

Conversores cc-ca

Prof. Clovis Antonio Petry.

Florianópolis, setembro de 2020.

Curso Básico de Eletrônica de Potência

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>



The screenshot shows the homepage of ProfessorPetry's website. At the top, it says "ProfessorPetry" and "Conhecimento para uma vida plena". Below the header is a navigation bar with links for "PRINCIPAL", "PROJETOS", "PUBICAÇÕES", and "CONTATO". The main content area features a large image of wind turbines in a field under a cloudy sky. Below the image, the text "Bem vindo ao Website pessoal de Clovis Antonio Petry" is displayed. A small note below states: "O objetivo desta página é a divulgação de informações sobre eletrônica, em especial eletrônica de potência. Todos os materiais disponibilizados podem ser livremente utilizados, desde que citados os autores. As disciplinas do semestre corrente podem ser acessadas clicando na imagem da esquerda abaixo. Material didático pode ser encontrado clicando na Imagem na direita abaixo." To the right of the main content, there is a sidebar titled "Eventos" with sections for "Outubro, 2020" (SNCT 2020) and "Setembro, 2020" (COBENGE 2020). Below the sidebar are two small images: one showing mathematical equations and another showing a pair of glasses.

www.ProfessorPetry.com.br



<https://www.youtube.com>

Agenda

Esta aula está organizada em:

1. Introdução aos conversores cc-ca:
 - Quadrantes de operação;
 - Modulação PWM senoidal;
 - Princípio de funcionamento.
2. Conversor meia ponte:
 - Onda quadrada;
 - PWM senoidal.
3. Conversor ponte completa:
 - Onda quadrada;
 - PWM senoidal.

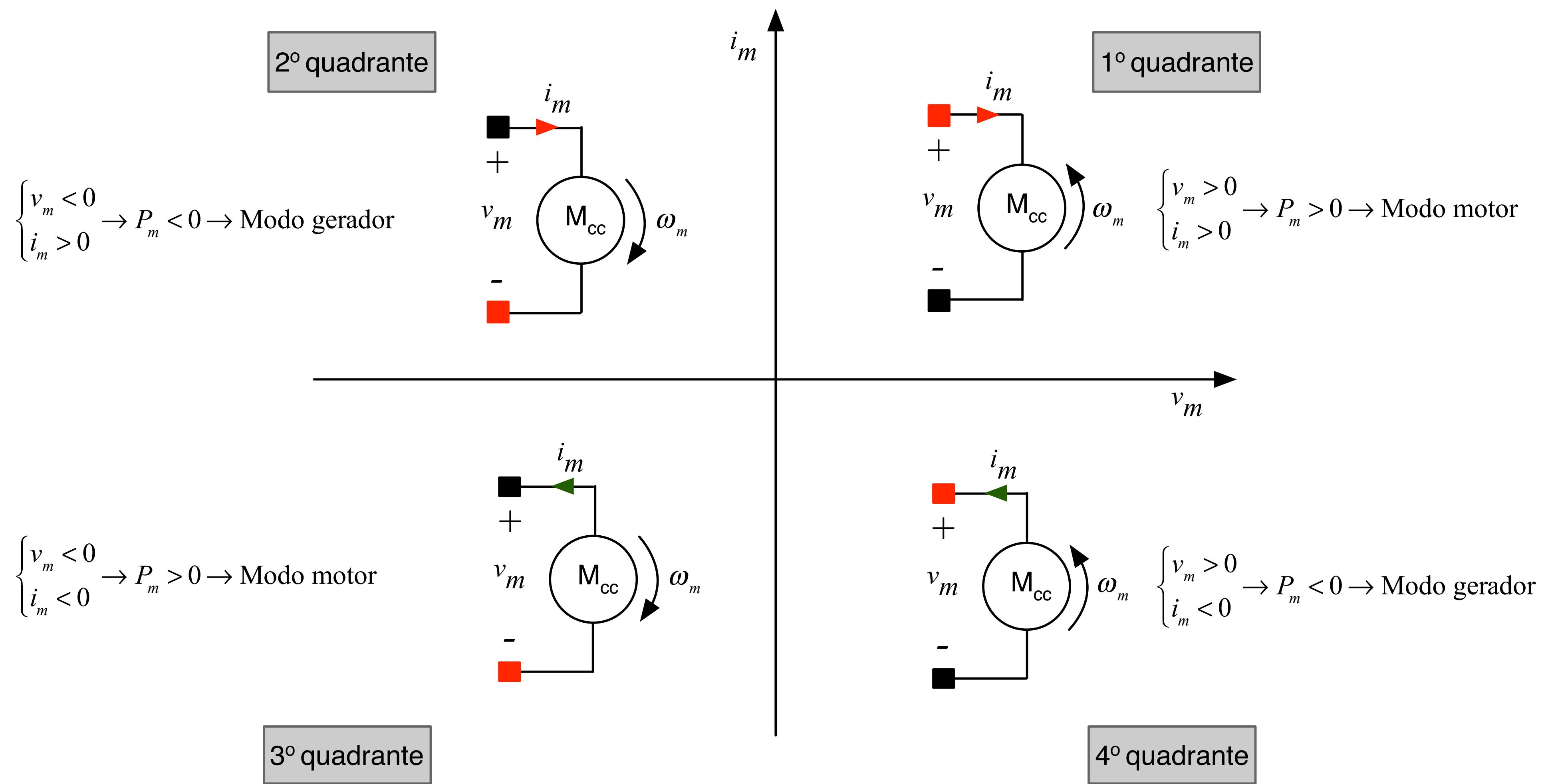


Motivação

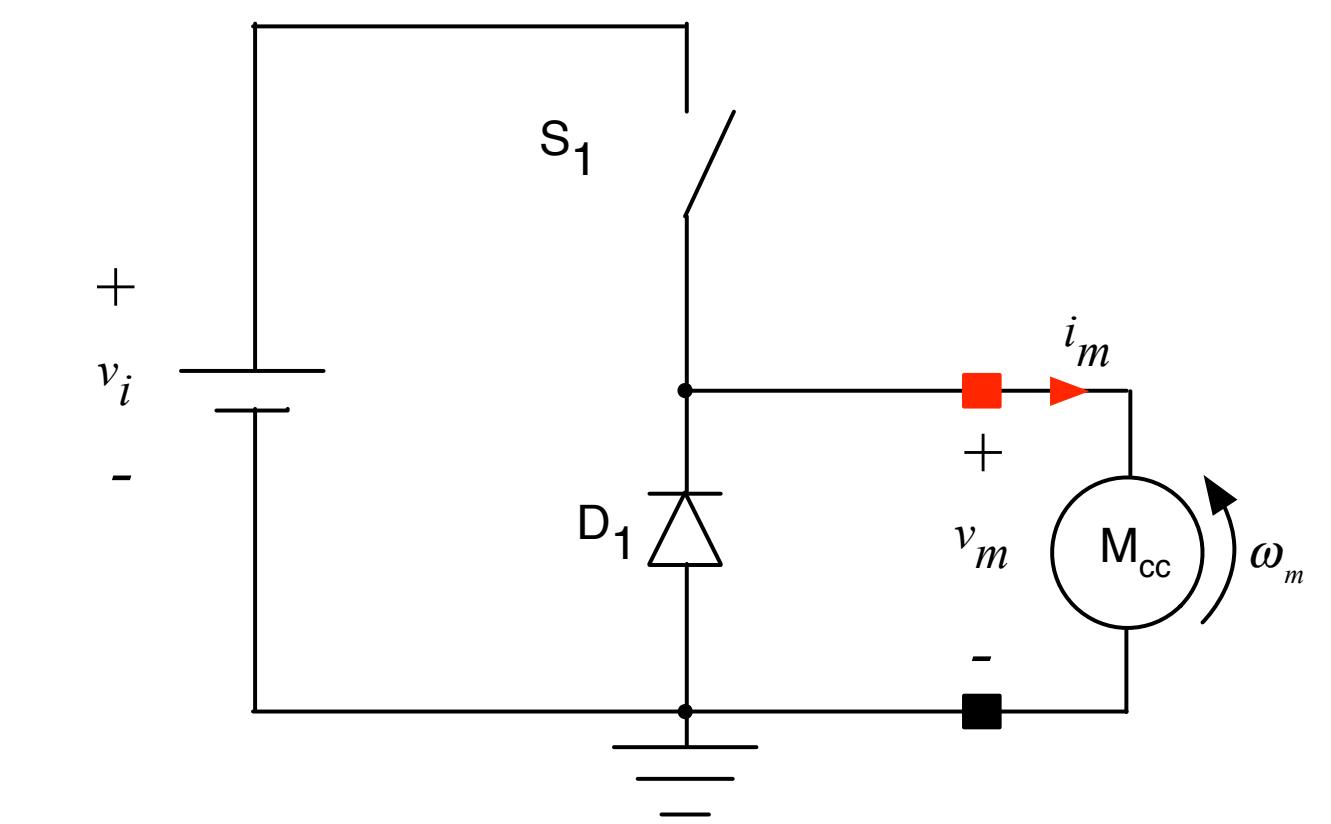
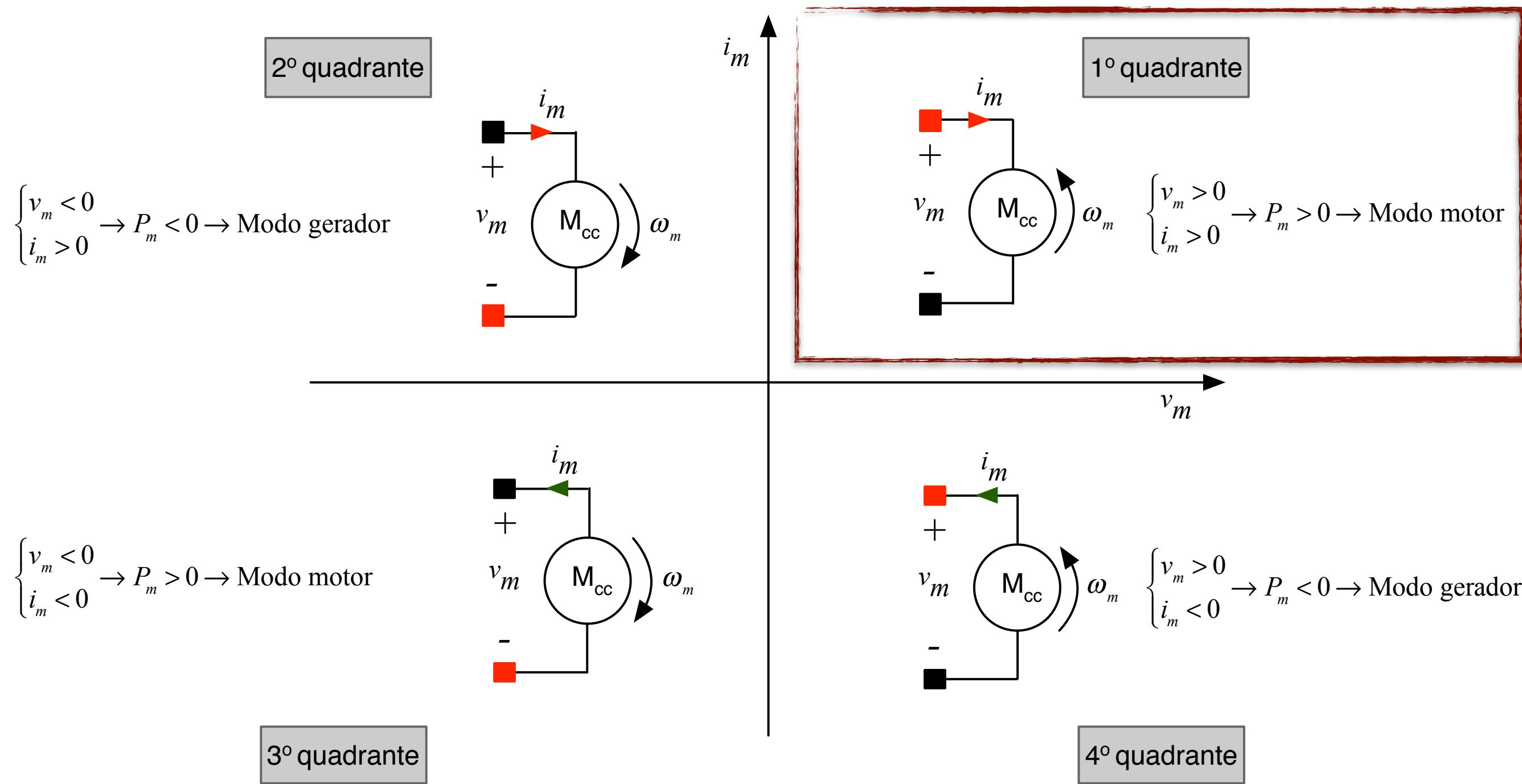
Os conversores cc-ca tem ampla utilização na indústria, por exemplo no acionamento de motores.



