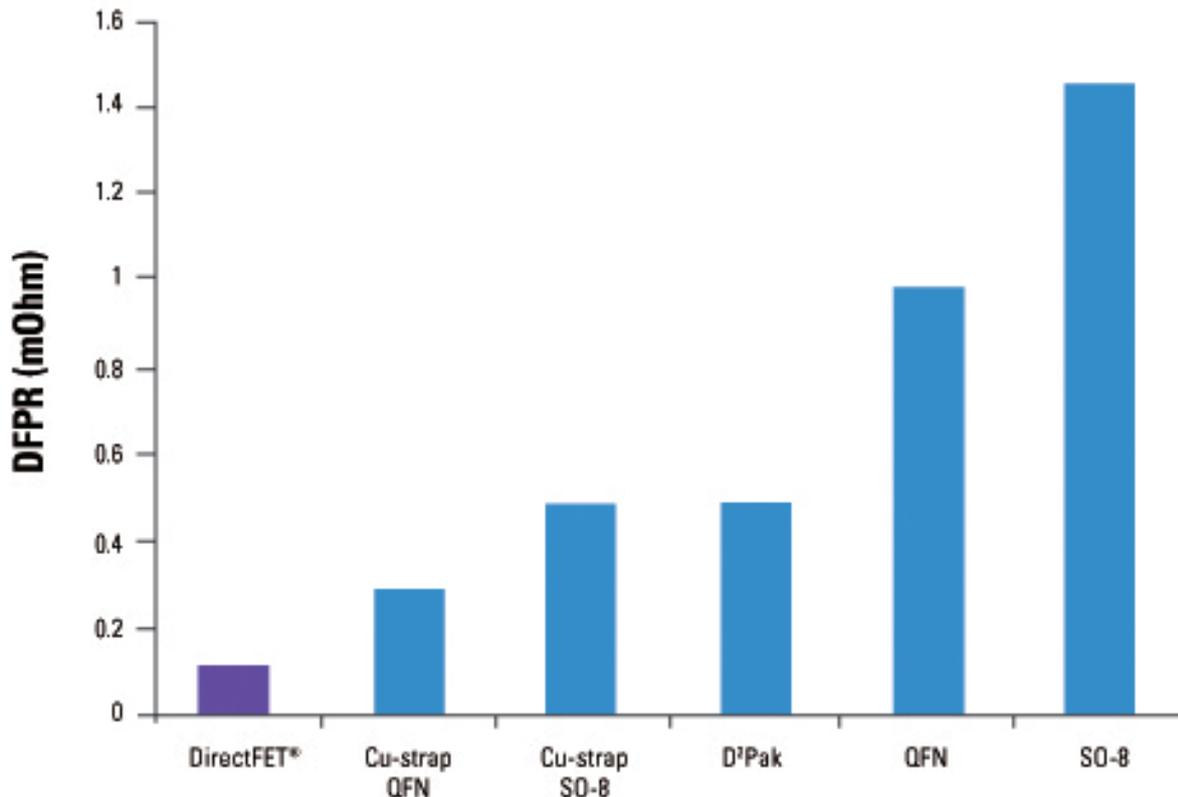


# Power Packages Unlock Discrete Semiconductor Performance

An Electronic Engineer builds a system out of components; resistors, ICs, MOSFETs and IGBTs. The Power Electronic Engineer has to go beyond the electrical parameters of components and start looking at thermal resistance and capacity, cooling and parasitic inductance. Increasingly the designer has to be just as focused on the attributes of the D2Pak and TO-220 package which houses the MOSFET or IGBT as they do on electrical properties of the components themselves. Automotive designers are looking ever more closely at the lead resistances on a TO-262 or consider complex 'slug-up' mechanical arrangements on a D2-Pak in an effort to reach tough efficiency and power density goals. But is power density and efficiency really such a coveted goal for automotive electronic Engineers?

