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# AN-9082

## Motion SPM® 5系列接触压力的热性能信息

### 概述

对于半导体器件而言，最敏感的因素是结温。随着结温升高，器件的工作特性也随之改变，故障率呈指数级上升。这使得封装的热设计在器件的开发阶段以及应用中，都成为一项十分重要的因素。

为了深入理解器件的热性能，标准做法是引入热阻概念。热阻可定义为两个邻近等温面之间的温差与它们之间传递总热量的比值。对于半导体器件，两个重要的温度是结温 $T_J$ 和参考温度 $T_x$ 。热量为器件工作时的功率耗散。参考点的选取是任意的，但是通常会选择散热片所附器件背面热量最集中的点。这个被称为结至壳热阻， $R_{\theta JC}$ 。当参考点为周围环境温度时，就被称为结至环境热阻， $R_{\theta JA}$ 。这两个热阻都用于描述器件的热性能。 $R_{\theta JC}$ 通常用于安装了散热片的器件，而 $R_{\theta JA}$ 图 1则用于其他情况。显示的是一个热网络，其中热量从Motion SPM®产品的结至环境处流出，包括散热片的热量。鉴于热阻过大，虚线表示的器件 $R_{\theta CA}$ 可以忽略。

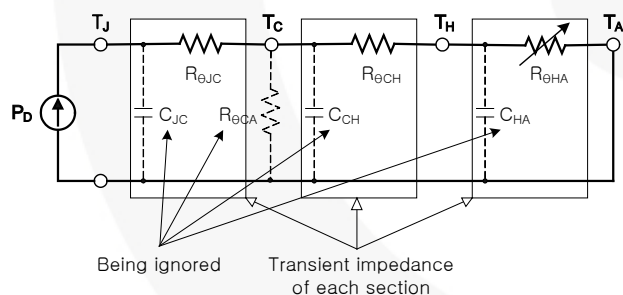


图 1. 带散热片的瞬态热等效电路

Motion SPM 5系列的封装没有任何螺孔，如图 2所示。

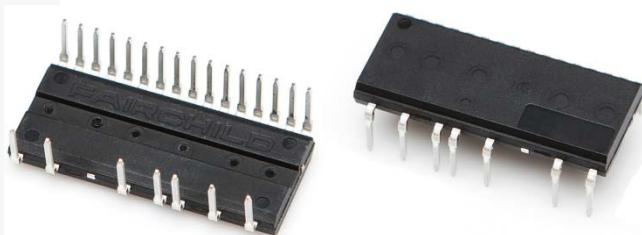


图 2. Motion SPM 5系列封装尺寸

在该器件应用中，芯片组壳体使用了散热片，如图 3所示。



图 3. Motion SPM 5系列芯片组配置

对于仿真模型，图 3可如图 4中所示的那样转换。器件表面和芯片组壳体之间存在热接口材料（TIM，如导热盘）。

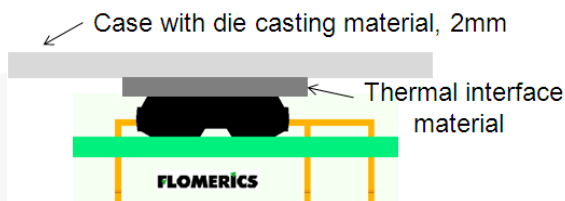


图 4. 热仿真模型

参考点为芯片组壳体温度时，这被称为结至芯片组外壳热阻 $R_{\theta JS}$ 图 5。显示的是热量从Motion SPM 5系列的结至芯片组外壳流出的热网络，包括一个TIM。 $T_J$ 表示TIM温度， $T_s$ 表示芯片组温度。鉴于热阻过大，虚线表示的器件 $R_{\theta CA}$ 亦可忽略。

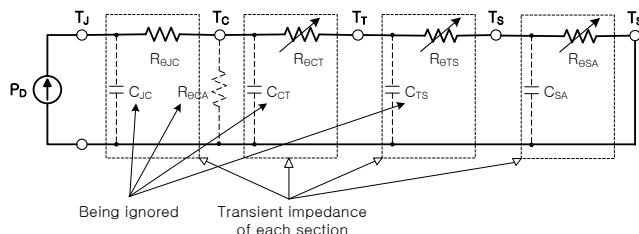


图 5. 带TIM的瞬态热等效电路

Motion SPM 5系列的热阻定义为:

$$R_{\theta JC} = \frac{T_J - T_C}{P_D} \quad (1)$$

其中:

$R_{\theta JC}$

(°C/W) 表示结至外壳热阻;  $P_D$

(W) 表示每个器件的功耗;  $T_J$

(°C) 表示结点温度;  $T_C$  (°C) 表示壳体参考温度

。

通过将 $T_C$ 替换为 $T_S$  (芯片组壳体温度), 可得结至芯片组外壳热阻 $R_{\theta JS}$ :

$$R_{\theta JS} = \frac{T_J - T_S}{P_D} \quad (2)$$

其中:

$R_{\theta JS}$

表示Motion SPM 5系列的整体热性能, 包括TIM和芯片组壳体;  $R_{\theta JS}$ 表示一系列热阻总和—— $R_{\theta JC}$ 、 $R_{\theta CT}$ 和 $R_{\theta TS}$ 定义为:

$$R_{\theta JS} = R_{\theta JC} + R_{\theta CT} + R_{\theta TS} \quad (3)$$

散热盘的厚度和热导率影响器件的热性能。

## 机械形变

由于厚度受壳体合压的影响, 有必要考虑封装的硬度。Motion SPM 5系列的硬度超过20,000 N。该数值足够大, 能耐受PCB弯曲或TIM偏转。壳体设计人员必须考虑PCB硬度和TIM形变。

图 7显示的是TIM厚度为2 mm时的形变测试结果。形变过程为: TIM → PCB和SPM封装引脚 → SPM封装。然而, PCB未发生弯曲, 因为Motion SPM 5系列产品的测试表面接触较宽的面积。

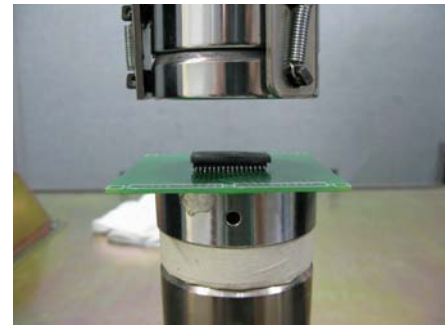


图 6. Motion SPM 5系列、PCB和2 mm TIM对比测试

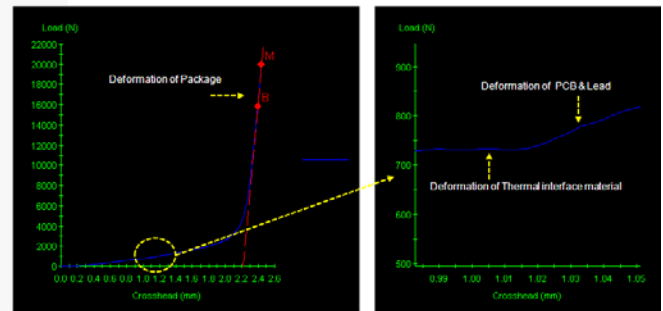


图 7. 对比测试结果:

X轴 - 形变厚度; Y轴 - 压力

## 热阻仿真

壳体厚度和表面直径未影响热阻性能, 如图 8所示。

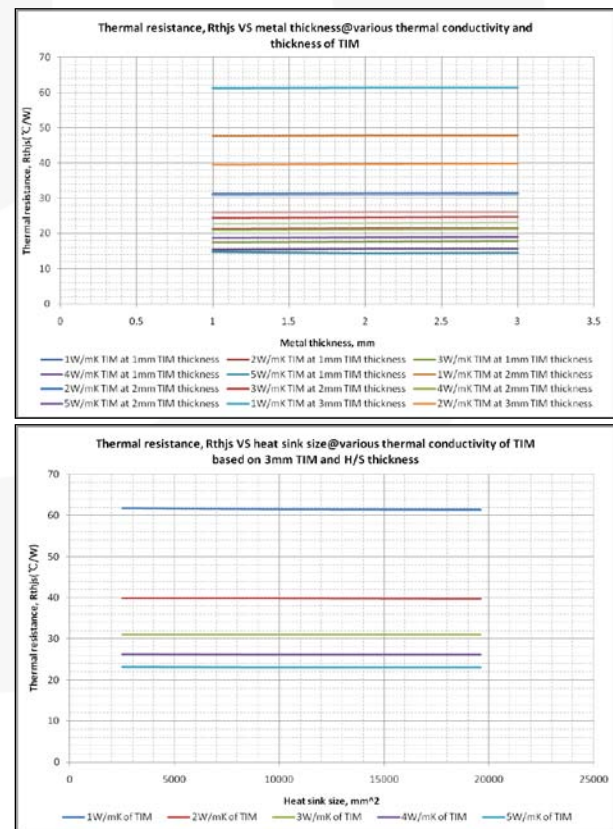


图 8. 金属厚度 (壳体厚度) 热阻和散热片尺寸 (壳体表面直径)