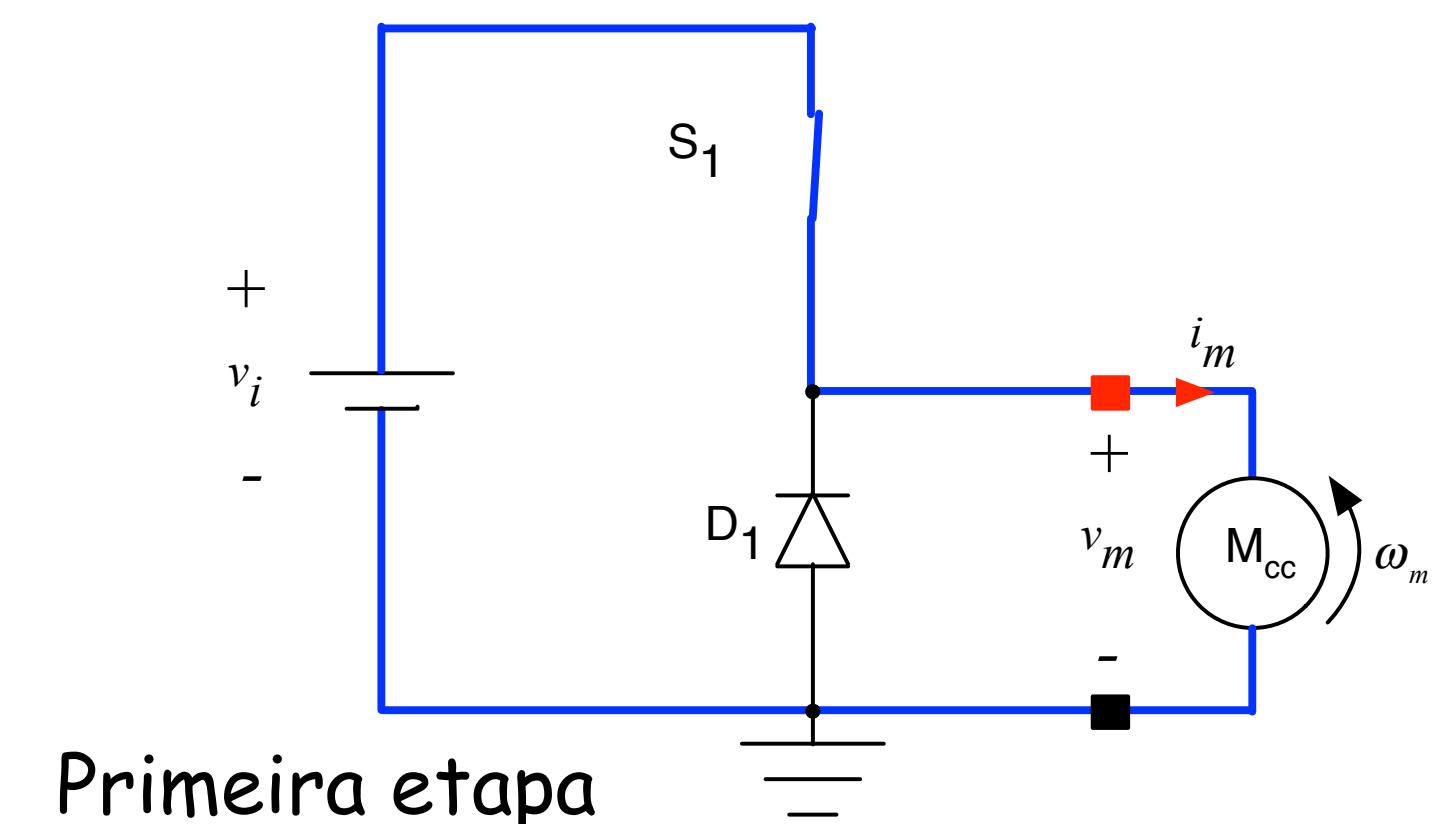
Quadrantes de Operação



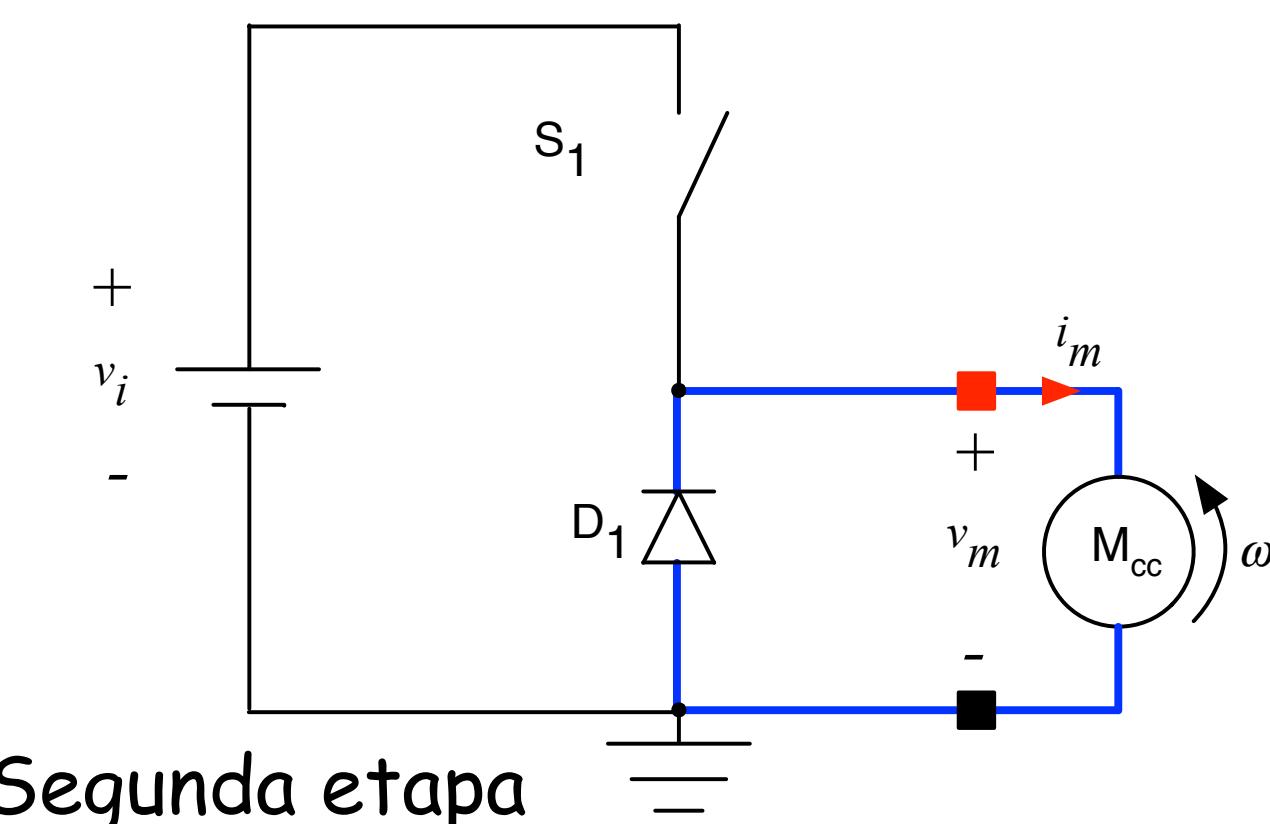
Quadrantes de Operação



Conversor simples com chave

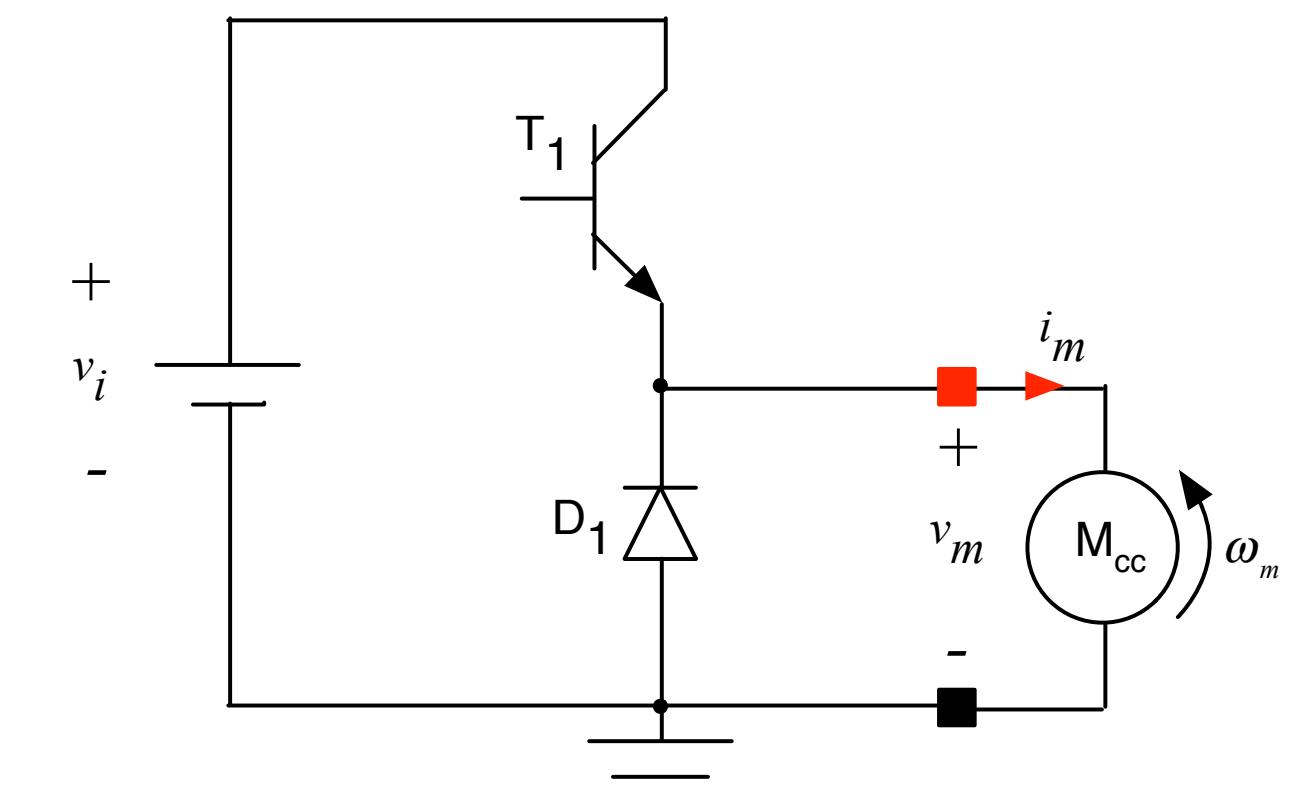
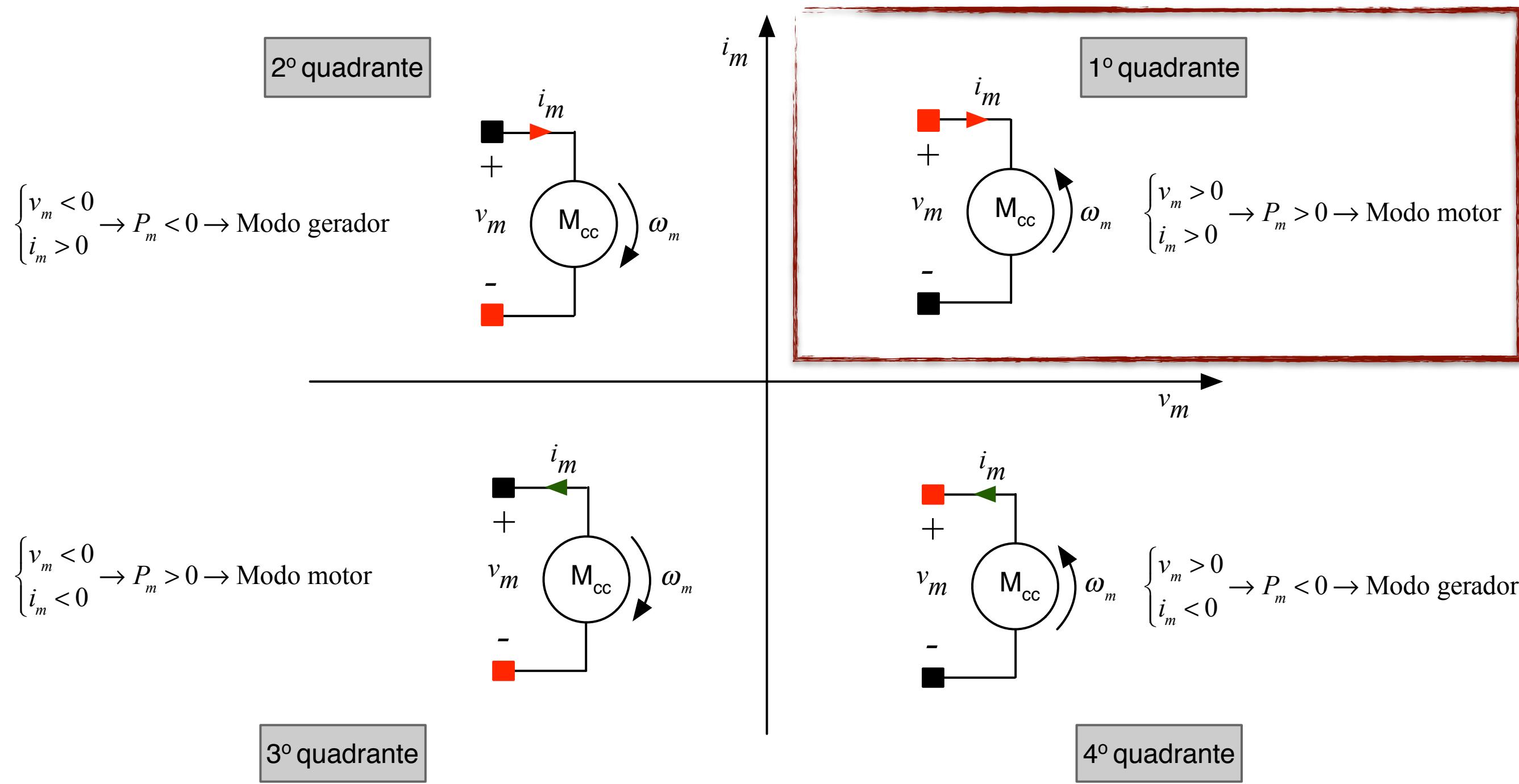


