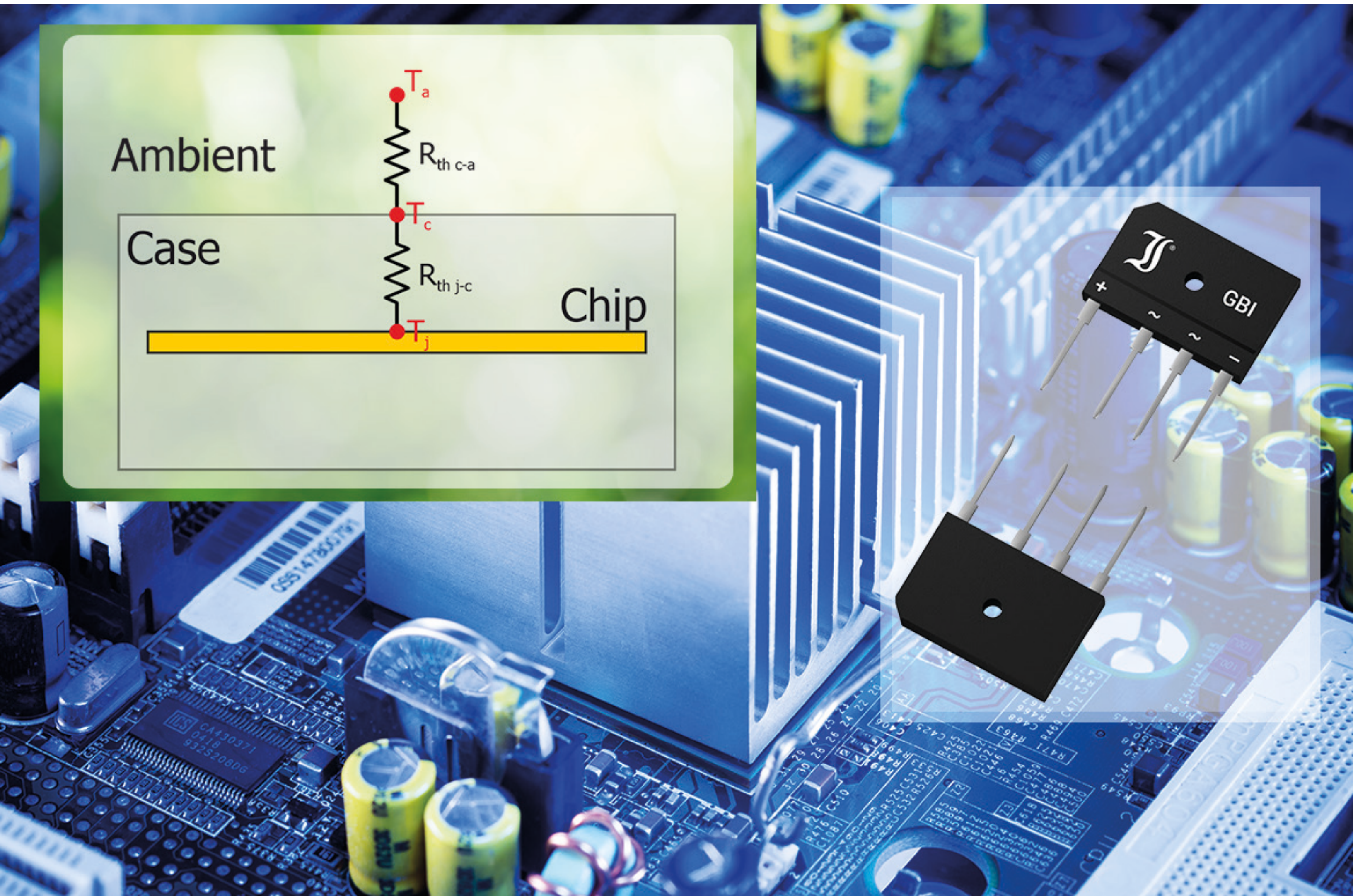
APPLICATION NOTE

Diotec Semiconductor



Understanding Thermal Specification of Bridge Rectifiers

Mastering thermal management of power applications is one of the highly underestimated challenges electronic designers must overcome. This application note explains the mechanisms of heat transfer in semiconductor components along with Diotec's datasheet parameters of 1ph and 3ph Bridge Rectifier. It further describes a way to determine whether a bridge is suitable for a given output current and ambient respectively case temperature. The conduction of electric current at a voltage generates heat in a semiconductor material thus increasing the temperature of the pn-junction. A higher temperature is directly tied to an increased probability of failures and a reduced component lifetime. In order to assure safe operation, designers must take measures to reduce the junction temperature during operation.

