IPC-7530A

Guidelines for Temperature Profiling for Mass Soldering Processes (Reflow and Wave)

Developed by the Thermal Profiling Guide Task Group (5-22h) of the Assembly & Joining Committee (5-20) of IPC

Supersedes:
IPC-7530 - May 2001

Users of this standard are encouraged to participate in the development of future revisions.

Contact:

IPC

Table of Contents

1 SCOPE 1
1.1 Purpose 1
1.2 Background 1
1.3 Terms and Definitions 1
1.3.1 Thermal Profile 1
1.3.2 Recipe 2
1.3.3 Pasty Range 2
1.3.4 Ramp Rate 3
1.3.5 Soak (Dwell) 3
1.3.6 Peak 3
1.3.7 Melting Point 3
1.3.8 Liquidus 3
1.3.9 Solidus 3
1.3.10 Eutectic 3
1.3.11 Time Above Liquidus (TAL) 3
1.3.12 True TAL 4
1.3.13 Delta T (Profile or Equipment) 4
1.3.14 Phase Diagram 4
1.3.15 Superheat 4
1.3.16 Cooldown 4
1.3.17 Preheat 4
1.3.18 Class 1 Radiant IR-Dominant Systems 4
1.3.19 Class 2 Convection/IR Systems 4
1.3.20 Class 3 Convection-Dominant Systems 4
1.3.21 Profile Zones 4
1.3.22 Reflow Program 4
1.3.23 Liquidus Time Delay (LTD) 4

2 APPLICABLE DOCUMENTS 4
2.1 IPC 4
2.2 Joint Industry Standards 5
2.3 JEDEC 5

3 CONVECTION REFLOW PROFILING 5
3.1 Thermal Profiles 5
3.1.1 Thermocouple Attachment 10
3.1.2 Preheat Zone 13
3.1.3 Soak Zone 13
3.1.4 Reflow Zone 13
3.1.5 Cooling Zone 13
3.1.6 Thermal Profile for Backward Compatibility .. 13
3.1.7 Unique Profile for Each PWBA 14
3.1.8 Flux 14
3.2 Material Issues 14
3.3 Reflow Soldering 14
3.3.1 True Time Above Liquidus (True TAL) 15
3.4 Equipment Settings 16
3.4.1 Reflow Oven Selection 16
3.4.2 IR vs. Convection 16
3.4.3 Heating Zone Selection 16
3.4.4 Clearance Height, Conveyor Belt Type/Width and Edge-Rail Support 17
3.4.5 Cover Gas 17
3.4.6 Profiling 17
3.4.7 Product Trackers 17

4 VAPOR-PHASE REFLOW PROFILING 17
4.1 Vapor-Phase Reflow 19

5 WAVE SOLDERING PROFILING 19
5.1 Machine Considerations 20
5.2 Conveyor Considerations 20
5.3 Preheat Considerations 21
5.4 Solder Pot Considerations 21
5.5 Profile Development Steps 21
5.6 Design for Mass Wave Soldering Considerations 22

6 SELECTIVE SOLDERING PROFILING 22
6.1 Solder Pot 22
6.1.1 Machine Considerations 23
6.1.2 Preheat Considerations 23
6.1.3 Solder Pot and Nozzle Considerations 23
6.1.4 Profile Development Steps 23
6.1.5 Design for Manufacturing (DfM) for Selective Soldering 24
6.1.6 Thermocouple Attachment for Wave and Selective Soldering 24
6.2 Alternatives to Selective Soldering 25
6.2.1 Paste-in-Hole Soldering 25
6.2.2 Laser Soldering 25

7 TEMPERATURE PROFILING TOOLS 26
7.1 Product Thermal Profilers 26
7.1.1 Thermal Profiler Usage Recommendations 27
7.1.2 Thermal Profiler Specifications 27
7.1.3 Thermal Barrier 27
7.1.4 Statistical Process Control (SPC) 27
7.2 Machine Profilers 27
7.2.1 Purpose 27
7.2.2 Measurement Parameters 28

