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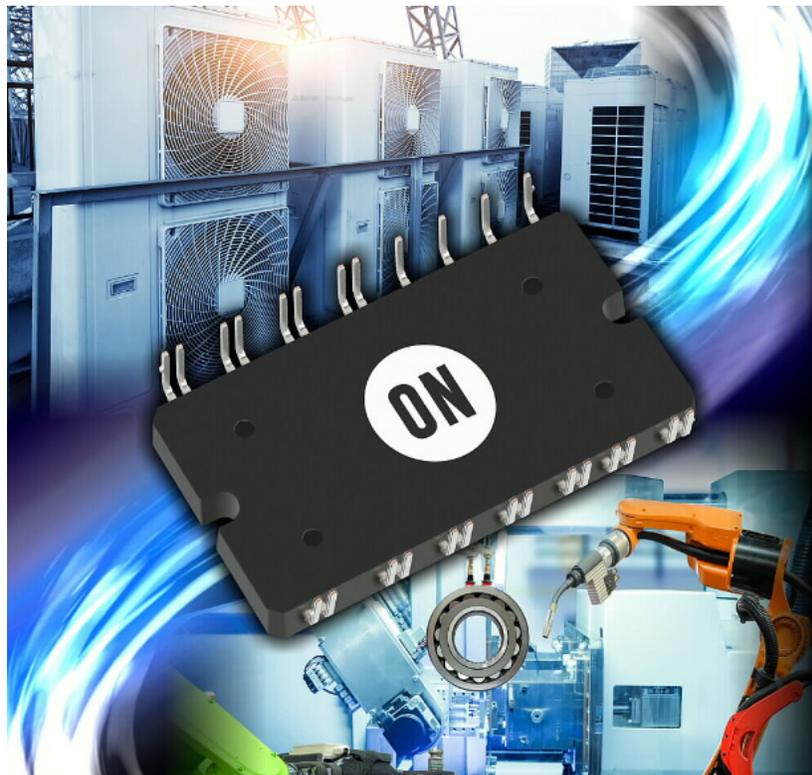
## DIP-26 Series: New Transfer Molded Power Integrated Module (TMPIM) for Industrial Drives



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### APPLICATION NOTE



## INTRODUCTION

### TMPIM Structure

This instruction applies to ON Semiconductor transfer molded power integrated module (TMPIM) in the category of DIP-26 series. TMPIM adopts transfer molding process to encapsulate the power devices and peripheral components with epoxy molding compound. The construction structure is shown in Figure 1. The power devices and passive component like thermistor are solder attached to Direct Bonded Copper (DBC) substrates and connected thru thick aluminum bond wires and leadframe.

DIP-26 series offer two platforms in substrate selection, Standard TMPIM and Enhanced TMPIM, as shown in Figure 2. Though both platforms look identical from outside look sharing the same pinout and size, they have different substrate internally. Standard TMPIM adopts standard

nickel plated Al<sub>2</sub>O<sub>3</sub> DBC substrate. Enhanced TMPIM uses thick copper advanced substrate for high reliability and lower thermal resistance.

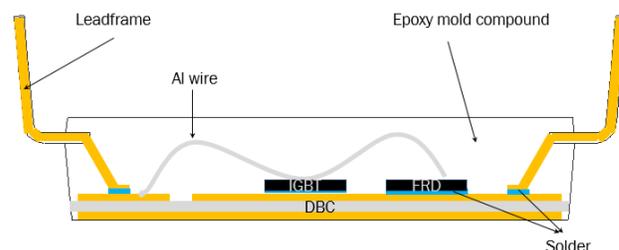


Figure 1. Internal Structure in TMPIM

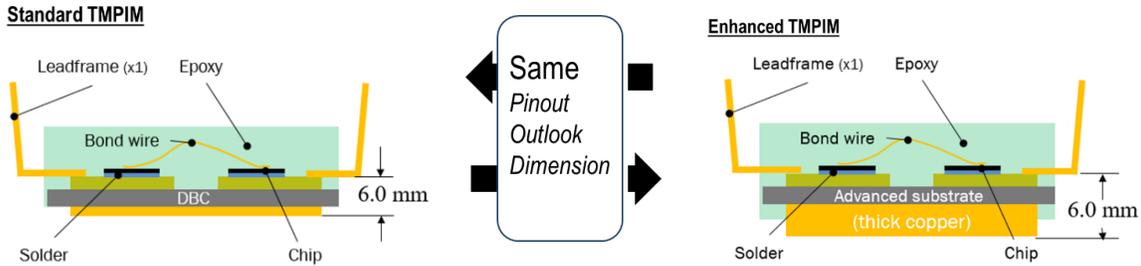


Figure 2. DIP-26 Series Structures: Standard and Enhanced Platforms

TMPIM series packaging has concise and robust manufacturing process. The transfer molding process eliminates the plastic housing, glue and the associated connection & curing procedure. The epoxy molding compound selected for encapsulation has demonstrated able to extend the module life time by times compared to gel filled module. Platform options with variable substrates

offer high power density and wide output power range, and customer design flexibility.

DIP-26 series provide module products in different topologies such as converter-inverter-brake (CIB), converter-inverter (CI), six-pack, and other multi-level converters. (C) I (B) topology the voltage and current rating parts are shown in Table 1.

