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ASPM 27 Series Package Assembly Guidance

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APPLICATION NOTE

INTRODUCTION

ASPM 27 series is an advanced Automotive SPM® module providing a fully−featured, high−performance inverter output stage for hybrid and electric vehicles. Target applications are E−compressor, Oil pump, Fuel pump, Water pump and Cooling Fans. Proper mounting is required to achieve good thermal performance and low mechanical stress during lifetime of the device. Figure 1 show the two types of assembly method for ASPM 27 packages. Assemblies commonly are done using method 1 or method 2 by customer's determination. This application note is intended to provide recommendations for proper handling, assembly of the package and potential rework in conjunction with industry standards. Following sections outline appropriate TIM (Thermal Interface Material) application and heat sink mounting as well as soldering procedures to ensure a reliable PCB (Printed Circuit Board) connection. Recommendations in this note are based on simulation and experimental results from laboratory and field tests.

Table 1. ASPM 27 SERIES

Device	IGBT Rating	Remark
FAM65V05DF1	50 A / 650 V	Version 1.0
NFVA33065L32	30 A / 650 V	Version 2.0
NFVA34065L32	40 A / 650 V	Version 2.0
NFVA35065L32	50 A / 650 V	Version 2.0

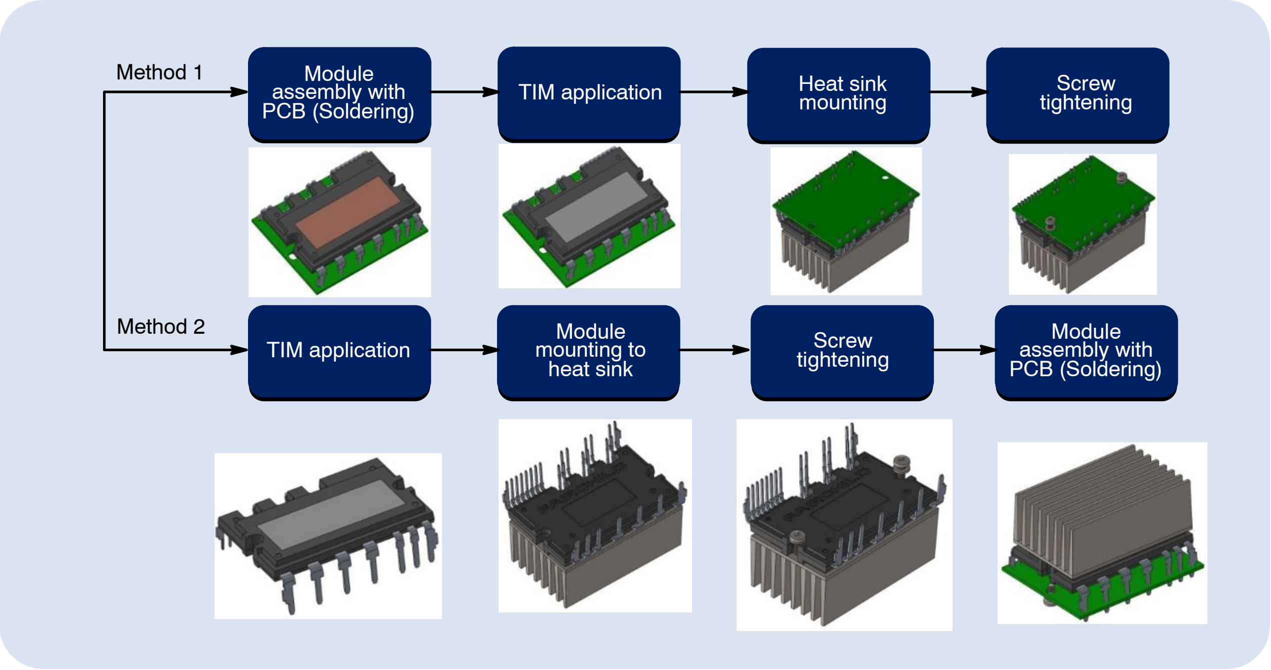


Figure 1. ASPM27 Module Assembly Process Flow

September, 2019 − Rev. 1

GENERAL PACKAGE INFORMATION

Package Surface Specification

The measurement area for the flatness of the package surface is specified by the package center and the four outside corners, as shown in *Figure 2*. Flatness for the ASPM 27 is specified in *Table 2*. The surface down with torque, the thermal compound spreads out and fills the air gaps between the two contact partners, finally ensuring full contact.

ASPM27

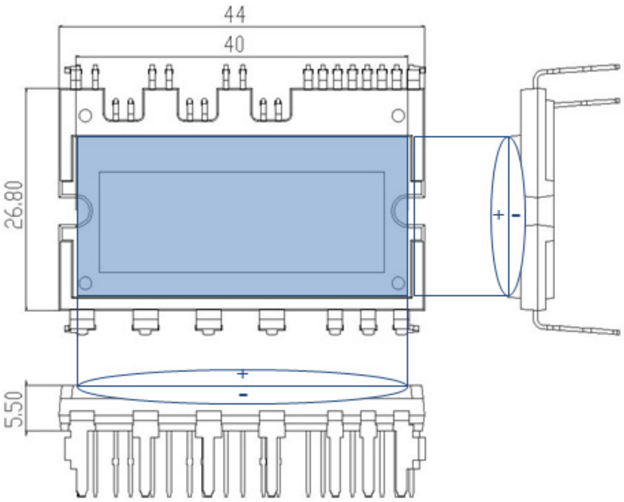


Figure 2. Device Flatness Measurement Zone

Table 2. SPECIFICATION OF THE ASPM 27 PACKAGE SURFACE

	Min.	Typ.	Max.
ASPM27	0	–	+150 μm

Heat Sink Surface Specification

A heat sink is a passive heat exchanger that is designed to absorb and disperse heat away from the power devices. The thermal performance of a module is influenced by the quality of the surface contact to the heat sink. To optimize the thermal dissipation it is required to maintain a high quality of the heat sink surface. Surface flatness and roughness are the key factors to be considered when manufacturing the heat sink. In order to obtain the specification given in *Table 3* and *Figure 3* needs to be followed. The surface of the heat sink must be clean and free of particles. Besides the surface quality, the heat sink design is also one of the key factors that improve the heat dissipation capability of a device.

