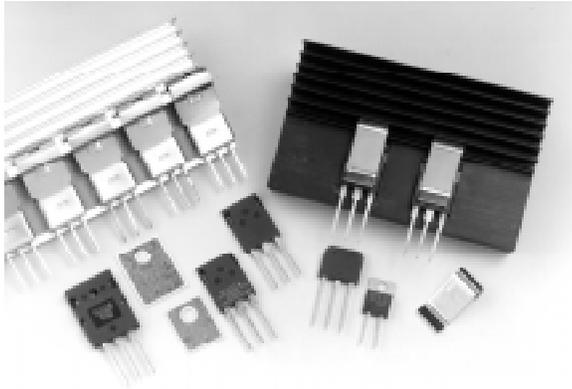


# New Packages for Pressure Mounting

## APPLICATION BRIEF AB-9801

Prepared by Ralph E. Locher



### Introduction

The use of pressure to mount discrete power semiconductor packages to heat sinks has been rapidly growing for many reasons. When properly executed, it has proven to be a cost effective technique and has been shown that it can improve the overall performance of the discrete power semiconductor. In recognition of this trend, IXYS has brought out new discrete packages housing power MOSFETs, IGBTs and FREDs to further enhance the overall performance of the equipment using these parts. Examples of pressure mounted packages and spring clip assemblies are shown in the picture on the left.

This application brief will discuss the advantages of these new packages and their mounting considerations.

### Pressure Mounting Trends

The use of spring clips and bars to secure TO-220, TO-247 and TO-264 parts to a heatsink is not new. Screwing these parts to a heatsink seems easy but suffers from the following disadvantages:

1. Their use is laborious because only one part can be mounted at a time and each screw must be accompanied by a lock or spring washer plus a flat washer to distribute the force from the screw head.
2. Torque limiting screw drivers must be used so as not to damage the silicon chip within the package or the interface pad if used.
3. Self-tapping screws should not be used due to the wide variance in applied pressure so that either the heatsink must be drilled and tapped or an additional nut will be required to secure the screw.
4. The popular discrete packages mentioned above all suffer from having only one screw hole so that the screw has a tendency to lift up the non-secured end resulting in increased case-to-sink thermal resistance  $R_{th}(cs)$ .
5. Finally new specifications on creep and strike distances to meet the safety standards of various safety agencies increases the difficulties to using screws in mounting these packages to grounded heatsink surfaces.

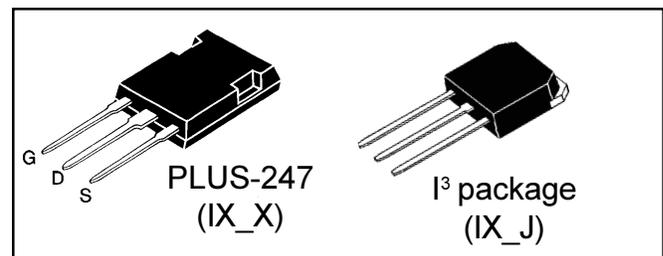
Pressure mounting presents solutions to these disadvantages as follows:

1. Elimination of the screw and associated hardware facilitates agency approval;
2. Springs apply pressure directly over the silicon chip to decrease  $R_{th}(cs)$ ;
3. Bar springs can be used to gang mount multiple devices;
4. Hardware is minimized;

### New Pressure Mounted Packages

As pressure mounting comes into its own, IXYS has brought out two new packages designed to take advantage of this trend. They are: a) the PLUS247™ package, also known as the ‘hole-less’ TO-247 but should have been called the ‘whole’ TO-247; and b) the leaded TO-268 package, also known as the I<sup>3</sup> PAK. Their package designations are the letters ‘X’ and ‘J’ respectively and are shown in the following illustration as well as in the picture above.

The major advantage of these new packages is that they



allow the semiconductor manufacturer to completely fill up the package with more silicon for maximum power efficiency. For example, in the PLUS247 package, IXYS can now offer 500V HiPerFET™ MOSFETs with an  $R_{ds(on)}=0.08 \Omega$  (IXFX55N50) or a 600V/75A rated IGBT with a companion FRED diode (IXGX50N60BU1). Likewise for the J package, one can now insert a 500V MOSFET with an  $R_{ds(on)}$  of  $0.15 \Omega$  (IXFJ32N50) in place of a pressure mounted TO-220. Indeed the driving force for the J-package was the recognition that it was the easiest, high power package to use to upgrade power conversion equipment now using TO-220 packages or other equipment with limited headroom above the PC board. Additionally it is the preferred package for high voltage since its strike distance between pins is 3.7mm (0.145”), 33% greater than the TO-247, and its creep distance has been increased to 4.5mm (0.177”), partly enhanced by a barrier ridge between each pair of pins.