Table 1. (C) | (B) PRODUCTS IN DIP-26

Config	Package	1200 V				650 V				
		25 A	35 A	50 A	75 A	35 A	50 A	75 A	100 A	150 A
CIB	DIP-26	x	x				x			
	Enhance DIP-26		x	x		x	x	x		
CI	DIP-26		x				x			
	Enhance DIP-26			x			x	x		
6-pack	DIP-26						x			
	Enhance DIP-26			x	x		x	x	x	x

NOTE: x = Released / x = Releasing

**Application Scheme**

The application scheme of TMPIM CIB power modules is shown in Figure 3. CIB internal connections are put in the black box, which consists of three sections: converter, inverter and brake. The initial letter of these three are C-I-B, and it is how we call the circuit. The CIB module is widely used in HVAC, motor drive and servo industrial application. During working, the input pins R/S/T at converter draw the power from three phase grid and the 6 rectifier diodes in converter regulate the AC current into DC. Three phase voltage are popular in two classes, 240 V class and 400 V class. According to the magnitude of DC voltage after regulation, 650 V class CIB module and 1200V class CIB module can be chosen. Immediate after the converter, DC bus capacitor would be connected to positive and negative DC bus, to smooth the voltage ripple from inverter dynamic power usage. By switching on and off the 6-IGBT and freewheeling diode (FRD) in the inverter circuit, it will chop the DC power into AC power and output to motor. The output voltage/current is controlled thru pulse width modulation signal, to generate the power that can drive the motor at desired speed and direction. When we defined the TMPIM power module how many Amperes, the current is referring to IGBT rating in inverter section. As a guideline,

1200 V 25 A TMPIM CIB module can deliver 5 kW motor power; 35 A TMPIM to deliver 7.5 kW; 50 A will deliver 10 kW. We have 15 kW and 20 kW covered by QLP which will come soon. It is noticeable this is only a general guideline. When users have different control and cooling setting, the output power rating can be greatly varied. For example, certain customer used 35 A module for 11 kW under fan cooling, and another customer used 50 A module for 24 kW under liquid cooling condition. The max output power is co-defined by power module itself and how module are going to be controlled and cooled during work. A simulation tool can be provided to customer in helping with defining the maximum output power. When motor is stopping and decelerating, it works in regenerative mode. The power is pump back from motor to DC bus capacitor. When the power is excessive, it can over charge the capacitor and cause damage. To prevent it happening, the brake IGBT turns on, an external brake resistor which is connected in series with the brake IGBT can discharge the regenerative power and keep the capacitor voltage at safe level. In certain applications like fan, pump and electrical heater, where regenerative power not significant, the brake circuit is not used and can be removed. Then the module is called CI module, standing for Converter Inverter module.

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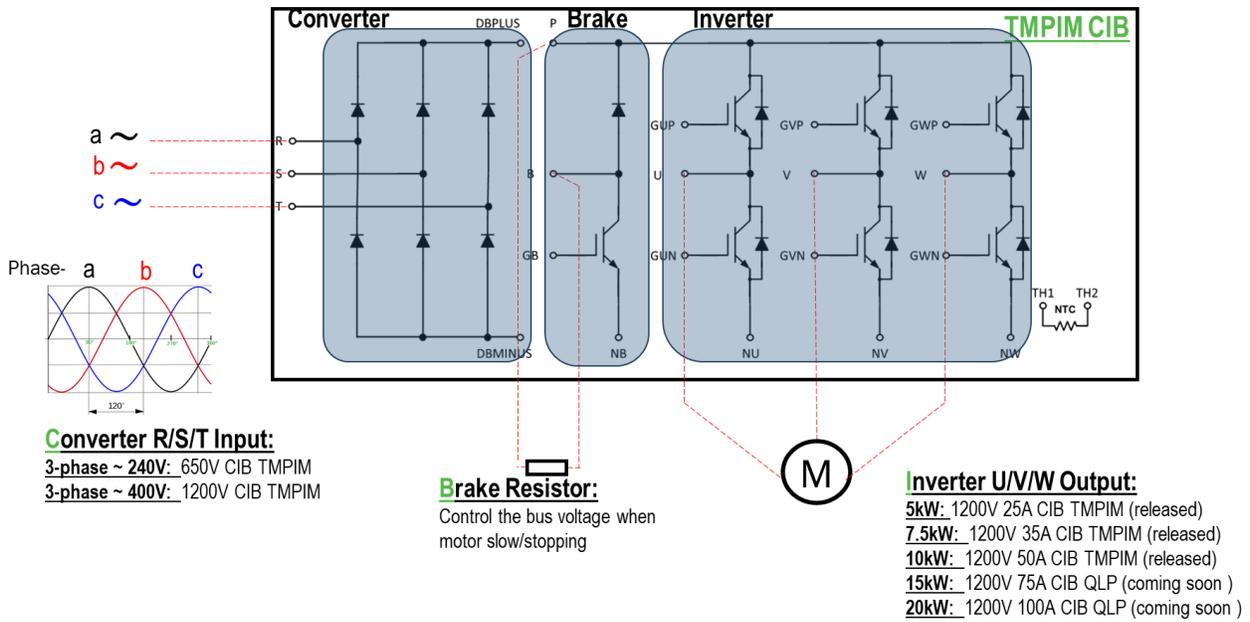


Figure 3. Application Scheme of TMPIM CIB Power Modules

## Drawing and Dimensions

The DIP-26 outline drawing and dimension is shown in Figure 4.