1. Mechanisms of heat transfer in semiconductor components (free standing)

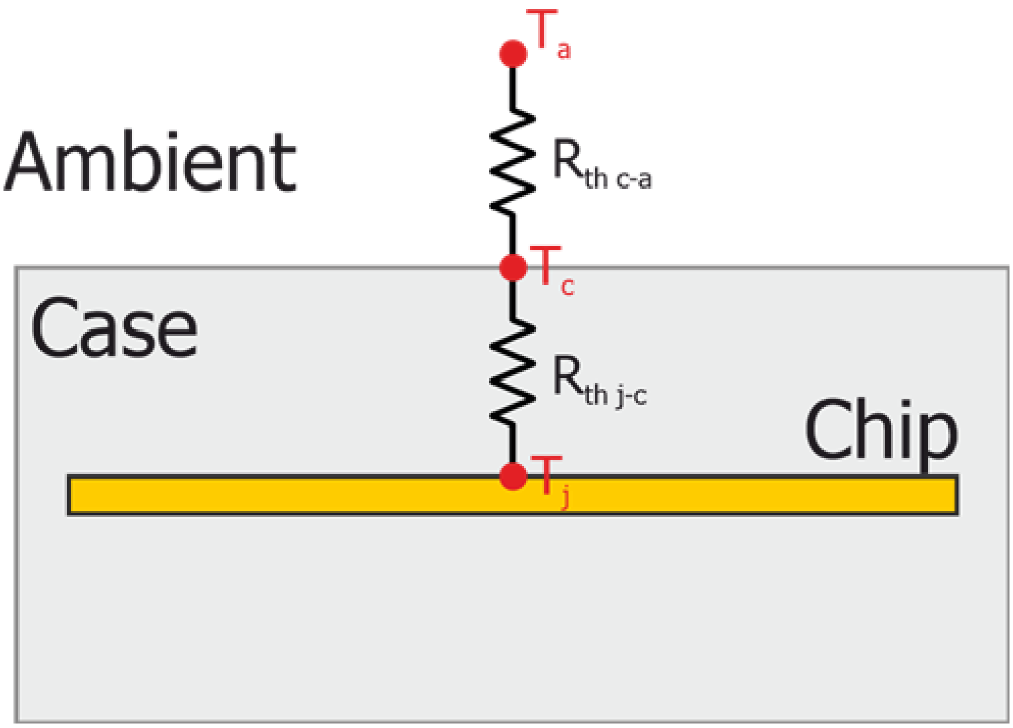


Figure 1 Heat Transfer Path when Free Standing

In semiconductor components, heat transfers from the hot areas to the cooler ones by different paths. Fig. 1 shows the thermal resistive path of heat transfer from the hot pn-junction to the ambient via the component case.

