The Solderability of the PowerPAK® SO-8 and PowerPAK 1212-8 When Using Different Solder Pastes and Profiles

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INTRODUCTION

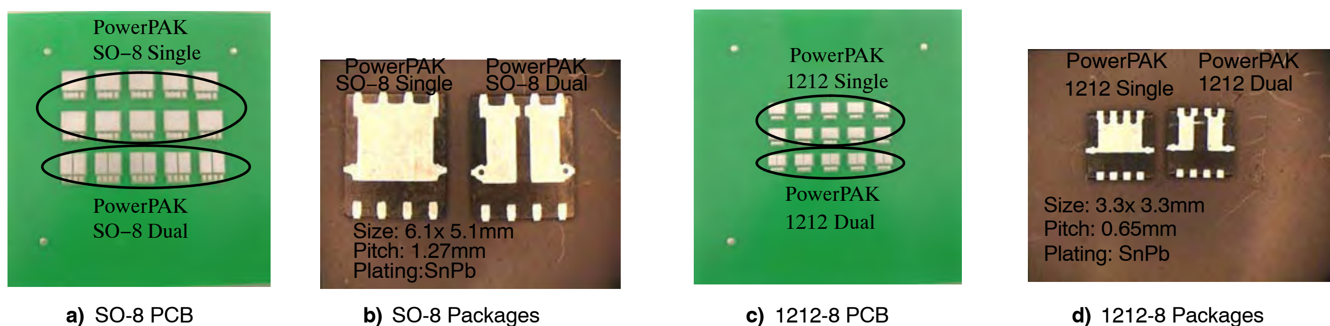
Next-generation PowerPAK packages from Vishay Siliconix feature very low thermal resistances, enabling higher power dissipation with the added benefit of reduced board space and increased available die area. With any new MOSFET packaging technology, concerns about manufacturability will arise, in particular with respect to yield figures, failure rates, solderability, short circuits caused by solder bridging, and drifting of the part during the mounting process. These concerns often relate to the solder profile, the pin layout, and the size of the package. However, in the case of the PowerPAK, the three major concerns are the shift in the position of the part during manufacturing, the possibility of solder bridging across the small pads and large pads, and the possibility of solder voids. To a certain extent, the first two issues can be resolved through visual inspection. The presence of voids, however, cannot be determined visually due to the nature of the package. As a result, the possible presence of solder voids is the greatest concern for manufacturers using the product.

The aim of this application note is to alleviate concerns about the use of these packages by illustrating through practical experimentation the solder joint quality and the voiding of several solder pastes when used with the PowerPAK SO-8 and PowerPAK 1212-8 packages.

PACKAGE TYPES

Four types of packages were chosen for investigation: the PowerPAK SO-8 single, the PowerPAK SO-8 dual, the PowerPAK 1212-8 single and the PowerPAK 1212-8 dual. The recommended landing patterns were used as described in Application Note AN826, *Recommended Minimum Pad Patterns With Outline Drawing Access for Vishay Siliconix MOSFETs*, (http://www.vishay.com/doc?72286).

Two separate boards, with an HASL surface finish, were built for the PowerPAK SO-8 and the PowerPAK 1212-8, with each board consisting of ten single devices and five dual devices are shown in Figure 1. Examples of the devices used for solderability study are also shown in Figure 1.



a) SO-8 PCB **b)** SO-8 Packages **c)** 1212-8 PCB **d)** 1212-8 Packages

FIGURE 1. PowerPAK PCBs and Packages Used in the Investigations

a) Dek Horizon Printer **b)** Siemens F5 SMT Machine **c)** Heller 1800EXL Oven **d)** Optek X-Ray Inspection System

FIGURE 2. Equipment Used for Solder Tests

PLACEMENT, SOLDERING, HEATING AND INSPECTION EQUIPMENT

The pick-and-place machine used was a Siemens F5 (Figure 2), configured with a six-nozzle collect-and-place head with a DCA vision module. The placement pressure was 2N (204 grams) with placement accuracy of 45 microns, and the components were picked from tape-and-reel. The stencil printing was achieved with a Dek Horizon printer (Figure 3) at 4-mil thickness, laser-cut 29 in. by 29 in. The print pressure was 10 kg front and rear, and the print speed was 20 mm/s front and rear. The oven reflow was a Heller 1800EXL oven with nine heating and two cooling zones. The solder and void inspections were achieved using an Optek X-ray machine.

SOLDER PASTES

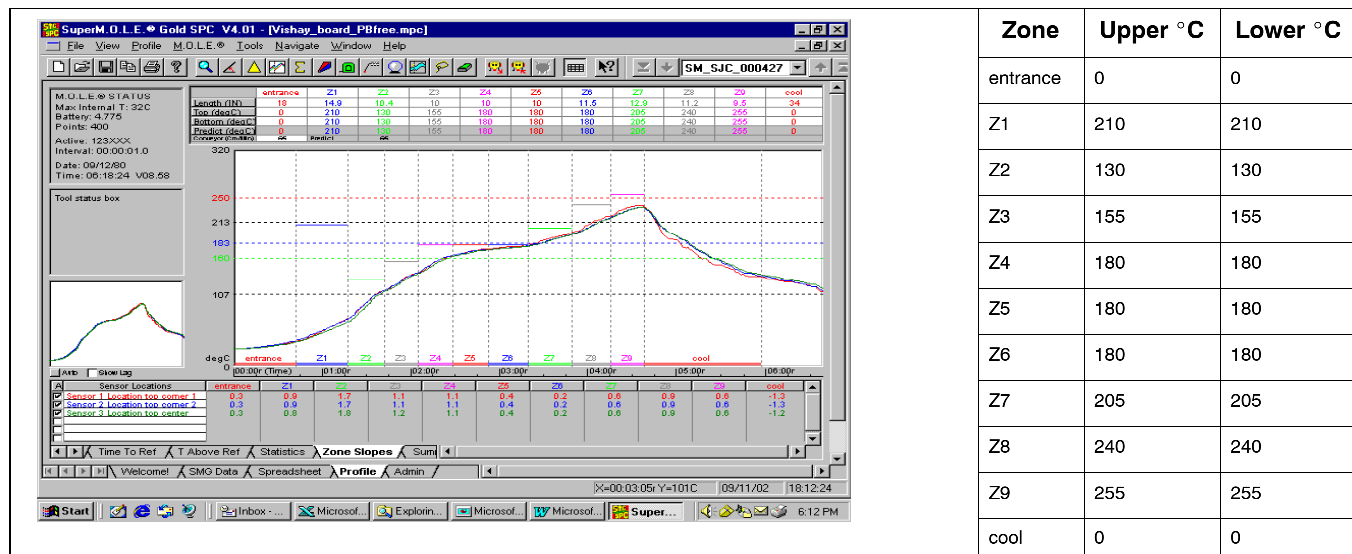
Several solder paste types, including lead-free, water-soluble, and no-clean, were used. Details are provided in Table 1.

