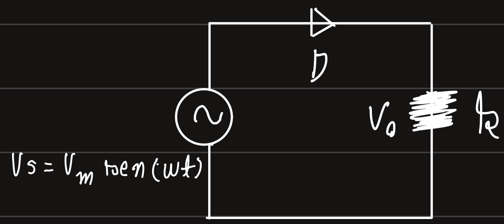
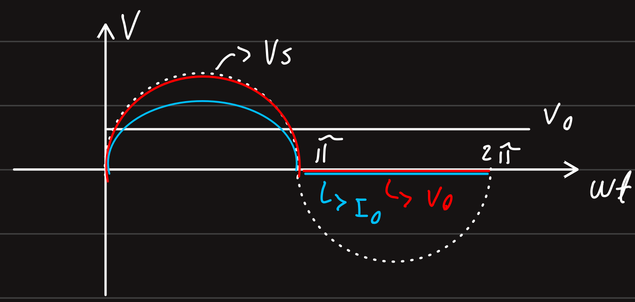
=> Retificadores não controlados de meia onda:

• Com carga resistiva:



-> Valor médio:

$$V_o = \frac{1}{2\pi}\int_0^{\pi} V_m \sin(\omega t)\, d(\omega t)$$



$$V_o = \frac{V_m}{2\pi} \cdot \left(-\cos(\omega t) \Big]_0^{\pi} \right)$$

$$V_o = \frac{V_m}{2\pi} \cdot (1+1) \Rightarrow V_o = \frac{V_m}{\pi}$$

-> Valor rms: $V_{o_{rms}} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} (V_m \cdot \text{sen}(\omega t))^2 \, d(\omega t)}$

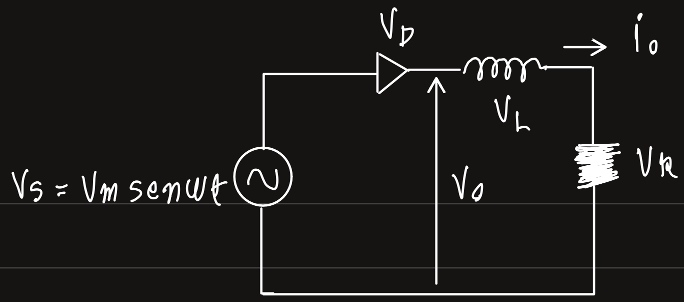
sen$(a+b)$ = sen$a$ cos$b$ + sen$b$ cos$a$
$\cos(a+b) = \cos a \cos b - \text{sen}\, a\, \text{sen}\, b \overset{b=a}{\Rightarrow} \cos 2a = \cos^2 a - \text{sen}^2 a$
$\text{sen}^2 a = \cos^2 a - \cos 2a = 1 - \text{sen}^2 a - \cos 2a$
$\text{sen}^2 a = \frac{1}{2}\left[1 - \cos 2a\right]$

$$V_{o_{rms}} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi}\left(\frac{1}{2} - \frac{1}{2}\cos(2\omega t)\right) d(\omega t)}$$

$$V_{o_{rms}} = \sqrt{\frac{V_m^2}{2\pi} \cdot \left\{ \left(\frac{1}{2}\,\omega t \Big]_0^{\pi}\right) - \frac{1}{2} \cdot \frac{\sin(2\omega t)}{2}\Big]_0^{\pi} \right\}}$$

$$V_{o_{rms}} = \sqrt{\frac{V_m^2}{2\pi} \cdot \left\{ \frac{\pi}{2} - \frac{1}{4}(0-0) \right\}} \Rightarrow V_{o_{rms}} = \frac{V_m}{2}$$

• Com carga RL



→ para o semiciclo positivo: $V_s = V_L + V_R$

$V_m \operatorname{sen} \omega t = L \frac{d i_0}{dt} + R i_0 \Rightarrow i_0' + \frac{R}{L} i_0 = \frac{V_m}{L} \operatorname{sen} \omega t$

$$\boxed{i_0(t) = i_{0_H} + i_{0_p}}$$

$\Rightarrow i_{0_H}$: $\frac{d i_0}{dt} + \frac{R}{L} i_0 = 0 \Rightarrow \frac{d i_0}{i_0} = -\frac{R}{L} dt \Rightarrow \ln i_0 = -\frac{R}{L} t + C$

$i_{0_H} = e^{-\frac{R}{L} t} \cdot C.$

$\Rightarrow i_{0_p}$: $i_0' + \frac{R}{L} i_0 = \frac{V_m}{L} \operatorname{sen} \omega t = \frac{V_m}{L} \cos(\omega t - 90°)$

$j\omega I_0 + \frac{R}{L} I_0 = \frac{V_m}{L} \angle -90° \Rightarrow I_0 = \frac{V_m/L \angle -90°}{j\omega + R/L} = \frac{V_m \angle -90°}{j\omega L + R}$

$I_0 = \frac{V_m \angle -90°}{|Z| \angle \emptyset}$; $|Z| = \sqrt{R^2 + (\omega L)^2}$ e $\emptyset = \tan^{-1}(\omega L / R)$

$I_0 = \frac{V_m}{|Z|} \angle -90° - \emptyset \Rightarrow i_0(t) = \frac{V_m}{|Z|} \cos(\omega t - \emptyset - 90°)$

$i_{0_p}(t) = \frac{V_m}{|Z|} \operatorname{sen}(\omega t - \emptyset)$

Logo, $i_0(t) = C e^{-\frac{R}{L} t} + \frac{V_m}{|Z|} \operatorname{sen}(\omega t - \emptyset)$; Sabe-se que em $i_0(t=0) = 0$

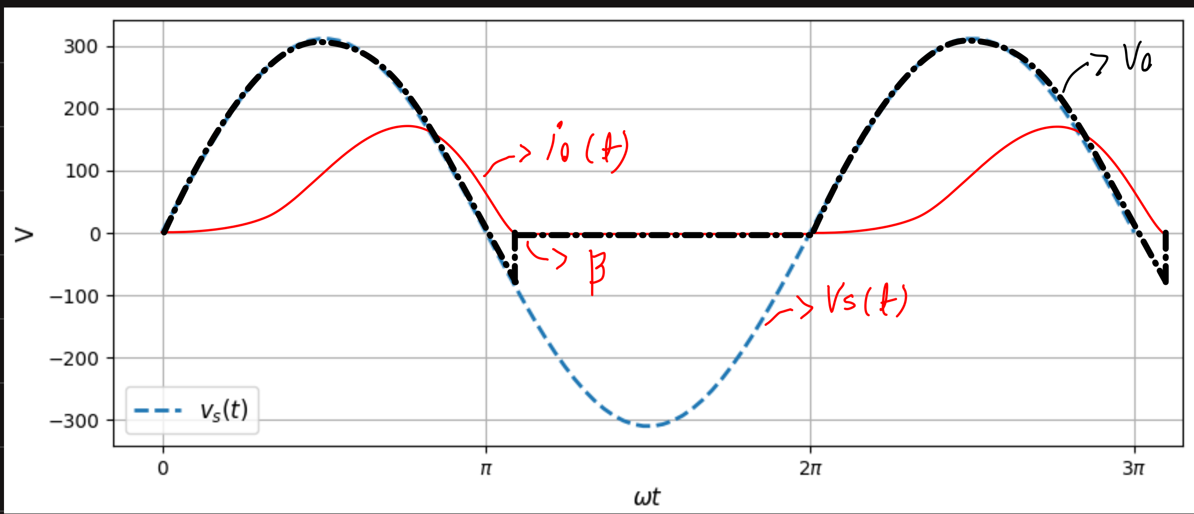
Assim, $0 = C + \frac{V_m}{|Z|} \operatorname{sen}(-\emptyset) \Rightarrow C = \frac{V_m}{|Z|} \operatorname{sen}(\emptyset)$

Com isso, $i_0(t) = \frac{V_m}{|Z|} \operatorname{sen} \phi \, e^{-\frac{R}{L}t} + \frac{V_m}{|Z|} \operatorname{sen}(\omega t - \phi)$

$$i_0(t) = \frac{V_m}{|Z|} \left[\operatorname{sen}(\omega t - \phi) + \operatorname{sen} \phi \, e^{-R/L \, t} \right]$$

$$i_0(\omega t) = \frac{V_m}{|Z|} \left[\operatorname{sen}(\omega t - \phi) + \operatorname{sen} \phi \, e^{-\frac{R}{\omega L} \cdot \omega t} \right]; \quad 0 \leq \omega t \leq \beta$$

$\beta \rightarrow$ Ângulo de extinção



Idealmente, o diodo para de conduzir quando $i_0(t) = 0$.

Nesse caso:

$$i_0(\beta) = \frac{V_m}{|Z|} \left(\operatorname{sen}(\beta - \phi) + \operatorname{sen}(\phi) e^{-\frac{R}{L\omega} \beta} \right) = 0$$

$$\operatorname{sen}(\beta - \phi) + \operatorname{sen}(\phi) e^{-\frac{R}{L\omega} \beta} = 0 \quad \text{(Equação transcendental)}$$

$\longrightarrow$ Valor médio: $V_0 = \frac{1}{2\pi} \int_0^{2\pi} v_0(\omega t) \, d(\omega t)$

Analisando o gráfico de V_0:

$$V_o = \frac{1}{2\pi}\int_0^{\beta} V_m \operatorname{sen}(\omega t)\, d(\omega t) = \frac{V_m}{2\pi}\left(-\cos(\omega t)\Big]_0^{\beta}\right)$$

$$V_o = \frac{V_m}{2\pi}\left(1-\cos(\beta)\right)$$

$\longrightarrow$ Valor rms: $V_{o_{rms}} = \sqrt{\dfrac{1}{2\pi}\displaystyle\int_0^{2\pi} V_o^2(\omega t)\, d(\omega t)}$

$$V_{o_{rms}} = \sqrt{\frac{1}{2\pi}\int_0^{\beta} (V_m \operatorname{sen}(\omega t))^2\, d(\omega t)}$$

$$V_{o_{rms}} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{\beta}\left(\frac{1}{2}-\frac{1}{2}\cos(2\omega t)\right) d(\omega t)}$$

$$V_{o_{rms}} = \sqrt{\frac{V_m^2}{2\pi}\left\{\frac{1}{2}\,\omega t\Big]_0^{\beta} - \frac{1}{2}\cdot\frac{\operatorname{sen}(2\omega t)}{2}\Big]_0^{\beta}\right\}}$$

$$V_{o_{rms}} = \sqrt{\frac{V_m^2}{2\pi}\left\{\frac{\beta}{2} - \frac{1}{4}\operatorname{sen}(2\beta)\right\}}$$

$$V_{o_{rms}} = V_m\sqrt{\frac{1}{2\pi}\cdot\frac{2\beta-\operatorname{sen}(2\beta)}{4}}$$

$$V_{o_{rms}} = V_m\sqrt{\frac{2\beta-\operatorname{sen}(2\beta)}{8\pi}}$$

Considerando o circuito do retificador mostrado na Fig. 6.2(a), onde a fonte v_s possui amplitude $V_m = 220\sqrt{2}$ V e frequência 60 Hz, e a carga RL é formado por $R = 45\ \Omega$ e $L = 100$ mH. Determine: (a) o ângulo de extinção β, (b) a tensão média V_o sobre a carga, (c) a corrente média na carga, (d) a corrente eficaz na carga e (e) a potência dissipada pelo resistor R.

a) $\phi = \tan^{-1}(2\pi 60 \cdot 0{,}1/45) \cong 22{,}73° = 0{,}397$ rad

$$\operatorname{sin}(\beta - 0{,}4) + \operatorname{sen}(0{,}4)\, e^{-1{,}19\beta} = 0$$

$\beta \cong 220°$

b) $V_o = \frac{V_m}{2\pi}(1 - \cos(\beta)) = 87{,}45$ V

c) $i_o(\omega t) = \frac{V_m}{|Z|}\left(\operatorname{sen}(\omega t - \phi) + \operatorname{sen}\phi\, e^{-\frac{R}{L\omega}\cdot \omega t}\right)$; $\phi = 0{,}4$ rad, $|Z| = 45\ \Omega$

$$i_o(\omega t) = 6{,}91 \operatorname{sin}(\omega t - 0{,}4) + 2{,}69\, e^{-1{,}19\omega t}$$

$$I_o = \frac{1}{2\pi}\int_0^{\beta}\left(6{,}91 \operatorname{sin}(\omega t - 0{,}4) + 2{,}69\, e^{-1{,}19\omega t}\right) d(\omega t)$$

$$I_o = \frac{1}{2\pi}\cdot\left\{ -6{,}91\cos(\omega t - 0{,}4)\Big]_0^{\beta} + 2{,}69\cdot \frac{e^{-1{,}19\omega t}}{-1{,}19}\Big]_0^{\beta}\right\};\ \beta = 3{,}84$$

$I_o = 2{,}298$ A

d) $$I_{o_{rms}} = \sqrt{\frac{1}{2\pi}\int_0^{\beta}\left(6{,}91 \operatorname{sin}(\omega t - 0{,}4) + 2{,}69\, e^{-1{,}19\omega t}\right)^2 d(\omega t)}$$

$$I_{o_{rms}} = \left\{\frac{1}{2\pi}\int_0^{\beta}\Big(\underbrace{47{,}75 \operatorname{sin}^2(\omega t - 0{,}4)}_{(a)} + \underbrace{37{,}17 \operatorname{sin}(\omega t - 0{,}4)\, e^{-1{,}19\omega t}}_{(b)} + \underbrace{7{,}24\, e^{-2{,}38\omega t}}_{(c)}\Big) d(\omega t)\right\}^{1/2}$$

Resolvendo cada integral:

(a) : $a = \int_0^{\beta} 47{,}75 \sin^2(\omega t - 0{,}4)\, d(\omega t)$; $\omega t - 0{,}4 = x$

$\frac{dx}{d\omega t} = 1$

$$a = \int_{-0{,}4}^{\beta - 0{,}4} 47{,}75 \sin^2(x)\, dx = 47{,}75 \int_{-0{,}4}^{\beta-0{,}4} \left(\frac{1}{2} - \frac{1}{2}\cos(2x)\right) dx$$

$$a = 47{,}75\left(\frac{1}{2} \cdot [\beta - 0{,}4 + 0{,}4] - \frac{1}{4}[\sin(2\beta - 0{,}8) - \sin(-0{,}8)]\right)$$ $\beta = 3{,}81$

$a = 76{,}29$

b) : $b = \int_0^{\beta} 37{,}17 \sin(\omega t - 0{,}4)\, e^{-1{,}19\omega t}\, d(\omega t)$; $\int u\,dv = uv - \int v\,du$

LIATE

$\xleftarrow{u}$

tomando, $u = \sin(\omega t - 0{,}4)$ $\quad dv = e^{-1{,}19\omega t}\, d(\omega t)$

$\frac{du}{d\omega t} = \cos(\omega t - 0{,}4)$ $\quad v = \frac{e^{-1{,}19\omega t}}{-1{,}19}$

$$b = 37{,}17 \int_0^{\beta} \sin(\omega t - 0{,}4)\, e^{-1{,}19\omega t}\, d(\omega t) =$$

$$= 37{,}17 \left\{ \left.\frac{\sin(\omega t - 0{,}4) \cdot e^{-1{,}19\omega t}}{-1{,}19}\right]_0^{\beta} - \int_0^{\beta} \frac{e^{-1{,}19\omega t}}{-1{,}19} \cos(\omega t - 0{,}4)\, d(\omega t) \right\}$$

$$= \frac{37{,}17}{-1{,}19}\left\{ \sin(\beta - 0{,}4)\, e^{-1{,}19\beta} + \sin(0{,}4) - \underbrace{\int_0^{\beta} e^{-1{,}19\omega t} \cdot \cos(\omega t - 0{,}4)\, d(\omega t)}_{X} \right\}$$

X : $u = \cos(\omega t - 0{,}4)$ $\quad dv = e^{-1{,}19\omega t}\, d(\omega t)$

$\frac{du}{d\omega t} = -\sin(\omega t - 0{,}4)$ $\quad v = \frac{e^{-1{,}19\omega t}}{-1{,}19}$

$$= \frac{37{,}17}{-1{,}19}\left\{ \sin(\beta-0{,}4)e^{-1{,}19\beta} + \sin(0{,}4) - \left(\left[\frac{\cos(\omega t-0{,}4)\cdot e^{-1{,}19\omega t}}{-1{,}19}\right]_0^{\beta} - \int_0^{\beta} \frac{e^{-1{,}19\omega t}}{-1{,}19} \cdot -\sin(\omega t-0{,}4)\, d\omega t \right) \right\}$$

$$= \frac{37{,}17}{-1{,}19}\left\{ \sin(\beta-0{,}4)e^{-1{,}19\beta} + \sin(0{,}4) - \left(-\frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19} + \frac{\cos(0{,}4)}{1{,}19} - \frac{1}{1{,}19}\int_0^{\beta} e^{-1{,}19\omega t} \cdot \sin(\omega t-0{,}4)\, d\omega t \right) \right\}$$

$$= \frac{37{,}17}{-1{,}19}\left\{ \sin(\beta-0{,}4)e^{-1{,}19\beta} + \sin(0{,}4) + \frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19} - \frac{\cos(0{,}4)}{1{,}19} + \frac{1}{1{,}19}\int_0^{\beta} e^{-1{,}19\omega t} \cdot \sin(\omega t-0{,}4)\, d\omega t \right) \right\}$$

$$= \frac{37{,}17}{-1{,}19}\left\{ \sin(\beta-0{,}4)e^{-1{,}19\beta} + \sin(0{,}4) + \frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19} - \frac{\cos(0{,}4)}{1{,}19} \right\}$$

$$- \frac{37{,}17}{1{,}19^2} \cdot \int_0^{\beta} e^{-1{,}19\omega t} \sin(\omega t)\, d(\omega t)$$

Assim:

$$b = 37{,}17 \int_0^{\beta} \sin(\omega t - 0{,}4)\, e^{-1{,}19\omega t}\, d(\omega t) =$$

$$\frac{37{,}17}{-1{,}19}\left\{ \sin(\beta-0{,}4)e^{-1{,}19\beta} + \sin(0{,}4) + \frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19} - \frac{\cos(0{,}4)}{1{,}19} \right\}$$

$$- \frac{37{,}17}{1{,}19^2} \cdot \int_0^{\beta} e^{-1{,}19\omega t} \sin(\omega t)\, d(\omega t)$$

$$37{,}17\int_0^{\beta} \sin(\omega t-0{,}4)\,e^{-1{,}19\omega t}\,d(\omega t)+\frac{37{,}17}{1{,}19^2}\cdot\int_0^{\beta} e^{-1{,}19\omega t}\sin(\omega t)\,d(\omega t)$$

$$=\frac{37{,}17}{-1{,}19}\left\{\sin(\beta-0{,}4)e^{-1{,}19\beta}+\sin(0{,}4)+\frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19}-\frac{\cos(0{,}4)}{1{,}19}\right\}$$

$$63{,}41\int_0^{\beta}\sin(\omega t-0{,}4)\,e^{-1{,}19\omega t}\,d(\omega t)=$$

$$\frac{37{,}17}{-1{,}19}\left\{\sin(\beta-0{,}4)e^{-1{,}19\beta}+\sin(0{,}4)+\frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19}-\frac{\cos(0{,}4)}{1{,}19}\right\}$$

$$37{,}17\cdot 1{,}706\int_0^{\beta}\sin(\omega t-0{,}4)\,e^{-1{,}19\omega t}\,d(\omega t)=$$

$$\frac{37{,}17}{-1{,}19}\left\{\sin(\beta-0{,}4)e^{-1{,}19\beta}+\sin(0{,}4)+\frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19}-\frac{\cos(0{,}4)}{1{,}19}\right\}$$

$$b=37{,}17\int_0^{\beta}\sin(\omega t-0{,}4)\,e^{-1{,}19\omega t}\,d(\omega t)=$$

$$\frac{37{,}17}{-1{,}19\cdot 1{,}7}\left\{\sin(\beta-0{,}4)e^{-1{,}19\beta}+\sin(0{,}4)+\frac{\cos(\beta-0{,}4)\cdot e^{-1{,}19\beta}}{1{,}19}-\frac{\cos(0{,}4)}{1{,}19}\right\}$$

$\Rightarrow$ $b = 7{,}25$

c): $$c=\int_0^{\beta} 7{,}24\,e^{-2{,}38\omega t}\,d(\omega t)=7{,}24\cdot\left.\frac{e^{-2{,}38\omega t}}{-2{,}38}\right]_0^{\beta}$$

$$c=-3{,}04\cdot\left(e^{-2{,}38\beta}-e^{0}\right);\ \beta=3{,}81$$

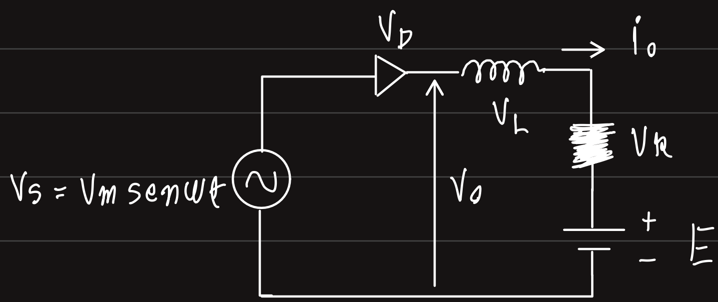
$c = 3{,}04$

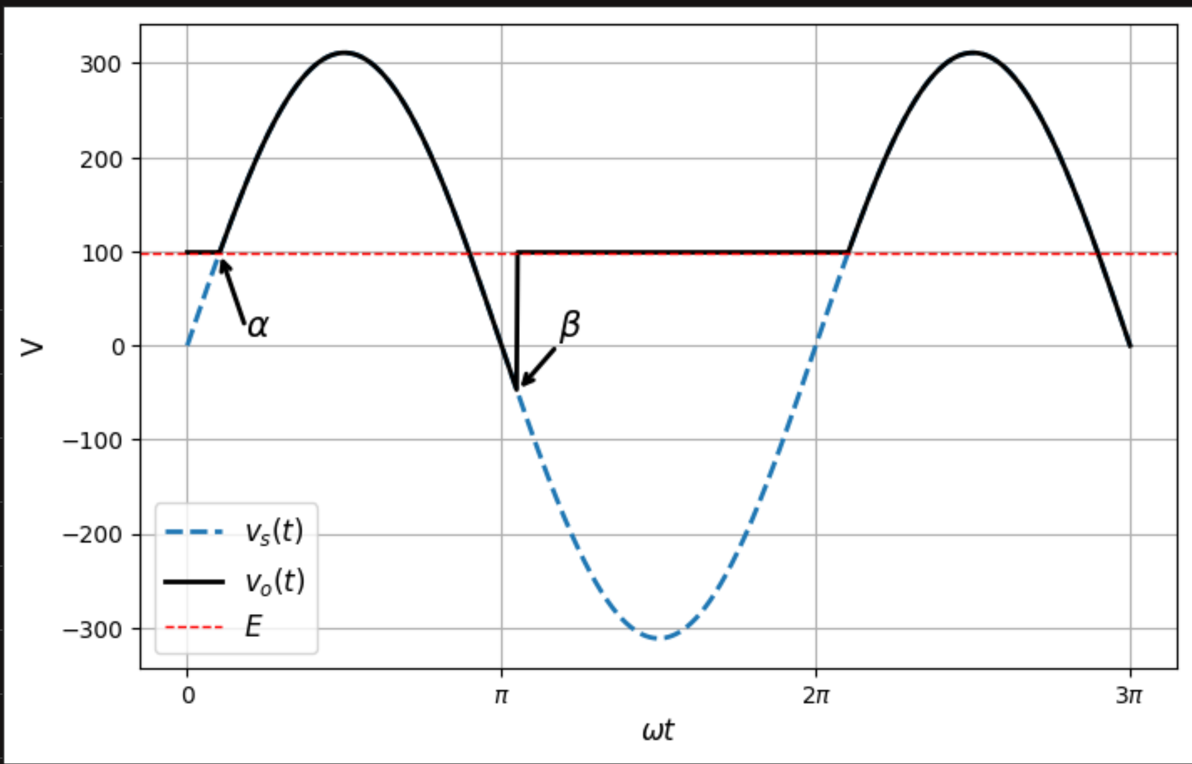
- Assim, $$I_{o_{rms}}=\sqrt{\frac{1}{2\pi}(a+b+c)}=\sqrt{\frac{1}{2\pi}(76{,}29+7{,}25+3{,}04)}$$

$$\boxed{I_{o_{rm}}=3{,}71\ A}$$

d) $P = R I_{o_{rms}}^2 \Rightarrow \boxed{P = 619{,}38 \text{ W}}$

• Com carga RLE





• O diodo passa a conduzir quando $v_s \geq E$.

Com isso, $V_s = V_m \operatorname{sen}(\omega t) = E$; $\omega t = \alpha$

$V_m \operatorname{sen}(\alpha) = E$

$$\alpha = \operatorname{arcsen}\left(\frac{E}{V_m}\right)$$

• Com o diodo conduzindo, tem-se as seguintes relações de tensão:

$$V_m \operatorname{sen}(\omega t) = L\frac{di(t)}{dt} + Ri(t) + E$$

$$L\frac{di(t)}{dt} + R\,i(t) = V_m \operatorname{sen}(\omega t) - E$$

A solução é dada por: $i_H + i_p = i(t)$

Solução homogênea

$$L\frac{di(t)}{dt} + R\,i(t) = 0$$

$$\frac{di(t)}{dt} = -\frac{R}{L}\,i(t)$$

$$\int \frac{di}{i} = \int -\frac{R}{L}\,dt$$

$$\ln(i) = -\frac{R}{L}\,t + C$$

$$i_H = C_1 \cdot e^{-\frac{R}{L}t}$$

Solução particular

$$L\frac{di(t)}{dt} + R\,i(t) = V_m \operatorname{sen}(\omega t) - E$$

$$i_{p1}: L\frac{di(t)}{dt} + R\,i(t) = V_m \operatorname{sen}(\omega t)$$

$$i_{p2}: L\frac{di(t)}{dt} + R\,i(t) = -E$$

$$L\,i_1' + R\,i_1 = V_m \operatorname{sen}(\omega t) = V_m \cdot \cos(\omega t - 90^\circ)$$

$$\Leftrightarrow L\,j\omega\,I_1 + R\,I_1 = V_m \angle -90^\circ$$

$$I_1 = \frac{V_m \angle -90^\circ}{R + j\omega L} = \frac{V_m \angle -90^\circ}{|Z| \angle \varnothing}$$

o qual: $|Z| = \sqrt{R^2 + (\omega L)^2}$

$$\varnothing = \arctan\left(\frac{\omega L}{R}\right)$$

$$I_1 = \frac{V_m}{|Z|} \angle -\varnothing - 90^\circ \Rightarrow i_{p1} = \frac{V_m}{|Z|} \cos(\omega t - \varnothing - 90^\circ)$$

$$i_{p1} = \frac{V_m}{|Z|} \operatorname{sen}(\omega t - \varnothing)$$

$$\cancel{L\frac{di(t)}{dt}}^{\,0} + R\,i(t) = -E \Rightarrow i_{p2} = \frac{-E}{R}$$

Assim,

$$i_p = \frac{V_m}{|Z|} \operatorname{sen}(\omega t - \varnothing) - \frac{E}{R}$$

• portanto,

$$i(t) = Ce^{-\frac{R}{L}t} + \frac{V_m}{|Z|}\,\text{sen}(\omega t - \phi) - \frac{E}{R}$$

assumindo $i(\alpha) = 0$

$$Ce^{-\frac{R}{L\omega}\alpha} + \frac{V_m}{|Z|}\,\text{sen}(\alpha - \phi) - \frac{E}{R} = 0$$

$$C = \left[\frac{E}{R} - \frac{V_m}{|Z|}\,\text{sen}(\alpha - \phi)\right] e^{\frac{R}{L\omega}\alpha}$$

$$i(t) = \left[\frac{E}{R} - \frac{V_m}{|Z|}\,\text{sen}(\alpha - \phi)\right] e^{\frac{R}{L\omega}\alpha} \cdot e^{-\frac{R}{L}t} + \frac{V_m}{|Z|}\,\text{sen}(\omega t - \phi) - \frac{E}{R}$$

Logo, $\boxed{i(\omega t) = \left[\frac{E}{R} - \frac{V_m}{|Z|}\,\text{sen}(\alpha - \phi)\right] e^{\frac{R}{L\omega}(\alpha - \omega t)} + \frac{V_m}{|Z|}\,\text{sen}(\omega t - \phi) - \frac{E}{R}}$

• O diodo para de conduzir quando $i(\beta) = 0$. $\Rightarrow$ Esboçar as curvas da tensões de saída

• Tensão média: $V_0 = \frac{1}{T}\int^{\langle T \rangle} v_0(\omega t)\, d(\omega t)$

$$V_0 = \frac{1}{2\pi}\left[\int_\alpha^\beta v_s(\omega t)\, d(\omega t) + \int_\beta^{2\pi+\alpha} E_d\, d(\omega t)\right] = \frac{1}{2\pi}\left[V_m \cdot (\cos\alpha - \cos\beta) + E_d(2\pi + \alpha - \beta)\right]$$

$$\boxed{V_0 = \frac{1}{2\pi}\left[V_m(\cos\alpha - \cos\beta) + E_d(\alpha - \beta + 2\pi)\right]}$$

- Potência média fornecida à carga:

$$P_o = \frac{1}{2\pi}\int_0^{2\pi} v_o(\omega t)\, i_o(\omega t)\, d(\omega t)$$

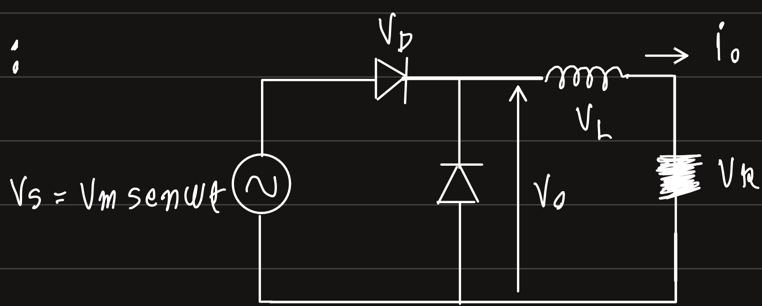
$$P_o = \frac{1}{2\pi}\left[\int_0^{2\pi} \left(v_R(\omega t) + v_L(\omega t) + E_d\right) i_o(\omega t)\, d(\omega t)\right]$$

$$P_o = \frac{R}{2\pi}\int_0^{2\pi} i_o^2(\omega t)\, d(\omega t) + \cancelto{0}{\frac{L}{2\pi}\int_0^{2\pi} \frac{di(\omega t)}{d(\omega t)} \cdot i(\omega t)\, d(\omega t)} + \frac{E_d}{2\pi}\int_0^{2\pi} i_o(\omega t)\, d(\omega t)$$

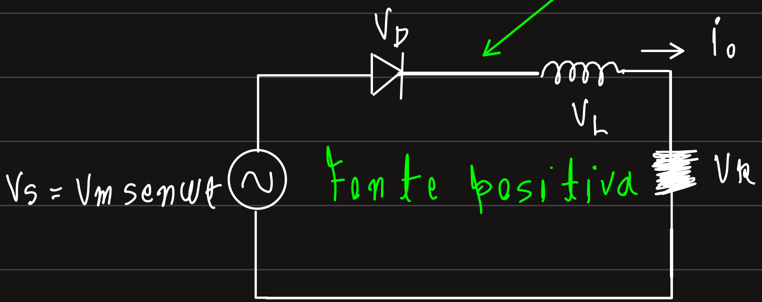
$$\boxed{P_o = R \cdot I_{o_{rms}}^2 + E_d \cdot I_o}$$

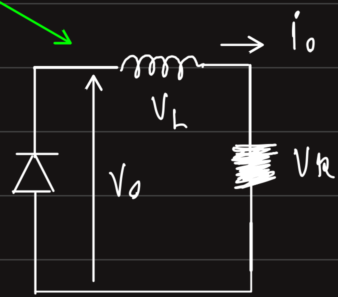
↳ Potência ativa média fornecida pela fonte CA.

Com diodo de roda livre:



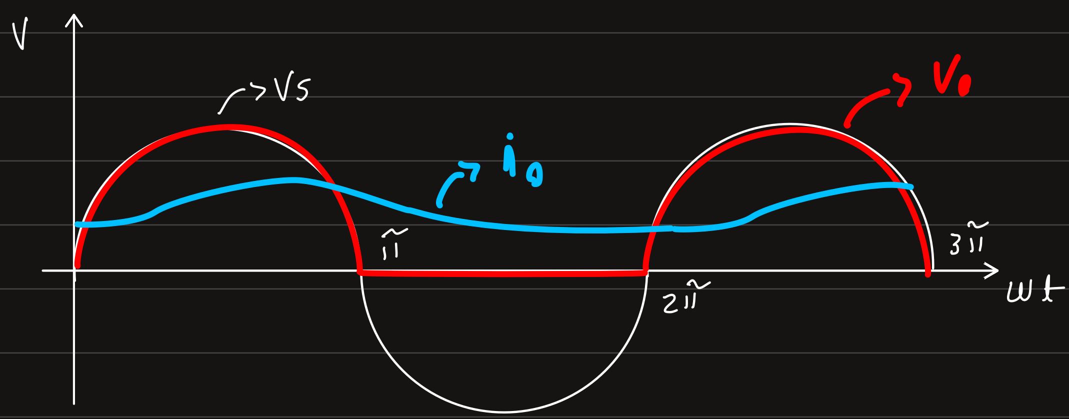
Dois casos





Fonte negativa

- **Formas de onda:**



Obs.: A curva de io é considerando o modo de condução contínua, ou seja, L muito grande.

- **Análise da corrente:**

$0 < \omega t < \pi$: $i_o(\omega t) = \frac{V_m}{|Z|}\left[\sin(\omega t - \phi) + \sin\phi\, e^{-\frac{R}{\omega L}\cdot \omega t}\right]$

$\pi < \omega t < 2\pi$: $v_L + v_R = 0 \Rightarrow \frac{di}{dt} + \frac{R}{L} i = 0 \Rightarrow \frac{di}{i} = -\frac{R}{L}\, dt$

$$i(t) = c\, e^{-\frac{R}{L}t} \Rightarrow i(\omega t) = c\, e^{-\frac{R}{L\omega}\cdot \omega t}$$

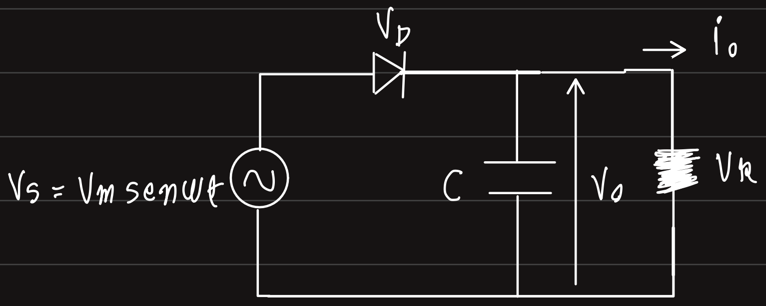
PVI: $i(\pi) = i_o(\pi) \Rightarrow$

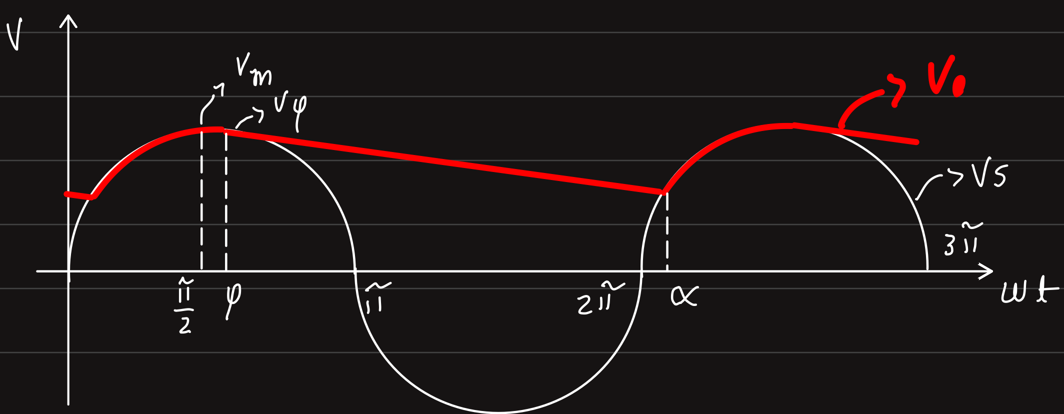
$$c\, e^{-\frac{R}{L\omega}\pi} = \frac{V_m}{|Z|}\left[\sin(\pi - \phi) + \sin\phi\, e^{-\frac{R}{\omega L}\cdot \pi}\right]$$

$$c = \frac{V_m}{|Z|}\left[\sin(\pi - \phi)\, e^{-\frac{R}{L\omega}\pi} + \sin\phi\right]$$

Assim, no semiciclo negativo a corrente decai exponencialmente.

• Com filtro capacitivo na saída:



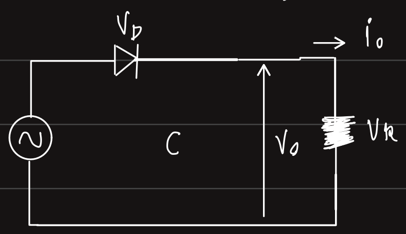


• $\varphi \cong \pi/2$; $V\varphi \cong V_m$ pois $RC >> 1/f$.

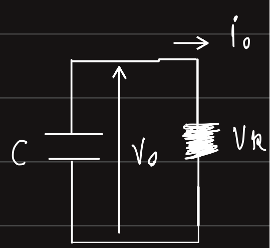
• Tensão sobre a carga:

$(2\pi + \alpha) < \omega t < (2\pi + \varphi)$

$V_o = V_m sen(\omega t)$



$\varphi < \omega t < 2\pi + \alpha$



$V_c + I_c R = 0$

$RC \frac{dV_c}{dt} + V_c = 0$

$\frac{dV_c}{dt} = -\frac{1}{RC} \cdot V_c \Rightarrow \frac{dV_c}{V_c} = -\frac{1}{RC} \cdot dt$

$\ln V_c = -1/RC\, t + k_c \Rightarrow V_c = k_c e^{-\frac{1}{RC} \cdot t}$

$V_c(\omega t) = k_c e^{-\frac{1}{RC\omega} \cdot \omega t}$

• PVI: $V_c(\varphi) = V_m sen(\varphi) = V(\varphi)$

$V_c(\varphi) = k_c e^{-\frac{1}{RC\omega} \cdot \varphi} = V(\varphi) \Rightarrow k_c = V(\varphi) e^{\frac{\varphi}{RC\omega}}$

$\therefore \quad V_c(\omega t) = V(\varphi) e^{\frac{1}{RC\omega}(\varphi - \omega t)}$

$$\boxed{V_o(\omega t) = \begin{cases} V_m \,\text{sen}(\omega t) & (2\pi+\alpha) < \omega t < (2\pi+\varphi) \\ V(\varphi)\, e^{\frac{1}{kc\omega}(\varphi-\omega t)} & \varphi < \omega t < 2\pi+\alpha \end{cases}}$$

- $V_{o\,min}$: (Aproximando $\alpha \cong \pi/2$) Logo, $V(2\pi+\alpha) = V(\varphi)\, e^{\frac{1}{kc\omega}(\varphi - 2\pi - \alpha)} = V_{o\,min}$

$$V_{o\,min} = V(\varphi)\, e^{\frac{1}{kc\omega}(\pi/2 - 2\pi - \pi/2)} = V(\varphi)\, e^{\frac{-2\pi}{kc\omega}}$$

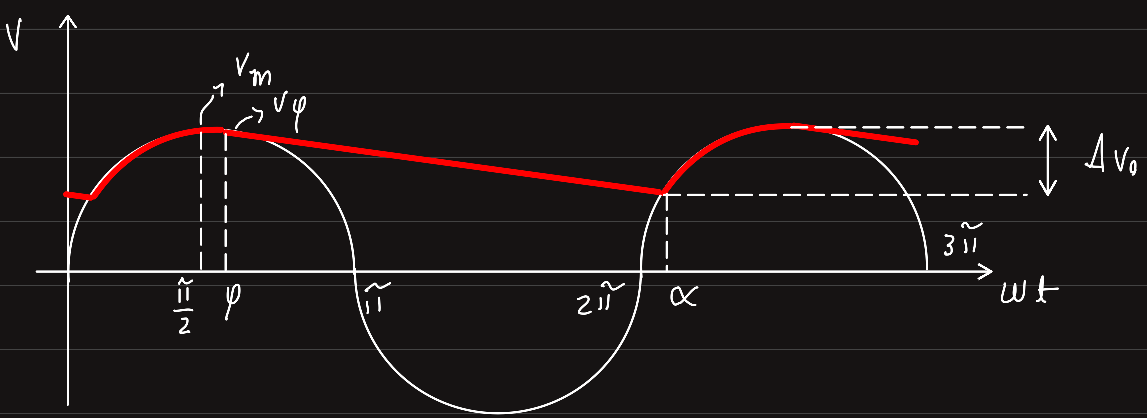
Utilizando a aproximação pela série de Taylor para os dois primeiros termos temos:

$$e^{\frac{-2\pi}{kc\omega}} = 1 - \frac{2\pi}{\omega kc}$$

Assim, $V_{o\,min} = V(\varphi)\left(1 - \frac{2\pi}{\omega kc}\right) = V_m \,\text{sen}(\pi/2)\left(1 - \frac{2\pi}{\omega kc}\right)$

$$\boxed{V_{o\,min} = V_m\left(1 - \frac{2\pi}{\omega kc}\right)}$$

- Oscilação da tensão de saída: $\Delta V_o = V_{o\,máx} - V_{o\,min}$



$$\Delta V_o = V_m \,\text{sen}(\pi/2) - V_m\left(1 - \frac{2\pi}{\omega kc}\right) = \frac{V_m 2\pi}{\omega kc} = \frac{V_m}{f kc}$$

$\therefore$

$$\boxed{\Delta V_o = \frac{V_m}{f kc}}$$

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