Table 3. HEAT SINK SURFACE REQUIREMENTS

(a) Flatness of heat sink	−50~100 (μm)
(b) Geometrical surface roughness (Rz)	≤10 (μm) to DIN EN ISO 4287

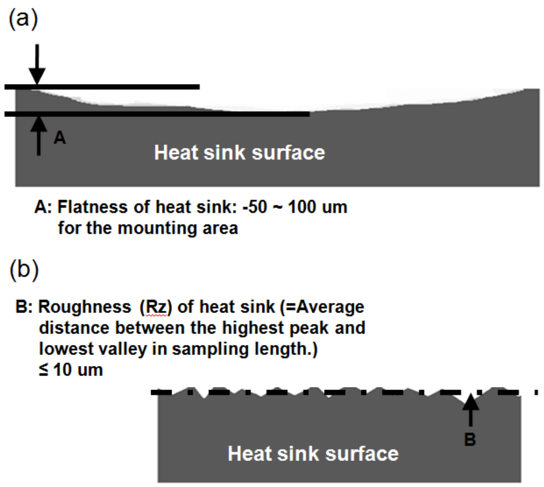


Figure 3. Microscopic View of Surfaces. A is Flatness and B is Roughness (Rz)

Specification of External Lead Pin

Table 4 shows technical features of leads. The capability of the leads in terms of pulling and bending are evaluated to check the devices to withstand stresses from actual handling and assembly of the devices in application.

Table 4. MECHANICAL CHARACTERISTICS OF THE LEADS

Parameter		Description
Material	Main material	Cu Alloy
	Plating material	Sn
Pulling strength, Load 19.6 N acc. to EIAJ−ED−4701		Min. 10 sec
Bending strength, Load 9.8 N 90 deg. bend acc. to JESD22−B105−C		Min 2 times

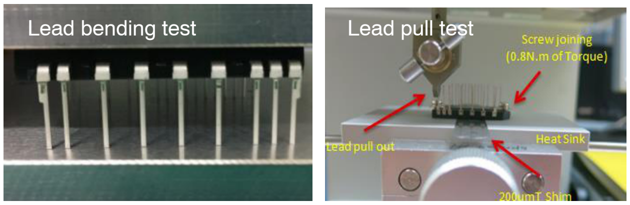


Figure 4. Lead Bending and Pull Test Images

Clearance and Creepage Distance

Since electrical isolation is directly related to the reliability of the product and its safety, it is considered as an important design factor of a power package. The spacing distance between components that are required to withstand a given working voltage and the environment (depending on the pollution degree, temperature and relative humidity) is specified in the terms of Clearance and Creepage in IEC 61800−5−1. Clearance is defined as the shortest distance through the air between two conductive parts. Creepage is defined as the shortest path between two conductive parts measured along the surface of an isolator.

The specification of the electric spacing for ASPM 27 is described in *Table 5* as well as in *Figure 6*. In order to maintaining certain spacing addressed in the relevant standard after heat sink and PCB assembly, Creepage and Clearance need to be checked and additional measures to enlarge the creepage and clearance distances may need to be applied. *Figure 5* shows one of example how to achieve the enlarger creepage and clearance by modify the heat sink shape.

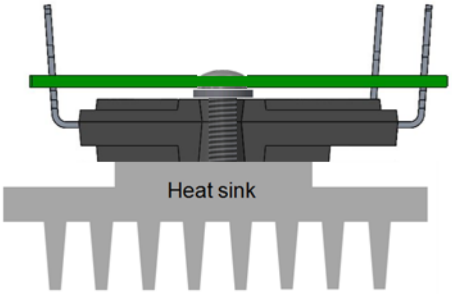
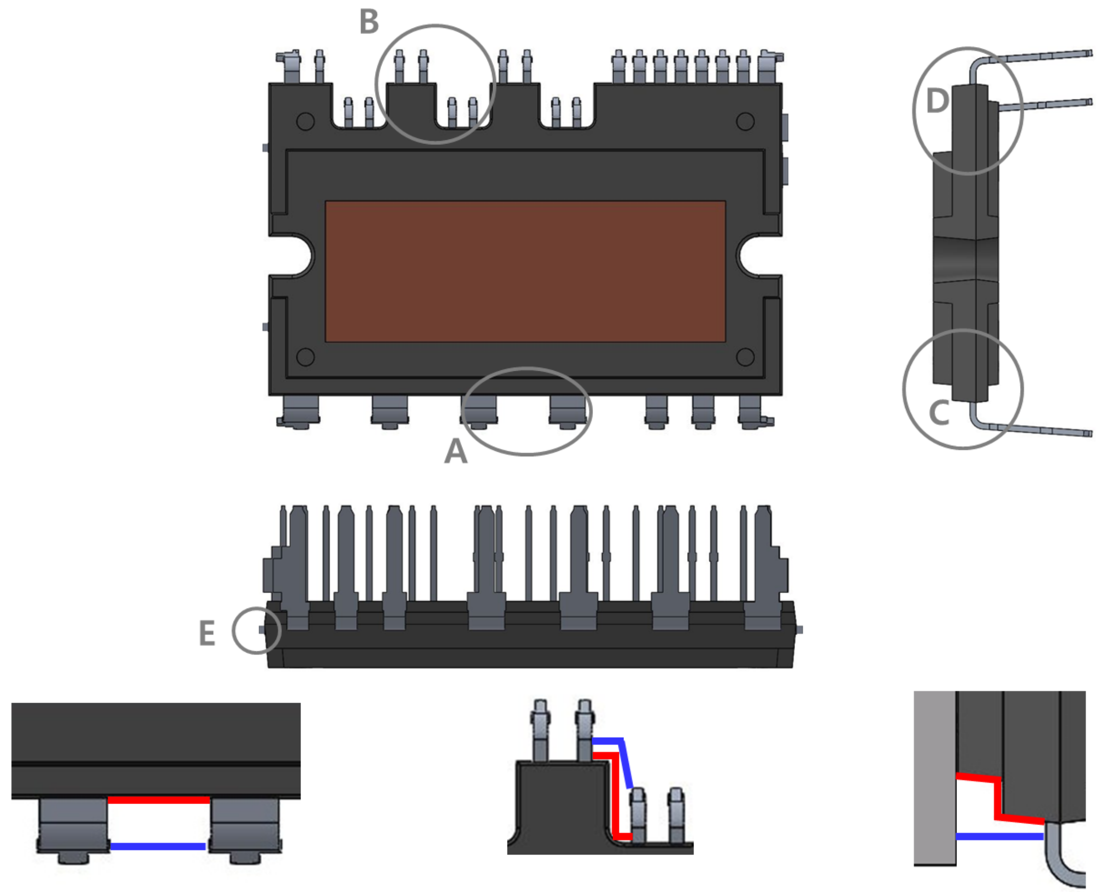


