Thermal Management of Delphi IPM series Power Modules

Introduction

The Delphi Series IPM non-isolated, fully integrated Point-of-Load (POL) power modules are the latest offerings from a world leader in power systems technology and manufacturing -- Delta Electronics, Inc. This product family works from a variety of wide range inputs and provides an easy-to-use single output in an industry standard, compact, IC-like, molded package. It is highly integrated and does not require external components to provide the point-of-load function. A copper pad on the back of the module; in close contact with the internal heat dissipation components; provides excellent thermal performance. The assembly process of the modules is fully automated with no manual assembly involved. These converters possess outstanding electrical and thermal performance, as well as extremely high reliability under highly stressful operating conditions. The IPM modules are available in either SMD or SIP packages.

This application note discuss the thermal management of Delphi IPM series power module which includes the thermal performance comparison of the two different packages, the copper pad enhancement in IPM power modules, and the enhancement from the different sized attachment area.

Heat transport in IPM power modules

There are three main heat transport mechanisms that are conduction, convection, and radiation. Figures 1 and 2 show the heat transfer in a typical SIP (single-in-line) packaged IPM module. There are 6 surfaces that can dissipate the heat through convection and radiation, and the copper pins can transfer the heat to the PWB mounted on by conduction.

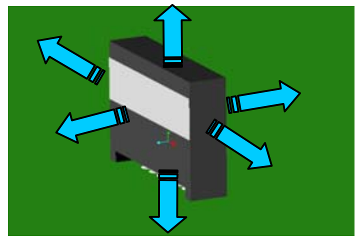


Figure 1: Heat transfer in SIP package by convection and radiation.

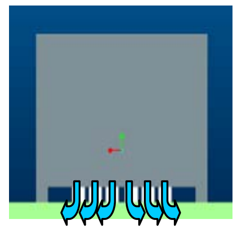


Figure 2: Heat transfer in SIP package through the pins to PWB mounted on by conduction.

For SMD packaged IPM module, it has 5 surfaces to dissipate the heat by convection and radiation as illustrated in Fig. 3 and conduction through the pins as shown in Fig. 4. The thermal performance will be worse than a SIP module without additional help. In order to improve the thermal performance of a SMD packaged IPM module, a copper pad is built into the back side of module which are in close contact with the internal heat dissipation components to provide enhanced thermal performance. Figure 5 shows this copper plate, it can improve the heat dissipation of conduction and subsequent enhance its thermal performance as shown in Figure 6.

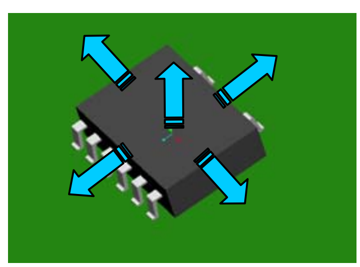


Figure 3: Heat transfer in SMD package by convection and radiation.

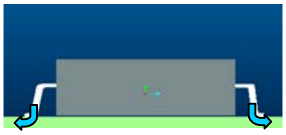


Figure 4: Heat transfer in SMD package through PWB by conduction.

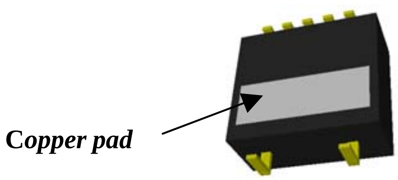


Figure 5: the built-in copper pad construction in the IPM module.

Figure 6: Heat transfer with built-in copper pad (conduction through copper pad).

The enhancement from the copper pad

Figure 7 shows the temperature profile of copper pad enhancement in the SMD packaged IPM module. The copper pad will give a lower thermal resistance, hence, improved thermal performance.

