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.

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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:

- θ_{JC} = 1.9°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_{JA}) of a power module mounted on the PCB, a brief analysis for θ_{JA} 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:

$$\theta_{JA} = (\theta_{JCA} \times \theta_{JTA})/(\theta_{JCA} + \theta_{JTA}) \quad (1)$$

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_{JA} 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:

$$\theta_{JA} = \theta_{JCA} - R_{JTA} = \theta_{JC} + \theta_{CA} - R_{JTA} \quad (2)$$

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 θ_{JC} 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

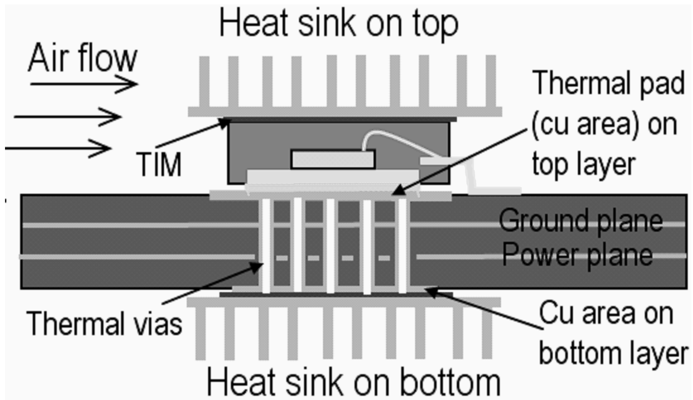

Figure 1. Thermal Management of the SIMPLE SWITCHER Power Module on a 4-Layer PCB

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.