Figure 5. Creepage and Clearance Improvements by Heat Sink Modification

Table 5. MINIMUM DISTANCE FOR ISOLATION FOR ASPM 27

Location		Clearance [mm]	Creepage Distance [mm]
A	Between power terminals	4.32	4.52
B	Between control terminals	3.05	5.24
C	Between power terminals & H/S	3.00	4.13
D1	Between control terminals & H/S	3.00	8.33
D2		3.00	4.53
E	Between Dummy terminals & H/S	3.00	4.13
F1	Between Dummy terminals & Washer	–	–
F2		–	–
G1	Between control terminals & DBC edge	–	12.79
G2		–	8.99
H	Between power terminals & DBC edge	–	7.29



Clearance Distance > 4.32 mm
Creepage Distance > 4.52 mm

A. Between power terminals

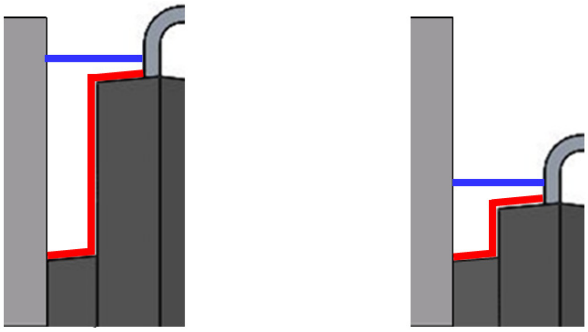
Clearance Distance > 3.05 mm
Creepage Distance > 5.24 mm

B. Between control terminals

Clearance Distance > 3.00 mm
Creepage Distance > 4.13 mm

C. Between power terminals & H/S

Figure 6. Distance for Isolation from Lead to Lead and from Lead to Heat Sink and DBC Edge (ASPM 27)



D1

Clearance Distance > 3.00 mm

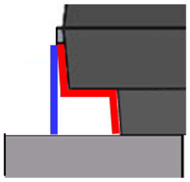
Creepage Distance > 8.33 mm

D2

Clearance Distance > 3.00 mm

Creepage Distance > 4.53 mm

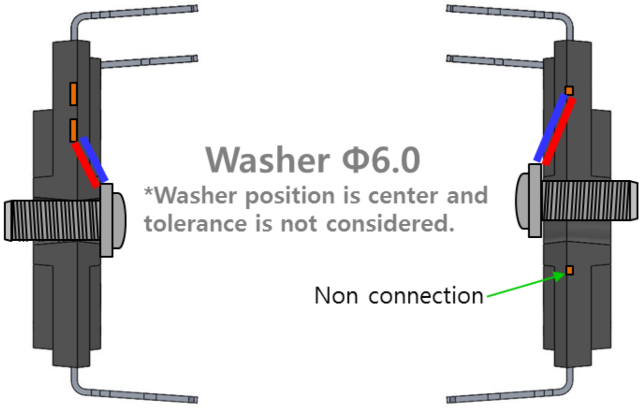
D. Between control terminals & H/S



Clearance Distance > 3.00 mm

Creepage Distance > 4.13 mm

E. Between Dummy terminals & H/S



F1

Clearance Distance > 4.80 mm

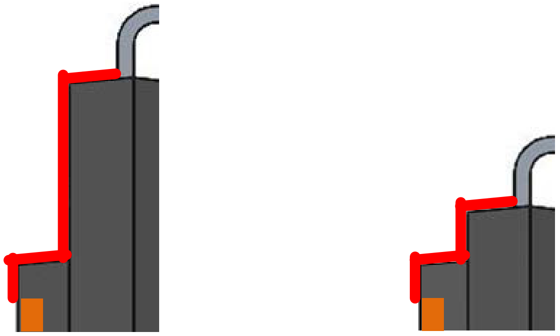
Creepage Distance > 4.80 mm

F2

Clearance Distance > 7.20 mm

Creepage Distance > 7.20 mm

F. Between Dummy terminals & Washer



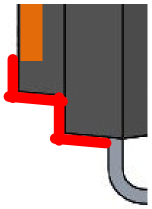
G1

Creepage Distance > 12.79 mm

G2

Creepage Distance > 8.99 mm

G. Between control terminals & DBC edge



Creepage Distance > 7.29 mm

H. Between power terminals & DBC edge

Figure 6. Distance for Isolation from Lead to Lead and from Lead to Heat Sink and DBC Edge (ASPM 27) (continued)

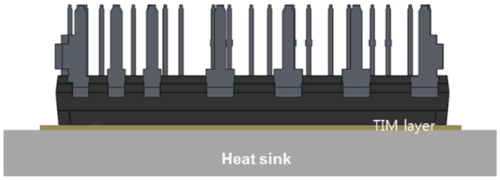
ASSEMBLY SEQUENCES

The assembly process can be done in two ways. One method is mounting the module onto the heat sink first and then proceeds with soldering. (Section Module Mounting to the Heat Sink First, then Soldering to the Board) On the contrary, soldering the module on the PCB can be done first then mounting on the heat sink is done after. (Section Soldering to the PCB, then Mounting to the Heat Sink)

Module Mounting to the Heat Sink First, then Soldering to the Board

When the module is mounted onto the heat sink before PCB mounting, a process flow as illustrated in *Figure 7* is recommendable. Firstly, apply TIM on the surface of the module or heat sink and place the module on the heat sink (a). Recommendable TIM application and screw tightening method are flowed in Section Thermal Interface Materials (TIMS) for Electronics Cooling and Screw Tightening Guideline. Tighten the screws down to heat sink (b).Then the module with the heat sink is placed onto the PCB (c). Finally, the solder joint between lead pins and PCB is formed (wave soldering process or manual soldering) (d).

(a) Apply thermal interface material on the module or heat sink surface and place module onto the heat sink



(b) Tighten up the modules with the heat sink using M3 screw.

