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**Introduction**

When using power semiconductors, there is usually the need to electrically isolate the devices from the heatsink, which could also be the equipment chassis. The three main reasons for this are: a) safety; b) the desire to reduce electromagnetic interference by reducing stray capacitance junction-to-ground; and c) the desire to heatsink many devices on the same heatsink frame. The major penalties involve increased thermal resistances, complex assembly and difficult isolation voltage testing to meet the world's many different safety standards.

The normal method is to use an insulating material sandwiched between the semiconductor device and the heatsink but this always increases the case-to-heatsink thermal resistance  $R_{(th)cs}$ .

Now IXYS is introducing a new family of internally isolated power semiconductors in the TO-247 package outline (see fig. 1).

As will be explained below, this new UL recognized ISOPLUS247™ (Table 1) package not only provides a 2500V(RMS) isolation voltage rating but also achieves lower junction-to-heatsink thermal resistance, lower junction-to-case capacitance and better power cycling, compared to conventionally isolated devices.

**Standard Isolation Methods**

The standard mounting method to isolate discrete devices involves placing an electrically isolating, thermally conductive interface between the copper baseplate and the heatsink. There are three major criteria to gauge the success of heatsinking the power semiconductor.

1. The first is low thermal resistance. The insulator must have both high thermal conductance and dielectric strength so that a thin layer can be used. There should be as few layers as possible between the chip and the heatsink.

2. The second is the mechanical ruggedness of the insulator so that the moutdown procedure does not impair its dielectric breakdown.
3. The third criterion involves reliability. It is always advantageous for the power device to operate at low junction temperatures. Additionally, to increase its power cycling capability or thermal fatigue, the silicon chip should be soldered to a material with a matching thermal expansion coefficient to avoid mechanical stressing the soft solder joints as the silicon chip heats and cools.

For example, Kapton foils have low thermal resistance but they have a higher susceptibility to puncture by dust particles or by burrs on either the semiconductor package or heatsink. Ceramic washers are a better choice to meet high isolation voltage because they combine high dielectric strength with good thermal conductivity. However, they are also brittle, are difficult to keep in place during assembly and require thermal grease to fill in air voids between the interface layers. If one uses a screw to hold the semiconductor package and interface material to the heatsink, there is the further complication of sufficient creep distance between the device mounting tab and the screw.

Table 1 (additional examples see table 2)

Part Type	Isolation Material	Thickness mm	$R_{(th)js}$ K/W	$P_d @ T_j = 150^\circ C$ $T_s = 80^\circ C$ W	$I_{DC} @$ $T_s = 80^\circ C$ A	$T_j @ I_{dc} = 50 A$ $T_s = 80^\circ C$ C
IXFR170N10	(Internal AlN DCB)	0.63	0.39	115.4	84.9	92.9
IXFR150N10	(Internal AlO3 DCB)	0.63	0.45	100.0	79.1	95.1
IXFX180N10	(External AlO3)	0.63	0.65	69.2	65.8	102.7
IXFX180N10	IMS	0.13	0.74	60.8	61.6	106.4
IXFX180N10	Kapton	0.05	0.88	51.1	56.5	112.4
IXFX180N10	Silicon fiber glass foil	0.38	1.12	40.2	50.1	123.6



Last year IXYS introduced the PLUS247™ package, a 'hole-less' TO-247 requiring a pressure mounting technique. This highly successful package not only reduced the assembly costs incurred by the equipment manufacturer but also allowed products with higher current ratings in the TO-247 case style. Without the screw hole, more area of the package could be used to encapsulate larger chips.

For many years, IXYS Corporation has produced low cost, transfer molded, TO-247 packaged devices as well as power modules using DCB (Direct Copper Bonded) ceramic substrates. The marriage of these two manufacturing techniques culminated in the production of our new ISOPLUS247™ package, shown in the picture Fig. 1 (= opened ISOPLUS), a transfer molded, hole-less, internally isolated, TO-247 package.

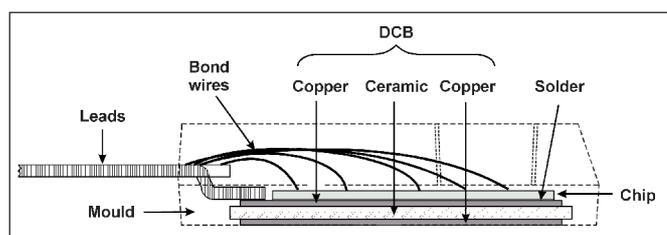


Fig. 1 TO-247 cross section

The ISOPLUS247™ is a fully isolated plastic package in the standard TO-247 outline without a screw hole. This allows a one-to-one replacement of a PLUS247 isolated by foil or ceramic washer with an ISOPLUS247™. The IXYS type designator is the letter "R", for example IXFR 26N50. The package, being hole-less, is designed for spring clip mounting. For maximum performance, it is recommended to use thermal grease between package and heatsink. Assembly without thermal grease is possible but increases the thermal resistance by about 50%. All parts are 100% isolation voltage tested to 2.5 kV(RMS). UL recognition is being applied for.