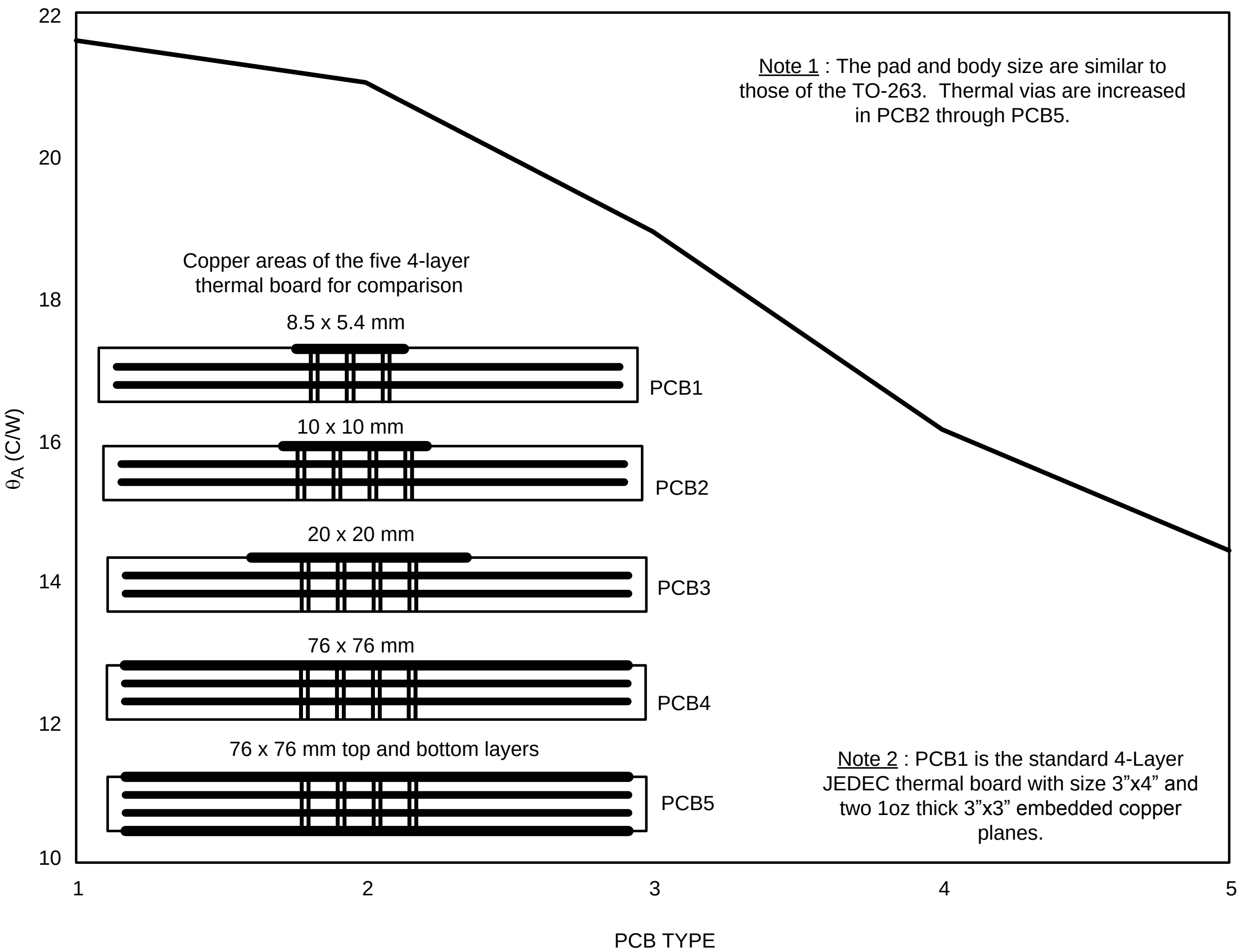

Figure 2. Effect of Cu Area on Top and Bottom Layers of 4-Layer PCB

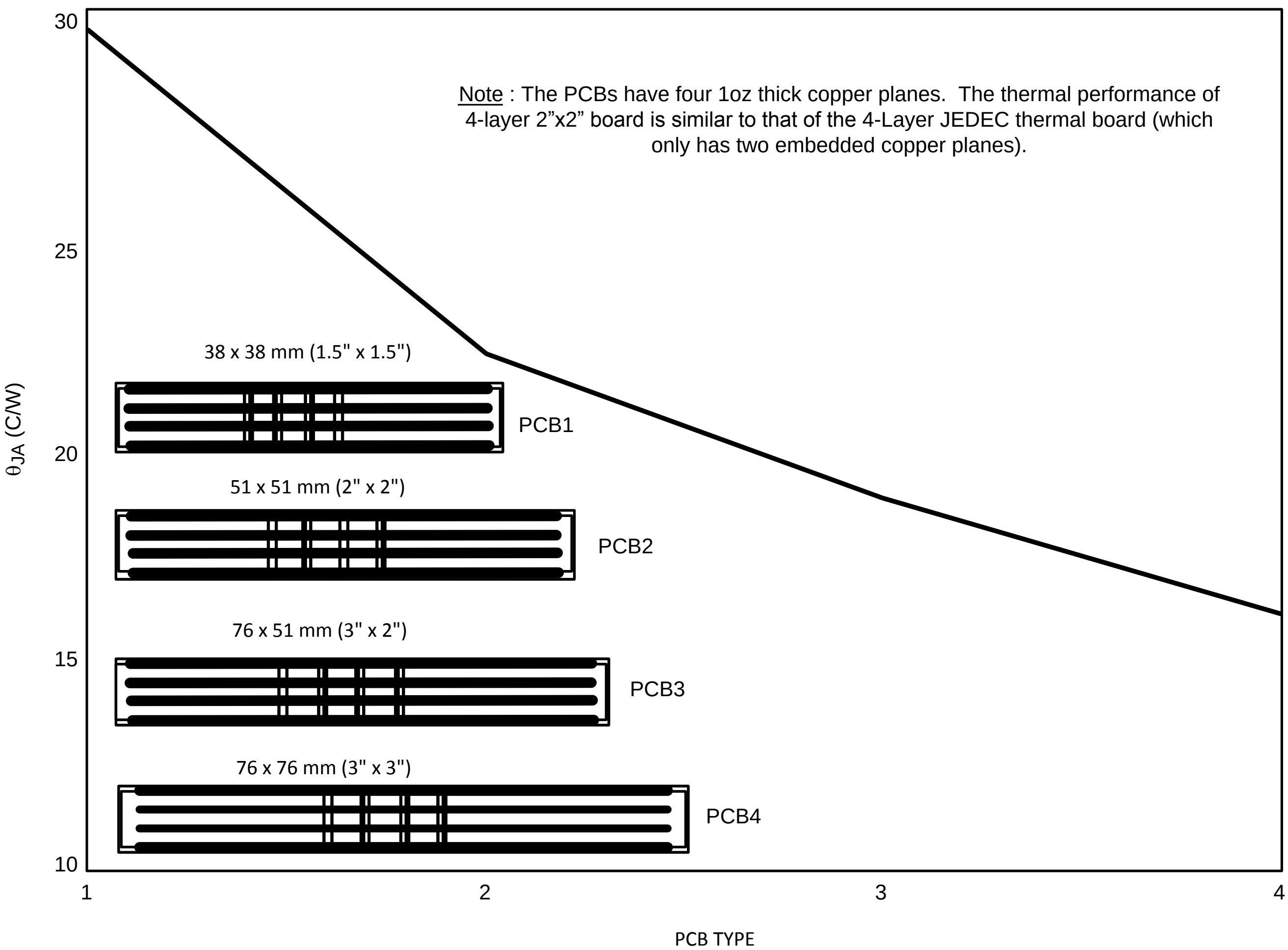

