

The maximum permissible junction temperature (T_{jmax}) of an IGBT is fixed and a suitable heatsink must be selected to keep the junction temperature (T_j) below this maximum. If T_{jmax} is exceeded damage may occur to the IGBT.

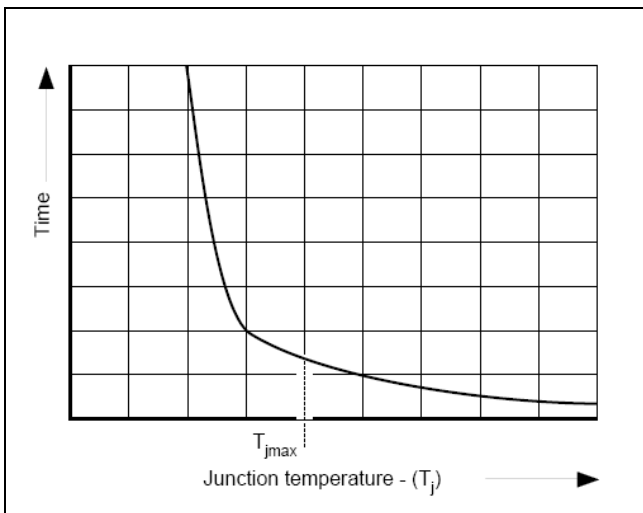


Fig. 1 Silicon semiconductor life expectancy

SILICON SEMICONDUCTOR LIFE EXPECTANCY

The relationship of life expectancy and operating junction temperature for a typical silicon semiconductor is shown in figure 1. Average life expectancy for a silicon semiconductor is greatly increased if a lower junction temperature is maintained. It is very important to consider these effects when defining cooling methods.

COOLING

The electrical connections of IGBT modules are usually electrically insulated from their base plates, allowing several devices to be mounted on the same heatsink. The method of cooling must ensure that the (T_{jmax}) of each module is not exceeded. A simple equivalent thermal circuit can be drawn to represent the heat conduction in a semiconductor device, in this case a single IGBT chip in a module. For the equivalent circuit it is assumed that the power loss (W) is generated in the 'virtual junction' (J) of the IGBT die. The equivalent thermal circuit used is shown in figures 2 and 3.

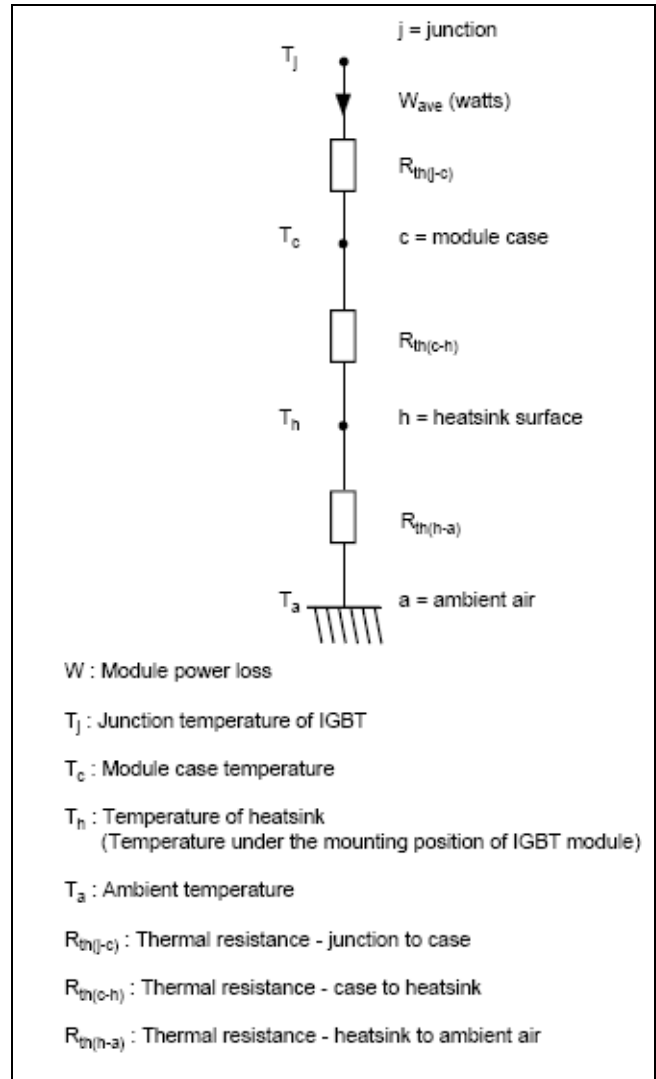
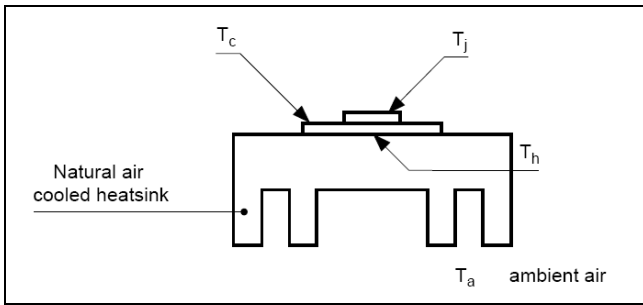


