Centro Federal de Educação Tecnológica de Santa Catarina
Departamento de Eletrônica

Eletrônica Básica

Circuitos com diodos e Diodos Zener

Prof. Clóvis Antônio Petry.

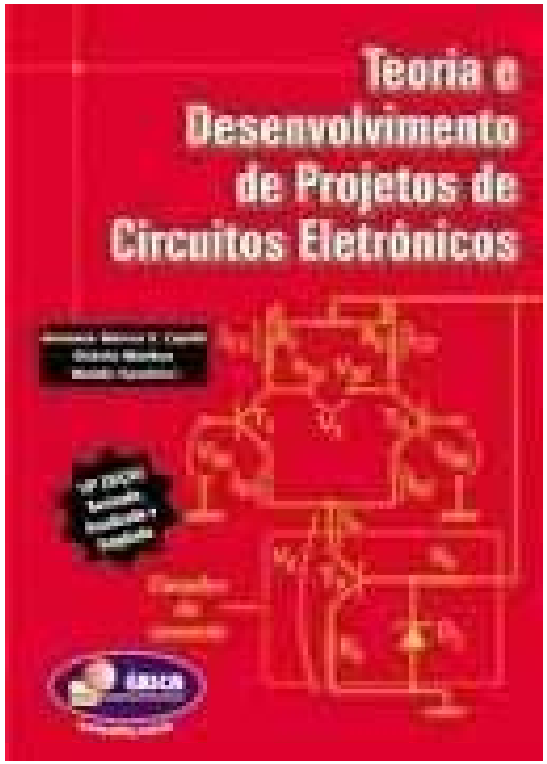
Florianópolis, outubro de 2007.

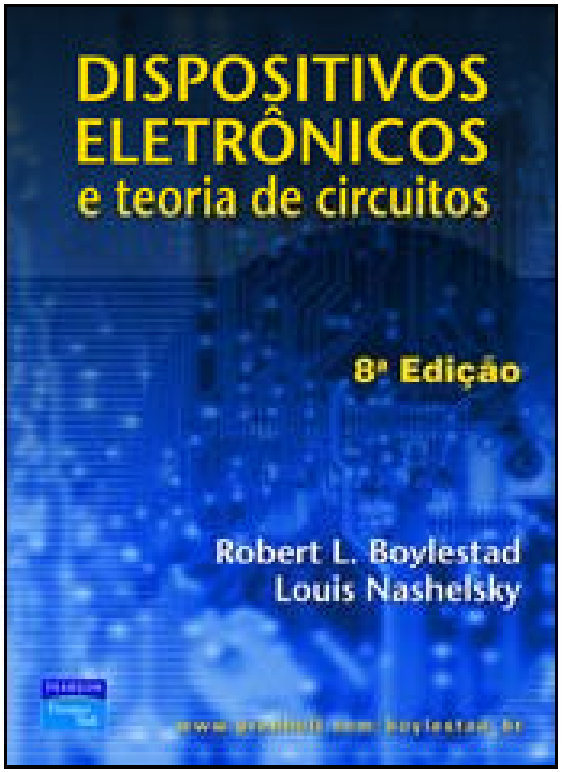
Nesta aula

Seqüência de conteúdos:

1. Ceifadores;
2. Grampeadores;
3. Multiplicadores de tensão;
4. Diodos Zener;
5. Reguladores com diodos zener.

Bibliografia





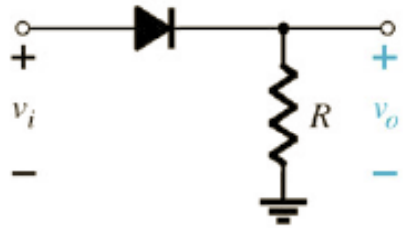
www.cefetsc.edu.br/~petry

Ceifadores

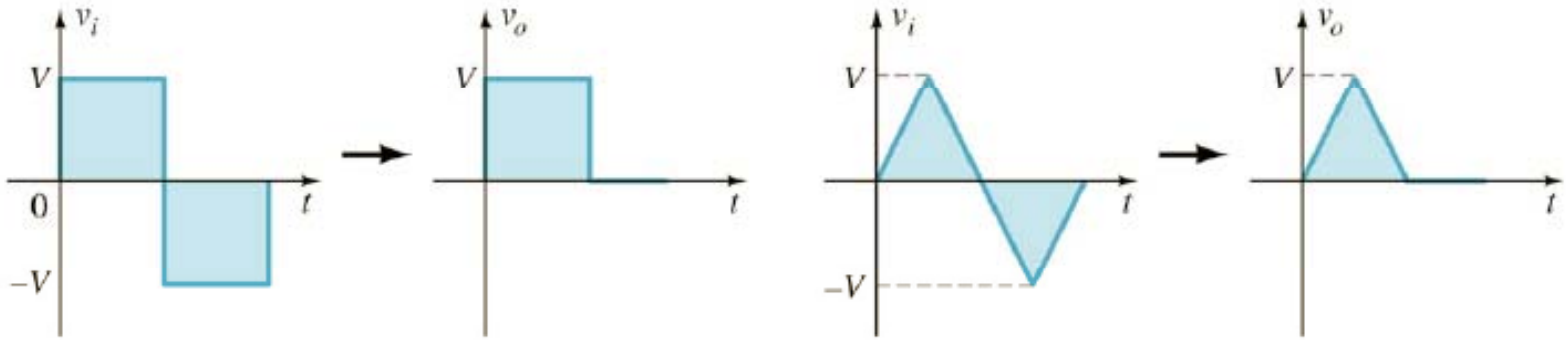
Circuitos ceifadores:

- Tem a capacidade de ceifar (cortar) uma parte do sinal;
- Podem ser em série ou em paralelo.

Ceifador série



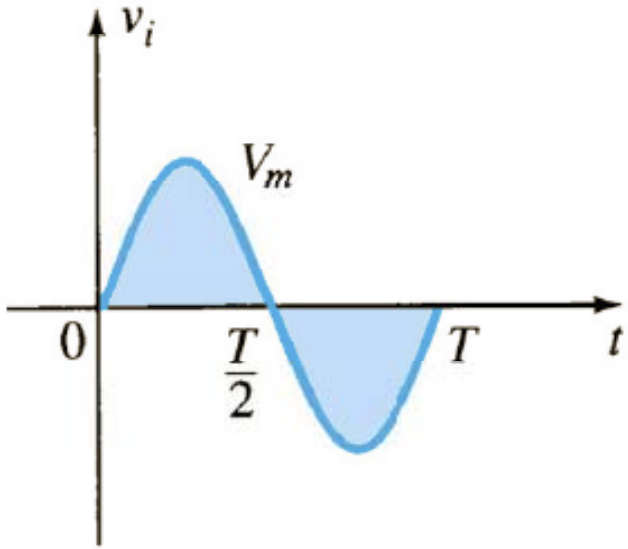
(a)

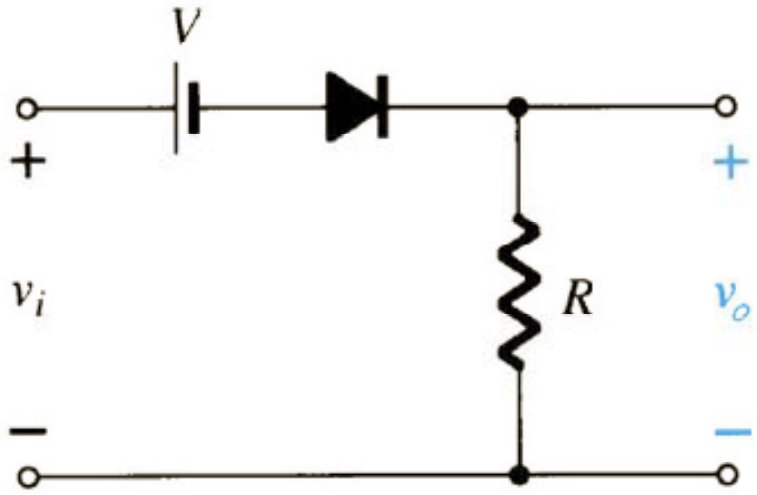


(b)

Ceifadores

Ceifador série com fonte:



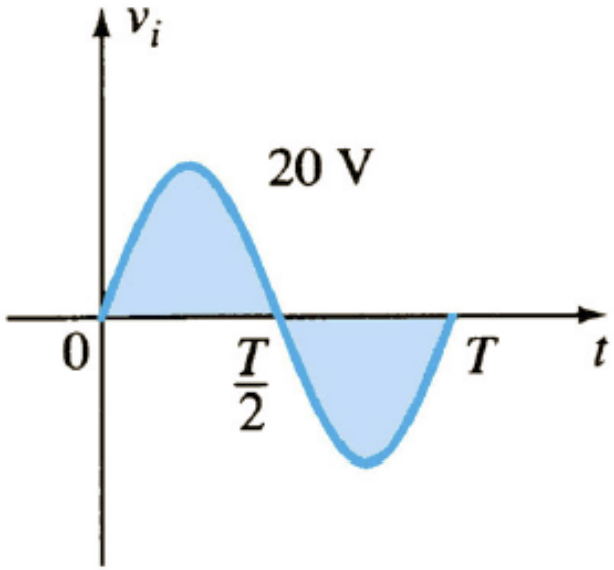


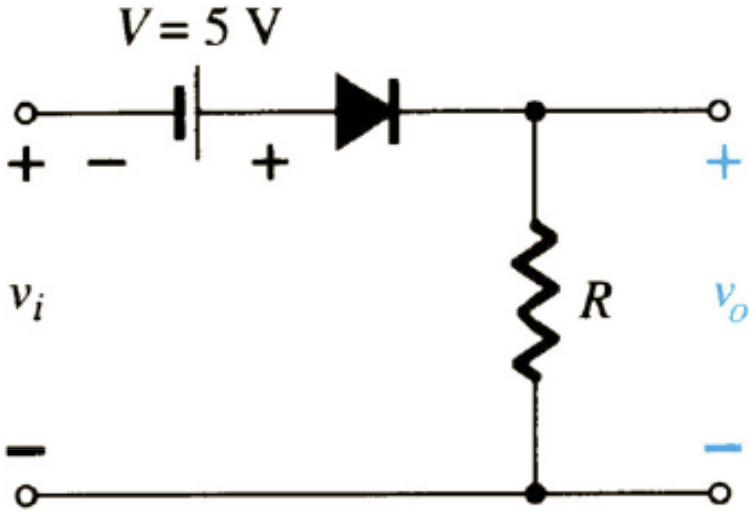
Ceifadores

Ceifador série com fonte:

Ceifadores

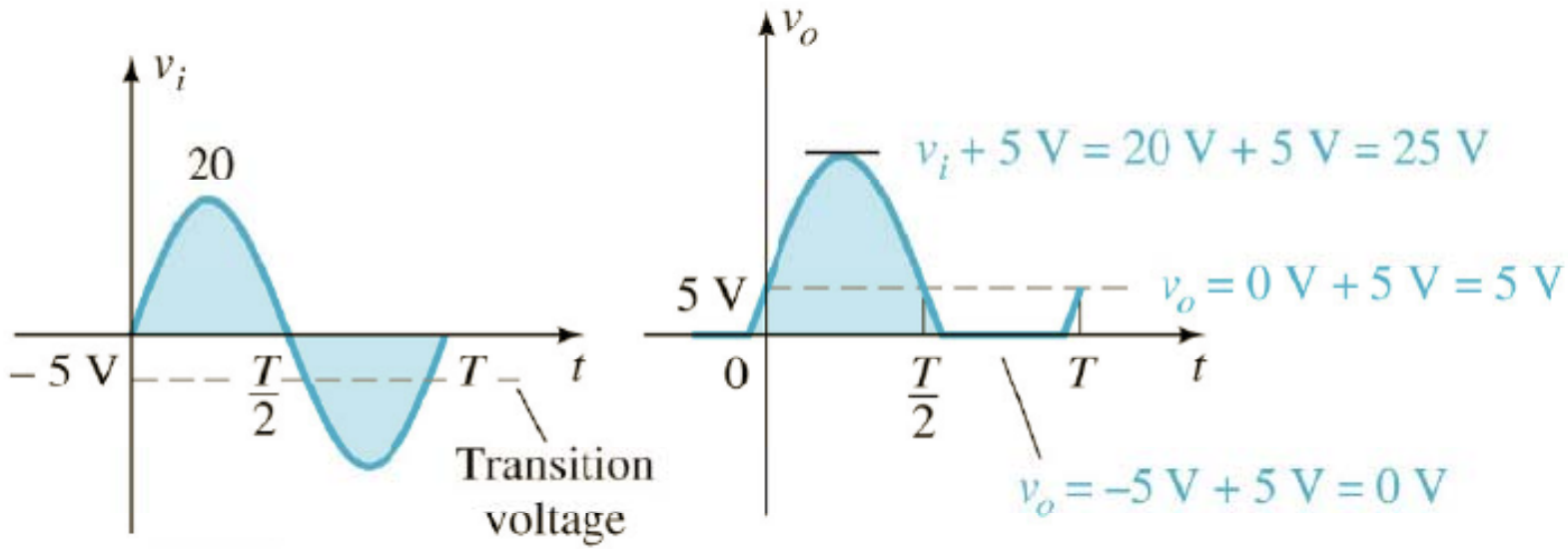
Ceifador série com fonte, exemplo:





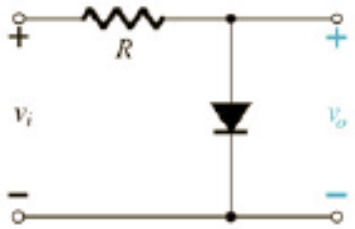
Ceifadores

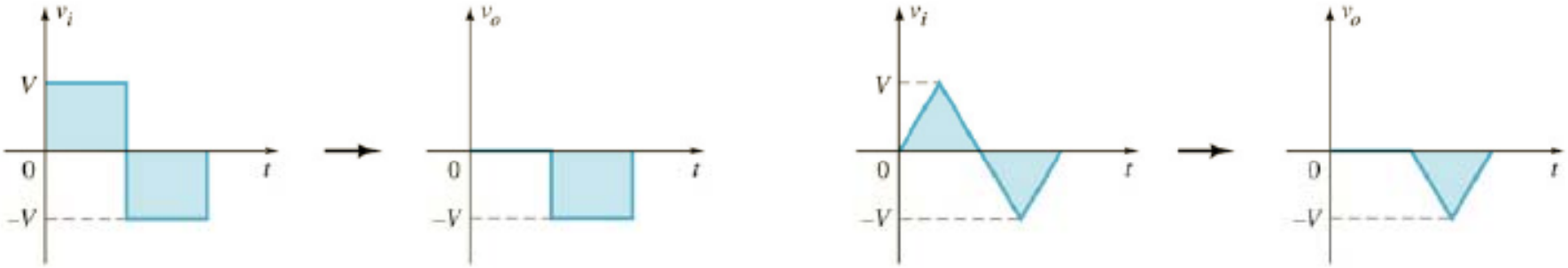
Ceifador série com fonte, exemplo:



Ceifadores

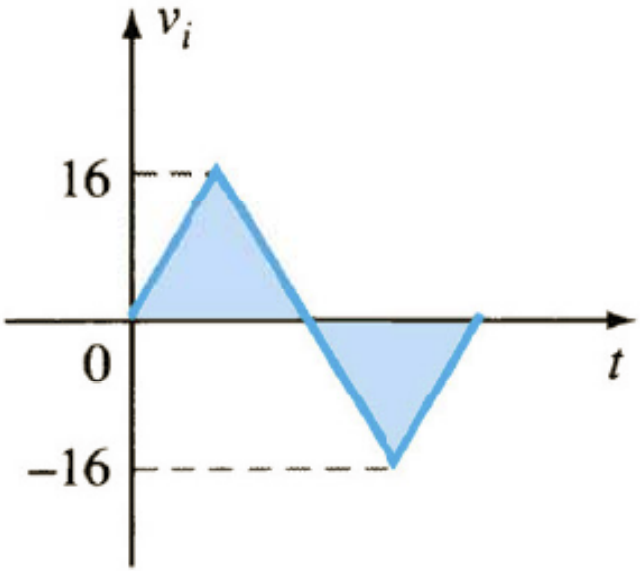
Ceifador paralelo

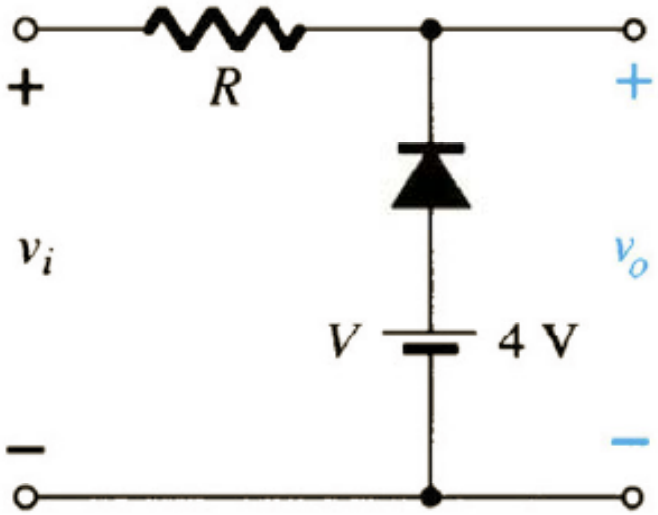




Ceifadores

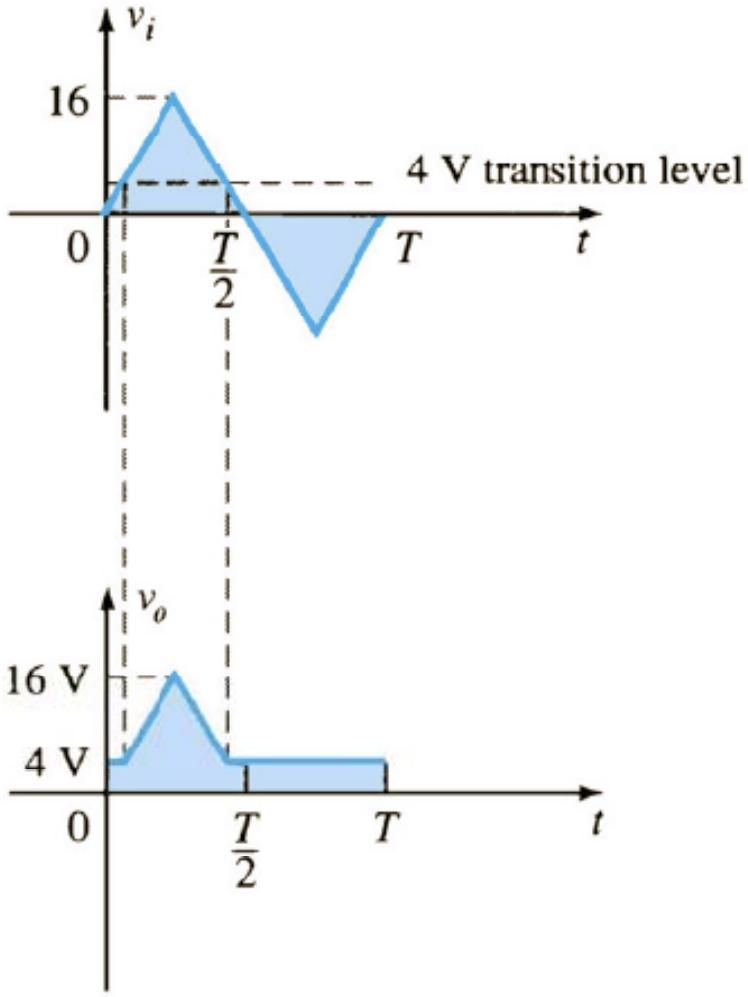
Ceifador paralelo com fonte, exemplo:



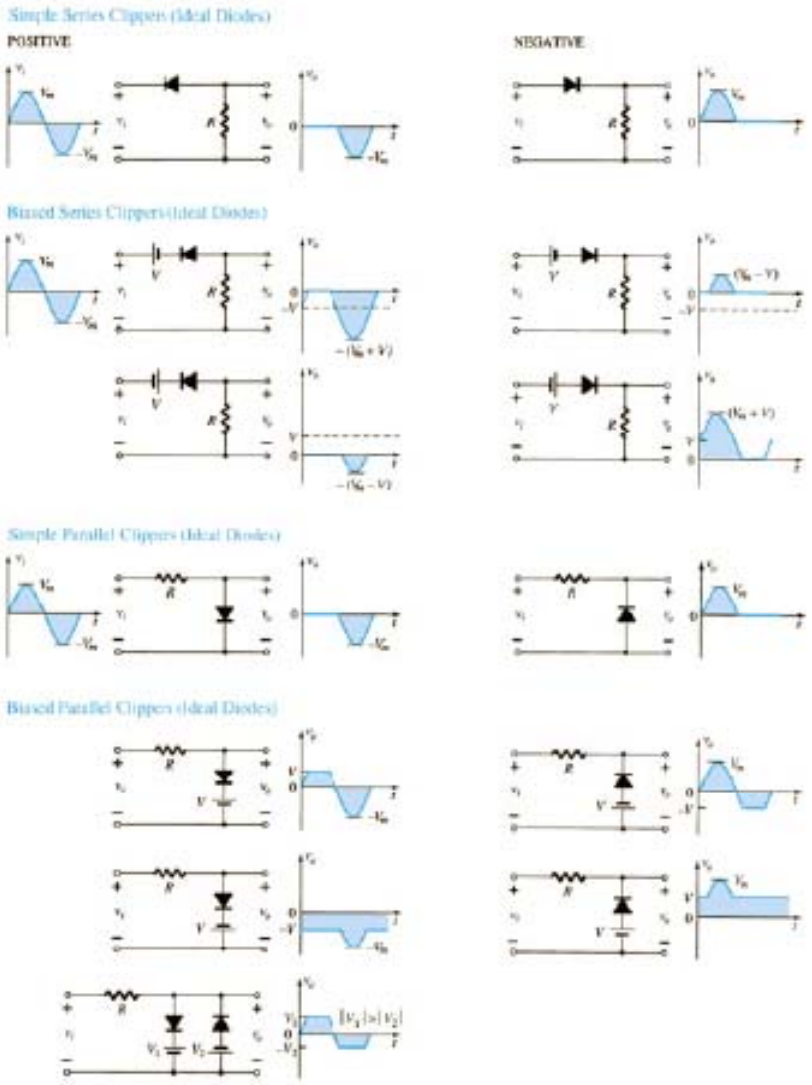


Ceifadores

Ceifador paralelo com fonte, exemplo:



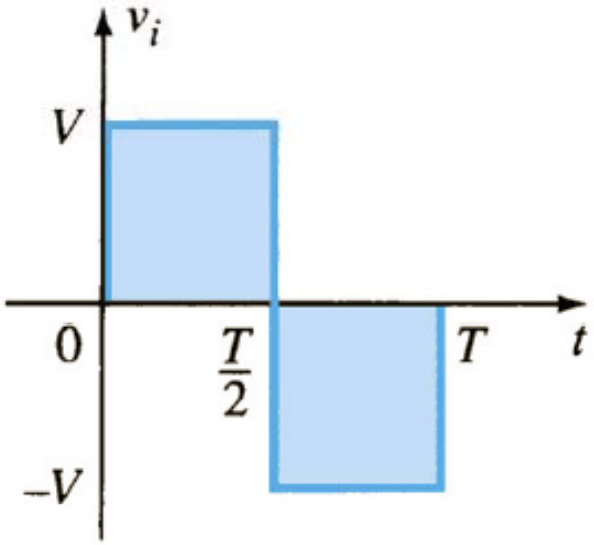
Ceifadores - resumo

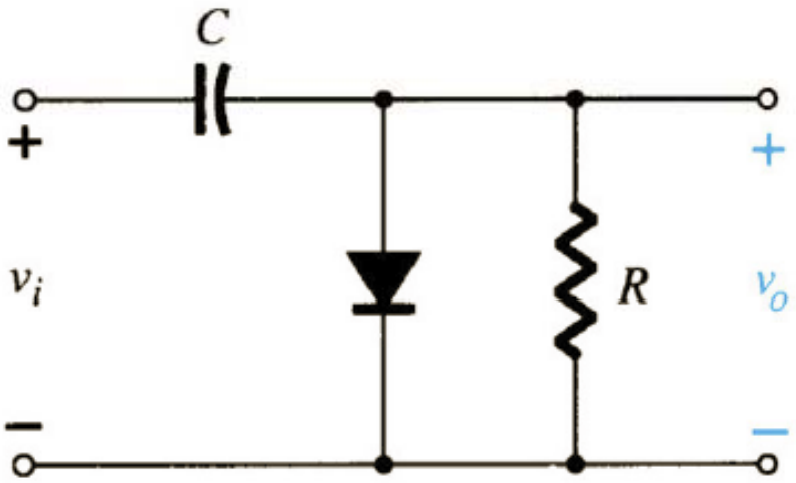


Grampeadores

Circuitos grampeadores:

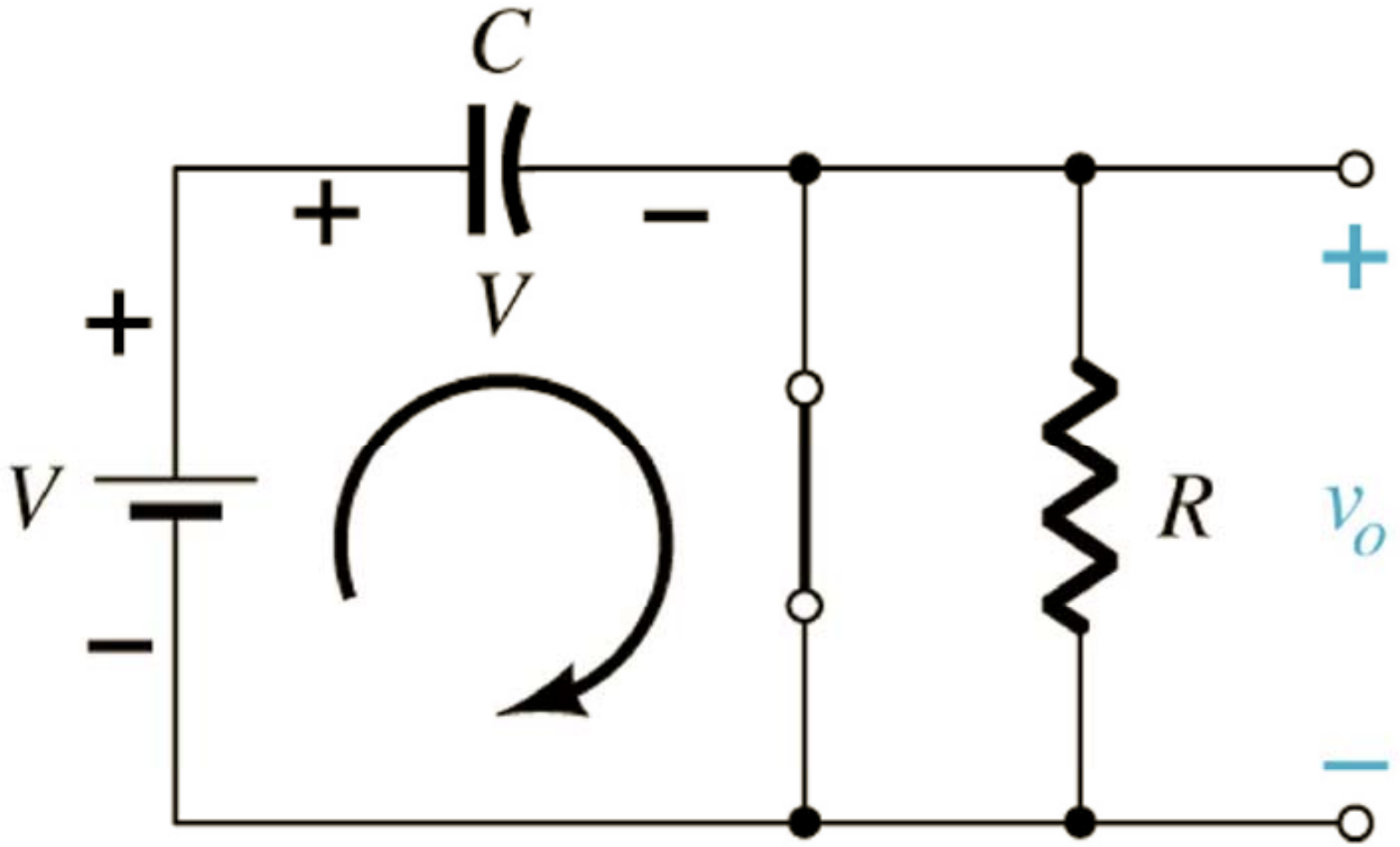
- Tem a capacidade de grampear um sinal em um valor cc diferente.





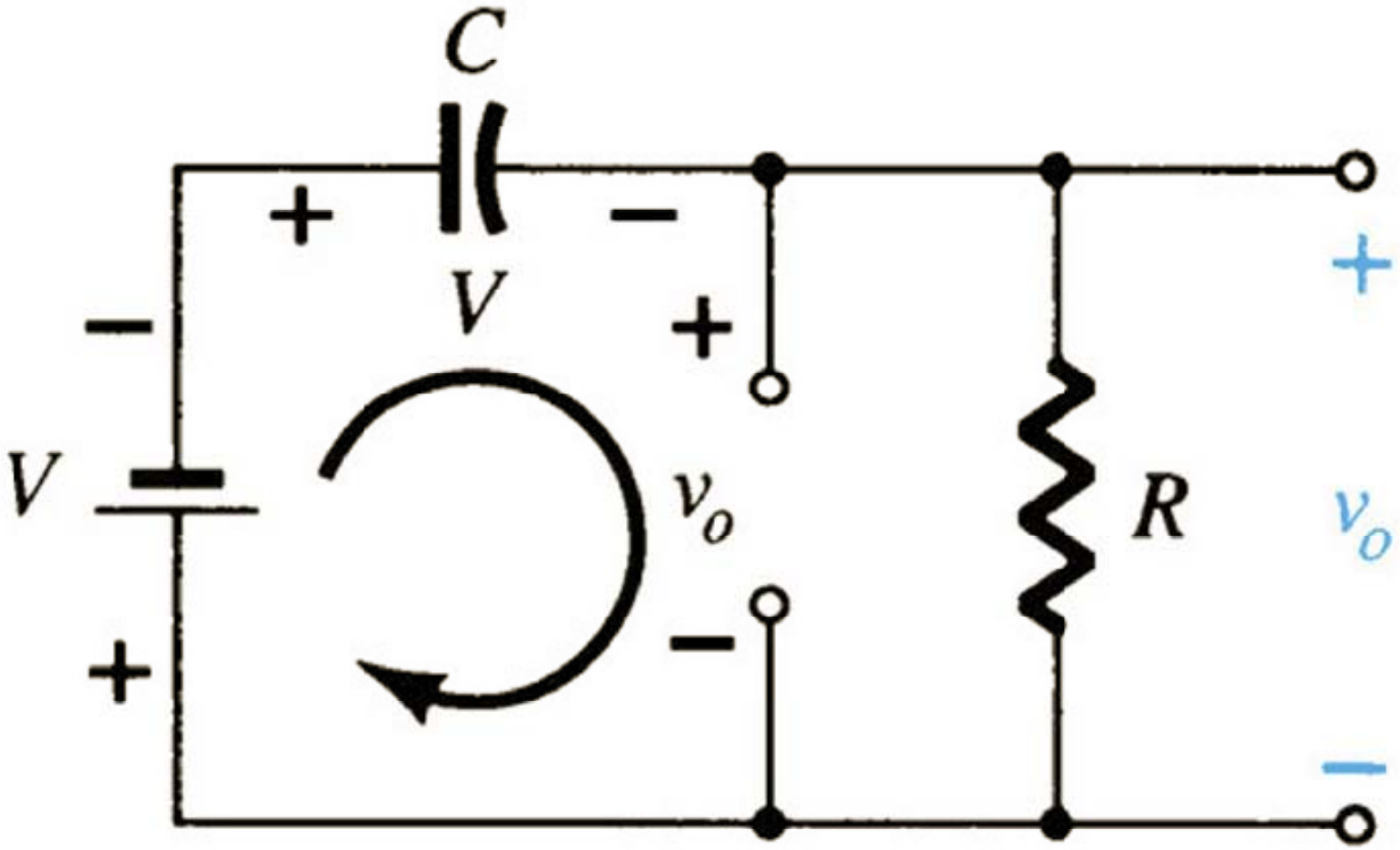
Grampeadores

Diodo em condução:

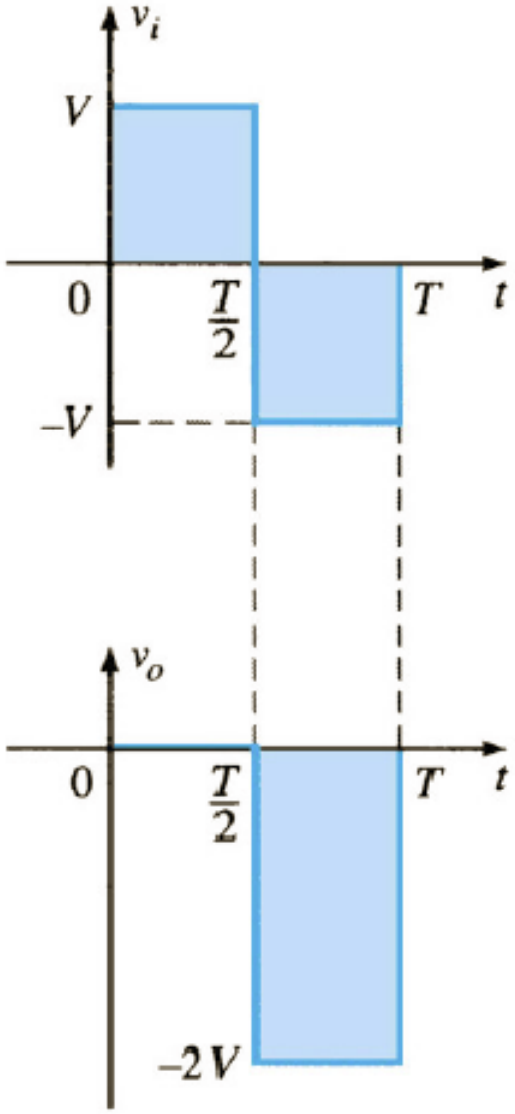


Grampeadores

Diodo bloqueado:



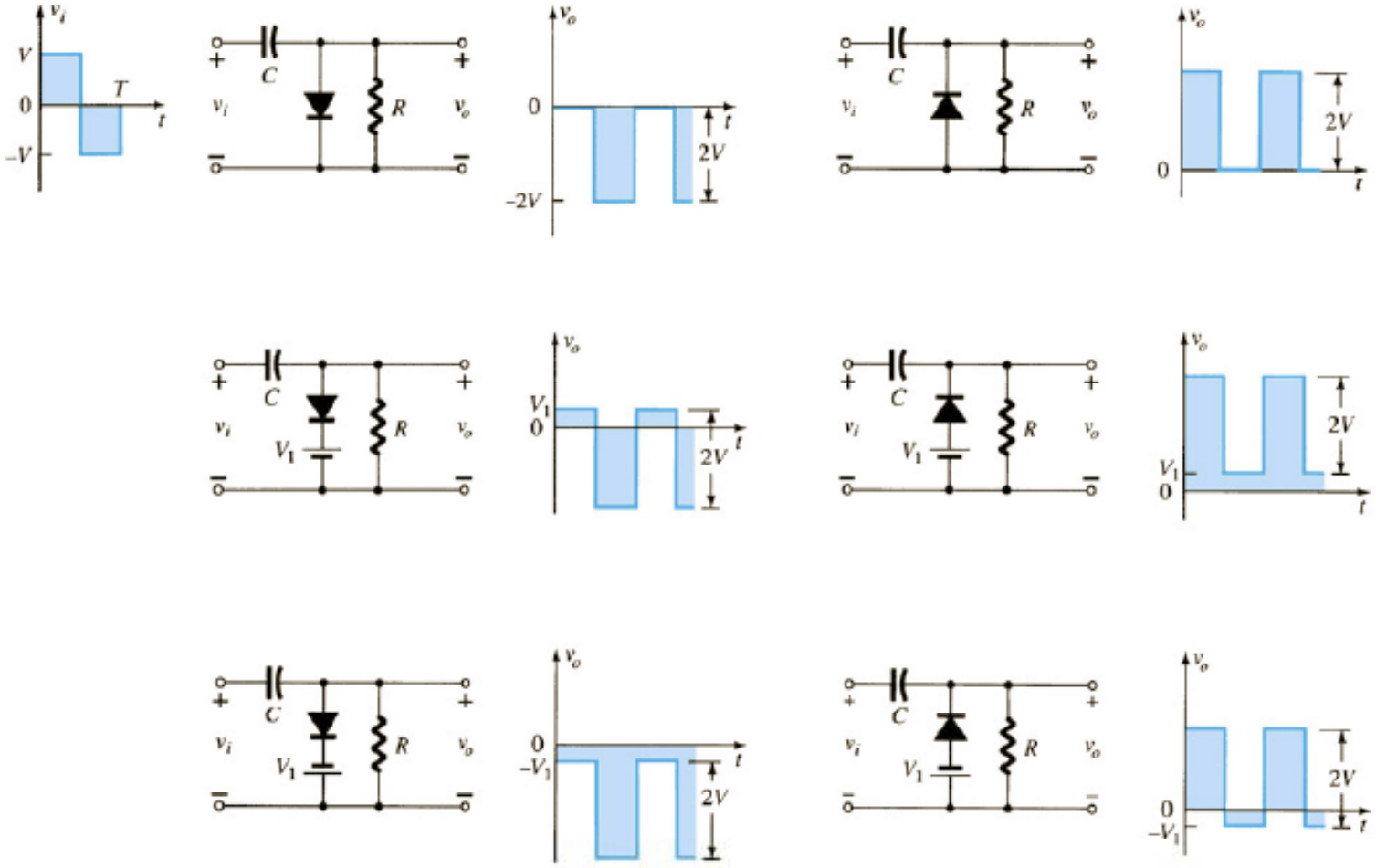
Grampeadores



A excursão total da saída é igual à excursão total do sinal na entrada.