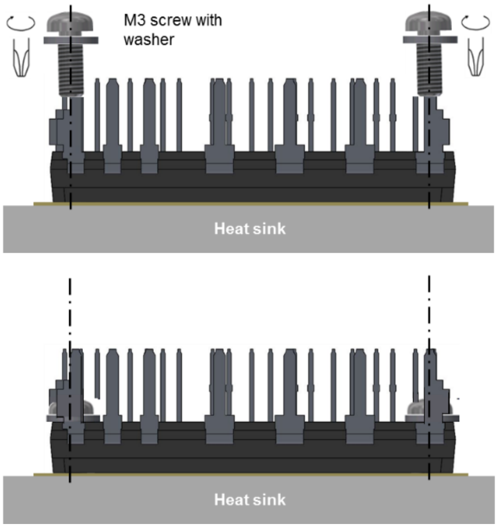


Figure 7. Process Flow of Soldering ASPM 27 Package (When Heat Sink Mounting First)

(c) Place the PCB until the stopper touch the PCB surface.
(d) Soldering the pins to the PCB

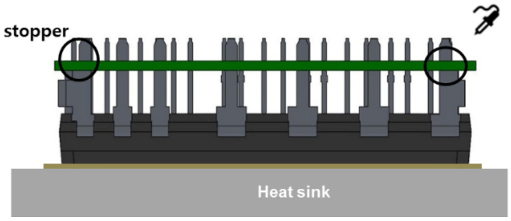


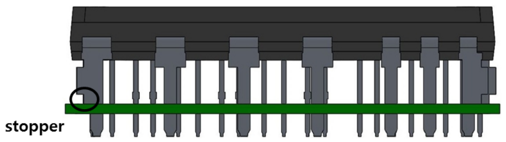
Figure 7. Process Flow of Soldering ASPM 27 Package (When Heat Sink Mounting First) (continued)

Manual soldering and wave soldering are the general practices to assemble the module onto the PCB. With manual soldering, both bottom side and top side soldering is available. Wave soldering system consists typically of solder fluxing, preheating zone, solder wave and the cooling zone. As the board enters the conveyorized process, solder flux is sprayed or foamed onto the modules. Then it moves to the preheating zones, normally done by convection, where the flux is activated. The assembly then moves to wave soldering. The assembly is slowly cooled down after. More details about the soldering process and the conditions for ASPM 27 packages are described in Section Soldering Guidelines.

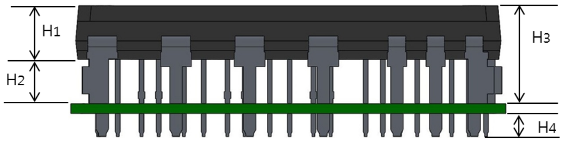
Soldering to the PCB, then Mounting to the Heat Sink

If module is assembled with the PCB first and heat sink mounting is conducted later, process flow described in *Figure 8* is recommendable. Firstly, the module is place on the PCB (a). Then, soldering to PCB is done (b). After PCB assembly is done, TIM (Thermal Interface Material) is applied on the surface of the module or heat sink (c). Place module onto the heat sink and screws to the heat sink (d).

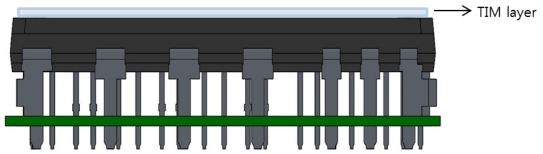
(a) Place the module on the PCB until the stopper touch the PCB surface.



(b) Soldering the pins to the PCB. (wave or manual soldering)



(c) Apply thermal interface material on the module or heat sink surface



(d) Place the module onto the heat sink and fasten the screws (Without spacers between PCB and heat sink.) Refer to Section 5.2 for more detail procedure

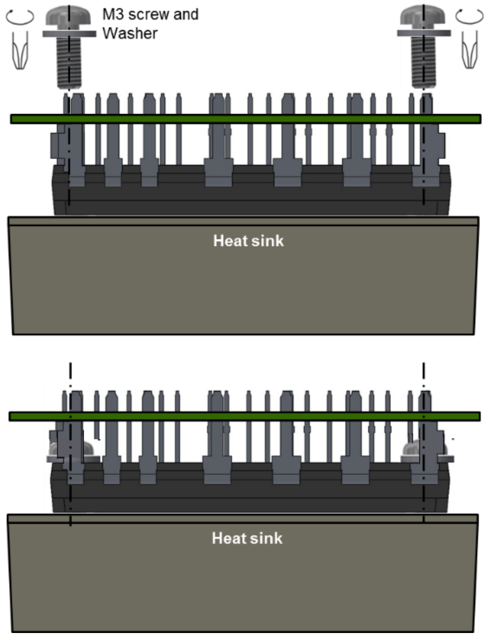


Figure 8. Process Flow of Soldering ASPM 27 Package (When PCB Mounting First)

Minimum distance between PCB and heat sink is designed to be H3 and the distance between module and PCB is H2, as described in *Table 6*.

Table 6. SPECIFICATION OF H1 AND H2 (UNIT: MM)

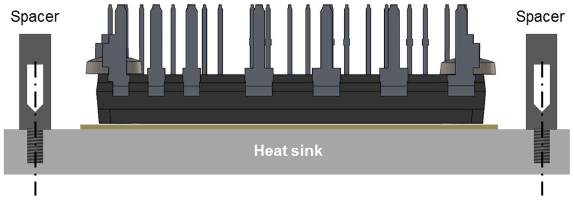
	H_1	H_2	H_3	$*H_4$
ASPM 27	5.50	1.50	7.00	4.80

*H4 is the extruded lead part from the PCB in case the PCB thickness is 1.6 mm.

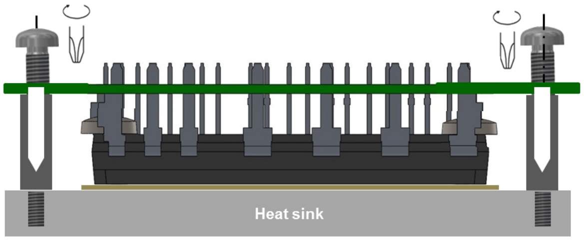
System Considerations

After module is assembled to the PCB and the heat sink as described above, the overall structural integrity need to be considered in terms of mechanical stress to any of the system components. In case the PCB is large and heavy with other components assembled to it, there is some risk the PCB can bend, creating mechanical stress to the module and the PCB. In addition, when multiple modules are applied to the same PCB, height tolerance between modules can result in mechanical stresses to the board and modules. *Figure 9* illustrates one of method to prevent PCB bending and stress by using spacers between PCB and heat sink. Various types of spacer should be added on the heat sink, to prevent any possible movement of the PCB.

