Is Now Part of

ON Semiconductor®

To learn more about ON Semiconductor, please visit our website at
www.onsemi.com

ON Semiconductor and the ON Semiconductor logo are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

AN-9082

Motion SPM® 5 Series Thermal Performance Information by Contact Pressure

Overview

Semiconductor devices are very sensitive to junction temperature. As the junction temperature increases, the operating characteristics of a device are altered and the failure rate increases exponentially. This makes the thermal design of the package a very important factor in the device development stage and in an application.

To gain insight into the device's thermal performance, it is standard to introduce thermal resistance, which is defined as the difference in temperature between two adjacent isothermal surfaces divided by the total heat flow between them. For semiconductor devices, the two temperatures are junction temperature, T_J, and reference temperature, T_x. The amount of heat flow is equal to the power dissipation of a device during operation. The selection of reference point is arbitrary, but the hottest spot on the back of a device on which a heat sink is attached is usually chosen. This is called junction-to-case thermal resistance, $R_{\theta JC}$. When the reference point is an ambient temperature, this is called junction-to-ambient thermal resistance, $R_{\theta JA}$. Both the thermal resistances are used for the characterization of a device's thermal performance. $R_{\theta JC}$ is usually used for heat sink carrying devices, while $R_{\theta JA}$ is used in other cases. Figure 1 shows a thermal network of heat flow from junction-to-ambient for the motion SPM® products including a heat sink. The dotted component of $R_{\theta CA}$ can be ignored due to its large value.

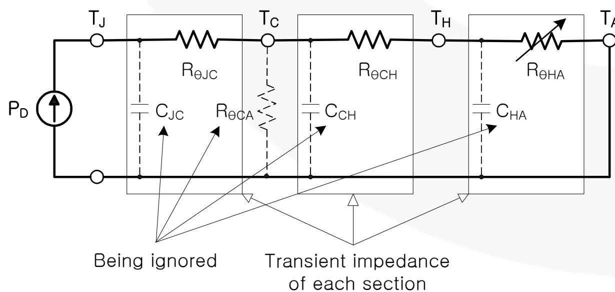


Figure 1. Transient Thermal Equivalent Circuit with Heat Sink

Motion SPM 5 Series doesn't have any screwing hole in the package, as shown in Figure 2.

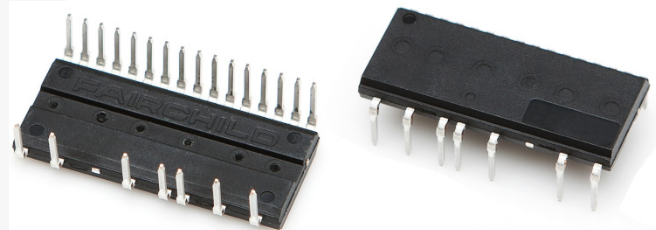


Figure 2. Package Outline of Motion SPM 5 Series

In this device application, a heat sink is used in the set case, like Figure 3.

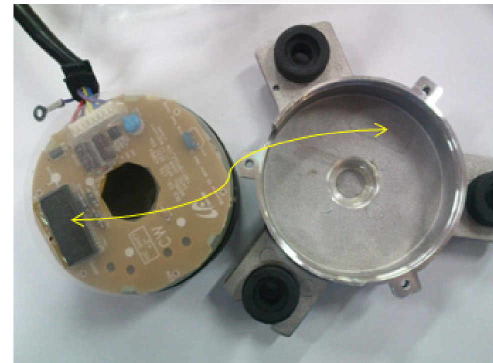


Figure 3. Set Configuration of Motion SPM 5 Series

For simulation models, Figure 3 can convert as shown in Figure 4. There is a Thermal Interface Material (TIM like a thermal pad) between the device surface and the set case.

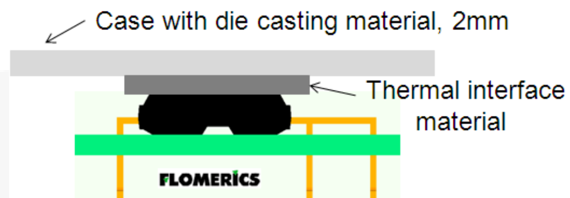


Figure 4. Thermal Simulation Model

When the reference point is a set case temperature, this is called junction-to-set-case thermal resistance, $R_{\theta JS}$. Figure 5 shows a thermal network of heat flow from junction-to-set-case for Motion SPM 5 series, including a TIM The T_J is the TIM temperature and Ts is the set case temperature. The

dotted component of $R_{\theta CA}$ can also be ignored due to its large value.

