

### OBJECTIVE

The objective of this application note is to provide the customer with a general understanding of ANADIGICS' products high temperature capabilities associated with 2<sup>nd</sup> level lead-free assembly. It also provides general information on the moisture sensitivity level (MSL) tests as required by JEDEC for sensitivity rating of products to be used in lead-free assembly environments. Finally, a brief look at the various tests used to qualify ANADIGICS products is also presented.

### INTRODUCTION

The world-wide lead-free initiative for microelectronics has caused the industry to revamp the design, material selection, and manufacturing processes of its products. Japan and Europe have launched industry wide programs banning lead from electronics products in 2005 and 2006, respectively. These programs are backed by OEMs in Japan and by the Parliament in Europe. Although the United States does not have any legislation for the removal of lead from electronic components, in order to remain competitive in this global market, the United States must follow suit or face exclusion from markets requiring the elimination of lead.

Lead based solders are now being replaced by lead-free solders for 2<sup>nd</sup> level interconnects. The most common replacements for 63Sn37Pb (eutectic point 187 °C) are the 96.5Sn3Ag0.5Cu (SAC305) and 95.5Sn4Ag0.5Cu (SAC405) solders, which have a eutectic point of 217 °C. Due to the non-uniformity of heat distribution on boards during 2<sup>nd</sup> level interconnection reflow, the SAC solders reflow profiles contain a peak temperature of 250 °C. This peak temperature could potentially be as high as 260 °C depending on the assembler's equipment and process capabilities; reflowing components at such high temperatures can cause a multitude of problems such as delamination at any of the various interfaces, solder extrusion, external cracking, and cracks on any of the internal features and I/Os.

In order to overcome these problems, ANADIGICS uses innovative designs, processes and materials

in the manufacture of its products. Products using these techniques exceed the standards set by JEDEC for exposure to high temperature reflows.

### LEAD-FREE SOLDERS

The following table provides a few lead-free solders being used in industry. Although no standard replacement has been identified by the microelectronics industry, research organizations specializing in lead-free solders have recommended several replacements for the standard Sn37Pb solder.

**Table 1: Common Lead-free Solders [1,3,5]**

Alloy	Melting Point (°C)	Industry
Sn3.5Ag	221 - 226	Automotive
Sn3.5Ag3Bi	208 - 217	Military/Aero-space
Sn3.5Ag1Bi4In	208 - 213	Consumer
Sn3.0Ag0.5Cu	217	Automotive Telecom.
Sn57Bi	138	Consumer
Sn0.7Cu	227	Consumer Telecom.
Sn9Zn	199	Consumer

### PROPERTIES OF LEAD-FREE SOLDERS [1]

Some of the properties common to lead-free solders are given below:

- Typically have much higher melting points than traditional Sn63Pb37
- Are stronger and less ductile than lead or indium-bearing alloys
- Typically exhibit poor wetting when compared to Sn37Pb

## High Temperature Report

SAC305 and SAC405 provide certain advantages over other lead-free compounds due to the presence of copper.

- Copper in solder retards the dissolution rate of copper from boards.
- Copper can improve the wettability of the solder during reflow.
- Copper can improve the thermo-mechanical properties of solder joints.
- Copper reduces the melting point slightly. 96.5Sn3.5Ag has a melting point of 221 °C.

**Table 2: SAC305/SAC403 Data [2,3]**

Category	Property
Melting point	217 °C
Tack Force	2.63g/mm <sup>2</sup>
Density	7.44
Elec. Resistivity	13 μΩ-cm
CTE	~14
Ultimate Tensile Strength	42 Mpa
Yield Strength	45 MPa
Shear Strength	27 MPa
Creep	27 MPa (100 h to failure)
Wetting time	~0.27 sec

### BACKGROUND ON MSL LEVELS

MSL levels are used to classify the sensitivity of a microelectronic package to moisture. Packages can be classified from level 1 (hermetic package) to level 6 (very sensitive). Knowledge of the MSL level of a package is crucial during 2<sup>nd</sup> level solder reflow for proper assembly of the product as these levels dictate the duration that the package can be exposed to the atmosphere before being exposed to solder reflow temperatures. Once this time limit expires, the package is at risk for catastrophic damage during reflow. Table 1 summarizes the different MSL levels as defined by JEDEC Standard J-STD-020B [4].