TABLE 1
Details Of Solder Pastes Used In The Investigations

Cat.#	Type	Manufacturer	Data In Appendix
UP78	No Clean	Ultraprint	1
Omnix 5000	No Clean	Alpha-Fry Corp.	2
NC-SMQ92J	No Clean	Indium Corp.	3
TLF-206-19	Lead Free	Tamura, Japan	4
NC73	No Clean	Loctite (Multicore)	5
RP15	No Clean	Loctite (Multicore)	6
WS22	Water Soluble	Loctite (Multicore)	7
CR39	Lead Free	Loctite (Multicore)	8
CR36	No Clean	Loctite (Multicore)	9
MP200	No Clean	Loctite (Multicore)	10

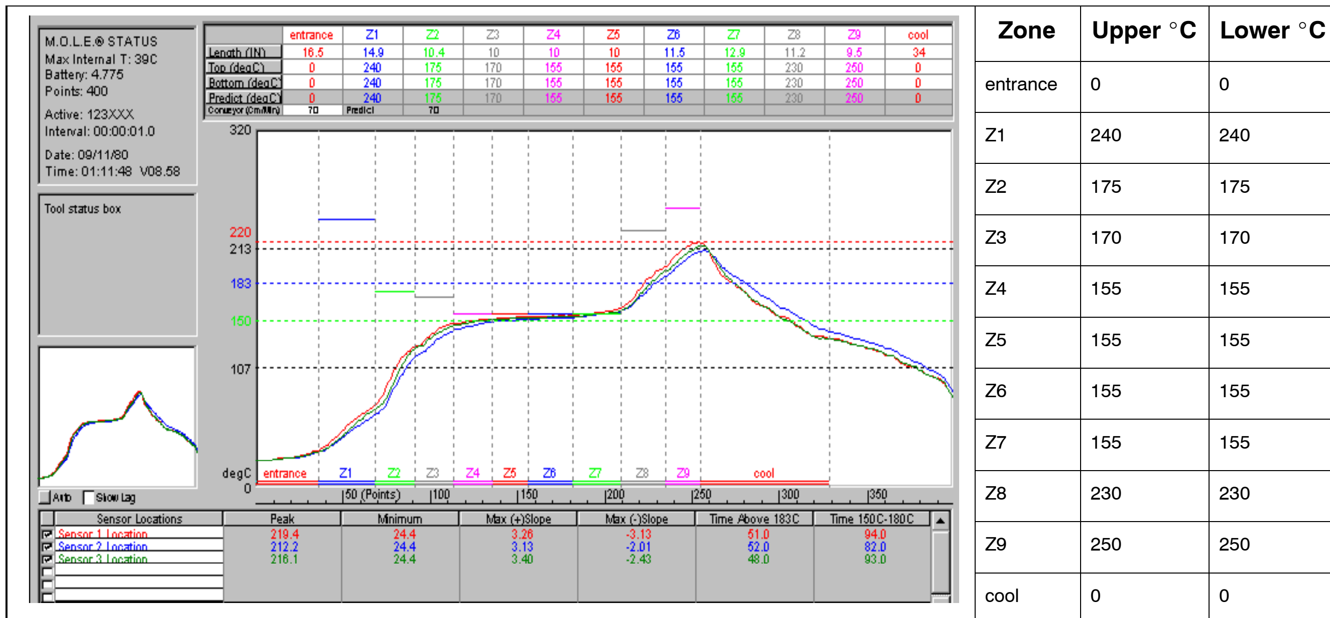
SOLDER PROFILE

To account for these different solders, three different oven profiles were required. These can be found in Figures 3, 4, and 5.



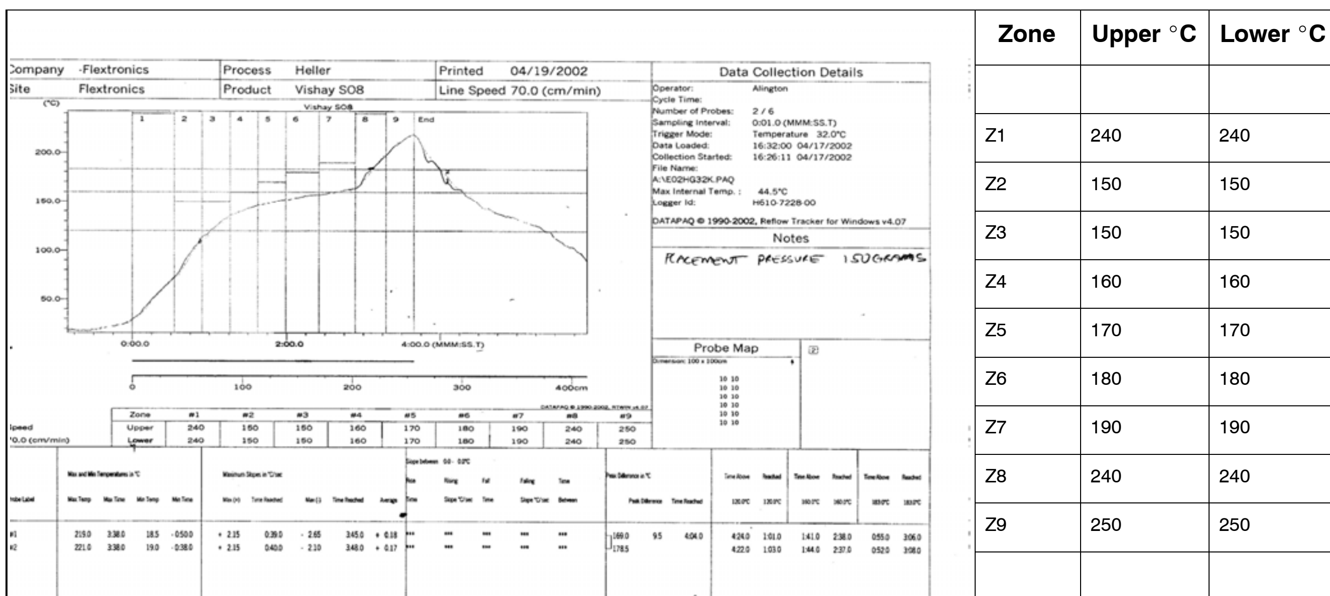
Zone	Upper °C	Lower °C
entrance	0	0
Z1	210	210
Z2	130	130
Z3	155	155
Z4	180	180
Z5	180	180
Z6	180	180
Z7	205	205
Z8	240	240
Z9	255	255
cool	0	0

FIGURE 3. Oven Profile for CR39 and TLF-206-19 Solders



Zone	Upper °C	Lower °C
entrance	0	0
Z1	240	240
Z2	175	175
Z3	170	170
Z4	155	155
Z5	155	155
Z6	155	155
Z7	155	155
Z8	230	230
Z9	250	250
cool	0	0

FIGURE 4. Oven Profile For RP15 Solder



Zone	Upper °C	Lower °C
Z1	240	240
Z2	150	150
Z3	150	150
Z4	160	160
Z5	170	170
Z6	180	180
Z7	190	190
Z8	240	240
Z9	250	250

FIGURE 5. Oven profile for UP78, Omnix 5000, NC-SMQ92J, NC73, and WS22

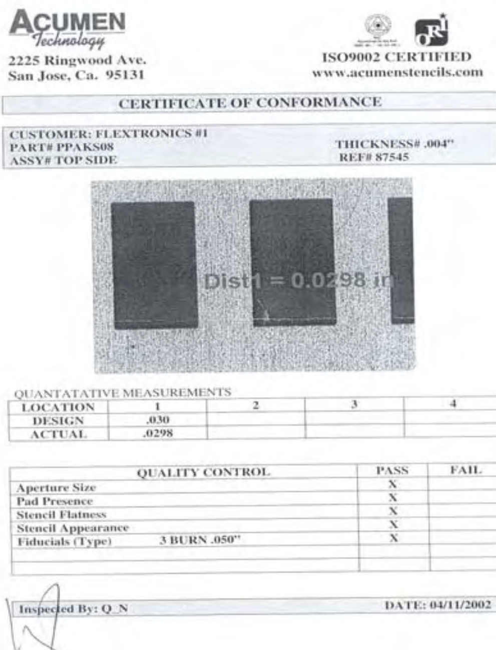
STENCILS

Examples of the design stencils used in the investigation of the PowerPAK SO-8 and 1212-8 are shown in Figure 6 and Figure 7, respectively.

INVESTIGATIONS INTO PACKAGE SHIFTING AND POSSIBLE SOLDER BRIDGING

The basic layout of the PowerPAK packages consists of small leads with a fine pitch located on one side of the device and a large lead on the other side of the package. This means that the lead frame is asymmetrical, resulting in two dissimilar metal masses, which could cause the device to move during mounting and soldering due to the different tensions exerted by the different metal masses. This is because the surface tension resulting from a large quantity of molten solder under the large leads and pads can produce a lateral shift of the part, possibly causing an electrical short circuit.