### Mechanical Construction

The key engineering achievement is the replacement of the normal copper lead frame with a DCB lead frame. The ceramic itself can withstand an isolation voltage higher than 6 kV, but for the ISOPLUS247™, it has been reduced to 2.5 kV, in respect to the short external creep and strike distances of the package. The silicon chip or chips are soldered to a pattern etched on one surface while the opposite side can be used for direct mounting to a heatsink (see cross section). The total number of layers from the heat source (chip) to the heatsink has been minimized to only one solder layer, the DCB ceramic and the external thermal grease. This results in an over all very low thermal resistance between chip and heatsink. Soldering the chip onto the DCB is a well-proven method for chip attachment to an isolator.

The initial engineering samples were made with alumina DCB. Additionally aluminum nitride DCB versions are pos-

sible for very large MOSFET chips to allow equipment manufacturers to control as much current as possible in the cost effective, discrete TO-247 case styles.

### Features

The primary advantage of ISOPLUS247 packaging is the very low thermal resistance achievable in a rugged, high voltage, isolated mounting system. Table 1 compares the thermal resistance of a 170A/100V MOSFET chip in the ISOPLUS package (Fig. 2) (IXFR170N10) to the hole-less TO-247 version (IXFX180N10) when isolated with various interface material. For the maximum power dissipation, depending on different isolation materials see Figure 2.

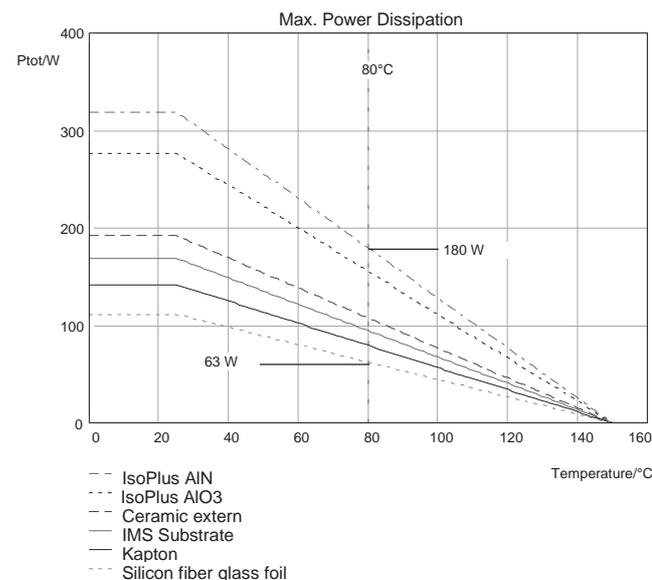


Fig. 2 (see also fig. 3)

Inspection of this table shows that depending upon the mounting technique, allowable current can be increased by about 50% for the same junction temperature. Conversely, the chip runs 31 °C cooler for the same operating conditions that translates into more reliable operation. Because there is such a potentially large decrease in  $R_{(th)j-s}$ , it may be possible to use a smaller chip for the same current, which would more than pay for the extra cost of the internal isolation.

Experience has shown that when using very thin foils (<50µm) with good thermal conductivity like Kapton, especially at high dV/dt's there may be problems with EMI/RFI caused by stray capacitance. The IXYS ISOPLUS247™ uses a 0.63 mm thick alumina DCB ceramic with an approximately 6 times lower stray capacitance.

The risk of isolation damage by burrs or contamination is more or less excluded by using the ISOPLUS247™ with the hard DCB base plate, which would eliminate this cause of failure during isolation voltage testing.

There is no question that the ISOPLUS247™ package will outperform the equivalent standard TO-247 package in temperature and power cycling test. Since silicon and DCB have matching temperature coefficients, the stresses on the chip and solder joint are lower during temperature cycling.

The exposed metal at the mold notches are electrically isolated from the chip, so no special care on strike and creep distance has to be taken with clip mounting.

Finally in comparison to an isolated standard TO247 solution, the ISOPLUS247™ is a “plug and play” version because there is no need to mount the part with additional isolation materials.

### **Applications**

The typical applications for these packages are in the low voltage range up to a maximum DC bus potential of 350V. The limitations for the present ISOPLUS247™ package style are its external creep and strike distances, which are the same as with the standard TO247 package. However for new automotive high power applications, this package is a likely candidate, thanks to its small stray inductance, low thermal resistance and projected reliability. Other applications are power supplies, UPS (uninterruptible power supplies), AC and DC motor control, and welding inverters with a line voltage up to 300 V.