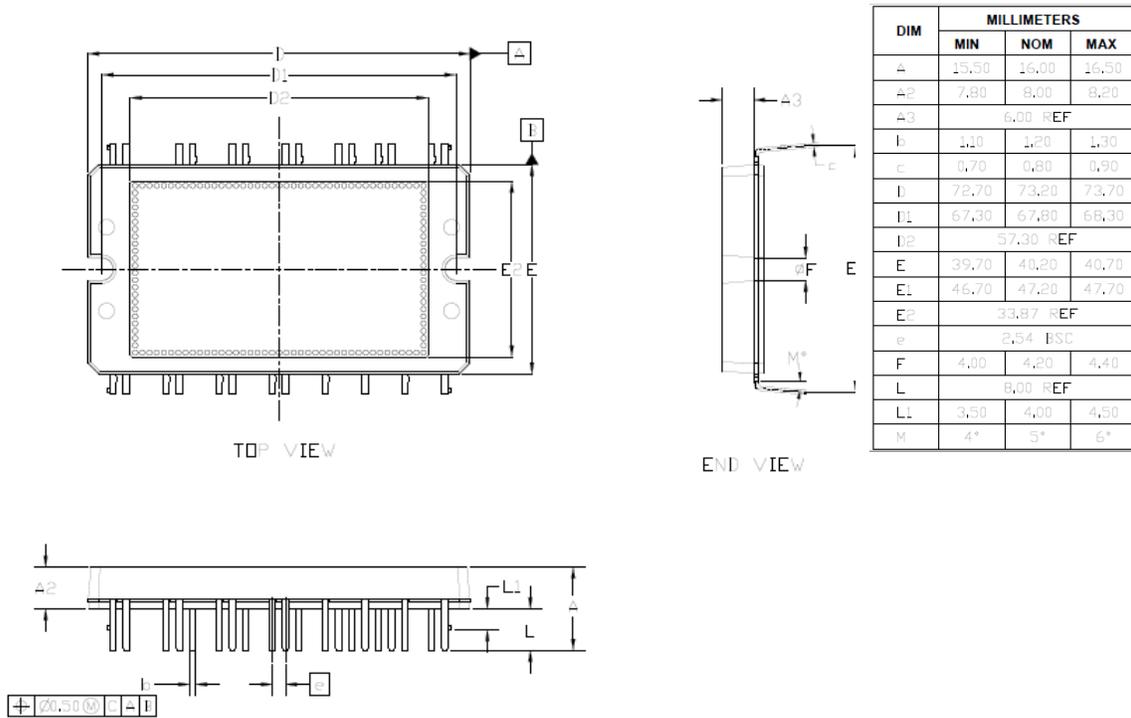


Figure 4. DIP-26 Outline Drawing and Dimension



**Reliability Test and Lifetime**

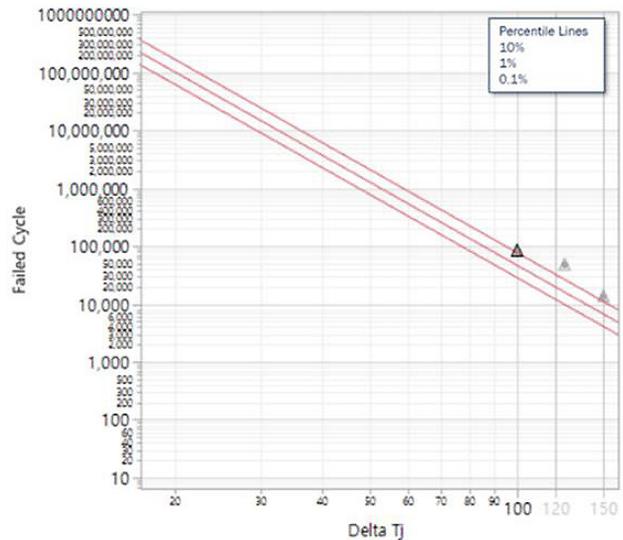
Accelerated temperature and electrical stress testing is to represent the normal use condition in the working life, and

to ensure power module product quality with the proper design and careful planning. The test items for transfer molded DIP-26 module are listed in Table 2.

**Table 2. TMPIM RELIABILITY TEST ITEMS**

Test	Name	Reference	Test Conditions
HTRB	High Temp Reverse Bias	JESD22-A108	Tj 150°C, V = 90% (Diode, IGBT) BV of (1,200 V)
H3TRB	High Humidity High Temperature Reverse Bias	JESD22-A101	T = 85°C, RH = 85%, time = 1008 hours, V = 80% BV
PCT -1	Power Cycling Test-1	MIL-STD-750 (M1036&M1037)	ΔT = 100°C, Tjunction max = 25-125°C, cycles = 62.5k
PCT -2	Power Cycling Test-2	MIL-STD-750 (M1036&M1037)	ΔT = 125°C, Tjunction max = 25-150°C, cycles = TTF
PCT -3	Power Cycling Test-3	MIL-STD-750 (M1036&M1037)	ΔT = 150°C, Tjunction max = 20C-170°C, cycles = TTF
Reflow	Reflow	JESD22-A103 cond. B	Tp = 210°C (solder melting temp 220°C)
HTSL	High Temp Storage Life	JESD22-A103 cond. B	Ta = 125°C or 150°C, time = 1008 hours
LTSL	Low Temp Storage Life	JESD22-A119, cond. A	T = -40°C, time = 1008 hours
THU	Temperature Humidity Unbiased	JESD22-A101	T = 85°C, RH = 85%, time = 1008 hours, no bias
TC	Temperature Cycling	JESD22-A104 cond. G, soak mode 4	Tmin = -40°C, Tmax = 125°C, cycles = 1000 cyc
Rthjc	Thermal resistance		Before/After TC 1000 cyc
VVF	Vibration Variable Frequency	JESD22-B103	25-500 Hz / 15 min, 10 G, each 2 hours X, Y, Z
PDD	Package drop	EIAJ-ED-4701 A124	drop from 75 cm onto 3 cm thick maple board 3 times
SD	Solderability	JESD22-B102	solder 215°C, 5 s