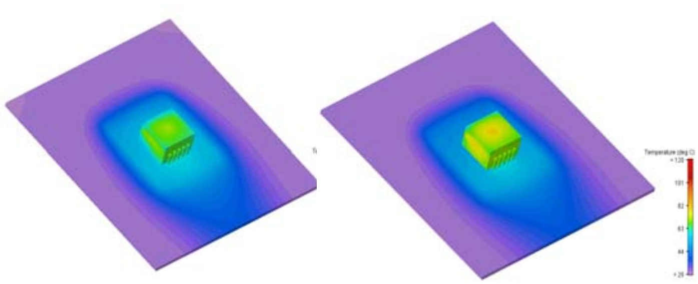


Fig. 7: Temperature profile of IPM module with copper pad (left) and without copper pad (right)

	With copper pad	Without copper pad
$R_{case\text{-}ambient}$ (℃/W)	12.9	15.8

Table 1: Thermal resistance of IPM module

The enhancement from larger sized PWB mounting area for SMD packaged IPM

With the built-in copper pad, larger sized PWB mounting area will further enhance the thermal conduction from power module to PWB and lower temperature of IPM power module.

Table 2 shows the mounting area in PWB for following thermal calculation. To simplify the calculation, 1x, 4x, and 9x of IPM module footprint are used for calculation and thermal characterization. The test panels are 6 layers of 2 oz copper each layer. Copper area is embedded in the PWB with no exposed bare copper on the surface of the PWB. Figure 8 shows the test panels with larger sized mounting area underneath the IPM modules.

Test panels type	Copper trace area (mm^2)
1x module area	361
4x module area	1444
9x module area	2916

Table 2: PWB mounting area in 1x, 4x, and 9x of module footprint.

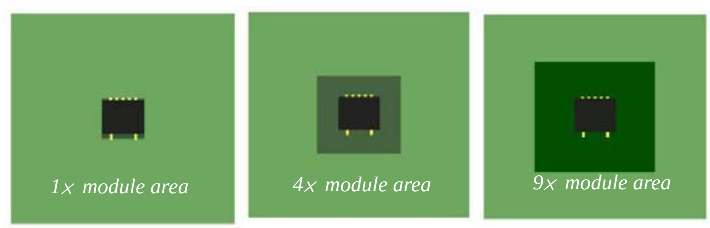


Fig. 8: IPM module on test panels with larger sized mounting area.

	IPM power module
Power dissipation	2.5W
Air velocity	100 LFM
Ambient temperature	25℃

Table 3: Input parameters used for following thermal simulation.

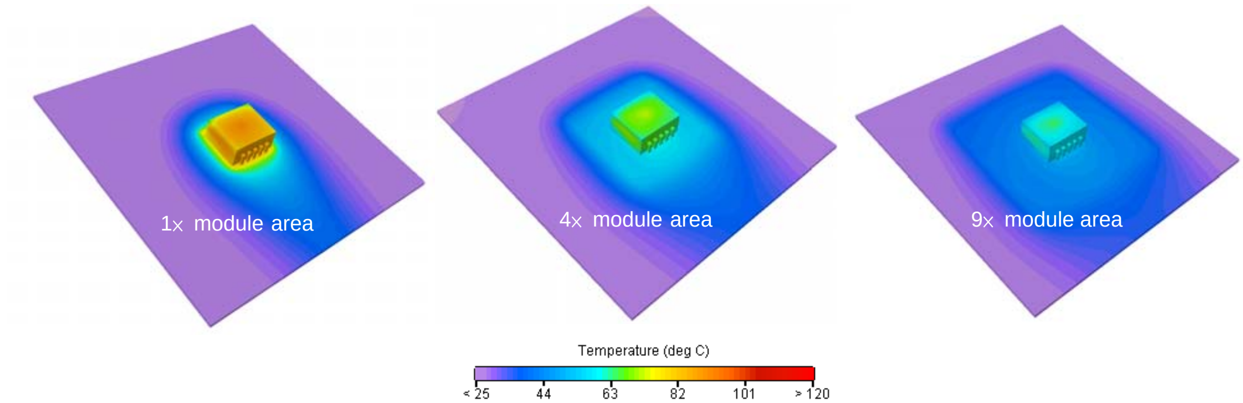


Figure 9: temperature profile with different mounting area

Table 4 below shows the effective thermal resistance as we increase the mounting area underneath the IPM module at 1x, 4x, and 9x of the IPM footprint. Figure 10 shows this reduction of thermal resistance as the mounting area increases.

	1x module area	4x module area	9x module area
$R_{case-ambient}$ (℃/W)	20.9	12.9	10.7

Table 4: Effective thermal resistance of power module ($R_{case-ambient}$) with different PWB mounting area.

