Zener Voltage Regulation with Current Changes

Zener diodes primarily serve as voltage regulators with variable operating currents when placed in parallel across a load to be regulated. From various categories, selected zener voltage (V_Z) nominals can be available from 1.6 to 200 volts with tolerances typically plus or minus 5% or less at rated test current (I_{ZT}) and 25ºC.

At other I_z operating currents, slight changes can be observed in the specified zener voltage from dynamic impedance (Z_z) effects. These considerations are important when tight tolerance voltage regulation is desired, or if using zeners below five volts where Z_z is comparatively high. For these reasons in characterizing voltage regulation, the maximum Z_{ZT} is provided for zeners at their specified test current I_{ZT}.

Dynamic impedance is used to calculate small voltage changes (ΔV_z) from the initial V_z at I_{ZT} when operating current is changed by some small value (ΔI_z) from rated test current I_{ZT}. This simply involves Ohm's Law whereby:

$$\Delta V_Z = \Delta I_Z \times Z_{ZT}$$

For I_z values that significantly deviate from I_{ZT}, this becomes less accurate since Z_z will change with current on all zeners. Typically the Z_z decreases with increasing zener current on a log-log-scale plot shown in Figure 1.

For zeners typically operating in the linear declining slope region in Figure 1,

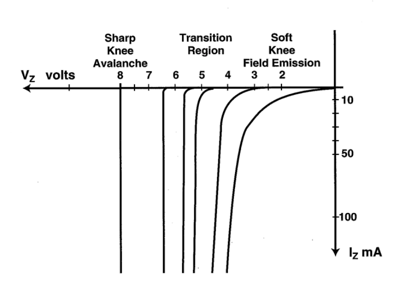

Figure 2. Typical Zener (I-V) Characteristics

it may be demonstrated that:

$$Z_Z \approx Z_{ZT} \times I_{ZT}/I_Z$$

A good approximation for the greater changes in zener voltage (ΔV_z) when current is notably changed from I_{ZT} to another value I_Z is as follows:

$$\Delta V_Z = 2(I_{ZT} \times Z_{ZT})(I_Z - I_{ZT})/(I_Z + I_{ZT})$$

The ΔV_Z is in volts, I_Z and I_{ZT} are in Amps and Z_{ZT} is in Ohms.

This is applicable only for operating currents in the linear operating region of Figure 1 where dynamic impedance values of the zener PN junction are still well above the minimal parasitic package resistance and other independent parasitic effects. During brief high current sureges, zener (or PN junction TVSs) are immediately driven deep into this minimal resistance avalanche region for good voltage clamping.

Zener voltage percent changes with operating current will be greater for low voltage zeners (below five volts) where dynamic impedance is much higher with field emission effects compared to the sharp knee avalanche characteristics of higher voltage zeners. These differences are illustrated in Figure 2.

The above equations for V_z voltage changes do not include additional ambient temperature changes or thermal self heating effects with applied zener power ($P = V_Z I_Z$) and device thermal resistance. These added effects can further notably influence V_z by voltage temperature coefficient characteristic inherent with zeners, particularly when applied power is significant relative to full rating or heatsinking is marginal. Ambient temperature and power heating effects on zener voltage regulators are further detailed in MCC Note B003 and C004. Zero temperature coefficient or "Zero-TC" reference diodes will also be described in additional MCC Note.

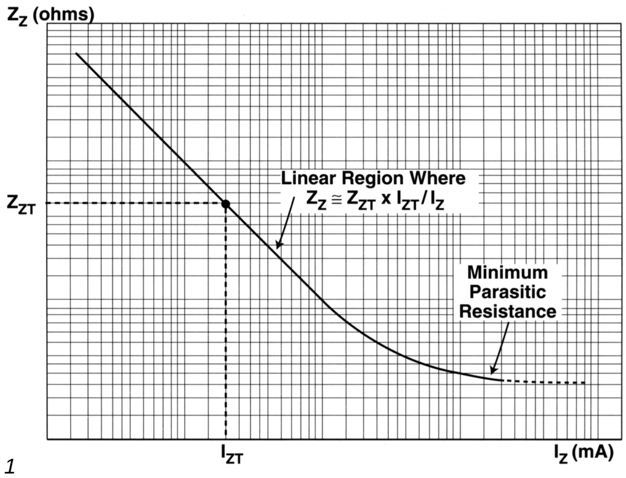

Figure 1
Typical Dynamic Impedance (Z_Z) versus Zener Current (I_Z) characteristics