With gas prices fluctuating unpredictably, motor companies bailed out by governments, and increasing regulations on emissions, the leading automobile manufacturers are pursuing fuel saving technologies aggressively. On traditional internal combustion engine platforms, designers are quickly banishing engine driven power steering, air conditioning and water pumps for electric replacement. But these new electrical systems have to deliver excellent power density and efficiency; all eyes turn to the power semiconductor.

Power MOSFET semiconductor technology has improved immeasurably over the last 20 years. The latest trench technology claim to offer low  $R_{DS(on)}$ , minimal gate charge and rugged avalanche performance in one. But while the silicon has advanced, the package needed to house the tiny die has remained unchanged; on a typical D2Pak-7P MOSFET in the 1 m-Ohm range, a good proportion of the on resistance is not from the semiconductor but from the package itself. Up to around 50 percent of the  $R_{DS(on)}$  is accounted for by the wirebonds inside of the package which make the connection from the die to the leads. While silicon performance gets increasingly better, the Engineer is on a curve of diminishing returns to unlock the full performance of the MOSFET due to the limitations imposed by the package. Figure 1 shows the Die Free Package Resistance of different types of power packages; this is the resistance which the power package adds on top of the  $R_{DS(on)}$ .



**Figure 1. Die-free package resistance of different types of power packages**

The wirebonds are the main source of this additional resistance between drain and source. Furthermore, due to the geometry of these tiny wire links, the skin effect becomes an issue at high frequencies as the die-free package resistance and conduction losses increase causing efficiency to fall off. Combined with the parasitic inductance that the wirebonds add, the limitations of the traditional plastic power package become apparent. Another must have feature for automobile manufacturers is reliability. Because of the inherently complex nature of wire bonding and the number of bond wires, these wires are always a weak link in the longevity and robustness of a component.

Power semiconductor manufacturers are creating new packaging solutions to overcome the limitations of existing packages. Once such bond-wireless, dual-sided coolable package has steadily proliferated the consumer market over the last eight years. Automotive DirectFET 2, an AEC-Q101 derivative of the original Direct FET, offers the features of this package to automotive system designers.

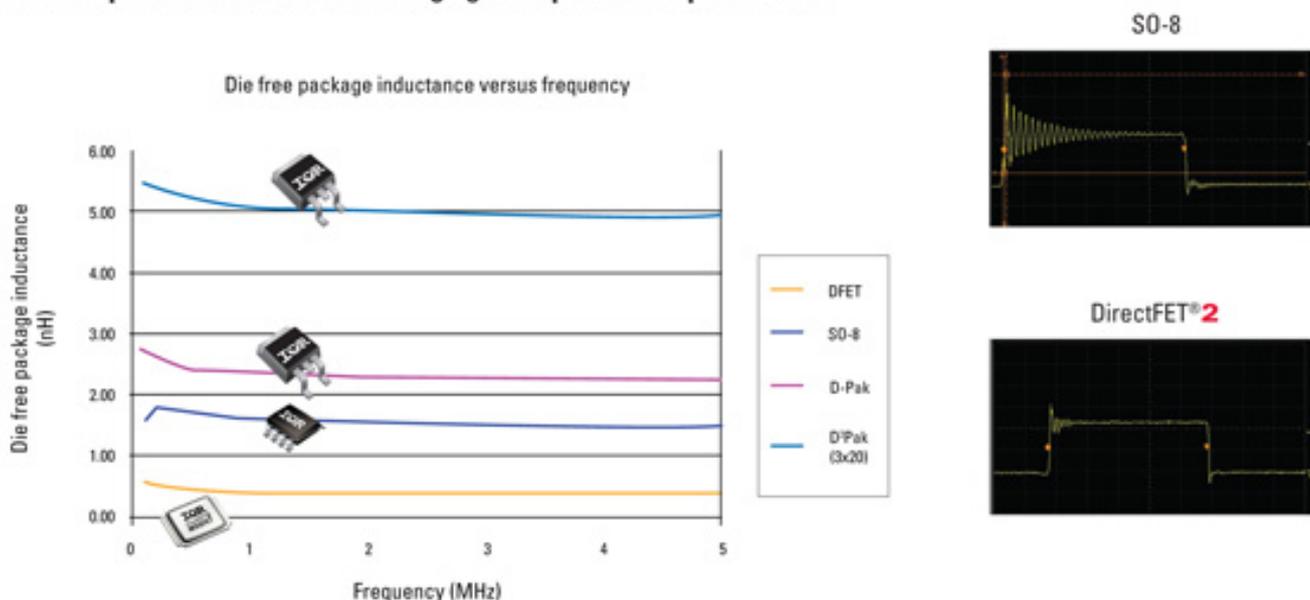
This package does away with wirebonds. Instead, solderable front metal (SFM) pads on the surface of the die allow direct connection from the silicon to the circuit board, so the package only adds 150 u-Ohms to the RDS(on) – small compared with the milliohms added by traditional power packages (see Figure 1). Losses are reduced and reliability improved. The ‘skin effect’ at higher frequency is also less pronounced; the removal of the wirebonds means that the package retains its low RDS(on) characteristic even in the MHz range making it an appropriate for the DC-

