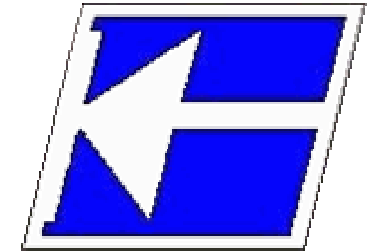


**Centro Federal de Educação Tecnológica de Santa Catarina**

**Departamento de Eletrônica**

**Curso Superior de Sistemas Digitais**

**Retificadores**



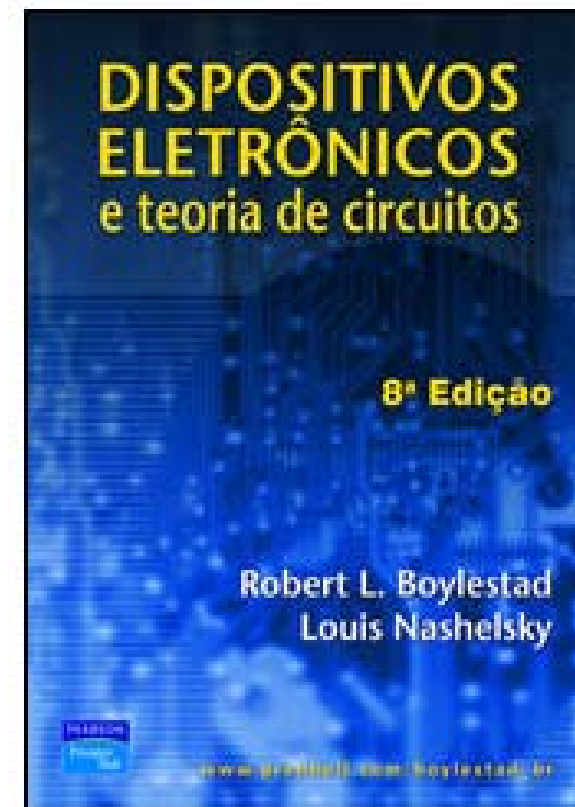
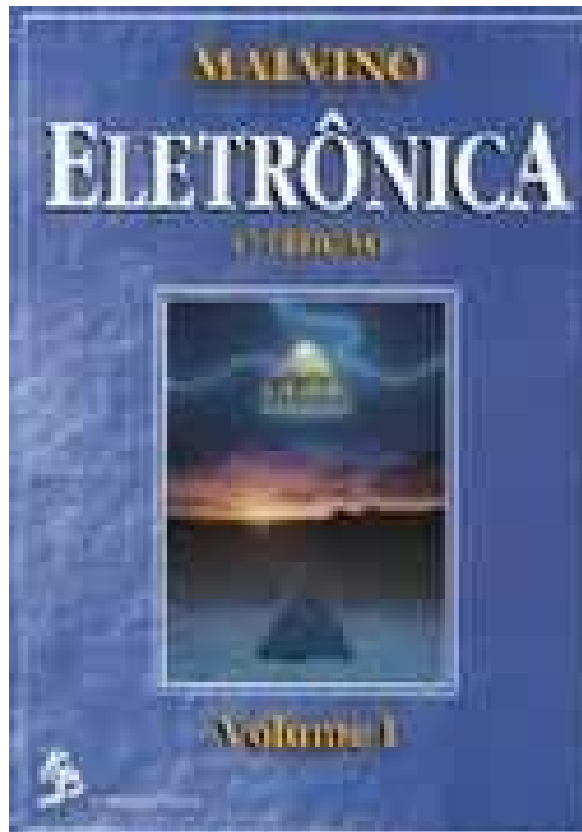
# **Aplicações dos diodos**

## **Parte 4**

**Prof. Clóvis Antônio Petry.**

**Florianópolis, maio de 2007.**

# Bibliografia para esta aula



# Nesta aula

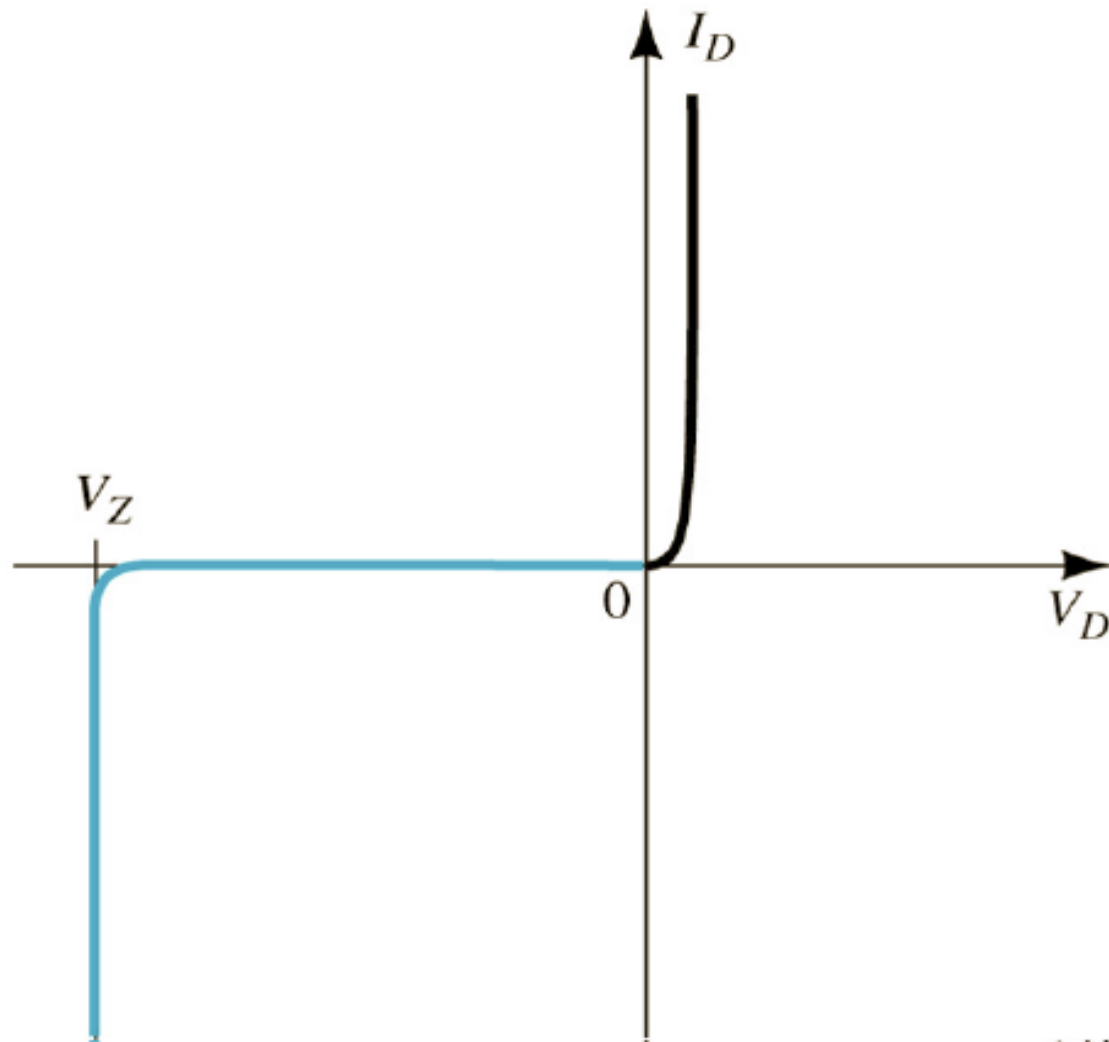
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## **Seqüência de conteúdos:**

