Curso Básico de Eletrônica de Potência

Conversores ca-cc

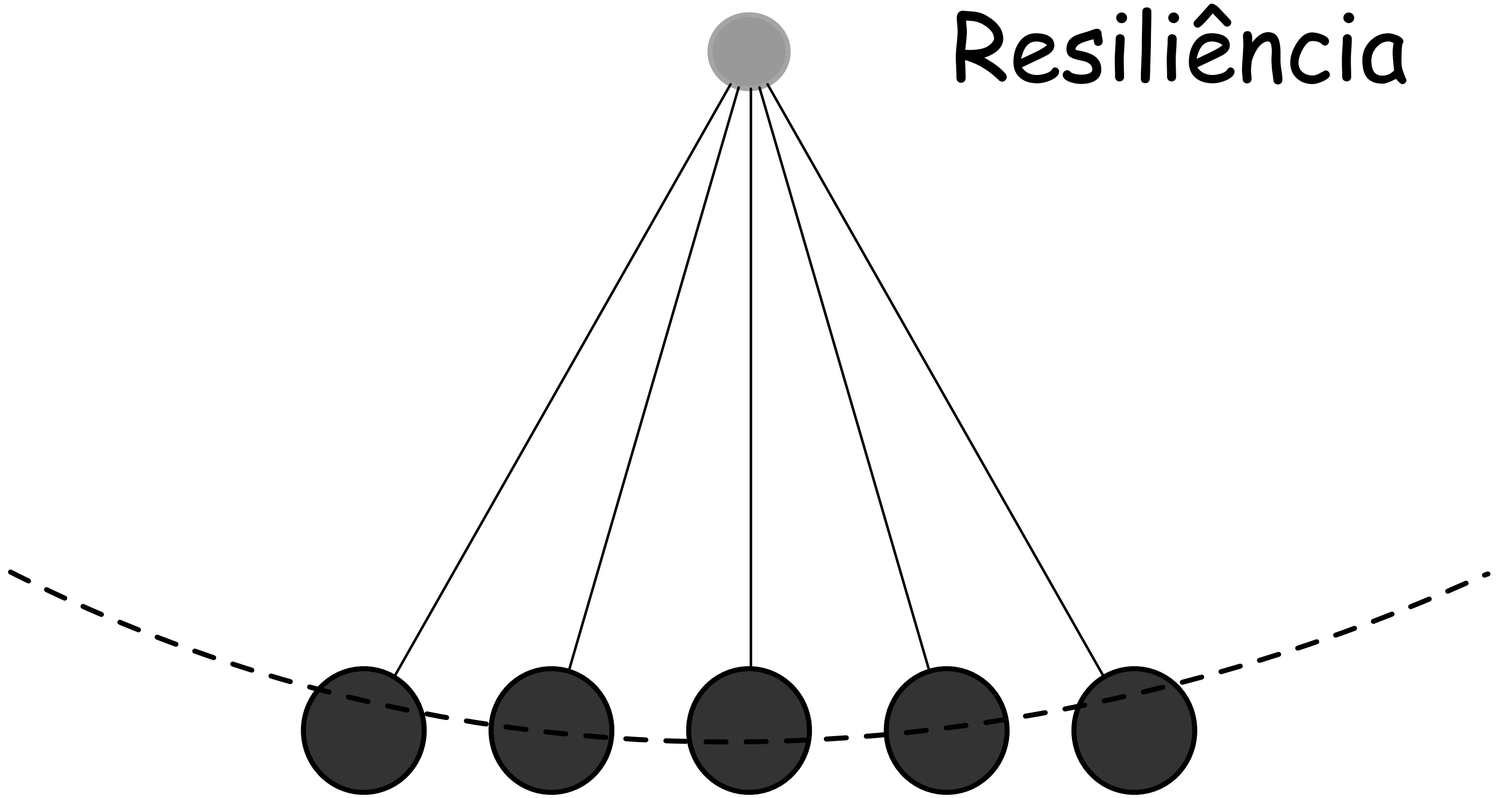
Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina
Departamento Acadêmico de Eletrônica
Eletrônica de Potência

Conversores ca-cc

Prof. Clovis Antonio Petry.

Florianópolis, julho de 2020.

Resiliência



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O material do curso está disponível em:

1. Moodle para os alunos matriculados na disciplina.
2. Página do professor.
3. Canal no youtube do professor.

https://moodle.ifsc.edu.br

www.ProfessorPetry.com.br

https://www.youtube.com

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Agenda

Esta aula está organizada em:

1. Formas de onda;
   - Senoidal;
   - Senoidal retificada em meia onda;
   - Senoidal retificada em onda completa;
   - Quadrada.
2. Retificador de meia onda;
   - Carga resistiva;
   - Carga mista (resistiva-indutiva).
3. Retificador de onda completa:
   - Com ponto médio;
   - Em ponte completa.
4. Retificadores com filtro capacitivo:
   - Meia onda;
   - Onda completa.
5. Retificadores controlados:
   - Meia onda;
   - Onda completa.