DC converters needed on hybrid vehicles.

## Reducing Parasitic Inductance and Thermal Resistance

Nobody understands and respects the hazards of parasitic inductance more than the Power Electronics Engineer, at best this phenomena causes inefficiency, at worst it causes a system to stop functioning. By removing the wirebonds, next generation power packages dramatically reduce parasitic inductance. This allows for the reduction or even elimination of external snubber networks. As a result, a more elegant design evolves; losses are cut along with system size and cost.

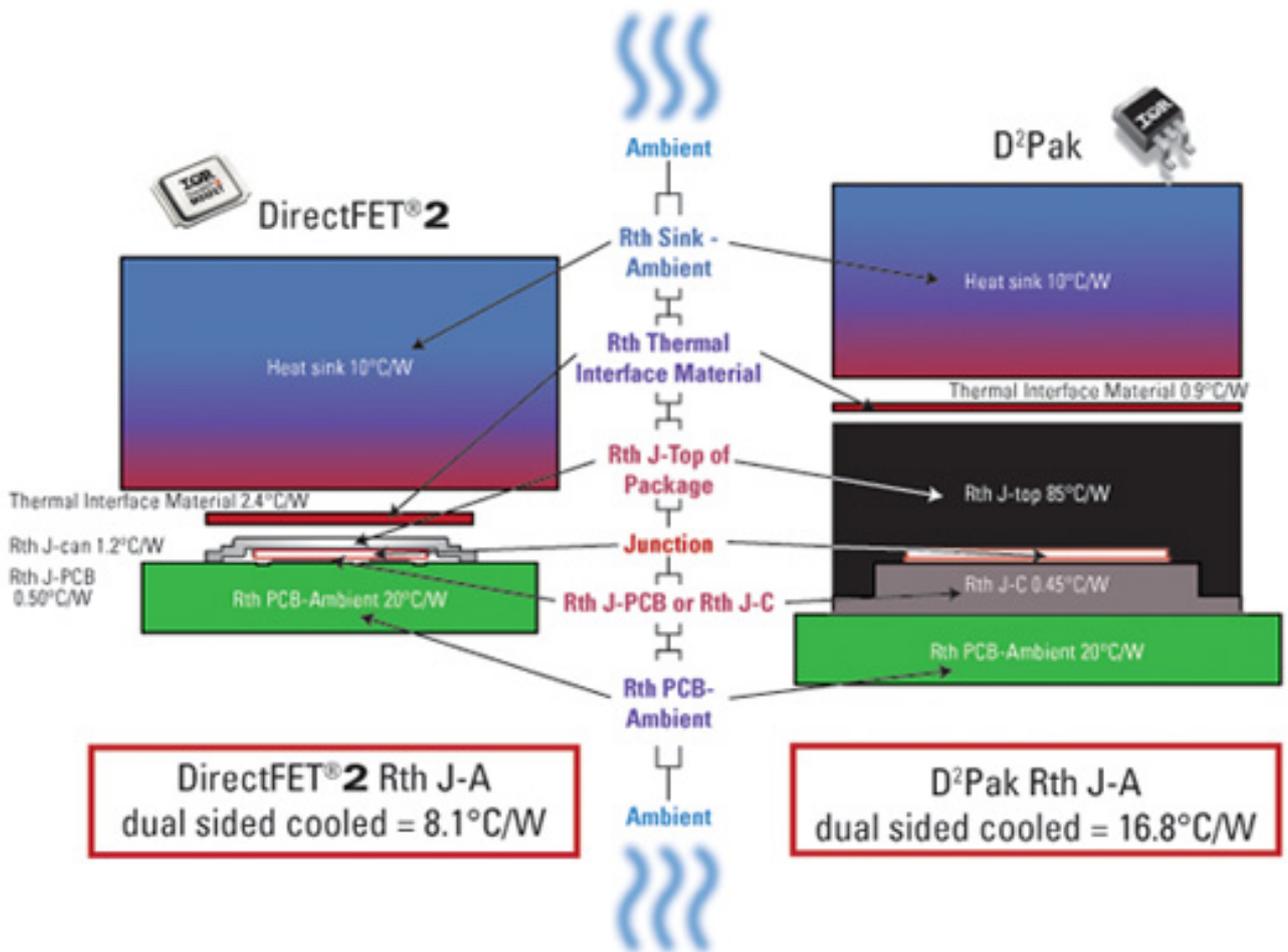
### Reduced parasitic inductance and ringing for improved EMI performance