Fig. 2 Equivalent Thermal Circuit

Using the equivalent circuit the average junction temperature can be calculated as follows:

$$T_j = W \times \{R_{th(j-c)} + R_{th(c-h)} + R_{th(h-a)}\} + T_a$$

The module power loss (W) includes the switching and conduction losses of the IGBT. The thermal capacity of the heat sink is significant and so the case to heat sink junction responds to the average heating effect.


Fig. 3

Note: The heatsink temperature (T_h) is measured directly below the IGBT module. The thermal capacity of the heatsink affects the short term overload current capability of the module and needs to be considered when selecting a heatsink.

CHOOSING THE RIGHT HEATSINK

When cooling is required several need consideration: -

- What is the maximum permitted junction temperature?
- What is the maximum junction temperature to achieve a semiconductor lifetime requirement?
- What overload current capability is required?
- What cooling methods are available?
- What are the costs of the cooling methods?
- How reliable is the cooling method?
- How much physical space is there for cooling?
- Etc.

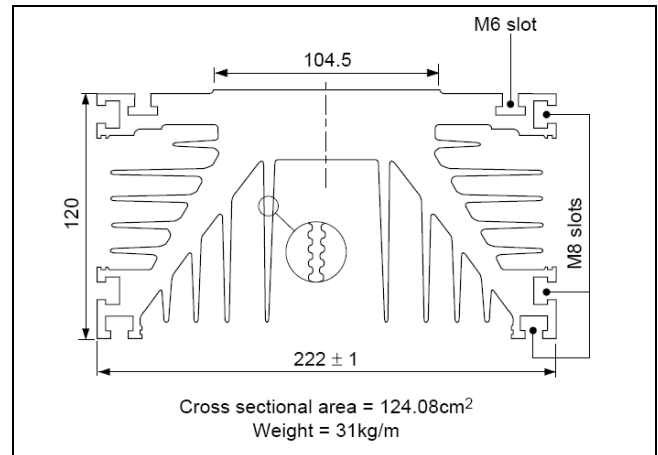
NATURALLY AIR COOLED ASSEMBLIES (AN)

If there are no physical constraints on the size of the heatsink a reliable cooling solution is a Naturally Air Cooled Heatsink (AN). The only failure that can occur in such an assembly is the in module. This method of cooling can be low cost. Orientation of the heatsink is important to take advantage of natural convection.

FORCED COOLED ASSEMBLIES (FC)

These are very similar to naturally air-cooled assemblies but here the air is forced along the heatsink fins instead of relying on air convection currents. This technique reduces heatsink size but the heatsink needs to be enclosed so that airflow is channeled down the fins. A fan forces the air through the fins and the power of the fan depends on the level of cooling required.

Failure of the fan causes the heatsink to become less effective and may result in module failure. A temperature sensor may be fitted to the heatsink, which can be used to shutdown the system if the heatsink goes over temperature.


Fig. 4 Typical air cooled heatsink outline

For high power applications, the Dynex Semiconductor EM heatsink is suitable for both AN and Forced cooled applications. The heatsink profile is shown in figure 4.

The thermal resistance of FC and AN cooled heatsinks can be reduced by black anodising the heatsink. The thermal resistance of the heatsink surface to air, $R_{th(h-a)}$, is improved because of increased radiation from the heatsink surface. Radiation effects are more significant at higher surface temperatures. The overall effect is that thermal resistance appears to decrease with increases in power dissipation.

WATER COOLED HEATSINKS

Water-cooled heatsinks are very efficient and have a high thermal capacity. These assemblies offer considerable space savings in comparison with air-cooled types.

MOUNTING RECOMMENDATIONS

Users should read these recommendations prior to mounting Dynex Semiconductor IGBT modules. Failure to follow the recommendations may lead to high thermal resistance case to heatsink, ($R_{th(c-h)}$), resulting in permanent damage to the module.