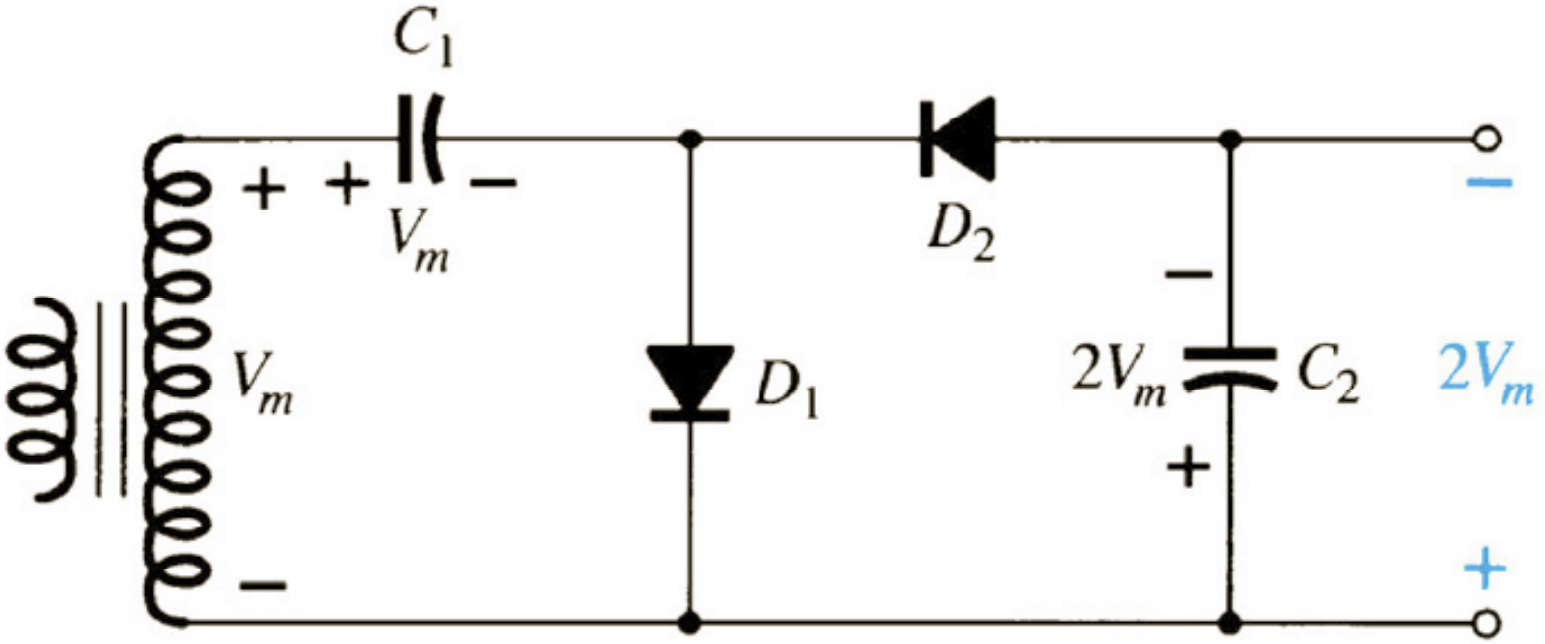
Grampeadores – alguns circuitos

Clamping Networks



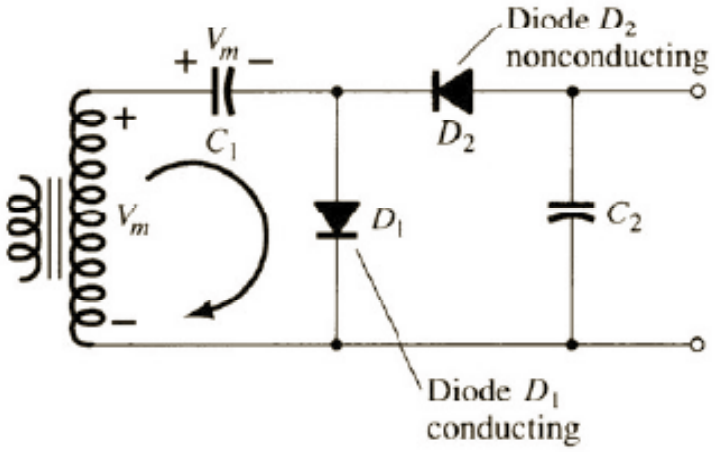
Multiplicadores de tensão

Dobrador de tensão de meia onda:

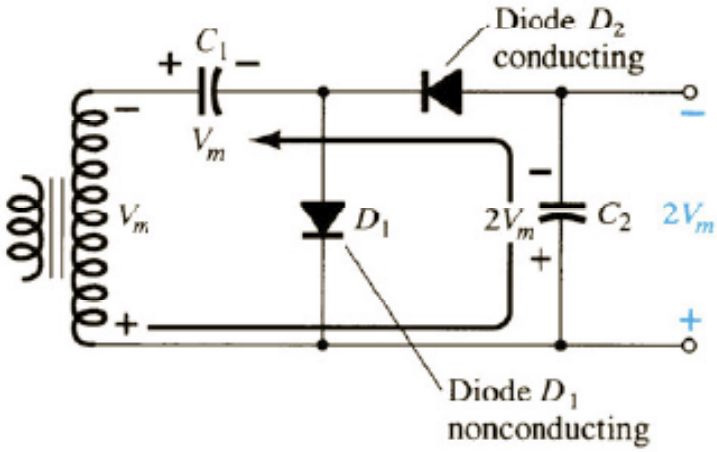


Multiplicadores de tensão

Dobrador de tensão de meia onda:



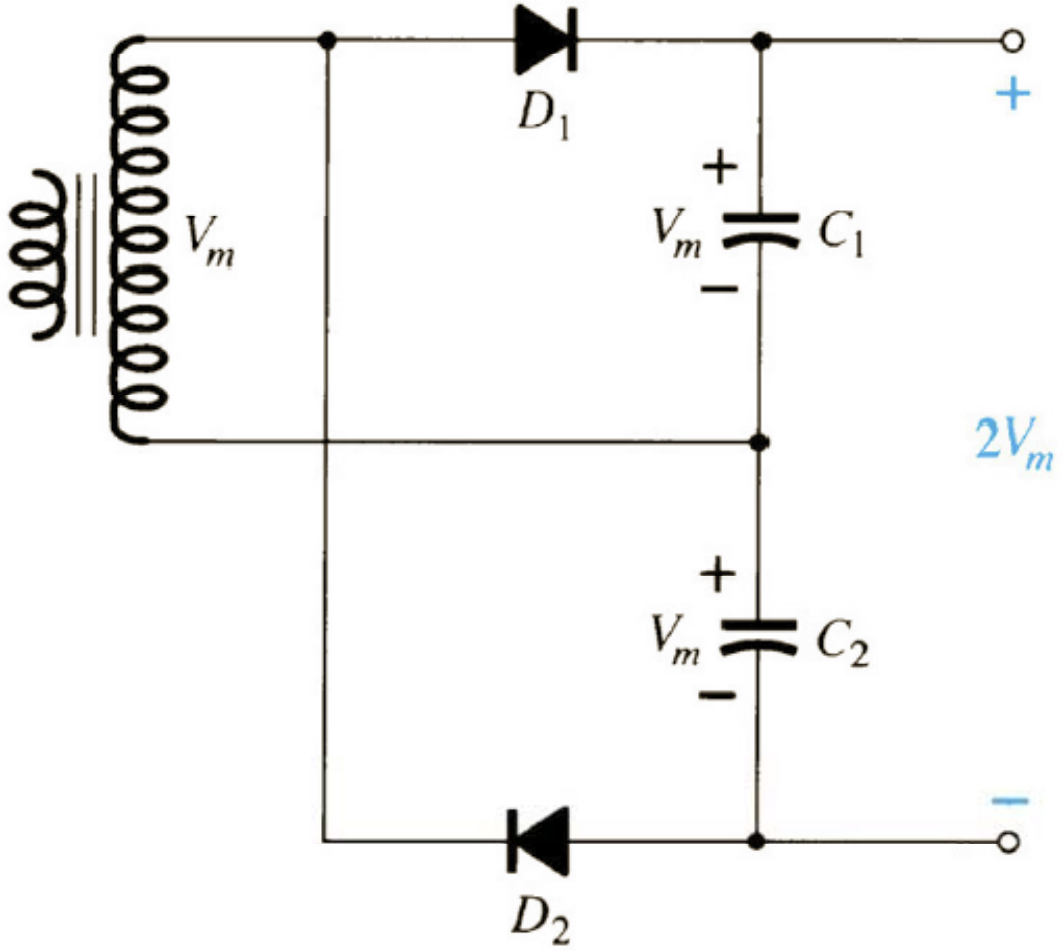
Semiciclo positivo.



Semiciclo negativo.

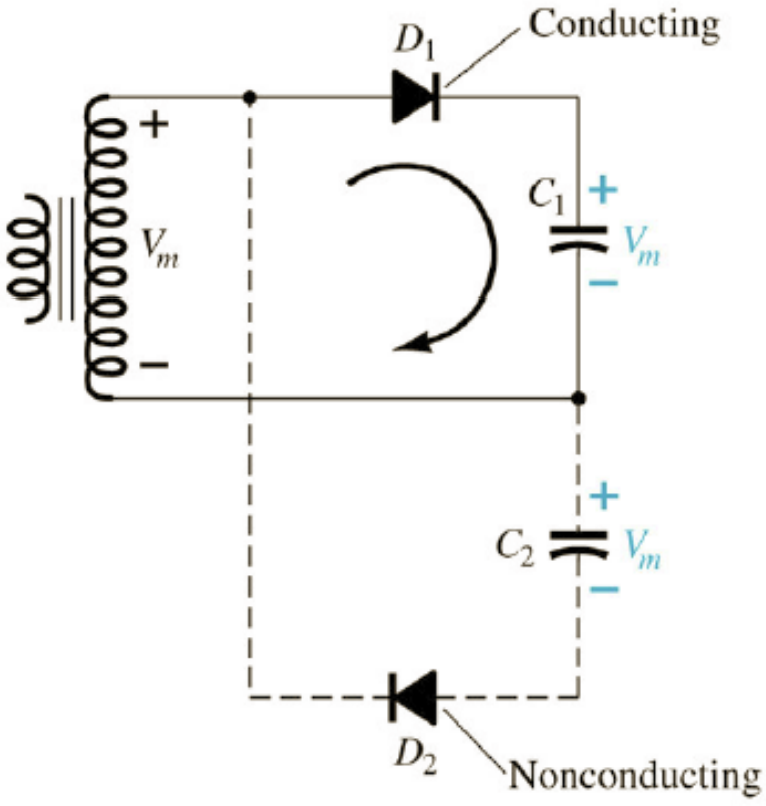
Multiplicadores de tensão

Dobrador de tensão de onda completa:

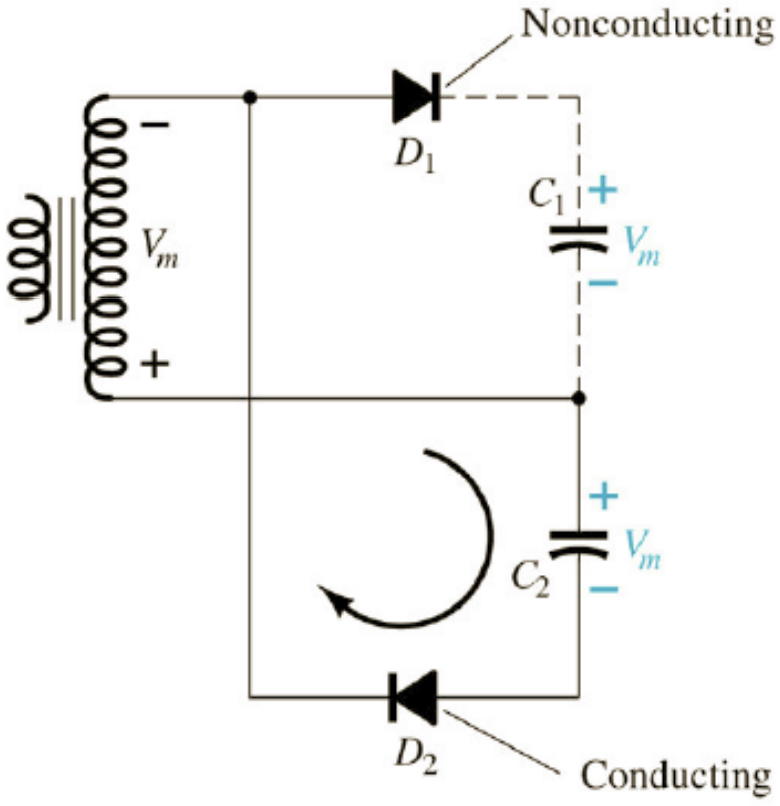


Multiplicadores de tensão

Dobrador de tensão de onda completa:



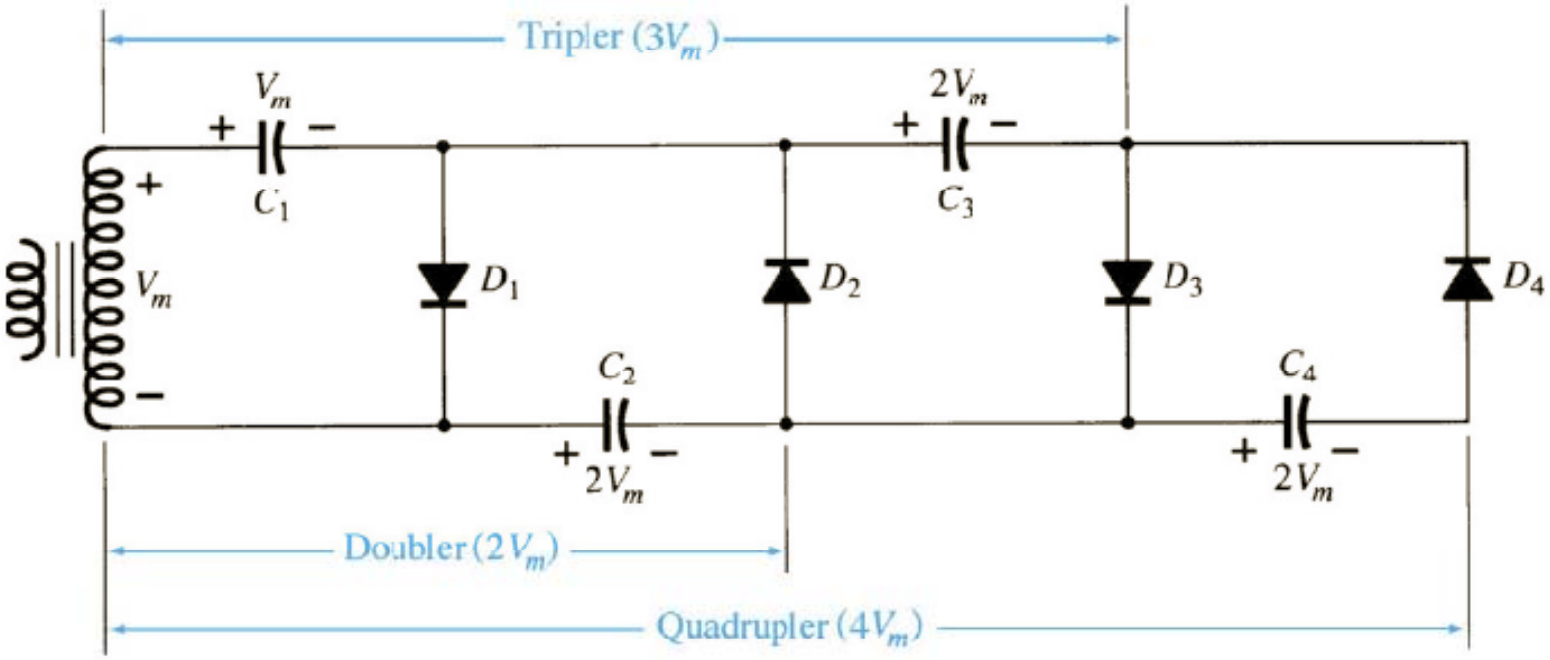
Semiciclo positivo.



Semiciclo negativo.

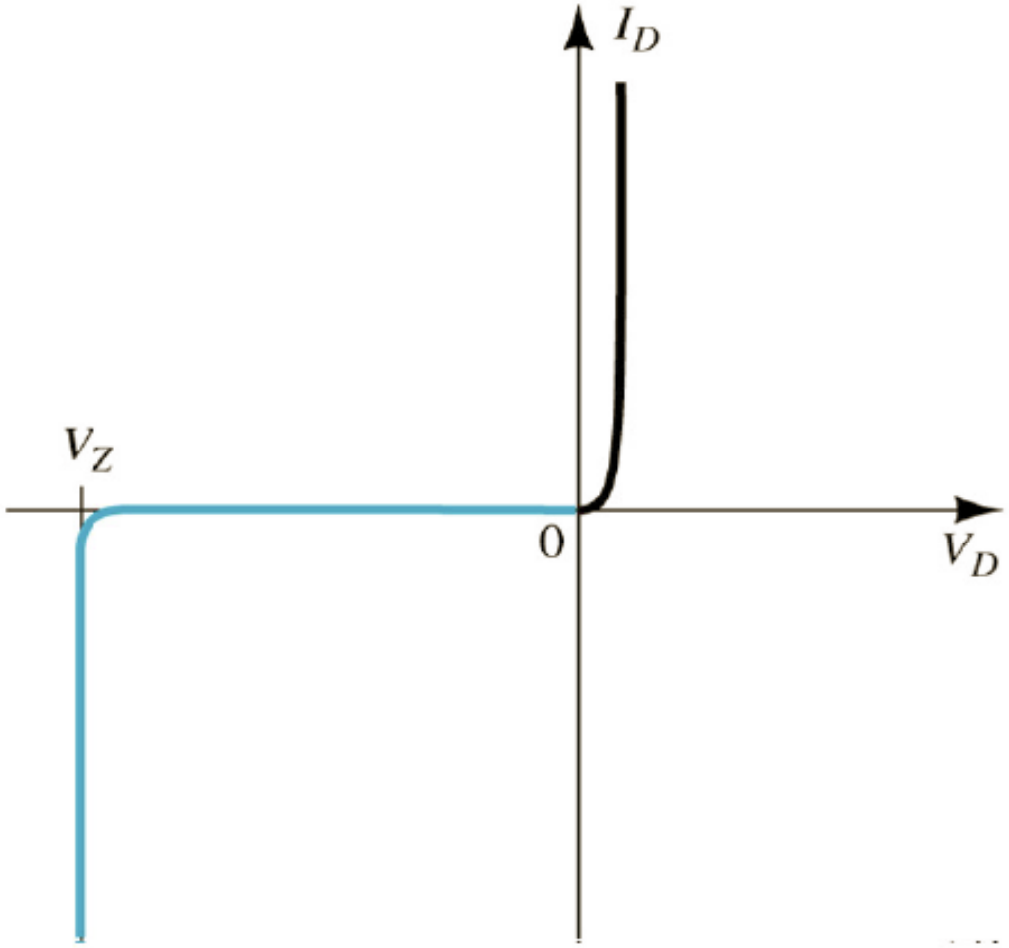
Multiplicadores de tensão

Triplicador de tensão:



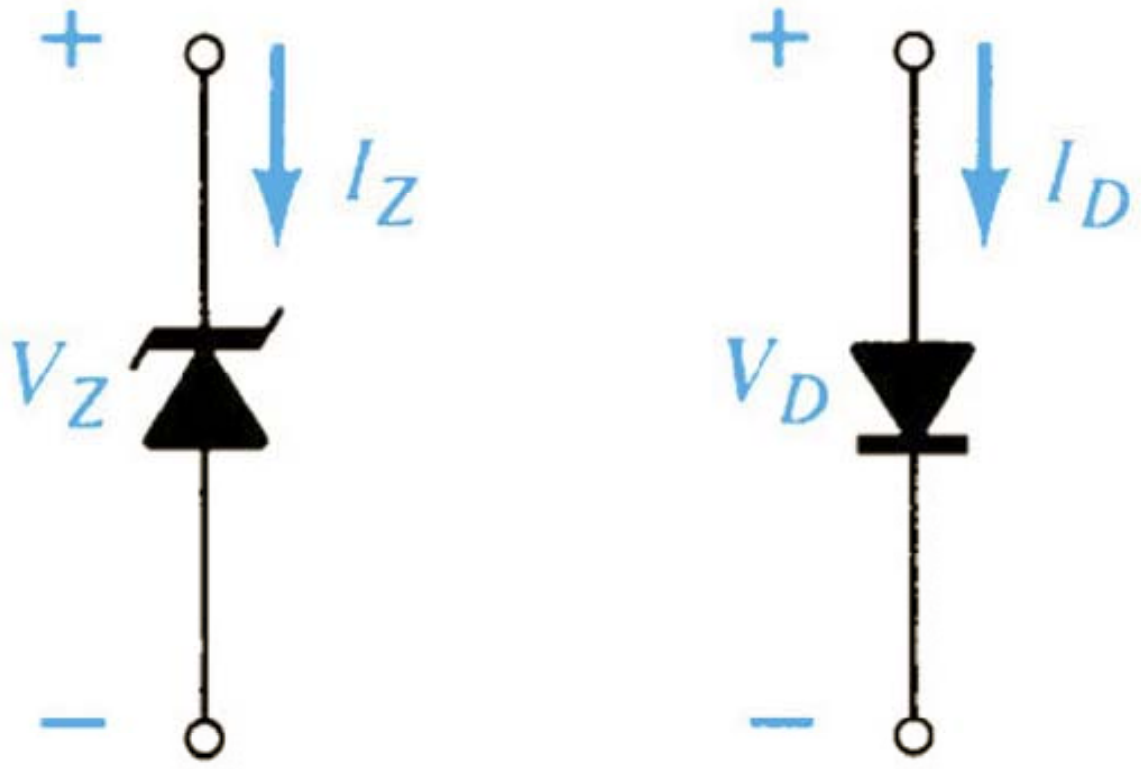
Diodos zener

Região de operação zener:



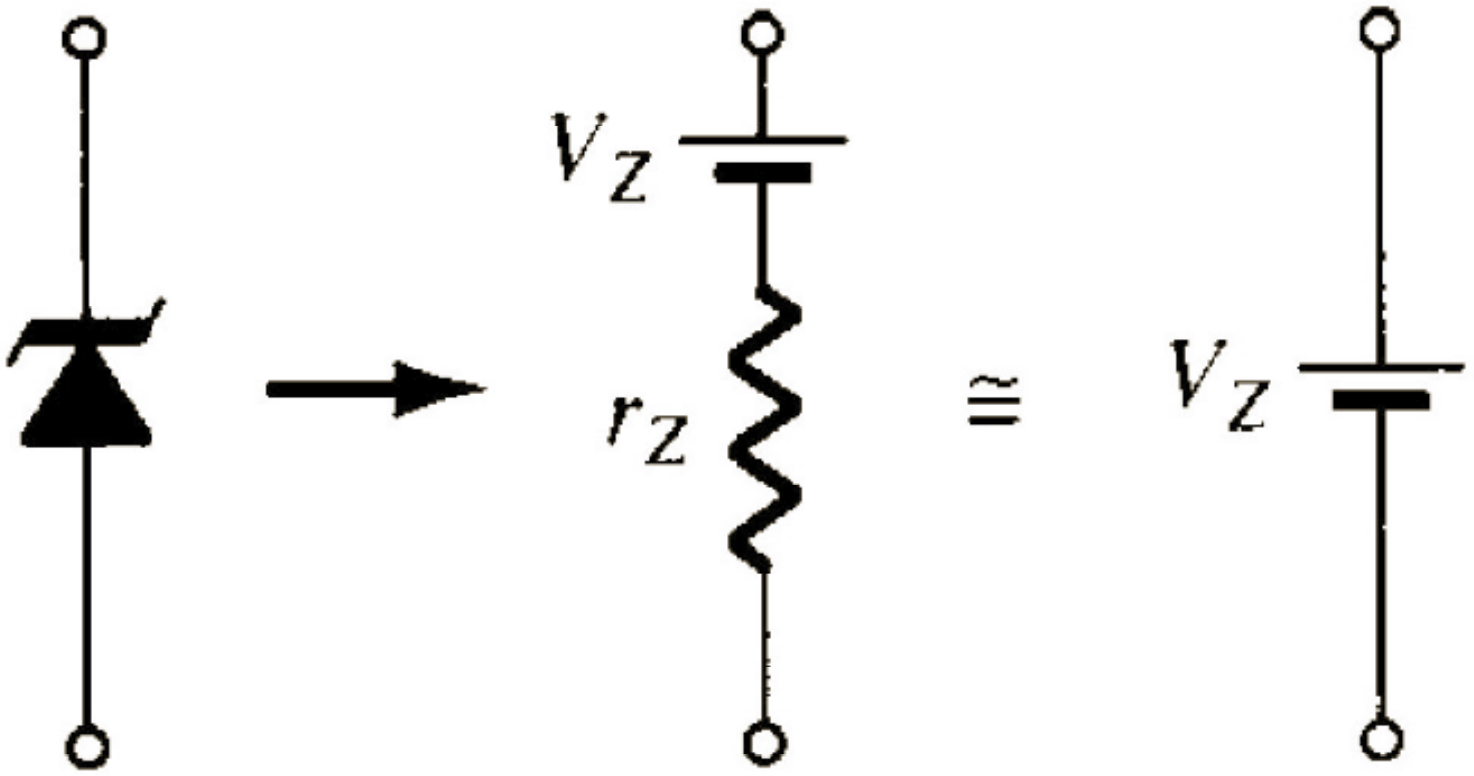
Diodos zener

Sentido de condução:



Diodos zener

Modelos equivalentes do diodo zener:

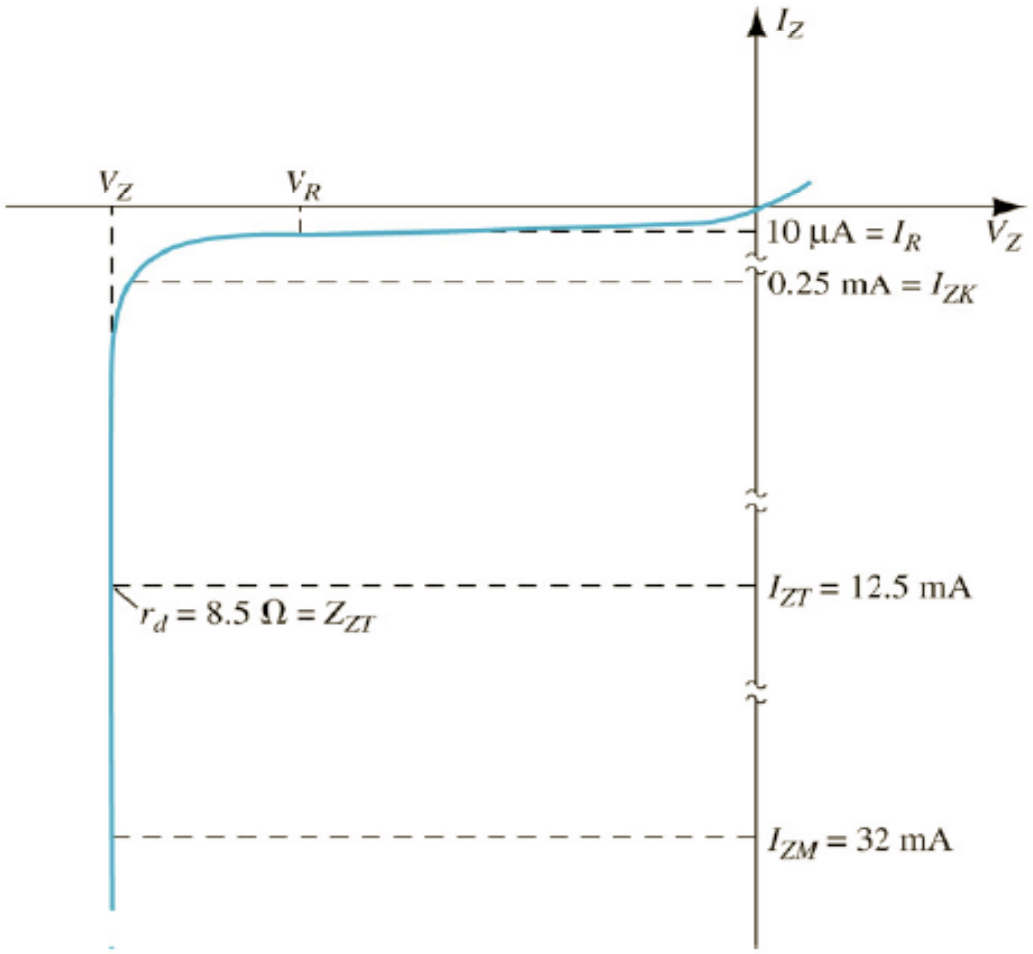


Completo

Simplificado

Diodos zener

Curva característica de um diodo zener:



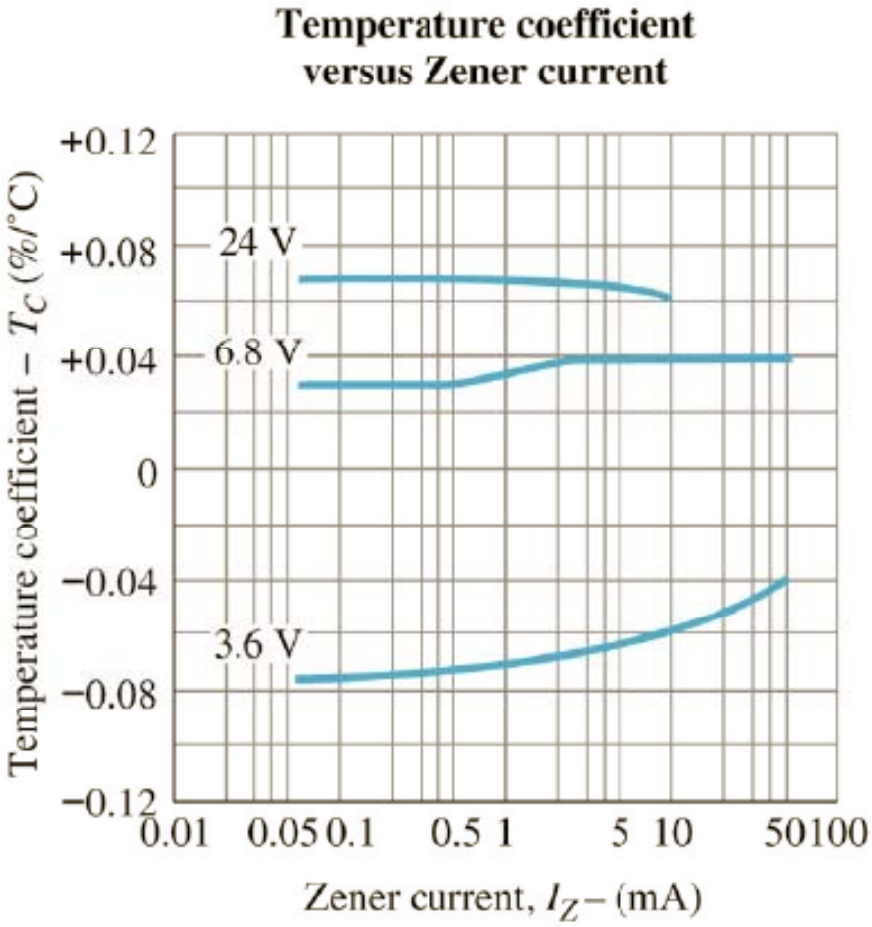
Diodos zener

Características elétricas:

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

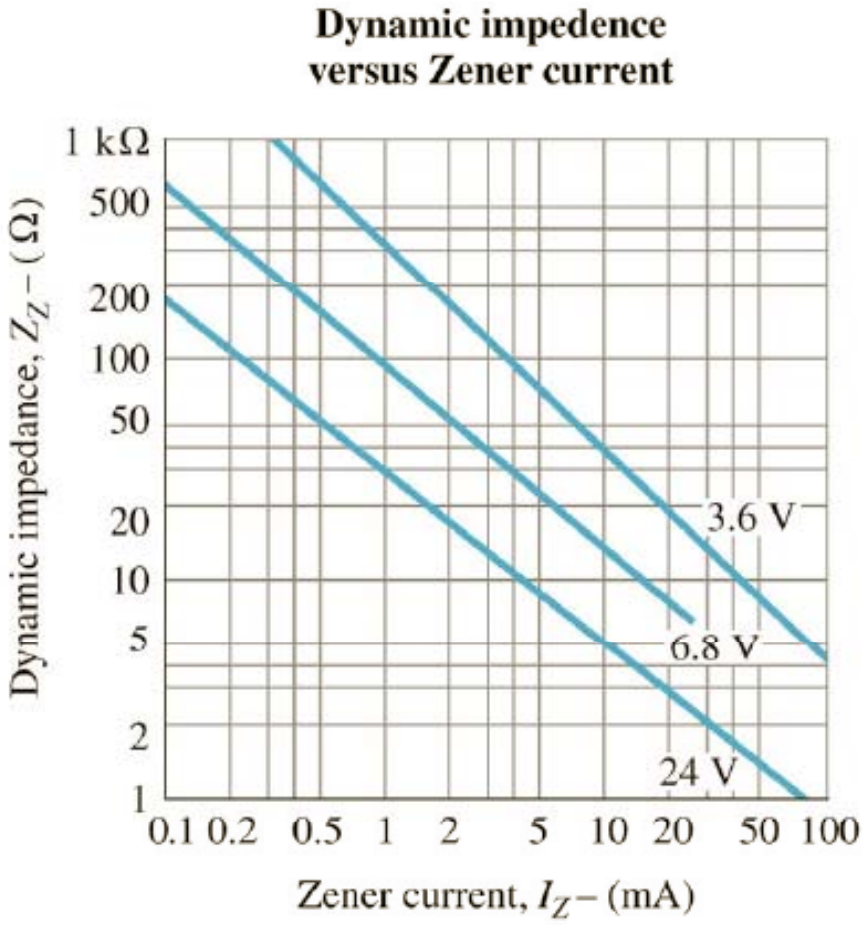
Diodos zener

Coeficiente de temperatura versus corrente zener:



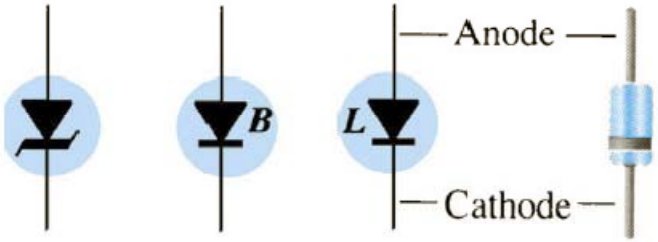
Diodos zener

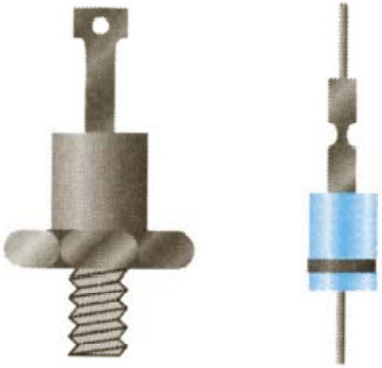
Impedância dinâmica versus corrente zener:

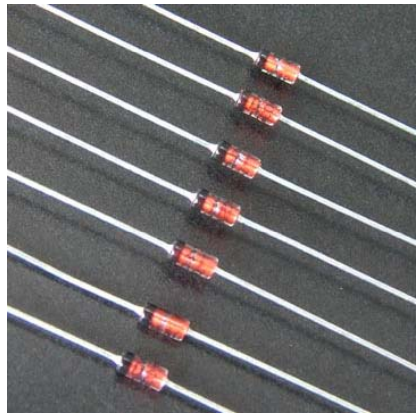


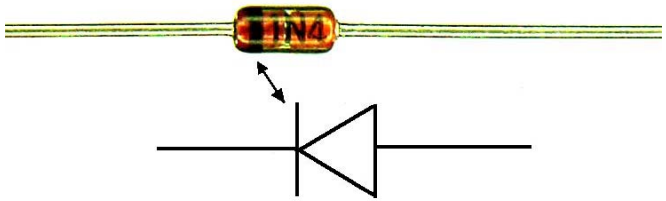
Diodos zener

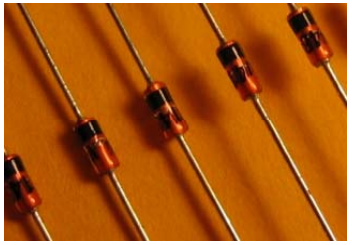
Aspectos de diodos zener:

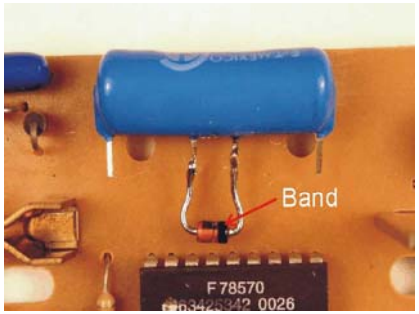






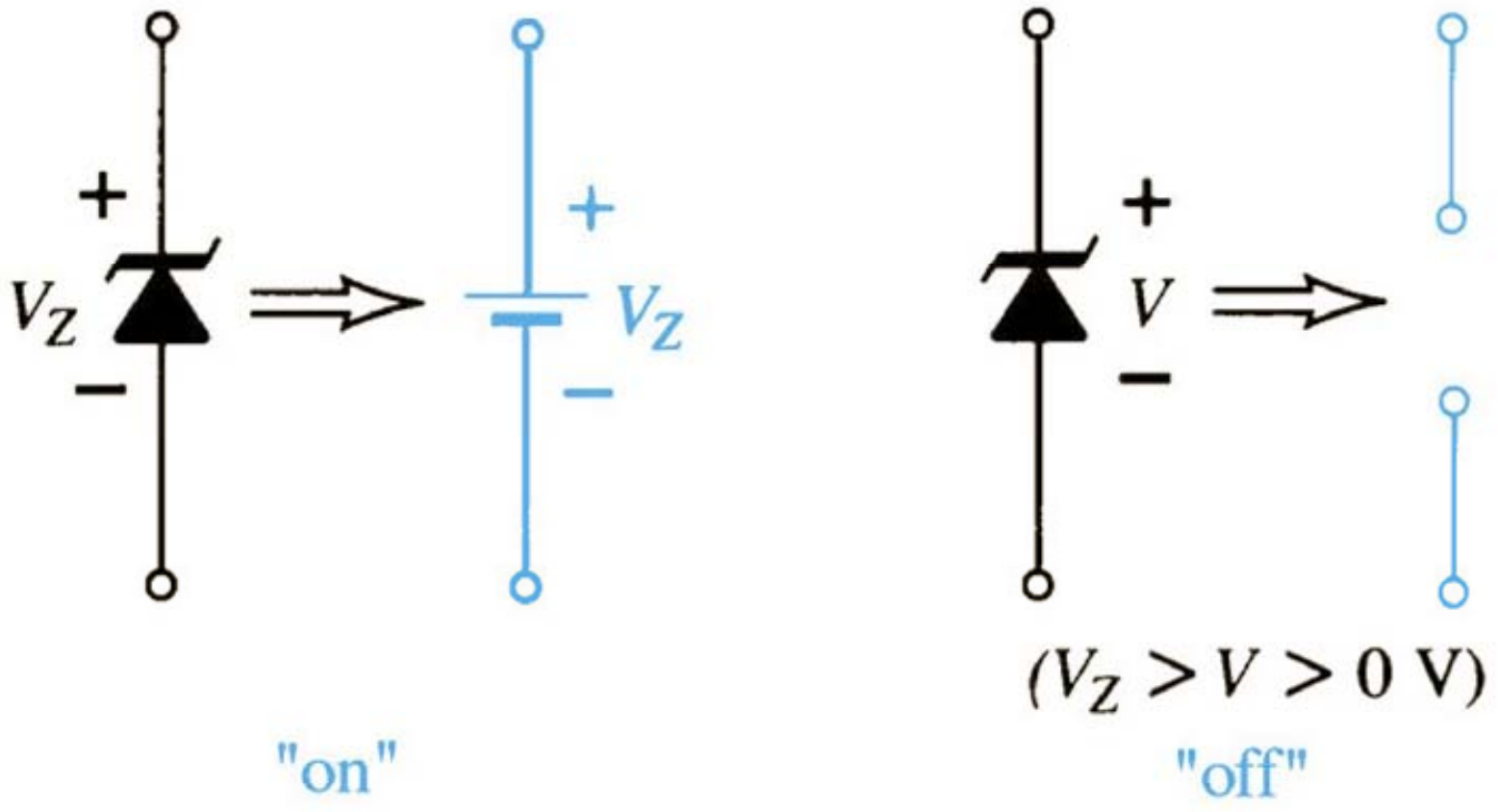






Diodos zener

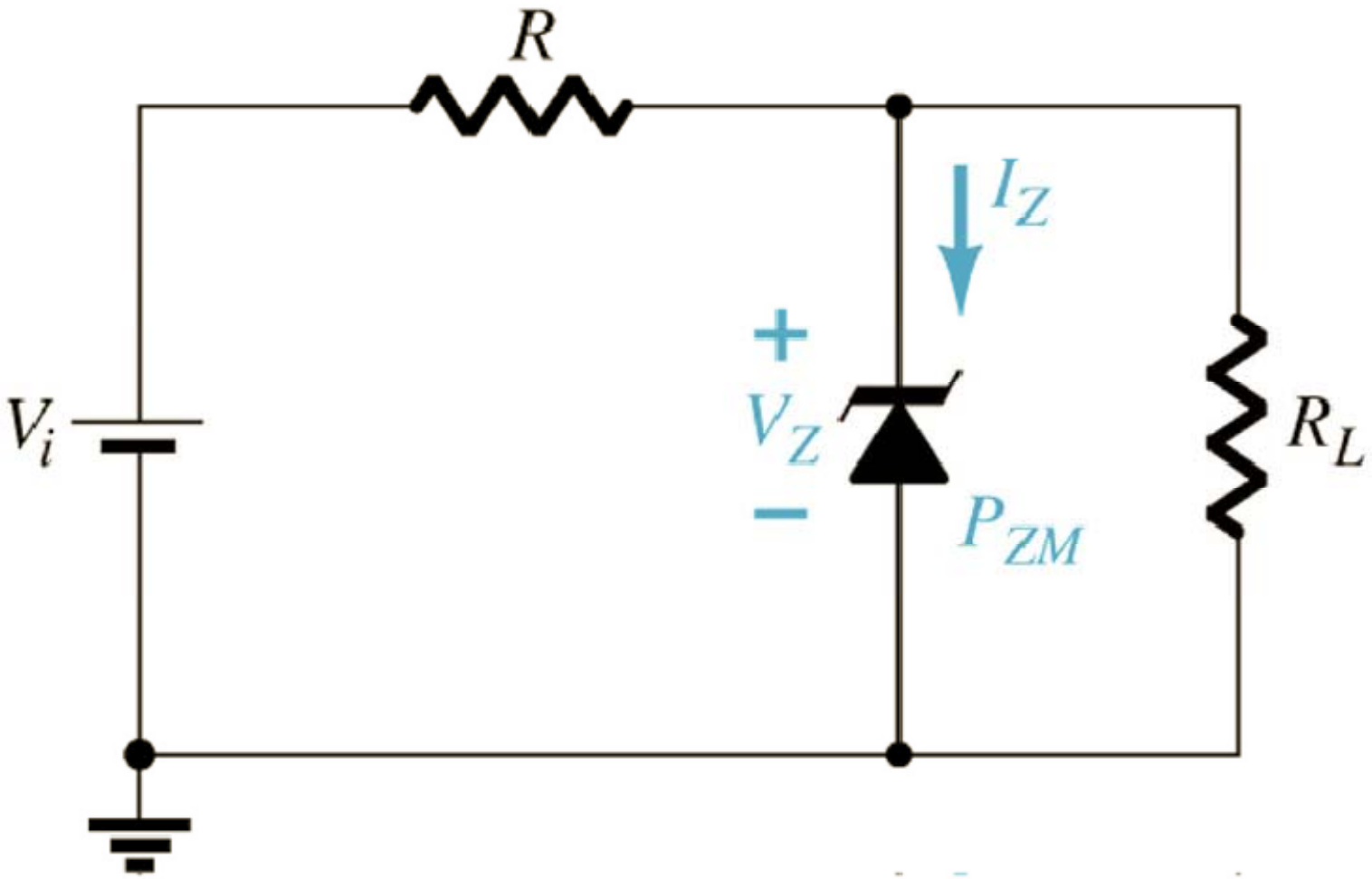
Regulador zener:



Comportamento do zener em condução e bloqueado.

