

AN-2026 The Effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER® Power Modules

ABSTRACT

This application report focuses on the low current modules that come in a 7 lead, 10.16 x 4.57 x 9.81 mm package.

Contents

1	Summary	2
	What Determines θ _{JA}	
	Parametric Study	
	Thermal Measurement and Simulation	
5	Conclusion	8

List of Figures

1	Thermal Management of the SIMPLE SWITCHER Power Module on a 4-Layer PCB	3
2	Effect of Cu Area on Top and Bottom Layers of 4-Layer PCB	4
3	Effect of PCB Size of 4-Layer PCB	5
4	Effect of Cu Area on Top and Bottom Layers of 2-Layer PCB	6
5	Effect of Airflow for Two PCBs	7
6	Effect of Heatsink	8

SIMPLE SWITCHER is a registered trademark of Texas Instruments. All other trademarks are the property of their respective owners. Summary

1 Summary

The SIMPLE SWITCHER® power modules use a TO-PMOD package similar to a TO-263. This package has excellent thermal performance enabled by an exposed pad that can be soldered to the PCB. The key thermal characteristics are:

- $\theta_{\rm JC} = 1.9^{\circ} {\rm C/W}$
- θ_{JC} 21.6°/W (On a 4-layer thermal board)

2 What Determines θ_{JA}

In order to understand how a PCB's thermal performance determines the thermal resistance (θ_{IA}) of a power module mounted on the PCB, a brief analysis for θ_{μ} is given as follows. There are two heat dissipation paths, that is, Junction-PCB-Ambient and Junction-PKG surface-Ambient. Because the two paths are in parallel, θ_{JA} can be expressed as:

$$\theta_{JA} = (\theta_{JCA} \times \theta_{JTA})/(\theta_{JCA} + \theta_{JTA})$$

 θ_{JCA} is the thermal resistance from junction to ambient through the PCB and θ_{JTA} is the thermal resistance through the package surface to ambient (mainly package top). For the situation where no heat sink is applied on the package top, 95% or more of the power dissipates through the PCB, meaning that θ_{IA} is dominated by θ_{JCA} (also meaning that θ_{JTA} is much bigger than θ_{JCA}). As a result, θ_{JA} can be simply expressed as:

$$\theta_{JA} = \theta_{JCA} - R_{JTA} = \theta_{JC} + \theta_{CA} - R_{JTA}$$

 θ_{CA} is the thermal resistance from package bottom case to ambient through the PCB. It is mainly dependent on the thermal conductivity of the PCB and the thermal connection between the package and the PCB. R_{JTA} gives a small reduction of θ_{JA} caused by the power dissipation through the package top.

So, it is seen from the equation above that on any given board, the small $\theta_{\rm sc}$ and large exposed thermal pad should make the power module better in thermal performance than other package types. For example, LGA packages have a θ_{JC} of about 5°C/W or larger for the similar package size, depending on the copper and thermal vias in its substrate.

3 **Parametric Study**

In order to optimize the PCB design to get the best thermal performance out of the SIMPLE SWITCHER power module and to understand the effect of environmental conditions, this application report analyzes how some factors affect the thermal performance of a PCB or the θ_{JA} of a package mounted on it. These factors include:

- Size of direct thermal attachment pad
- Copper layers (2 or 4 layers)
- PCB size
- Air flow
- Heat sink

Figure 1 shows these factors schematically.

For the parametric study, the above factors were varied as follows:

- The sizes of copper area on top and bottom layers include:
 - Copper Area = DAP size (8.5x5.4mm)
 - Copper Area = Package body size (10x10mm)
 - Copper Area = 2 X package body size (20x20mm)
 - Copper Area = Full copper layer (4 solid copper layers)
- 2 layer and 4 layer boards
- The PCB size varies from 4"x3" (102x76mm) to 1.5"x1.5" (38x38mm)
- The air flow includes Natural Convection, 200LFPM, and 400LFPM
- The heat sink may be on the package top or on the PCB bottom side

(1)