(a) Add spacers if necessary.



(b) Place the PCB until the PCB surface touch the top of spacers. Screwing the PCB with spacers.



(c) Soldering the pins with PCB.

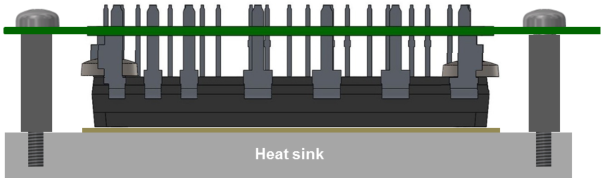


Figure 9. Robust Assembly Method of ASPM 27 Package to Reduce Stresses from PCB Bending

Figure 10 shows examples of spacer type. Option 1 shows individual spacers between heat sink and PCB. Option 2 shows one body spacer type of heat sink. And, option 3 shows a spacer between module and the PCB.

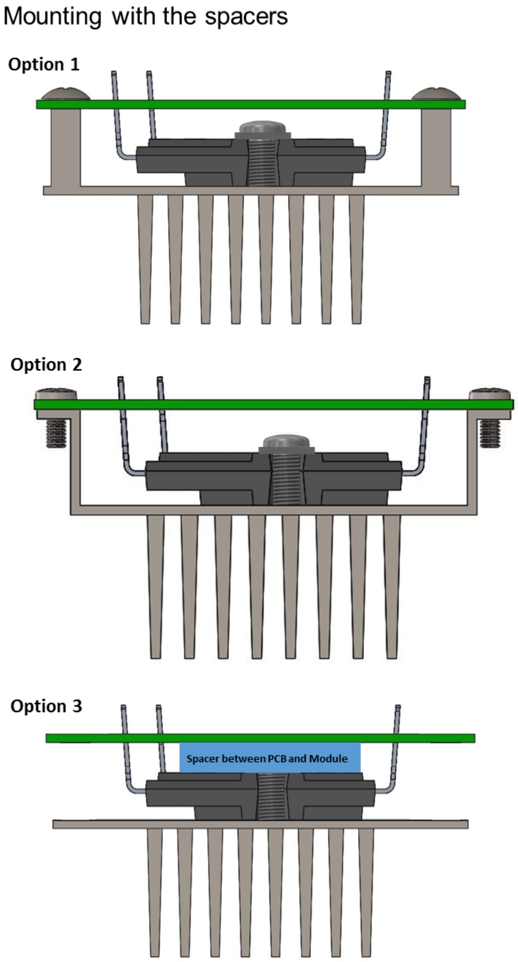


Figure 10. Examples of the Spacer Type

THERMAL INTERFACE MATERIALS (TIMS) FOR ELECTRONICS COOLING

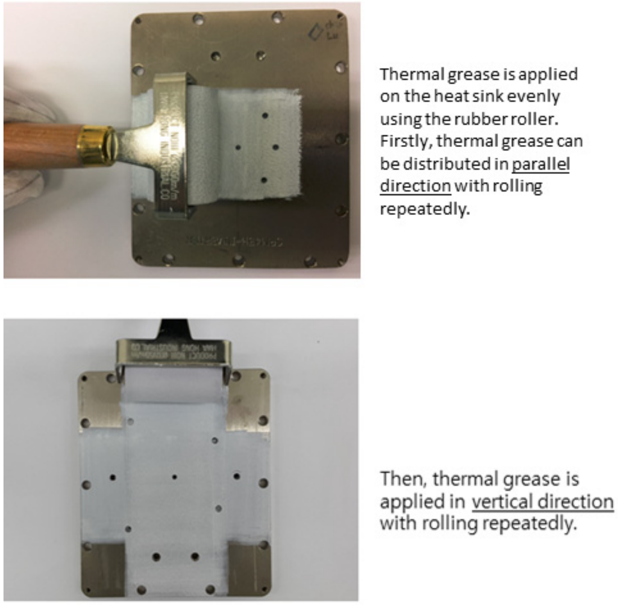
Since the contact surfaces are not perfectly flat, multiple air gaps can form between two solid contact surfaces. Air is a poor heat conductor preventing the heat transfer and limiting the effective contact area. Thermal Interface Materials (TIMs) need to be applied between the heat sink and the module surface to fill any air gaps and to achieve a low thermal resistance. The following are the general considerations when choosing the material for the application. Besides its thermal conductivity also handling and rework performance may be important factors while selecting the proper TIM.

- High thermal conductivity
- Ease of distribution with low contact pressure
- Minimal thickness
- Degradation of characteristics over time
- Environmental
- Ease in handling during application or removal

Though thermal interface materials with improved performance are available nowadays, still the most commonly used in the industry is thermal grease. Thermal greases consists of silicone or hydrocarbon oils that contain various fillers which have good surface wetting characteristics and flow easily to fill void even at low mounting pressure. Standard thermal compounds have a thermal conductivity between 0.7 – 0.9 W/m−k while the thermal conductivity of high end compounds is in the range of 2.0 – 4.0 W/m−k or even above. As an alternative PCM (Phase Change material) provide improved reliability and high thermal performances as well as lower overall costs due to a simplified assembly process. It is recommended to contact your local On semiconductor representative for more information regarding PCM pre−applied modules.

Manual TIM Application

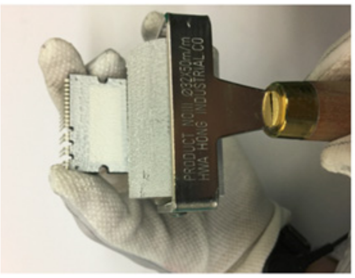
Thermal grease can be applied to the heat sink or the module back surface using a rubber roller or spatula or by screen printing. A rubber roller, as shown in *Figure 11*, is an easy and fast method for applying thermal grease. Since the thermal grease has the lowest thermal conductivity in the thermal path, a layer as thin as possible is necessary to keep the overall thermal resistance low. Recommended thickness of printing layer is uniform dispense of a minimum 150 μm. The thermal grease thickness can be checked using thickness gauges, such as wet film combs or wet film wheels. Since manual control of printing pressure and speed can be learned by experience, training is needed to achieve a technique for good quality printing in the application.