During DIP-26 power cycling, the IGBT is heated up by high current and temperature rises more than 100°C in couple of seconds, then cool down rapidly by cutting off current and active cooling. This acceleration test is to mimic the aging effect by power devices self-heating during work. While temperature changes rapidly, high stress is introduced between material with different coefficient of thermal expansion, and even stress inside homogenous material with temperature gradient. When range of temperature, or ΔTj increases, normally more degradation in each cycle and shorter life time span can be expected. Thru test at different ΔTj and extrapolating with aging mechanism, we can predict the lifetime of the module, as Figure 6. It is seen DIP-26 has exceptionally long life time, as encapsulant acting to prevent the bond wire from liftoff and solder from detaching.



**Figure 6. Lifetime Curve of DIP-26**

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## PRODUCTION LIST

Below are the products currently released under 1200 V class.

**Table 3.**

Part #	Voltage	Current	Topology	Platform	Pin Type
NXH25C120L2C2SG	1200 V	25 A	CIB	Standard DIP-26	Solder Pin
NXH35C120L2C2SG	1200 V	35 A	CIB	Standard DIP-26	Solder Pin
NXH35C120L2C2S1G	1200 V	35 A	CI	Standard DIP-26	Solder Pin
NXH35C120L2C2ESG	1200 V	35 A	CIB	Enhanced DIP-26	Solder Pin
NXH50C120L2C2ESG	1200 V	50 A	CIB	Enhanced DIP-26	Solder Pin
NXH50C120L2C2ES1G	1200 V	50 A	CI	Enhanced DIP-26	Solder Pin

## Nomenclature

The nomenclature of the TMPIM product is shown as Table 4:

Example: **NXH50C120L2C2ES1G-AA**

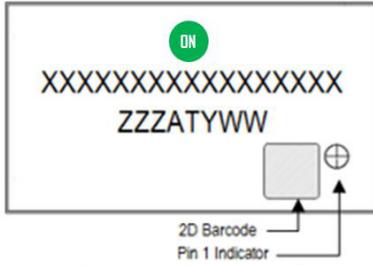
**Table 4. TMPIM NOMENCLATURE**

N	X	H	50	C	120	L2	C2	ES1	()	G	A	A
1	2	3	4	5	6	7	8	9	10	11	12	13

No.	Description
1	Product Class: N = ON Semiconductor Standard;
2	Product Group: X = Power Module
3	Product Family: H = IGBT Power Integrated Module
4	Current Rating in Ampere @ 100°C For example: 8 = 8 A (minimum); 80 = 80 A; 3600 = 3600 A (maximum)
5	Configuration: C = converter Inverter Brake S = Six Pack M = Customized
6	Voltage Rating: Nomenclature = (Voltage/10 (V)) For example: 06 = 60 V (minimum); 120 = 1200 V; 330 = 3300 V (maximum)
7	Optional Performance Attributes: L2 = Field Stop Gen II IGBT L4 = Field Stop Gen IV IGBT R = Reverse conducting (monolithic) M = Full SiC module S = Special (S1, S2, etc)
8	Package Designator: C2 = DIP-26 C2E = enhanced DIP-26
9	Pin Type: S = solder pin; P = press-fit pin Pinout Revision Blank = original; Revision = 1-9
10	DBC Process Standard = Blank; T = Pre-applied TIM on the backside of the product
11	Lead Free Designator Suffix: G = Lead Free
*12	Internal usage only. They may or may not display on module depending on customer request.
*13	Internal usage only. They may or may not display on module depending on customer request.

**Product Marking**

TMPIM product will be marked in the way to trace the assembly and test site, time and lot number. The explanation of the part marking is shown in Figure 7.



**Figure 7. TMPIM Part Marking**

- Line 1: Device name
- Line 2: ZZZATYWW
- ZZZ: lot code
- AT: Assembly + Test site code
- YWW: Date Code
- 2D Barcode: 2DID mark <Lot#> <8 digit unit#>

**MODULE STORAGE AND TRANSPORTATION**

DIP-26 module has been qualified through low/high temperature storage, humidity and vibration test. Every the module has passed the high voltage (3000 V) isolation test. However, it is not recommended to store and transport under these extreme conditions.

Below conditions are recommended:

- Ambient temperature: 5°C ~ 40°C
- Relative Humidity: 10% ~ 75%

**SAFETY STANDARD**

TMPIM DIP-26 modules are certified according to UL1557 standard under C2 series. The isolation voltage is 2500 Vrms under 1minute type test. Before out of factory every TMPIM module product is tested at 3000 Vrms minimum 1 second.