This lateral shift and the packages' lead frame design could cause solder bridging between the small and the large leads of the device, and the solder pads on the PC board, and also between the solder pads themselves.



ACUMEN Technology
2225 Ringwood Ave.
San Jose, Ca. 95131

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CERTIFICATE OF CONFORMANCE

CUSTOMER: FLEXTRONICS #1
PART# PPAKS08
ASSY# TOP SIDE
THICKNESS# .004"
REF# 87545

Dist1 = 0.0298 in

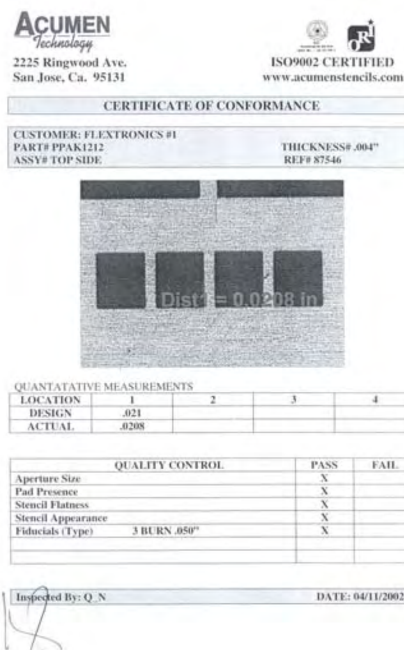
QUANTATATIVE MEASUREMENTS

LOCATION	1	2	3	4
DESIGN	.030			
ACTUAL	.0298			

QUALITY CONTROL		PASS	FAIL
Aperture Size		X	
Pad Presence		X	
Stencil Flatness		X	
Stencil Appearance		X	
Fiducials (Type)	3 BURN .050"	X	

Inspected By: Q_N
DATE: 04/11/2002

FIGURE 6. Stencil for PowerPAK SO-8



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CERTIFICATE OF CONFORMANCE

CUSTOMER: FLEXTRONICS #1
PART# PPAK1212
ASSY# TOP SIDE
THICKNESS# .004"
REF# 87546

Dist1 = 0.0208 in

QUANTATATIVE MEASUREMENTS

LOCATION	1	2	3	4
DESIGN	.021			
ACTUAL	.0208			

QUALITY CONTROL		PASS	FAIL
Aperture Size		X	
Pad Presence		X	
Stencil Flatness		X	
Stencil Appearance		X	
Fiducials (Type)	3 BURN .050"	X	

Inspected By: Q_N
DATE: 04/11/2002

FIGURE 7. Stencil for PowerPAK 1212-8

Therefore, the PowerPAK devices were examined for solder bridging in three areas: between two consecutive leads, lead-to-pad, and pad-to-pad. The manufacture was achieved using the recommended pad patterns, described earlier, with a stencil controlling the thickness and its openings. The operating pressure for the squeegee and pick-and-place machine was selected to ensure that an adequate amount of solder paste was spread under the part.

PowerPAK SO-8

Figure 8 shows first the shifting of the part to the left during placement (b and c), and then the self-alignment of the part after reflow (d and e). The X-ray (c) shows the shift of the lead frame with respect to the pads and solder paste. The X-ray of the part after reflow (e) shows that the part has self-aligned to the pads and that there are no short circuits due to solder bridging. It also shows the solder spreading is limited to the pad size. This is confirmed by the Metcal APR 5000 visual inspection shown in Figure 8 (f).

PowerPAK 1212-8

Figure 9 shows the photographs and X-rays of the 1212-8 package during placement and reflow. Figure 9 (b and c) show that the part has shifted during placement, and the X-ray shows potential solder bridging concerns. However, during the reflow process, the part realigns itself (d and e) to the pads, and as such the solder spreading is again limited to the pads. This is confirmed by the optical visual inspection, where the gap between the two drain pads and pins 2 and 3 can be seen.

This investigation has shown that the PowerPAK SO-8 and PowerPAK 1212-8 packages are suitable for SMD assembly using industry-standard reflow procedures and processes. The results show that there are no solder bridges on the fine-pitch gaps between consecutive leads, or even from lead-to-pad or pad-to-pad. The results also show no electrical shorts as the part self-aligns on the pad pattern. The way to achieve this result is to use the recommended pad patterns and solder mask.

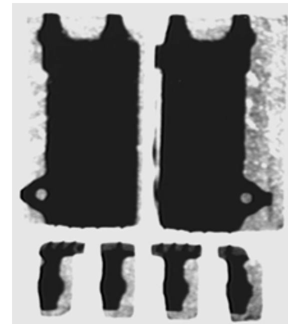
SOLDER VOIDS

One of the issues with the PowerPAK package is the lack of visibility of the solder joint between the printed circuit board and the leads of the package, and also the lack of visibility of any possible solder voids in larger pin-pad solder joints. The reason for these voids could be due to the large lead and pads, which have a high metal mass and use a large amount of molten solder. The latter can entrap hot air and gases from the solder paste, resulting in solder voids. Therefore, to ensure that the PowerPAK device performs well in terms of solderability, the investigation included the use of several solder pastes in mounting the PowerPAK devices. The results are provided below.

A variety of solder pastes were used to determine solder paste suitability. These pastes included no-clean, water-soluble, and lead-free pastes from a number of different manufacturers, including Ultraprint, Alpha, Indium, Tamura and Loctite. Through the joint expertise of a solder manufacturer (Loctite) and a contract manufacturer (Flextronics), the reflow profile was modified to minimize voids.

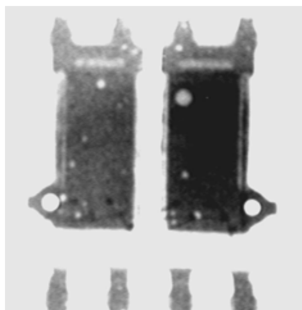
a) Solder Paste Application

b) Part Placement



c) X-Ray of Part Placement

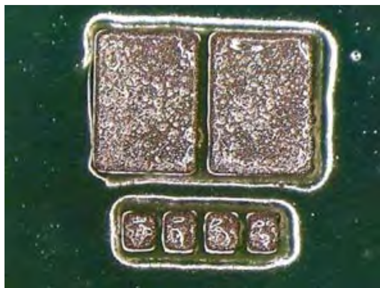
d) Part Placement After Reflow



e) X-Ray After Reflow

f) Optical Visual Inspection

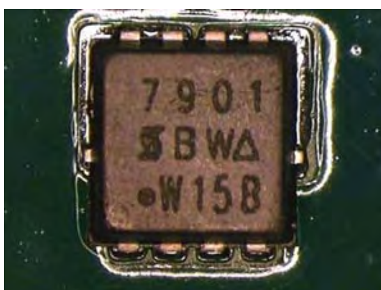
FIGURE 8. Example Of The Lateral Shift and Then Self-Centering and Realignment Of The PowerPAK SO-8



a) Solder Paste Application

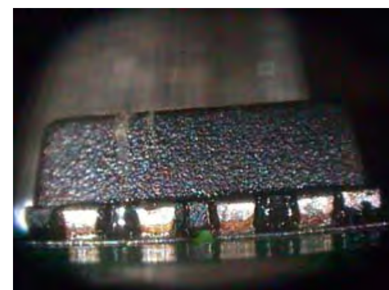
b) Part Placement

c) X-Ray of Part Placement



d) Part Placement After Reflow

e) X-Ray After Reflow



f) Optical Visual Inspection

FIGURE 9. Example Of The Lateral Shift and Then Self-Centering and Realignment Of The 1212-8 PowerPAK

UP-78 SOLDER PASTE

Figures 10 shows the solder voids using UP-78 solder paste. The worst-Case parts showed voids of greater than 30%. An improved solder profile, Figure 11, showed improvements, but the voiding for this solder paste is still classified as between 20% and 50%.

a) Best-Case (<20%) **b)** Worst-Case (>30%) **c)** Best-Case (<20%) **d)** Worst-Case (>30%)

Single PowerPAK SO-8 **Dual PowerPAK SO-8**

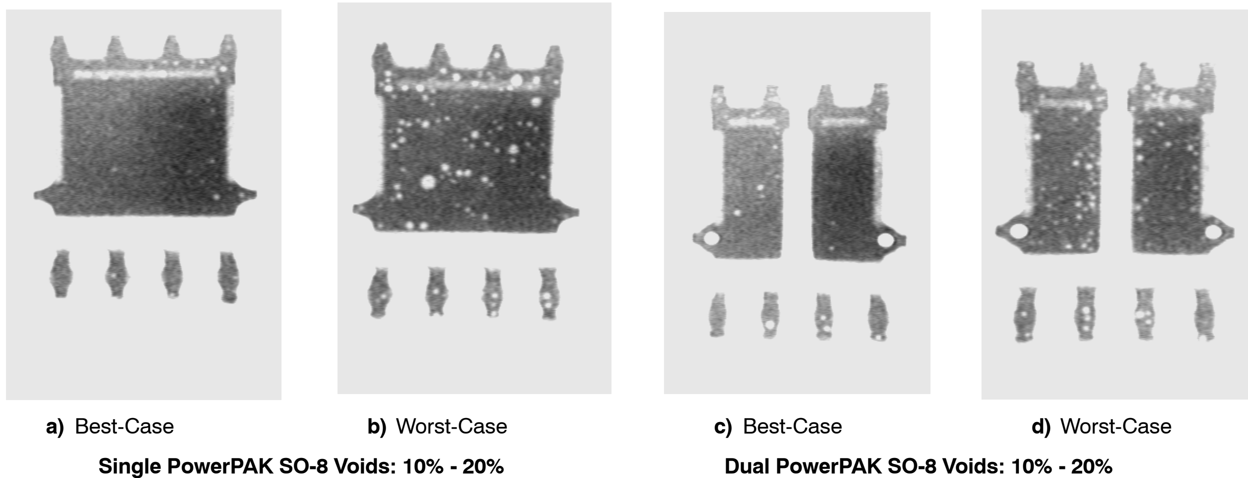
FIGURE 10. Solder Voids For UP-78 Solder Paste Using Initial Oven Profile

a) Voids: <20% Single PowerPAK SO-8 **b)** Voids: <20% Dual PowerPAK SO-8 **c)** Voids: <20% Single PowerPAK 1212 **d)** Voids: <20% Dual PowerPAK 1212

FIGURE 11. Solder Voids For UP-78 Solder Paste Using Improved Oven Profile

OMNIX 5000 SOLDER PASTE

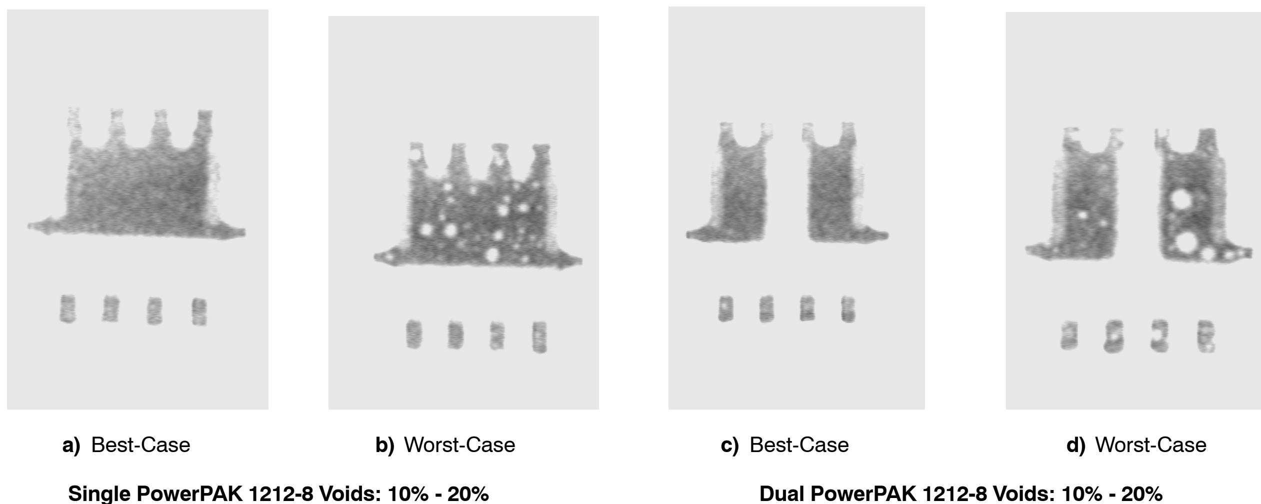
The Omnix solder paste performed very well. The solder voids are shown in Figures 12 and 13 for the PowerPAK SO-8 and 1212-8 respectively. The maximum voids in this case were classified as less than 20%.



a) Best-Case **b)** Worst-Case **c)** Best-Case **d)** Worst-Case

Single PowerPAK SO-8 Voids: 10% - 20% **Dual PowerPAK SO-8 Voids: 10% - 20%**

FIGURE 12. Solder Voids For Omnix 5000 Solder Paste



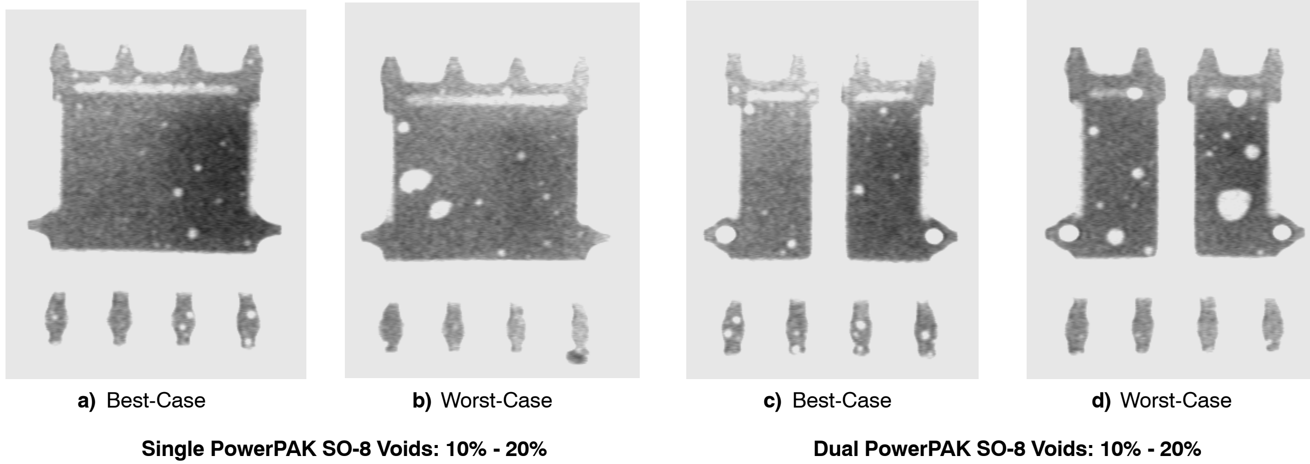
a) Best-Case **b)** Worst-Case **c)** Best-Case **d)** Worst-Case

Single PowerPAK 1212-8 Voids: 10% - 20% **Dual PowerPAK 1212-8 Voids: 10% - 20%**

FIGURE 13. Solder Voids For Omnix 500 Solder Paste

INDIUM SOLDER PASTE

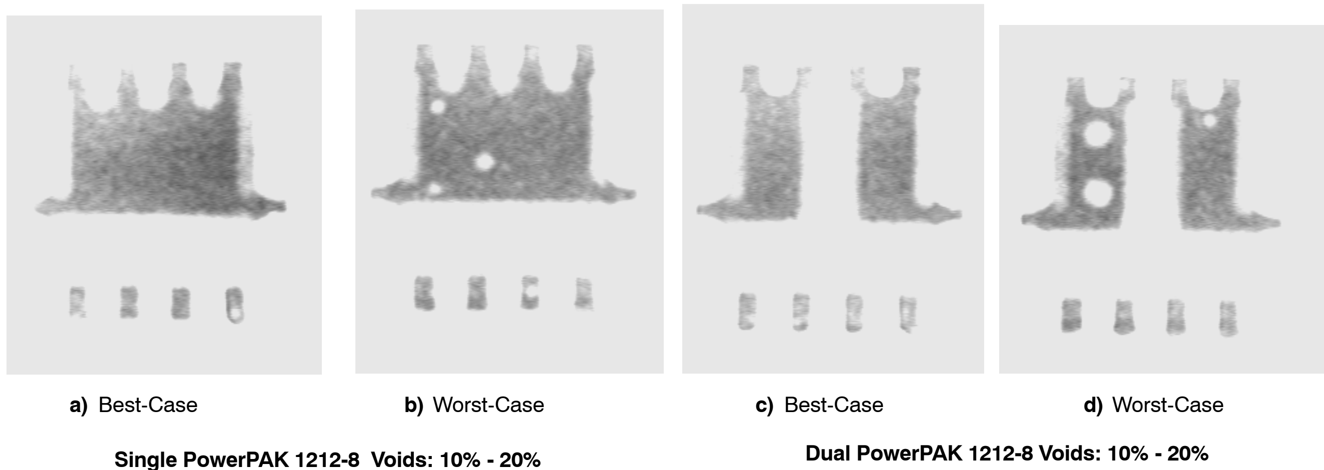
The Indium solder paste was also a success, with all the boards having voids of less than 20%, as shown in Figures 14 and 15.



a) Best-Case **b)** Worst-Case **c)** Best-Case **d)** Worst-Case

Single PowerPAK SO-8 Voids: 10% - 20% **Dual PowerPAK SO-8 Voids: 10% - 20%**

FIGURE 14. Solder Voids For Indium Solder Paste



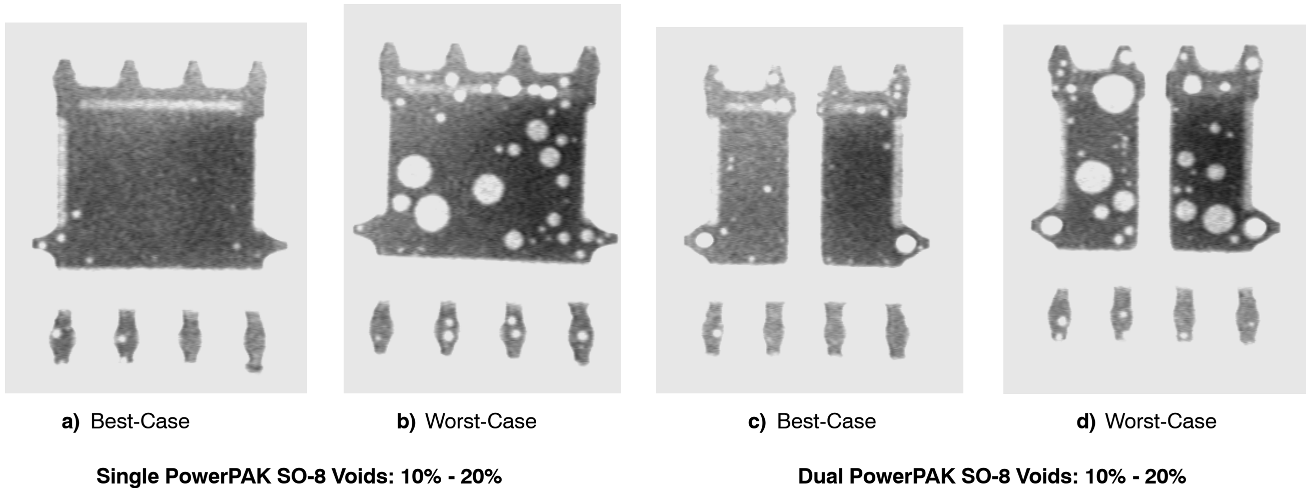
a) Best-Case **b)** Worst-Case **c)** Best-Case **d)** Worst-Case

Single PowerPAK 1212-8 Voids: 10% - 20% **Dual PowerPAK 1212-8 Voids: 10% - 20%**

FIGURE 15. Solder Voids For Indium Solder Paste

TAMURA SOLDER PASTE

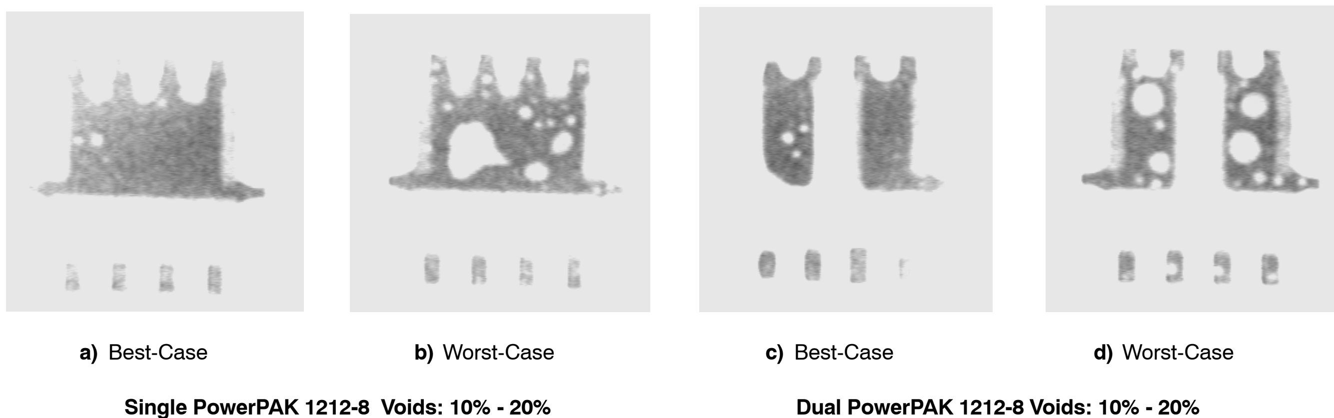
Tamura solder paste did not perform as well as some of the other solder pastes under the reflow conditions specified. As such, the Tamura solder paste was classified as having 20% to 50% voiding, as shown in Figures 16 and 17.



a) Best-Case **b)** Worst-Case **c)** Best-Case **d)** Worst-Case

Single PowerPAK SO-8 Voids: 10% - 20% **Dual PowerPAK SO-8 Voids: 10% - 20%**

FIGURE 16. Solder Voids For Tamura Solder Paste



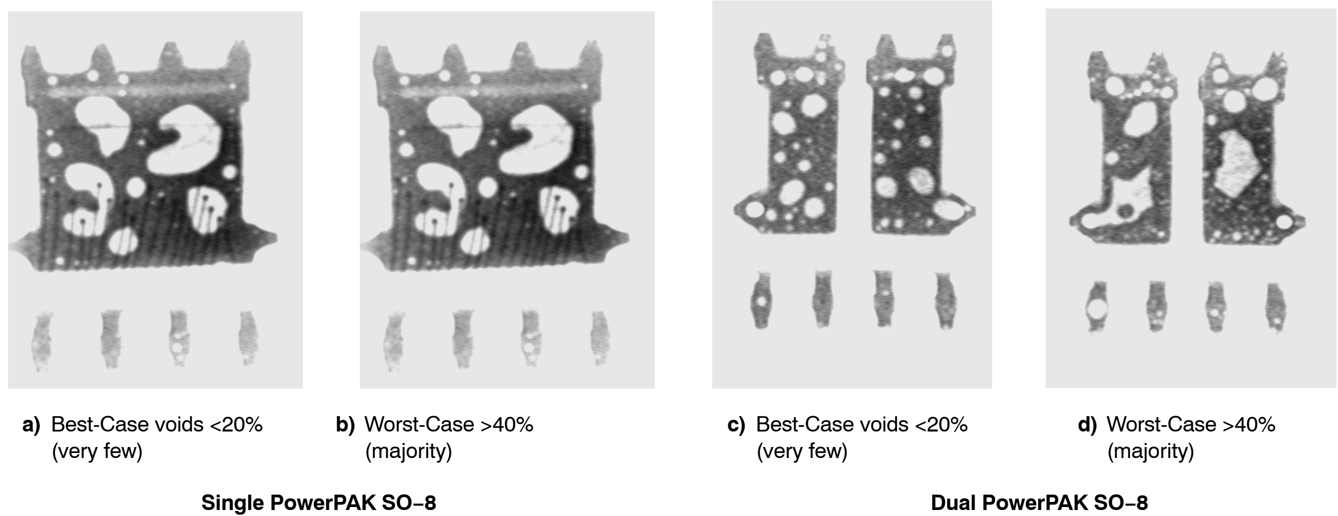
a) Best-Case **b)** Worst-Case **c)** Best-Case **d)** Worst-Case

Single PowerPAK 1212-8 Voids: 10% - 20% **Dual PowerPAK 1212-8 Voids: 10% - 20%**

FIGURE 17. Solder Voids For Tamura Solder Paste

NC-73 SOLDER PASTE

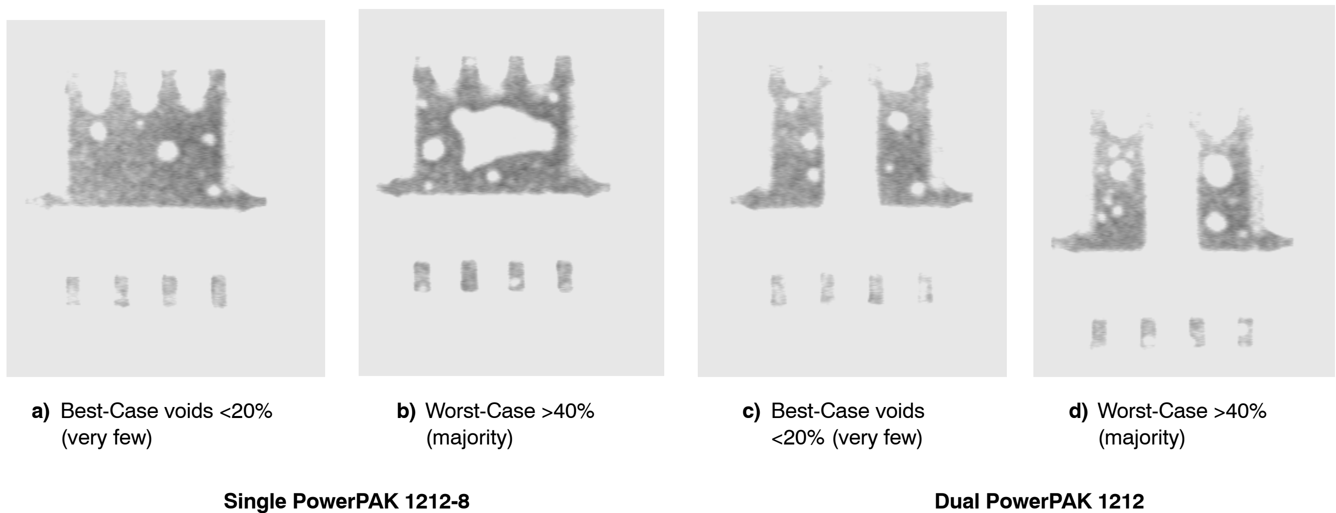
The NC-73 solder paste did not perform very well, as shown in Figures 18 and 19, with the majority of parts having a greater than 40% voiding. The PowerPAK SO-8 devices were classified as having a greater than 50% void, whereas the PowerPAK 1212-8 devices were classified as having a void of 20% to 50%.



a) Best-Case voids <20% (very few)
b) Worst-Case >40% (majority)
c) Best-Case voids <20% (very few)
d) Worst-Case >40% (majority)

Single PowerPAK SO−8 **Dual PowerPAK SO−8**

FIGURE 18. Solder Voids For NC-73 Solder Paste



a) Best-Case voids <20% (very few)
b) Worst-Case >40% (majority)
c) Best-Case voids <20% (very few)
d) Worst-Case >40% (majority)

Single PowerPAK 1212-8 **Dual PowerPAK 1212**

FIGURE 19. Solder Voids For NC-73 Solder Paste

RP-15 SOLDER PASTE

The RP-15 solder paste resulted in a high percentage of voiding, even with a suggested low voiding oven profile (Figure 20). As with the NC-73 solder paste, the voiding for the PowerPAK SO-8 was classified as being greater than 50%, whereas the PowerPAK 1212-8 MOSFETs had a 20% to 50% voiding level. See Figures 21 and 22.

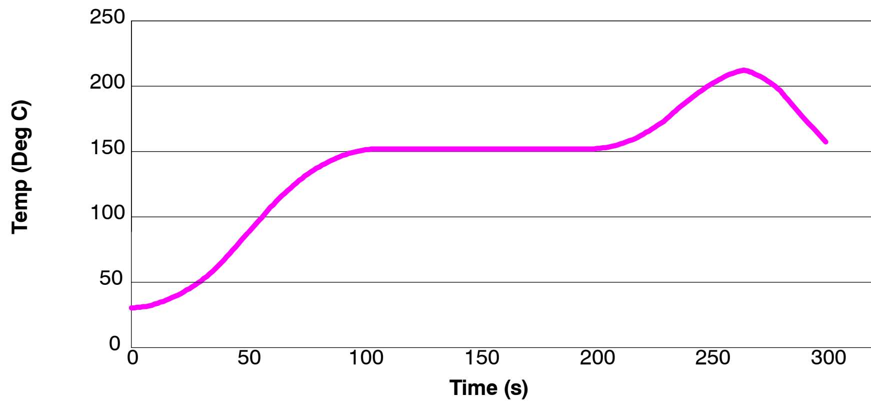
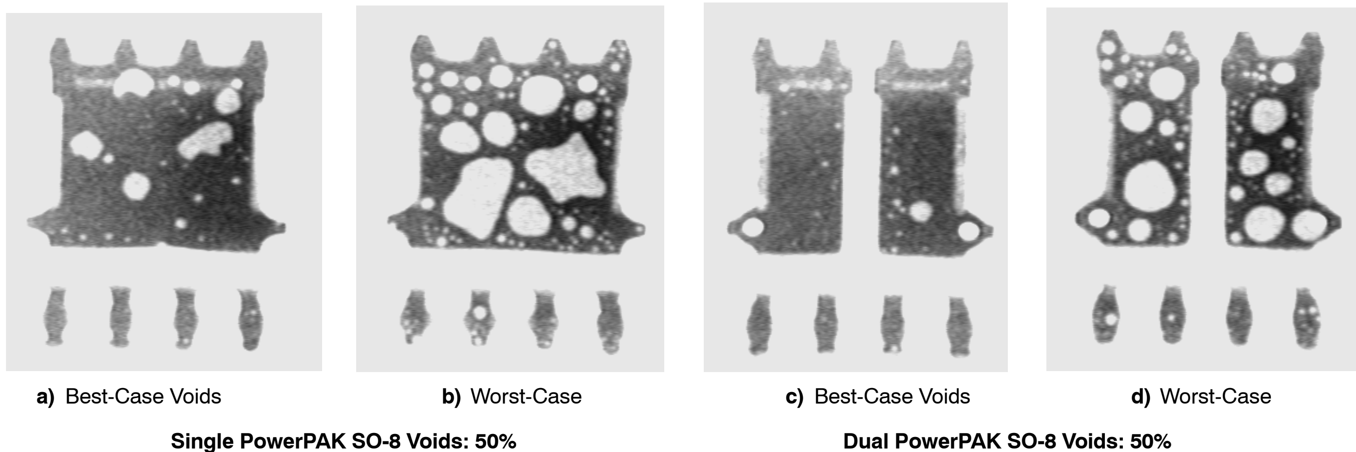