$$T_j = P * R_{(th\ j\text{-}a)} + T_a \quad (1)$$

$$R_{(th\ j\text{-}a)} = R_{(th\ j\text{-}c)} + R_{(th\ c\text{-}a)}$$

T_j: Temperature of pn-junction

T_a: Temperature of ambient

P: Power Dissipation

$R_{(th\ j\text{-}a)}$: Thermal Resistance junction-to-ambient

$R_{(th\ j\text{-}c)}$: Thermal Resistance junction-to-case

$R_{(th\ c\text{-}a)}$: Thermal Resistance case-to-ambient

2. Mechanisms of heat transfer in semiconductor components (on heatsink)

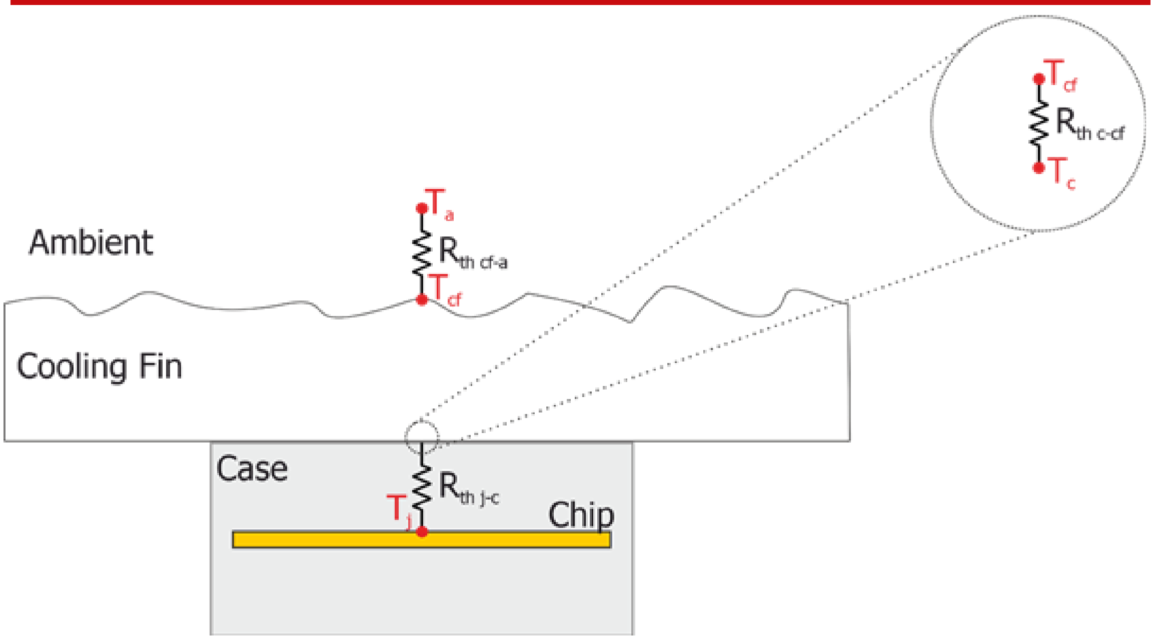


Figure 2 Heat Transfer Path with Cooling Fin

A heatsink improves the heat transfer by introducing an additional path with a low thermal resistance.

$$T_j = P * R_{(th\ j\text{-}a)} + Ta \quad (2)$$

$$R_{(th\ j\text{-}a)} = R_{(th\ j\text{-}c)} + R_{(th\ c\text{-}cf)} + R_{(th\ cf\text{-}a)}$$

$R_{(th\ c\text{-}cf)}$: Thermal Resistance case-to-cooling fin

$R_{(th\ cf\text{-}a)}$: Thermal Resistance cooling fin-to-ambient

A thermal paste applied between the thermal pad of the component case and the cooling fin improves the heat transfer at the contact area. Recommendations of the thermal paste manufacturer must be respected and the thermal resistance of the paste must be taken into account.

3. Datasheet Specifications of Bridge Rectifiers

3.1 Free standing

For free standing bridge rectifiers, Diotec specifies a maximum average rectified current at a certain ambient temperature. This is sampled close to the component case (as specified in the datasheet footnotes). If the application requires a maximum ambient temperature higher than the datasheet specification, the max. current must be derated. For a reliable design, operation at maximum values is to be avoided with appropriate safety margins in place.

3.2 Cooling fin

When mounted on a heatsink (e.g. a cooling fin), the total thermal resistance between pn-junction and ambient is reduced. The larger the cooling fin area, the lower the thermal resistance and the better the thermal transfer. Diotec specifies a maximum average rectified current for a specific case temperature and area of the cooling fin. Due to the improved thermal resistance, the maximum value for the current is higher than for applications where the bridge rectifier is free standing.

3.3 Forced cooling

For applications without a heatsink, an active cooling (e.g. cooling fan) can be used to improve heat transfer.

4. Estimation of junction temperature at given output current

Formulas (1) and (2) allow to determine the junction temperature at given ambient respectively case temperature, when power losses P are known. No matter if single or three phase bridge, always only two diodes are conducting at the same time. Depending on how R_{th} is defined, this has to be considered accordingly. The duty cycle per diode is 1/2 for the single phase bridge and 1/3 for the three phase one. Power dissipation P becomes then as follows:

$$P = V_F * I_{FAV} * n * m$$

V_F: Forward voltage drop of the single diode at I_{FAV} and T_j

I_{FAV}: Average current at the output of the bridge

n= 1/2 (for 1ph bridges) or n= 1/3 (for 3ph bridges)

m= 2 (if R_{th} is „per device") or m= 1 (if R_{th} is „per diode")

Since V_F is difficult to be measured in the real application, one can use the maximum value at 25°C as specified in the data sheet. Since real diodes will get hot during operation and V_F thus will get down (due to its negative temperature coefficient), this procedure leads automatically to a certain safety margin. As such it covers unforeseeable, short overloads which might occur in the application.

It is a good practice to use the bridge at junction temperatures of not much higher than 100°C, even if maximum rating is at 150°C. According to Arrhenius' law, every 10K of reduced T_j improves the lifetime by a factor of 2. So in order to achieve a long lifetime and high reliability, it is worth to spend some effort in improved cooling or to choose a higher rated device.