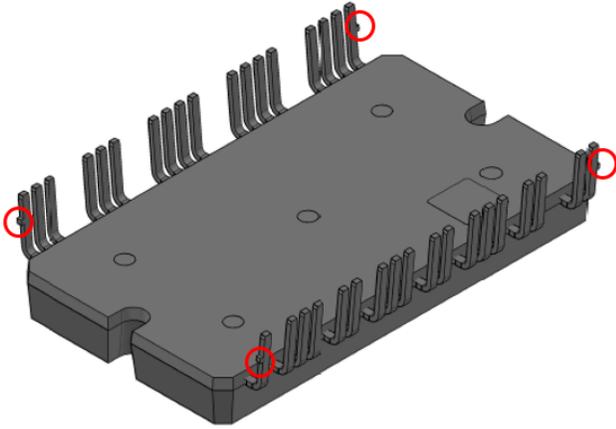


**Figure 8. Safety Standard**

**MODULE HANDLING**

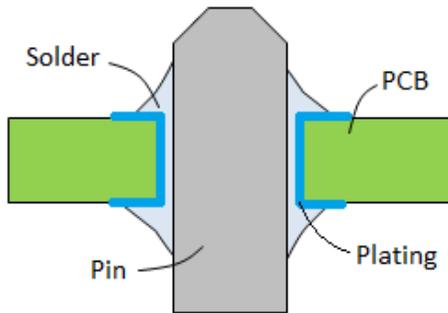
**PCB Tolerance, Design and Soldering**

DIP-26 has power connectors/terminals (max 52 pins) inline on two sides of the module. Electrical connection is made through attaching these terminals to the print circuit board (PCB) atop with solder. PCB can be further fixed onto heatsink with the screw and spacer with height at 12mm which is defined by four stopper at the most external pins, as shown in Figure 9. Soldering is recommended after mounting crew tighten, PCB installed and final inspection done – to reduce the residual stress.



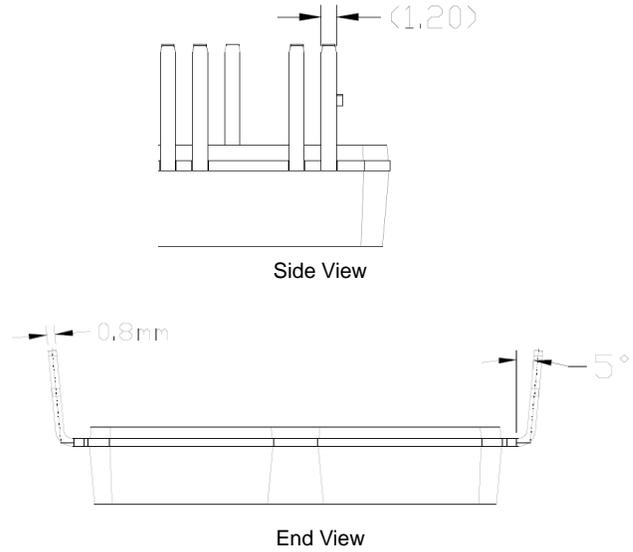
**Figure 9. Stopper to define the 12 mm Mounting Height**

PCB holes with fully plated inside will enable 100% wetting and fillet between pin and both sides of PCB as in Figure 10.



**Figure 10. Solder Wetting of PCB Through Hole**

The terminals in TMPIM is  $1.2 \text{ mm} \pm 0.05 \text{ mm}$  in length and  $0.8 \text{ mm} \pm 0.05 \text{ mm}$  in width as in Figure 11. All the terminals are plated with null tin and need plug in and be soldered to PCB. The terminal through hole on PCB should be slightly larger than 1.5 mm with consideration the PCB manufacturing tolerance.



**Figure 11. Terminal in TMPIM Module (Unit in mm)**

Wave soldering profile shown in Figure 12.

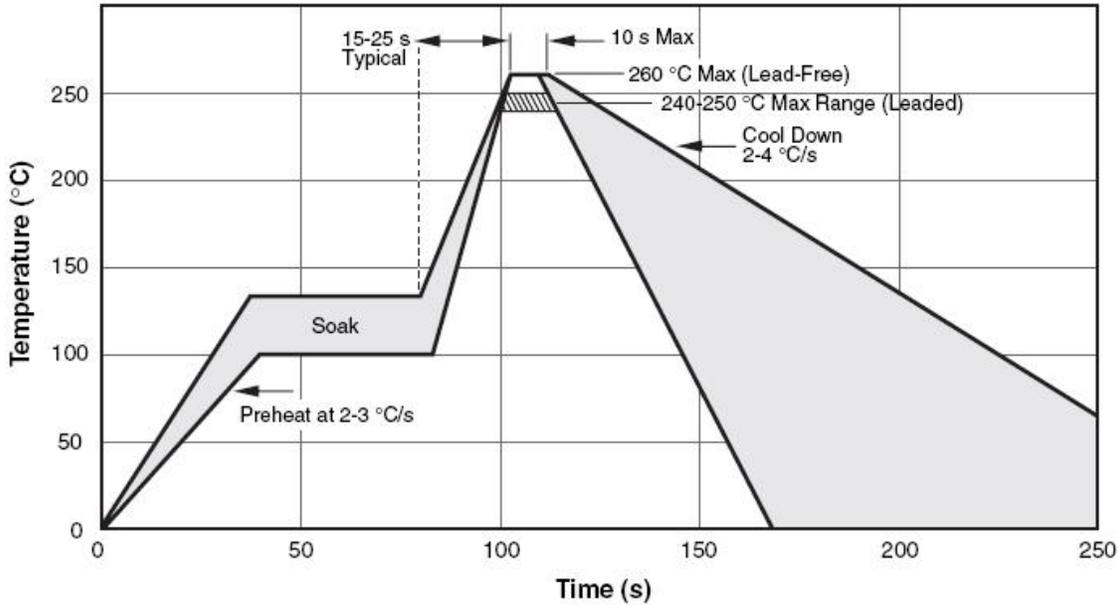


Figure 12. Profile for Wave Soldering

- Hand soldering
  - ◆ Solder iron temperature = 350°C (max).
  - ◆ Contact time = 10 sec (max).
  - ◆ Number of heat cycles = 3 (max).