1. Diodos zener.

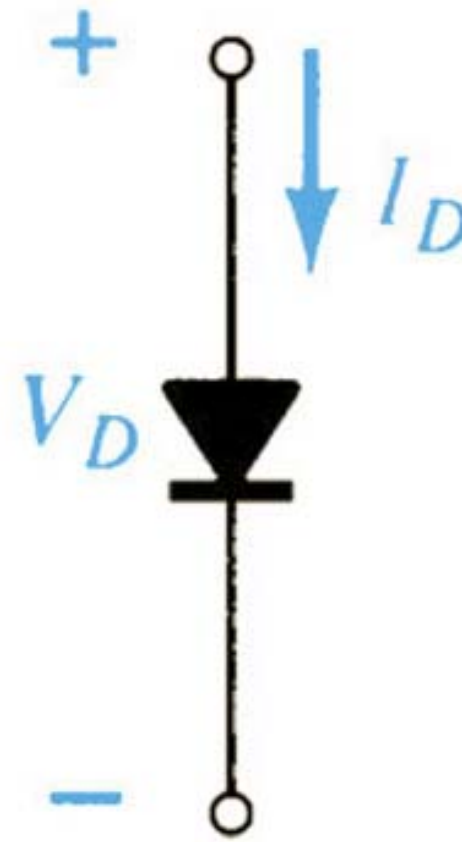
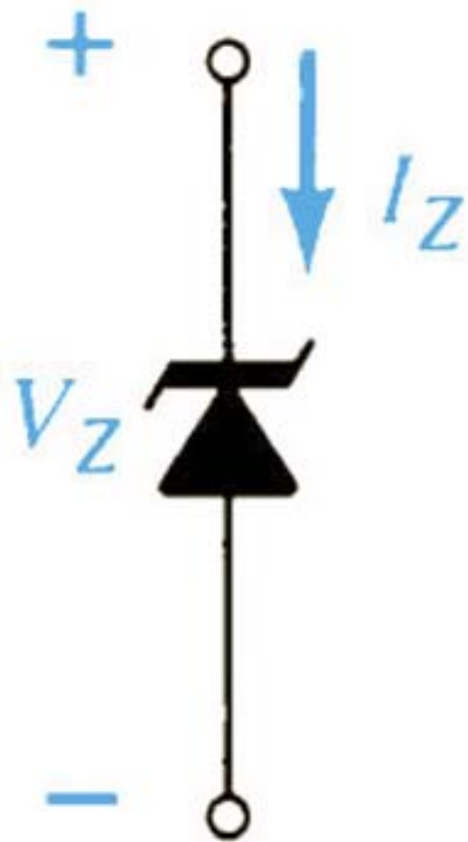
# Diodos zener

Região de operação zener:



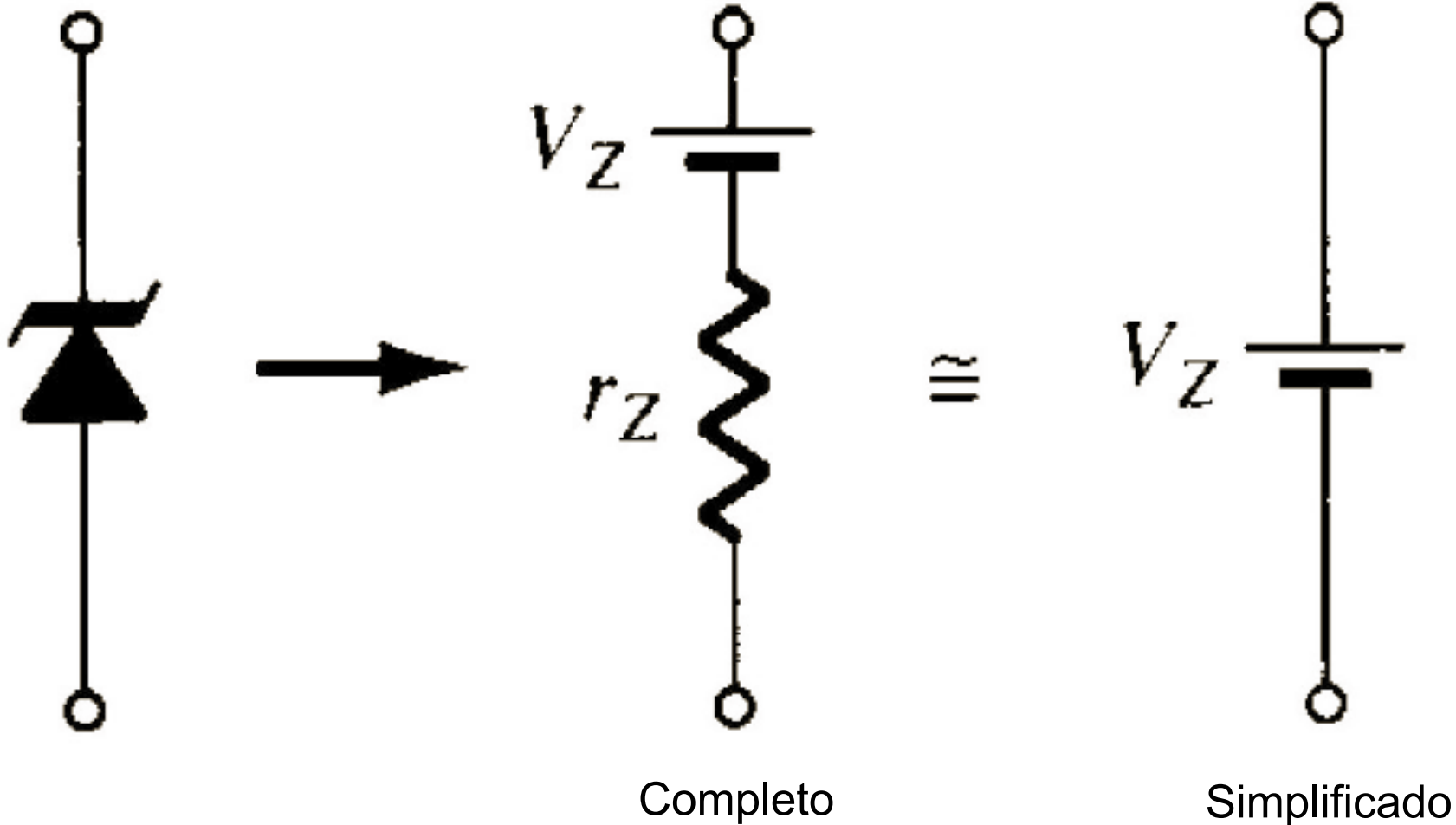
# Diodos zener

Sentido de condução:



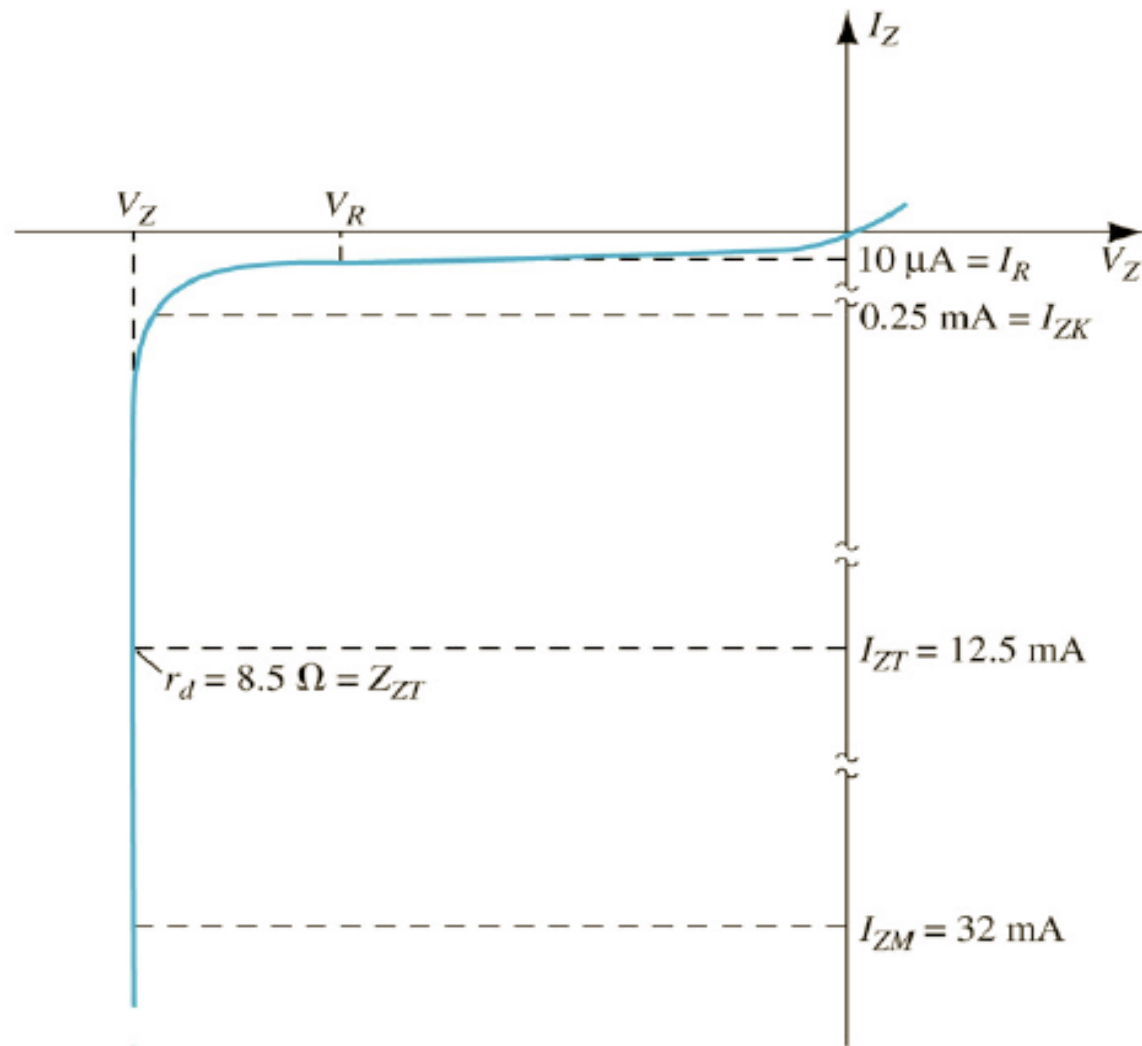
# Diodos zener

Modelos equivalentes do diodo zener:



# Diodos zener

Curva característica de um diodo zener:



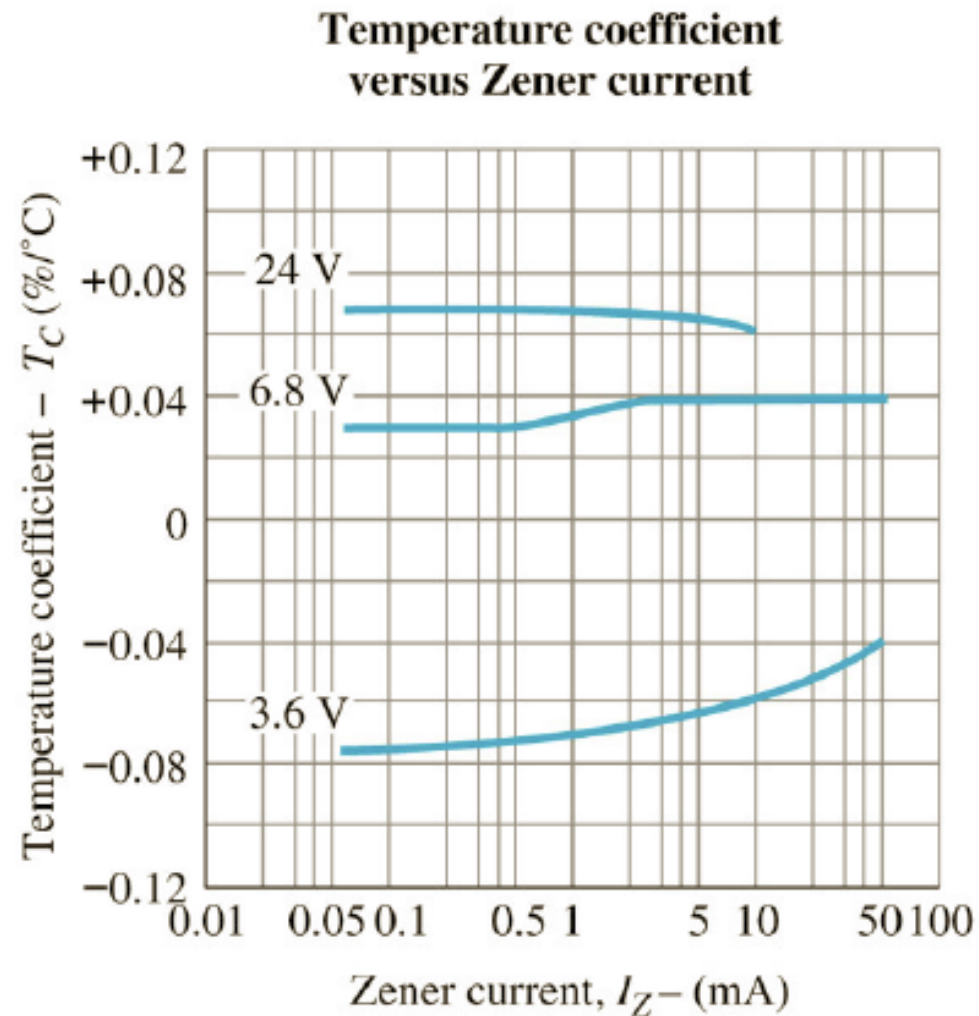
# Diodos zener

## Características elétricas:

- Tensão zener nominal –  $V_z$  [V];
- Corrente de teste –  $I_{ZT}$  [mA];
- Impedância dinâmica –  $Z_{ZT}$  @  $I_{ZT}$  [ $\Omega$ ];
- Corrente de joelho –  $I_{ZK}$  [mA];
- Impedância de joelho máxima –  $Z_{ZK}$  @  $I_{ZK}$  [ $\Omega$ ];
- Corrente reversa máxima –  $I_R$  @  $V_R$  [ $\mu$ A];
- Tensão de teste –  $V_R$  [V];
- Corrente máxima de regulação –  $I_{ZM}$  [mA];
- Coeficiente de temperatura típico - %/ $^{\circ}$ C.