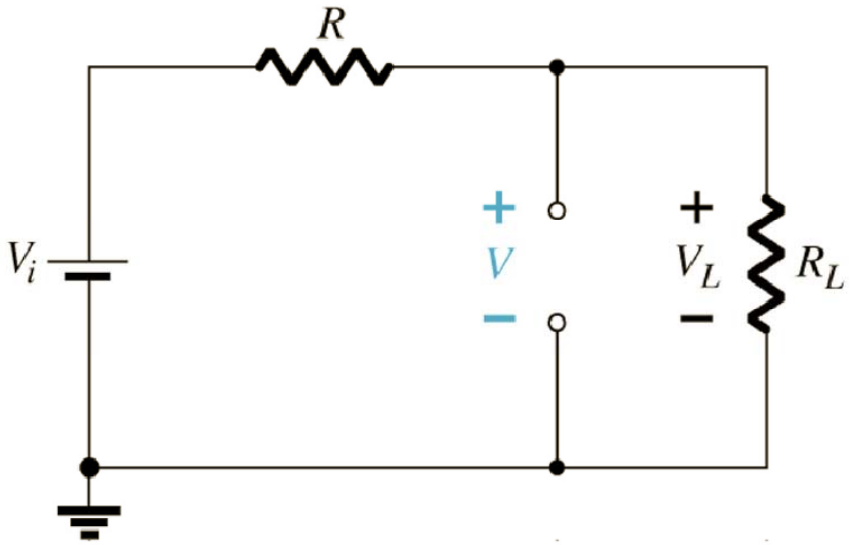
Diodos zener

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



Diodos zener

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



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

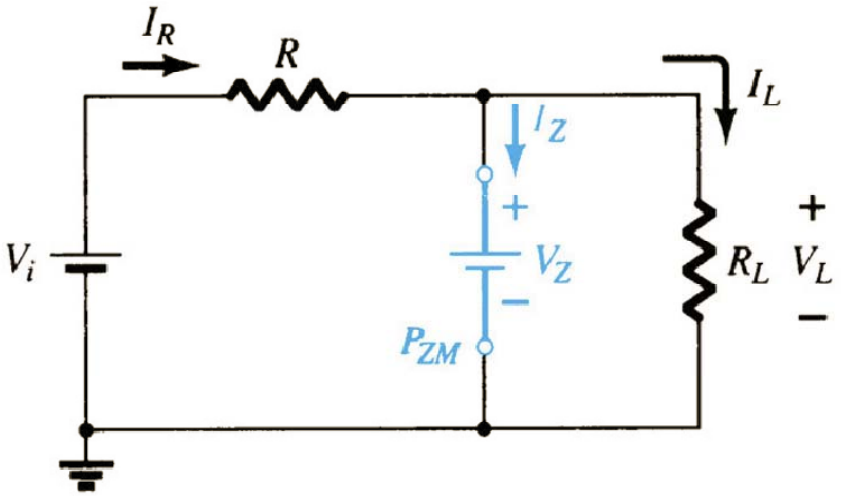
$$V_L = V_Z$$

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**



$$I_R = I_Z + I_L$$

$$I_Z = I_R - I_L$$

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

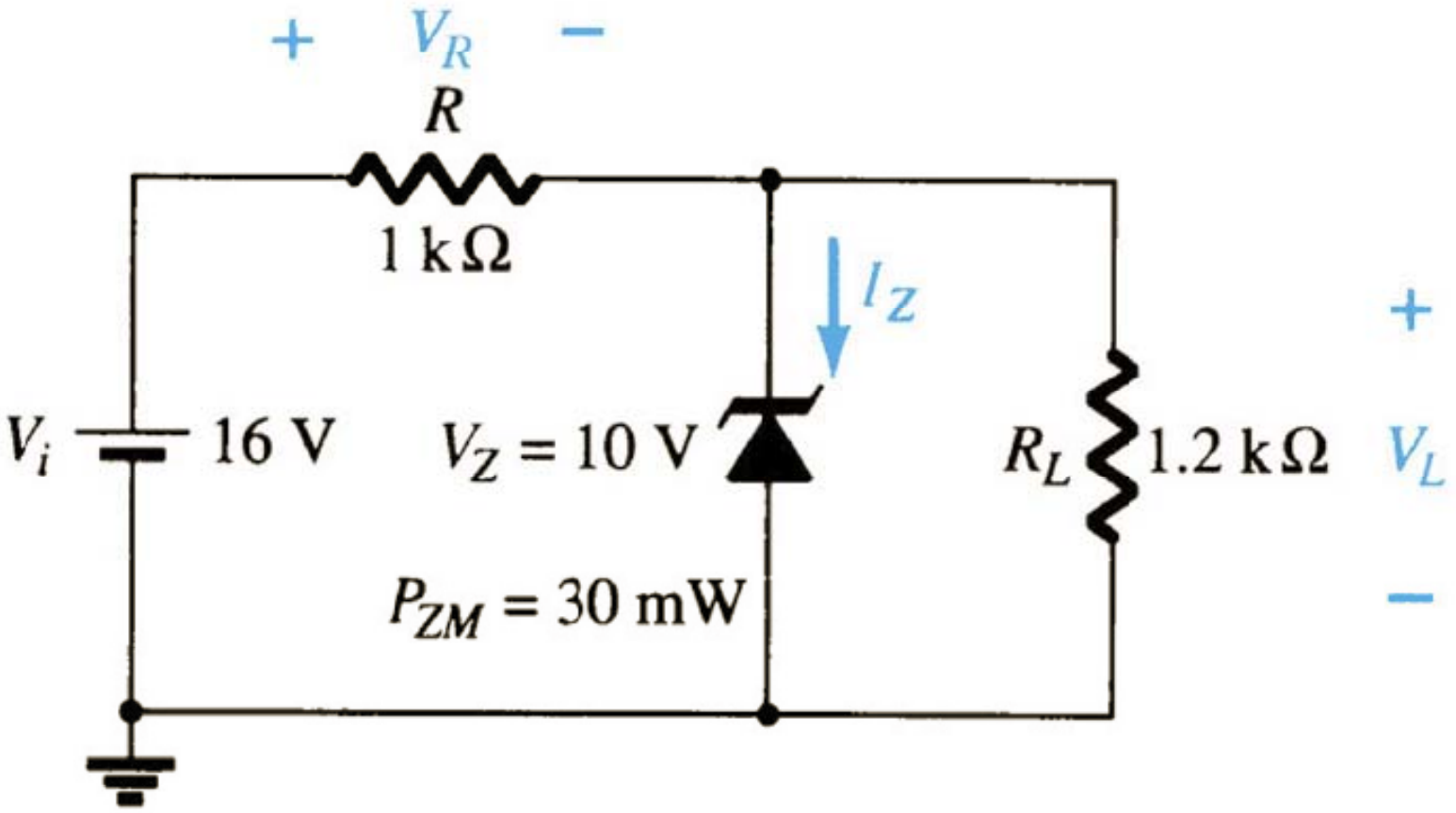
Se:

$$V_L \geq V_Z$$

$$P_Z = V_Z \cdot I_Z$$

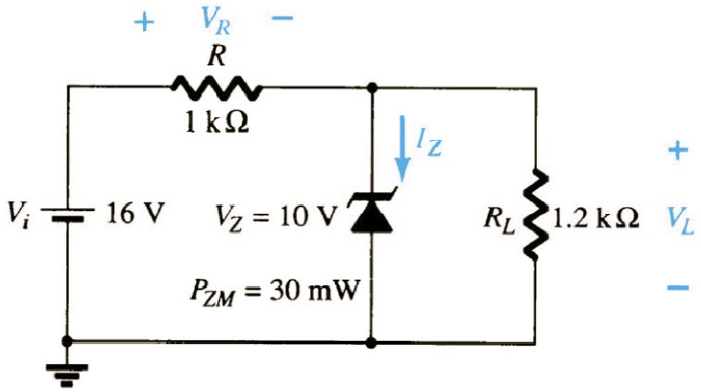
Diodos zener

Circuito regulador zener básico, exemplo: **V_i e R_L fixos**



Diodos zener

Circuito regulador zener básico, exemplo: **V_i e R_L fixos**



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

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

Como:

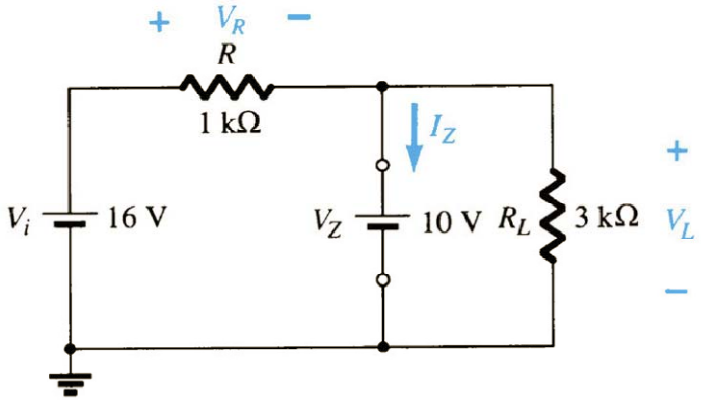
$$8,73 < 10$$

$$V_L < V_Z$$

O diodo está bloqueado.

Diodos zener

Circuito regulador zener básico, exemplo: **V_i e R_L fixos**



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

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

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

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

$$V_L = V = 12V$$

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

$$I_Z = 2,67mA$$

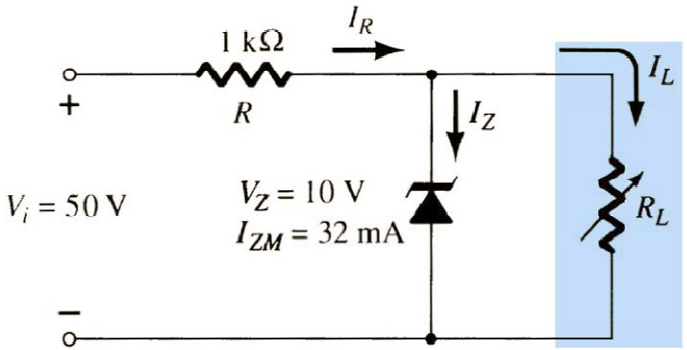
Como: $12 > 10$

O diodo está conduzindo.

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

Diodos zener

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



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

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

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

$$V_R = V_i - V_Z$$

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

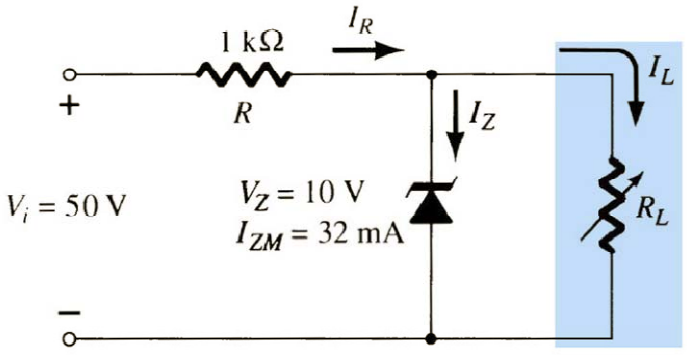
$$I_Z = I_R - I_L$$

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

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

Diodos zener

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



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

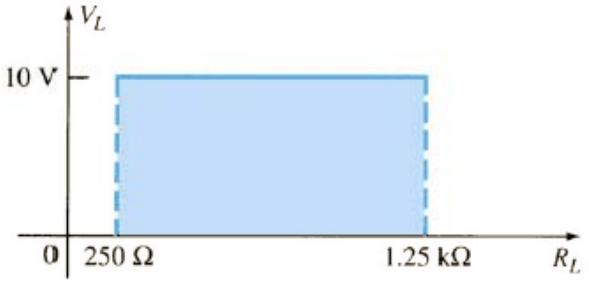
$$V_R = V_i - V_Z = 50 - 10 = 40V$$

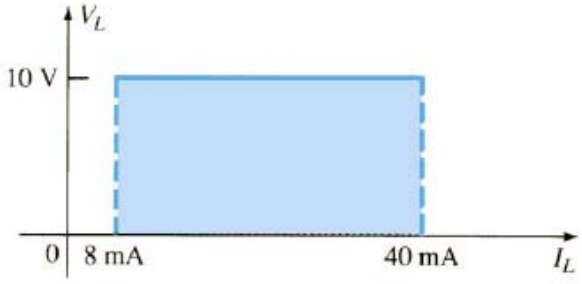
$$I_R = \frac{V_R}{R} = \frac{40}{1k} = 40\,mA$$

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

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

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





Diodos zener

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

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

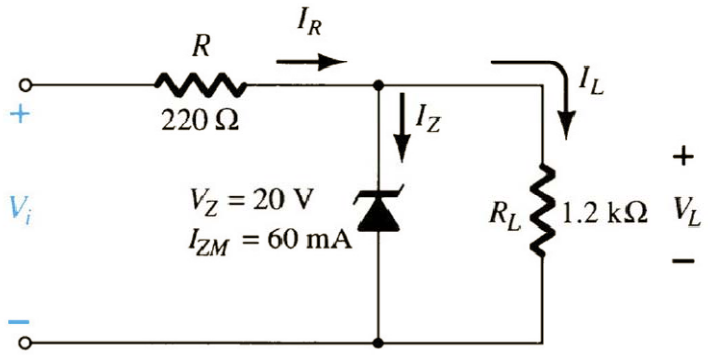
$$V_{imin} = \frac{\left(R_L + R\right) \cdot V_Z}{R_L}$$

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

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

Diodos zener

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

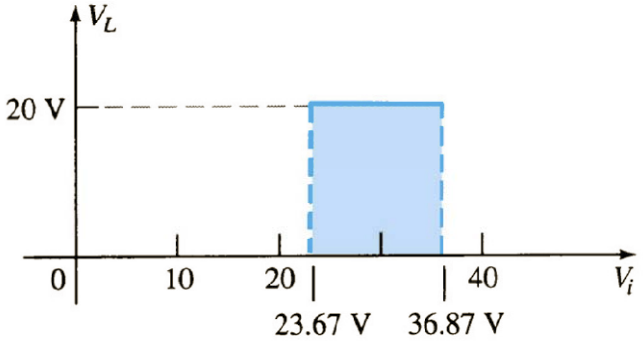


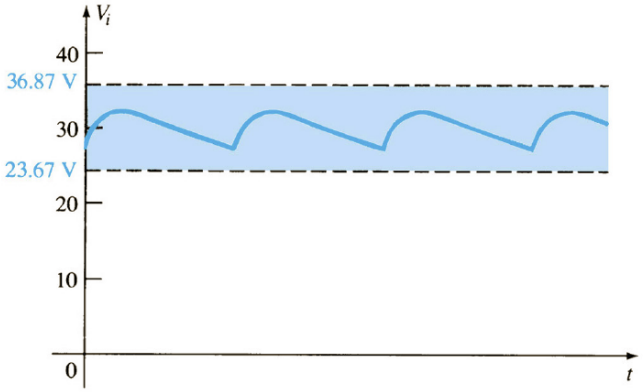
$$V_{imin} = \frac{(R_L + R)\cdot V_Z}{R_L} = \frac{(1200 + 220)\cdot 20}{1200} = 23,67V$$

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

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

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





Na próxima aula

Seqüência de conteúdos:

1. Transistores bipolares.