Diotec Semiconductor

Application Note

Thermal Resistance of Rectifiers – The Tricks and the Truth

Semiconductor Rectifier Devices have three important absolute maximum ratings:

- ➔ The Maximum Breakdown Voltage
- ➔ The Maximum Surge Rating
- ➔ The Maximum Junction Temperature

Rectifiers are essentially limited by the Maximum Junction Temperature (T_{jmax}), not by their maximum Average Forward Rectified Current rating (I_{FAV}). Both are linked via the power dissipation and the thermal resistance. However it is exceeding the maximum T_j that damages the rectifiers.

There have been over the past decades several attempts by marketing people to make their rectifier datasheets more attractive. They increase the Ifav to make the rectifier look more powerful than their competitor's device. The trick to do this is to specify the rectifiers in unrealistic environments on layouts that have a thermal resistance that is not encountered in normal situations. A typical trick used is to specify the rectifier on a hybrid substrate.

The Laws of Physics are the same for all rectifier manufacturers. The key formula is:

$$\mathbf{T_j = P_d \times R_{thA} = V_F \times I_{FAV} \times R_{thA} <= T_{jmax}}$$

This equation is an approximation and ignores the losses due to the leakage current and the reverse switching losses as well as temperature dependence of Forward Voltage Drop V_F. All the losses however have to be multiplied also by the thermal resistance. When comparing rectifiers, do not compare I_{FAV} in the datasheet but compare the V_F rating in the datasheet. The V_F is directly linked to the die size and allows you to compare apples to apples. Also look at the Typical $V_F$curves available in most datasheets. This simple exercise allows you to determine and compare the die size of the product you are buying. Please note that Fast Efficient Rectifiers are the exception because the V_F here is also determined by the amount of Au or Pt dopant material used to reduce the Reverse Recovery Time t_{rr}.

There are a few rectifier manufacturers that define their I_{FAV} with a duty cycle of 50%. The industry standard is 100%. This obviously gives them better values so look also at the small print on duty cycles.
From the above equation for T_{jmax} it becomes immediately clear that you can increase the datasheet I_{FAV} by decreasing the Thermal Resistance Junction to Ambient R_{thA}. This marketing trick is used by several manufacturers.

The Derating Curve shown in Fig. 1 is an example for such marketing trick. The product, made by a competitor, is specified under 2 conditions. The normal condition for the rectifier is: "mounted on a glass Epoxy PCB or FR4 ". Sometimes a lower grade PCB may be used and in that case the thermal resistance usually even increases. The "Aluminum Substrate" curve is an indication of the power derating in a hybrid circuit. Obviously that curve looks more favourable, but please note that this may only be relevant in 1% of all applications! Some rectifier manufacturers only publish this curve. The curves shown in Diotec's data sheets however are always related to the common standard material Glass Epoxy/FR4.

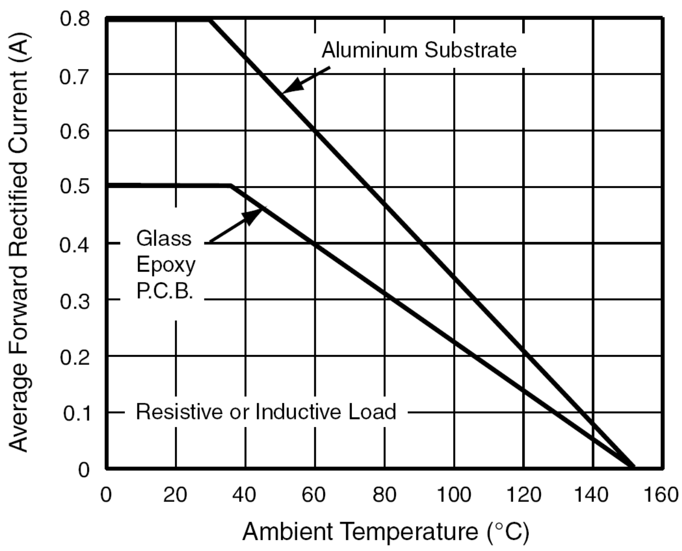

Fig. 1: Marketing trick No. 1 – Aluminum Substrate gives higher rated currents

Another footnote to compare is the set up of the Thermal Resistance test. In the example shown – quite typical for the industry – the device was mounted on a glass Epoxy PCB substrate on 1.3 x 1.3 mm pads. By changing the solder pads and by increasing their size, one reduces thermal resistance. From a design perspective, this is very good as a reduced junction temperature increases the lifetime and reduces MTBF. However this is also exploited by marketing people making their rectifier look more powerful. Again here make sure you are comparing apples to apples.