### **Internal or External Isolation?**

The overall key question is: what does it cost? The answer can not easily be given without considering all of the many specific application circumstances. The short answer is that the ISOPLUS247™ device is more expensive than an equivalent device in a standard non-isolated TO-247 package. But when the user takes into account the lower assembly cost, the cost for the separate insulator, higher isolation voltage test yield, and the lower thermal resistance (which may lead to a smaller silicon chip or a higher current out per silicon area), the ISOPLUS247™ is an economical approach to isolated power design.

### **Outlook**

The ISOPLUS247™ HiPerFET is only the first product to be made with this new technique to be announced by IXYS Corporation. Due to the fact that the copper surface of the DCB can be patterned like a PC board, it is possible to realize other multi-chip configurations; for example a series or common anode connection of FRED or Schottky diodes. Larger packages with more pins will allow many more circuit configurations.

The first available products are MOSFETs from 100V to 500V. However, all the other chip products from IXYS can be housed in the ISOPLUS247™ package so that, in near future, IXYS will be announcing other various types in this and other package styles. Patent pending for ISOPLUS247™ DCB transfer mould technique.

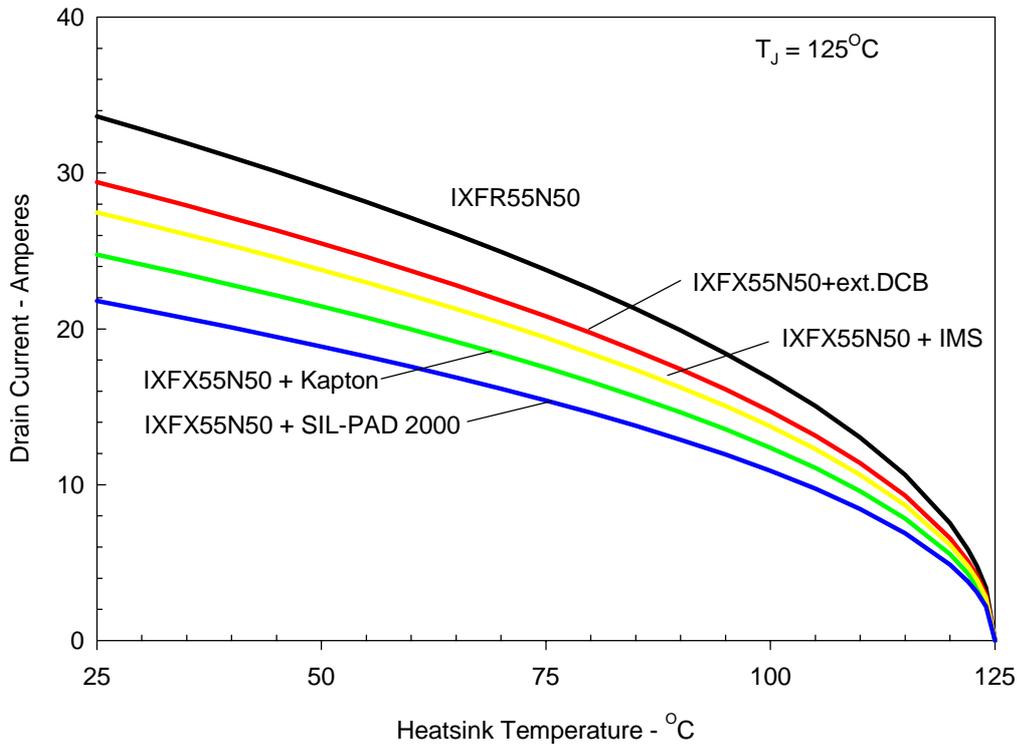
For questions on these parts pls. contact the IXYS sales team, or visit us on our website under [www.ixys.com](http://www.ixys.com).

Table 2: Performance Comparison of ISOPLUS247 IXFR55N50 to IXFX55N50 Mounted Using Various Interface Materials

Part Type	Isolation	Thickness	Isolation	R(th)js	Pd@Tj=150C	Id @ Tj=150C	Tj @ Idc=15A
	Material		Voltage		Ts=80C	Ts=80C	Ts=80C
		(mm)	(kV)	(K/W)	(W)	(A)	(C)
IXFR55N50	(Internal alumina DCB)	0.63	2.5	0.52	135	28.1	96
IXFX55N50	External alumina DCB	0.63	2.5	0.68	103	24.6	102
IXFX55N50	Kapton	0.05	4.5	0.96	73	20.7	112
IXFX55N50	IMS	0.13	6	0.78	90	23.0	105
IXFX55N50	SIL-PAD 2000(TM)	0.38	4	1.24	56	18.2	125

SIL-PAD is a trademark of Bergquist Co.

Figure 3: Graphical comparison showing the current handling capability of the ISOPLUS247 IXFR55N50 MOSFET vs the IXFX55N50 MOSFET as a function of heatsink mounting conditions.



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