7.2.3 Machine Verification 28
7.2.4 Continuous Real-Time Convection Oven Profilers 29
7.3 Thermocouple Types and Selection 29
7.3.1 Thermocouple Type 29
7.3.2 Thermocouple Wire Gauge 29
7.3.3 Insulation 29
7.3.4 Wire Length 30
7.4 Thermocouple Junction 30
7.5 Calibration and Test 30
7.6 Thermocouple Attachment 30
7.6.1 High-Temperature Solder 30
7.6.2 Adhesives 30
7.6.3 Aluminum/Copper Tape 30
7.6.4 Embedded Thermocouple 31
7.6.5 Thermally Conductive Adhesive 31
7.6.6 Mechanical Attachment 31

8 TROUBLESHOOTING 31
8.1 Solder Reflow Defects 31
8.1.1 Voids 31
8.1.2 Head on Pillow (HoP) 32
8.1.3 Bridging 32
8.1.4 Solder Balls 33
8.1.5 Cold Solder/Incomplete Solder 33
8.1.6 Solder Beading (Squeeze Balls) 34
8.1.7 Grainy Solder 34
8.1.8 Tombstoning 34
8.1.9 Solder Wicking 35
8.1.10 Blow Holes/Pin Holes 35
8.1.11 Additional Root Causes of Defects 36
8.2 Solder Joint Accept/Reject Criteria 36
8.3 Control of Wave Soldering Defects 36

Figures

Figure 1-1 Phase Diagram for SnPb Solder 2
Figure 1-2 Pasty Range of SAC Solder 3
Figure 3-1 Thermal Profile Schematic 7
Figure 3-2 SnPb Profile With Multiple Thermocouples 8
Figure 3-3 SAC 305 Profile for a Single-Sided PWBA (Belt Speed for Single-Sided PWBA 24 Inches per Minute) 8
Figure 3-4 Example of a SAC 305 Profile for a Double-Sided Board (Speed 21 Inches per Minute) 9
Figure 3-5 Example of Ramp to Peak (RP) Profile (Left) Ramp to Soak to Peak (RSP) Profile (Right) ... 9
Figure 3-6 Locations of Thermocouples on a Board with Large and Small Components 10
Figure 3-7 Recommended Locations of Thermocouples on a BGA 10
Figure 3-8 First Example of Thermocouple on Inner and Outer Rows – Drilling From Bottom of BGA and Other Components 11
Figure 3-9 Second Example of Thermocouple on Inner and Outer Rows – Drilling From Bottom of BGA and Other Components 12
Figure 3-10 Curing Profile 15
Figure 3-11 Role of Liquidus Time Delay (LTD) in Head on Pillow 15
Figure 3-12 TAL vs. True TAL 15
Figure 4-1 VPS Profile Showing Wicking and Opens 18
Figure 4-2 Profile for VPS With Preheat Resembles Convection Profile (Time in Minutes) 18
Figure 5-1 Dual-Wave Solder Profile 20
Figure 5-2 Peak Topside Preheat Temperature 21
Figure 5-3 Mass Wave Soldering Thermal Profile Illustration for a Single-Wave Solder Pot 21
Figure 5-4 Mass Wave Soldering Thermal Profile Illustration for a Dual-Wave Solder Pot 21
Figure 6-1 Selective Soldering Thermal Profile Illustration for Selective Soldering 24
Figure 6-2 Thermocouple Attachment for Wave and Selective Soldering 24
Figure 7-1 Typical Thermal Profiler, Thermocouples, Thermal Barrier and Carrier 26
Figure 7-2 Thermocouple Attachment (Solder Method) 30
Figure 7-3 Thermocouple Attachment (Adhesive Method) 30
Figure 7-4 Thermocouple Attachment (Tape Method) 30
Figure 8-1 Reflow Defects – Voids 31
Figure 8-2 Reflow Defects – Head on Pillow 32
Figure 8-3 Reflow Defects – Bridging 32
Figure 8-4 Reflow Defects – Solder Balls 33
Figure 8-5 Reflow Defects – Cold Solder/ Incomplete Solder 33
Figure 8-6 Reflow Defects – Solder Beading 34
Figure 8-7 Reflow Defects – Grainy Solder 34
Figure 8-8 Reflow Defects – Tombstoning 34
Figure 8-9 Reflow Defects – Solder Wicking 35
Figure 8-10 Reflow Defects – Blow Holes/Pin Holes 35

Tables

Table 3-1 Profile Comparison Between SnPb, SAC 305 and Mixed Alloys 6
Table 3-2 Profile Comparison Between SAC Alloy, SnBi (Low-Temperature) Alloys and Resin-Containing SnBi Solder Pastes 7
Table 5-1 Mass Wave Soldering Parameter Summary 22
Table 6-1 Selective Soldering Parameter Summary 24
Table 8-1 Additional Root Causes of Defects in Solder Joints 36

Guidelines for Temperature Profiling for Mass Soldering Processes (Reflow and Wave)

1 SCOPE

This standard describes thermal profile guidelines and practical guidelines to meet requirements to produce acceptable solder joints in mass soldering processes, including but not limited to reflow and wave soldering.

Thermal profile is a unique temperature vs. time plot for each fully populated printed wiring board assembly (PWBA), using thermocouples attached with high-temperature solder or copper or aluminum tapes to selected representative components of the PWBA as it travels at a given belt speed (i.e., transport speed) through various temperature zones of an oven or soldering system.

1.1 Purpose The purpose of this standard is to provide useful and practical information for developing thermal profiles to produce acceptable SnPb and Pb-free electronics assemblies. This standard is for managers, design and process engineers and technicians who deal with mass soldering processes.

1.2 Background During mass soldering, it is important that all solder joints reach the minimum soldering temperature. Minimum soldering temperature is the minimum temperature necessary to ensure metallurgical bonding of the solder alloy and the base metals to be soldered. Metallurgical bonding requires that the surfaces to be soldered and the solder reach this minimum soldering temperature for a sufficient time to allow wetting of the solder surfaces and the formation of a layer(s) of intermetallic compound(s) of some of the base metal(s) with one or more constituents of the solder alloy.

As a practical matter, minimum soldering temperature is somewhat (~ 25 °C) above the liquidus temperature of the solder alloy. The solder joint on a given PWBA that is the last to reach minimum soldering temperature (typically on or underneath one of the components with the highest thermal mass) determines the temperature profile setting for a given PWBA and soldering process/machine. Developing a good profile is a balancing act for the process engineer, who also needs to make sure smaller and temperature-sensitive components do not overheat or become damaged.

Reflow soldering requires controlled rates of heating and subsequent cooling; however, too rapid a heating rate can damage PWBAs and components. High cooling rates can also damage components and result in temperature gradients of sufficient magnitude to warp PWBAs and larger components and also fracture solder joints. Because of this, appropriate temperature profiling is essential for ensuring high-quality solder joints.

Even though different products, based on their thermal mass, require different amounts of thermal input, all products must achieve the minimum temperature (temperature above liquidus) without exceeding the maximum temperature (without damage to any components) within a defined time period (thermal profile). This is the key reason for developing a unique profile for each product.

Thermal input is determined by temperature/gas flow settings in each zone, the number of zones and the belt speed, which stays the same in each zone. Establishing minimum temperature, maximum temperature and duration in a zone ensures formation of intermetallic bonding between the component leads and their corresponding footprint or land patterns on those pads. All components, even though their thermal masses are different, must meet the same minimum and maximum temperature requirements. This is the biggest challenge for developing a profile, so developing a thermal profile for a PWBA with very large thermal mass components (e.g., a large ball grid array (BGA)) and small thermal mass components (e.g., 0201 or smaller chip resistors and capacitors) is a balancing act. In addition, different heating and cooling rates will have various effects on a variety of defects, adding more complexity to the balancing act. For example, a slower heating rate will help reduce voids in a BGA, but it will increase the potential for head on pillow (HoP) in the same BGA.

1.3 Terms and Definitions Other than those terms listed below, the definitions of terms used in this standard are in accordance with IPC-T-50.

1.3.1 Thermal Profile A unique temperature vs. time plot for each fully populated PWBA, using thermocouples attached with high-temperature solder or copper or aluminum tapes to selected representative components of the PWB as it travels at a given belt speed through various temperature zones of an oven or soldering system. Each product requires unique oven settings and belt speed (recipe) to achieve the desired profile on the PWBA.