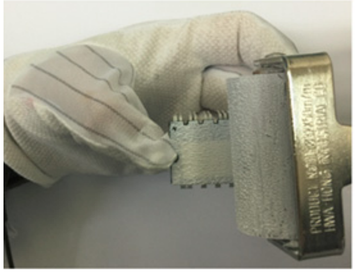
Thermal grease is applied on the heat sink evenly using the rubber roller. Firstly, thermal grease can be distributed in parallel direction with rolling repeatedly.

Then, thermal grease is applied in vertical direction with rolling repeatedly.

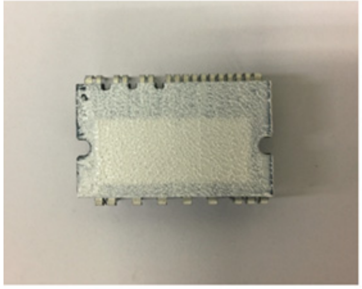
Figure 11. Example of Thermal Grease Application Using a Rubber Roller



Thermal grease being applied to the device in vertical direction with several repetitions of rolling.

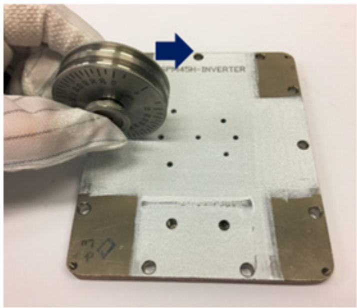


Thermal grease being applied to the device in parallel direction with several repetitions of rolling.



Since the thermal grease has the lowest thermal conductivity in the thermal path, a layer as thin as possible is necessary to keep the overall thermal resistance low.

Recommended thickness of printing layer is 150 - 200 um.



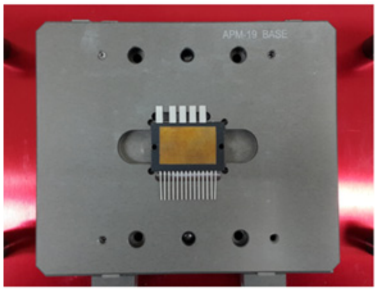
Check the thermal grease thickness with thickness gauges, such as wet film comb or wet film wheels.

Figure 11. Example of Thermal Grease Application Using a Rubber Roller (continued)

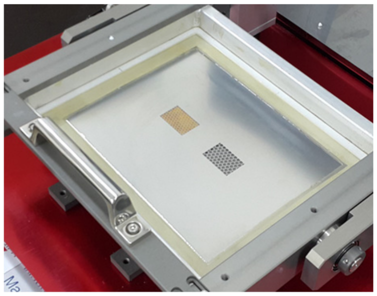
TIM Application by Manual Screen Printer

Stencil/screen printing can be utilized for the application of thermal paste. It allows a fast, clean and easy handling of spreadable TIMs. They can be applied to the substrate area, leaving out other parts of the module package using specifically designed stencils. An optimization of the screen mask pattern and thickness is required to achieve a good quality of the print and finally and optimum contact. *Figure 12* shows and example of thermal paste application process using a manual screen print.

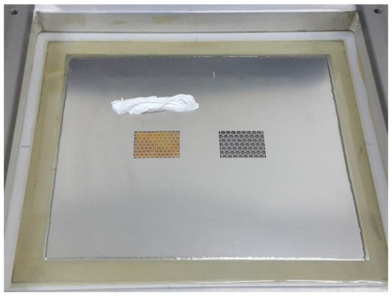
Fully automated screen printing is recommended in mass production. It has a good quality of printing layer with high accuracy and repeatability.



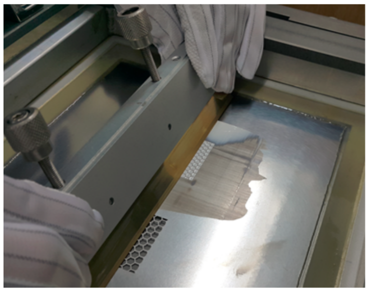
Place the module on the mounting jig. Ensure the DBC area is clean.



Aligning and positioning of the screen mask to the module DBC area

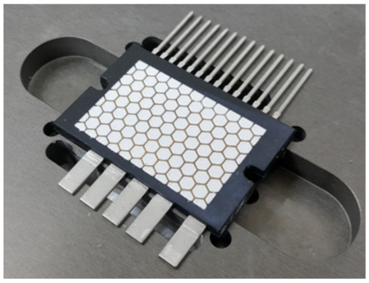


Dispense the thermal interface material on th screen mask



Place the squeegee or spatula behind the TIM and tilt down it to have 45° angle around. Apply a certain pressure and draw the squeegee downwards slowly.

Maintaining the constant printing pressure and speed make possible to achieve uniform pattern of printing layer.



Lift the screen mask and do visual inspection after application

Figure 12. Example of Thermal Grease Application Using a Manual Screen Print

SCREW TIGHTENING GUIDELINE

Screw and Mounting Torque

ASPM 27 package should be secured on the heat sink via two M3 screws. The location of the screw holes are illustrated in *Figure 13*. *Table 7* shows the screw specification and *Table 8* is showing the recommended torque ranges for the ASPM 27 package. Contact pressure and mounting torque may affect the thermal performance. The thermal resistance specified can be achieved with the minimum specified torque in the *Table 8*. Electric screwdrivers can tighten the screws with the specified torque. Considering the electrical spacing specified in Section Clearance and Creepage Distance, additional flat or spring washers can be applied on packages during mounting. *Figure 14* shows SEMS (Pre−assembled washers and screw) which is a recommended screw type. Appendix I shows thermal resistance variance under various torque levels.

