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Zener Diode

- Diodes operating in the breakdown region can be used as voltage regulator: almost constant voltage drop.

- Special diodes are designed to operate specifically in the breakdown region: breakdown diodes, or zener diodes.

- Circuit symbol:
Modeling the Zener Diode

- **Knee current:** $I_{ZK}$. If current is greater than $I_{ZK}$, i-v characteristic is almost-linear, i.e., straight line.
- **Test current:** $I_{ZT}$ and corresponding voltage $V_Z$ at current $I_{ZT}$.
- **Zener voltage changes by $\Delta V$**
  \[ \Delta V = r_Z \Delta I \]
- **$r_Z$: incremental resistance**, or dynamic resistance is an inverse slope of i-v curve at point Q
- Usually, $I_{ZK}$, $V_Z$ and $r_Z$ are specified by manufacturer, for example, 6.8V drop at a specified test current of 10mA.
- $r_Z$ is in the range of a few $\Omega$ to a few hundreds of $\Omega$.
- Steeper line (**lower** $r_Z$) is desirable due to almost constant voltage over a wide range of current.
• Model of Zener Diode: \( V_Z = V_{Z0} + r_Z I_Z, I_Z > I_{ZK} \)
Example

\[ V_Z = 6.8V, I_Z=5mA, r_Z=20 \Omega \text{ and } I_{ZK}=0.2mA. \] The supply voltage \( V^+ \) is normally 10V but may vary by \( \pm 1 \text{V} \).

- Find \( V_o \) with no load (\textit{assume} \( V^+=10V \)).
- Find the change in \( V_o \) resulting from \( \pm 1 \text{V} \) at power supply. Note that \( \Delta V_o/\Delta V^+ \) usually expressed in mV/V known as line regulation
- Find the change in \( V_o \) resulting from connecting a load resistance \( R_L \) that draws a current \( I_L = 1mA \)
- Find the change in \( V_o \) when \( R_L = 2k \Omega \)
Find the minimum \( R_L \) for which the diode still operates in the breakdown region.