Heat-flow density advances

The advent of dual-sided cooling of power semiconductors not only improves the transfer of heat in inverters but can also help to lower the cost of hybrid and electric vehicles

Hybrid and electric vehicles (HEVs) passed the tipping point a long time ago. The benefits of HEVs have been widely acknowledged and reflected in the growth of the number of vehicles sold. However, one of the biggest remaining obstacles hindering faster adoption is cost. Besides the battery, the second most expensive component is the traction inverter. A large part of its cost comes from the semiconductor power modules. In some estimates this cost is as high as 25% to 30% of the inverter cost.

One major factor affecting the cost of power semiconductor switches is the physical size of the power switch die. Efforts to improve the performance and minimize the cost of semiconductor switches have resulted in smaller devices with every new generation. But with the power losses still relatively high, a new challenge has arisen: removing the heat from the semiconductor switches through the shrinking surface area. In short, the heat-flow density must be increased.

In conventional power modules, the top of the device is used only for electrical connections implemented with wire bonds, while the bottom, which is typically attached to a DBC substrate, is used for electrical connection and heat transfer. The conventional approach is limited to heat removal through one side of the semiconductor device and the heat transfer problem can only be solved by reducing the thermal resistance between the semiconductor and the coolant using materials with high thermal conductivity and with improved heatsinks. Improvement potential is limited and the cost goes up.

A breakthrough can be achieved by using both sides of the semiconductor to remove the heat. This is possible only by eliminating traditional wire bonds. The CooliR2DIE technology being developed by International Rectifier offers this capability.

With this technology, the heat transfer occurs through the bottom and top of the semiconductor switch. Theoretically, the thermal transfer capability is doubled and the thermal resistance between the device and the coolant can be reduced by 50%. Importantly, the two-times improvement can be achieved with the existing thermal transfer and cooling materials and technology – no other improvements are needed.

Cost optimization, mechanical constraints and other practical reasons may limit the performance of the top-side heat transfer path. The coolant flow, the heatsink size and the thickness of the thermal interface material on the top may be inferior when compared with the bottom. Luckily, as shown in Figure 3, the dual-sided cooling performance exhibits low sensitivity to the effectiveness of the additional cooling path. Even with the top-side thermal resistance being twice as high as at the bottom, the resulting dual-sided cooling thermal resistance is still approximately 35% lower than single-sided cooling.

The improved heat transfer with dual-sided cooling allows the semiconductor switches to work harder and conduct more current, while the current density of power semiconductor devices is greatly increased. It has been estimated that an approximately 50% increase in current density can be achieved. Fifty percent higher current density means devices that are 33% smaller can be used for the same current rating, or 50% more current can be handled at the same cost.

The consequence being lower cost of automotive power electronics, more HEV vehicles on the roads and a greener future.

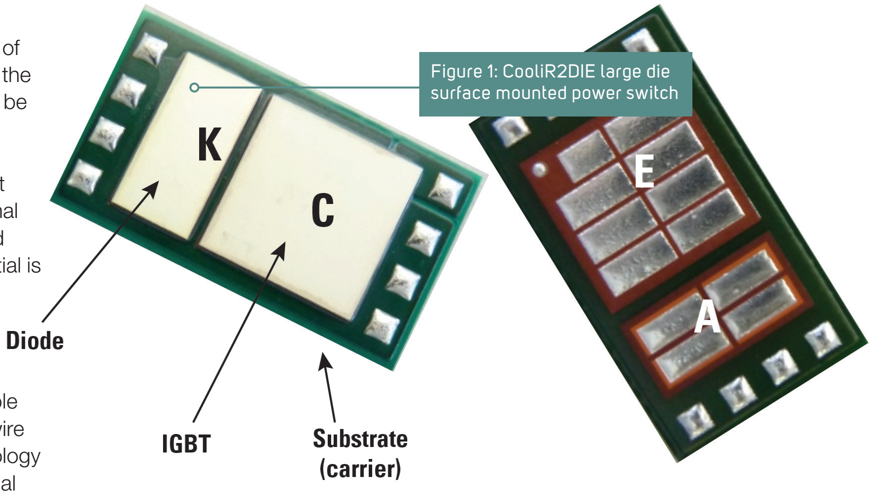


Figure 1: CooliR2DIE large die surface mounted power switch

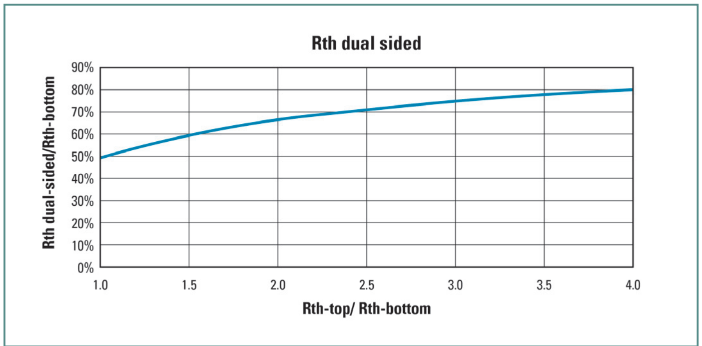
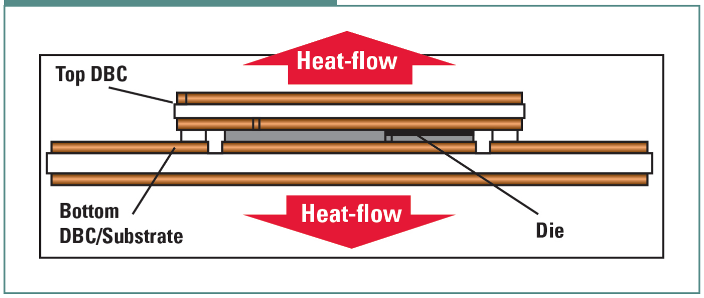


Figure 3: Dual-sided junction-coolant thermal resistance as a function of top-side cooling effectiveness

Figure 2: CooliR²DIE power switch cross-section and heat-flow paths



CONTACT
Sarah Hurstwaite at International Rectifier
T. +44 1737 227 266
E. shurstw1@irf.com
W. www.irf.com

ONLINE READER ENQUIRY NO. 511