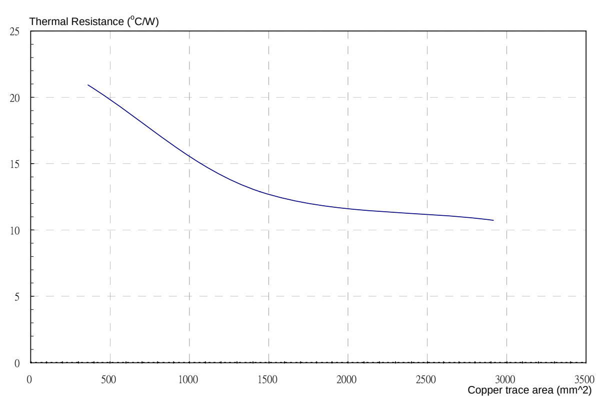
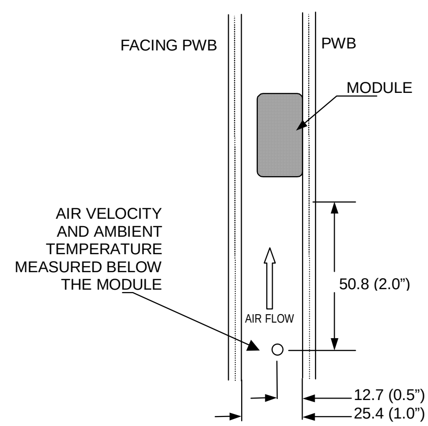


Figure 10: Thermal resistance vs. mounting area

Thermal characterization setup

Delta's DC/DC power modules are characterized in heated horizontal and vertical wind tunnels to simulate the thermal environments encountered in most electronics equipment.

Figure 11 shows the wind tunnel characterization setup. The power module is mounted on a test PWB and is vertically positioned within the wind tunnel.



Note: Wind Tunnel Test Setup Figure Dimensions are in millimeters and (Inches)

Figure 11: Wind tunnel setup, dimensions are in millimeters and (inches)

Test fixtures for various IPM packages

Figure 12 shows the test panels for SIP and SMD IPM modules. The test panels are 6 layers of 2 oz copper each layer. Copper area is embedded in the PWB with no exposed bare copper on the surface of the PWB.

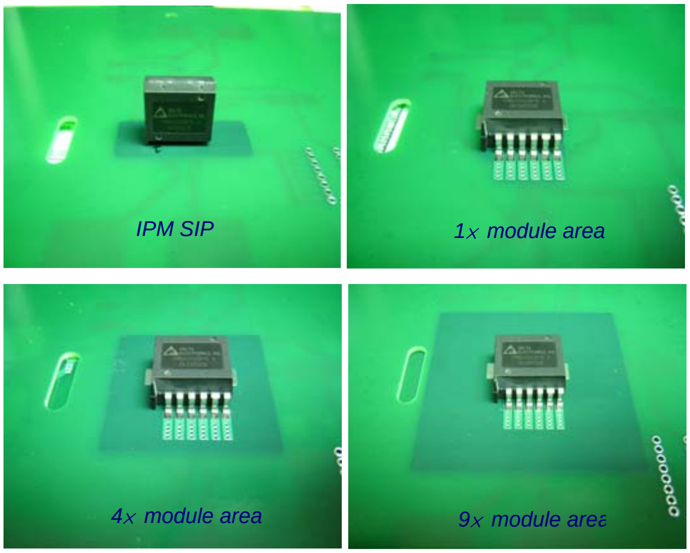


Figure 12: test panel for SIP and SMD IPM modules.

The thermal performance comparison for IPM12S series (SIP and SMD type)

Figure 13 below shows the output current versus ambient temperature for a 12V input, 5V, 8A output IPM module in SIP and SMD packages mounted on various sized PWB copper area. Figure 13 indicates the larger PWB mounting area for SMD packages will help to more output current at higher ambient temperatures. For actual derating curves without the larger copper area, please refer to the datasheet thermal section.