**Thermal Grease Applying**

The backside of TMPIM module and surface of heatsink are not ideally smooth. TIM is used to reduce the contact air cavities and help the thermal dissipation. Such TIM material may be thermal pad, foil, grease, and any other similar. The material selection should consider the thermal conductivity,

dry out during aging, and shape maintaining/elastic property during power ON/OFF cycling. When applying thermal grease, the material needs be applied uniformly on the whole surface that contacts with module substrate. If module is reinstalled, thermal grease needs be applied again.

- Recommended thermal paste thickness for DIP-26 is 50–100 μm.

A good practice to apply thermal grease is through screen printing. An example of printing stencil used for TMPIM is shown in Figure 13. Based on viscosity of thermal grease, the honeycomb dimension could be slightly tuned.

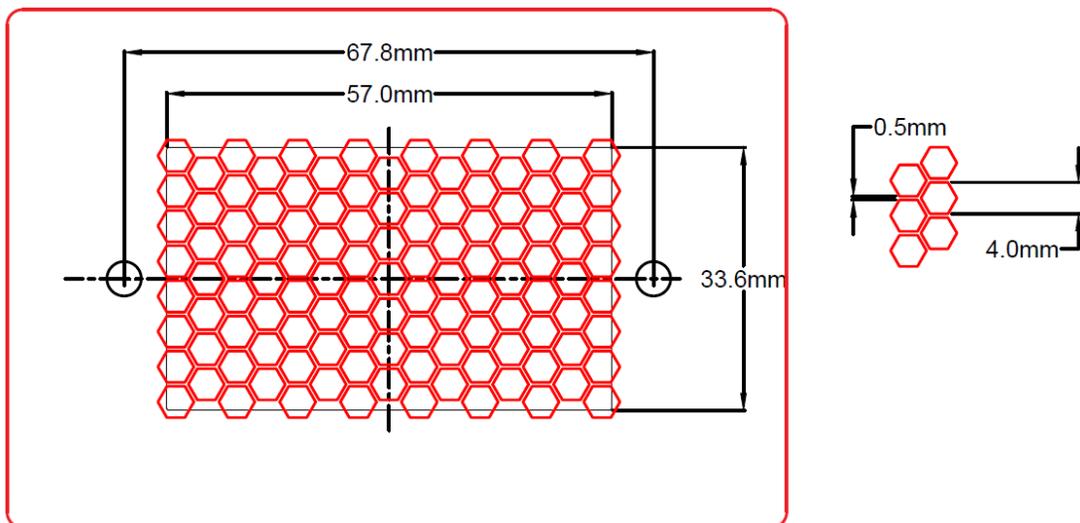


Figure 13. An Example of Grease Printing Stencil for TMPIM Module

**Heatsink Spec and Mounting**

The heatsink should have no contamination, unevenness, and burrs on the surface contacting with module.

- The roughness of heatsink surface need be less than 50 μm.
- Screw holes on heatsink need be countersunk.

The TMPIM module is mounted on the cooling plate/heatsink using mounting screw/washer. To achieve a better thermal dissipation contact, thermal interface material (TIM) is usually pre-applied on the surface of heatsink – some modules may have TIM pre-applied on the backside of the power module. To reduce the module stray inductance

During heatsink mounting, the screws should be half-tightened in both sides and sequentially fully tighten.

- Metric screw M4 with JIS B 1256 flat washers (D:9mm, d:4.8mm and t:0.8mm as in Figure 15)
- Mounting torque: Temporary tightening : 0.40 ~ 0.60Nm; Final torque 1.2-1.5 Nm ;
- The screw depth in heatsink > 6 mm

The procedure to mount PIM on a Heat Sink is shown in Figure 14.

1<sup>st</sup>: Tighten maintaining a left/right balance with temporary torque;

2<sup>nd</sup>: Finally tighten maintaining a left/right balance with final torque 1.2~1.5 Nm;

Thus mounting example is as: 1<sup>st</sup> ① → ②, 2<sup>nd</sup> ① → ②

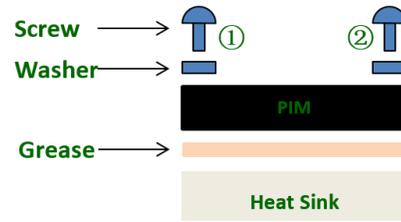


Figure 14. Mounting Sequence on Heatsink

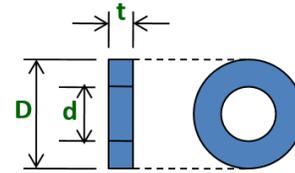


Figure 15. Size of Washer

**Temperature Monitoring (NTC, Thermal Coupler)**

TMPIM substrate/DBC temperature can be monitored through thermistor installed in the module. The thermistor has the characteristic of reducing resistance with increased temperature (negative temperature coefficient). As such, by retrieving the resistance (Ω) thru signal pickup circuit, the module substrate temperature can be looked up using the thermistor Resistance–Temperature curve in Figure 16.