Primeira etapa

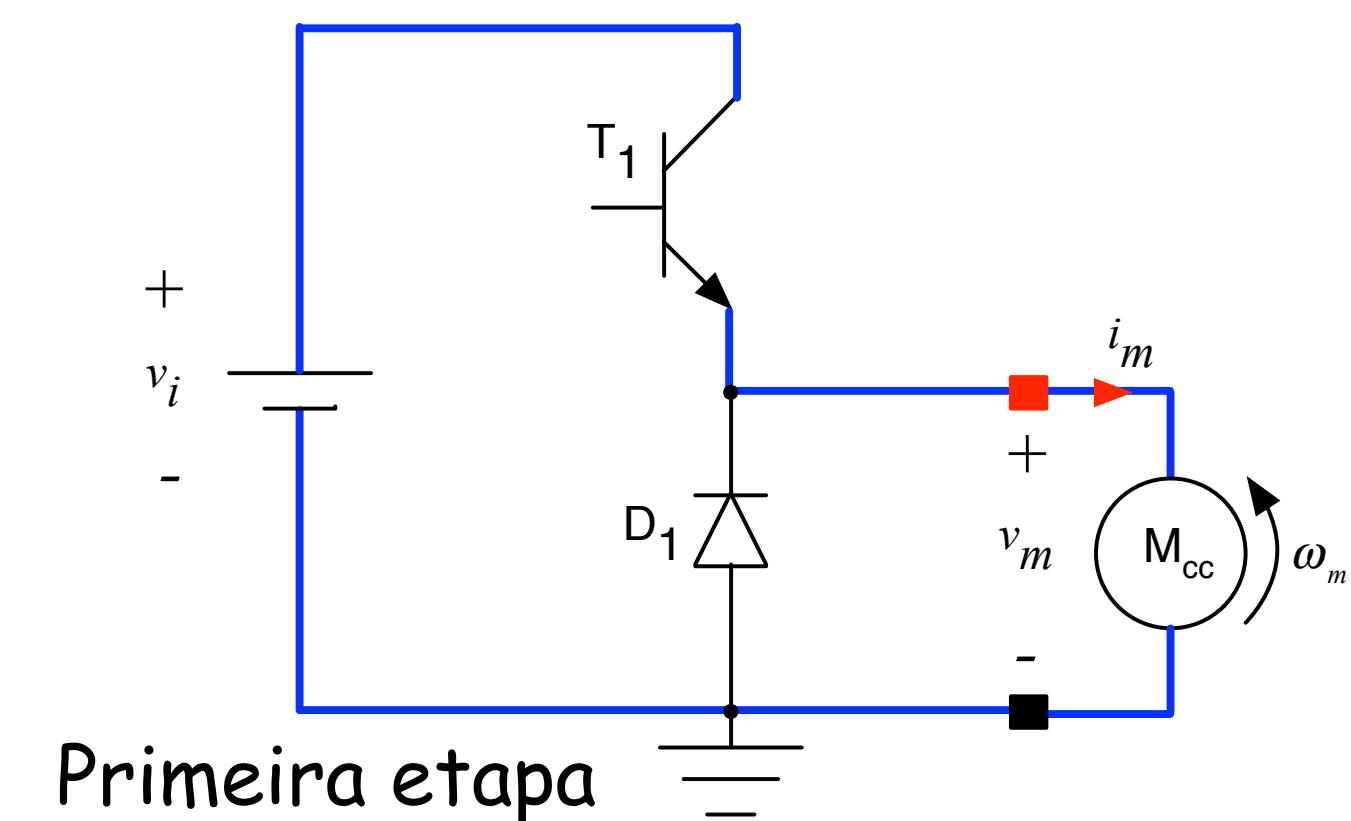


Segunda etapa

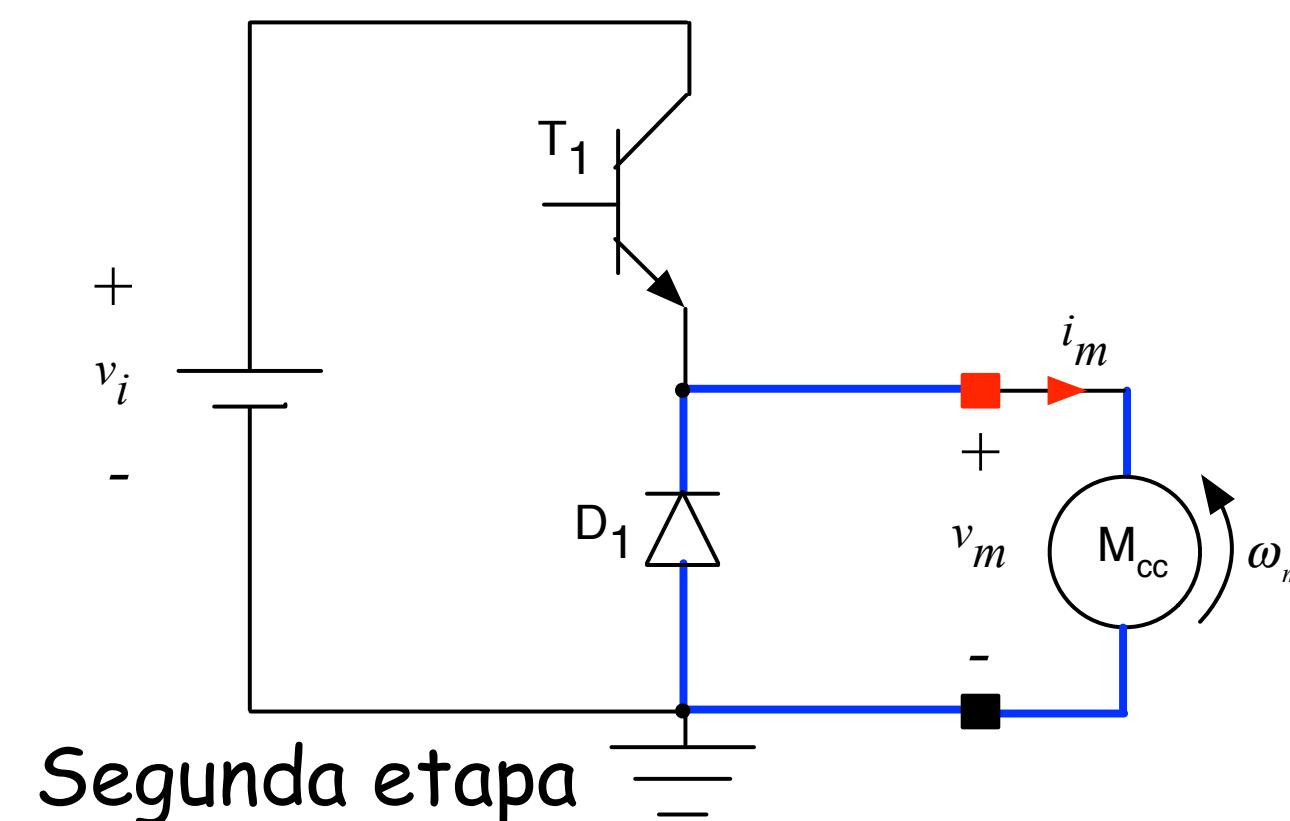
Quadrantes de Operação



Conversor simples com transistor

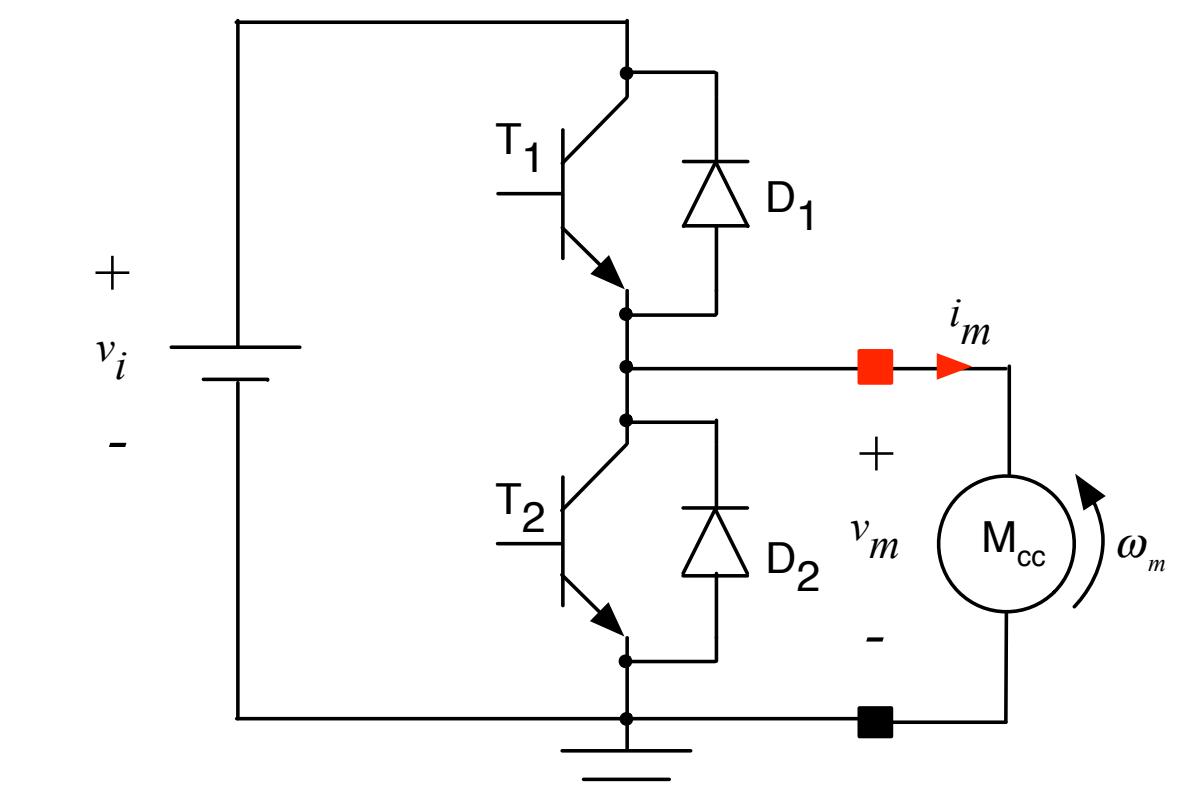
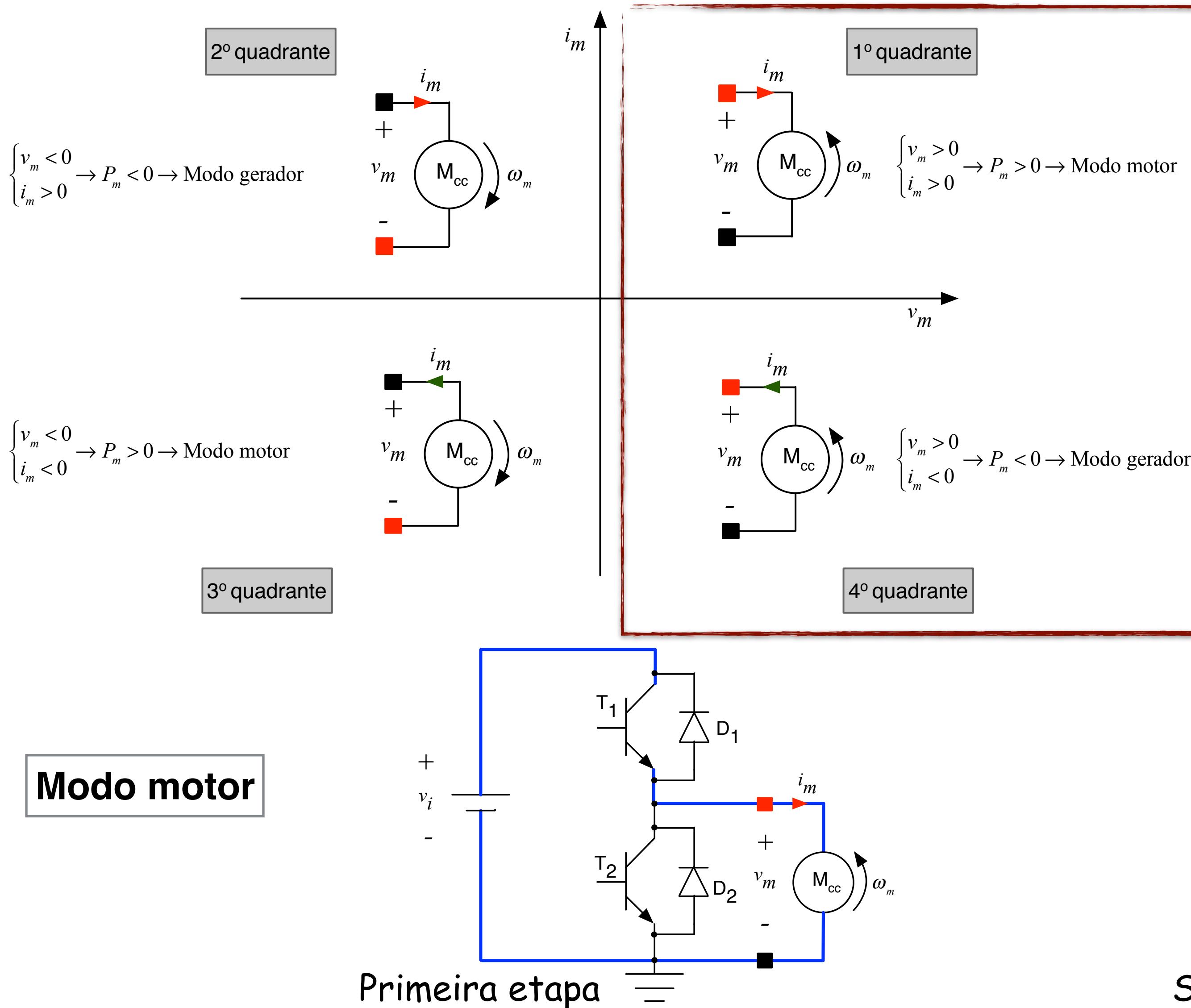


Primeira etapa

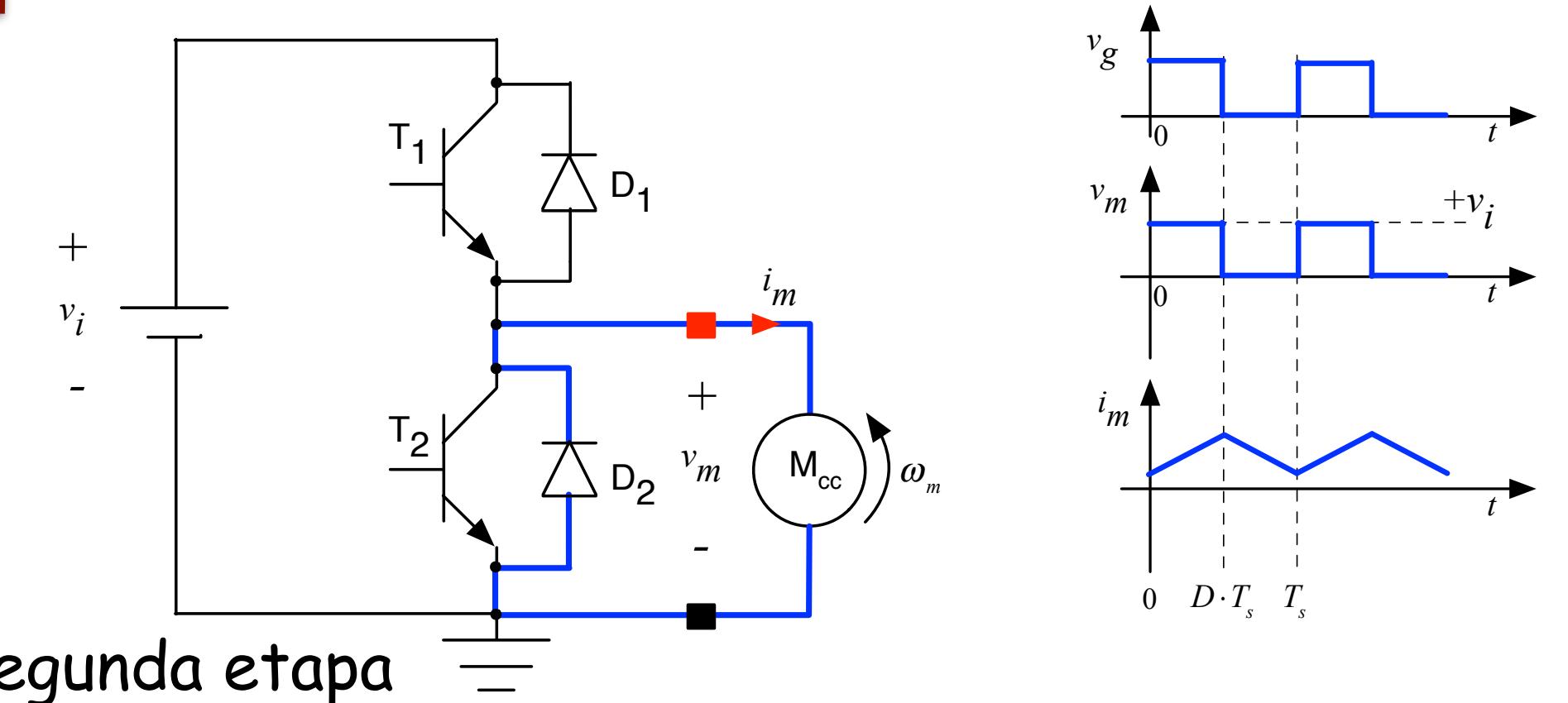


Segunda etapa

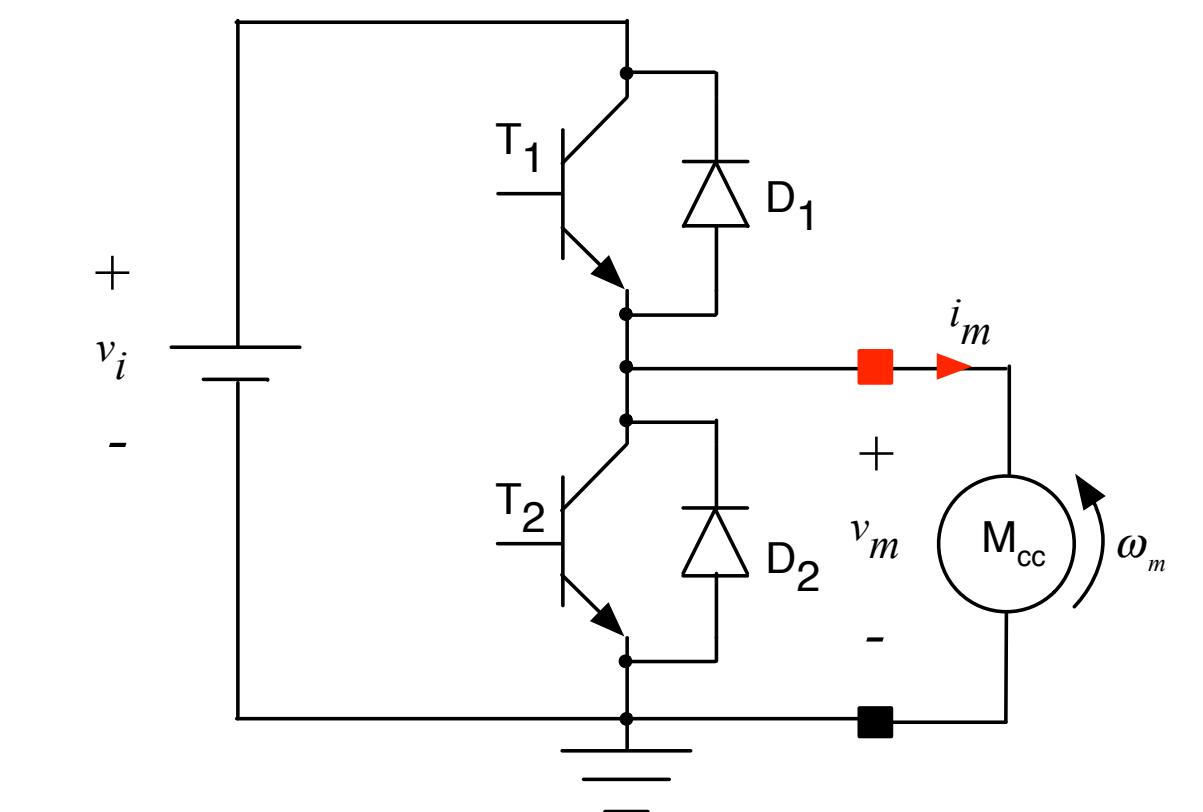
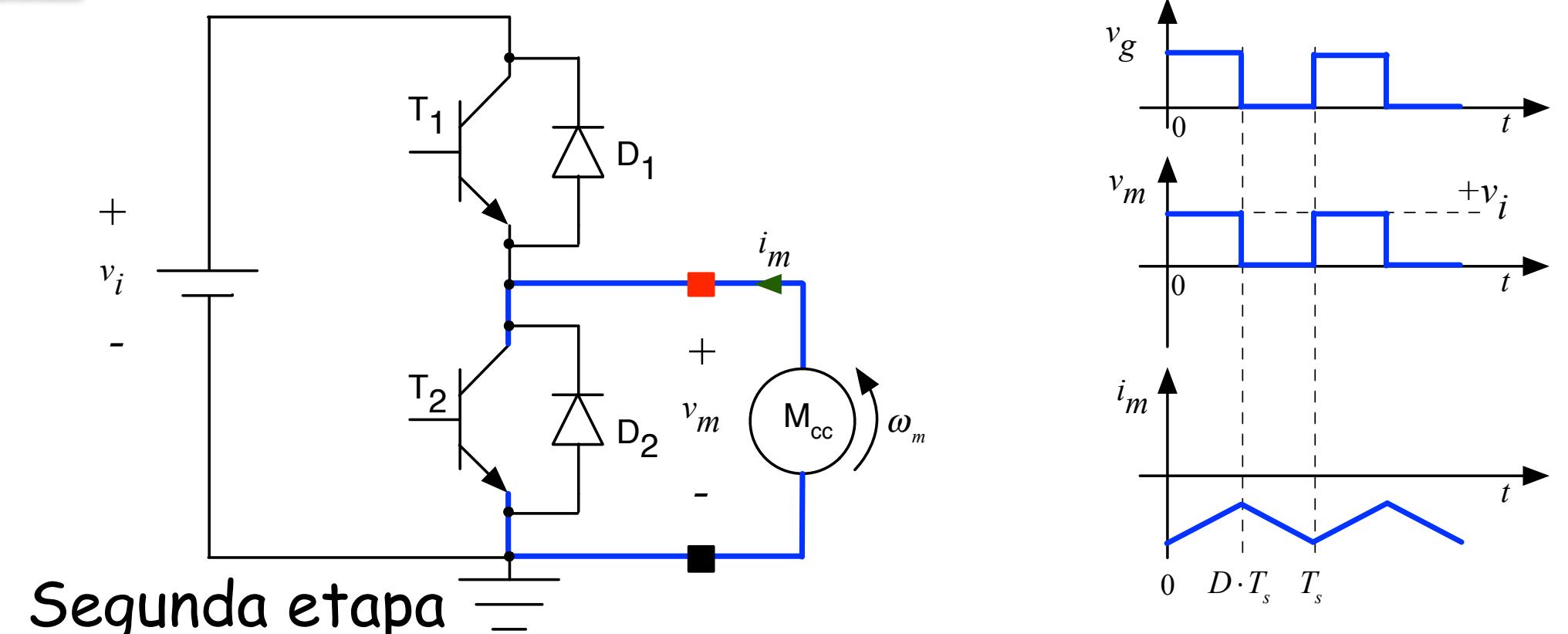
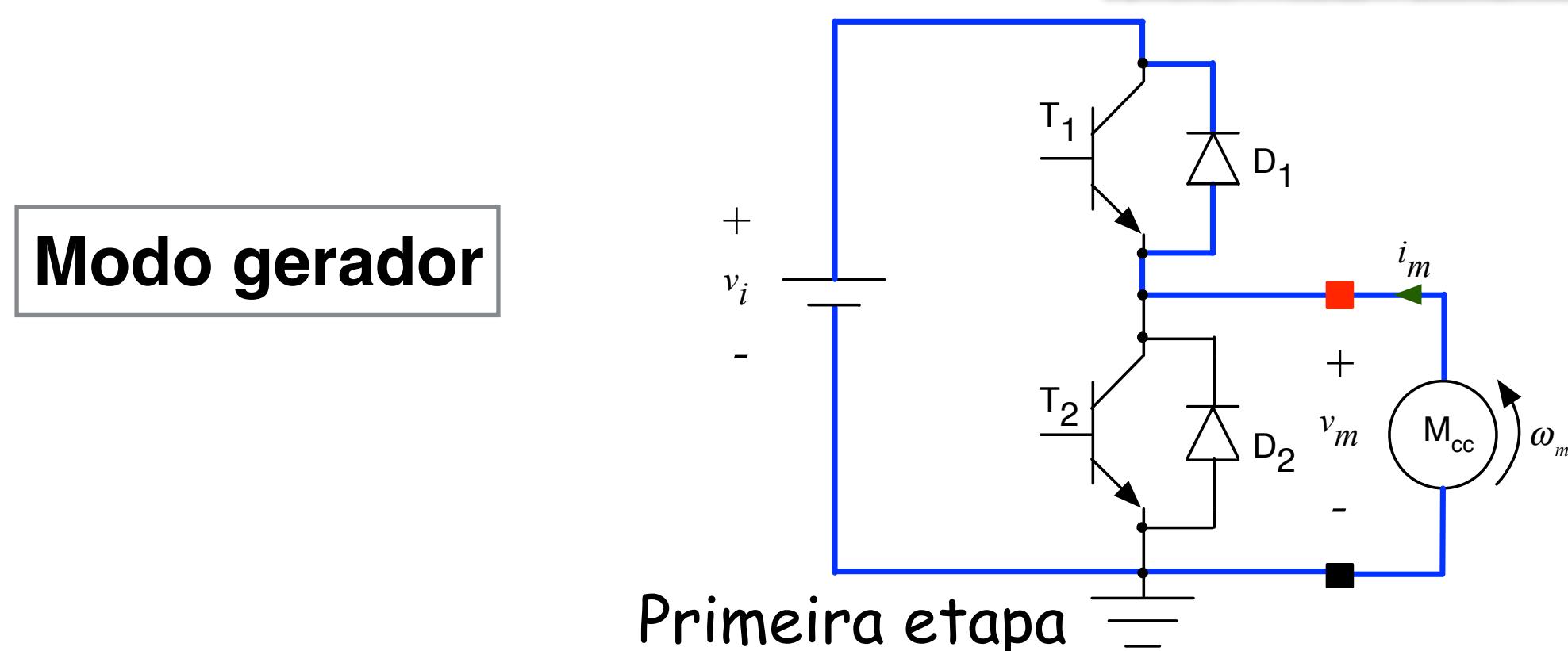
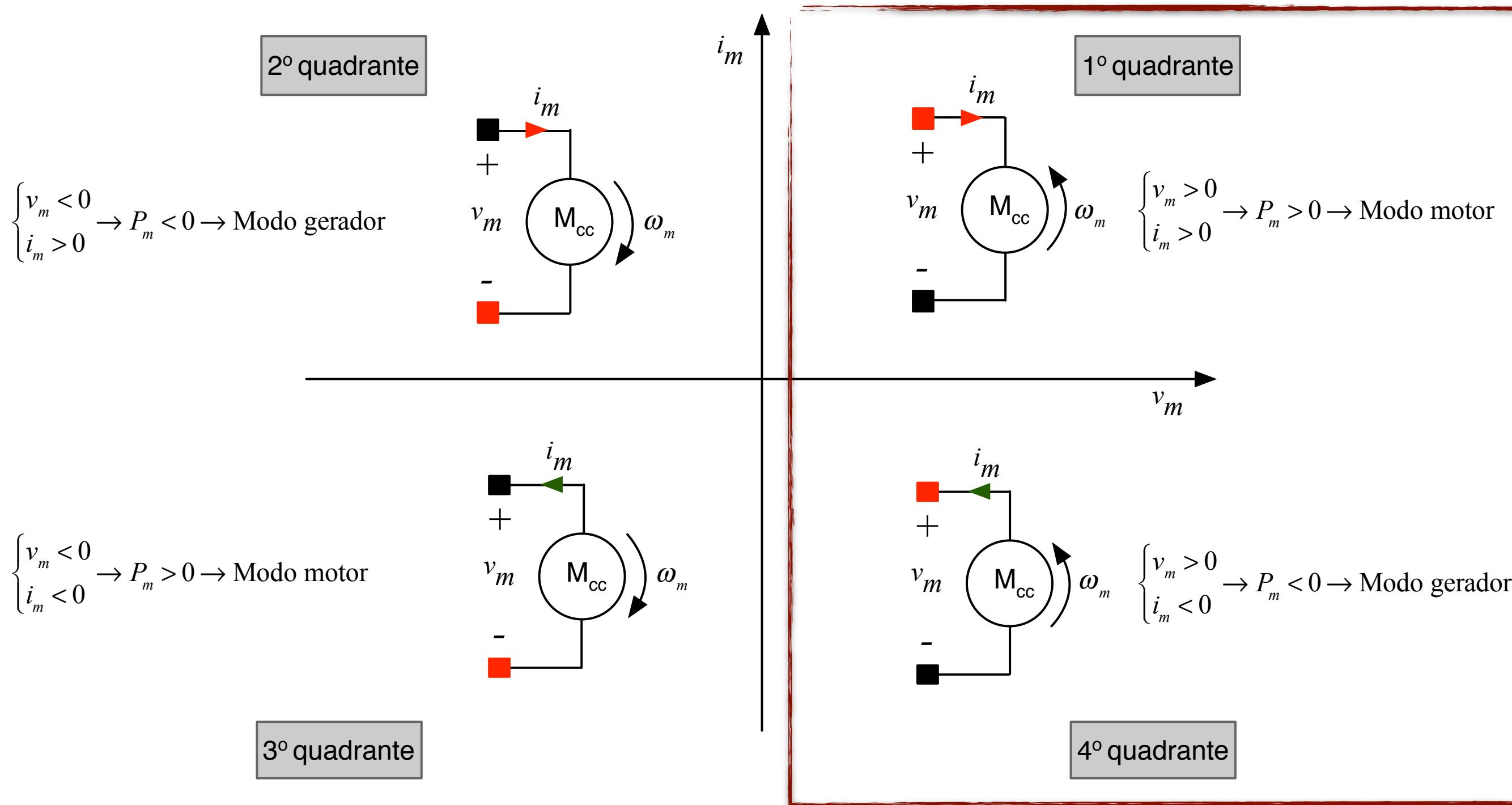
Quadrantes de Operação