影响热阻性能最大的因素是TIM的导热率和厚度，如图9所示。

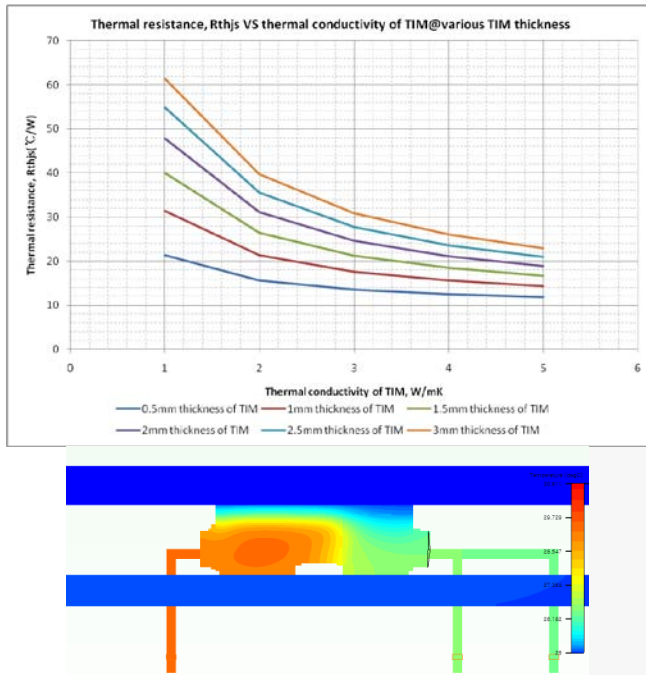


图 9. TIM的导热率对热阻的影响和仿真结果  
(0.5 mm, 5 W/mK)

## 热性能

使用FSB50550A（一款Motion SPM 5系列版本2产品）时，热性能由下式计算得出：

$$R_{\theta JS} = R_{\theta JC} + R_{\theta CT} + R_{\theta TS} \quad (4)$$

热阻 $R_{\theta JS}$ 不受金属厚度和散热片尺寸影响，因此可忽略 $R_{\theta SA}$ 图 10。显示的是TIM厚度为0.5和1.0 mm且导热率为1和5 W/mK时的仿真结果。

## 仿真条件：

$V_{PN}= 400\text{ V}$ 、 $V_{CC}= 15\text{ V}$ 、 $V_{CE(SAT)}= \text{典型值}$ 、开关损耗= 典型值、 $T_J= 150^\circ\text{C}$ 、 $T_C=100^\circ\text{C}$ 、 $PF = 0.9$ 、PWM方法 = 三相连续型PWM。

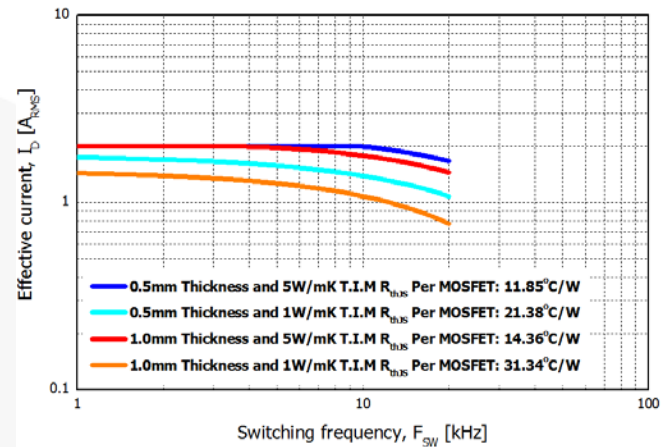


图 10. 仿真结果（有效电流载波频率特性）

图 10显示的是在 $T_C=100^\circ\text{C}$ 条件下工作的逆变器示例。它显示了有效电流 $I_D$ 在结温 $T_J$ 上升至 $150^\circ\text{C}$ 的平均结温时仍可输出（FSB50550A安全工作的最大值）。

## 结论

根据仿真结果，结至外壳热阻受TIM的厚度和导热率影响。因此，更薄的导热盘和更佳导热率可降低热阻。Motion SPM和TIM之间的接触足够强时，即可达到这一要求。

设计人员可参考本应用笔记中的仿真结果计算功率损耗，调节输出功率水平。

## 相关数据手册

[FSB50250 - 智能功率模块 \(SPM®\)](#)

[FSB50450 - Motion SPM®](#)

[FSB50450S - 智能功率模块 \(SPM®\)](#)

[FSB50550T - 智能功率模块 \(SPM®\)](#)

[FSB50325T - 智能功率模块 \(SPM®\)](#)

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[FSB50250US - 智能功率模块 \(SPM®\)](#)

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