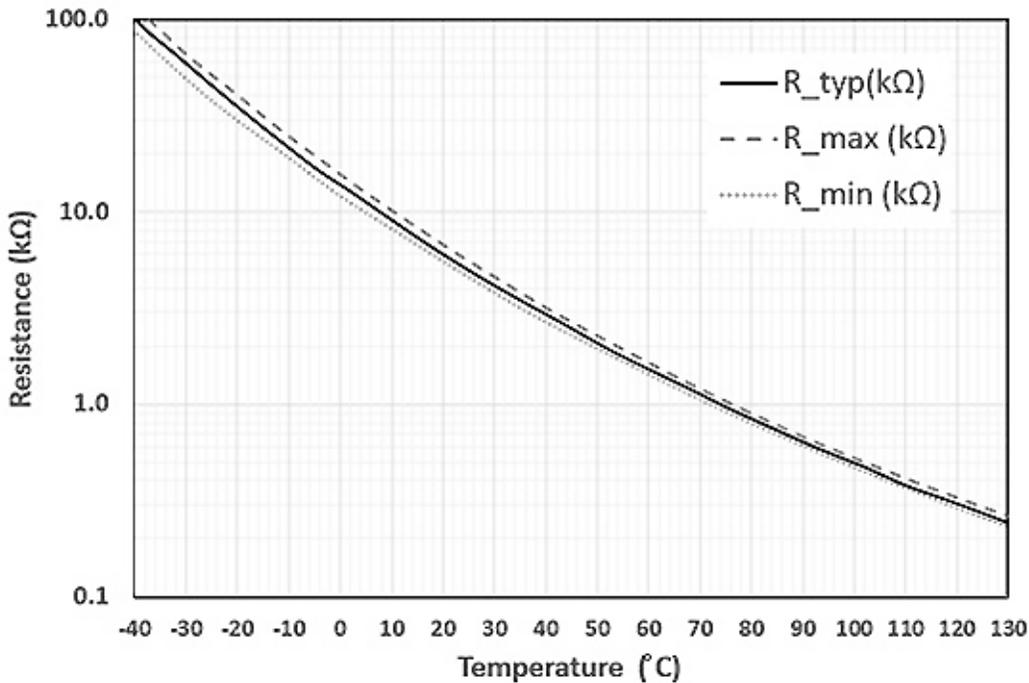


Figure 16. TMPIM Resistance–Temperature Curve

Alternatively, the thermistor resistance at given temperature,  $R(\theta)$  can also be calculated as,

$$R(\theta) = R_{25} \cdot e^{B \left( \frac{1}{T_2} - \frac{1}{T_1} \right)}$$

Where,

B: B-value of the thermistor as given in product datasheet.

For DIP-26 module,  $B(25/50) = 3375$  ;  $B(25/100) = 3433$

$T_2 = \text{Temp NTC} + 273.15 \text{ K}$

$T_1 = 298.15 \text{ K}$

$R_{25}$  is the rated resistance at  $25^\circ\text{C}$ . i.e.,  $R_{25} = 5 \text{ k}\Omega$

**Power Loss and Heat Dissipation**

There will be the voltage drop when there is certain level of current conducting in the IGBT/FRD and rectifier. The voltage drop is physically and design defined by the p-n junction band gap, resistivity modulation in drift region and die size. The power devices also need time to turn ON and OFF by injecting or eliminating the carries inside. This ON and OFF periods, representing in waveform, show both high current and high voltage generating power loss at each switching moment. For IGBT it is shown as  $E_{on}$  and  $E_{off}$

representing the energy consumed during turn on and turn off. For diode, it is shown as  $E_{rr}$  representing the energy to turn off the diode and sweeping off the carriers. The diode turn on energy is small and normally negligible for thermal evaluation.

Based on the electrical Data from product datasheet, we can simulate the power loss of the module at given working condition. The DC data will be used to calculate the conduction loss using voltage drop multiplying by current. The switching loss occurs at each switching moment. By accumulating the power loss at each moment, we can find the total power loss of the device.

With known the thermal resistance of the power devices, the temperature rise of the component can be calculated by multiplying power loss with thermal impedance. A module with low thermal resistance will dissipate heat out effectively, having higher output power capability when maximum operating temperature is defined.

A PTS tool can be provided upon request to customer for power loss and junction temperature simulation under desired working condition as in Figure 17.

