ON Semiconductor

Is Now

onsemi™

To learn more about onsemi™, please visit our website at
www.onsemi.com

---

onsemi and onsemi and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

FAIRCHILD™

Is Now Part of

ON Semiconductor®

To learn more about ON Semiconductor, please visit our website at
www.onsemi.com

ON Semiconductor and the ON Semiconductor logo are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

AN-9078

Surface Mount Guidelines for Motion SPM® 7 Series

Introduction

This application note provides assembly guidelines for the PQFN package of the Motion SPM® 7 series. This document focuses on the design of stencil, which plays a crucial role in producing reliable solder joints. The setting conditions comply with general recommendations. The reference design and related application notes are listed in the Related Resources section.

Package Description

Power Quad Flat No-lead (PQFN) is a surface-mount plastic package with lead pads located on the bottom surface of the package. Figure 1 shows the external appearance of package for the Motion SPM® 7 series.

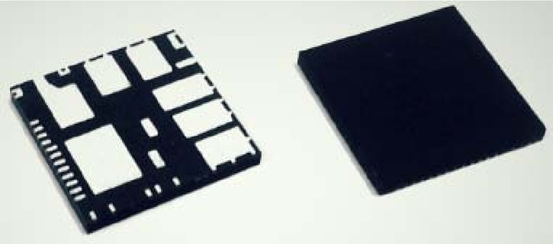


Figure 1. **External Appearance of PQFN Package for Motions SPM® 7 Series**

The SPM 7 series has six fast-recovery MOSFETs (FRFET®) and a three-phase HVIC. Figure 2 shows the structure of the Motion SPM® 7 series.

The bottom side of the copper lead frame is plated with tin (Sn) to ensure enhanced adhesion of solder.

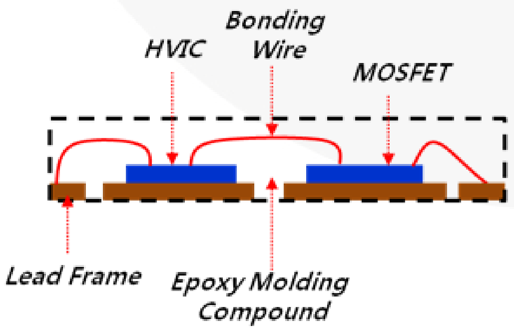


Figure 2. **Structure of Motion SPM® 7 Series**

Soldering Condition

Solder Paste

The SPM® 7 series performs well with lead-free solder. An evaluation test was performed with solder paste, HeeSung LFM-48W NH(M), which is lead-free and halogen-free. Table 1 shows information for this solder paste.

Table 1. **Information for Solder Paste**

Part Number	Powder Size [μm]	Composition [%]	Flux [%]
LFM-48W NH(M)	20-38	Sn / Ag / Cu 96.5 / 3.0 / 0.5	11.0

The SPM 7 series performs similarly well with solder paste Senju M705-GRN360-K2-V.

Solder paste is applied to lands using stencil to print. The printing process of solder paste is very important to prevent defects in PCB assembly.

Reflow Soldering Profile

Heating is necessary to melt solder paste on adjacent lands without overheating and damaging electrical components. Heating can be accomplished by passing the assembly through a reflow oven, under an infrared lamp, or by soldering individual joints with a hot-air pencil. Reflow soldering is the most common method of attaching surface-mount components to a circuit board by heating. Figure 3 shows the recommended reflow-profile provided by the maker of solder paste, HeeSung LFM-48W NH(M).

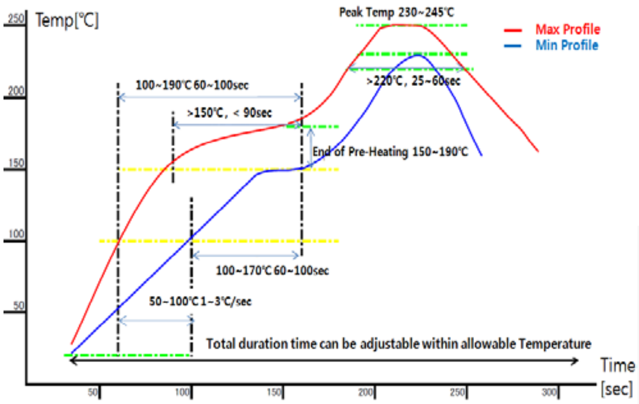


Figure 3. **Recommended Reflow Profile**

The reflow-profile is usually adjusted by the SMT machine to optimize the thermal profile for mass production. Figure 4 shows the measured reflow-profile implemented in the evaluation. The setting of the moving speed is ~0.79 m/min.