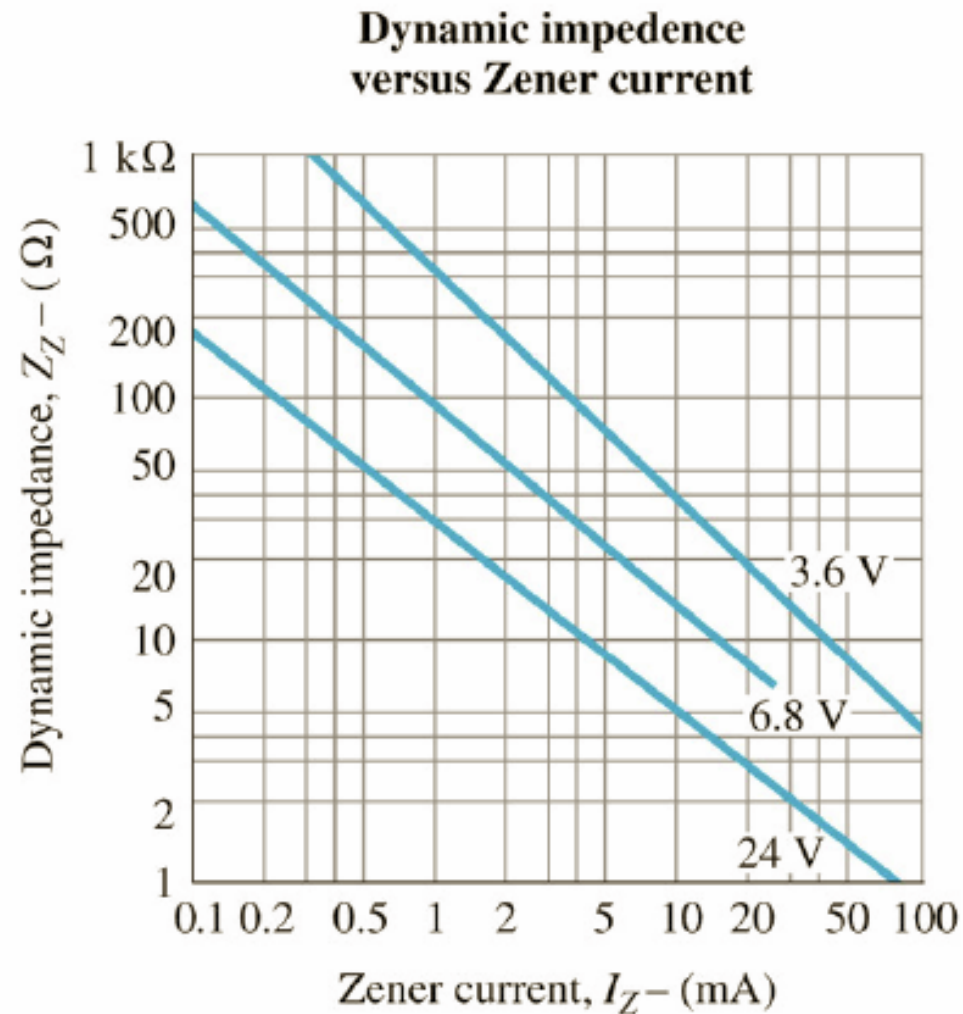
# Diodos zener

Coeficiente de temperatura versus corriente zener:



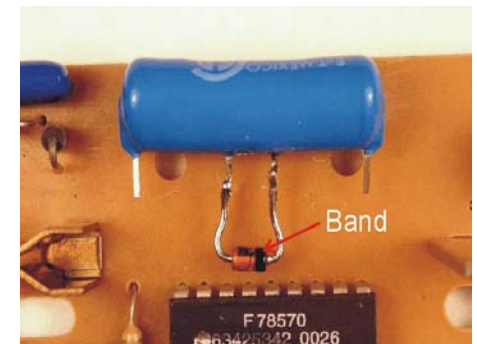
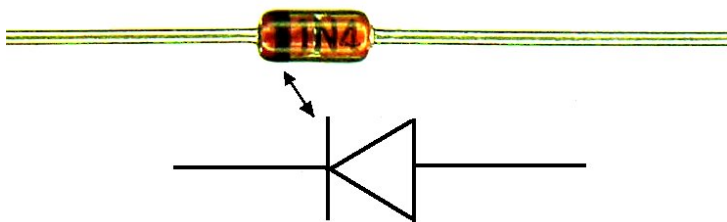
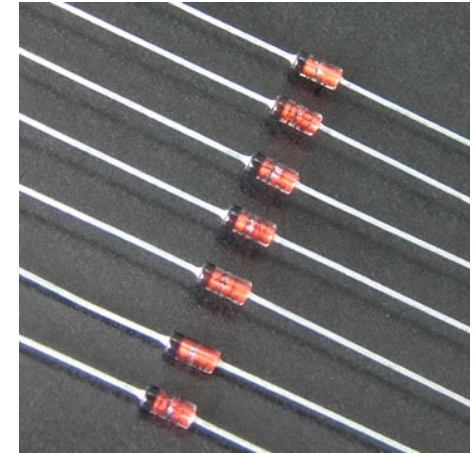
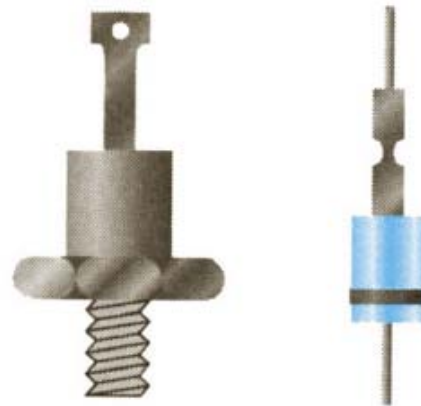
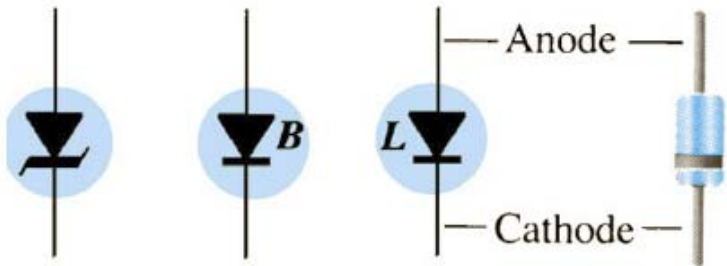
# Diodos zener