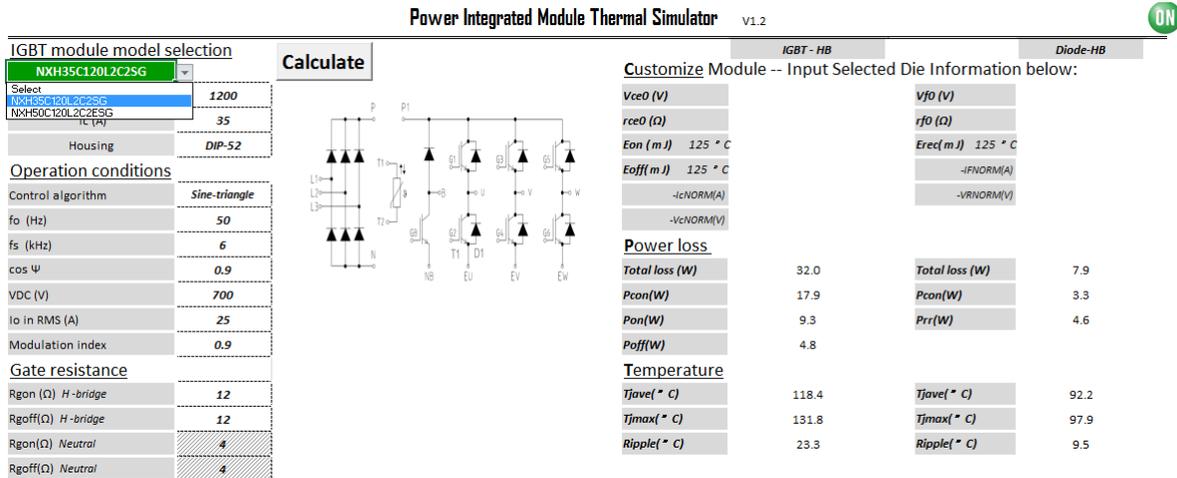


Figure 17. PTS Power Loss and Temperature Simulation Tool

PCB LAYOUT

PCB Reference Design and Evaluation Board

One reference PCB design for the 1200 V released CIB modules with pad size are shown in Figure 18.

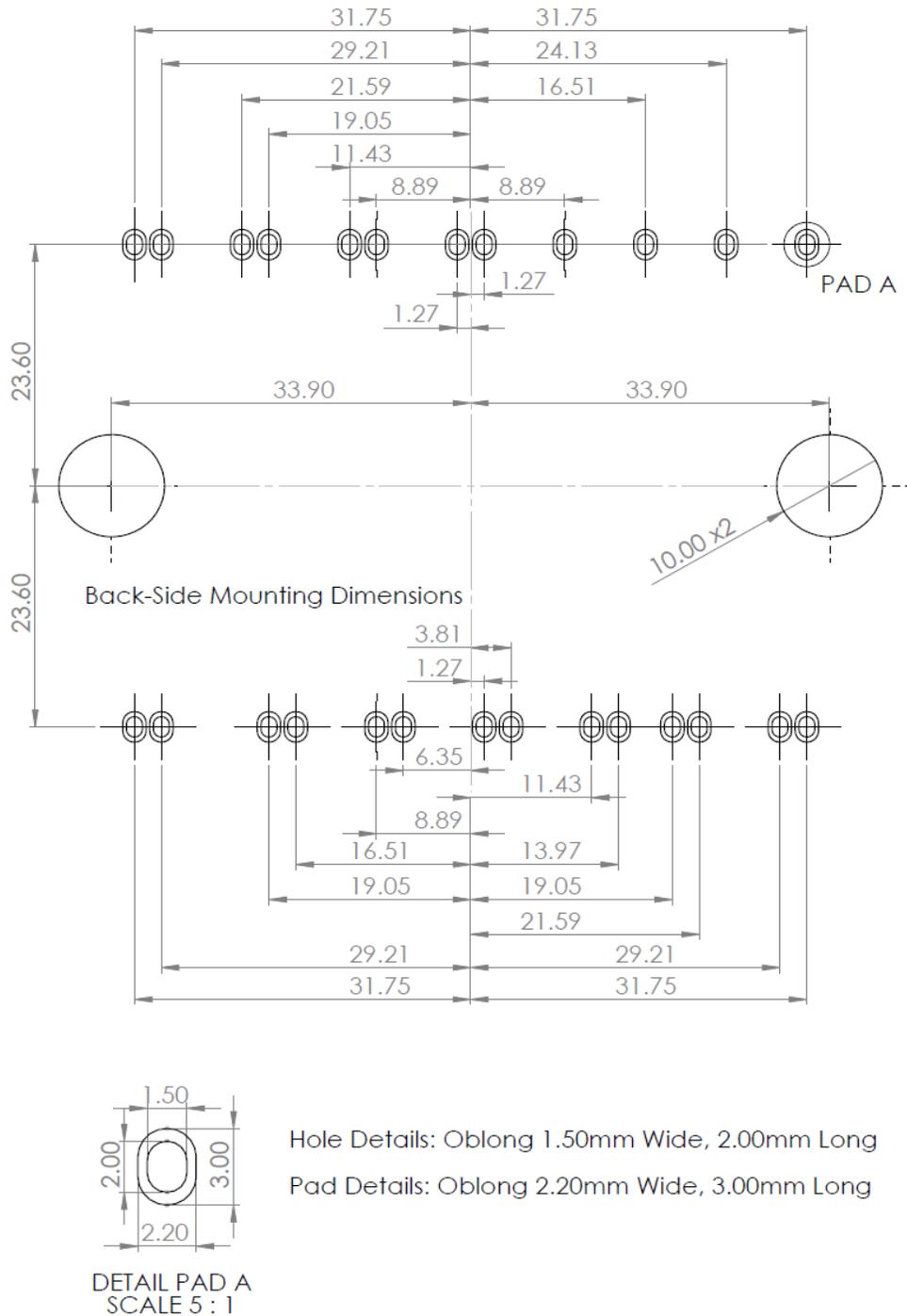


Figure 18. PCB Reference Design and Solder Pack

Interested customer can also find the TMPIM evaluation board reference design at [www.onsemi.com](http://www.onsemi.com). On this board, TMPIM module, the gate driver, current sensors, power

terminals and PWM signal connector are all integrated. The user can evaluate the TMPIM module performance with minimal effort by making a few wire connection.

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