Application Brief

Achieving High Thermal Performance in Compact Buck Power Modules

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Modern communications equipment, personal electronics, and test and measurement equipment require highly-efficient, ultra-compact, and low-profile power solutions. Power modules with integrated passives provide customers with a smaller total solution size and ease the effort of power supply design.

However, modules suffer from extra heat generated by losses in the integrated inductor, and typically have a lower output current capability at high temperatures. Minimizing thermal resistance through good module package design is critical in enabling power modules to be as thermally effective at higher temperatures as their larger discrete counterparts.

The TPSM82822 is an example of a high thermal -performance step-down MicroSiP™ power module. It integrates the power inductor and supports output currents up to 2 A. The module is manufactured by first embedding the IC (integrated circuit) inside a PCB laminate substrate, and then mounting the inductor on top of the PCB laminate. Figure 1 shows the power module.

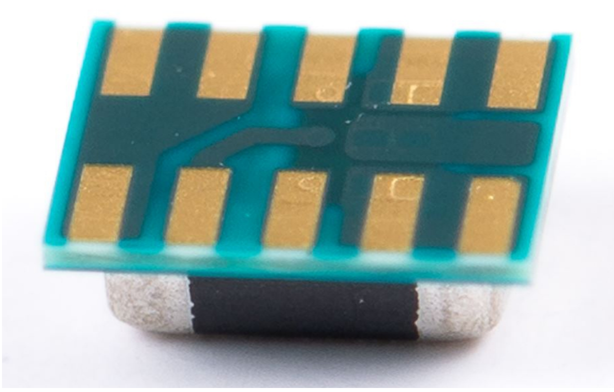

Figure 1. TPSM82822 Power Module

Thermal Performance

Power modules typically have the inductor mounted on top of the package. Due to this, in addition to the IC losses, the heat generated from the direct current resistance (DCR) and core losses in the inductor add to the total power dissipated in the package. Under the same operating conditions as a larger discrete solution, in which the IC and the inductor are side by side, the module has the challenge of dissipating more heat through a smaller surface area. This results in a significant temperature increase of the IC within the module, which worsens at high load currents where the amount of power dissipated within the module rises. Since the temperatures of both the inductor and IC have maximum-rated values, there is a limitation on the maximum output current that modules can deliver at higher ambient temperatures.

In order for modules to be competitive with discrete solutions in terms of efficiency and maximum deliverable output currents, it is important that the module solution has a low junction-to-ambient thermal resistance ($R_{ΘJA}$). $R_{ΘJA}$ is a measure of how easy it is to move the heat of the module to the ambient environment. $R_{ΘJA}$ is a measure of thermal performance.

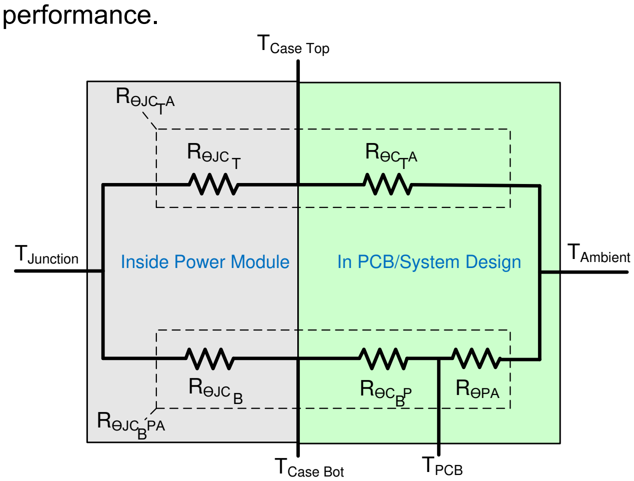

Figure 2. Thermal Resistance from Junction to Ambient

$R_{ΘJA}$ is comprised of two parallel thermal resistance paths: 1) Junction to case top – case top to ambient (represented as $R_{ΘJC_TA}$) and 2) Junction to case bottom – case bottom to PCB – and PCB to ambient (represented as $R_{ΘJC_BPA}$).

$$R_{\theta JA} = \frac{R_{\theta JC_T A} \times R_{\theta JC_B PA}}{R_{\theta JC_T A} + R_{\theta JC_B PA}} \quad (1)$$

Since most of the heat of the module is dissipated through $R_{\Theta JC_B PA}$ with little heat being dissipated through the top of the module, $R_{\Theta JA}$ can be approximated to be equal to $R_{\Theta JC_B PA}$.

$$R_{\theta JA} \approx R_{\theta JC_B PA} = R_{\theta JC_B} + R_{\theta C_B P} + R_{\theta PA} \quad (2)$$

where, $R_{\Theta JC_B}$ is the junction to case metal pad thermal resistance, $R_{\Theta C_B P}$ is the thermal resistance from case metal pad to PCB and $R_{\Theta PA}$ is the thermal resistance from PCB to ambient.

$R_{\Theta JC_B}$ is minimized during module package development and care should be taken to minimize $R_{\Theta C_B P}$ and $R_{\Theta PA}$ during PCB design and layout. Adding ground planes, increasing copper layer thickness, and adding vias beneath exposed thermal pads are some of the ways to improve thermal performance through PCB design.

Table 1 compares the $R_{\Theta JA}$ of the module TPSM82822 with the discrete IC of TPS62822. It can be seen that the module has around 20% lower $R_{\Theta JA}$ compared to the discrete solution on a high-K (JEDEC 51-7) PCB.

Table 1. Junction-to-Ambient Thermal Resistance ($R_{\Theta JA}$)

THERMAL PARAMETER	TPS62822	TPSM82822
$R_{\Theta JA}$	114.1	92.5

Choosing the right inductor also plays an important role in the module performance. The integrated inductor in the TPSM82822 module is chosen based on small size, low DCR, and low core losses.

Output Current Capability

Figure 3 shows the maximum output current that the TPSM82822 can deliver safely at a 1.2-V output voltage for various ambient temperatures and input voltages when used on the TI EVM board. This current is limited by a maximum inductor and junction temperature of 125°C. The TPSM82822 is able to deliver the rated 2-A current at 85°C for input voltages above 2.7 V.

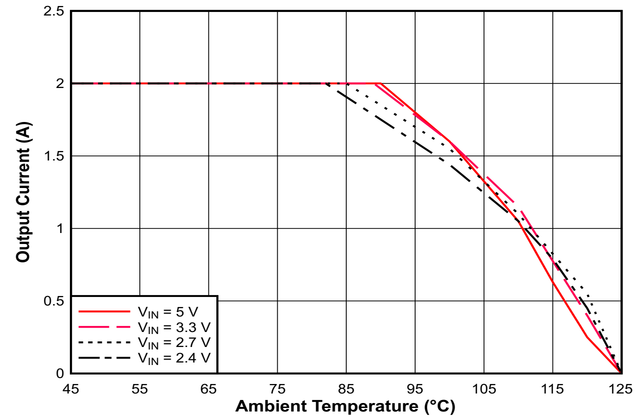

Figure 3. Safe Operating Area of TPSM82822

Conclusion

Power modules, like the TPSM82822, offer a high power density solution with less design effort compared to discrete solutions. The TPSM82822 is also currently the industry's smallest 2-A module, measuring just 2 mm × 2.5 mm × 1.1 mm tall. Choosing the right integrated inductor, along with a good thermal design of the power module package, benefits power modules in performance parameters like efficiency and safe operating area of output current.