Base plate

The base plate of high power IGBT modules is designed with a convex shape to ensure optimized thermal contact when mounted properly on the heatsink. However due to manufacturing processes there is always some unevenness and there may be areas of local concavity.

Heatsink specification:

The surface condition of a heatsink also has an important influence on the thermal dissipation of the system. The mounting area on the heatsink and the module should be clean and free of particles to promote maximum thermal conductivity between the two surfaces.

The recommended mechanical specification of the mounting area is:

Flatness: $\leq 30\mu\text{m}$ over entire contact area
Roughness: $\leq 10\mu\text{m}$

Mounting of module to the heatsink:

Dynex offer a guide for module mounting. However, it is the responsibility of the user to confirm the suitability of the process for their heatsink and grease combination.

A recommended layer of suitable thermal grease or paste, approximately 100um thick, should be applied to the module base plate surface.

It is necessary to fill all air gaps caused by the base plate profile when mounted under pressure to the heatsink.

- Ideally the grease or paste should be applied using a stencil designed specifically for the module being mounted. Dynex can provide advice on the stencil if required.
- A simpler method would be to use either a roller or a toothed spatula. This manual approach will generate large errors in the paste thickness. Dynex therefore recommend that trials are conducted and assessed using a “Wet film thickness gauge” to determine the ideal paste thickness for the chosen method.

In all cases, grease or paste should be kept away for the heatsink and bolt threads as it will compromise the mounting torque settings.

Mounting bolt sub-assemblies. The use of spring washers will help compensate for any settling effects of the paste by ensuring the mounting bolt tension is maintained. They also assist in counteracting any loosening of the mounting bolts.

Put the recommended fixing bolts in the holes and finger tighten.

Select the appropriate outline, and note the sequence for tightening the mounting bolts.

Using a torque wrench, tighten the bolts in the correct sequence to:

- 10% of the data sheet mounting torque.
- 50% of the data sheet mounting torque.
- Leave for a minimum of 30 minutes. The time is paste viscosity dependant, and trials may be necessary to confirm paste movement has ceased.
- Complete to 100% of the data sheet mounting torque.

After tightening, the heatsink compound should “overflow” slightly around the module perimeter.

Note: When mounting a single module place it in the centre of the heatsink with the longest side of the module parallel to the direction of the heatsink fins. (see figure 7). This reduces the effect of heatsink distortion due to temperature change.

When mounting more than one module on the same heatsink care must be taken to allow adequate area for modules that require greater cooling to maintain the desired junction temperature.

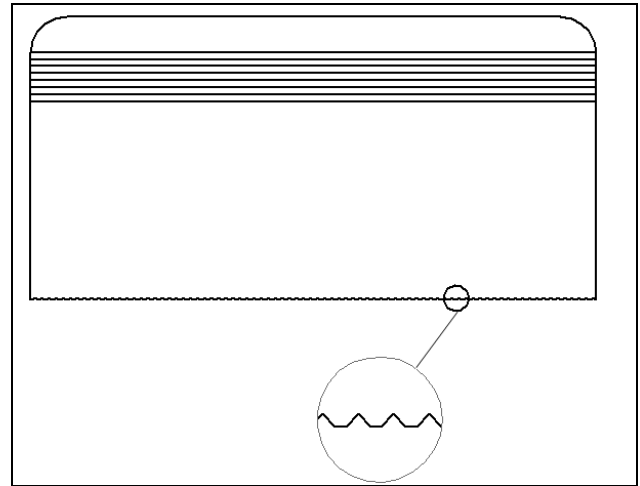
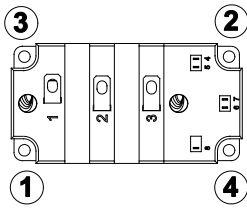
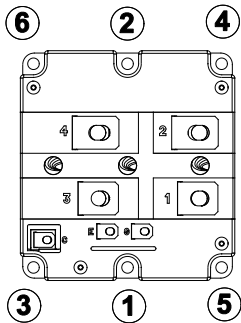