The derating curve is a tool that is often misunderstood. Obviously at the maximum junction temperature the current has to be zero. However the other parts in the curve can be influenced by marketing people. It becomes obvious from comparing the curves in Fig. 1 and Fig. 2 that some products are specified using Ambient Temperature and some products are specified using Lead Temperature.

The total thermal resistance consists in the Junction to Lead portion and the Lead/PCB contact point to ambient. The second part of the thermal resistance – Lead to Ambient is more than 90% of the total thermal resistance in most designs. So just looking at derating curves using the Lead temperature may give misleading results. In most PCB designs the lead temperature is limited to 95°C or lower.

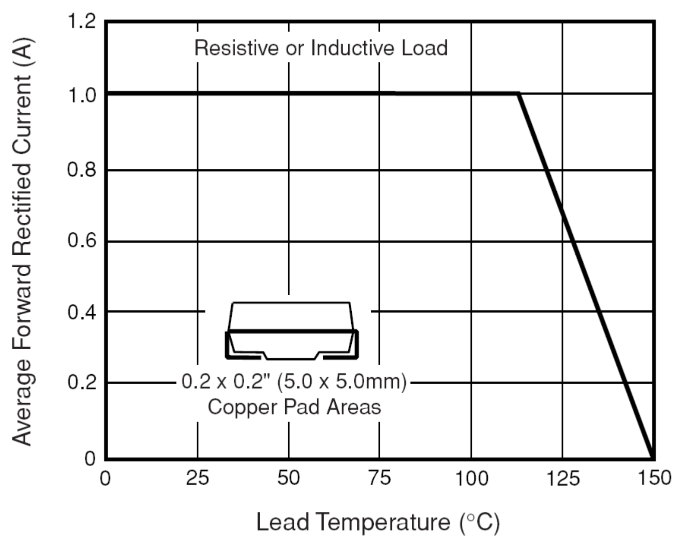

Fig. 2: Marketing trick No. 2 – Referencing to Lead Temperature gives better looking curve

The slope of the derating curve is determined by the thermal resistance of the design. The real thermal resistance is the thermal resistance on the designer's PCB. The manufacturer's datasheet may have no link to your specific design and may be too optimistic.

The point where the derating curve starts is chosen by the manufacturer and can be used as a marketing tool to make a rectifier look more attractive. If one starts derating the diode at 110°C the diode will look more powerful than when derating at 25°C.

Also, try to understand the structure of the components you are buying:

A MiniMELF for example is only 3.5mm long but the fact that massive copper plugs are soldered to the die means that the heat is very efficiently transferred away from the junction, see Fig. 3. This is an advantage over a lead frame construction (see Fig. 2) or constructions using wire bonds. There the cross section of copper contact is much smaller, leading to increased thermal resistance and thus reduced current ratings.

The MELF technology in contrast allows Diotec to offer 1 Amp rectifier diodes in the small MiniMELF package, and 3 Amp ones in the 5mm long MELF.

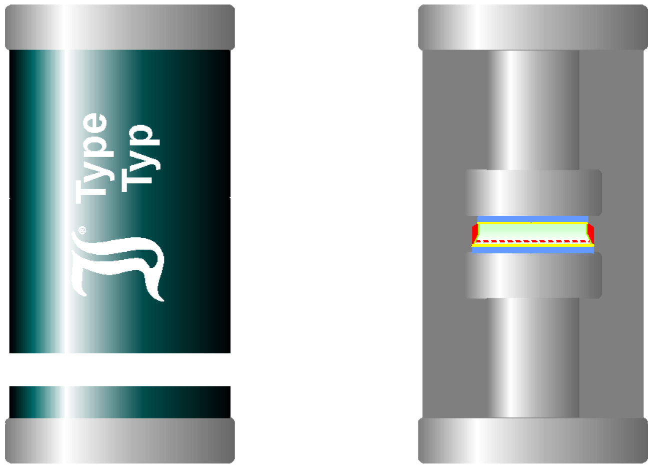

Fig. 3: Semiconductor Die in (Mini)MELF package: Optimum Thermal Construction

The Rectifier industry tends to be underestimated. Ten of Billions of rectifiers are manufactured every year and they are by far the highest volume Power Semiconductor. Most rectifiers dissipate a lot of power and experience high voltages. Their junction temperatures can be quite high. As such, from a reliability and MTBF perspective they receive a lot of stress. But they are always under price pressure.

One of the better ways to improve reliability is to be conservative on thermal resistance. Thermal resistance measurements tend to be not the most reliable measurements so it is best to actually look for and measure the real temperatures in your design. Manufacturer's datasheet need to be examined carefully to evaluate that the conditions stated are realistic for your design.

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