(2)

www.ti.com

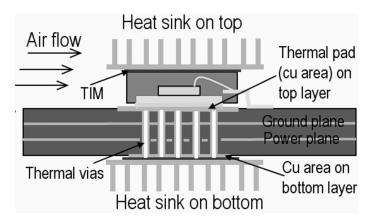


Figure 1. Thermal Management of the SIMPLE SWITCHER Power Module on a 4-Layer PCB

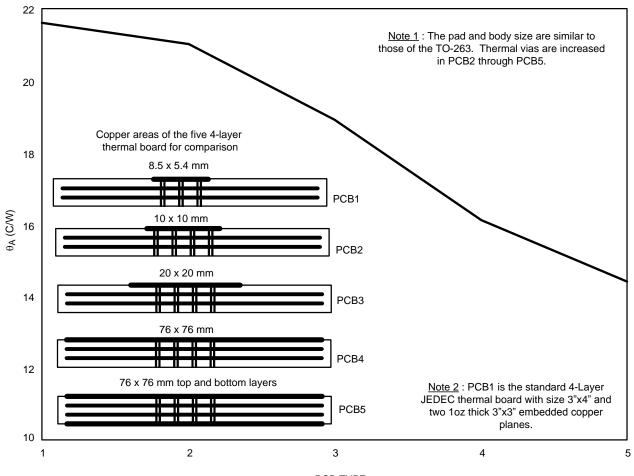
4 Thermal Measurement and Simulation

The thermal performance of the module on a 4-layer evaluation board is measured. This is used to validate our thermal model for the parametric study. The 4-layer evaluation board is 3"x1.75" with a thickness of 1.6mm and 4 solid copper layers of 1oz thickness. Thermal simulations are carried out using CFD software Flotherm, where ambient temperature is 25°C and power dissipation is 1.82W. The thermal model is validated by comparing measured and simulated data. Finally, a parametric study for the previously mentioned five factors is done using the validated simulation model. The results are plotted in Figure 2 through Figure 6Figures 2-6.

- **NOTE:** θ_{JC} is the junction-to-case thermal resistance, which characterizes the thermal performance of package itself, and can be used to rate different packages.
- **NOTE:** θ_{JA} is the junction-to-ambient thermal resistance, which is used to evaluate the thermal performance of a package in an application environment.