Figure 3. Effect of PCB Size of 4-Layer PCB

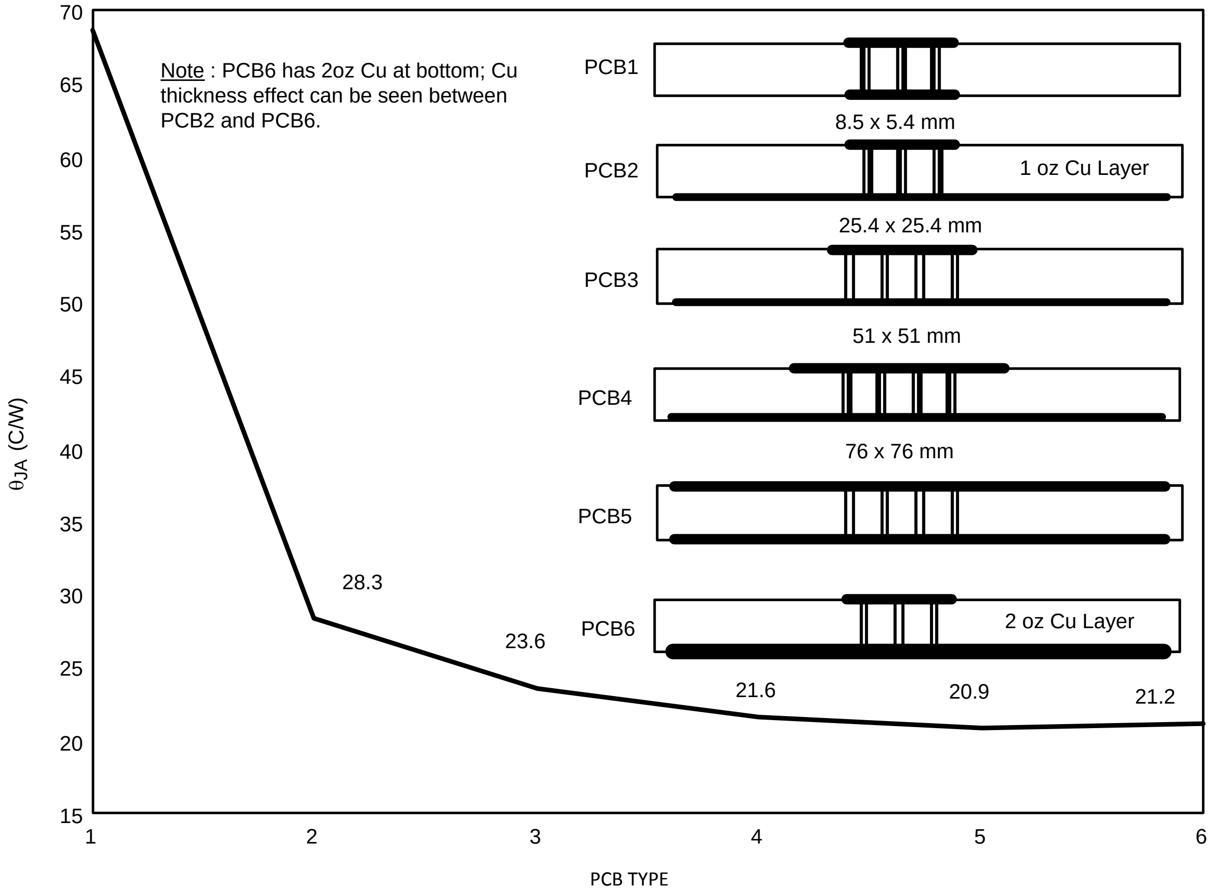

Figure 4. Effect of Cu Area