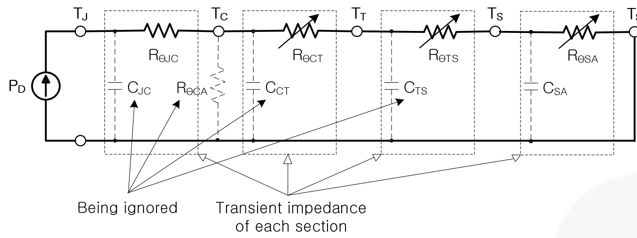


Figure 5. Transient Thermal Equivalent Circuit with TIM

The thermal resistance of Motion SPM 5 series is defined in the following equation:

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

where:

$R\theta_{JC}$ (°C/W) is the junction-to-case thermal resistance;
P_D (W) is power dissipation per device;
T_J (°C) is junction temperature; and
T_C (°C) is case reference temperature.

By replacing T_C with T_S (set case temperature), the junction-to-set case thermal resistance $R_{\theta JS}$ can be obtained as:

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

where:

$R_{\theta JS}$ indicates the total thermal performance of Motion SPM 5 series, including the TIM and the set case; and $R_{\theta JS}$ is a serial summation of various thermal resistances, $R_{\theta JC}$, $R_{\theta CT}$, and $R_{\theta TS}$ defined in:

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

The thickness and thermal conductivity of Thermal pad influenced in the device thermal performance.

Mechanical Deformation

Because thickness is affected by case joint pressure, it is necessary to consider the hardness of the package. Hardness of Motion SPM 5 series is over 20,000 N. This value is large enough to endure PCB bending or TIM deflection. The case designer must consider PCB hardness and TIM deformation.

Figure 7 shows the deformation test results when thickness of TIM is 2 mm. It is said that the deformation process is: TIM → PCB and SPM package lead → SPM package. However, the PCB is not bent because the test surface contacts a wide surface are in the PCB for Motion SPM 5 series products.

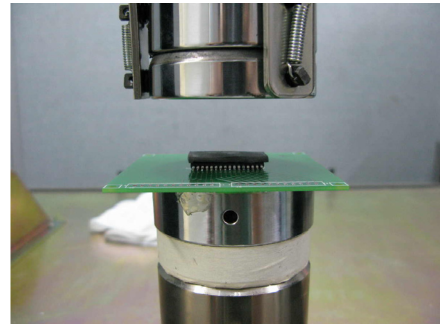


Figure 6. Compression Test with Motion SPM 5 Series, PCB, and 2 mm TIM

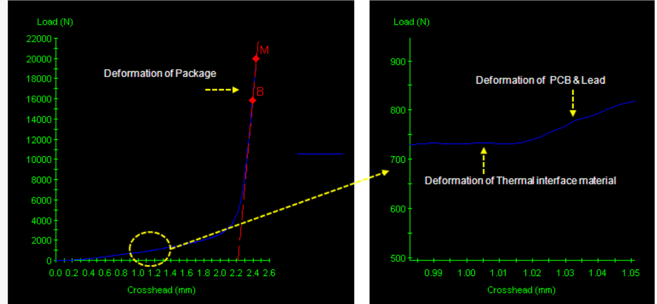


Figure 7. Compression Test Results: X Axis – Deformation Thickness, Y Axis - Pressure

Thermal Resistance Simulation

Case thickness and surface diameter are not affected at thermal resistance shown in Figure 8.