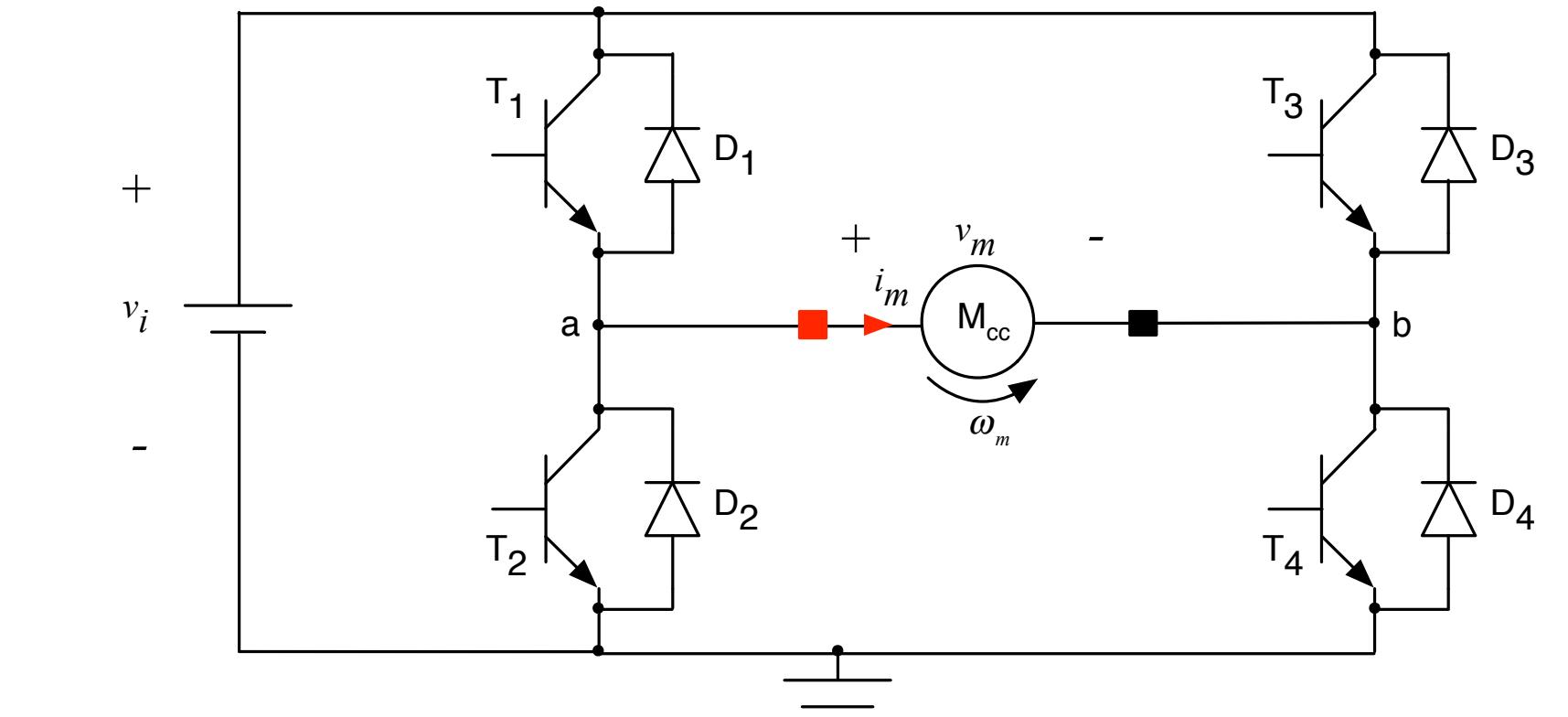
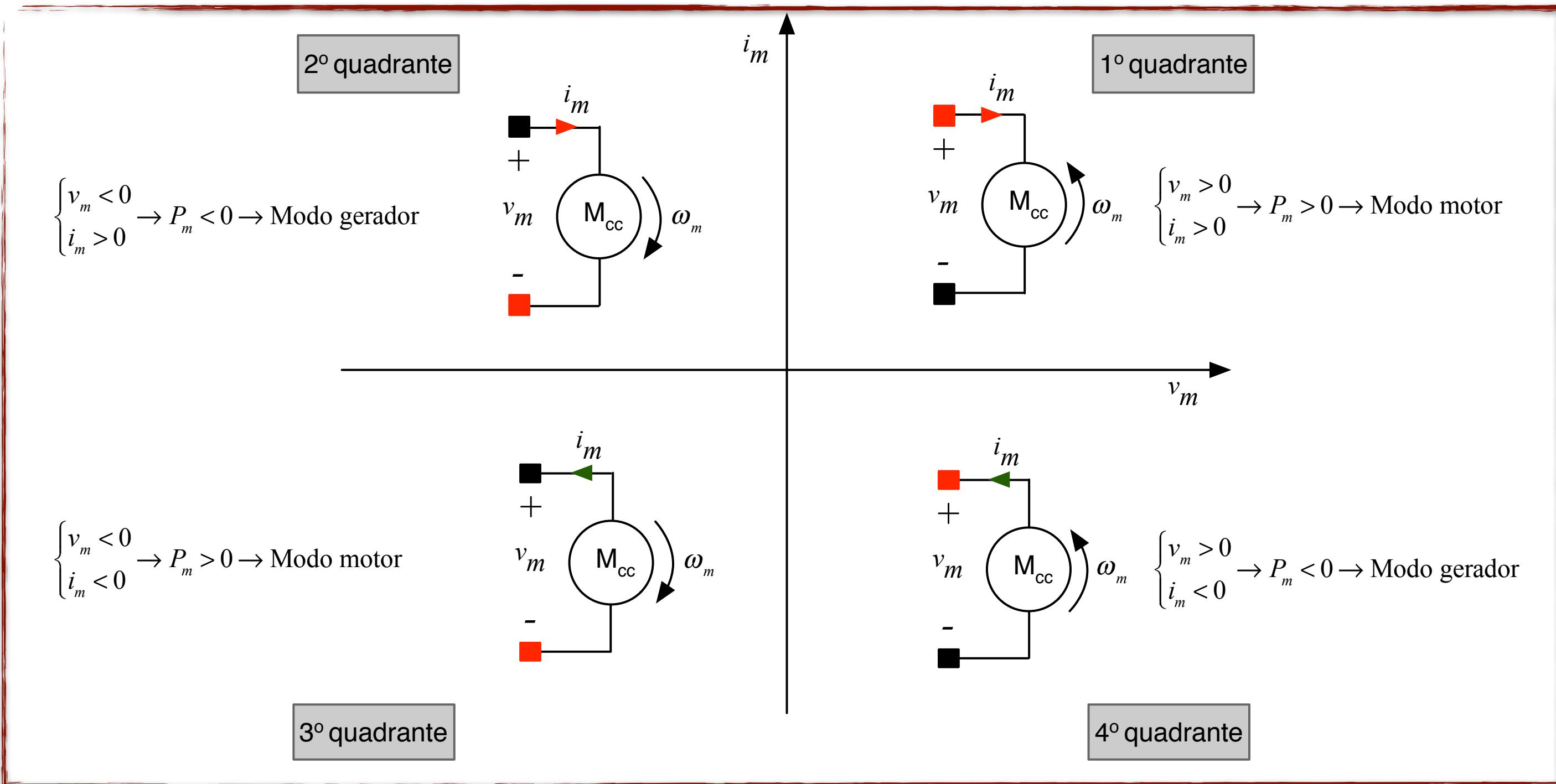
Conversor meia ponte



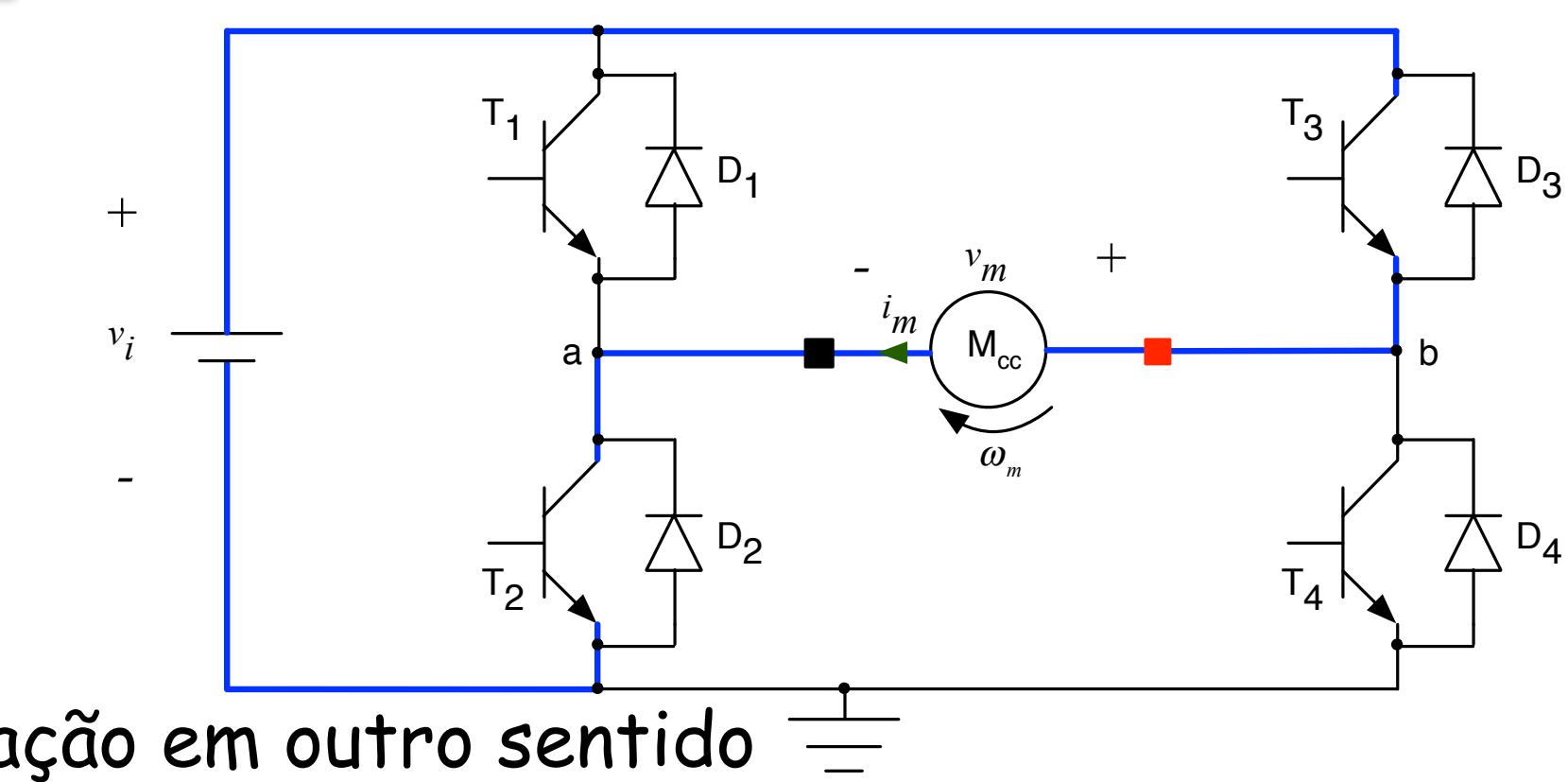
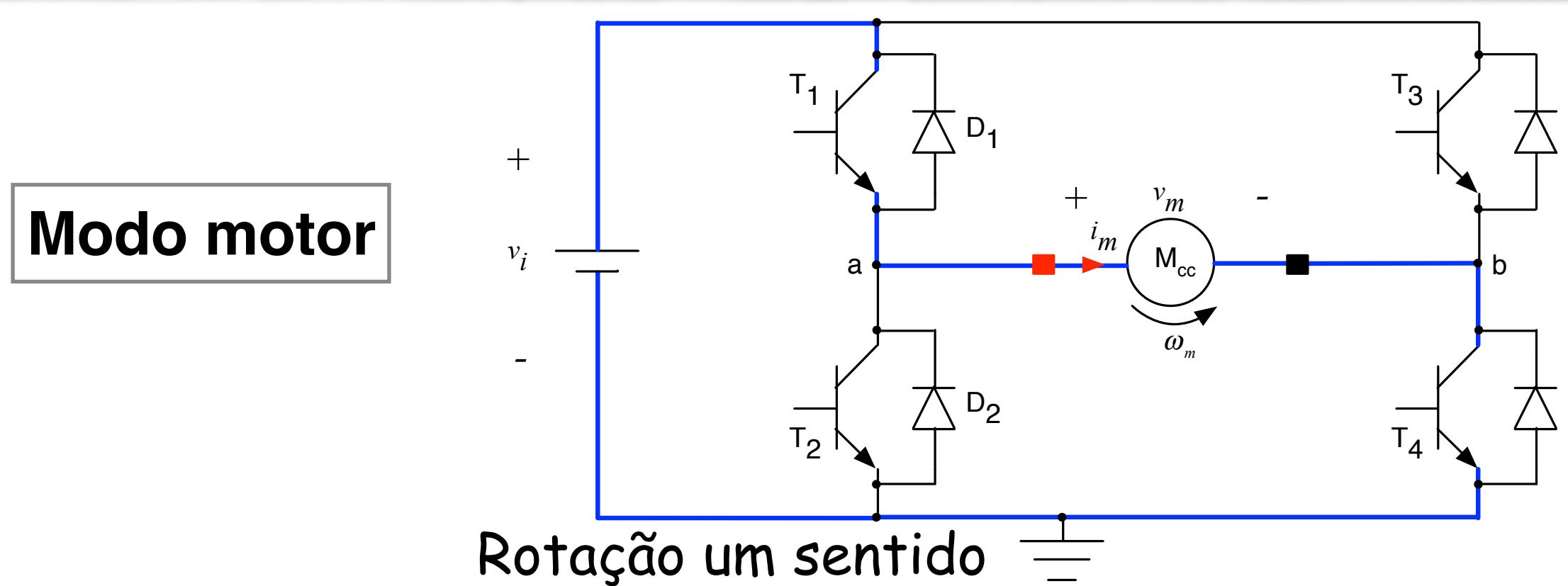
Quadrantes de Operação