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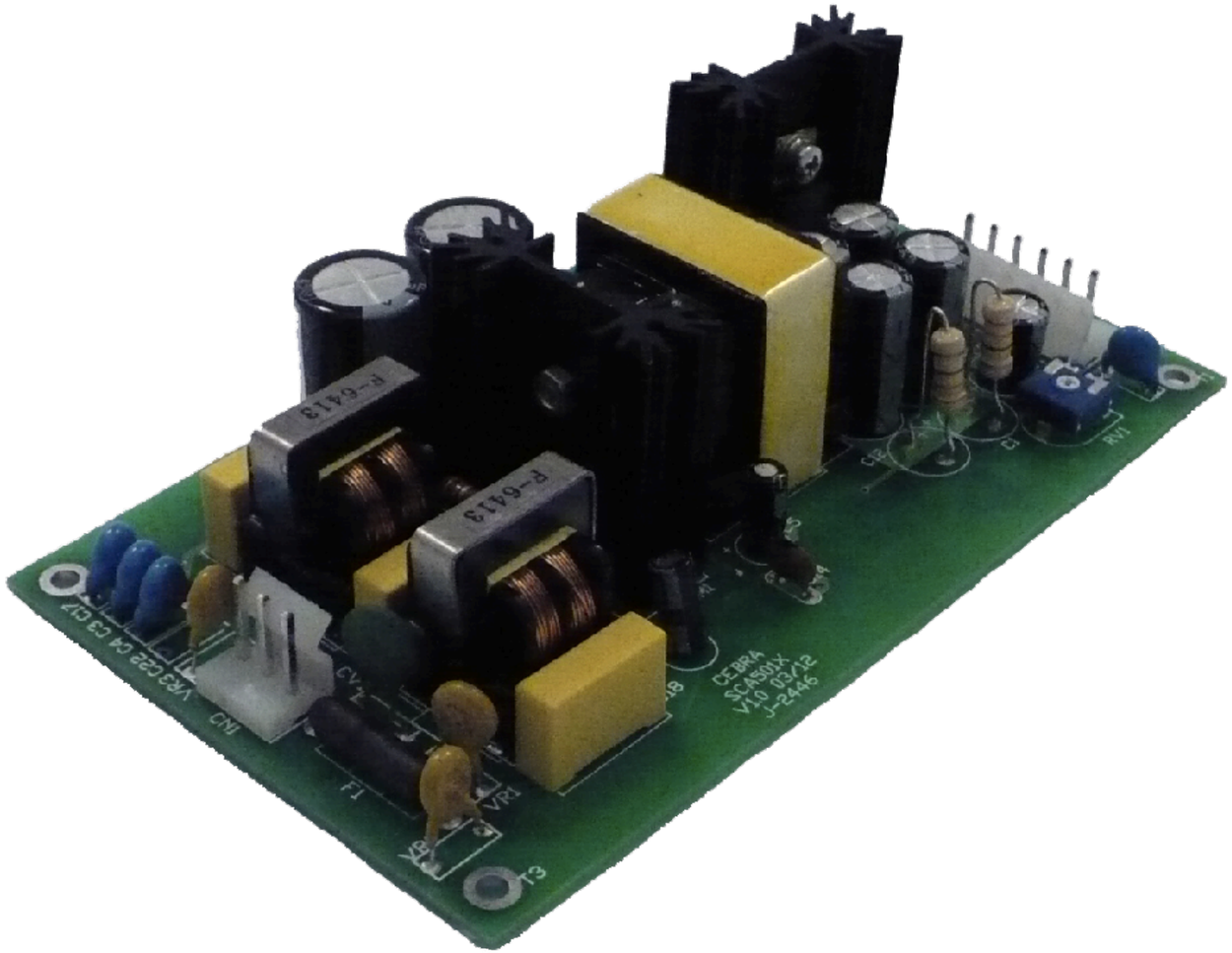
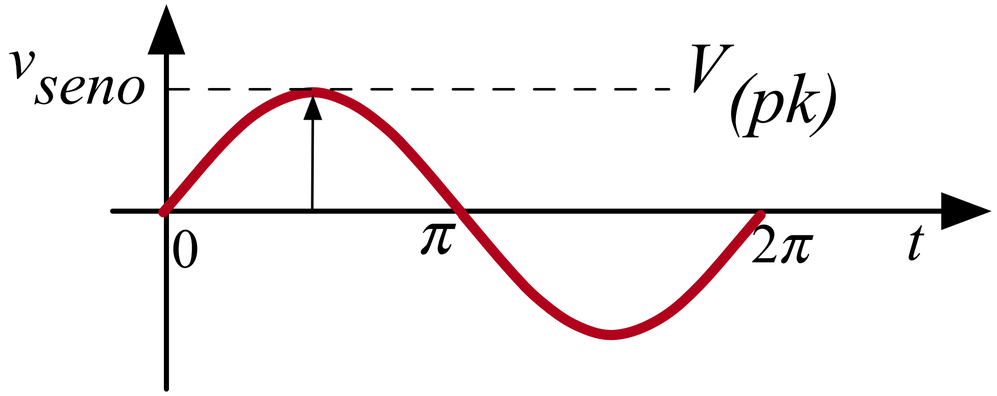
Motivação

Os equipamentos eletrônicos em geral utilizam uma fonte linear ou chaveada que possui um conversor ca-cc (retificador).



http://www.cebra.com.br/

Forma de onda senoidal



$$T = \frac{1}{F} = \frac{1}{60} = 16{,}67ms$$

$$\omega = 2\pi \cdot F = 2\pi \cdot 60 \cong 377rad/s$$

$$2\pi = 360^{o}$$

$$\omega = 2\pi \cdot F\left[rad/s\right]$$

$$F = \frac{1}{T}\left[Hz\right]$$

$$V_{(pk)} = \text{definido}$$

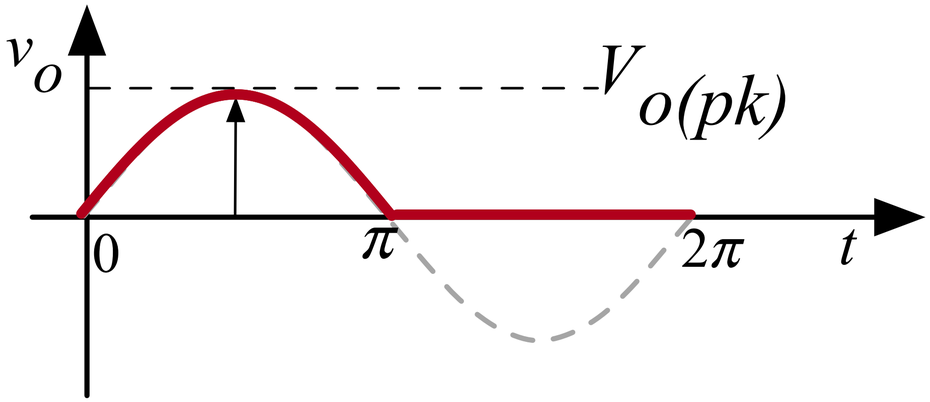
$$v(t) = V_{(pk)} \cdot seno\left(\omega \cdot t + \phi\right)$$

onde ϕ é ângulo de defasagem.

$$V_{(ef)} = V_{(RMS)} = \frac{V_{(pk)}}{\sqrt{2}}$$

$$V_{(med)} = V_{(cc)} = V_{(avg)} = 0$$

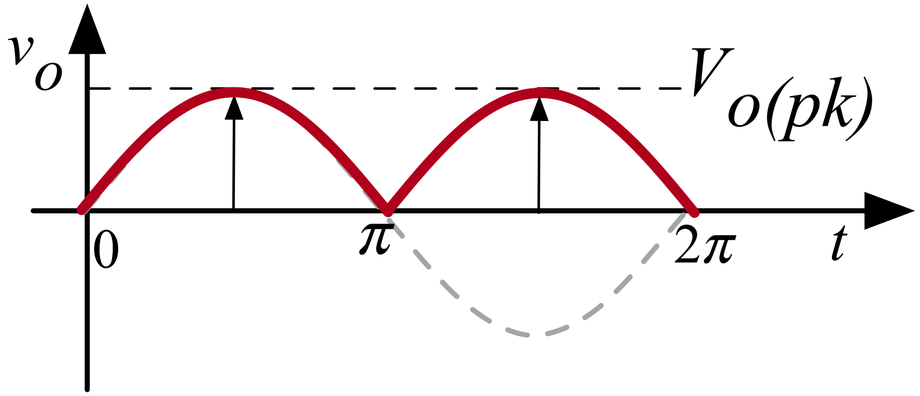
Senoidal retificada: meia onda e onda completa



$$V_{o(pk)} = \text{definido}$$

$$V_{d(ef)} = \frac{V_{d(pk)}}{2}$$

$$V_{d(med)} = \frac{V_{d(pk)}}{\pi}$$

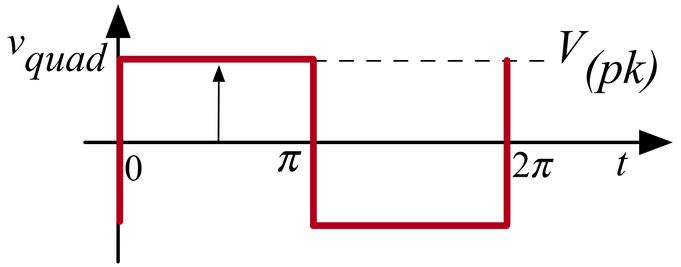


$$V_{o(pk)} = \text{definido}$$

$$V_{d(ef)} = \frac{V_{d(pk)}}{\sqrt{2}}$$

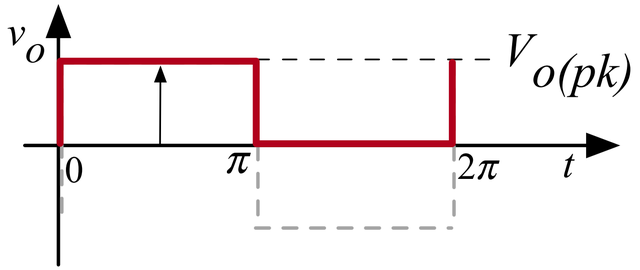
$$V_{d(med)} = 2 \cdot \frac{V_{d(pk)}}{\pi}$$

Forma de onda quadrada



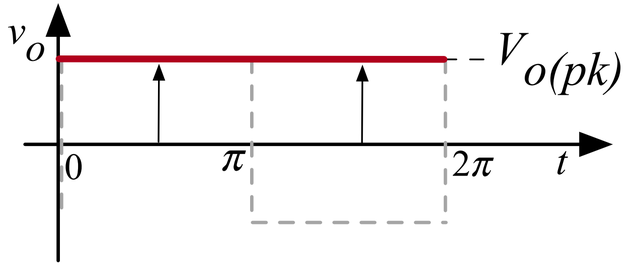
$$V_{d(ef)} = V_{d(pk)}$$

$$V_{d(med)} = 0$$



$$V_{d(ef)} = \frac{V_{d(pk)}}{\sqrt{2}}$$

$$V_{d(med)} = \frac{V_{d(pk)}}{2}$$

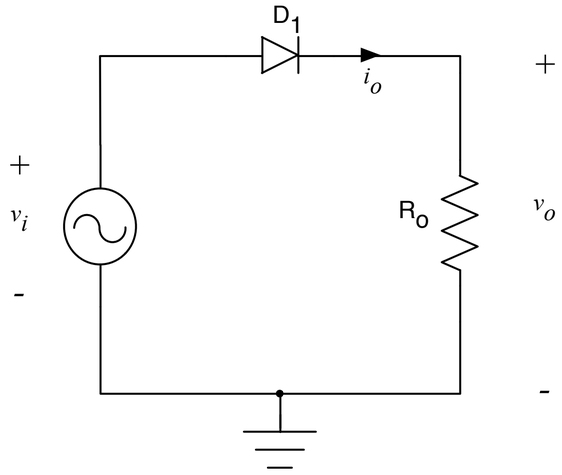


$$V_{d(ef)} = V_{d(pk)}$$

$$V_{d(med)} = 2 \cdot \frac{V_{d(pk)}}{2} = V_{d(pk)}$$

$$V_{(pk)} = \text{definido}$$

Retificador de meia onda (carga resistiva)

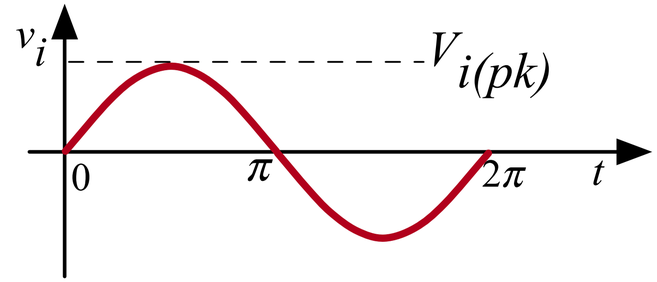


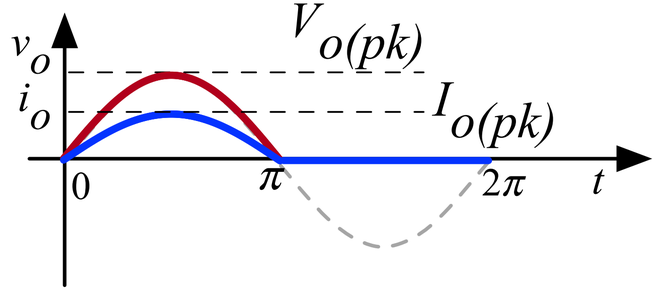
$$V_{i(pk)} = \text{definido}$$

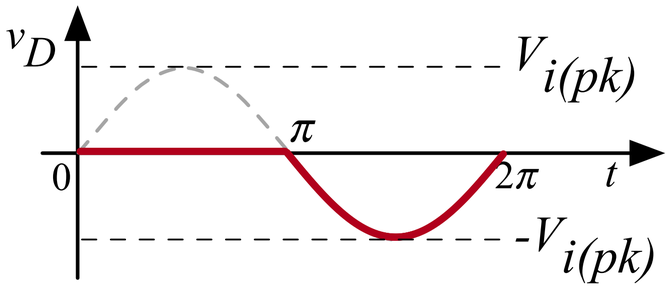
$$V_{o(pk)} = V_{i(pk)} \rightarrow I_{o(pk)} = \frac{V_{o(pk)}}{R_o}$$

$$V_{d(ef)} = \frac{V_{d(pk)}}{2} \rightarrow I_{o(ef)} = \frac{V_{o(ef)}}{R_o}$$

$$V_{d(med)} = \frac{V_{d(pk)}}{\pi} \rightarrow I_{o(med)} = \frac{V_{o(med)}}{R_o}$$







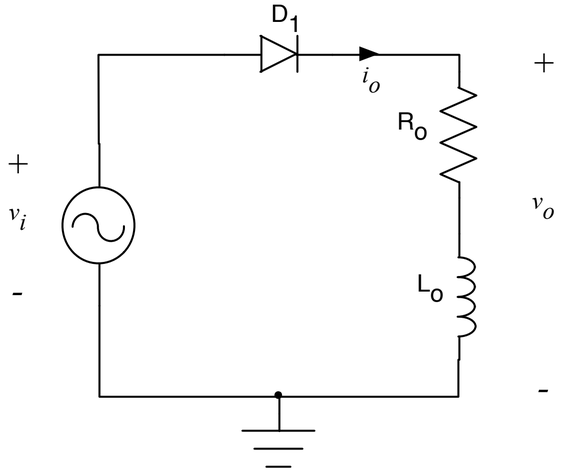
Retificador de meia onda (carga mista)

$$X_{Lo} = \omega \cdot L_o = 2\pi \cdot F \cdot L_o \rightarrow Z_o = R_o + j \cdot X_{Lo} \rightarrow \left|Z_o\right| = \sqrt{R_o^2 + X_{Lo}^2} \rightarrow \phi = \tan^{-1}\left(\frac{X_{Lo}}{R_o}\right)$$

$$\beta = 1{,}14 \cdot \phi + 180\left[^o\right] \rightarrow 0 \le \phi \le 70^o$$

$$\beta = 3 \cdot \phi + 50\left[^o\right] \rightarrow 70 \le \phi \le 360^o$$

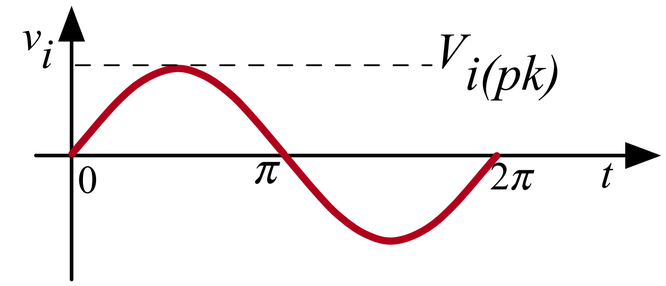
$$\beta = 360^o \rightarrow 85 \le \phi \le 90^o$$

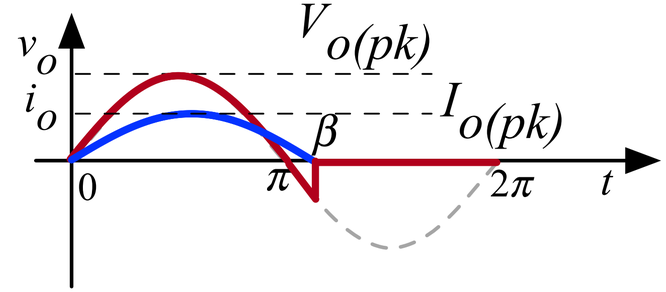


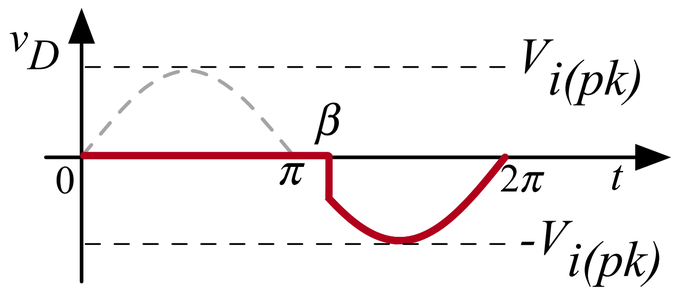
$$V_{o(pk)} = V_{i(pk)} \rightarrow I_{o(pk)} = \frac{V_{o(pk)}}{Z_o}$$

$$V_{d(ef)} = \frac{V_{d(pk)}}{2} \cdot \sqrt{\frac{\beta - \cos(\beta) \cdot \operatorname{sen}(\beta)}{\pi}} \rightarrow I_{o(ef)} \cong \frac{V_{o(ef)}}{R_o} \rightarrow \text{ou} \rightarrow I_{o(ef)} \cong 1{,}7 \cdot I_{o(med)}$$

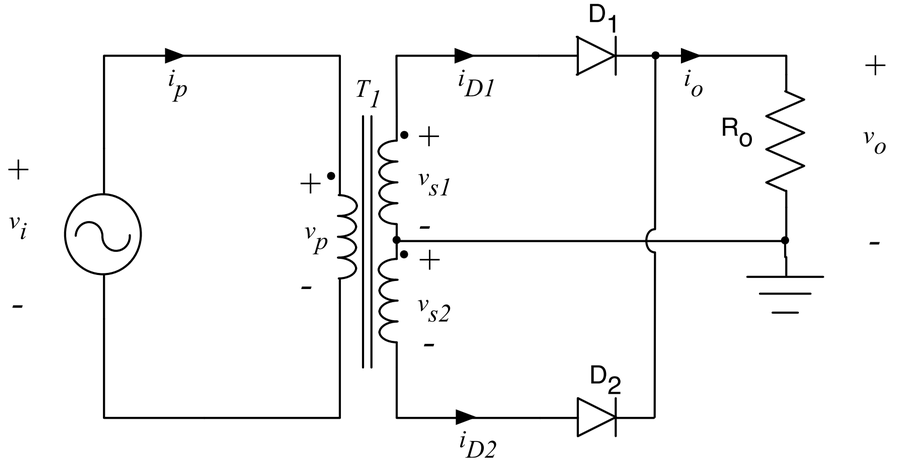
$$V_{d(med)} = \frac{V_{d(pk)}}{2\pi} \cdot \left(1 - \cos(\beta)\right) \rightarrow I_{o(med)} = \frac{V_{o(med)}}{R_o}$$

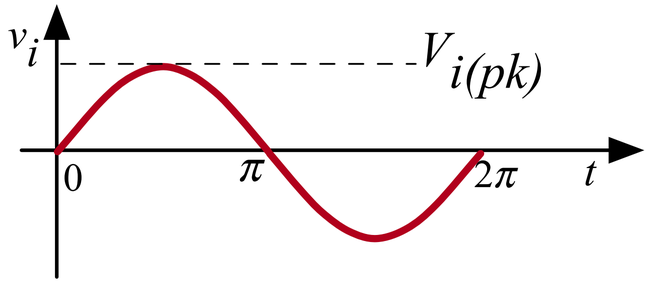


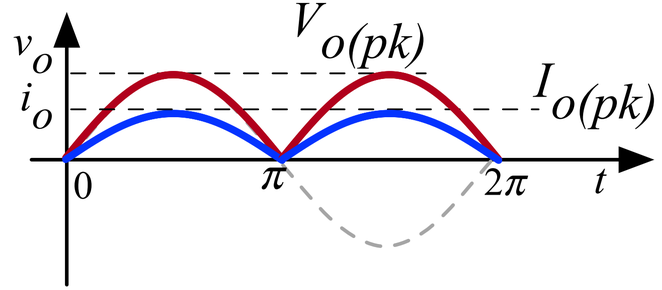


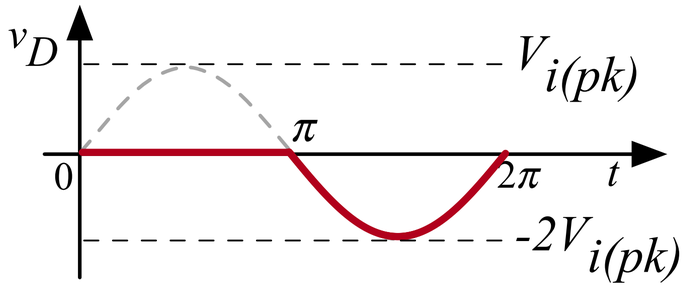


Retificador onda completa com ponto médio









$$V_{i(pk)} = \text{definido}$$

$$V_{s1(pk)} = V_{s2(pk)} = \frac{V_{p(pk)}}{n} = \frac{V_{i(pk)}}{n} \rightarrow n = \frac{V_p}{V_s}$$

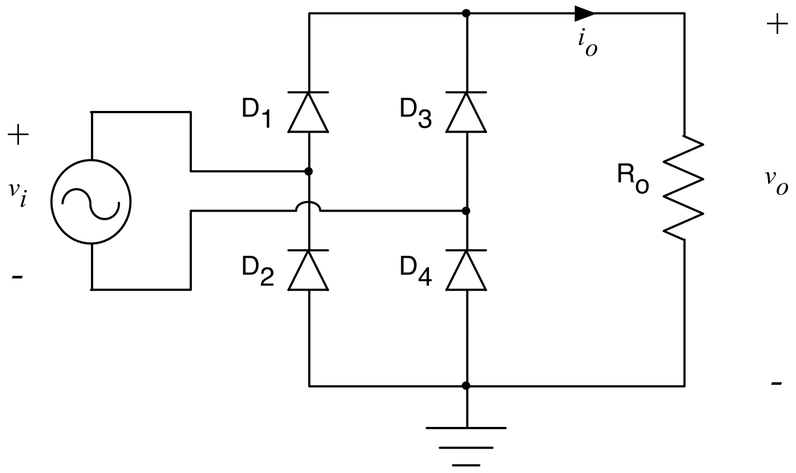
$$V_{o(pk)} = V_{s(pk)} \rightarrow I_{o(pk)} = \frac{V_{o(pk)}}{R_o}$$

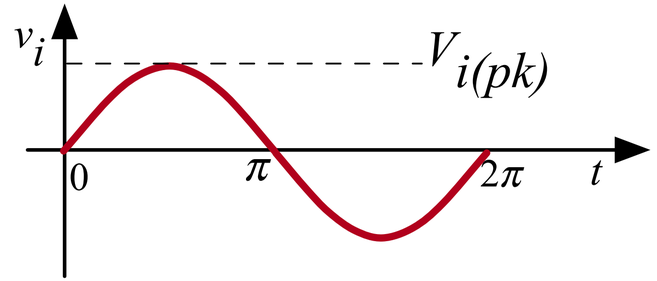
$$V_{o(ef)} = V_{s(ef)} = \frac{V_{s(pk)}}{\sqrt{2}} \rightarrow I_{o(ef)} = \frac{V_{o(ef)}}{R_o}$$

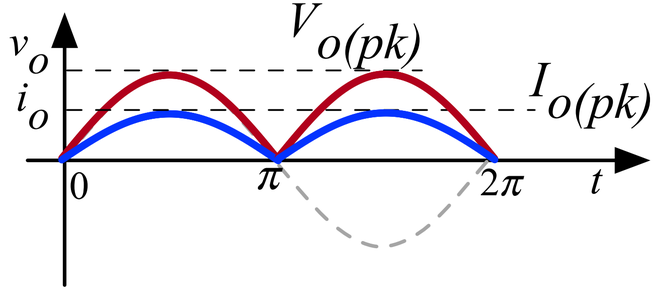
$$V_{o(med)} = 2 \cdot \frac{V_{o(pk)}}{\pi} \rightarrow I_{o(med)} = \frac{V_{o(med)}}{R_o}$$

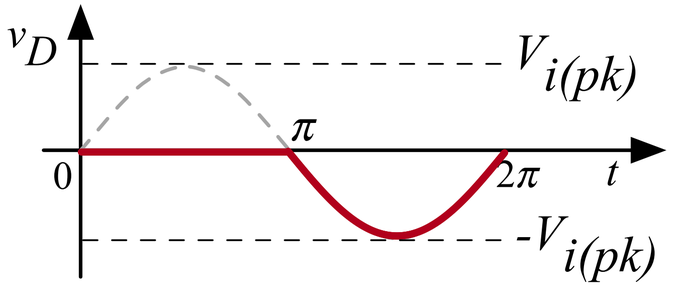
$$V_{RRM} = 2 \cdot V_{i(pk)}$$

Retificador onda completa em ponte completa









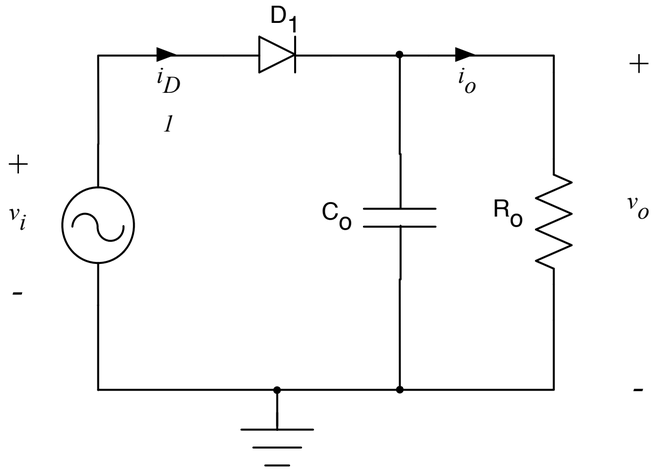
$$V_{i(pk)} = \text{definido}$$

$$V_{o(pk)} = V_{i(pk)} \rightarrow I_{o(pk)} = \frac{V_{o(pk)}}{R_o}$$

$$V_{o(ef)} = V_{i(ef)} \rightarrow I_{o(ef)} = \frac{V_{o(ef)}}{R_o}$$

$$V_{o(med)} = 2 \cdot \frac{V_{o(pk)}}{\pi} \rightarrow I_{o(med)} = \frac{V_{o(med)}}{R_o}$$

Retificador meia onda com filtro capacitivo



$$P_o = \frac{V_o^2}{R_o}[W]$$

$$V_{i(pk)} = \text{definido}$$

$$V_{c(\max)} = V_{o(\max)} = V_{i(pk)}$$

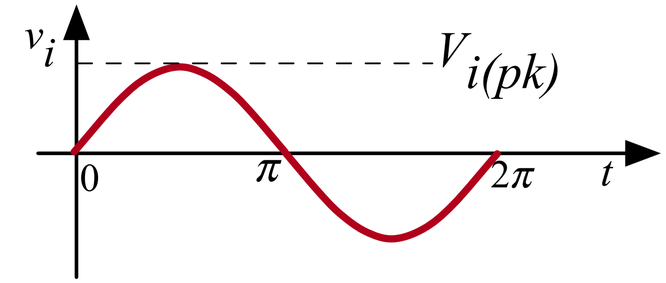
$$V_{c(\min)} = V_{o(\min)} = V_{i(pk)} - \Delta V_o$$

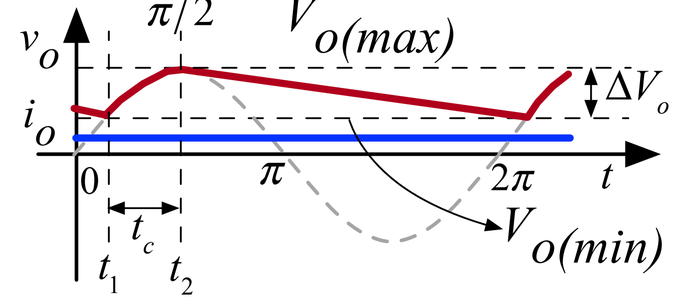
$$\Delta V_o = \Delta V_o\% \cdot V_{i(pk)}$$

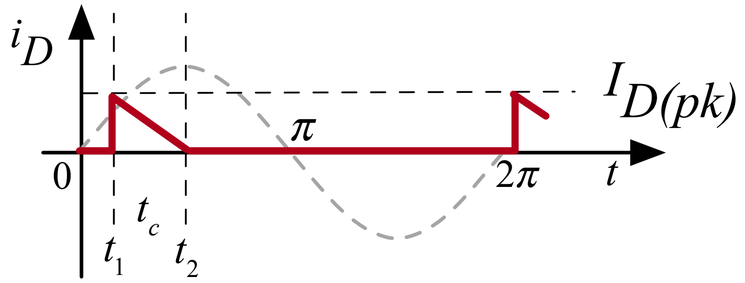
$$V_o = V_{o(med)} = \frac{V_{o(\max)} + V_{o(\min)}}{2}$$

$$C_o = \frac{2 \cdot P_o}{F_i \cdot \left[\left(V_{c(\max)}\right)^2 - \left(V_{c(\min)}\right)^2 \right]}[Farad]$$

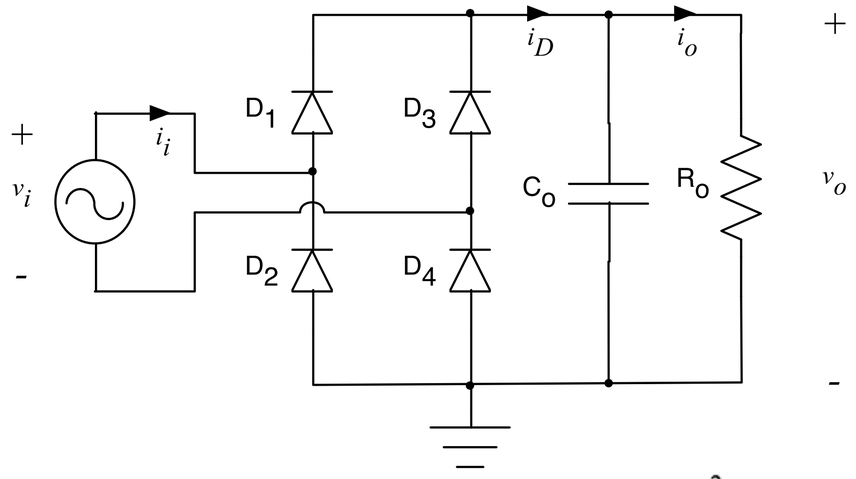
$$t_c = t_2 - t_1 = \frac{\cos^{-1}\left(\frac{V_{o(\min)}}{V_{o(\max)}}\right)}{2\pi \cdot F_i} \rightarrow I_{D(\max)} = \frac{2 \cdot C_o \cdot \Delta V_o}{t_c}$$







Retificador onda completa com filtro capacitivo



$$V_{i(pk)} = \text{definido}$$

$$V_{c(\max)} = V_{o(\max)} = V_{i(pk)}$$

$$V_{c(\min)} = V_{o(\min)} = V_{i(pk)} - \Delta V_o$$

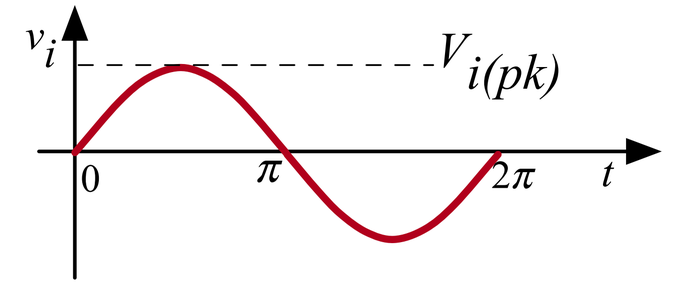
$$\Delta V_o = \Delta V_o\% \cdot V_{i(pk)}$$

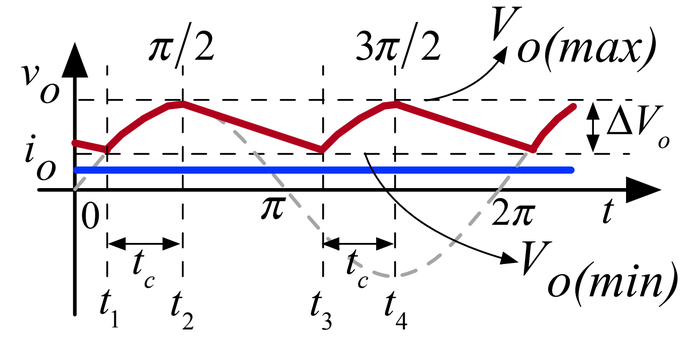
$$V_o = V_{o(med)} = \frac{V_{o(\max)} + V_{o(\min)}}{2}$$

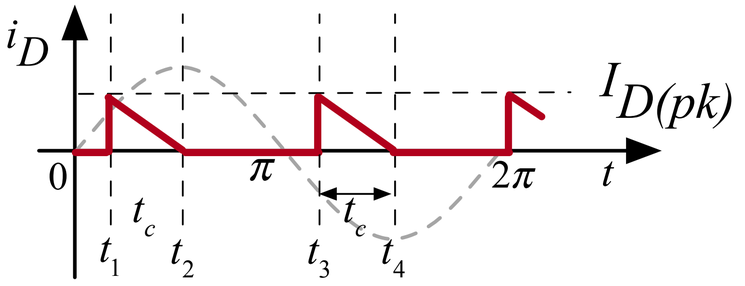
$$P_o = \frac{V_o^2}{R_o}[W]$$

$$C_o = \frac{P_o}{F_i \cdot \left[\left(V_{c(\max)}\right)^2 - \left(V_{c(\min)}\right)^2\right]}[Farad]$$

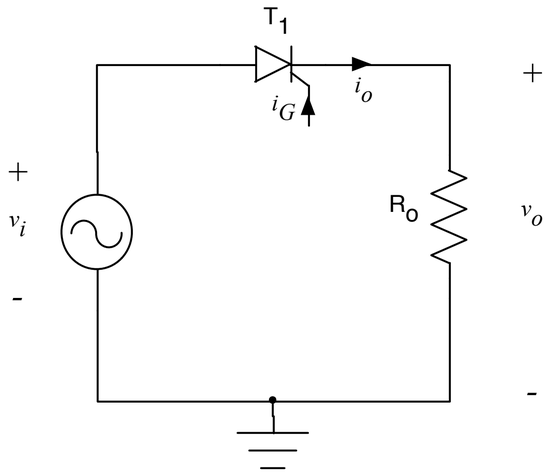
$$t_c = t_2 - t_1 = \frac{\cos^{-1}\left(\frac{V_{o(\min)}}{V_{o(\max)}}\right)}{2\pi \cdot F_i} \rightarrow I_{D(\max)} = \frac{2 \cdot C_o \cdot \Delta V_o}{t_c}$$







Retificador controlado de meia onda

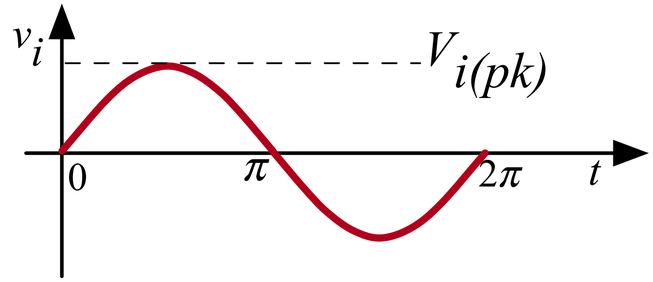


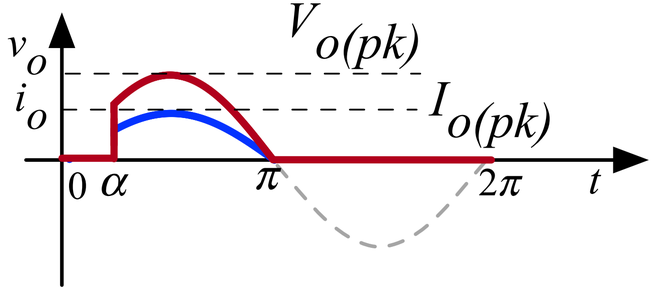
$$V_{i(pk)} = \text{definido}$$

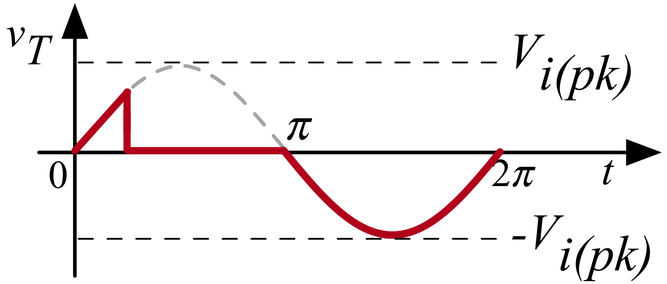
$$V_{o(pk)} = \begin{cases} V_{i(pk)} \rightarrow \alpha < 90^o \\ V_{i(pk)} \cdot sen(\alpha) \rightarrow 90^o \le \alpha \le 180^o \end{cases} \rightarrow I_{o(pk)} = \frac{V_{o(pk)}}{R_o}$$

$$V_{o(ef)} = \frac{V_{o(pk)}}{2} \cdot \sqrt{\frac{\pi - \alpha + \cos(\alpha) \cdot \text{sen}(\alpha)}{\pi}} \rightarrow I_{o(ef)} = \frac{V_{o(ef)}}{R_o}$$

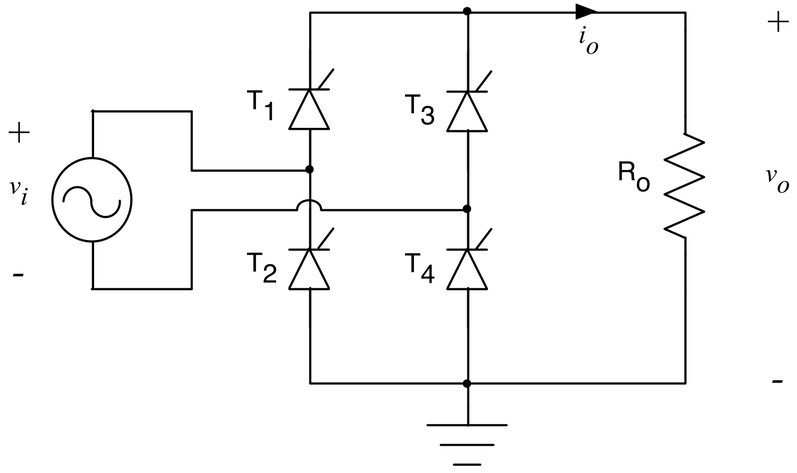
$$V_{o(med)} = \frac{V_{o(pk)}}{2\pi} \cdot (1 + \cos(\alpha)) \rightarrow I_{o(med)} = \frac{V_{o(med)}}{R_o}$$







Retificador controlado de meia onda

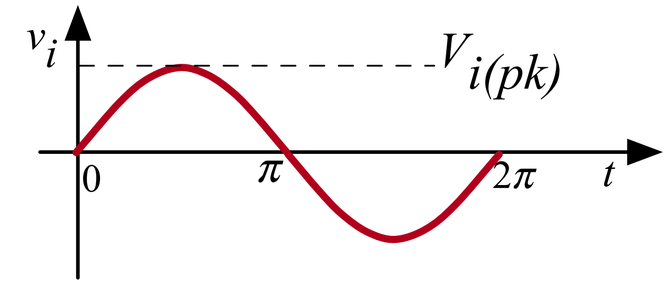


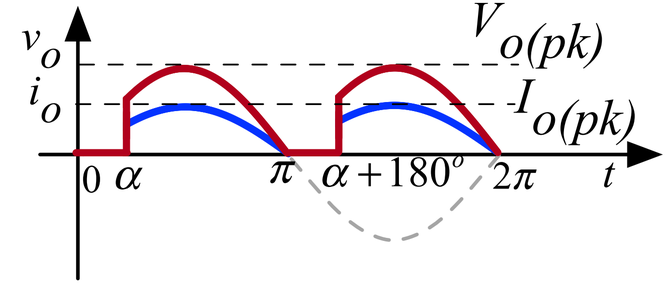
$$V_{i(pk)} = \text{definido}$$

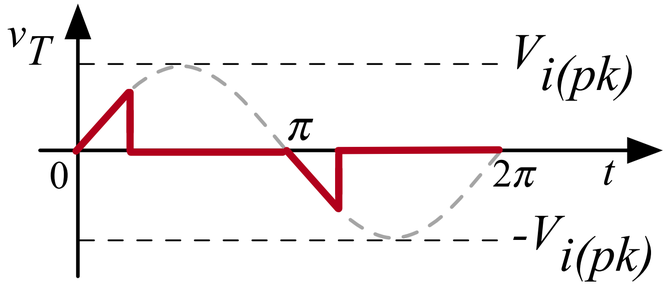
$$V_{o(pk)} = \begin{cases} V_{i(pk)} \cdot sen(\alpha) \rightarrow \alpha < 90^o \\ V_{i(pk)} \rightarrow 90^o \leq \alpha \leq 180^o \end{cases} \rightarrow I_{o(pk)} = \frac{V_{o(pk)}}{R_o}$$

$$V_{o(ef)} = V_{o(pk)} \cdot \sqrt{\frac{\pi - \alpha + \cos(\alpha) \cdot \text{sen}(\alpha)}{2\pi}} \rightarrow I_{o(ef)} = \frac{V_{o(ef)}}{R_o}$$

$$V_{o(med)} = \frac{V_{o(pk)}}{\pi} \cdot (1 + \cos(\beta)) \rightarrow I_{o(med)} = \frac{V_{o(med)}}{R_o}$$

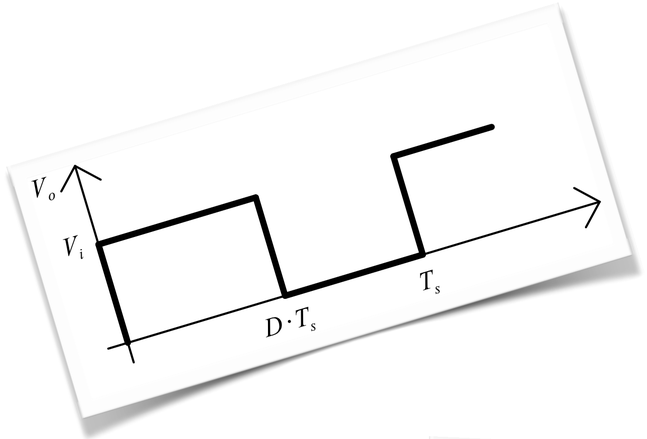


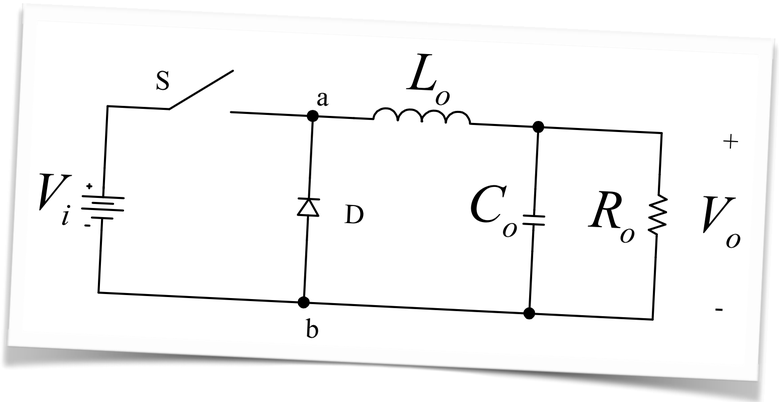




Próxima Aula

Conversores cc-cc





Obrigado!
Até a próxima aula...