on Top and Bottom Layers of 2-Layer PCB

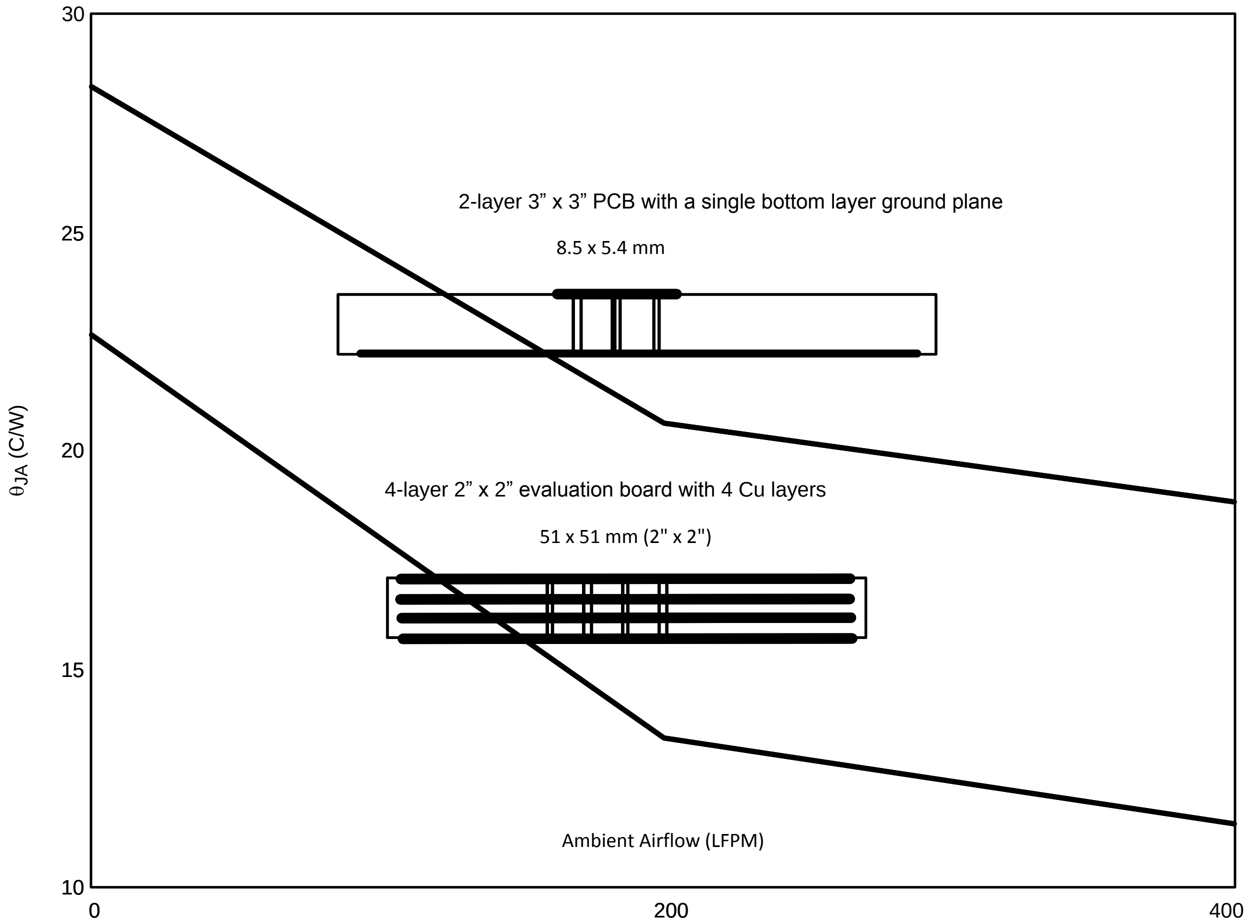

Figure 5. Effect of Airflow for Two PCBs