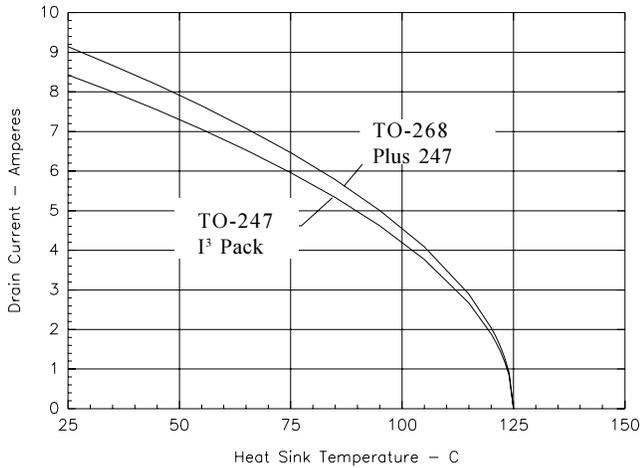


Figure 2: Comparison of allowable current ratings for a 1000V/12A rated MOSFET chip in four different packages.

All power semiconductors are limited by junction temperature so that their maximum power output is only as good as the overall thermal design of the equipment. The total thermal resistance junction-to-ambient  $R(\text{th})_{\text{ja}}$  can be subdivided into three components, namely the thermal resistances between junction-to-case, case-to-sink and sink-to-ambient. In equation form:

$$R(\text{th})_{\text{ja}} = R(\text{th})_{\text{jc}} + R(\text{th})_{\text{cs}} + R(\text{th})_{\text{sa}}$$

As larger and larger silicon chips have been encapsulated into discrete housings, the importance of  $R(\text{th})_{\text{cs}}$  has grown because it has not decreased at the same rate as  $R(\text{th})_{\text{jc}}$ .  $R(\text{th})_{\text{cs}}$  is a function of many factors, as explained in the next section, but one important contributor is the area of the heat flow path. It turns out that the PLUS247 package has the same tab area as the TO-264 package, so that they share the same value for  $R(\text{th})_{\text{cs}}$  of 0.15K/W. As shown in Figure 2, this results in an immediate increase of about 10% in current handling capability for the same size silicon chip housed in the standard TO-247 package. The smaller J package shares the same value as the TO-247.

### Pressure Mounting Considerations

$R(\text{th})_{\text{cs}}$  is a function of many factors, such as flatness and surface preparation of both the discrete package and heatsink, type of insulating washer and or thermally conductive compound, mountdown pressure and, as already mentioned, the area of the heat flow path. The best conducting contact is metal to metal but there are always air voids in a dry contact due to surface finish. Depending upon the thermal and electrical requirements of the system, the packaging engineer will choose a thermal grease and/or some form of lubricating or insulating washer to fit between the device and the heatsink to eliminate air voids.

The requirements and preparation of the mounting area on the heatsink for pressure mounted parts depends upon the selection of the thermally conducting compound or washer.

### Thermal Grease

Thermal greases are effective in reducing  $R(\text{th})_{\text{cs}}$  where the maximum air gap between surfaces is less than 25 $\mu\text{m}$  (0.001"). This means that extruded aluminum heatsinks will require some surface milling for housings larger than TO-220 because the nominal flatness specification is 4 $\mu\text{m}/\text{mm}$  (0.004"/in). To minimize the effects of heatsink finish, the heatsink mounting surfaces should be flat within 0.001"/in and the roughness should not exceed 125 microinches.

IXYS recommends Dow Corning 340 heatsink compound or Berulub FZ1E3 (Bechem, silicone free), which contains alumina oxide particles to reduce  $R(\text{th})_{\text{cs}}$ .  $R(\text{th})_{\text{cs}}$  of a 'greased' interface is typically 30-50% less than a dry joint and varies less with pressure. The grease should be rolled onto the heatsink surface to thickness of 30 - 50 $\mu\text{m}$  (0.001" - 0.002"). A range of 150kPa - 300kPa (20-40 PSI) is usually sufficient to ensure good thermal conduction.

### Thermally Conductive Pads

Today the packaging engineer has a literal cornucopia of pads to choose from to meet his needs of isolation voltage, environmental restrictions, moisture and thermal conductance. Reference 1 has a more thorough comparison of various materials used in these pads. Mica washers coated with thermal grease on both sides provide a very low cost, good thermal conductive joint with high dielectric strength. Its major disadvantage is its brittleness and susceptibility to puncture by burrs on either the heatsink or semiconductor package. A better choice to meet high isolation voltage requirements are ceramic washers because they combine high dielectric strength with good thermal conductivity. However, they are also brittle and require thermal grease to fill in air voids between the interface layers.

IXYS manufactures its own Direct-Copper-Bonded (DCB) ceramic substrates for its multitudinous power module families of products. It has developed DCB pads for the TO-247 and TO-264 packages, which can be bought individually. Again either thermal grease or a non-insulating grease replacement material such as Q-Pad 3<sup>®</sup> from Bergquist or Thermstrate<sup>®</sup> from Power Devices. Both materials conform to the mating surfaces when exposed to modest heat and pressure to achieve relatively low thermal resistance.