**Table 3: Moisture Sensitivity Levels by JEDEC**

Level	Floor Life
1	Unlimited
2	1 year
2a	4 weeks
3	168 hours
4	72 hours
5	48 hours
5a	24 hours
6	Time on Label

Traditionally ANADIGICS has provided qualified laminate-based modules rated at MSL 3 and standard plastic leaded packages rated at MSL 1, with a tolerance for a peak reflow temperature of 240 °C. ANADIGICS is now capable of providing 260 °C tolerant packages. The laminate-based modules are qualified at MSL 3 and standard plastic leaded packages at MSL 1, for applications requiring this capability.

### HIGH TEMPERATURE REFLOW PROFILES

In order to qualify the products at the desired MSL level, it needs to be subjected to, and pass, the environmental conditions and stress tests as specified in J-STD-020B. While, this standard specifies a peak reflow temperature of 250 °C, ANADIGICS has decided to exceed this specification by 10 °C to provide the customers with a greater reflow margin, thus delivering a more tolerant and robust product.

The following flowchart shows the flow of the tests for an MSL test.

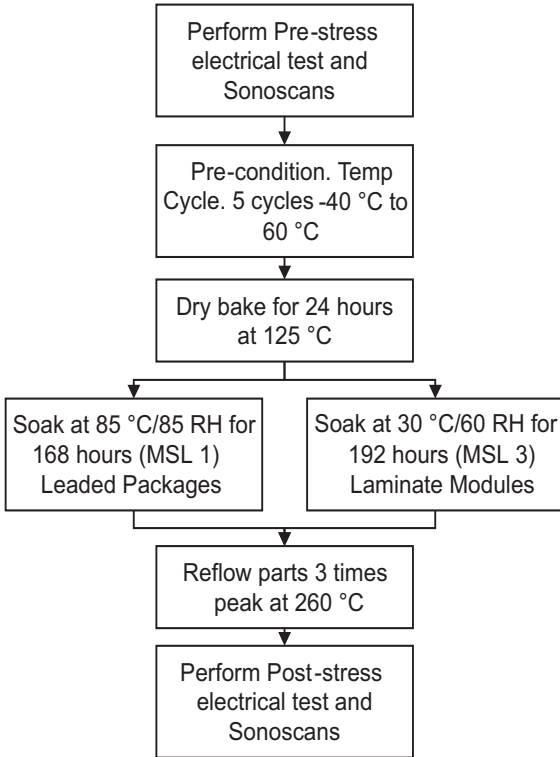


Table 4 provides a breakdown of the reflow conditions [4].

**Table 4: Lead-free MSL Reflow Profile Breakdown**

Profile Feature	JEDEC Specifications
Avg. Ramp-up ( $T_L$ to $T_P$ )	3 °C/second max
Dwell Time (175 ± 25 °C)	60-180 seconds
Ramp-up 200 °C to 217 °C	3 °C/second max
Time above 217 °C	60-150 seconds
Time within 5 °C of peak	10-30 seconds max
Peak Temperature (JEDEC)	250 -5/+0 °C
Peak Temperature (ANAD)	260 -5/+0 °C
Average Ramp-down	6 °C/second max

**NOTES:**

1.  $T_L$  is the solder Eutectic temperature
2.  $T_P$  is the peak temperature

After soaking in the moisture chamber for the required time, the parts are subjected to the reflow conditions specified in J-STD-020B. Three successive profile passes are required according to JEDEC specifications. Table 5 is an example of three passes from one of the tests.

**Table 5. Breakdown of Lead-free Reflow Profiles**

Profile Feature	Run 1	Run 2	Run 3
Average Ramp-up (°C/s)	0.91	0.92	0.90
Dwell Time (sec)	109	104	110
Ramp-up 200 to 217 (°C/s)	1.89	1.94	1.98
Time above 217 °C (s)	68	68	69
Time within 5 °C of peak (s)	22	23	25
Peak Temperature (°C)	259.3	260.6	260.7
Average Ramp-down (°C/s)	1.35	1.45	1.47