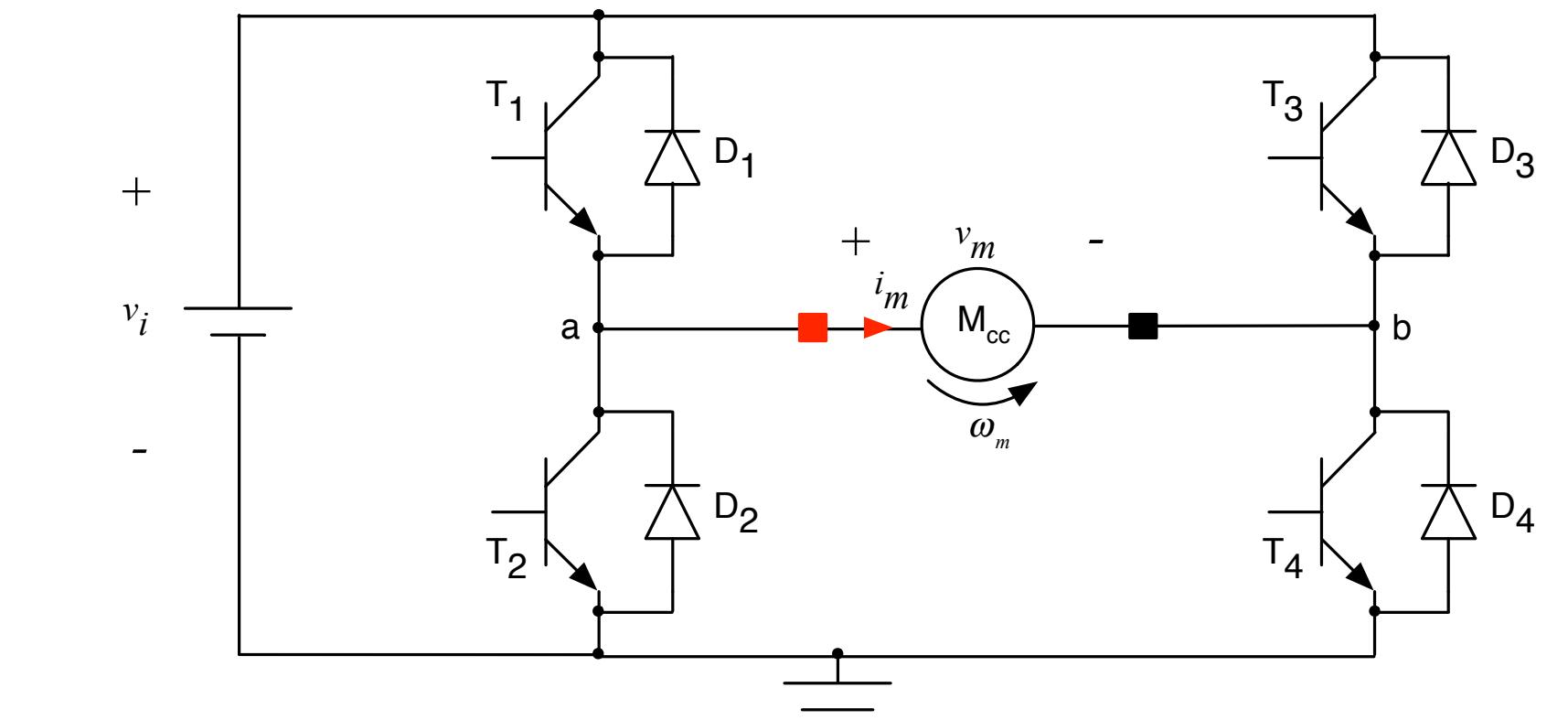
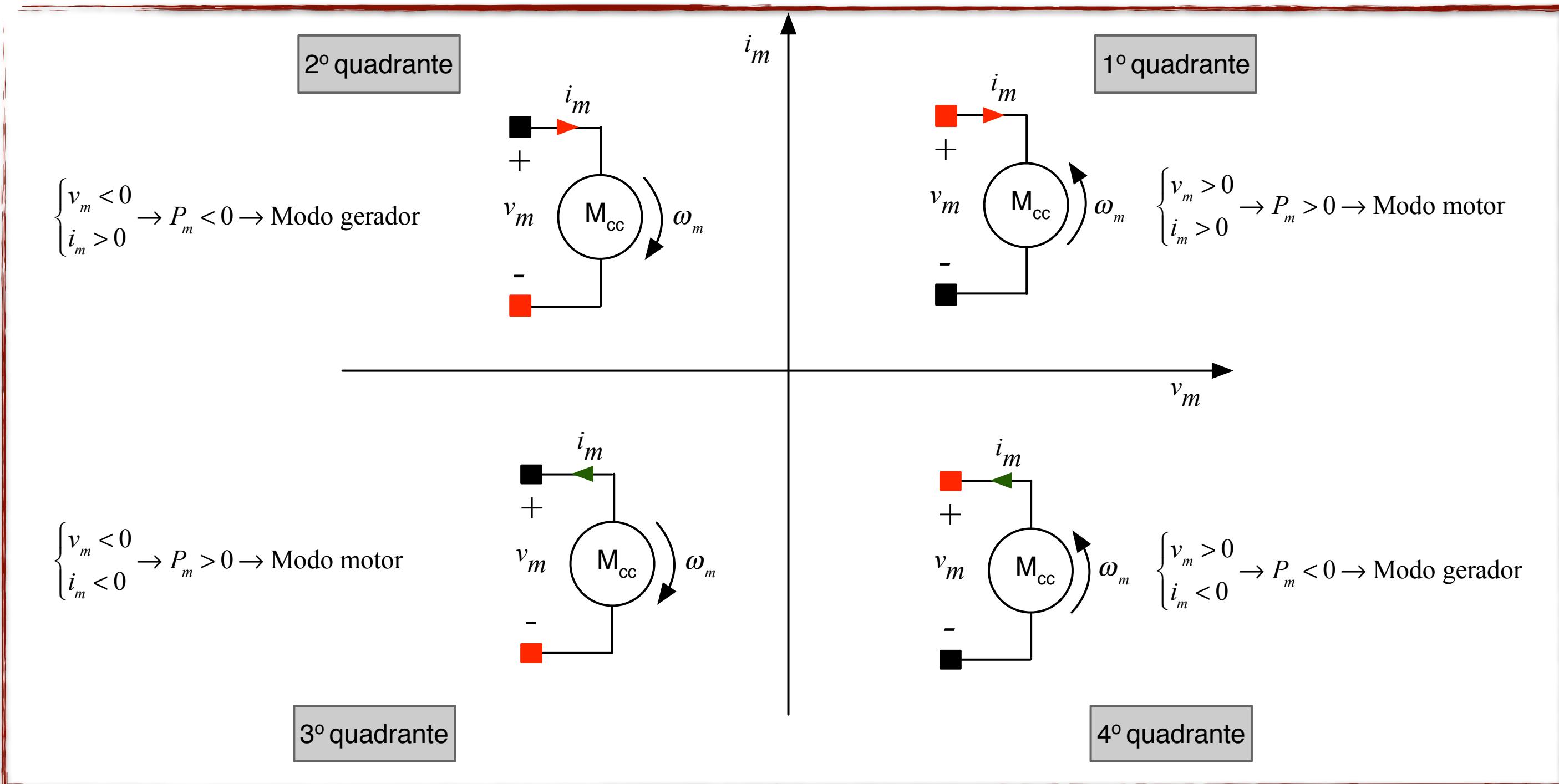
Quadrantes de Operação



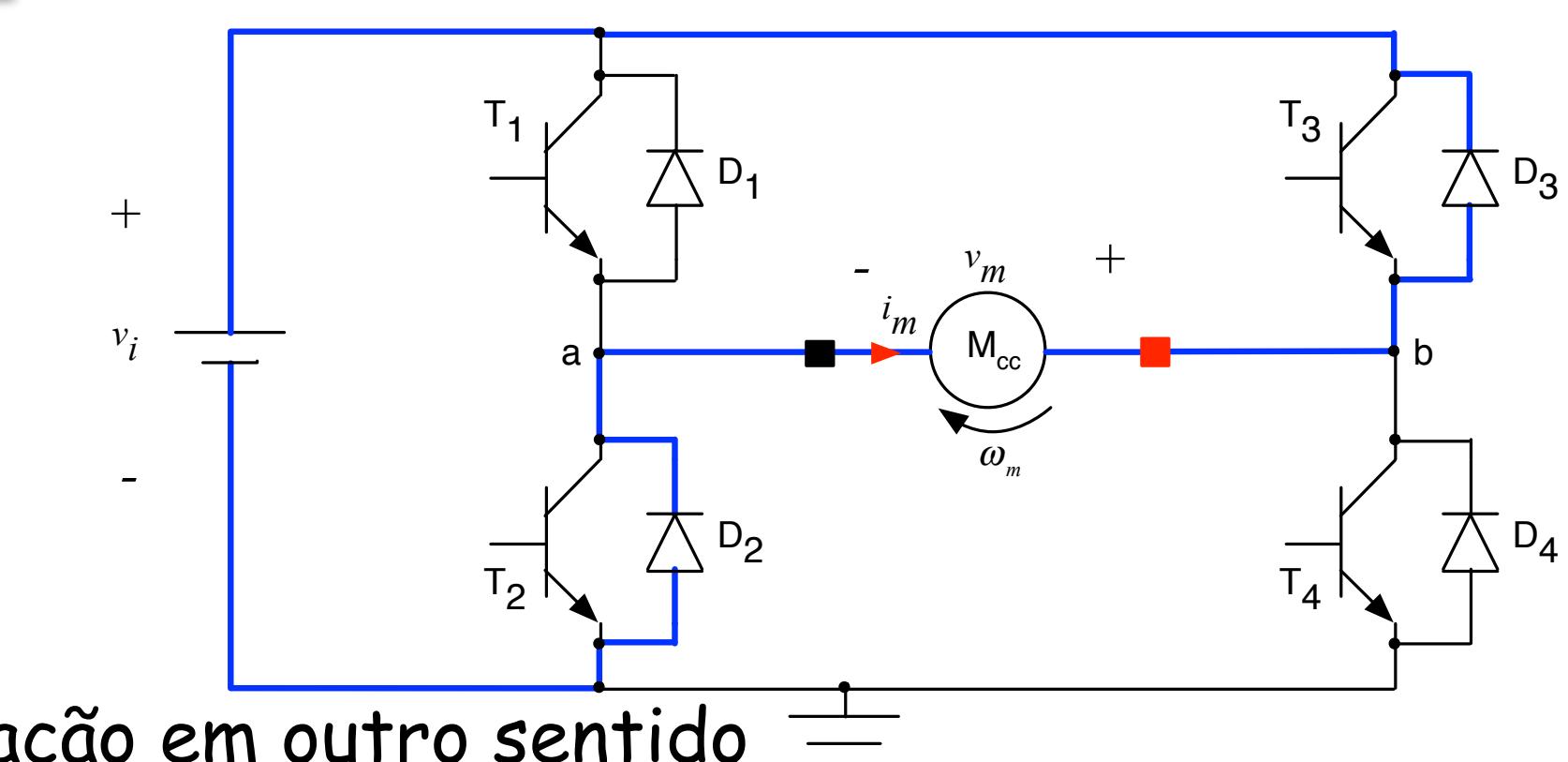
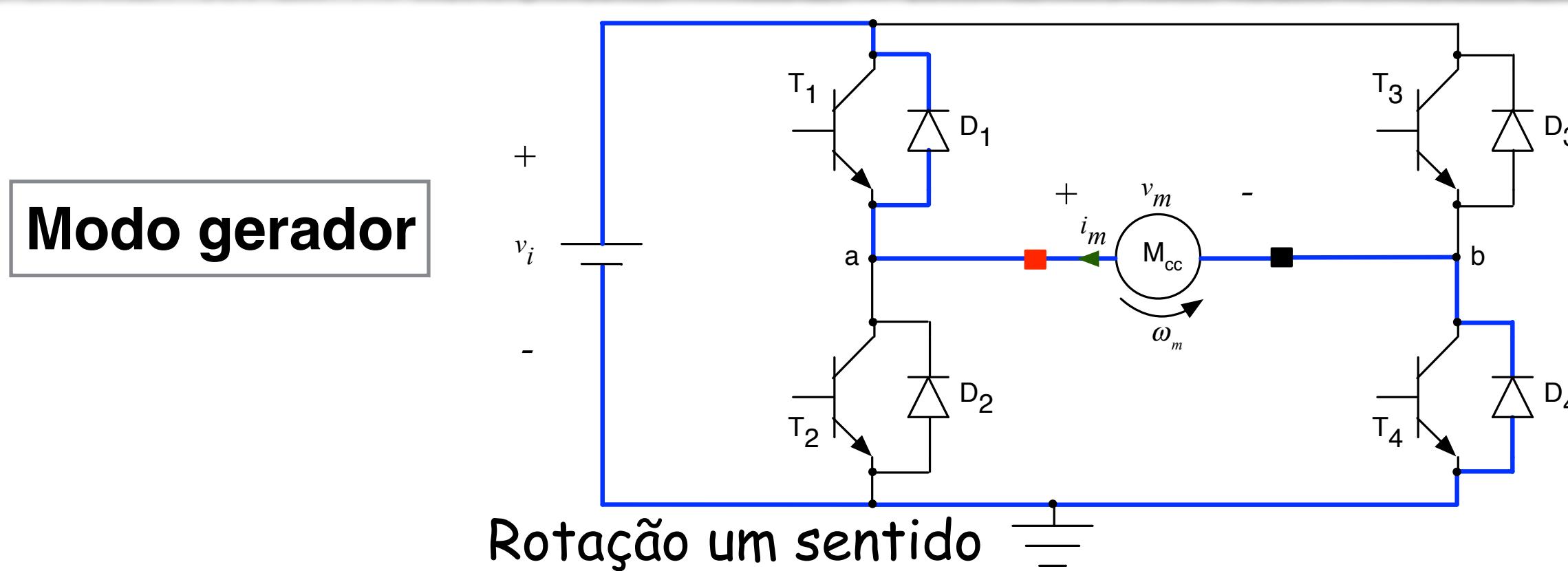
Conversor ponte completa