www.ti.com



PCB TYPE

Figure 2. Effect of Cu Area on Top and Bottom Layers of 4-Layer PCB





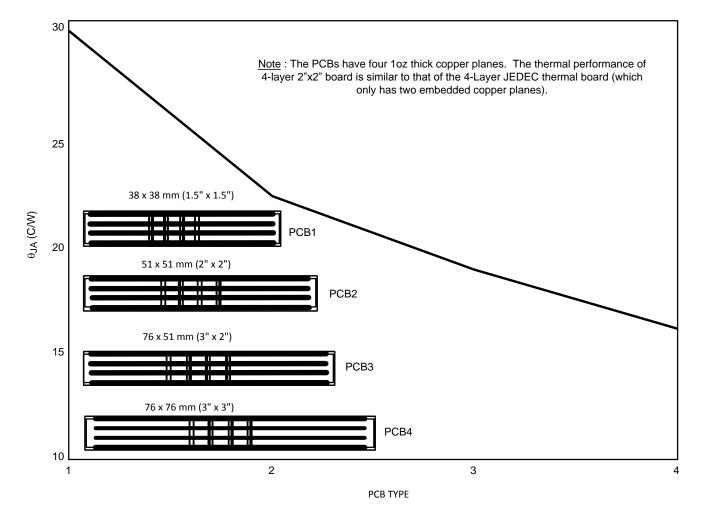


Figure 3. Effect of PCB Size of 4-Layer PCB



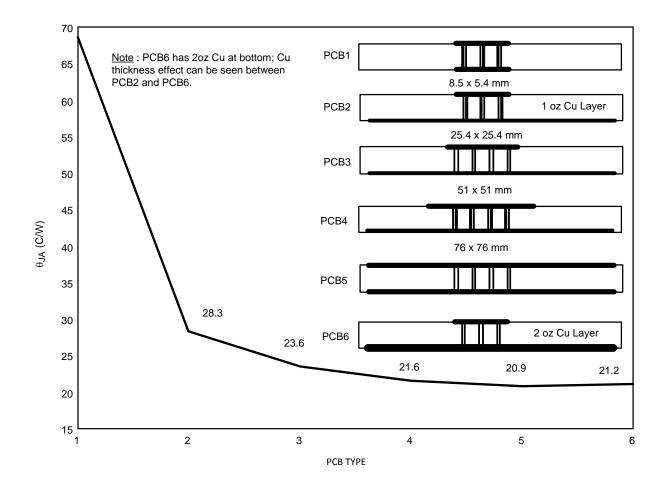


Figure 4. Effect of Cu Area on Top and Bottom Layers of 2-Layer PCB





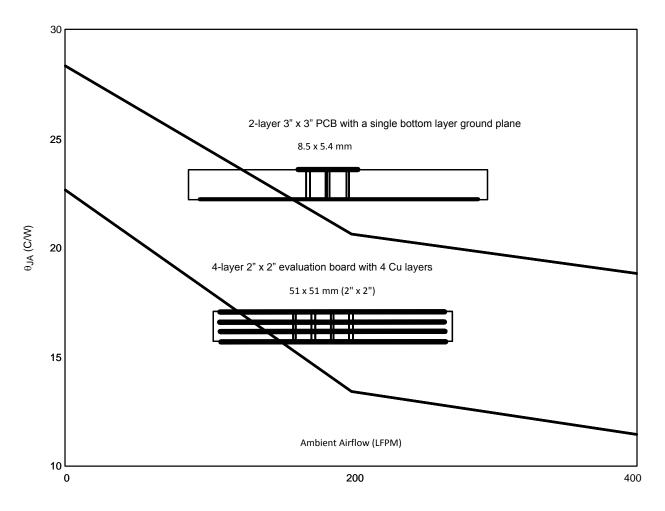


Figure 5. Effect of Airflow for Two PCBs

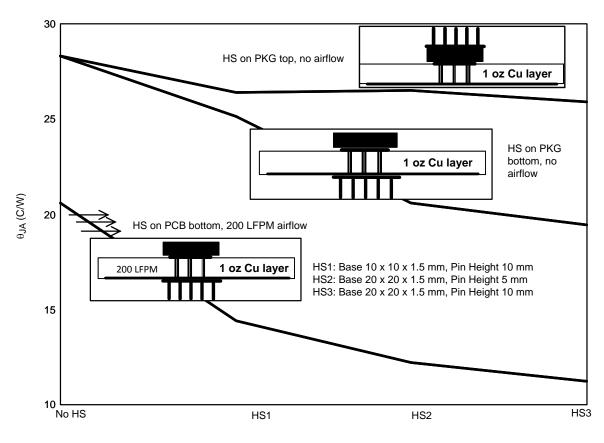


Figure 6. Effect of Heatsink

5 Conclusion

8

The TO-PMOD package has excellent thermal performance, as demonstrated by its low θ_{JA} and θ_{JC} . The thermal performance of any package strongly depends on its application environment. But how well a package can take advantage of a high thermal conductivity PCB is determined by the package itself, that is, its θ_{JC} and its exposed pad size. The TO-PMOD package module has been optimized on both sides, giving excellent thermal performance. For a specific application, users of the SIMPLE SWITCHER power module can refer to the results of the parametric study plotted in Figure 2 - Figure 6 to quickly estimate the real θ_{JA} and evaluate the maximum power dissipation that the device can handle. Note that the effect of other heating sources on the same PCB is not considered in this thermal analysis. So, a system level simulation may be needed when other complicated factors are involved. For this purpose, a Flotherm model is available upon request.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have *not* been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		Applications		
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive	
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications	
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers	
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps	
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy	
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial	
Interface	interface.ti.com	Medical	www.ti.com/medical	
Logic	logic.ti.com	Security	www.ti.com/security	
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense	
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video	
RFID	www.ti-rfid.com			
OMAP Applications Processors	www.ti.com/omap	TI E2E Community	e2e.ti.com	
Wireless Connectivity	www.ti.com/wirelessconnectivity			

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2013, Texas Instruments Incorporated