ASPM 27

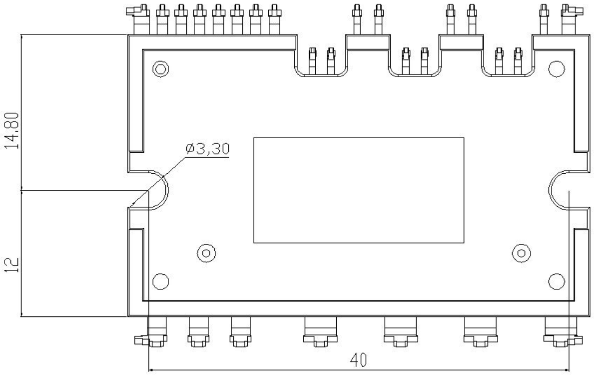


Figure 13. Dimension of Screw Clamping Zone (mm)

Table 7. SCREW AND WASHER INFO

Parameter	Description
Mounting Screw	Metric 3 screw
Spring Washer	D (Nominal) = ø5.5 (mm), t = 1.2
Plain Washer	D (Nominal) = ø7.0 (mm), t = 0.5 (mm)
Recommended thread engagement for screws with property class 4.8 to 6.8 for different materials	

Table 8. MOUNTING TORQUE SPECIFICATION FOR ASPM 27

Parameter	Unit	Min.	Typ.	Max.
Pre−Torque	[N·m]	0.2	−	0.3
	[kgf·m]	2.0	−	3.1
Final Torque	[N·m]	0.6	0.7	0.8
	[kgf·cm]	6.1	7.1	8.2
Generally, pre−torque is 20 − 30% of the final torque Recommended final torque is 0.7 N·m				

Figure 14. SEMS (Pre−assembled Washers and Screw, Spring Washer ø5.5 and Plain Washer ø7.0)

Screw Tightening Method

Screw tightening can be done in various ways. *Figure 15* describes one recommended method for fastening the module to the heat sink. Fasten two screws with final torque simultaneously to prevent tilting or rising of top side of module during fastening. The recommended final torque is in the range of 0.6 − 0.8 Nm (6.1 − 8.2 kgf·cm), as shown in *Table 8*. Method 1 enables to maintain an even thermal grease layer after mounting.

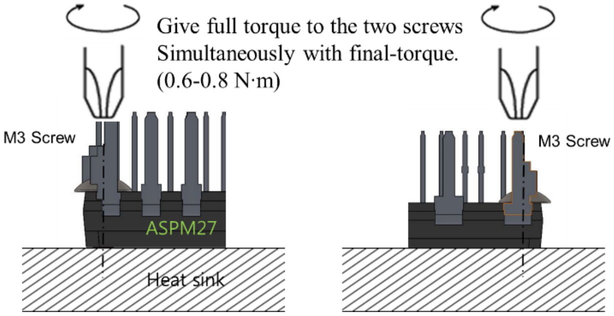
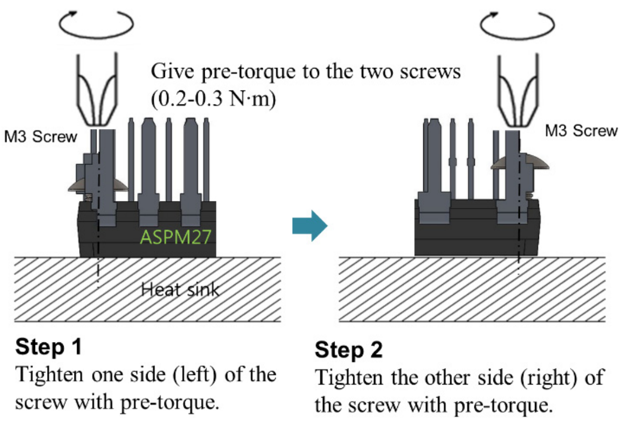


Figure 15. Illustration of Screw Clamping with Heat Sink (Method 1)

Alternatively, *Figure 16* shows another recommended method to tighten the screws. Fasten the first screw with pre−torque to prevent one side tilting or rising of the module (Step 1). Then insert the second screw to the other side with same pre−torque (Step 2). The pre−screwing torque is set to 20 − 30% of final torque rating. After that, apply full final torque to the second screw (Step 3). Finally, apply full torque to the first screw for proper mounting to the heat sink (Step 4). An insufficient tightening torque may cause an increased thermal resistance or loosening of the screws during operation.

Pre−torque (Step 1 → Step 2)



Final Torque (Step 3 → Step 4)

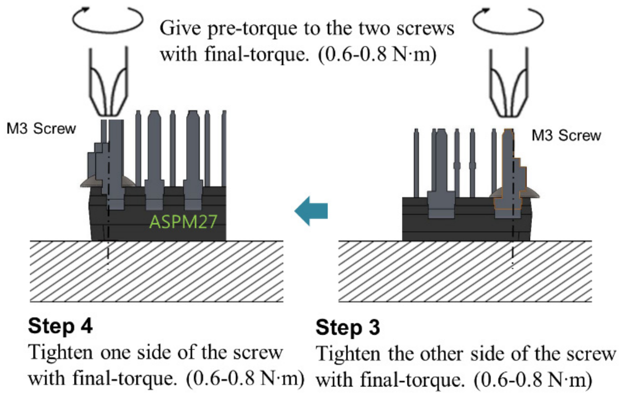


Figure 16. Illustration of Screw Clamping with Heat Sink (Method 2)

NOTE:

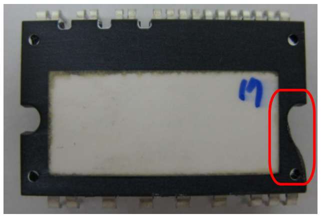
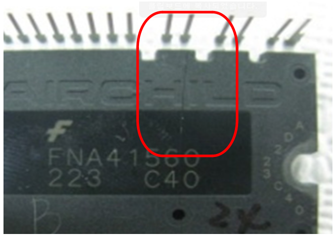
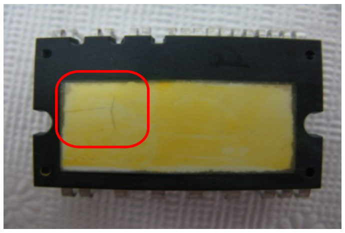
- Avoid applying over torque when mounting screws. Excessive fastening force may cause damages to the semiconductor devices, the package or its isolation, as well as damages to the screws or heat−sink.
- Uneven mounting can cause the ceramic substrate to be damaged. A smooth surface free of burrs and protrusions or indentations is required (*Table 3*). No foreign materials except thermal interface materials are allowed between surface of the module and the heat sink**.**
- The mounting area should be treated as a functional layer. Do not touch the mounting area of the heat sink and the substrate of the module.