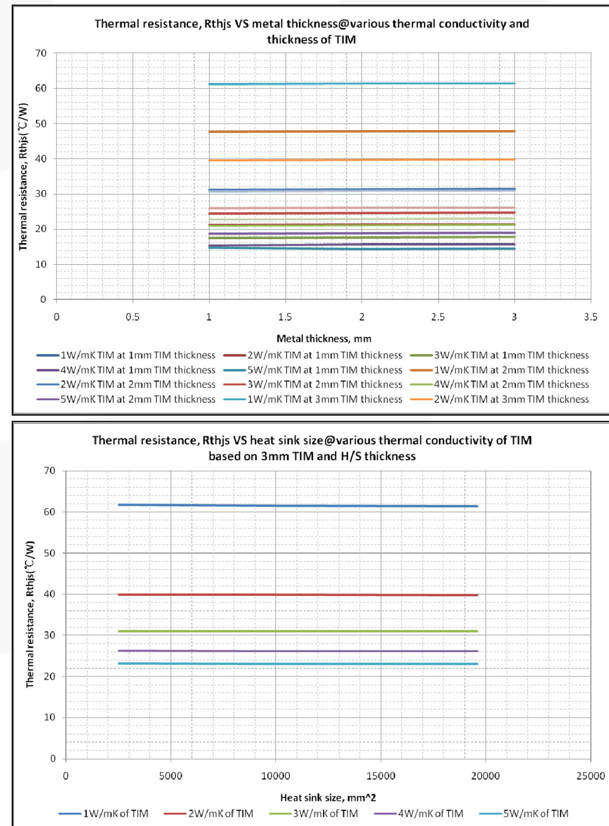


Figure 8. Thermal Resistance by Metal Thickness (Case Thickness) and Heat Sink Size (Case Surface Diameter)

© 2012 Fairchild Semiconductor Corporation

The most affected thermal resistance is the thermal conductivity and thickness of TIM, as shown in Figure 9.

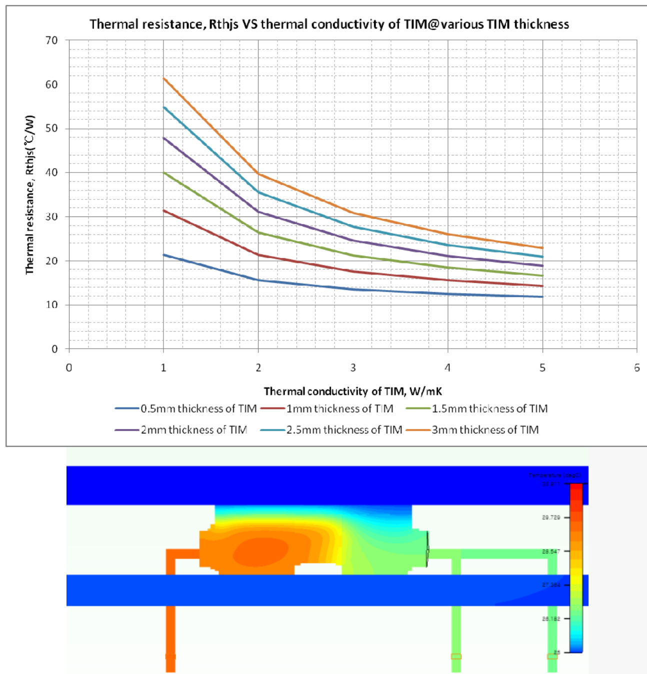


Figure 9. Thermal Resistance by Thermal Conductivity of TIM and Simulation Result (0.5 mm, 5 W/mK)

Thermal Performance

In the case of FSB50550A, which is a Motion SPM 5 series ver.2 product, thermal performance is calculated as:

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

Thermal resistance $R_{\theta JS}$ is not affected by metal thickness and heat sink size, so $R_{\theta SA}$ is ignored. Figure 10 shows the simulation results when the thickness of TIM is 0.5 and1.0 mm and thermal conductivity is 1 and 5 W/mK.

Simulation Condition:

V_{PN}= 400 V, V_{CC}= 15 V, $V_{CE(SAT)}$= typical, switching loss= typical, T_J= 150°C, T_C=100°C, P_F= 0.9, PWM method = 3-phase continuous PWM.