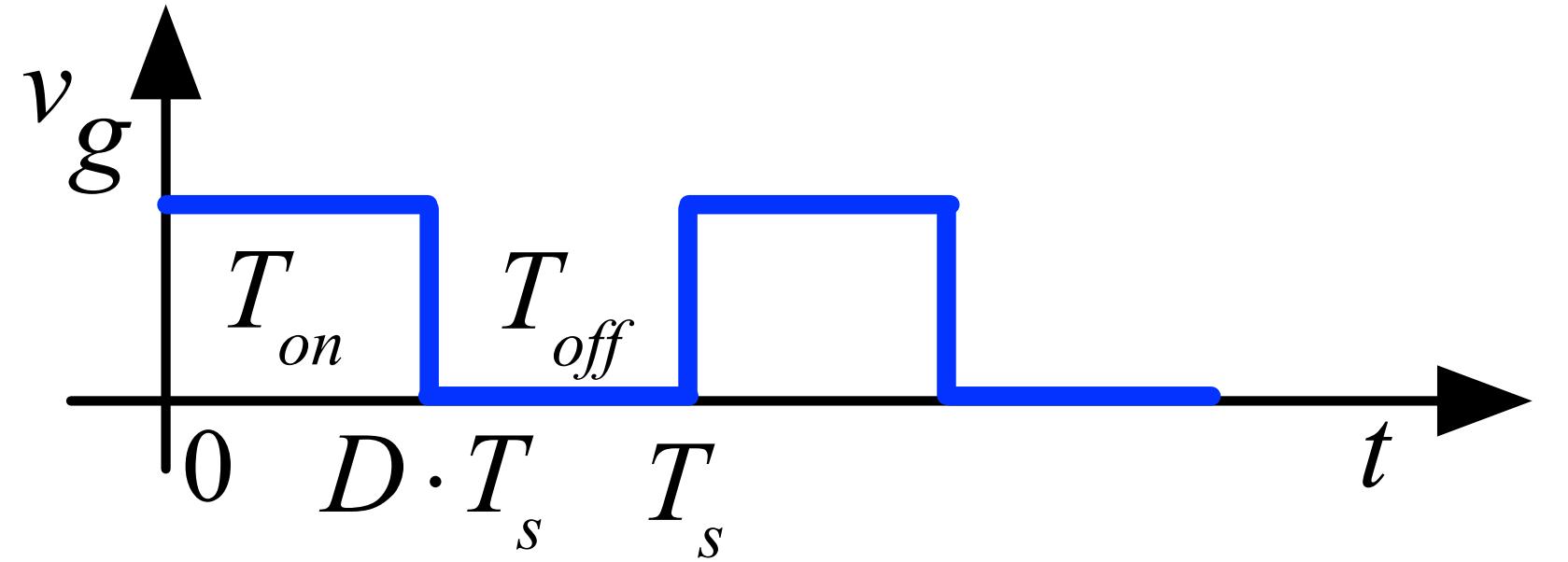
Quadrantes de Operação



Conversor ponte completa



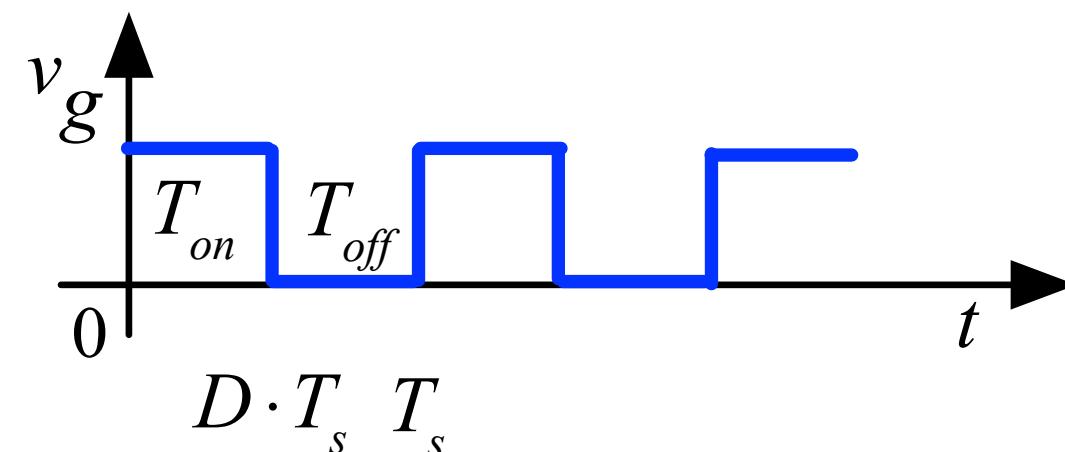
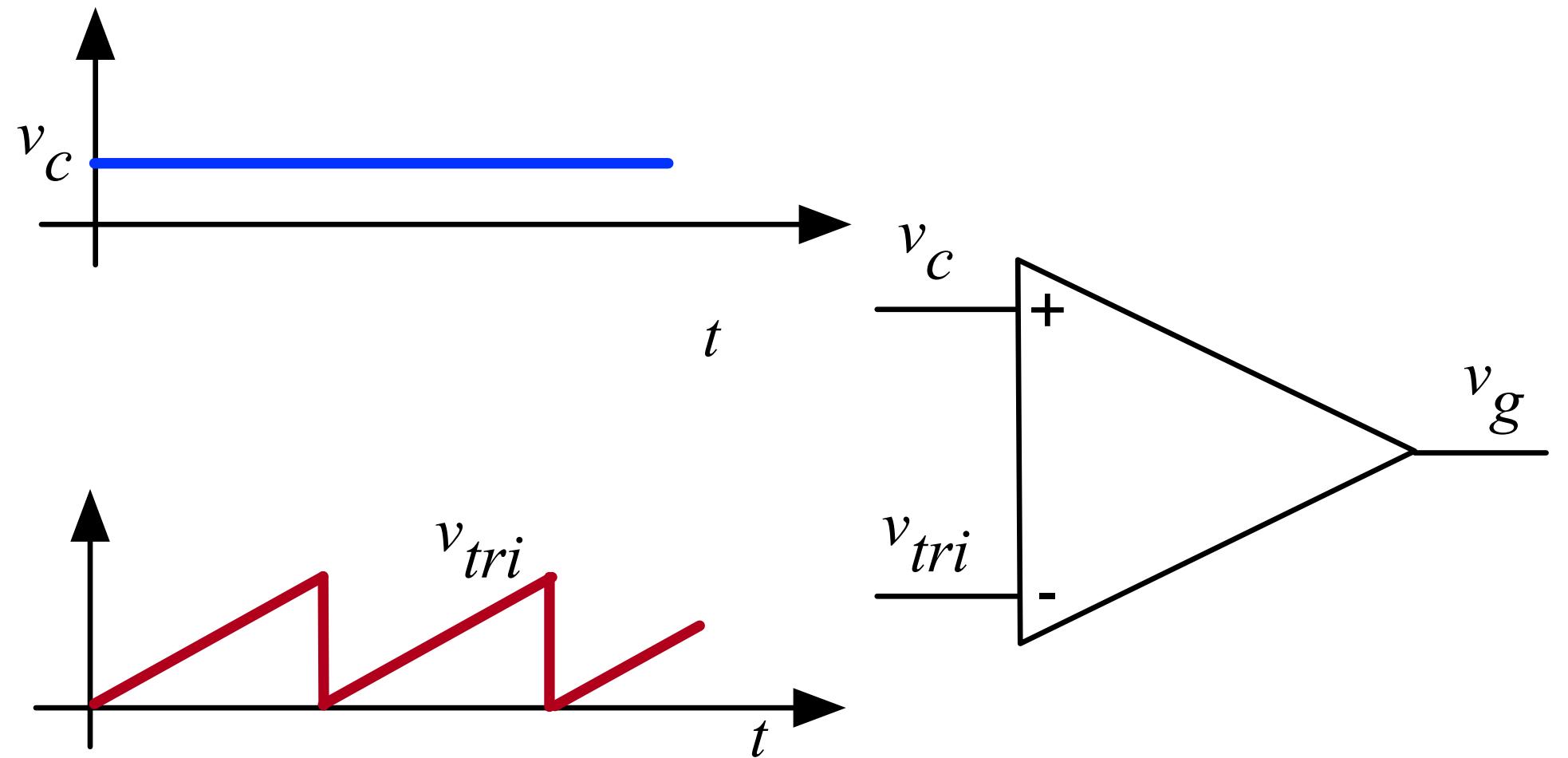
Modulação PWM



$$T_s = \frac{1}{F_s}$$

$$T_{on} = D \cdot T_s$$

$$T_{off} = T_s - T_{on} = T_s - D \cdot T_s = (1 - D) \cdot T_s$$



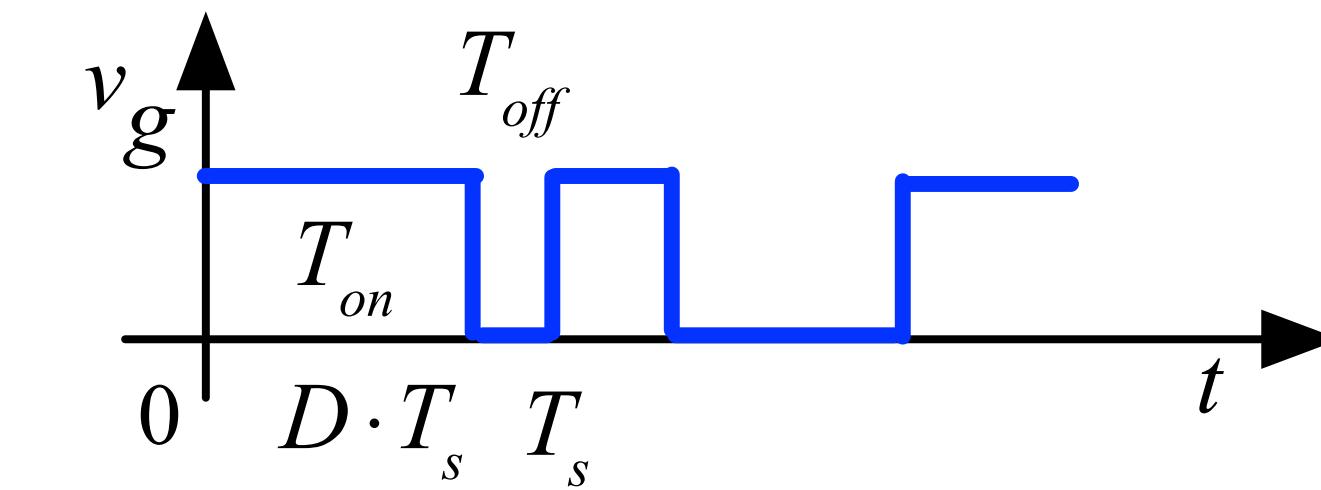
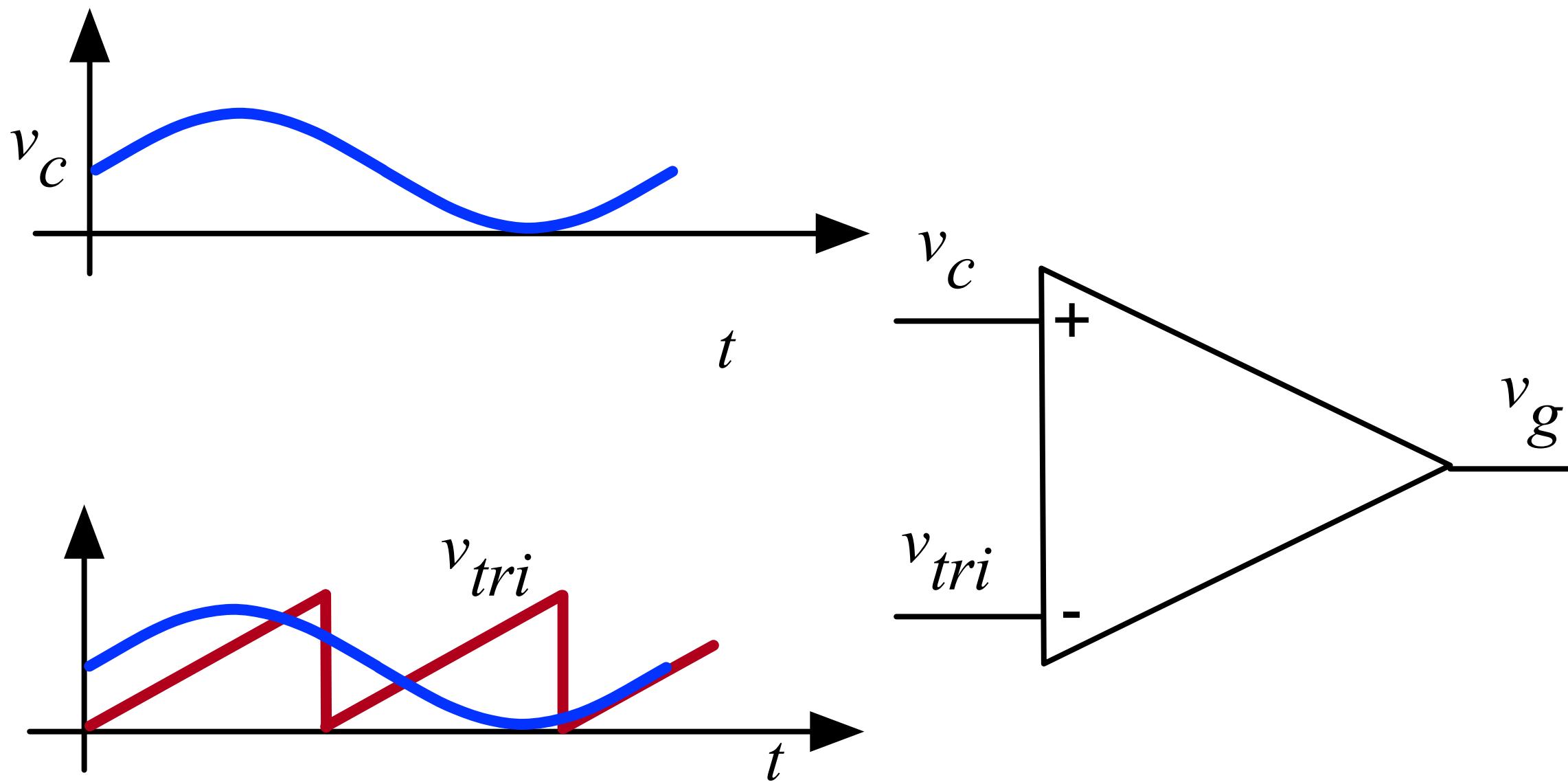
$$D = \frac{T_{on}}{T_s}$$

$$D = \frac{V_c}{V_{tri}}$$

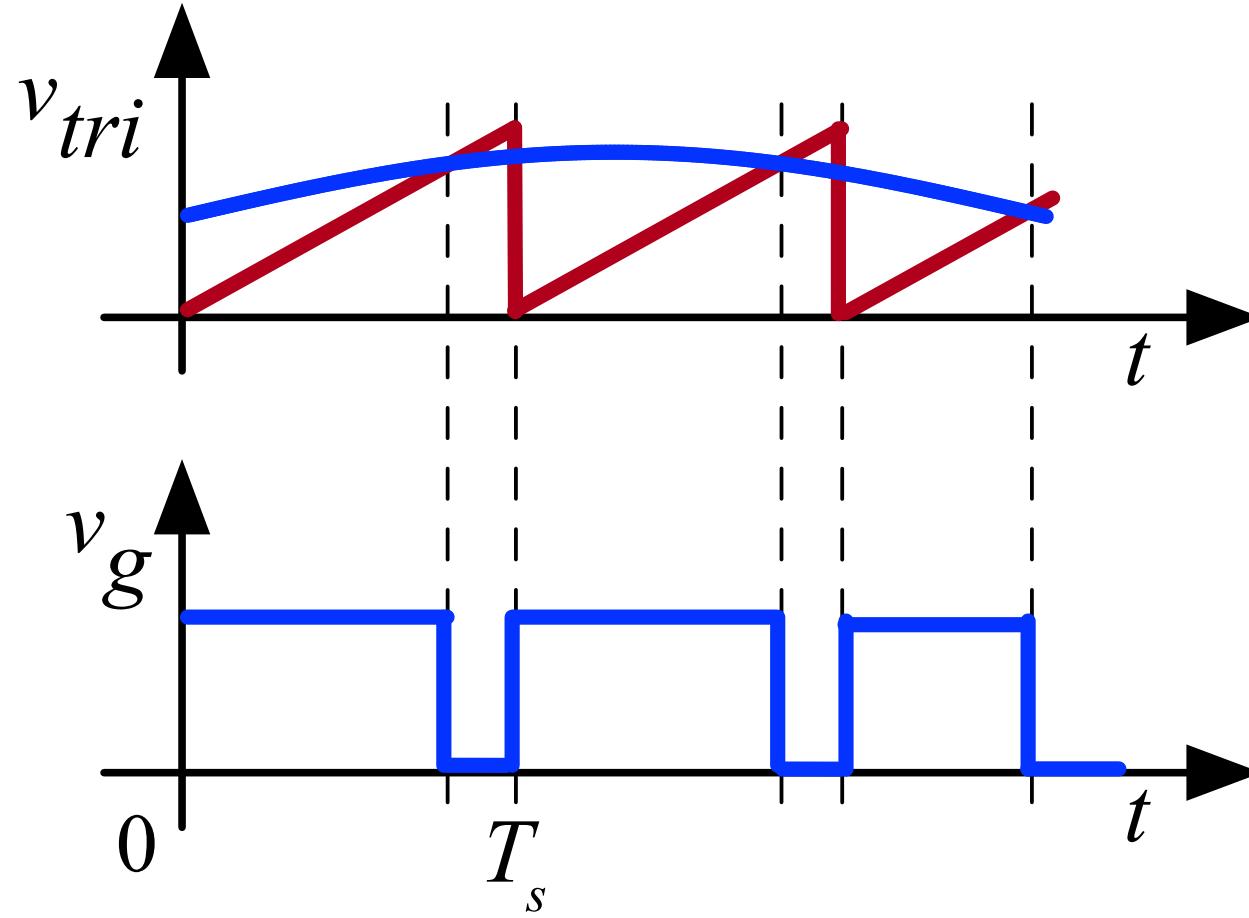
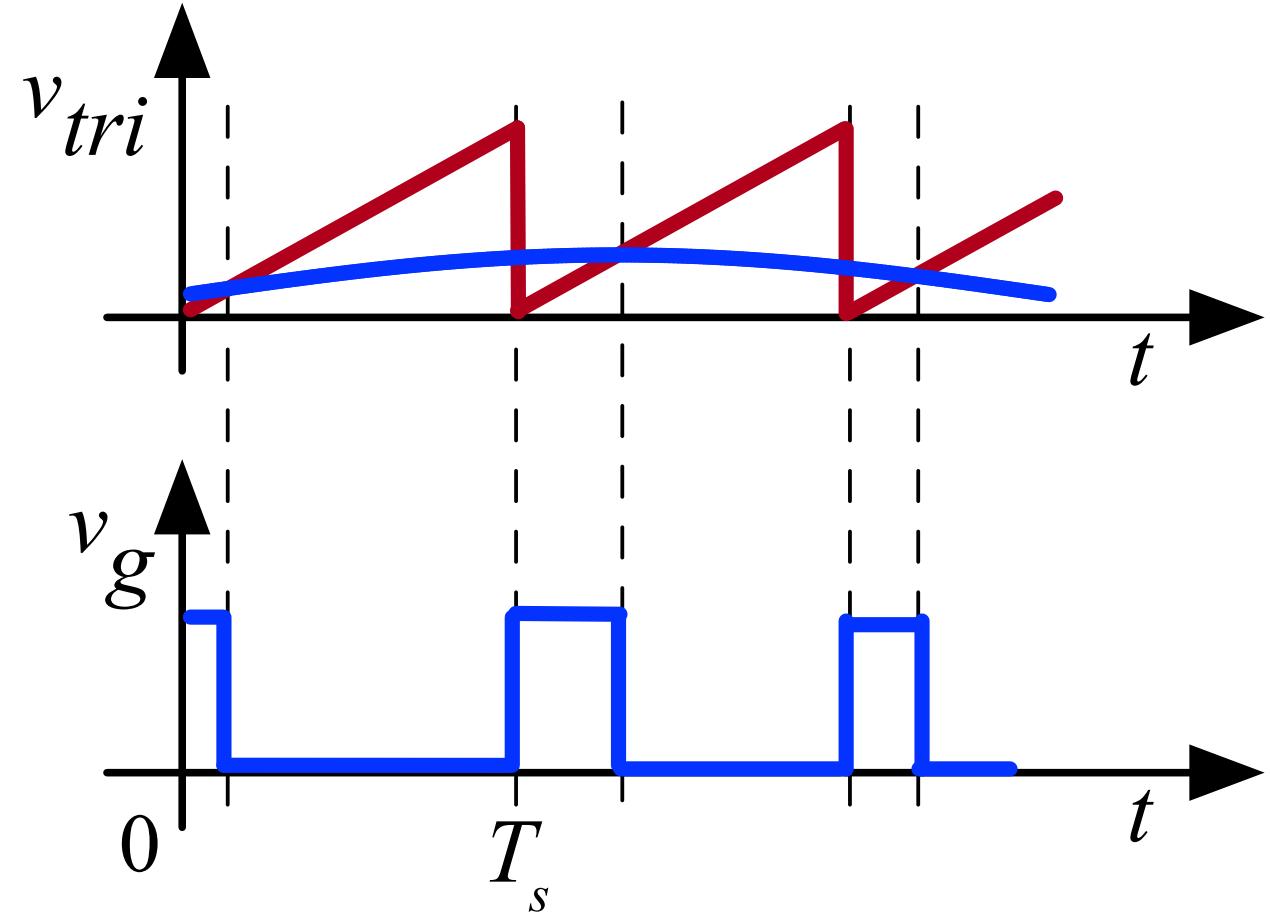
Modulação PWM Senoidal

$$d(t) = \frac{v_c(t)}{v_{tri}(t)} = \frac{V_c \cdot \text{seno}(t)}{V_{tri}} = \frac{V_c}{V_{tri}} \cdot \text{seno}(t)$$