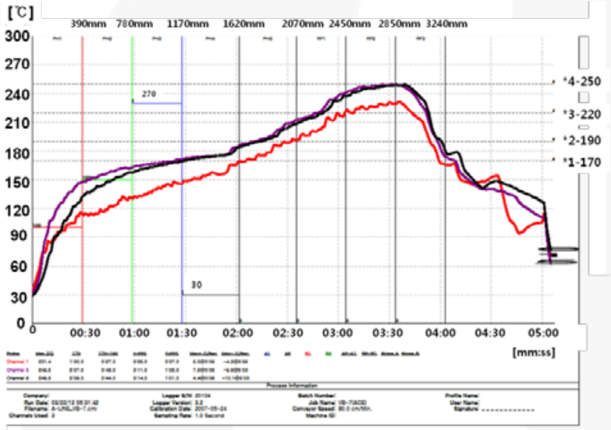


Figure 4. **Measured Reflow-Profile**

Figure 5 shows the measuring point for temperature. The red line is for an adjacent point and can be ignored.

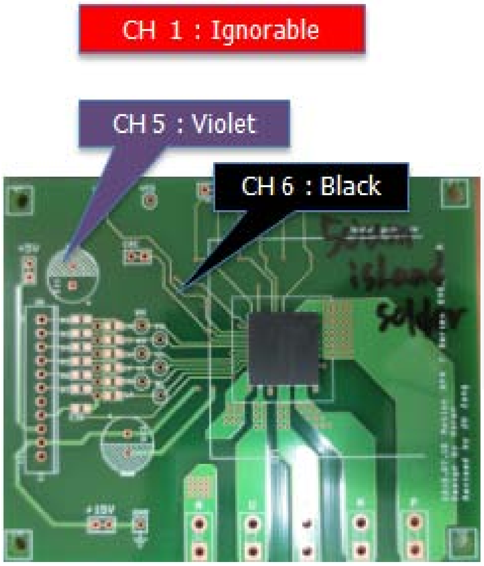


Figure 5. **Measuring Point for Temperature**

SMT Machine (Reflow Oven)

Table 2 shows information for the SMT machine used in the evaluation test and Figure 6 shows its picture.

Table 2. **SMT Machine Specifications**

Maker	Model Name	Heating Zone
TSM	AIS-K20-82C	8

Figure 6. **Picture of SMT Machine**

Recommended Land Pattern

Proper board design for land pattern is critical to ensure reliable solder joint with adjoining melted solder paste. Figure 7 shows the recommended land pattern specified in the datasheet of the SPM® 7 series. Isolated pattern 23a and 24a can be omitted because they are connected to pattern 23 and 24, respectively, by the lead frame. If soldered, pattern 23a and 24a may create solder bridging between the two pads. This bridging problem can be caused by large volume of solder paste.

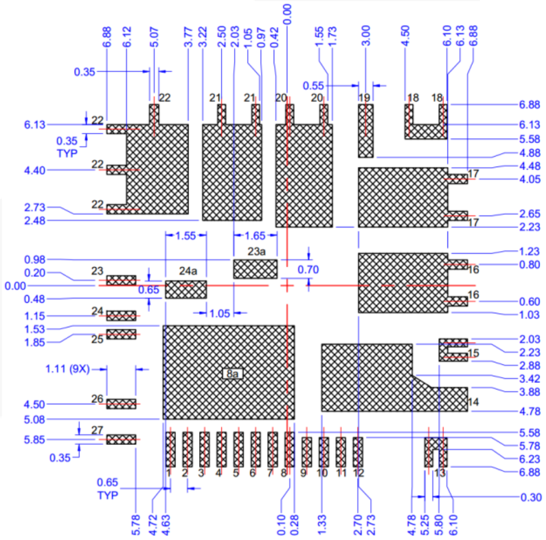


Figure 7. **Recommended Land Pattern**

Recommended Stencil Design

Figure 8 shows recommended stencil design of the SPM 7 series. To ensure reliable solder joints, 150 µm thickness is generally recommended. The thickness of stencil determines the amount of solder in combination with the opening width, which creates solder joints.