Potential Failure Modes

The following are possible root causes of mounting failures which should be avoided during the mounting process. *Table 9* lists representative examples of mounting failure mode.

- Excessive torque is applied without pre−torque
- Misalignment of screw during tightening with heat sink
- Mechanical stress by mounting height tolerances when multiple module mounted on the same PCB
- Inappropriate type of screws are used

Table 9. EXAMPLES OF MOUNTING FAILURE MODE

Failure Mode and Cause	Example
1) EMC broken due to too high torque	
2) Package crack by abnormal heat sink flatness	
3) Ceramic crack (Ceramic substrate is inked with yellow color)	
4) Bolts broken	

SOLDERING GUIDELINES

Wave soldering or hand soldering are the general practice for through−hole type (THT) components. This section assesses characteristics of the soldering process for ASPM 27 modules at the assembly to a PCB (Printed Circuit Board).

Wave Soldering

Assemblies are placed on a carrier belt moving through the soldering process contacting a solder wave. The wave soldering process typically uses a thermal profile which consists of four stages: solder fluxing, preheating zone, solder wave and cooling zone. Solder flux is either sprayed or foamed onto the components. Then the parts move to the preheating zones, normally done by convention, where the flux is activated. The assembly then moves to wave soldering and finally is getting cooled down slowly. Key elements such as preheat ramp rate, conveyor speed, peak temperature and time forms a wave solder profile. The wave soldering profile should be optimized in the assembly site since it strongly depends on the equipment condition and the material type used in application. A typical soldering profile and its conditions are illustrated in *Figure 17* and *Table 10*.

Preheat: Preheating is required to avoid thermal stress due to overheat. Preheat temperatures and the preheating time should be set according to the flux specification. Too high temperature and too long preheat time may break down the flux activation systems which causes shorts. On the other hand, too low preheat temperature may cause unwanted residues left on the PCB. A ramp up rate between 1~4°C per second is suggested in the preheat zone.

Wave soldering: Dual−wave soldering is the most common method. The 1st wave which has turbulent wave crest ensures wetting of all the land pads allowing the molten solder to find its way to all joints on the PCB. The 2nd wave, which has a laminar flow, drains the excess solder from the board after the 1st wave thus removing the solder bridges. It is recommended to keep the maximum soldering temperature up to 260°C for 10 sec to establish a good quality of the solder joint and to avoid package damage by thermal shock.

Cooling: Gradually cool the processed board down. A cooling down rate between 1 − 5°C/s is recommended in general.

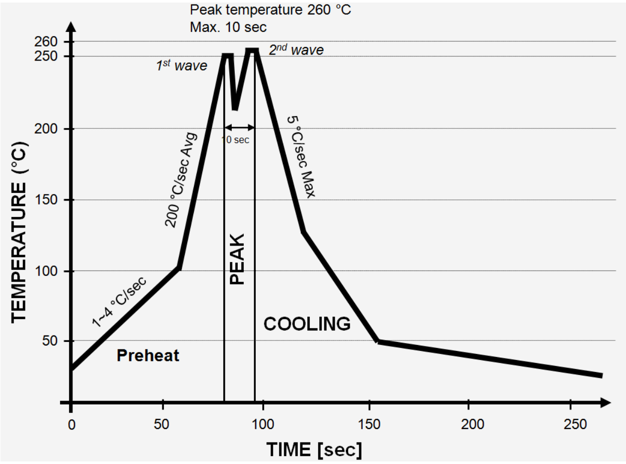


Figure 17. Typical Dual Wave Soldering Profile

Table 10. TYPICAL DUAL WAVE SOLDERING CONDITION (AT LEAD SURFACE)

Profile Feature	SnPb Eutectic Assembly	Pb−free Assembly
Average ramp up rate	~200°C/sec	~200°C/sec
Preheat ramp up rate	Typical 1 − 2, max 4°C/sec	Typical 1 − 2, max 4°C/sec
Final preheat temp.	~130°C	~130°C
Peak wave soldering temperature	max 235°C, max 10 sec	max 260°C, max 10 sec
Ramp down rate	5°C/sec max	5°C/sec max

Detailed conditions of the soldering profile should be defined by users as it depends on the equipment and the materials.

Manual Soldering

The recommended conditions for manual soldering are listed in *Table 11*. Considering the glass transition temperature (Tg) of the package mold resin and the thermal withstand capability of internal chips and assembly, the temperature of the lead root part should be kept below 150°C. Iron tip should touch the lead at its tip, away from the package mold body.

Manual soldering is not recommended for mass production as it may be difficult to control the amount of solder applied and the time and temperature of the soldering step.

Table 11. EXAMPLE OF MANUAL SOLDERING CONDITION

Parameter	Single Side Circuit Board	Double / Multi Layers Circuit Board
Iron tip temperature	385 ±10°C	420 ±10°C
Soldering time	2~6 seconds	4~10 seconds

Soldering Quality Inspection

Monitoring the soldering quality is essential since abnormal solder joints are potential risks. IPC−A−610 standard specifies the soldering quality criteria for soft soldering. For the examination of a solder joint, visual or X−ray inspection and automatic optical inspection (AOI) are suitable evaluation methods.

APPENDIX I

Thermal Performance under Various Mounting Torque

Since the module surface and heat sink are not perfectly flat, contact pressure and mounting torque can affect thermal performance. According to the results shown in *Figure 18*, thermal resistance values (Rthjc) were measured stable values at torque levels ranging between 5~7 (kg·f−cm) with ASPM 27 package.

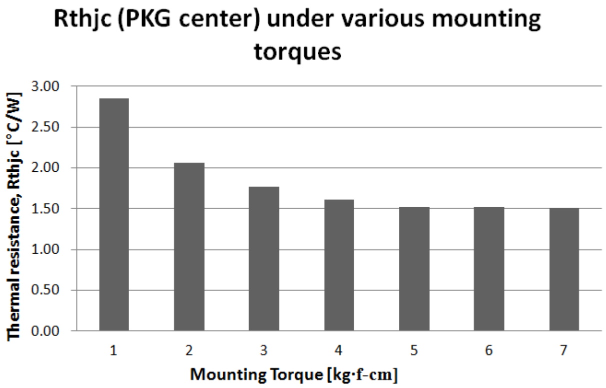


Figure 18. Thermal Resistance under Various Mounting Torque

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