There are many objections to the use of thermal greases due to their messiness, incompatibility with soldering systems, possibility of outgassing and drying out with time. There has also been much research work performed to develop 'low pressure' types of interface tabs, for which the power industry probably has to thank the IC industry for developing high speed digital products that require heatsinking. Consequently there is not only a very large selection of both insulating and non-insulating interface pads available on the market today from many different manufacturers but also new pads designed specifically for low pressure applications.

In theory the measurement of  $R(\text{th})_{\text{cs}}$  is simple but it has proven very difficult to duplicate measurements amongst different test labs. There are too many variables involved, includ-

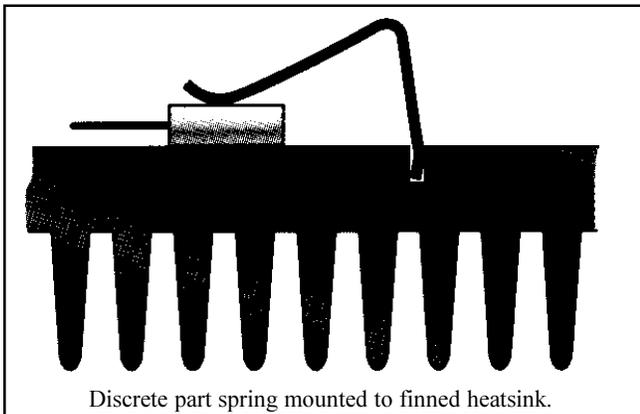
## IXAN0029

ing type of package, heatsink flatness and finish, and the test environmental factors of time, pressure and temperature. Consequently today it is the exception to find graphs plotting R(th)cs vs. pressure for different washers and therefore the user must make his own side-by-side comparison of various materials in his equipment.

For low pressure mounting, Bergquist offers their Sil-pad 800-S® and 900-S®. Both Chomerics and Power Devices have pads that undergo a phase change and flow to conform to the mating surfaces. Pads with a pressure sensitive adhesive may also provide low R(th)cs at very low pressures.

### Pressure Mounting Springs and Clips

As explained above, mounting pressure plays a key role in reducing R(th)cs. Mounting clips come in many different forms from the spring inserted into a slot on the heat sink (see illustration) to various U-shaped and saddle clips to spring bars to



hold down the semiconductor.

However, the typical spring clips today can only apply between 10 - 50N (2 - 10 lbs) of force, which equates to a range in pressure of 60kPa (8 PSI) to 300kPa (40 PSI) for the TO-220 to slightly more than one-half of this for the PLUS TO-247 package. It certainly helps that the force is centered over the semiconductor chip as illustrated in the drawing but the low pressures cited above emphasize the need to choose the appropriate thermal conducting materials.

IXYS epoxy molded packages can easily withstand pressures up to 2.27MPa (300PSI), achievable with screw mounting. The width of the spring should be about 80% of the package width and the contact area of the spring on top of the package adjusted so as not to exceed that limit.

### List of Manufacturers of Thermally Conductive Materials

1. The Bergquist Co.  
5300 Edina Industrial Blvd.  
Minneapolis, MN 55439  
Tel: 612-835-2322
2. Power Devices, Inc.  
Thermal Interface Products Group  
26941 Cabot Road, Bldg. 124

Laguna Hills, CA 92643

Tel: 714-582-6712

3. Chomerics  
6 Flagstone Drive  
Hudson, NH 03051  
Tel: 781-939-4453
4. Thermagon, Inc.  
3256 West 25th St.  
Cleveland, OH 44109  
Tel: 888-246-9050 or 216-741-7659
5. Kunze Folien GmbH  
Postfach 66; D-82033 Oberhaching  
Germany  
Tel: 089/6 13 38 84

### List of some Spring Clip Manufacturers

1. Thermalloy, Inc. UK office:  
PO Box 810839 Cheney Manor  
Dallas, TX 75381 Swindon, Wiltshire SN2 2QN  
Tel: 214-243-4321 Tel: +44 1793-537861
2. Aavid Thermal Technologies  
One Kool Path  
Laconia, NH
3. EG&G Wakefield Engineering  
Components Division  
60 Audubon Road  
Wakefield, MA 01880  
Tel: 617-246-0874
4. Kunze Folien GmbH  
Postfach 66; D-82033 Oberhaching  
Germany  
Tel: 089/6 13 38 84
5. Austerlitz Electronic gmbh  
Ludwig Feuerbach - Strasse 38  
90961 Nuernburg, Germany

### References:

1. *A Comparison of Semiconductor Isolation Materials* by Kevin Hanson, available from the Bergquist Co.

Q-Pad 3® Sil-pad 800-S® and 900-S® are registered trade marks of The Bergquist Co.

Thermstrate® is a registered trade mark of Power Devices, Inc. PLUS247™ is a trademark of IXYS Corporation.