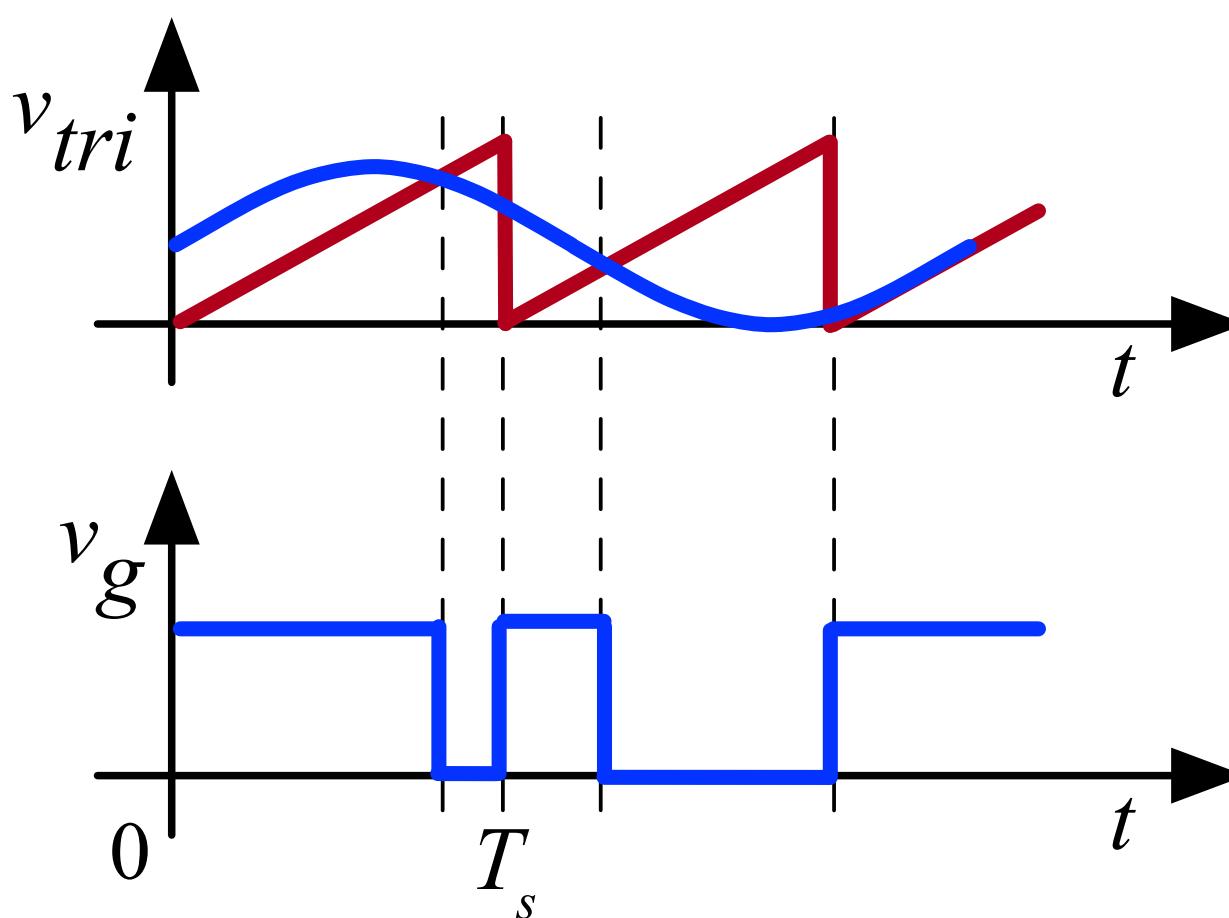
$$IM = \frac{V_c}{V_{tri}} \rightarrow d(t) = IM \cdot \text{seno}(t)$$



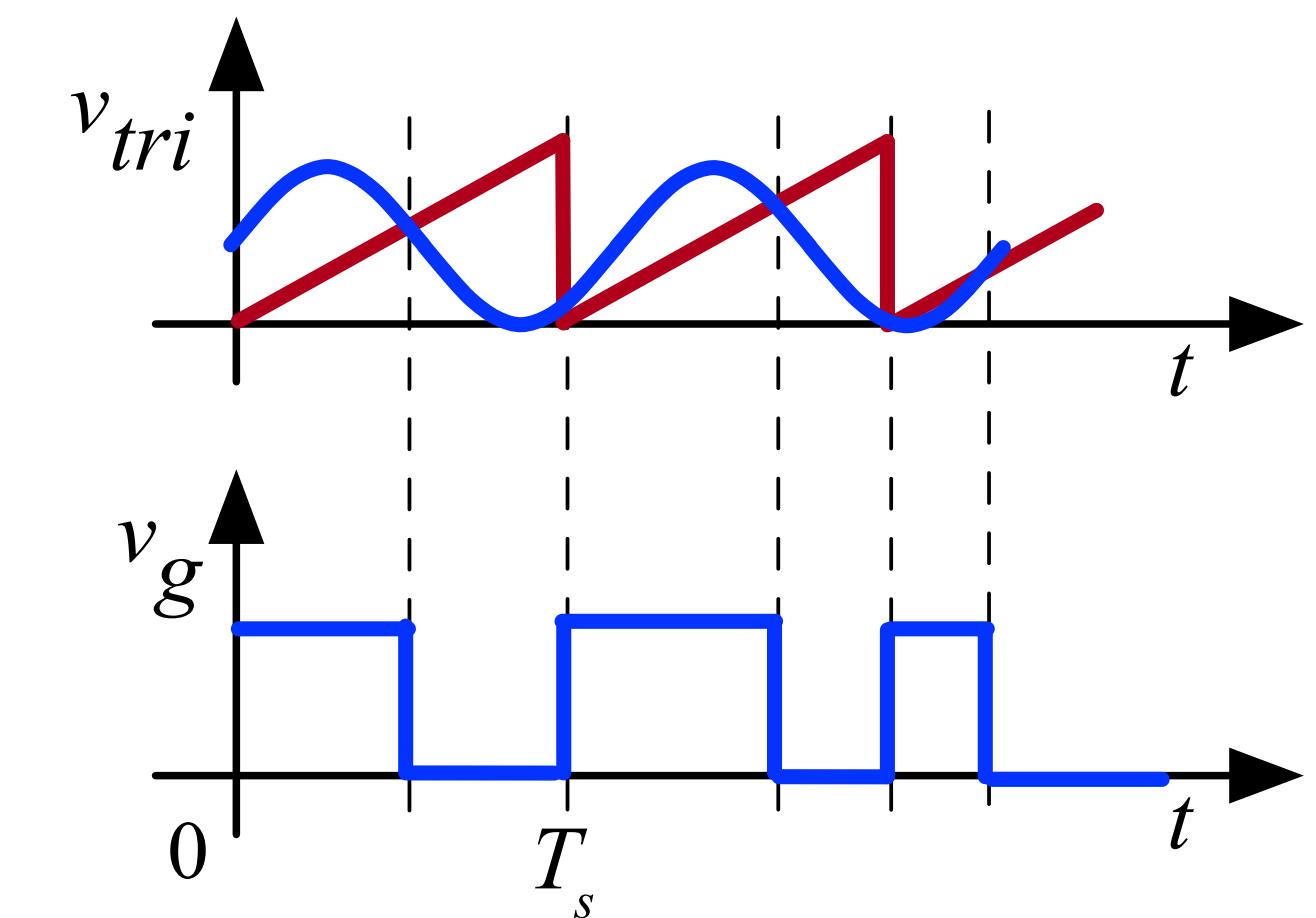
Modulação PWM Senoidal



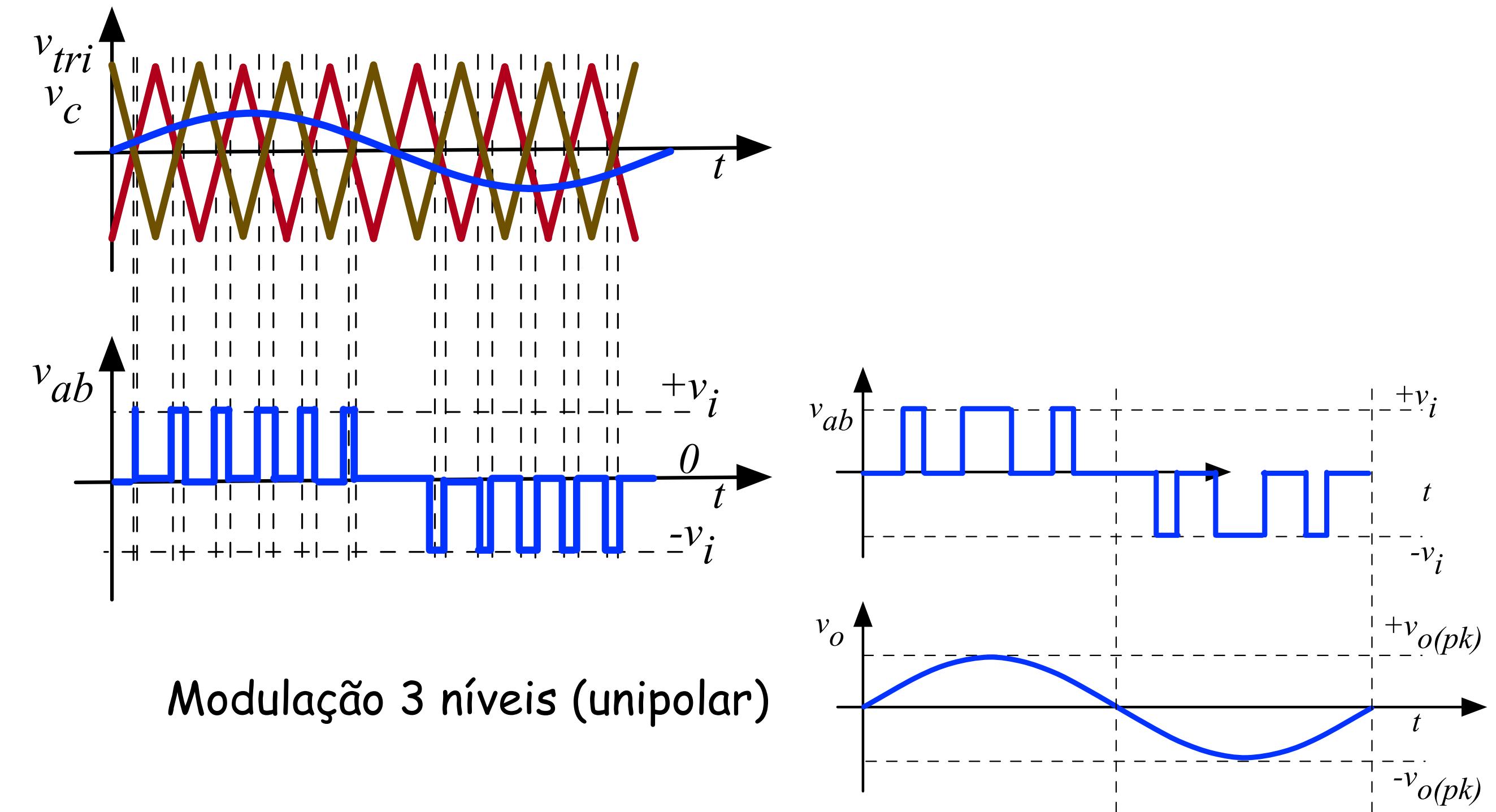
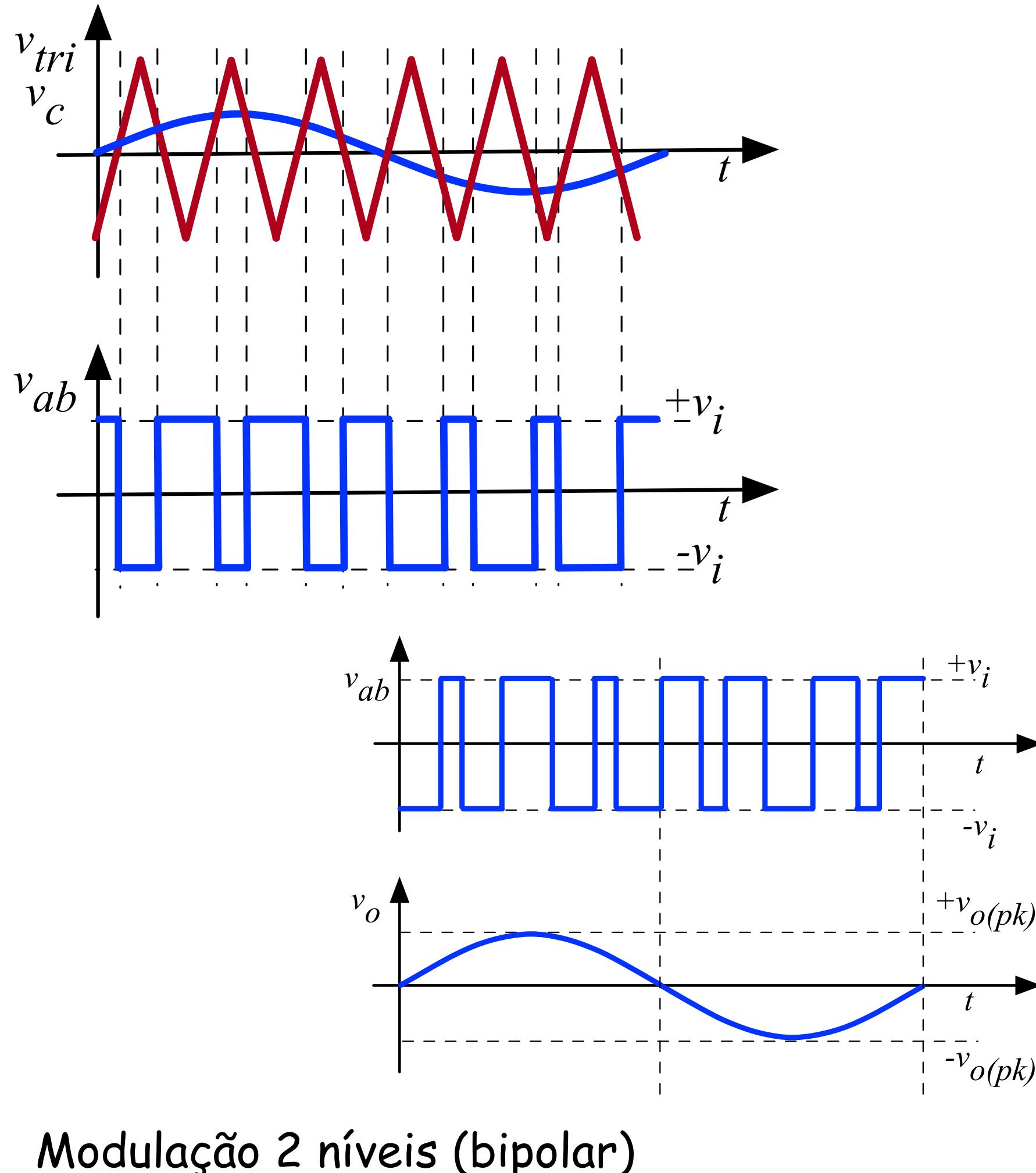
Modificação na amplitude da modulante