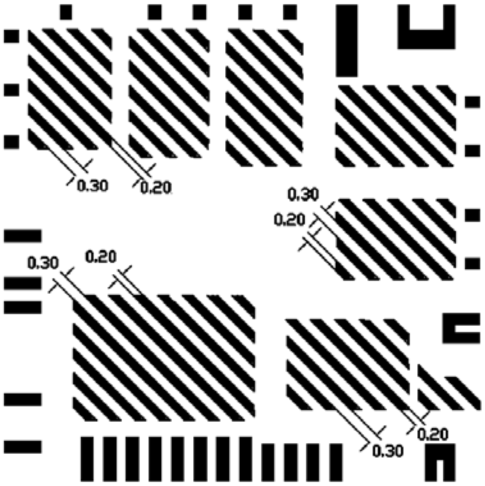


Figure 8. **Recommended Stencil Design**

Figure 9 shows overlapped image of stencil and land pattern. Based on the evaluation results, isolated pattern 23a and 24a are masked to prevent solder bridging phenomenon caused by large volume of solder paste.

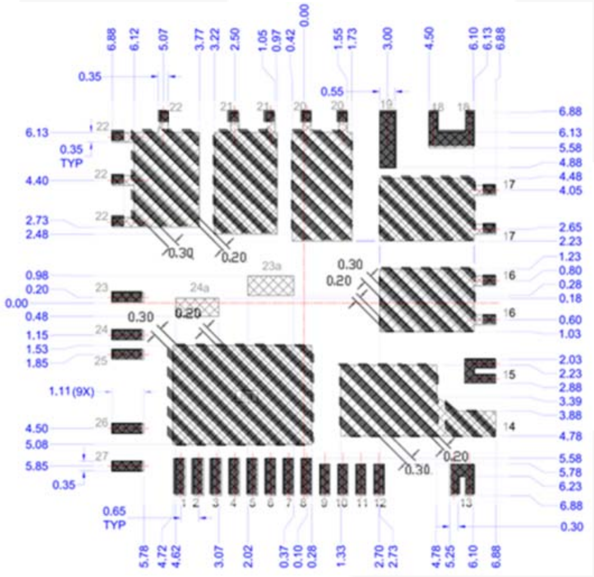


Figure 9. **Overlapped Stencil and Land Patterns**

Evaluation Test Results

Definition of Solder Void

A solder void means an empty space in solder joints and is one of the main causes of defects in solder joints. The red area shown in Figure 10 indicates solder voids.

Solder voids are largely caused by the amount of out-gassing flux trapped in the solder during reflow.

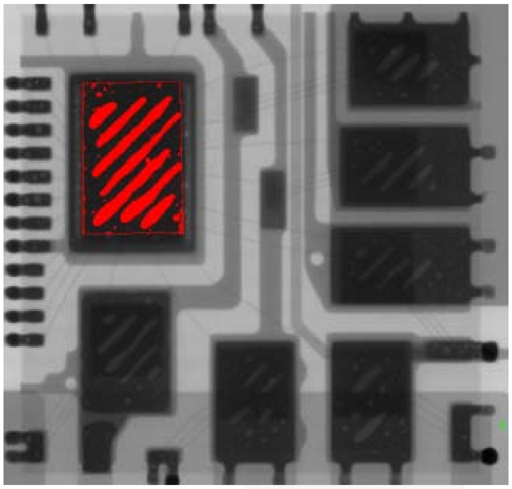


Figure 10. **Solder Void**

Pattern of Stencil

To determine the appropriate pattern of the stencil, several designs were evaluated, as shown in Table 3.

The void level is referenced to the solder joint of the HVIC part and calculated as follows:

Void level [%] = Sum of single void area / total area X 100

As shown in Table 3, the comb pattern shows relatively smaller void level without overflowed solder.

In the square pattern with via holes, solder overflowed around the island area. Overflowed solder is caused by a large amount of solder paste. It can be difficult to control the solder amount for the various requirements of parts on the same PCB and the solder amount may be insufficient for the SPM 7 series because of the via holes.

Table 3. **Type of Pattern**

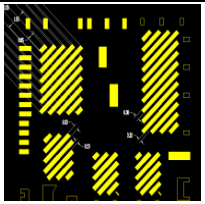
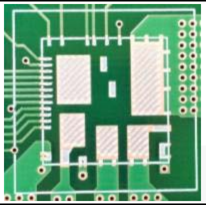
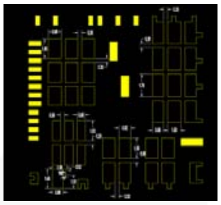
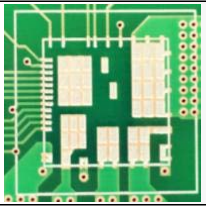
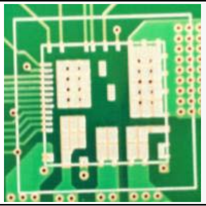
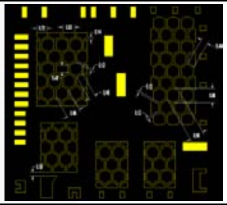
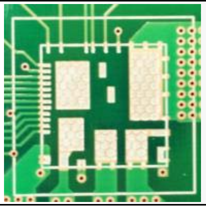
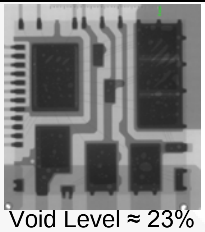
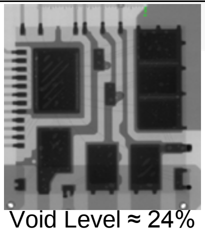
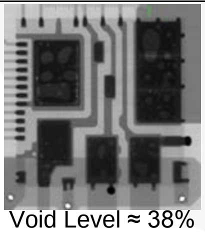
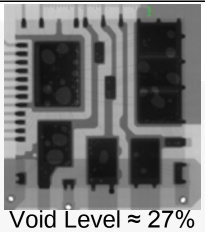
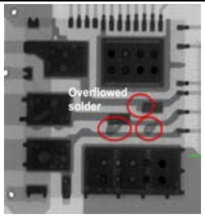
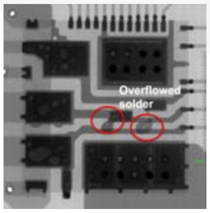
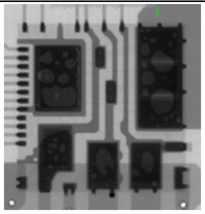
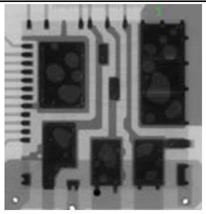
Pattern	Stencil	PCB
Comb		
Square without Via Holes		
Square with Via Holes		
Honeycomb		

Table 4. **Result for Different Patterns**

Pattern	X-Ray	
Comb	 Void Level ≈ 23%	 Void Level ≈ 24%
Square without Via Holes	 Void Level ≈ 38%	 Void Level ≈ 27%
Square with Via Holes	 Void Level ≈ 10%	 Void Level ≈ 18%
Honeycomb	 Void Level ≈ 42%	 Void Level ≈ 38%

Note:

1. Thickness of stencil is 100 µm.

Thickness and Opening Width of Stencil

To determine the appropriate pattern of the stencil, several thickness and opening width were evaluated as shown in Figure 11 and Table 5. With the results of the void level, 150 µm thickness and 200 µm opening width are preferred; as shown in Table 10 in comparison with Table 7, Table 6, and Table 5. Generally, 50 µm and 100 µm thickness are not recommended for PQFN package because solder amount may not be sufficient to ensure reliable solder joints.

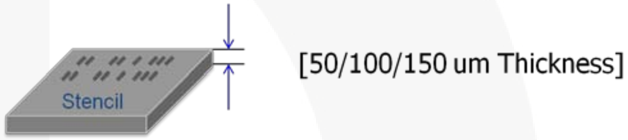


Figure 11. **Thickness of Stencil**

Table 5. **Opening width of Stencil**

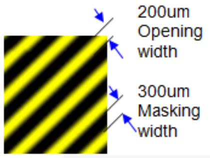
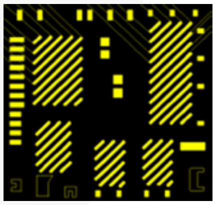
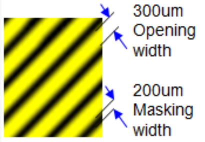
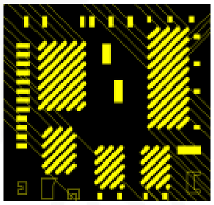
Opening Width	Stencil	
200 µm		
300 µm		

Table 6. **Result for 100 µm Thickness, 300 µm Opening Width**

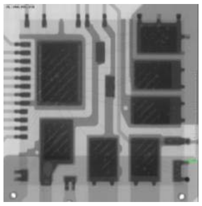
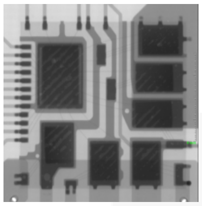
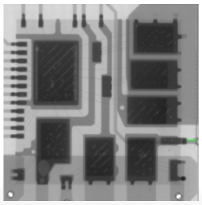
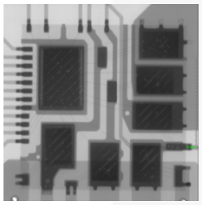
Condition	X-Ray	
50 µm Thickness 300 µm Opening Width	 Void Level ≈ 20%	 Void Level ≈ 22%
	 Void Level ≈ 21%	 Void Level ≈ 20%

Table 7. **Result for 100 µm Thickness, 300 µm Opening Width**

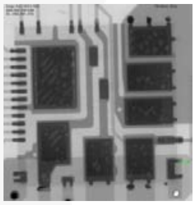
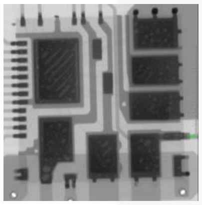
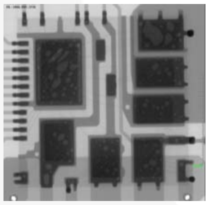
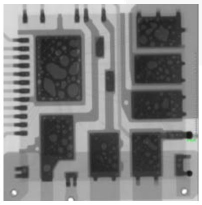
Condition	X-Ray	
100 µm Thickness 300 µm Opening Width	 Void Level ≈ 23%	 Void Level ≈ 25%
	 Void Level ≈ 30%	 Void Level ≈ 38%

Table 8. **Result for 100 µm Thickness, 200 µm Opening Width**

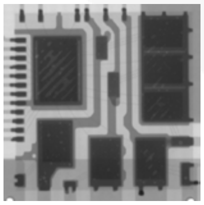
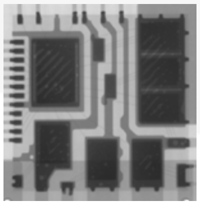
Condition	X-Ray	
100 µm Thickness, 200 µm Opening Width	 Void Level ≈ 19%	 Void Level ≈ 20%

Table 9. **Result for 150 µm Thickness, 300 µm Opening Width**

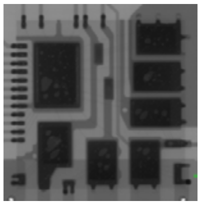
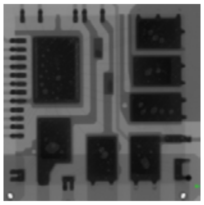
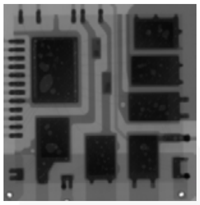
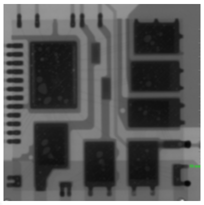
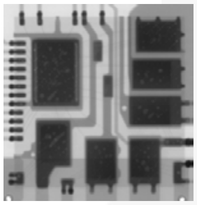
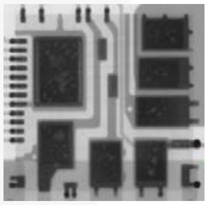
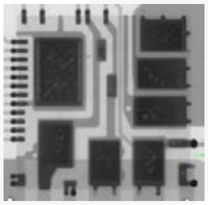
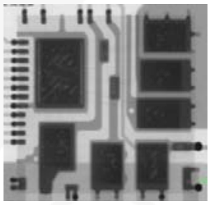
Condition	X-Ray	
150 µm Thickness 300 µm Opening Width	 Void Level ≈ 25%	 Void Level ≈ 24%
	 Void Level ≈ 25%	 Void Level ≈ 22%

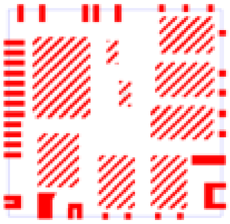
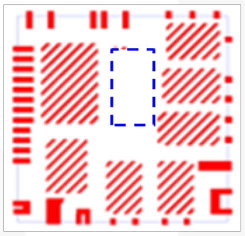
Table 10 shows the best performance, with proper 30 µm push depth, which represents reaming thickness of solder paste after pushing the device and prior to reflow.

Table 10. **Result for 150 µm Thickness, 200 µm Opening Width**

Condition	X-Ray (Best Case)	
150 µm Thickness 200 µm Opening Width	 Void Level ≈ 18%	 Void Level ≈ 20%
	 Void Level ≈ 18%	 Void Level ≈ 17%

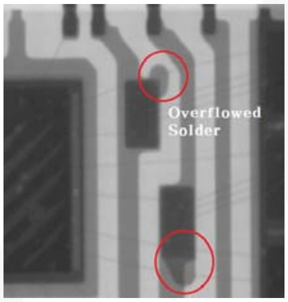
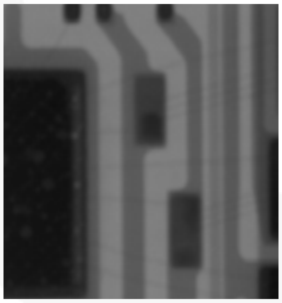
To determine effectiveness of masking for the island, partial masking was evaluated, as shown in Table 11.

Table 11. **Island of Stencil**

Type	Stencil
Island Soldering	
Island Masking	

As shown in Table 12, overflowed solder was found intermittently. Therefore, island masking is recommended.

Table 12. **Results for Island Masking**

Type	Stencil
Island Soldering	
Island Masking	

Reflow Direction

Figure 12 shows the direction of reflows performed in this evaluation.

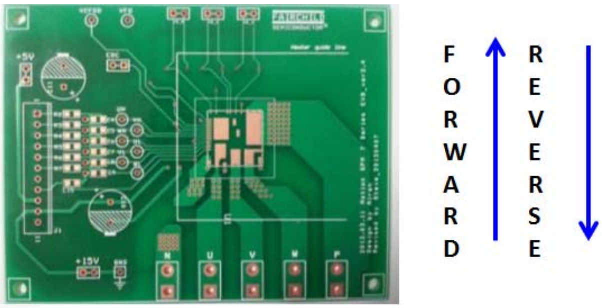


Figure 12. **Reflow Direction**

Figure 13 and Figure 14 show the similar void levels in each reflow direction. Judging from the X-ray comparison, there is no significant difference.

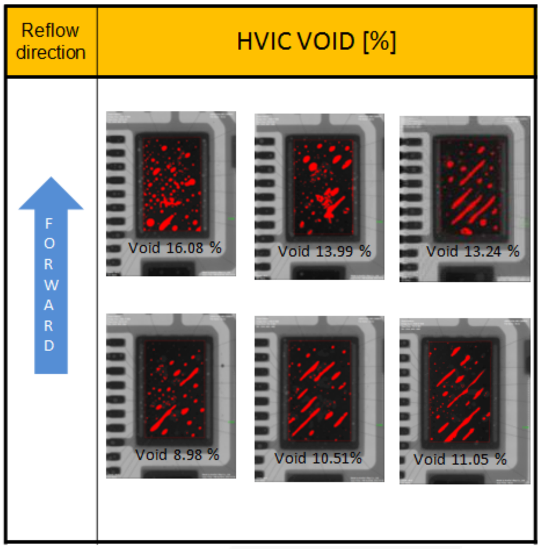


Figure 13. **HVIC Solder Void for Forward Direction**

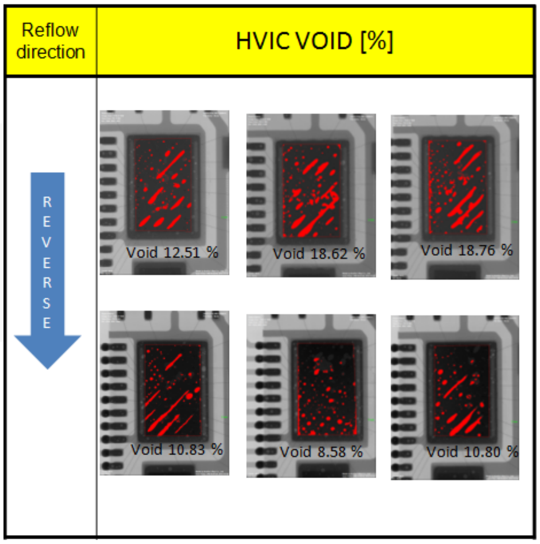


Figure 14. **HVIC Solder Void for Reverse Direction**

Summary and Conclusions

The evaluation was conducted to find optimized soldering conditions for the SPM7 series in PQFN packages.

Different stencil designs were studied to reduce solder voids that can lead to defects in solder joints. Judging from the evaluation results, the recommended design of the stencil is comb pattern, 200 µm width mask openings, 150 µm stencil thickness, and island masking.

Figure 15 shows the guidelines for selecting recommended conditions related to stencil design.

Large solder voids on solder joints can lead to failures and reliability problems. Figure 16 shows the difference between the worst and the best mounting on PCB (100 µm thickness of stencil and honeycomb pattern was the worst case). To ensure expected performance in the field, board level tests were performed after soldering with the recommended conditions. The conditions and results are listed in Table 13.