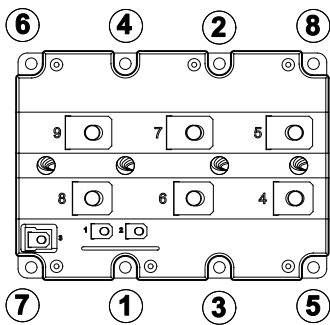
Fig. 5 Spatula Profile



Tightening Sequence: 1, 2, 3, 4



Tightening Sequence: 1, 2, 3, 4, 5, 6



Tightening best Sequence: 1, 2, 3, 4, 5, 6, 7, 8

Fig. 6 Screw/bolt tightening sequence for Dynex Semiconductor IGBT modules

THERMAL EFFECTS OF PARALLELING IGBT DEVICES

When operating IGBTs in parallel consideration should be given to current sharing, so that individual units operate within their limits (see figure 8). The most important parameters to consider are on-state voltage ($V_{ce(on)}$), current (I_c) and temperature. The

V_{ce} versus I_c characteristic varies as a function of the temperature and for this reason it is good practice to mount several modules on the same heatsink to ensure they have similar a T_j . Using separate heatsinks can cause large current mismatches due to unequal heatsink temperatures.

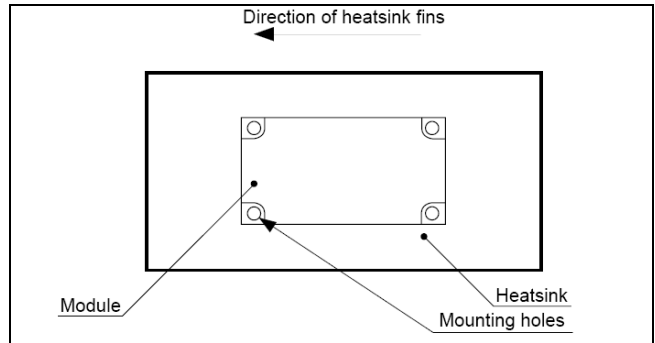


Fig. 7 Mounting Orientation

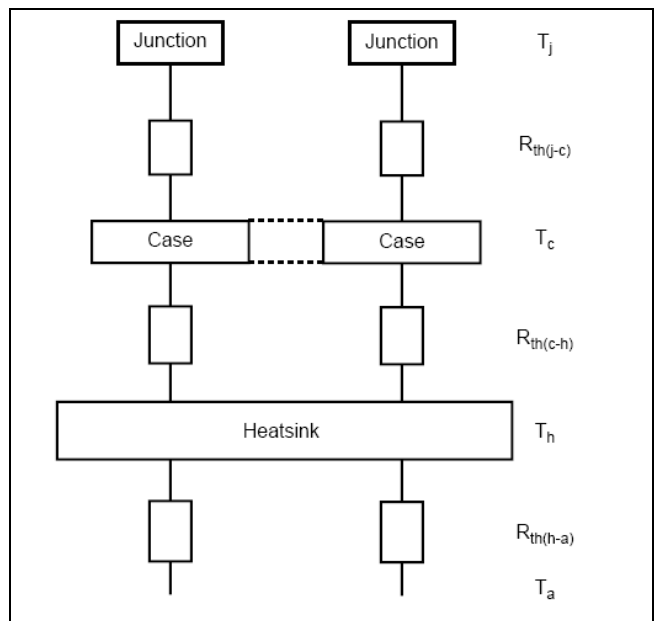


Fig. 8 Paralleling considerations

POWER ASSEMBLY CAPABILITY

The Power Assembly group was set up to provide a support service for those customers requiring more than the basic semiconductor, and has developed a flexible range of heatsink and clamping systems in line with advances in device voltages and current capability of our semiconductors.

We offer an extensive range of air and liquid cooled assemblies covering the full range of circuit designs in general use today. The Assembly group offers high quality engineering support dedicated to designing new units to satisfy the growing needs of our customers.

Using the latest CAD methods our team of design and applications engineers aim to provide the Power Assembly Complete Solution (PACs).

HEATSINKS

The Power Assembly group has its own proprietary range of extruded aluminium heatsinks, which have been, designed to optimise the performance of Dynex semiconductors. Data with respect to air natural, forced air and liquid cooling (with flow rates) is available on request.

For further information on device clamps, heatsinks and assemblies, please contact your nearest sales representative or Customer Services.

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The products must not be touched when operating because there is a danger of electrocution or severe burning. Always use protective safety equipment such as appropriate shields for the product and wear safety glasses. Even when disconnected any electric charge remaining in the product must be discharged and allowed to cool before safe handling using protective gloves.

Extended exposure to conditions outside the product ratings may affect reliability leading to premature product failure. Use outside the product ratings is likely to cause permanent damage to the product. In extreme conditions, as with all semiconductors, this may include potentially hazardous rupture, a large current to flow or high voltage arcing, resulting in fire or explosion. Appropriate application design and safety precautions should always be followed to protect persons and property.

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