Zener Voltage Regulation With Temperature

Zener diodes are affected by temperature changes associated with their voltage temperature coefficient (α_{vz}). This characteristic α_{vz} is usually included in the applicable zener specification data sheet where it is often stated in a percent change in zener voltage per degree centigrade (%/°C), or occasionally in mV/°C. The αvz can be as low as -0.09 %/°C for low voltage zeners, or as high as +0.110 %/°C for high voltage zeners. This is further illustrated in figure 1.

The temperature coefficient is used in predicting voltage- temperature behavior. The zener junction temperature (T_J) will be affected by both the ambient environment and the self heating effects from applied zener power ($P = V_Z \times I_Z$). Self heating is generated by zener package thermal resistance from junction to case ($R\theta_{JC}$) or lead ($R\theta_{JL}$). This MCC Note will focus primarily on

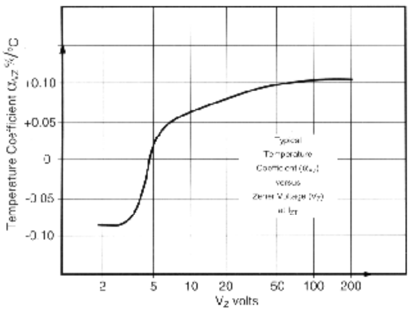

Figure 1. Temperature Coefficient vs Zener Voltage

outside ambient temperature (T_A) and its effect on zener voltage V_Z. Internal heating and heat sink mounting considerations will be further described in MCC Note C004.

Figure 1 shows that a negative to positive temperature coefficient "transition" will occur in the vicinity of five volts for most zener product designs. When well above five volts, the positive α_{vz} for avalanche breakdown is generally independent of operating current (I_Z). When in the five volt zener device region or below where transition to field emission or "tunneling breakdown" occurs, negative values of α_{vz} are observed that are also notably affected by various operating current values. This phenomenon and its typical characteristics are illustrated in figure 2 for 500 mW zeners. At very low zener voltages where field emission predominates, the α_{vz} is again unaffected by current variations.

Zeners are specified for voltage (V_Z) at ambient T_A of 25°C. The voltage change (ΔV_Z) may be calculated for PN junction temperature change ΔT_J from an initial T_A of 25°C using the formula:

$$\Delta V_Z = \alpha_{vz} \times V_Z \times \Delta T_J / 100$$

For low power levels or pulse test methods the T_J temperature will approximate T_A. However, most zener JEDEC "1N" diode registrations are specified for V_Z at dc thermal equilibrium conditions at their specified test current I_{ZT}. These dc power test conditions require a period of time in self heating before thermal equilibrium is achieved with internal zener junction temperature T_J above ambient T_A. A difference will then exist in zener voltage pulse testing compared to specified thermal equilibrium that often require

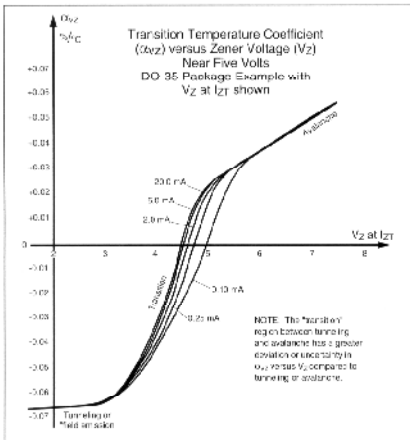

Figure 2. Transition Temperature Coefficient vs Zener Voltage Near Five Volts

20 seconds or longer to achieve. The described voltage shift is easily observed for axial lead package configuration tested at 25% of full rated power, despite heatsinking at typical specified lead lengths of 0.375 inch (10 mm) from the body.

When zener thermal equilibrium conditions have already been included for V_Z reference and an external ambient temperature change of ΔT_A causes further changes in voltage ΔV_Z, a similar calculation applies. This can simply be expressed as:

$$\Delta V_Z = \alpha_{vz} \times V_Z \times \Delta T_A / 100$$

Additional important considerations to package mounting and thermal resistance on PN junction temperatures and zener voltage will be further described on MCC Note C004.