Impedância dinâmica versus corrente zener:



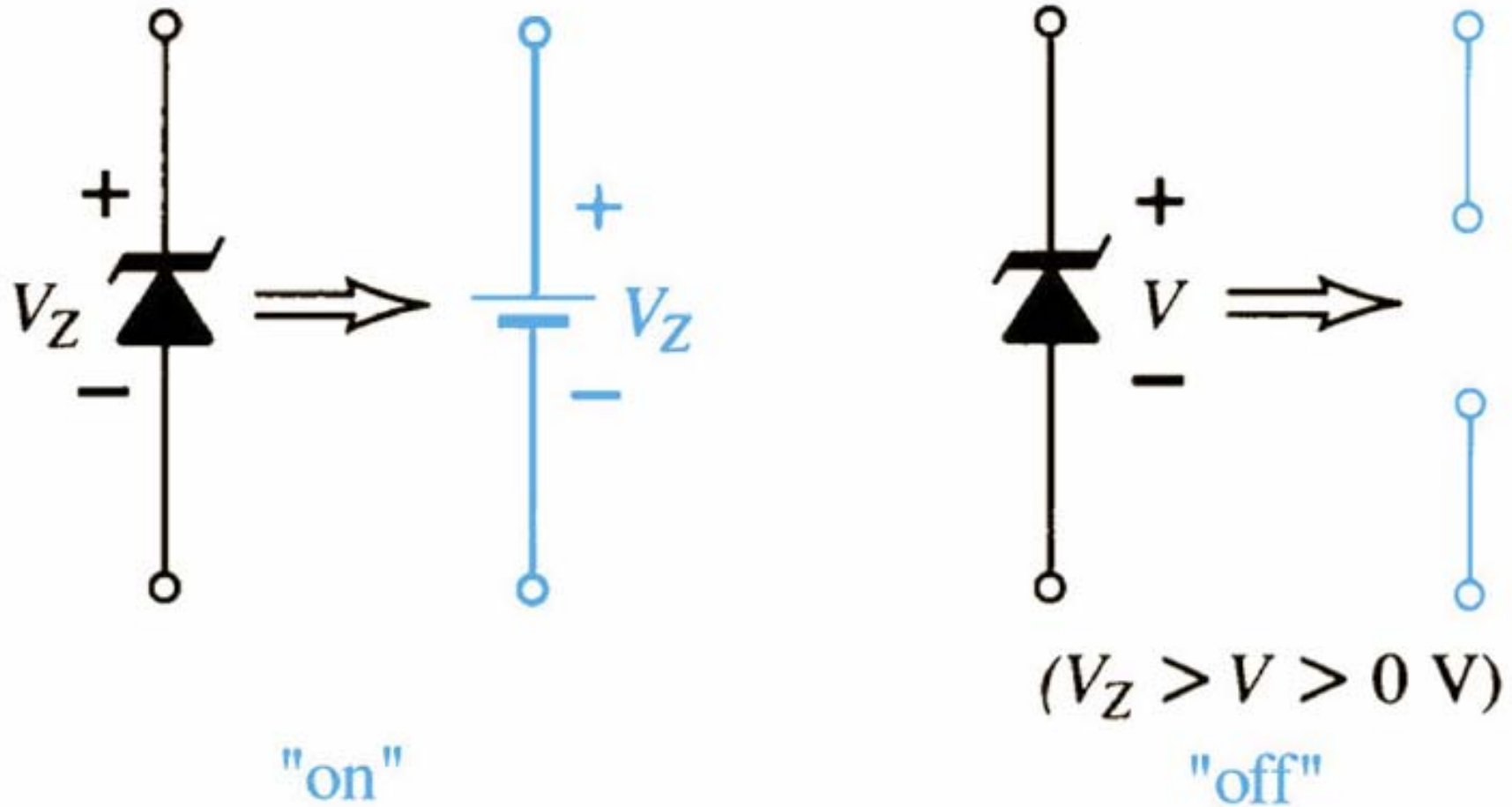
# Diodos zener

Aspectos de diodos zener:



# Diodos zener

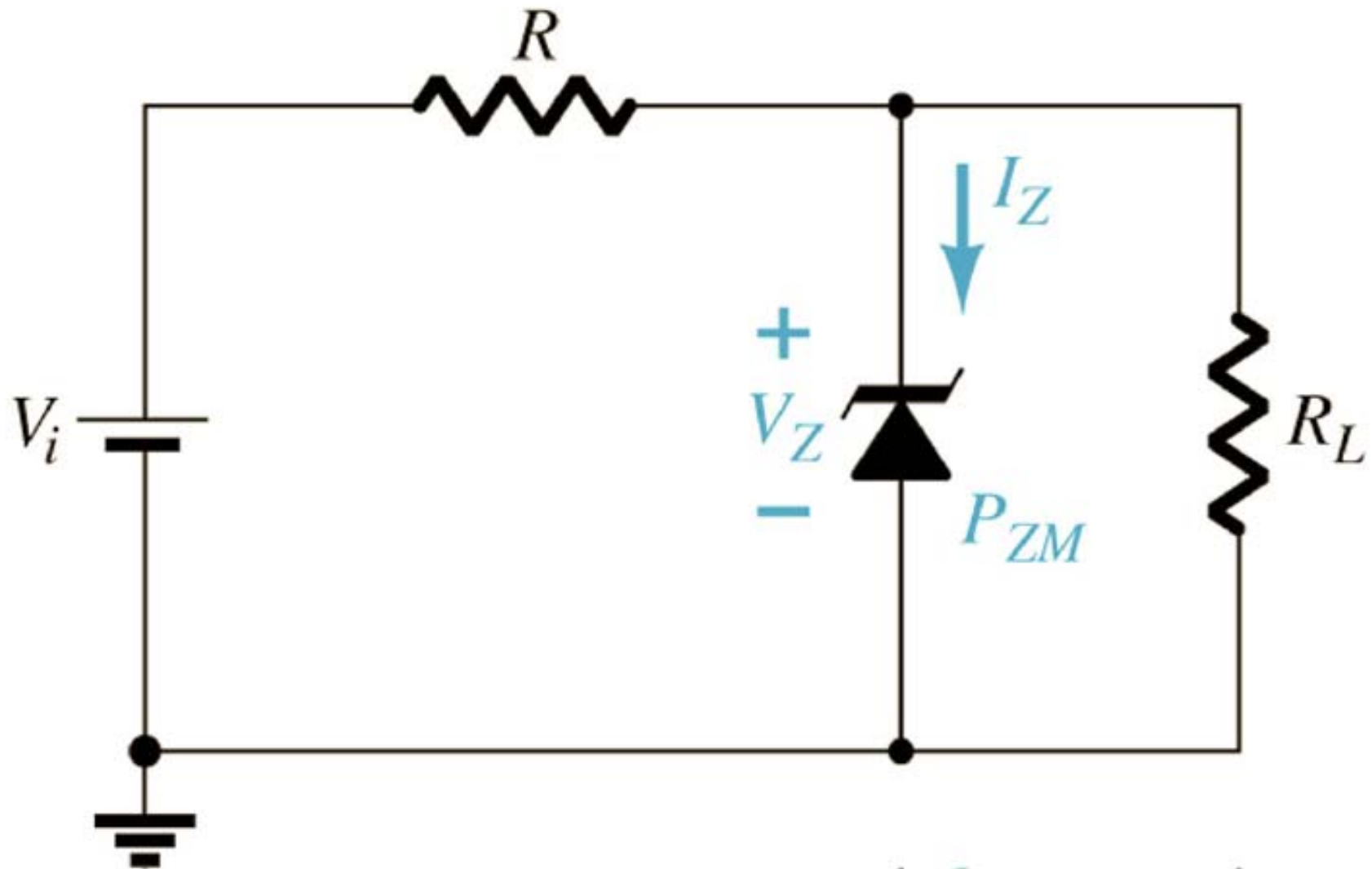
Regulador zener:



Comportamento do zener em condução e bloqueado.