**Figure 2: Die-free package inductance of different types of power packages and switching waveform performance.**

Finally, heating in the junction of a MOSFET is undesirable, in a car such loss, albeit arguably small, be traced back directly to the gasoline that is used to fill the car up and the CO<sub>2</sub> flowing out of the exhaust. Therefore, it is important to effectively get the heat out of MOSFET junction. By doing so, power density and efficiency is increased and system size and cost can be reduced.

Figure 3 compares and contrasts the thermal routes for getting the heat out of a Large Can DirectFET package and a D2Pak. In both cases, the designer has attempted to achieve the lowest thermal resistance from junction to ambient by using both the downward thermal path from the junction to the PCB and up through the package to a heat sink on top of the part.



**Figure 3: Comparison of Rth J-A for a dual sided cooled DirectFET L can and D2Pak**

In both cases, the packages have good thermal resistance from the junction to the PCB with values of 0.5°C/W and 0.45°C/W for the Rth J-PCB of the DirectFET and D2Pak respectively. However, the thermal route can be reduced dramatically when paths are put in parallel. Indeed the D2pak was never designed to be cooled through the top of its thick plastic package; but if this is attempted, an Rth J-TOP (junction to top of package thermal resistance) of around 85°C/W is achieved. Compare this with the DirectFET which has an considerably lower value of 1.2 °C/W; this results in a halving of the overall thermal resistance from junction to ambient when dual sided cooling is used on the next-generation power package.

**Conclusion**

Performance, Power Density and Efficiency are goals not normally associated with electrical systems on automobiles. That was yesterday, now the pistons, valves and fuel pumps of the last 150 years are being replaced by the electric motors, inverters and batteries of today. As power semiconductor manufacturers look to new materials such as Silicon Carbide and Gallium Nitride an exotic semiconductor toolbox is presented to the automotive system designer. But while the semiconductor technology advances it’s important that the performance of the ultimate gatekeeper between the semiconductor and the outside world, the power package, keeps up.

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