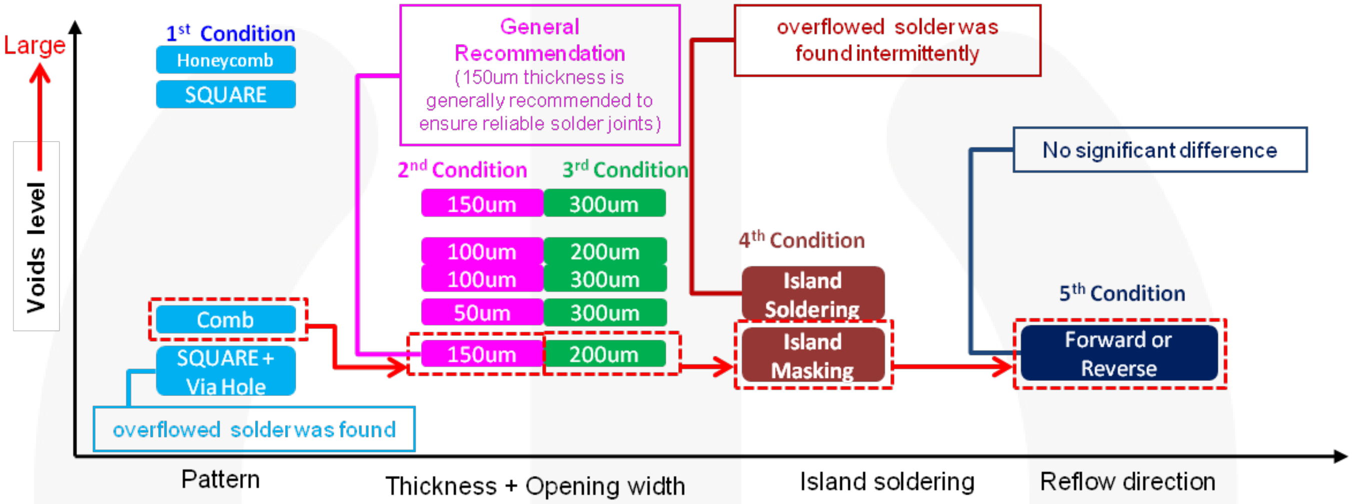


Figure 15. **Chart for Selection of Recommended Conditions**

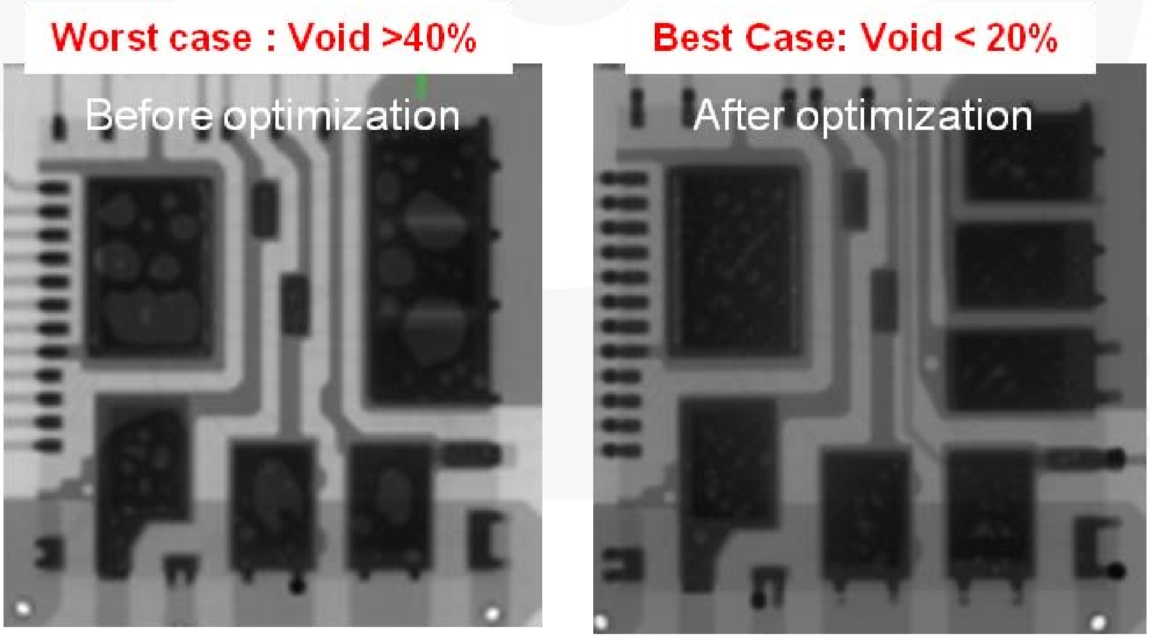


Figure 16. **X-Ray Comparison of Worst Case and Best Case**

Table 13. **Result of Board\-Level Test (Temperature Cycling)**

Test Conditions	PCB Type	Reference Standard	Result
▪ Temperature Cycling ▪ -40°C / +80°C temperature extremes ▪ 10 Minute Dwell Time ▪ ≤0 Minute Dwell Rate ▪ 400 Temperature Cycles	CEM3 (1.0t)	IPC-9017	Passed
	FR4 (1.0t)		
	FR4 (1.2t)		
	FR4 (1.6t)		

Note:

2. Soldering condition is based on the recommended condition in Figure 15.

Related Resources

AN-9077 — Surface Mount Guidelines for Motion SPM® 7 Series

RD-356 — Fairchild Motion SPM® 7 Series Reference Design

FSB70325 — Motion SPM® 7 Series

FSB70625 — Motion SPM® 7 Series

FSB70250 — Motion SPM® 7 Series

FSB70450 — Motion SPM® 7 Series

FSB70550 — Motion SPM® 7 Series

SPM® Module Design Guide

Motion Control Design Tool

ON Semiconductor and ON are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent−Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative

© Semiconductor Components Industries, LLC