

## High Temperature Reverse Bias (HTRB)

Schottky rectifiers are comparatively sensitive to temperature in reverse leakage current, particularly as junction temperature ( $T_J$ ) approaches maximum rating ( $T_{J(MAX)}$ ) for their barrier metal design. Therefore Schottky rectifier applications with high temperature and reverse bias require precautions compared to operating other conventional pn junction design rectifiers. This includes HTRB test methods that may optionally be performed for screening purposes.

For conventional pn junction rectifiers HTRB is often performed at 150°C. However, these pn junction diodes have comparatively low reverse leakage currents up to junction temperatures ( $T_J$ ) of 150°C, hence negligible reverse power is generated under HTRB conditions.

Schottky rectifiers normally have leakage currents significantly higher than pn junction devices, particularly as maximum rated  $T_J$  is approached for low energy barrier metal designs. In high temperature applications, this can contribute excessive reverse power ( $P_R$ ) and self heating during a poorly controlled HTRB. When reverse power exceeds the device capability along with its mounting to dissipate heat at the same rate it is generated, the Schottky will exceed  $T_{J(MAX)}$  and will go into thermal runaway. To determine

maximum ambient operating temperatures versus rated  $T_{J(MAX)}$  or simply determine maximum HTRB operating temperatures for accelerating and identifying “infant mortality” failures in screening, the following is provided to better understand and control thermal conditions for Schottkys.

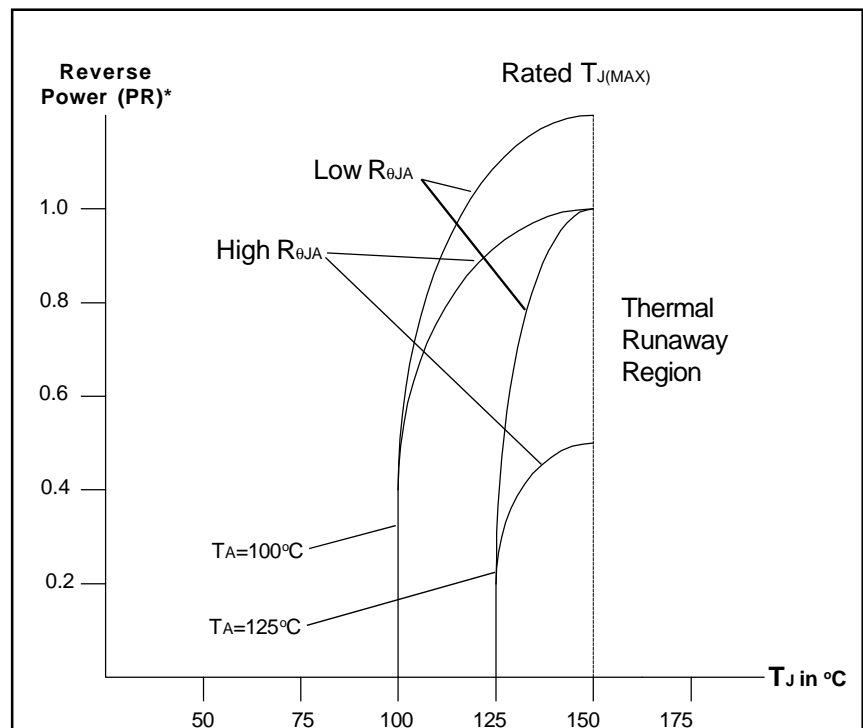
Most HTRB testing is provided at an elevated ambient temperature

( $T_A$ ) which affects junction temperature of the device as follows:

$$T_J = T_A + [R_{\theta JA} \times P_R]$$

The  $R_{\theta JA}$  is the total thermal resistance from junction to ambient and the  $P_R$  is the reverse power

*A comparative illustration of reverse power versus junction temperature for various thermal resistance and ambient conditions is provided in Figure 1 for the typical behavior of Schottky rectifiers with a  $T_{J(MAX)}$  rating of 150°C.*



**FIGURE 1**

Typical Reverse Power vs. Junction Temperature for Schottky Rectifiers rated with  $T_{J(MAX)}$  of 150°C

\* Power Normalized to 1.0 for rated  $I_o \times V_F$ . The  $I_o$  is rated average forward current and  $V_F$  is the forward voltage at  $I_o$

# MicroNotes

## Series 402

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generated. This power is a product of current leakage ( $I_R$ ) and the reverse working voltage ( $V_W$ ), or  $P_R = I_R \times V_W$ . This overall effect may then be expressed as follows:

$$T_J = T_A + [R_{\theta JA} \times I_R \times V_W]$$

As may be seen, the added product of thermal resistance, leakage current, and reverse voltage provides an increase in  $T_J$  beyond ambient. This is a sensitive relation since  $I_R$  also exponentially increases with  $T_J$  as well. This can rapidly develop into a thermal runaway condition when approaching the  $T_{J(MAX)}$  for a specific Schottky design. The  $T_{J(MAX)}$  is determined primarily by the metal energy barrier height of the Schottky rectifiers described in MicroNote 401. Since  $R_{\theta JA}$  is greatly influenced by a high package thermal resistance of junction to case or lead ( $R_{\theta JC}$  or  $R_{\theta JL}$ ) as exhibited on smaller Schottky devices, it can also have

a significant influence on  $T_J$ . Also a contributing part of  $R_{\theta JA}$  is the parasitic thermal resistance portion from mounting ( $R_{\theta CA}$  or  $R_{\theta LA}$ ). This is case or lead to ambient through the heat sink and is additive to the device ( $R_{\theta JA}$  or  $R_{\theta JL}$ ). Also the last influencing factor to proportionally increase  $T_J$  above ambient  $T_A$  is the reverse working voltage  $V_W$ .

In those cases where an ACOL burn-in is applied to Schottky rectifiers, the effective total power for determining device heating will include forward power effects from the average forward current ( $I_O$ ) imposed on the device as well as the average reverse power effects when reverse biased in the cycle.

For HTRB screening at 80% of the Schottky voltage rating, this can often mandate guardbands in ambient temperatures of 25 to 50°C below the rated maximum junction temperature. This is required when considering typical mounting thermal resistance where for example axial leaded diode lead temperatures ( $T_L$ ) run well above ambient at their mounting location, particularly when power generation becomes significant as  $T_{J(MAX)}$  is approached.

For example, an axial leaded Schottky rated at  $T_{J(MAX)}$  of 150°C

should often not be exposed to ambient temperatures  $T_A$  above 100°C in HTRB screening environments with typical lead mounting practices. When mounting procedures are not optimized, further guardbands may be necessary in reducing ambient temperatures. For lower operating temperatures when leakage currents and power dissipation are negligible, the junction temperatures approach the ambient provided by an HTRB. Since leakage current and self heating also increase exponentially with applied voltage when thermionic emission begins to predominate with increased  $T_J$ , some Schottky rectifiers have been derated in reverse working voltage ( $V_{RWM}$ ) as well as average forward current ( $I_O$ ) by these cumulative effects with power and heating.

For high current rated Schottky diodes in large stud metal packages, minimal thermal resistance involved in good mounting practices is vital. Good thermal management with more effective cooling methods (less thermal resistance) is particularly important for those Schottky rectifiers with low barrier heights that are used to reduce forward voltage power losses.

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