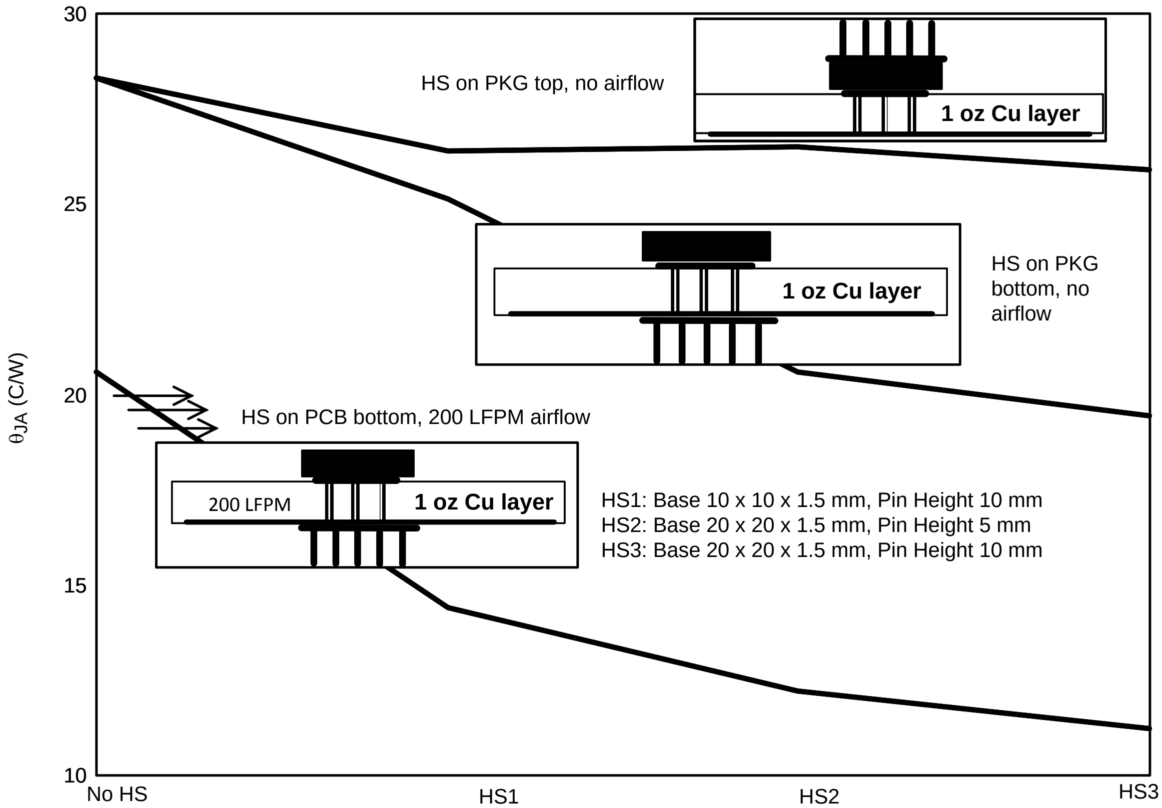

Figure 6. Effect of Heatsink

5 Conclusion

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.