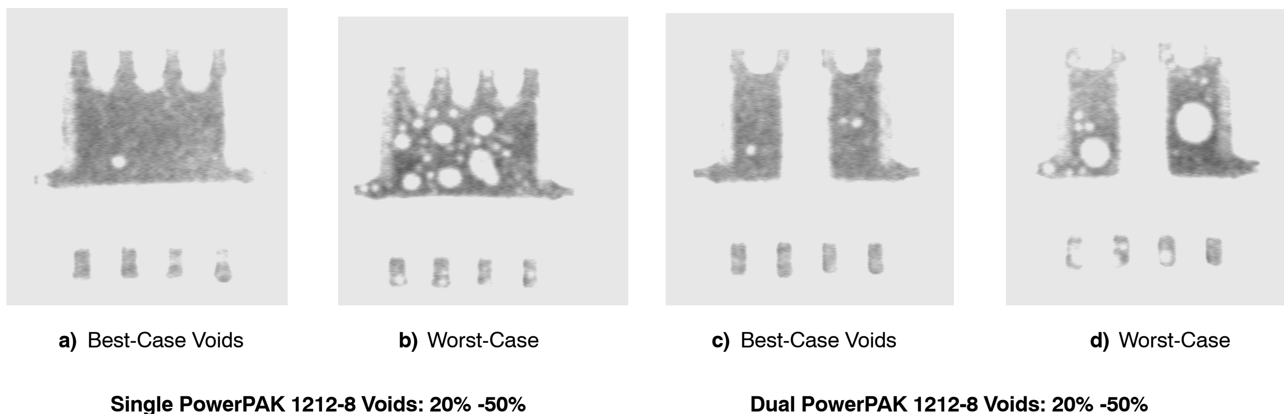
FIGURE 20. Suggested Improved Low Voiding Oven Profile for RP15



a) Best-Case Voids **b)** Worst-Case **c)** Best-Case Voids **d)** Worst-Case

Single PowerPAK SO-8 Voids: 50% **Dual PowerPAK SO-8 Voids: 50%**

FIGURE 21. Solder Voids For RP-15 Solder Paste



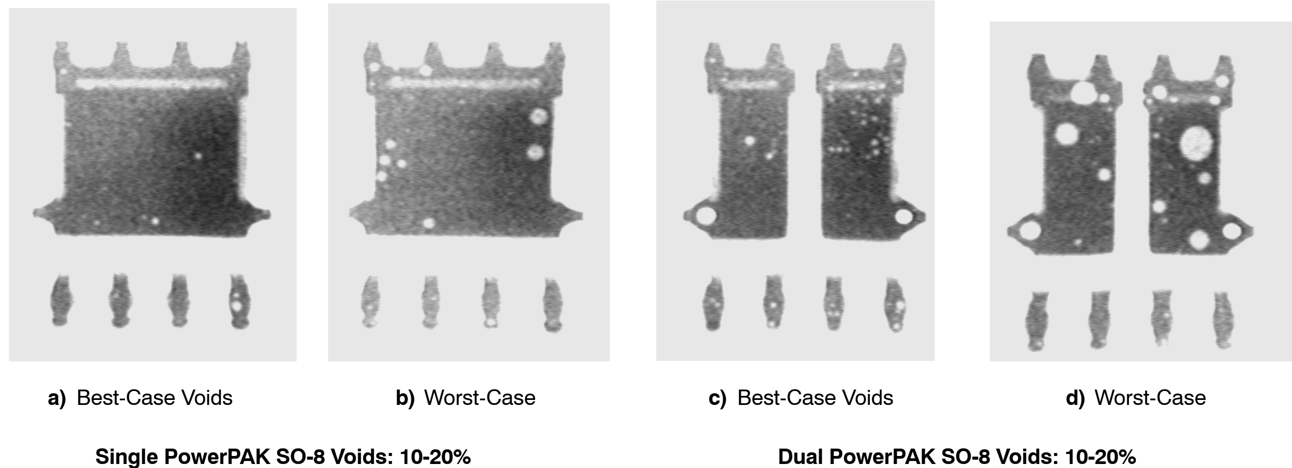
a) Best-Case Voids **b)** Worst-Case **c)** Best-Case Voids **d)** Worst-Case

Single PowerPAK 1212-8 Voids: 20% -50% **Dual PowerPAK 1212-8 Voids: 20% -50%**

FIGURE 22. Solder Voids For RP-15 Solder Paste

WS-22 SOLDER PASTE

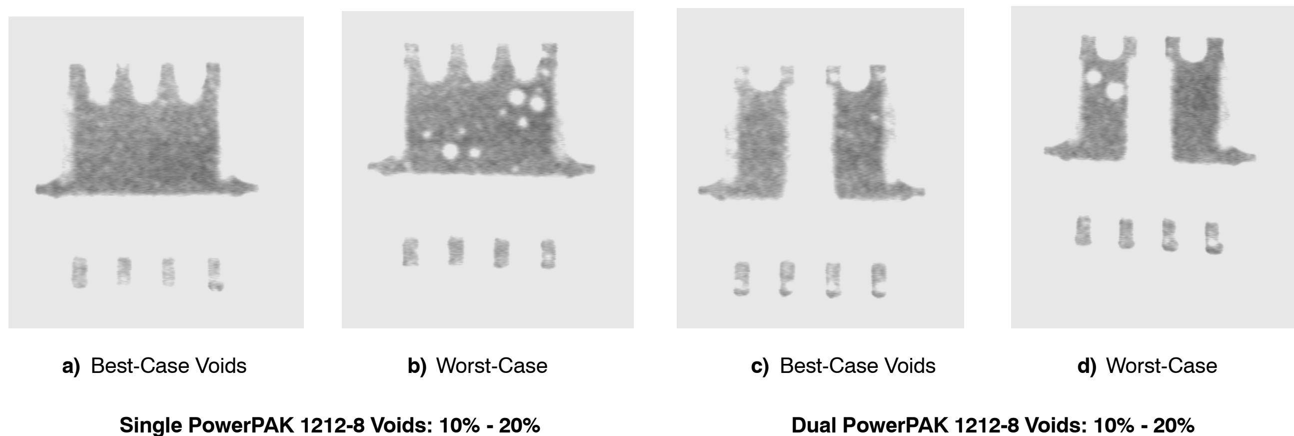
The WS-22 solder paste resulted in successful placement of both the PowerPAK SO-8 and 1212-8. The voiding level was very good and classified as being 10% to 20%, as shown in Figures 23 and 24.



a) Best-Case Voids **b)** Worst-Case **c)** Best-Case Voids **d)** Worst-Case

Single PowerPAK SO-8 Voids: 10-20% **Dual PowerPAK SO-8 Voids: 10-20%**

FIGURE 23. Solder Voids For WS-22 Solder Paste



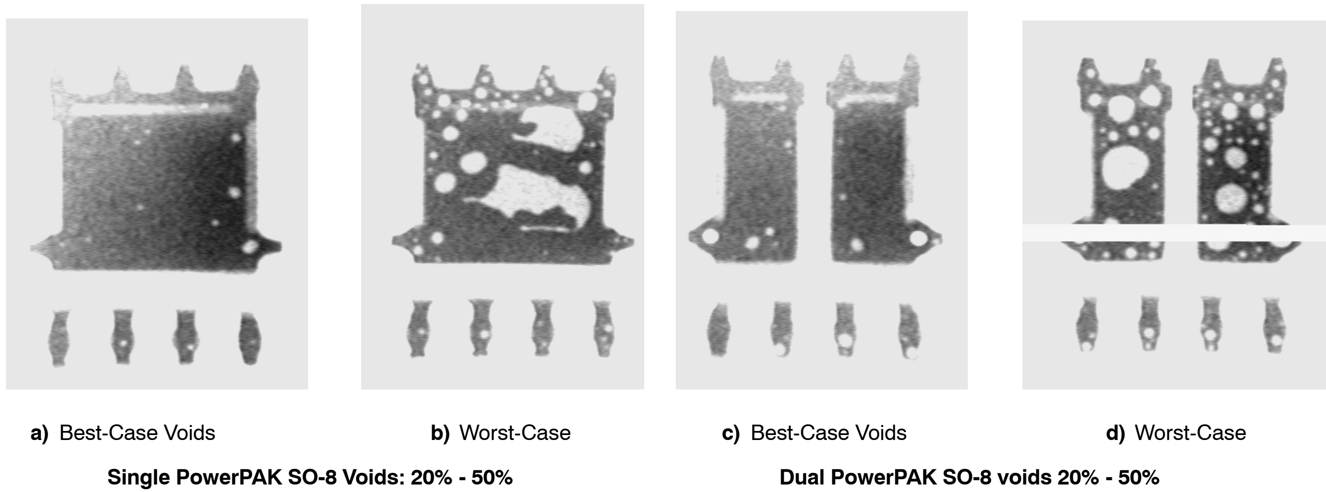
a) Best-Case Voids **b)** Worst-Case **c)** Best-Case Voids **d)** Worst-Case