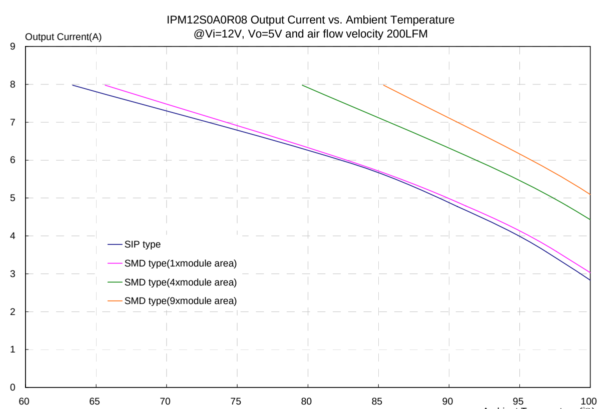


Figure 13: Output current vs. ambient temperature @ 200LFM for 12V input, 5V output IPM module.

Table 5: Thermal resistance for various mounting PWB area and different air flow.

Soldering copper area	$R_{case-ambient}$ (℃/W)			
	Natural	100LFM	200LFM	400LFM
1x module area (361 mm^2)	22.34	18.74	14.87	11.08
4x module area (1444 mm^2)	17.79	14.36	11.59	8.39
9x module area (2916 mm^2)	15.37	12.73	10.59	7.85

Table 5 shows the thermal resistance at several air flow velocity and PWB mounting copper area. The results are also plotted in Figure 14.

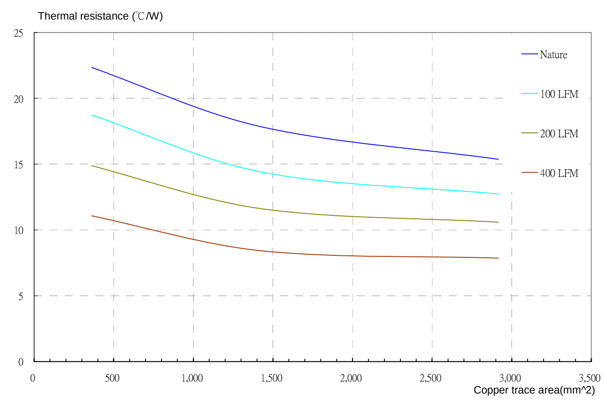


Figure 14: Thermal resistance vs. PWB mounting area at different airflow.

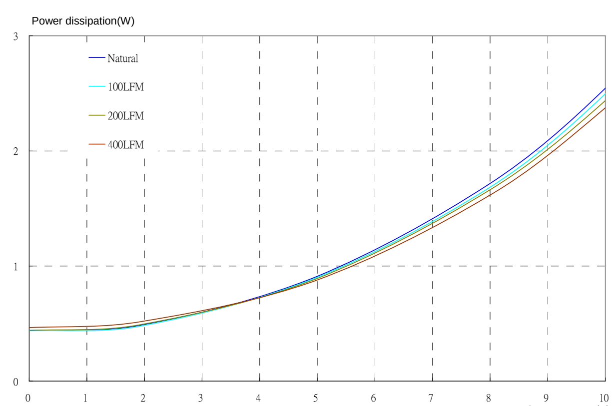


Figure 15: Power dissipation versus output current for IPM04S, 3V-5.5V input IPM modules

Application example using above curves

What is the minimum PWB mounting area necessary for an IPM power module, operating at Vi=5V, Io=10A, 63℃ ambient temperature and an airflow of 100LFM?

Solution:

Given: Vi=5V; Io=10A
Air flow velocity=100LFM
Max ambient temperature=63℃

Determine Pd (Use Figure 15), Pd=2.5W

And we know IPM04S hot spot case temperature can not be over 113℃ (from datasheet).

Determine Thermal Resistance Rc-a
Rc-a=(Tc-Ta)/Pd
Rc-a=(113-63)/2.5=20℃/W
So the minimum copper trace area is 500mm^2 (Use Figure 14)

Authors: Norman Hsu, Allen Hsieh, Steve Chen

CONTACT: www.delta.com.tw/dcdc

USA:
Telephone:
East Coast: (888) 335 8201
West Coast: (888) 335 8208
Fax: (978) 656 3964
Email: DCDC@delta-corp.com

Europe:
Telephone: +41 31 998 53 11
Fax: +41 31 998 53 53
Email: DCDC@delta-es.tw

Asia & the rest of world:
Telephone: +886 3 4526107 x 6220
Fax: +886 3 4513485
Email: DCDC@delta.com.tw

Printed in Taiwan
February 2005, AN-305