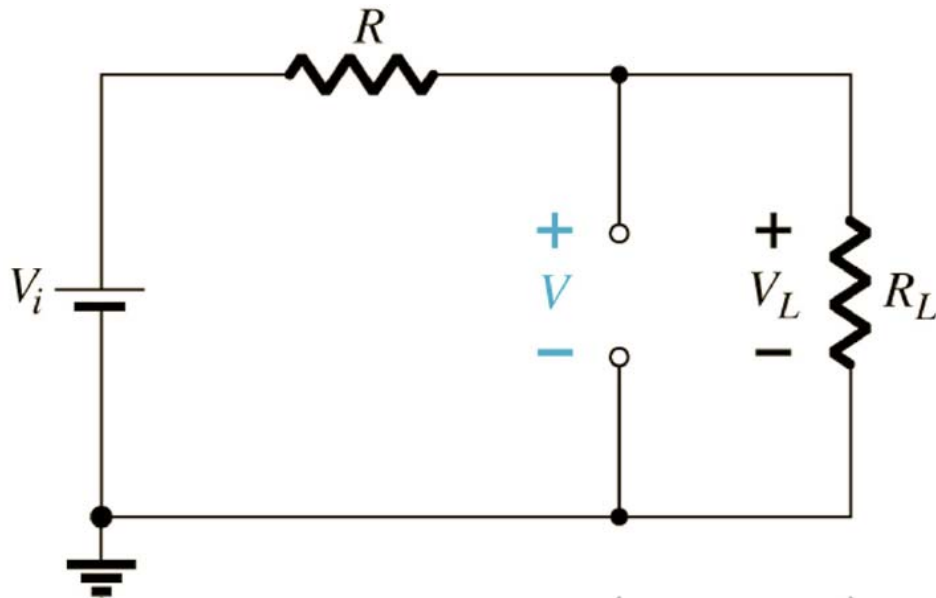
# Diodos zener

Circuito regulador zener básico:  $V_i$  e  $R_L$  fixos



# Diodos zener

Circuito regulador zener básico:  $V_i$  e  $R_L$  fixos



$$V = V_L = \frac{R_L \cdot V_i}{R + R_L}$$

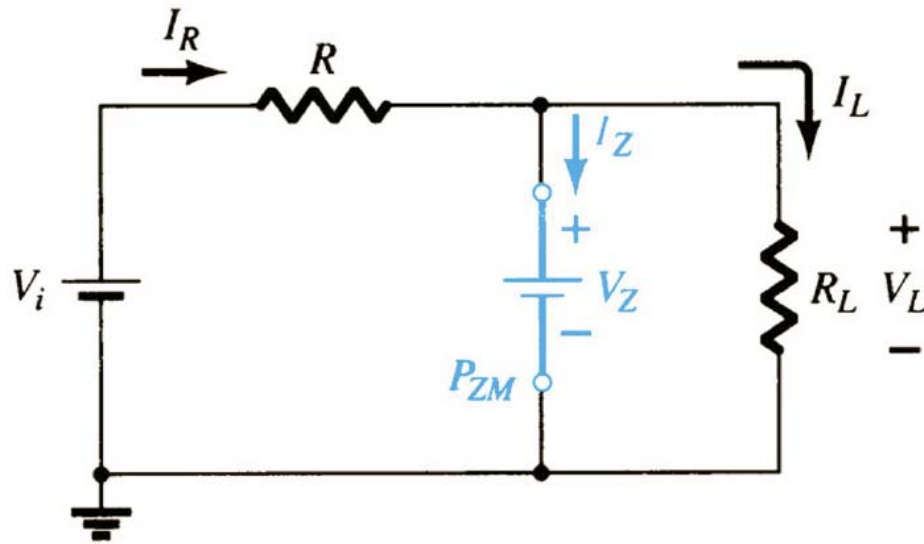
$$V_L = V_Z$$

Para verificar se o zener está ligado, retira-se o mesmo do circuito e calcula-se a tensão sobre o zener. Se a tensão for maior que a tensão zener, ele estará ligado.

→  $V_L \geq V_Z$

# Diodos zener

Circuito regulador zener básico:  $V_i$  e  $R_L$  fixos



$$I_R = I_Z + I_L$$

$$I_Z = I_R - I_L$$

$$I_L = \frac{V_L}{R_L} \quad I_R = \frac{V_R}{R} = \frac{V_i - V_L}{R}$$

Se:

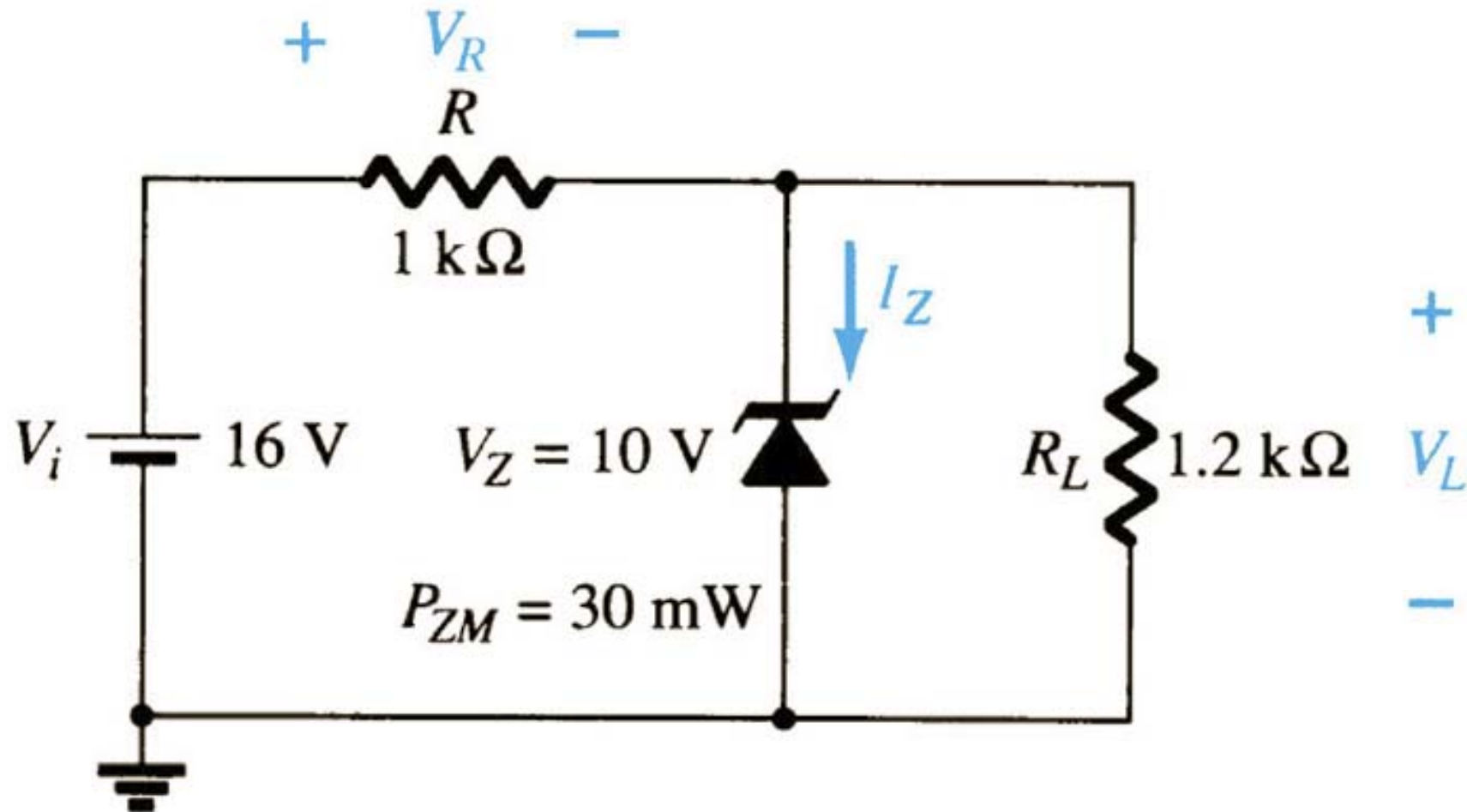
$$V_L \geq V_Z$$

$$P_Z = V_Z \cdot I_Z$$

# Diodos zener

Circuito regulador zener básico, exemplo:

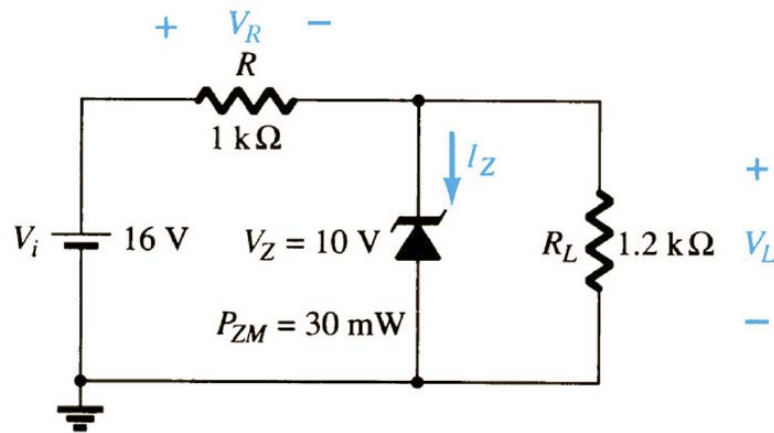
$V_i$  e  $R_L$  fixos



# Diodos zener

Circuito regulador zener básico, exemplo:

$V_i$  e  $R_L$  fixos



Como:

$$8,73 < 10$$

$$V_L < V_Z$$

O diodo está bloqueado.

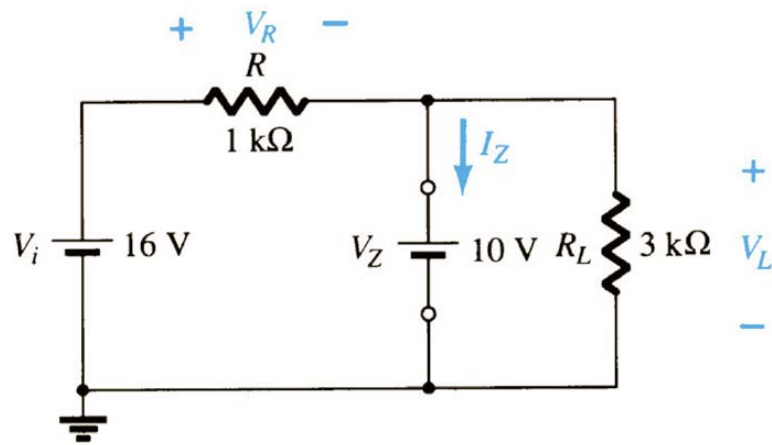
$$V = \frac{R_L \cdot V_i}{R + R_L} = \frac{1,2k \cdot 16}{1k + 1,2k} = 8,73V$$

$$V_L = V = 8,73V$$

# Diodos zener

Circuito regulador zener básico, exemplo:

$V_i$  e  $R_L$  fixos



$$V = \frac{R_L \cdot V_i}{R + R_L} = \frac{3k \cdot 16}{1k + 3k} = 12V$$

$$V_L = V = 12V$$

Como:  $12 > 10$

O diodo está conduzindo.

$$V_R = V_i - V_L = 16 - 10 = 6V$$

$$I_L = \frac{V_L}{R_L} = \frac{10}{3k} = 3,33mA$$

$$I_R = \frac{V_R}{R} = \frac{6}{1k} = 6mA$$

$$I_Z = I_R - I_L = 6m - 3,33m$$

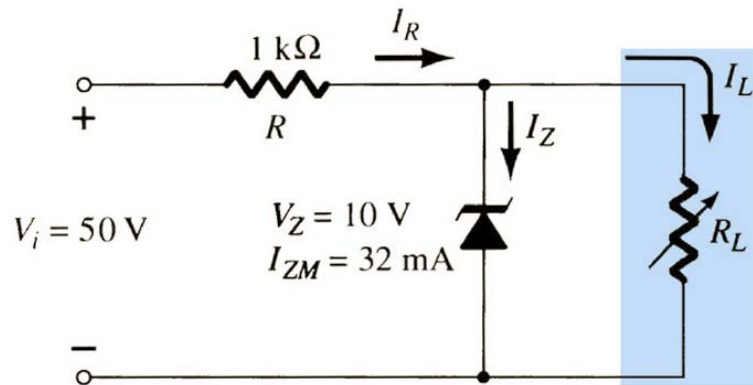
$$I_Z = 2,67mA$$

$$P_Z = V_Z \cdot I_Z = 10 \cdot 2,67m = 26,7mW$$

# Diodos zener

Circuito regulador zener básico:

$V_i$  fixo e  $R_L$  variável



$$V_L = V_Z = \frac{R_L \cdot V_i}{R + R_L}$$

$$R_{Lmin} = \frac{R \cdot V_Z}{V_i - V_Z}$$

$$I_{Lmax} = \frac{V_L}{R_L} = \frac{V_Z}{R_{Lmin}}$$

$$V_R = V_i - V_Z$$

$$I_R = \frac{V_R}{R}$$

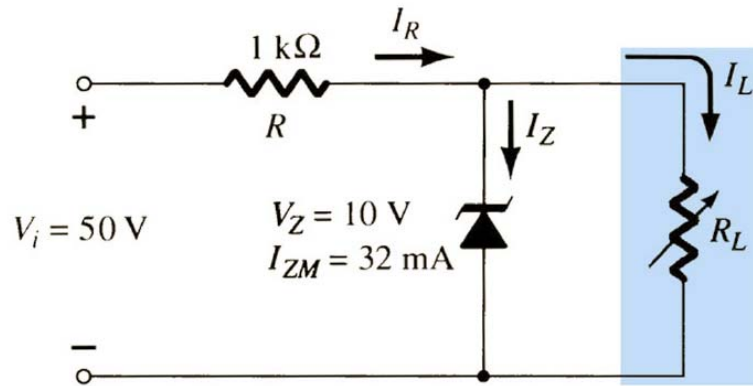
$$I_Z = I_R - I_L$$

$$I_{Lmin} = I_R - I_{ZM}$$

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}}$$

# Diodos zener

Circuito regulador zener básico, exemplo:  $V_i$  fixo e  $R_L$  variável



$$I_{Lmin} = I_R - I_{ZM} = 40m - 32m = 8mA$$

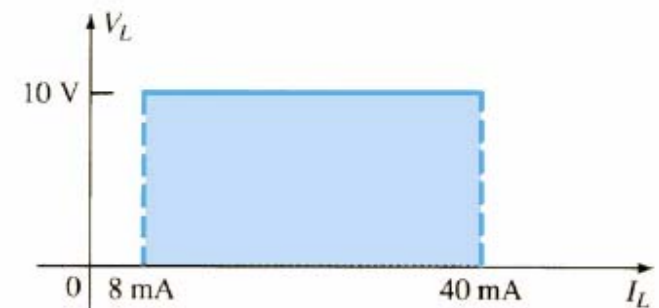
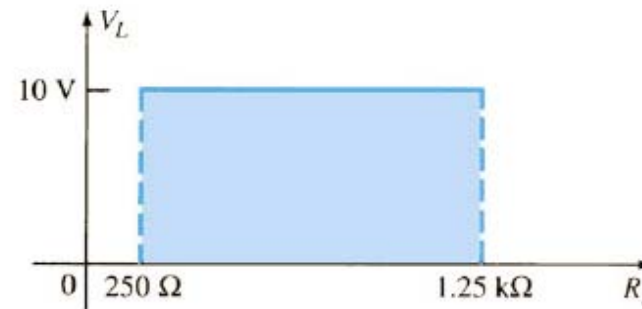
$$R_{Lmax} = \frac{V_Z}{I_{Lmin}} = \frac{10}{8m} = 1,25k\Omega$$

$$P_{max} = V_Z \cdot I_Z = 10 \cdot 32m = 320mW$$

$$R_{Lmin} = \frac{R \cdot V_Z}{V_i - V_Z} = \frac{1k \cdot 10}{50 - 10} = 250\Omega$$

$$V_R = V_i - V_Z = 50 - 10 = 40V$$

$$I_R = \frac{V_R}{R} = \frac{40}{1k} = 40mA$$



# Diodos zener

Circuito regulador zener básico:  $V_i$  variável e  $R_L$  fixo

$$V_L = V_Z = \frac{R_L \cdot V_i}{R + R_L}$$

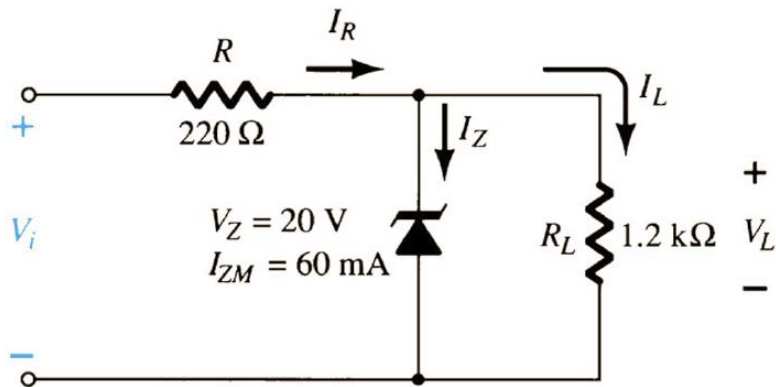
$$V_{imin} = \frac{(R_L + R) \cdot V_Z}{R_L}$$

$$I_{Rmax} = I_{ZM} + I_L$$

$$V_{imax} = I_{Rmax} \cdot R + V_Z$$

# Diodos zener

Circuito regulador zener básico, exemplo:  $V_i$  variável e  $R_L$  fixo

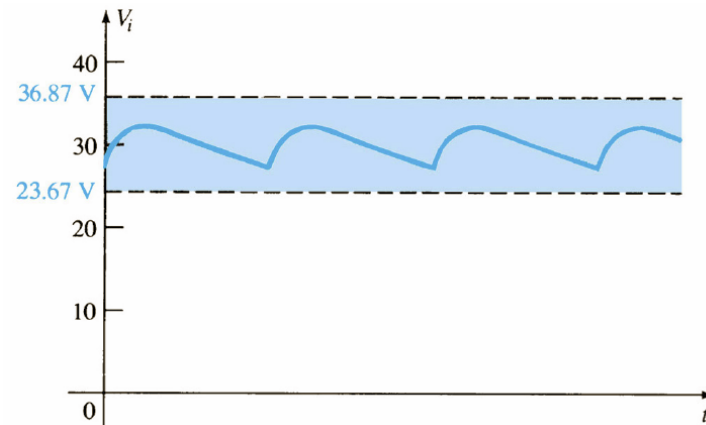
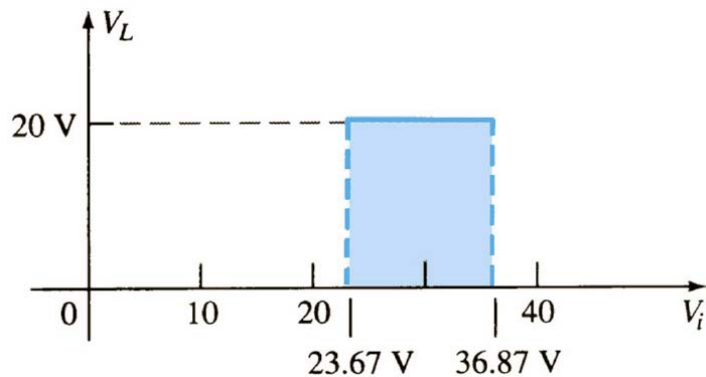


$$V_{imin} = \frac{(R_L + R) \cdot V_Z}{R_L} = \frac{(1200 + 220) \cdot 20}{1200} = 23,67V$$

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{20}{1,2k} = 16,67mA$$

$$I_{Rmax} = I_{ZM} + I_L = 60m + 16,67m = 76,67mA$$

$$V_{imax} = I_{Rmax} \cdot R + V_Z = 76,67m \cdot 0,22k + 20 = 36,87V$$



# Na próxima aula

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## **Seqüência de conteúdos:**

1. Diodos zener - Laboratório.