Single PowerPAK 1212-8 Voids: 10% - 20% **Dual PowerPAK 1212-8 Voids: 10% - 20%**

FIGURE 24. Solder Voids For WS-22 Solder Paste

CR-39 SOLDER PASTE

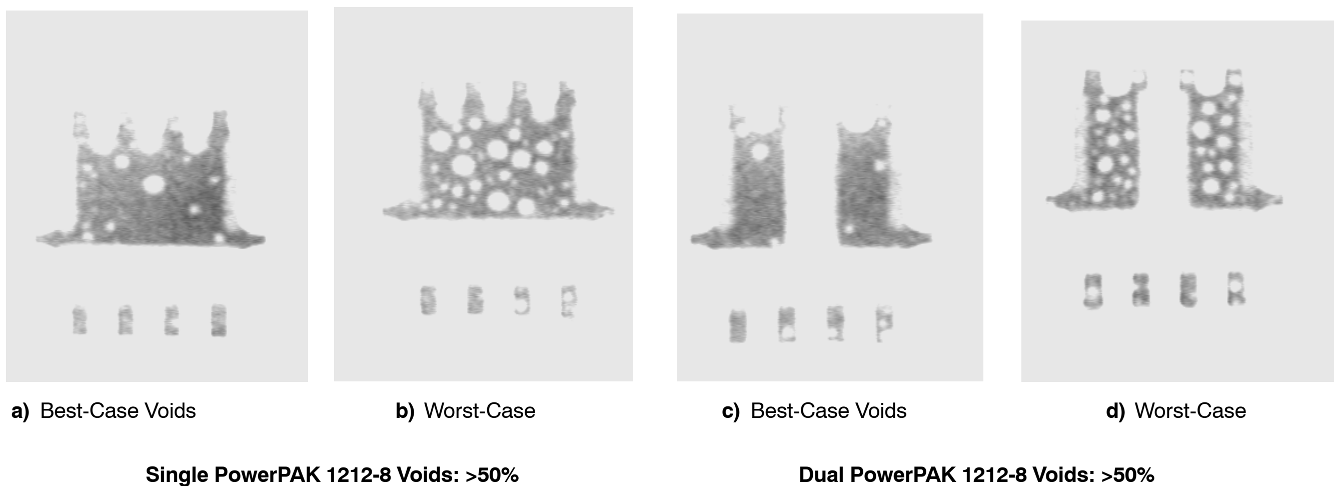
CR-39 solder paste exhibited void levels for the PowerPAK 1212-8 of greater than 50% (Figure 26), whereas the PowerPAK SO-8 parts had voiding levels of 20 to 50% (Figure 25).



a) Best-Case Voids **b)** Worst-Case **c)** Best-Case Voids **d)** Worst-Case

Single PowerPAK SO-8 Voids: 20% - 50% **Dual PowerPAK SO-8 voids 20% - 50%**

FIGURE 25. Solder Voids For CR-39 Solder Paste



a) Best-Case Voids **b)** Worst-Case **c)** Best-Case Voids **d)** Worst-Case

Single PowerPAK 1212-8 Voids: >50% **Dual PowerPAK 1212-8 Voids: >50%**

FIGURE 26. Solder Voids For CR-39 Solder Paste

A summary of all the solder paste void tests is given in Table 2, which shows results for single and dual versions of the PowerPAK SO-8 and PowerPAK 1212-8. Four boards of each package type were evaluated for each variety of solder paste. Each PC board contained five single-channel and five dual-channel devices.

TABLE 2
Summary of Solder Paste Voids

Solder Paste	Board #	Voids PKSO-8			Voids PK1212-8		
		10–20%	20–50%	50+%	10–20%	20–50%	50+%
UP78	1		X			X	
(no clean)	2		X			X	
	3		X			X	
	4		X			X	
Omnix 5000	1	X			X		
(no clean)	2	X			X		
	3	X			X		
	4	X			X		
Indium	1	X			X		
(no clean)	2	X			X		
	3	X			X		
	4	X			X		
Multicore NC73	1			X		X	
(no clean)	2			X		X	
	3			X		X	
	4			X		X	
Multicore WS22	1	X			X		
(no clean)	2	X			X		
	3	X			X		
	4	X			X		
Loctite RP15	1			X		X	
(no clean)	2			X		X	
	3			X		X	
	4			X		X	
Loctite CR39	1		X				X
(Lead–free)	2		X				X
	3		X				X
	4		X				X
Tamura	1	X				X	
(Lead–free)	2		X			X	
	3	X				X	
	4	X				X	

CONCLUSIONS

This note effectively considers two issues: the movement of the part during placement and any associated solder bridging, and the solder voids beneath the mounted part.

Solder Bridging and Part Movement During Placement

The pick-and-place machine caused spreading of the solder paste before reflow, which in turn reduced the pad-to-pad gap, albeit temporarily. Before the reflow process, the MOSFET can shift off-center as a result of operating pressure during part placement. The specifics of how this happens also depend on the tolerances of the pick-and-place machine. But the PowerPAK devices realign themselves during the reflow process. No solder bridges were observed during these movements and realignments. Therefore, it has been shown that the PowerPAK SO-8 and PowerPAK 1212-8 packages are suitable for surface mounting assembly using industry standard re-flow procedure and process.

Nor did the results show any solder bridges on the fine gaps between two consecutive leads, or on the gaps between the lead and pad, or between the pads themselves. There were also no electrical shorts on the mounted device as the part aligned itself on the pad pattern during the re-flow period. To ensure that there are no solder bridges or shorts, the recommended pad patterns must be used in conjunction with the corresponding solder masks. Use of the recommended pad pattern greatly reduces pad-to-pad solder-bridging and shift or pull of the part due to surface tension.

Solder Voids

To investigate the possibility of solder voids, a variety of solder pastes were used to mount the PowerPAK SO-8 and 1212-8 MOSFETs. The manufacturers' recommended oven profiles were used for the reflow process. For the solder pastes which generated large voids, the reflow profile was varied to try and minimize the solder voids. Only marginal improvements were noticed in the results, although solder paste manufacturers are attempting to produce an oven reflow profile that will improve the voiding of some of these solder pastes.

The contract manufacturer specified that a solder void of less than 20% was acceptable. It was also noted that an adequate amount of paste, by means of a good stencil design, is important for fault-free soldering, and an appropriate selection of pressure and speed parameters on the solder paste printing machine and pick-place machine are also critical in obtaining good results.

Typically, the solder profiles are recommended by the solder manufacturers, but marginal variance is applied to improve upon solder voids. However, an excessive increase in the reflow temperature can lead to burnt (dry) solder, whereas decreasing the reflow temperature can lead to an incomplete solder joint. The study showed that by using the correct solder paste, oven profile, and solder mask, it was possible to obtain solder joints with less than 20% voiding.