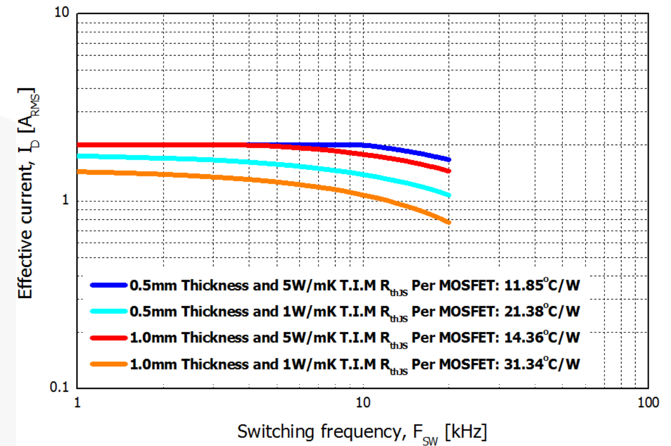


Figure 10. Simulation Results (Effective Current Carrier Frequency Characteristics)

Figure 10 is an example of an inverter operated under the condition of T_C=100°C. It shows the effective current, I_D, which can be output when the junction temperature, T_J, rises to the average junction temperature of 150°C (up to which the FSB50550A operates safely).

Conclusion

According to the simulation results, thermal resistance of junction to case is affected by the thickness and thermal conductivity of the TIM. Thus, thinner thermal pad and better thermal conductivity are required to reduce thermal resistance. This requirement can be achieved when the contact between Motion SPM and the TIM is strong enough.

Designer can adjust output power level with calculating power loss referring to the simulation result in this application note.

Related Datasheets

FSB50250 – Smart Power Module (SPM®)

FSB50450 – Motion SPM®

FSB50450S – Smart Power Module (SPM®)

FSB50550T – Smart Power Module (SPM®)

FSB50325T – Smart Power Module (SPM®)

FSB52006S – Smart Power Module (SPM®)

FSB50250US – Smart Power Module (SPM®)

FSB50250UD – Smart Power Module (SPM®)

FSB50250UTD – Smart Power Module (SPM®)

FSB50450US – Smart Power Module (SPM®)

FSB50450UD – Smart Power Module (SPM®)

FSB50550US – Smart Power Module (SPM®)

FSB50550UTD – Smart Power Module (SPM®)

FSB50825US – Smart Power Module (SPM®)

FSB50250A – Smart Power Module (SPM®)

FSB50250AS – Smart Power Module (SPM®)

FSB50250AT – Smart Power Module (SPM®)

FSB50450A – Smart Power Module (SPM®)

FSB50550A – Smart Power Module (SPM®)

FSB50550AS – Smart Power Module (SPM®)

FSB50550AT – Smart Power Module (SPM®)

FSB50325A – Smart Power Module (SPM®)

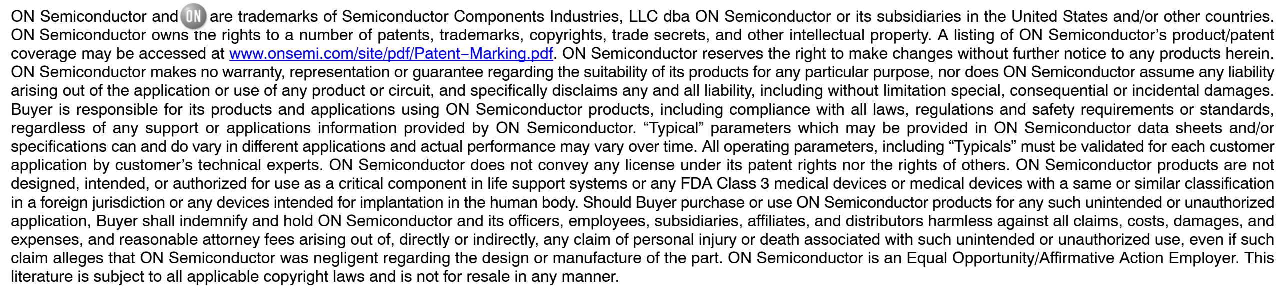
FSB50325AT – Smart Power Module (SPM®)

FSB50825AS – Smart Power Module (SPM®)

DISCLAIMER
FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION, OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

LIFE SUPPORT POLICY
FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF FAIRCHILD SEMICONDUCTOR CORPORATION.
As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



ON Semiconductor and ON are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent−Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative