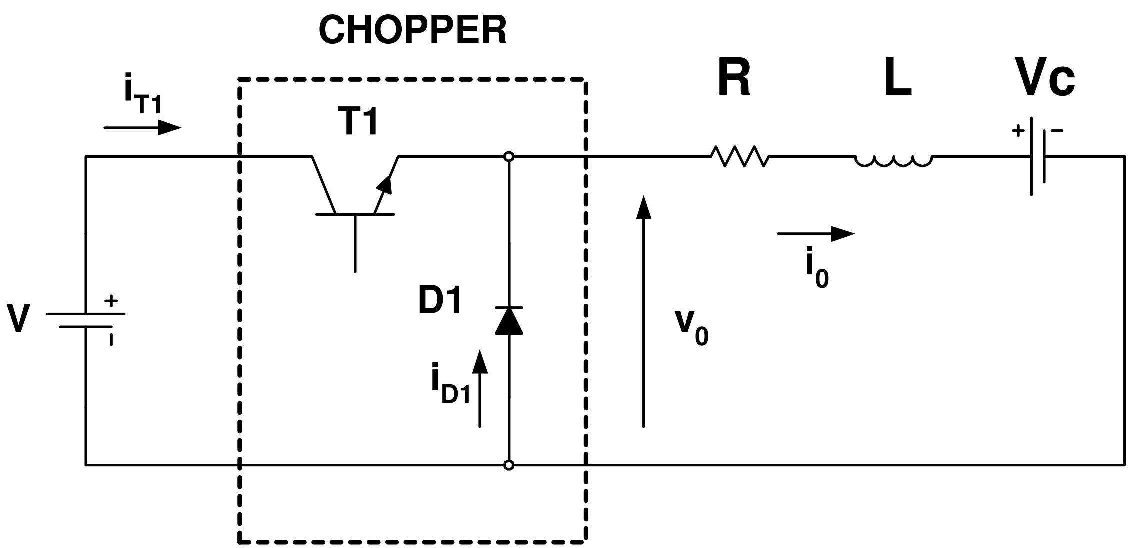
CONVERSORES CC/CC
(CHOPPERS)

Prof. Azauri Albano de Oliveira Júnior

CHOPPER DE UM QUADRANTE
(chopper não regenerativo, chopper tipo A ou regulador buck)

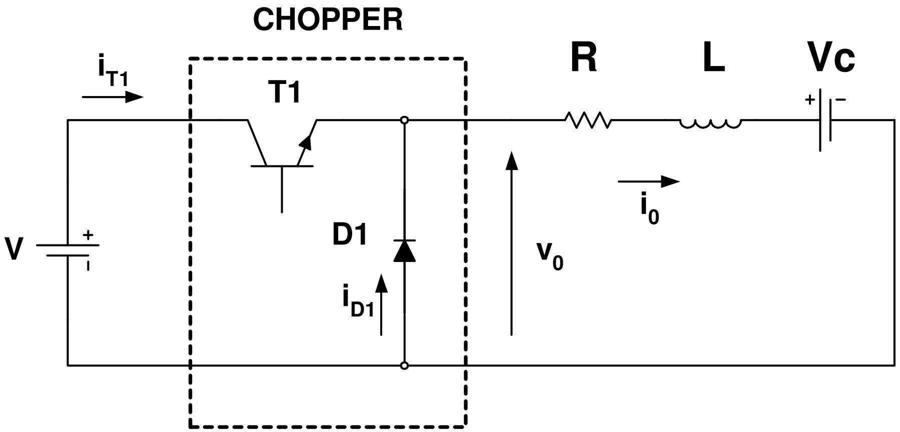


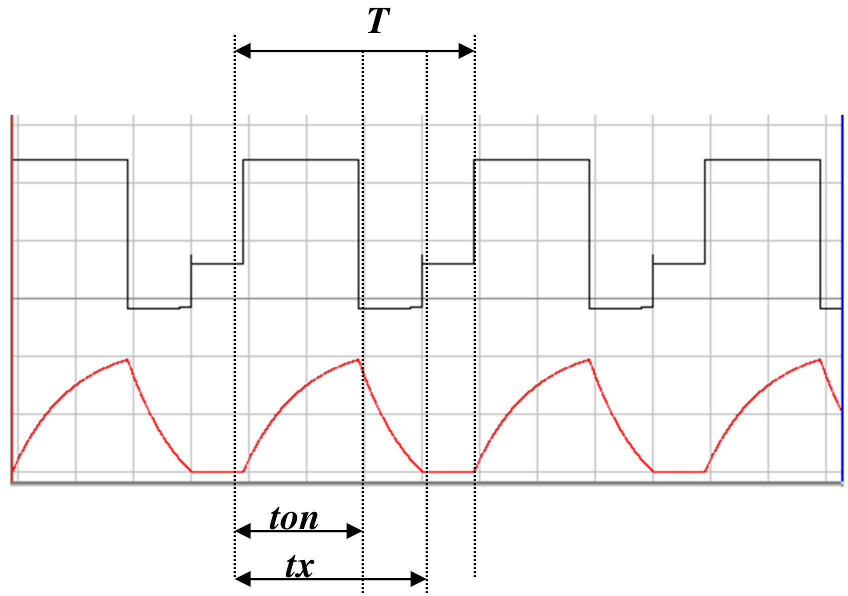
$$V = v_{T1} + v_0$$

$$i_0 = i_{T1} + i_{D1}$$

$$v_0 = -v_{D1} = v_{\text{carga}} = Ri_0 + L\frac{di_0}{dt} + Vc$$

CHOPPER DE UM QUADRANTE
EM
CONDUÇÃO DESCONTÍNUA





$$i_{T1} = i_0 = \frac{V - Vc}{R}\left(1 - e^{-t/\tau}\right)$$

para $0 \le t \le t_{ON}$

$$i_{D1} = i_0 = -\frac{Vc}{R}\left(1 - e^{-(t - t_{ON})/\tau}\right) + I_{max} e^{-(t - t_{ON})/\tau}$$

para $t_{ON} \le t \le t_x - t_{ON}$

$$t_x = \tau \ln\left\{ e^{ton/\tau}\left[1 + \frac{V - Vc}{Vc}\left(1 - e^{-ton/\tau}\right)\right]\right\}$$

$$I_{max} = \frac{V - Vc}{R}\left(1 - e^{-t_{ON}/\tau}\right)$$

$$\tau = \frac{L}{R}$$

CHOPPER DE UM QUADRANTE EM CONDUÇÃO DESCONTÍNUA (SÉRIE DE FOURIER)

$$v_0 = V_0 + \sum_{n=1}^{\infty} a_n \operatorname{sen}(n\omega t) + \sum_{n=1}^{\infty} b_n \cos(n\omega t)$$

$$v_0 = V_0 + \sum_{n=1}^{\infty} c_n \operatorname{sen}(n\omega t + \theta_n)$$

$$c_n = \sqrt{a_n^2 + b_n^2}\ ;\ \theta_n = \arctan\frac{b_n}{a_n}\ ;\ \ \omega = \frac{2\pi}{T} = 2\pi . f$$

$$V_0 = \frac{t_{ON}}{T}V + \frac{(T - t_x)}{T}Vc = \delta \bullet V + Vc - \frac{t_x}{T}Vc$$

$$a_n = \frac{V}{n\pi}\left[1 - \cos(n\omega t_{ON})\right] - \frac{Vc}{n\pi}\left[1 - \cos(n\omega t_x)\right]$$

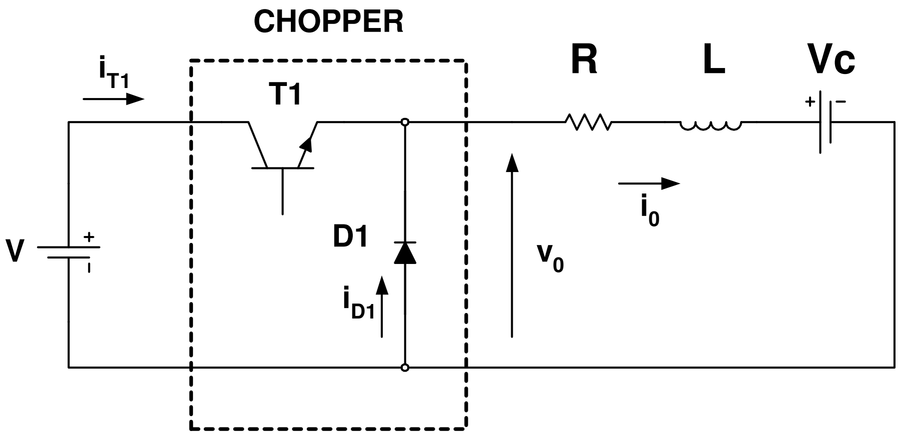
$$b_n = \frac{V}{n\pi}\operatorname{sen}(n\omega t_{ON}) - \frac{Vc}{n\pi}\operatorname{sen}(n\omega t_x)$$

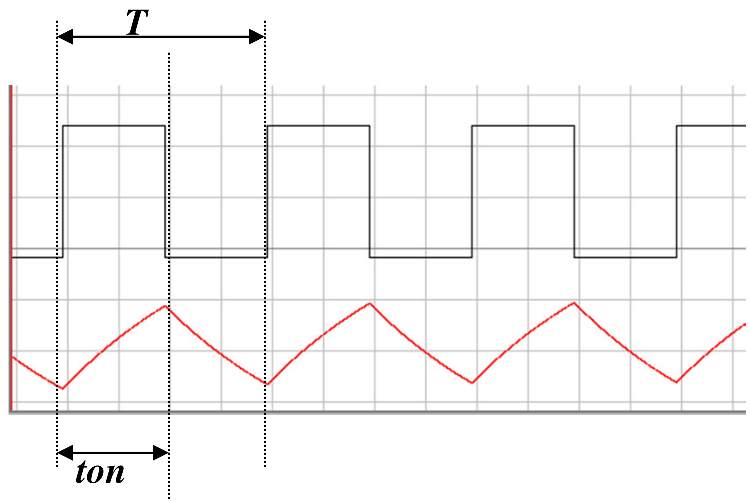
$$i_0 = I_0 + \sum_{n=1}^{\infty} d_n \operatorname{sen}(n\omega t + \theta_n - \phi_n)$$

$$I_0 = \frac{V_0 - Vc}{R}\ ;\ \ d_n = \frac{c_n}{Z_n}$$

$$Z_n = \sqrt{R^2 + (n\omega L)^2}\ ;\ \ \phi_n = \arctan\frac{n\omega L}{R}$$

CHOPPER DE UM QUADRANTE
EM
CONDUÇÃO CONTÍNUA





$$i_{T1} = i_0 = \frac{V - Vc}{R}\left(1 - e^{-t/\tau}\right) + I_{\min} e^{-t/\tau}$$

para $0 \le t \le t_{ON}$

$$i_{D1} = i_0 = -\frac{Vc}{R}\left(1 - e^{-(t - t_{ON})/\tau}\right) + I_{\max} e^{-(t - t_{ON})/\tau}$$

para $t_{ON} \le t \le T - t_{ON}$

$$I_{\max} = \frac{V}{R} \bullet \frac{\left(1 - e^{-t_{ON}/\tau}\right)}{\left(1 - e^{-T/\tau}\right)} - \frac{Vc}{R}$$

$$I_{\min} = \frac{V}{R} \bullet \frac{\left(e^{t_{ON}/\tau} - 1\right)}{\left(e^{T/\tau} - 1\right)} - \frac{Vc}{R}$$

$$\tau = \frac{L}{R}$$

CHOPPER DE UM QUADRANTE EM CONDUÇÃO CONTÍNUA (SÉRIE DE FOURIER)

$$v_0 = V_0 + \sum_{n=1}^{\infty} a_n \,\mathrm{sen}(n\omega t) + \sum_{n=1}^{\infty} b_n \cos(n\omega t)$$

$$v_0 = V_0 + \sum_{n=1}^{\infty} c_n \,\mathrm{sen}(n\omega t + \theta_n)$$

$$c_n = \sqrt{a_n^2 + b_n^2}\ ;\ \theta_n = \arctan\frac{b_n}{a_n}\ ;\ \omega = \frac{2\pi}{T} = 2\pi . f$$

$$V_0 = \frac{t_{ON}}{T} V = \delta \bullet V$$

$$a_n = \frac{V}{n\pi}\left[1 - \cos(n\omega t_{ON})\right]$$

$$b_n = \frac{V}{n\pi}\,\mathrm{sen}(n\omega t_{ON})$$

$$c_n = \frac{\sqrt{2}.V}{n\pi}\left[1 - \cos(n\omega t_{ON})\right]$$

$$i_0 = I_0 + \sum_{n=1}^{\infty} d_n \,\mathrm{sen}(n\omega t + \theta_n - \phi_n)$$

$$I_0 = \frac{V_0 - Vc}{R}\ ;\ d_n = \frac{c_n}{Z_n}$$

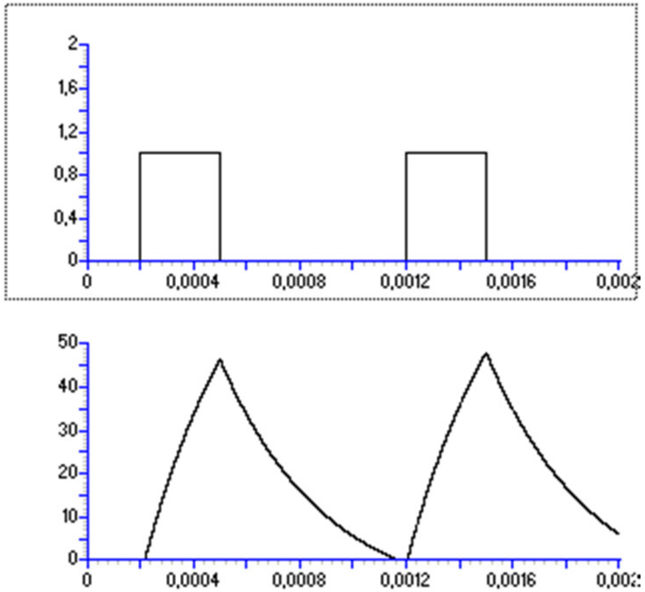
$$Z_n = \sqrt{R^2 + (n\omega L)^2}\ ;\ \phi_n = \arctan\frac{n\omega L}{R}$$

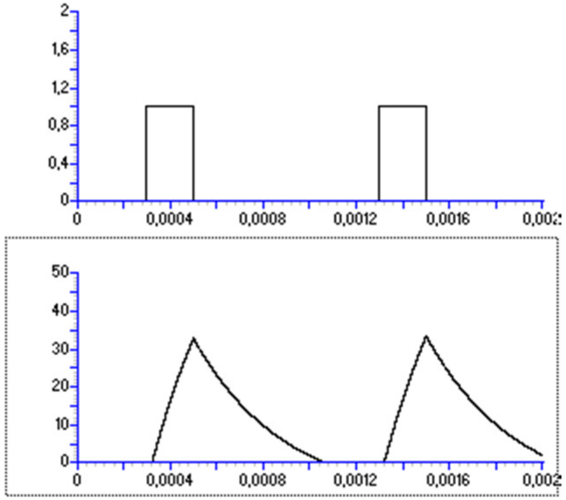
CHOPPER DE UM QUADRANTE
LIMITE ENTRE CONDUÇÃO CONTÍNUA E DESCONTÍNUA

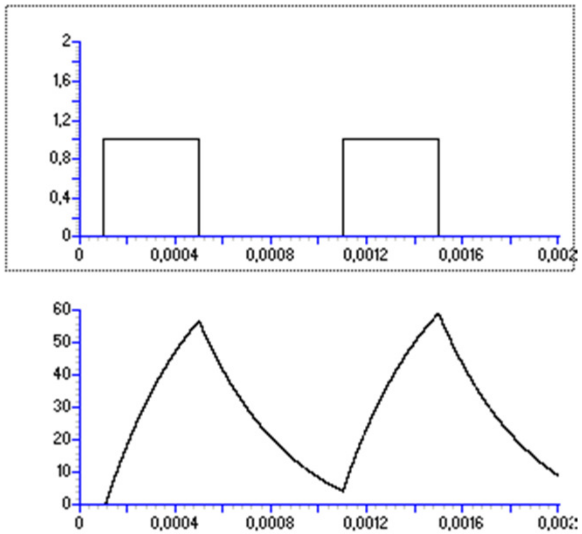
$$t_{ON}^{x} = \frac{T}{\sigma}.\ln\left[m.\left(e^{\sigma} - 1\right) + 1\right]$$

para $t_{ON} < t_{ON}^{x} \Rightarrow$ **condução descontínua**

para $t_{ON} > t_{ON}^{x} \Rightarrow$ **condução contínua**





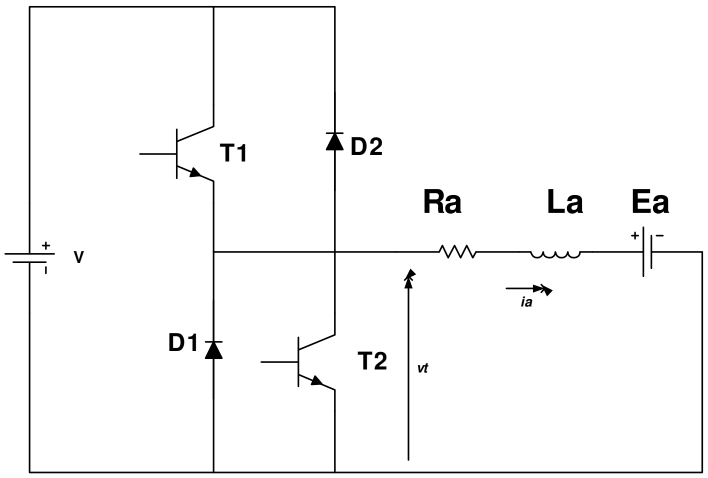


CHOPPERS DE DOIS E QUATRO QUADRANTES

CHOPPER DE DOIS QUADRANTES

•Chopper Regenerativo

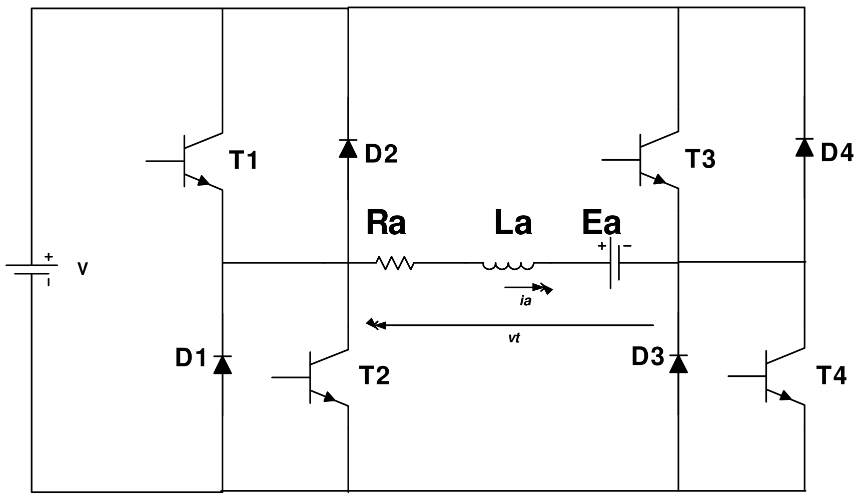
•Só opera em condução contínua



CHOPPER DE QUATRO QUADRANTES

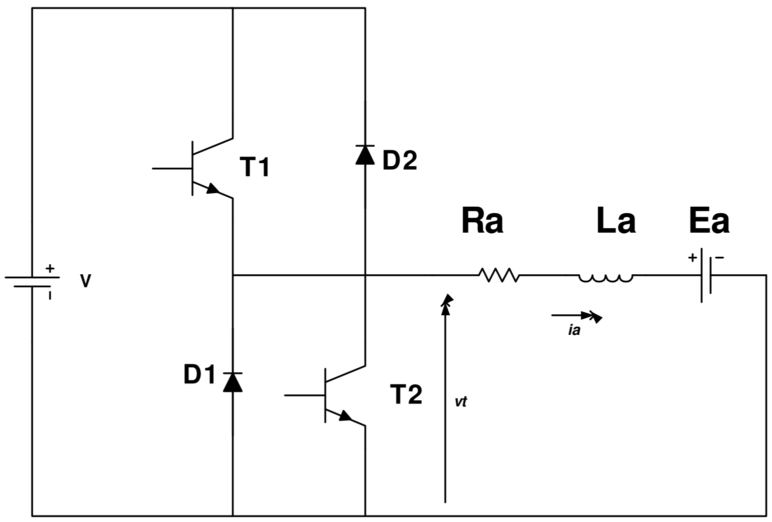
•Chopper Regenerativo e Reversível

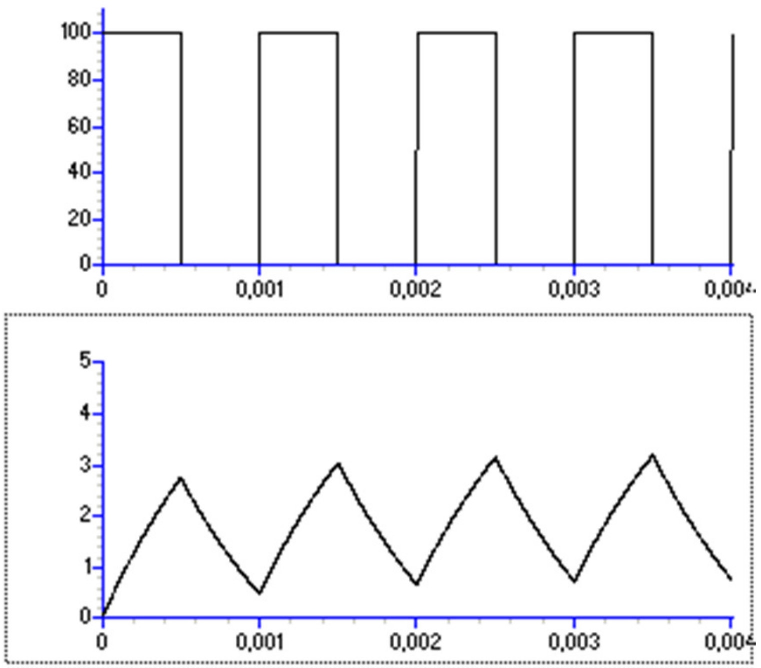
•Só opera em condução contínua



CHOPPERS DE DOIS QUADRANTES

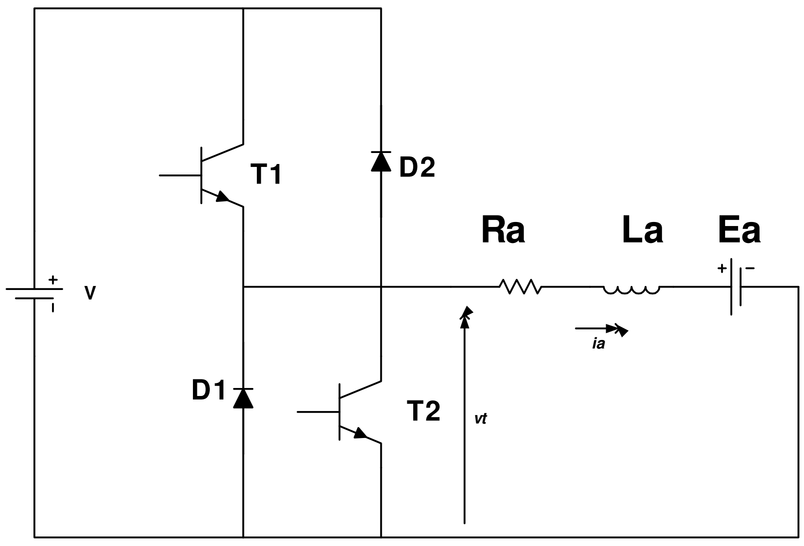
(OPERAÇÃO NO PRIMEIRO QUADRANTE)

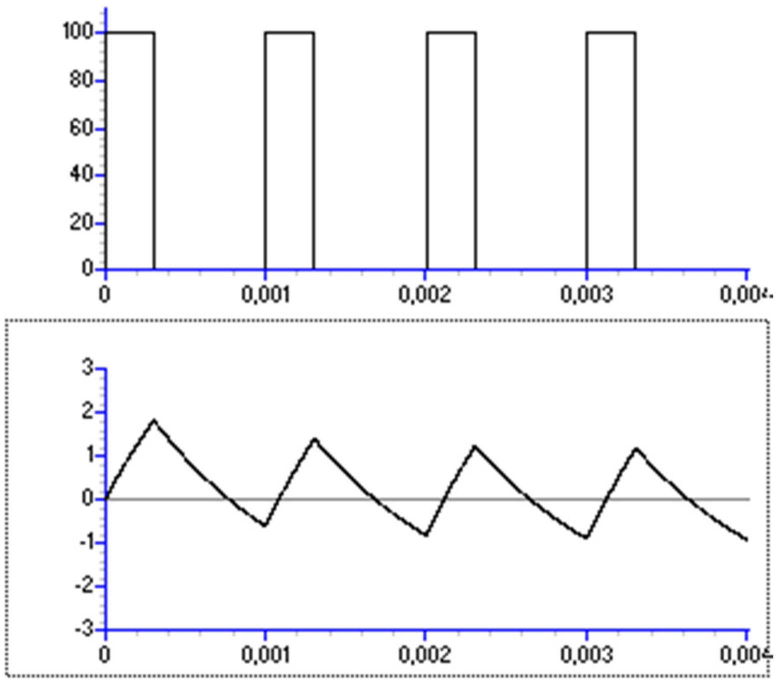




CHOPPERS DE DOIS QUADRANTES

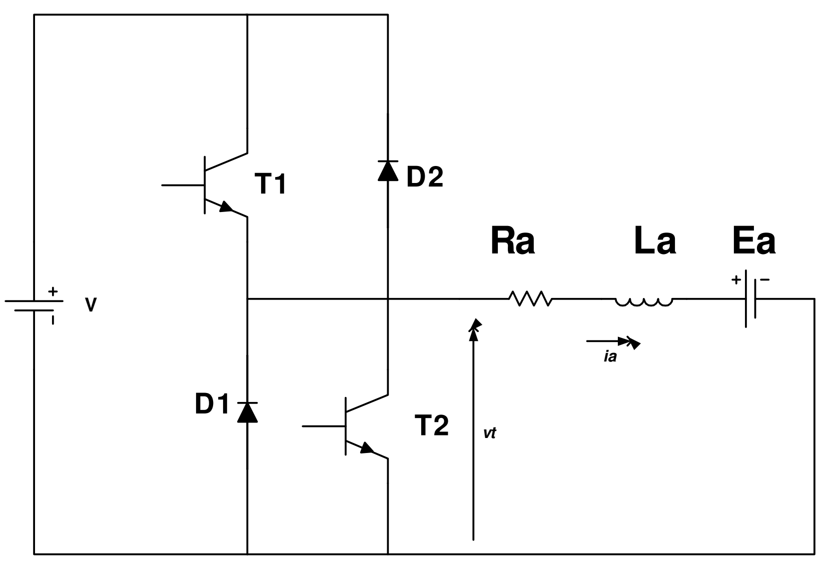
(OPERAÇÃO NO PRIMEIRO OU SEGUNDO QUADRANTES)

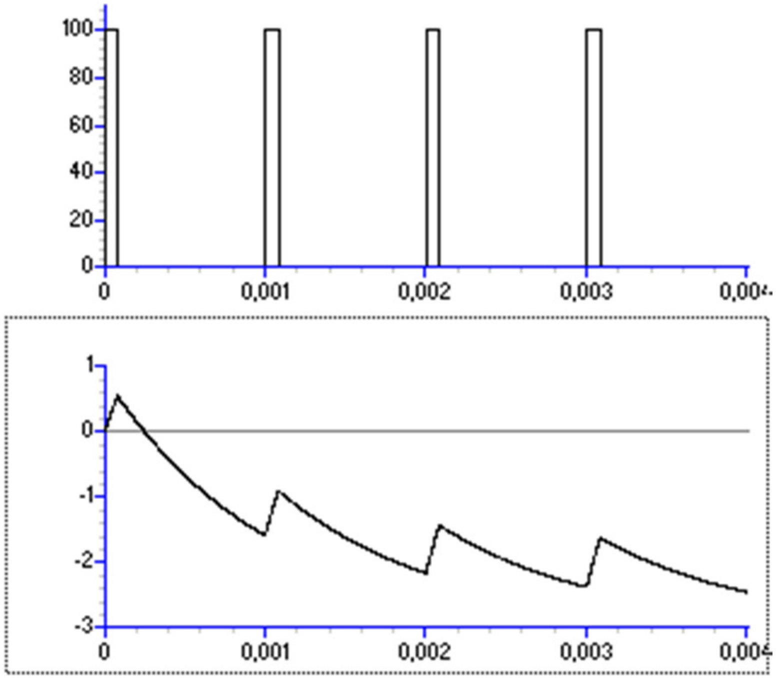




CHOPPERS DE DOIS QUADRANTES

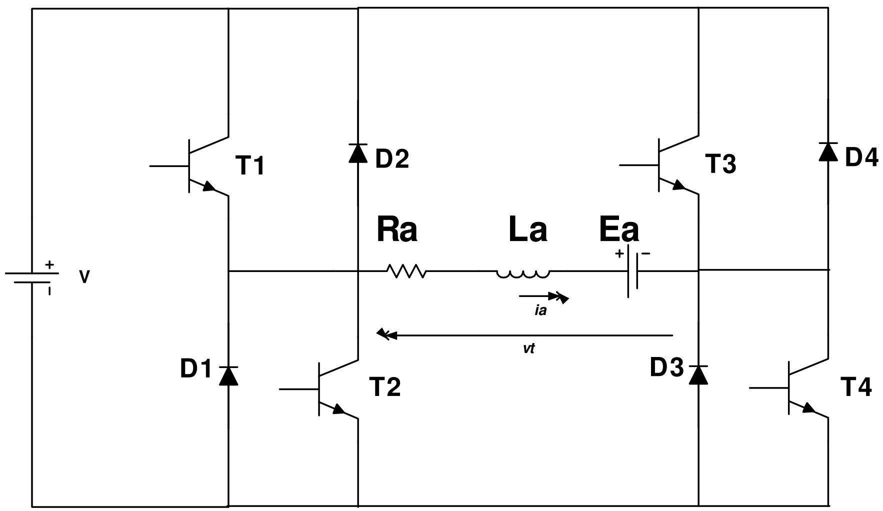
(OPERAÇÃO NO SEGUNDO QUADRANTE)

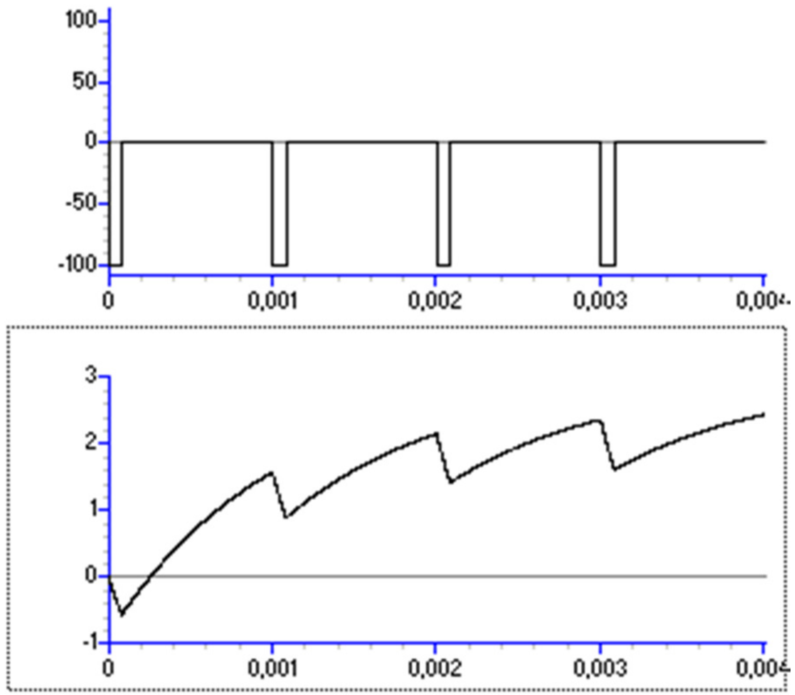




CHOPPERS DE QUATRO QUADRANTES

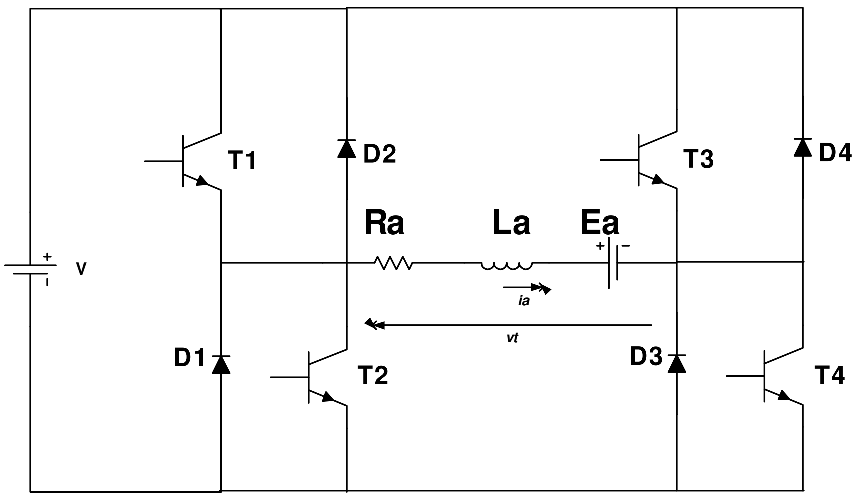
(OPERAÇÃO NO QUARTO QUADRANTE)

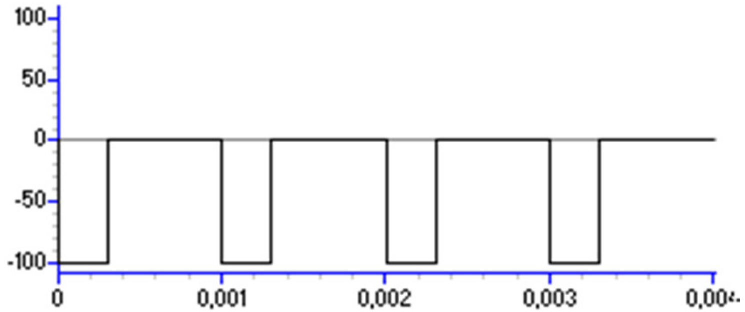


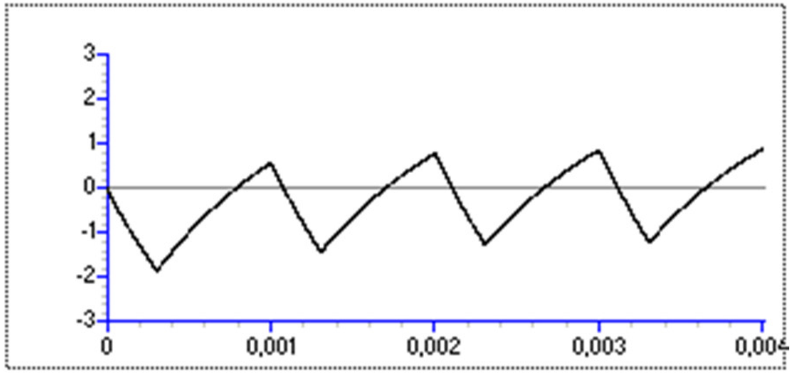


CHOPPERS DE QUATRO QUADRANTES

(OPERAÇÃO NO TERCEIRO OU QUARTO QUADRANTES)







CHOPPERS DE QUATRO QUADRANTES

(OPERAÇÃO NO TERCEIRO QUADRANTE)