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AN INTRODUCTION TO ZENER DIODES

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Solid state voltage regulator diodes or Zeners have been popular since the late 1950's when they replaced bulky vacuum tubes. Discrete zeners ranging from 500 mW to 5 watts or less have particularly remained a commonly used semiconductor product, despite the evolution of integrated circuits. High power zeners above 5 watts have increasingly been replaced by regulator ICs for power supply outputs, nevertheless power zeners are still used in a variety of areas.

A zener diode is a specially processed single PN junction that provides relatively constant voltage across two terminals despite changes in zener current. Because of this unique characteristic, it is used as a voltage regulator when placed in parallel across a load to be regulated. In special compensated multiple PN junction configurations, it may also be used as a "Zero-TC" reference voltage diode for very small changes in voltage over a wide operating temperature range. Other zener configurations for transient suppression have also evolved into their own specialized design features. These have been identified as Transient Voltage Suppressors described separately in the MicroNote™ No. 101 series.

Discrete zeners provide optimum versatility in many applications with significant levels of dc and transient power capability compared to those designed into application specific integrated circuits. These devices are typically available up to 200 volts and dc power levels to 50 watts or higher. Transient power capabilities are significantly higher.

A zener diode is operated in reverse bias for normal voltage regulation. When sufficient reverse voltage is applied (cathode end biased positively), the zener is driven into its reverse

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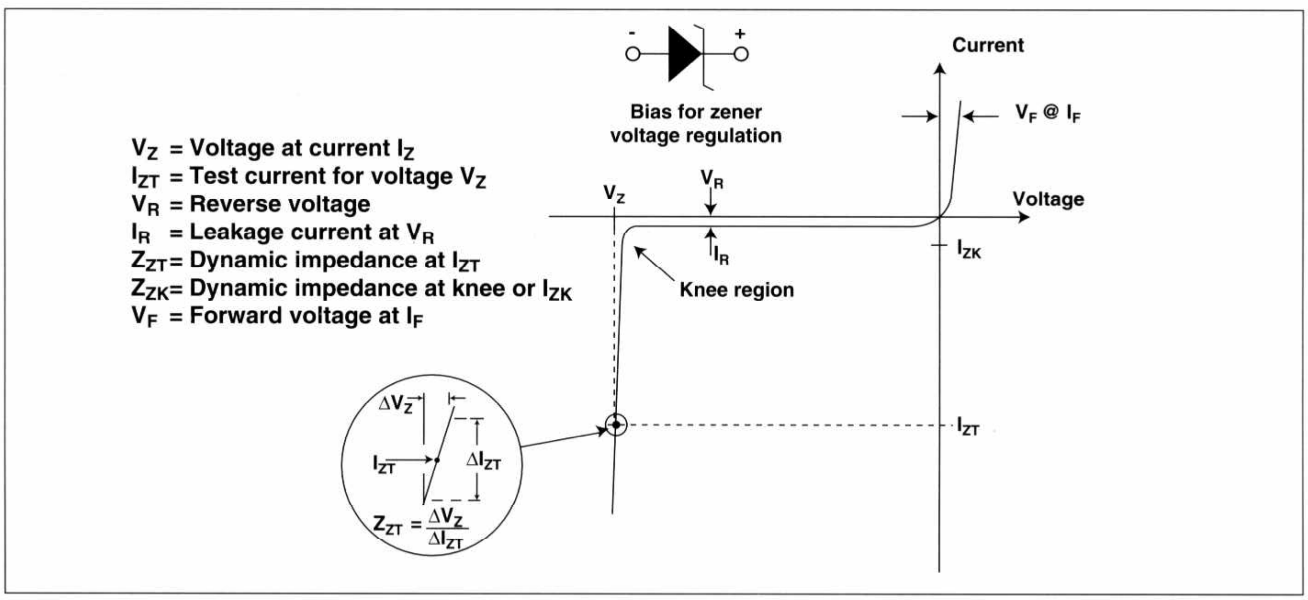

Figure 1. Zener Characteristics and Parameters

breakdown avalanche mode of operation. This is usually displayed in the third quadrant of a diode current-voltage relation as shown in Figure 1. The initial transition into avalanche breakdown is often called the "knee" region of the zener. In the avalanche operating region, only minor change in voltage (ΔV_Z) will occur as further increases in operating current (ΔI_Z) occur. When applied voltage is still below the avalanche region of the zener, leakage current (I_R) is very low typically less than a microamp. In the forward voltage direction (first quadrant), the voltage is comparatively low for current flow similar to rectifiers.

A measure of the voltage regulation capability is called dynamic impedance (Z_Z) in ohms which equates to the quotient of $\Delta V_Z/\Delta I_Z$ at a given operating current I_Z. The lower this value in ohms, the better the voltage regulation of a zener diode. Zeners will experience some operating current fluctuations in typical applications, since it is powered by a higher unregulated voltage source as shown in Figure 2. The operating current I_Z is determined by a resistor value R placed between the zener and the higher voltage source by:

$$I_Z = [(V_S - V_Z)/R] - I_L$$

where V_S is the higher unregulated voltage source and I_L is the current through the load.

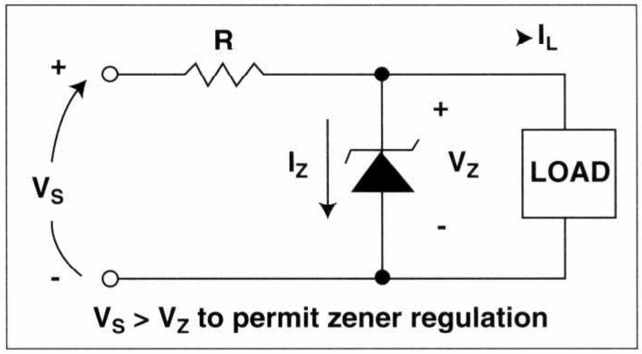

Figure 2. Typical Zener Circuit Application

When dynamic impedance is specified at the rated test current (I_{ZT}) for voltage V_Z, it is called Z_{ZT}. When specified at a lower current near the knee region, it is called Z_{ZK}. This latter value of Z_{ZK} is always higher in ohms compared to Z_{ZT} since it is closer to the transition knee region of the device. At operating currents above I_{ZT}, the dynamic impedance will be lower. Dynamic impedance is useful in determining voltage changes with operating current as described in MicroNote No. 202. Temperature and applied power also influence zener voltage. These will be further described in MicroNote No's. 203 and 204 for zener diodes.

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