Figure 1 Graphical Representation of ANADIGICS 260 °C Profiles

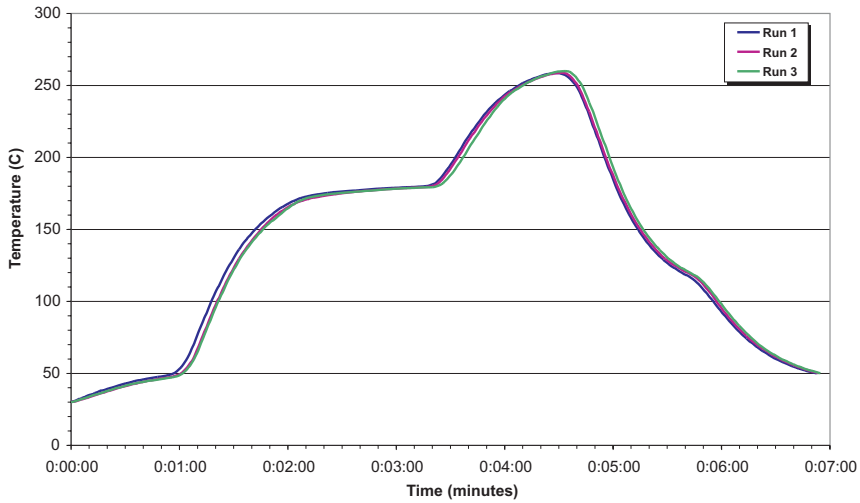
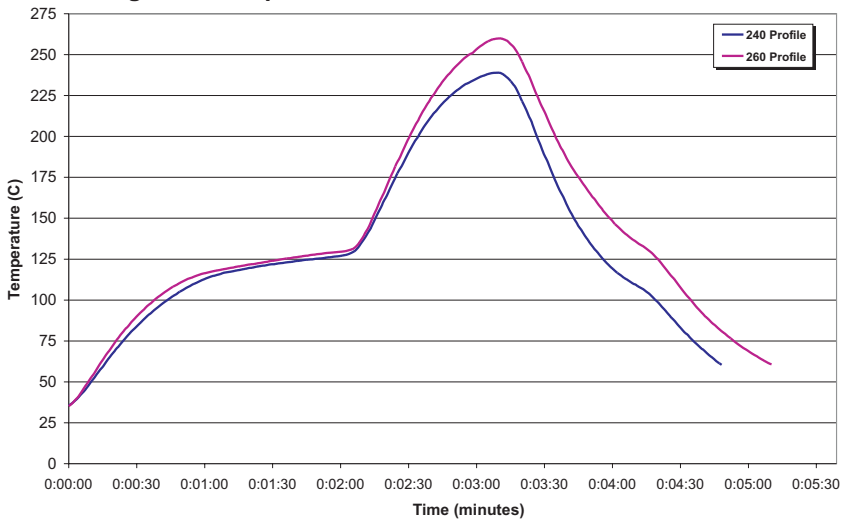


Figure 2: Comparison of 240 °C and 260 °C Reflow Profile



## QUALIFICATION TESTS

Apart from MSL, the qualification of packages, that are reliable in lead-free assembly conditions, also requires a number of additional tests. According to ANADIGICS' internal specification, such packages were successfully submitted to reliability/environmental stresses in accordance to JEDEC standards, as applicable. Qualification testing results are available upon request.

## LEAD-FREE ORGANIZATIONS

The following are some of the organizations that are actively pursuing lead-free activities.

- JEDEC            [www.jedec.org](http://www.jedec.org)
- IPC              [www.ipc.org](http://www.ipc.org); [www.lead-free.org](http://www.lead-free.org)
- NEMI            [www.nemi.org](http://www.nemi.org)
- NCMS           [lead-free.ncms.org](http://lead-free.ncms.org)
- JEIDA           [www.jeida.or.jp](http://www.jeida.or.jp)
- ITRI             [www.itri.co.uk](http://www.itri.co.uk)

## REFERENCES

[1] [http://www.kester.com/lead-free\\_alloys.htm](http://www.kester.com/lead-free_alloys.htm)

[2] [http://www.omnixsolderpaste.com/pdfs/OM\\_310.PD](http://www.omnixsolderpaste.com/pdfs/OM_310.PD)

[3] John H. Lau, *Electronic Manufacturing with lead-free, halogen-free & conductive-Adhesive Materials*. McGraw Hill Publishing. 2003.

[4] JEDEC Standard J-STD-020B. *Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices*. July 2002.

[5] Jennie Hwang, *Environment-Friendly Electronics: Lead-free Technology*. Electrochemical Publications Ltd. Isle of Man, 2001.



NOTES



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