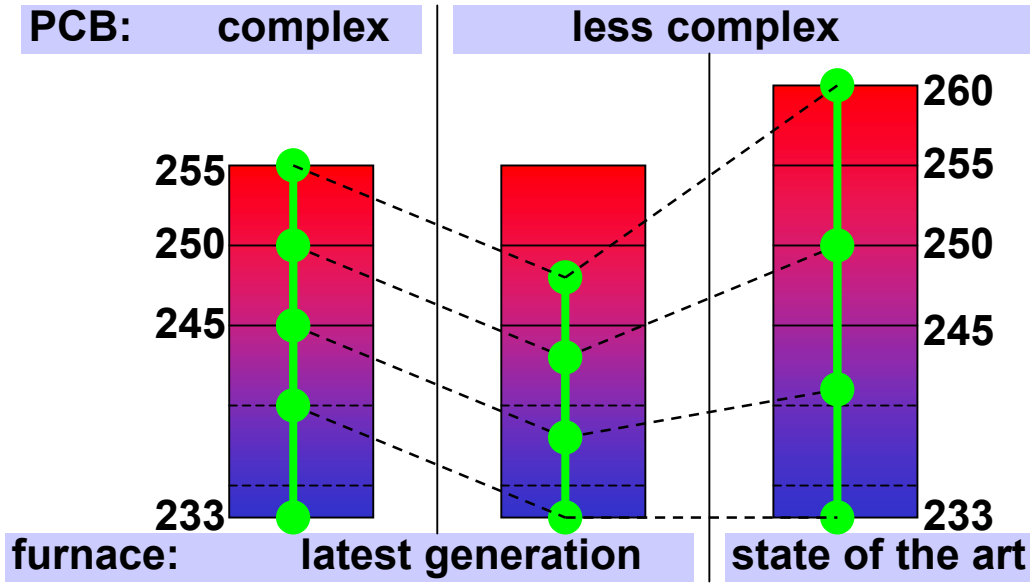
- above mentioned tolerances (3,0 K / 5 K) were added as described
- influence of longitudinal position of device on PCB is taken into account (0 -1,5 K)
- result from the 4 best furnaces out of 7
- 3 classes of devices are the result of this study (small devices are about 255 °C)

package (measurement on top of package)	measurement	final values with tolerances
	[°C]	[°C]
coldest solder joint	233,0	**236,0**
PLCC 84 (30 x30)	232,5	**241,0**
QFP160 (28 x 28)	233,5	**242,0**
PLCC 68 (24 x 24)	233,5	**242,5**
PLCC 44 (17 x 17)	234,0	**242,5**
PLCC 52 (19 x 19)	234,0	**243,0**
DO218	236,0	**244,5**
MO-166	237,0	**246,0**
QFP-exposed pad (20 x 14)	237,5	**246,0**
SO28	237,5	**246,0**
PLCC 28 (12 x 12)	238,0	**246,0**
QFP144 (28 x 28)	237,0	**246,5**
MO-188 (14 x 14)	237,5	**247,0**
QFP80 (20x14)	238,5	**247,0**
TO 263	239,5	**247,5**
SO 44 XL	240,0	**248,0**
QFP 80 (14 x 14)	240,5	**248,5**
BGA (24 x 24)	240,5	**249,5**
LQFP-MS026 (20x20)	242,0	**251,5**
LQFP 100 (14 x 14)	243,5	**252,5**
temperature on pw b	247,0	**255,0**

Special remarks regarding the reflow qualification profile:

1.) Why do we need 260 °C for small devices (on top of packages)?

- The value of 255 °C in the study for small components only could be obtained by 4 out of 7 full convection reflow furnaces, which are of the latest generation with a very high performance. Therefore only little bit more than half of the furnace suppliers would reach the goal of 255 °C.
- Less complex PCBs could be soldered using **state of the art reflow equipment** if it were possible heating the small components up to 260°C.



2.) Why do we need a minimum ramp up rate of 3K/s up to 150 °C?

- Typical reflow profiles in serial production show the value of 3K/sec.

3.) Why do we need min. 110 s @ 190 °C < T < 200 °C?

- In order to obtain a small temperature split in the peak region it is absolutely necessary to use a soak type profile in the preheating.

4.) Why do we use a relative short soldering profile in comparison to the profile in J-STD-020B?

- A time above solidus (liquidus) of 90 s is a realistic value for a solder peak width. Otherwise you overstress the PCB.
- A total time from 25 °C up to T(peak) of 300 s instead of 480 s like proposed in the J-STD-020B is enough and a realistic value for a solder profile length. Current Pb-free solder pastes do not work with longer solder profiles.

5.) Why is the proposed classification of devices that complicated?

- The temperature of the device during reflow soldering is a result of the heat capacity, heat conductivity and geometry of the devices.
- Because these criteria are very difficult to handle, we stay with the volume and thickness classification. Our measurements showed that the proposed classification is necessary. A classification following J-STD-020B would lead to a higher temperature for the large devices.
- As option to the classification using 3 groups it is possible to use a classification with only 2 groups, to make the classification easier. The group of large and very large devices could be merged.

small devices (260 - 0 °C)	h<1,8 mm **or** V<350 mm³	thin **or** small volume	eg. SOT, QFN, SO28, LQFP
large devices (250 - 0 °C)	all others		eg. BGA (24x24mm), PQFP80, SO44XL,
			SOP20, PLCC28, MO188, TO263
			PQFP160, PLCC44, PLCC52