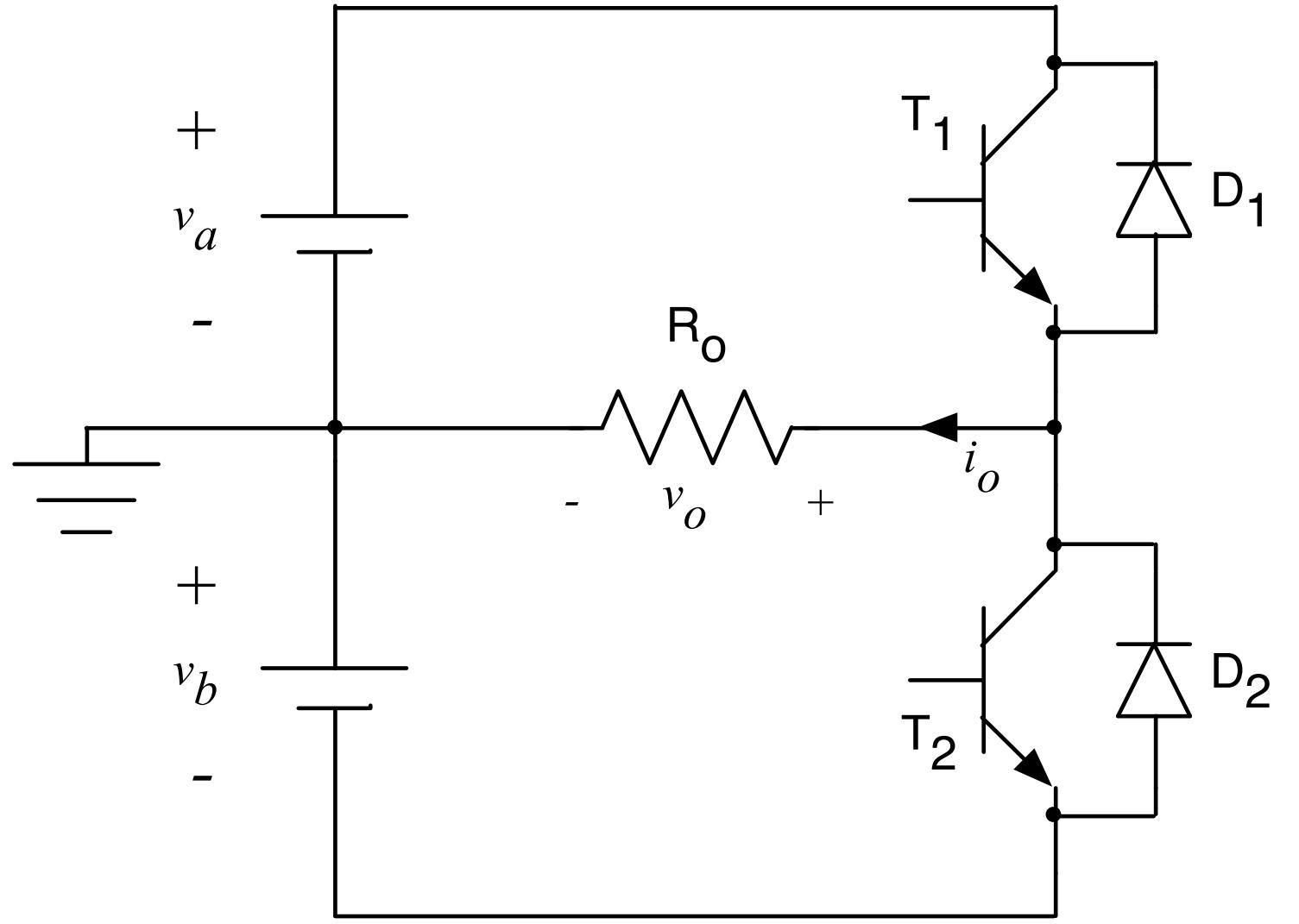
Modificação na frequência da modulante



Modulação PWM Senoidal



Princípio de funcionamento



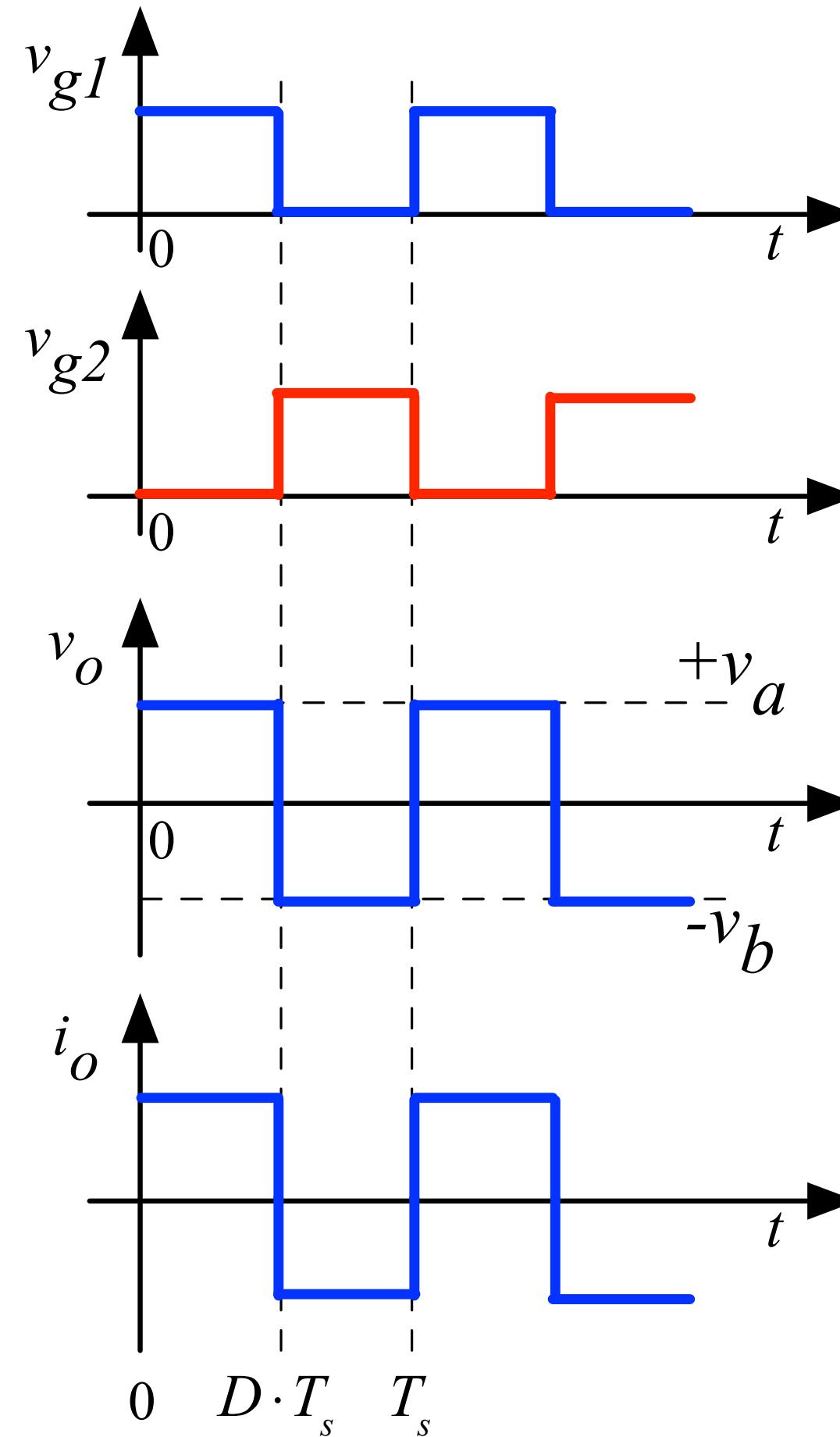
$$\begin{cases} v_a = V_a \\ v_b = V_b \end{cases} \rightarrow \text{definidas}$$

$$V_a = V_b = \frac{V_i}{2}$$

$$\begin{aligned} +V_{o(\max)} &= V_{a(\max)} \\ -V_{o(\max)} &= V_{b(\max)} \end{aligned}$$

$$V_o = \frac{1}{T_s} \cdot V_a \cdot D \cdot T_s + \frac{1}{T_s} \cdot (-V_b) \cdot (1-D) \cdot T_s$$

$$V_o = V_a \cdot D - V_b \cdot (1-D)$$

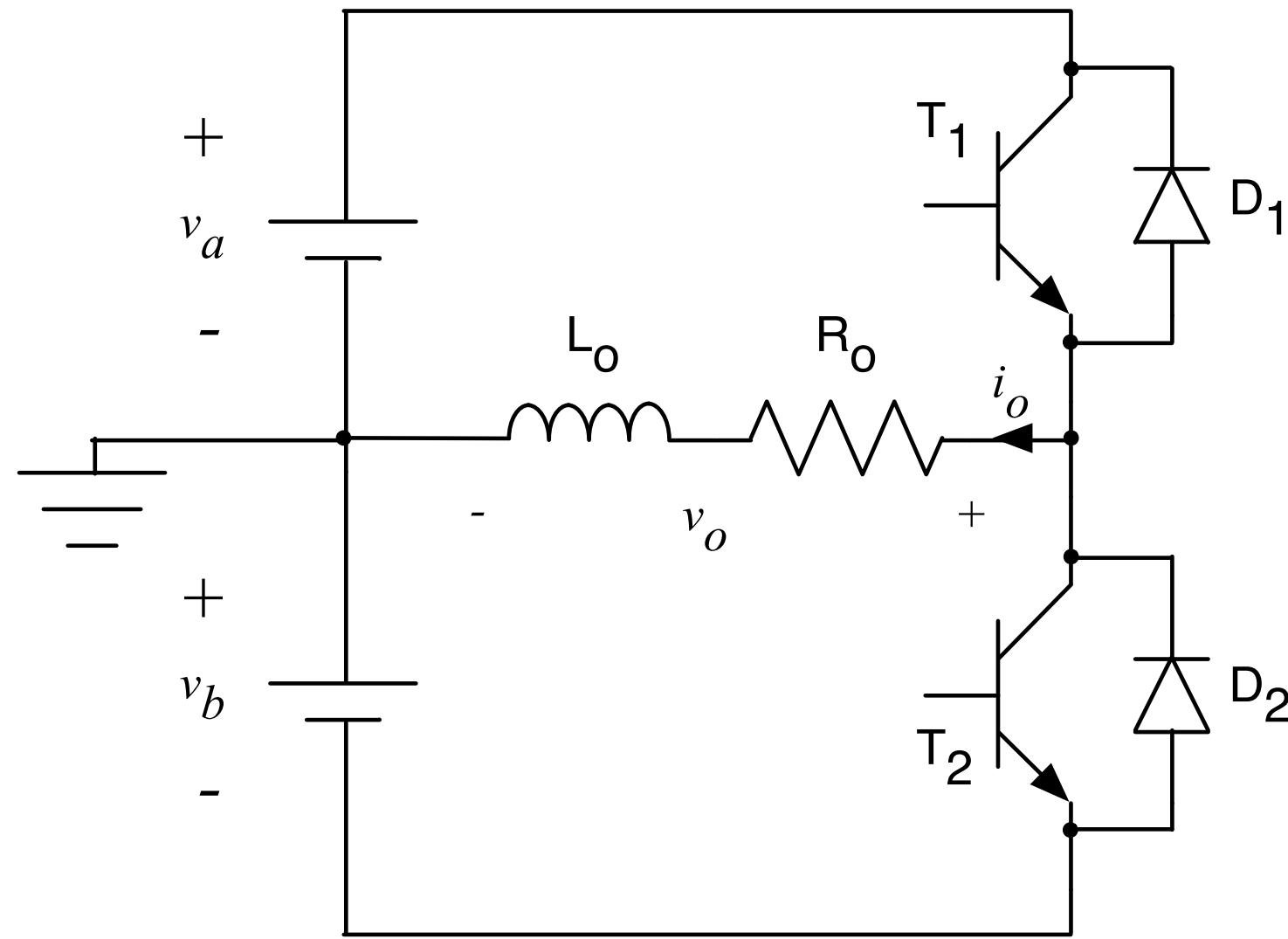


$$V_o = \frac{V_i}{2} \cdot (2 \cdot D - 1)$$

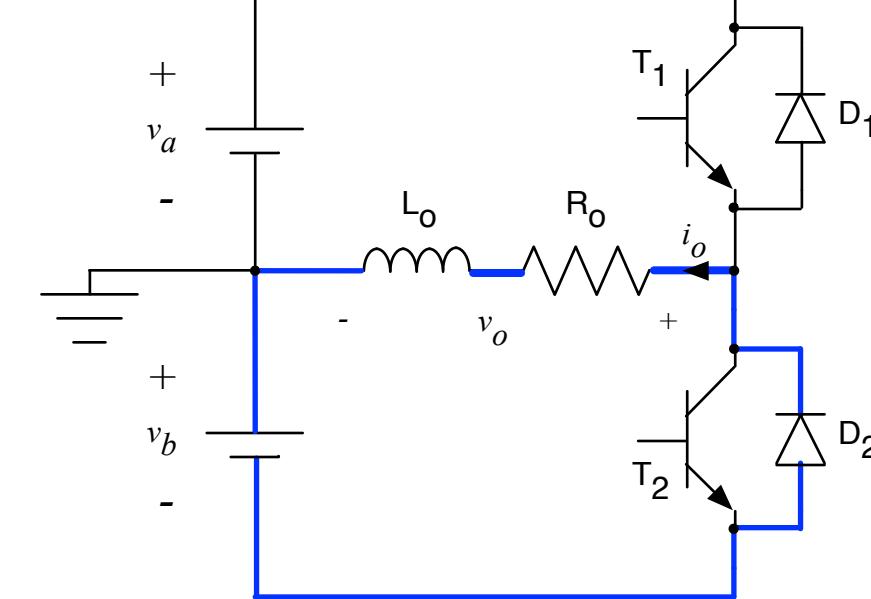
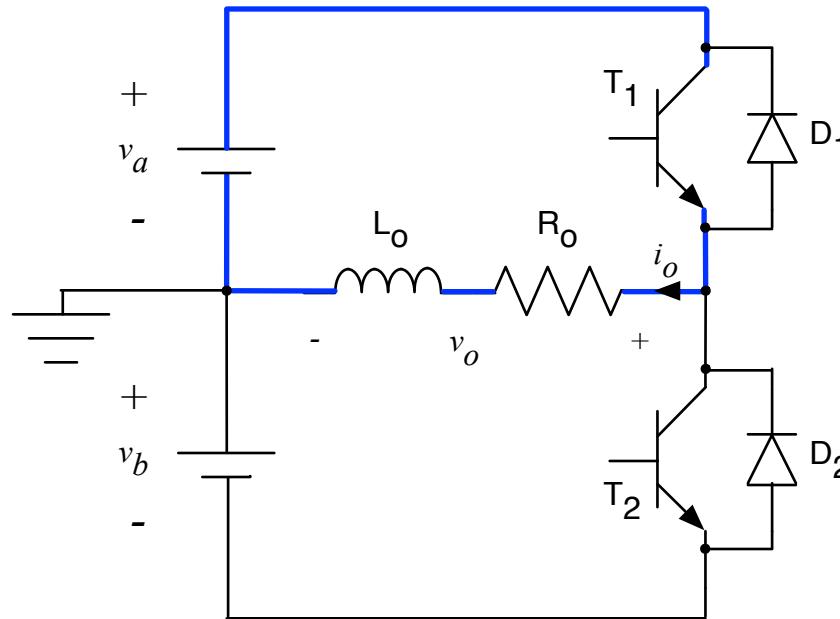
$$V_o = \begin{cases} D = 0 \rightarrow -\frac{V_i}{2} \\ D = 0,5 \rightarrow 0 \\ D = 1 \rightarrow +\frac{V_i}{2} \end{cases}$$

$$D = \frac{1}{2} + \frac{V_o}{V_i}$$

Princípio de funcionamento

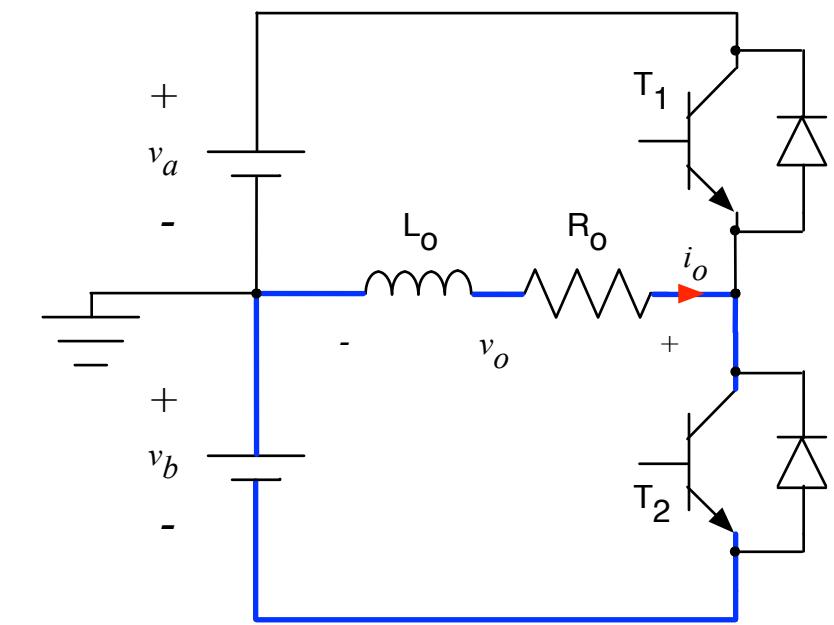


Primeira etapa

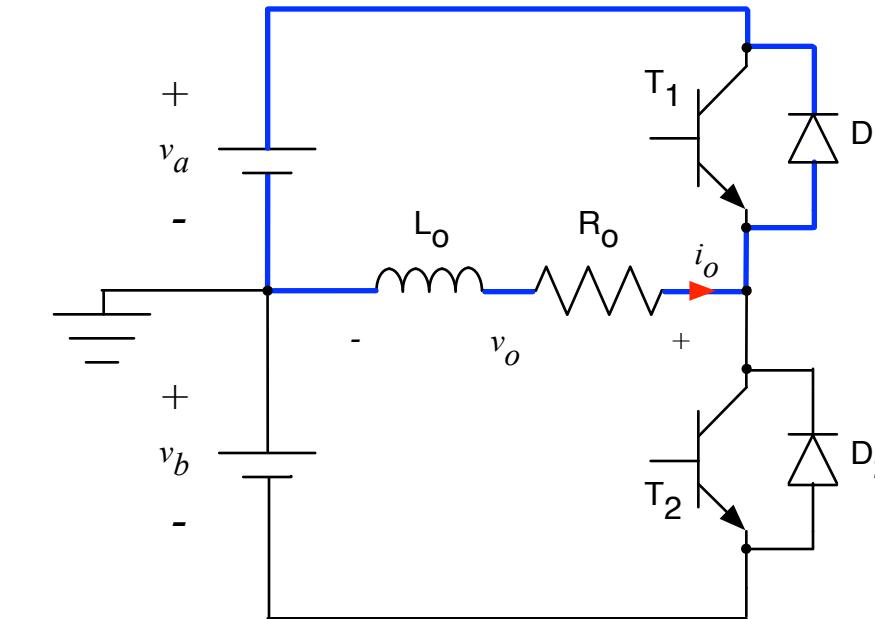


Segunda etapa

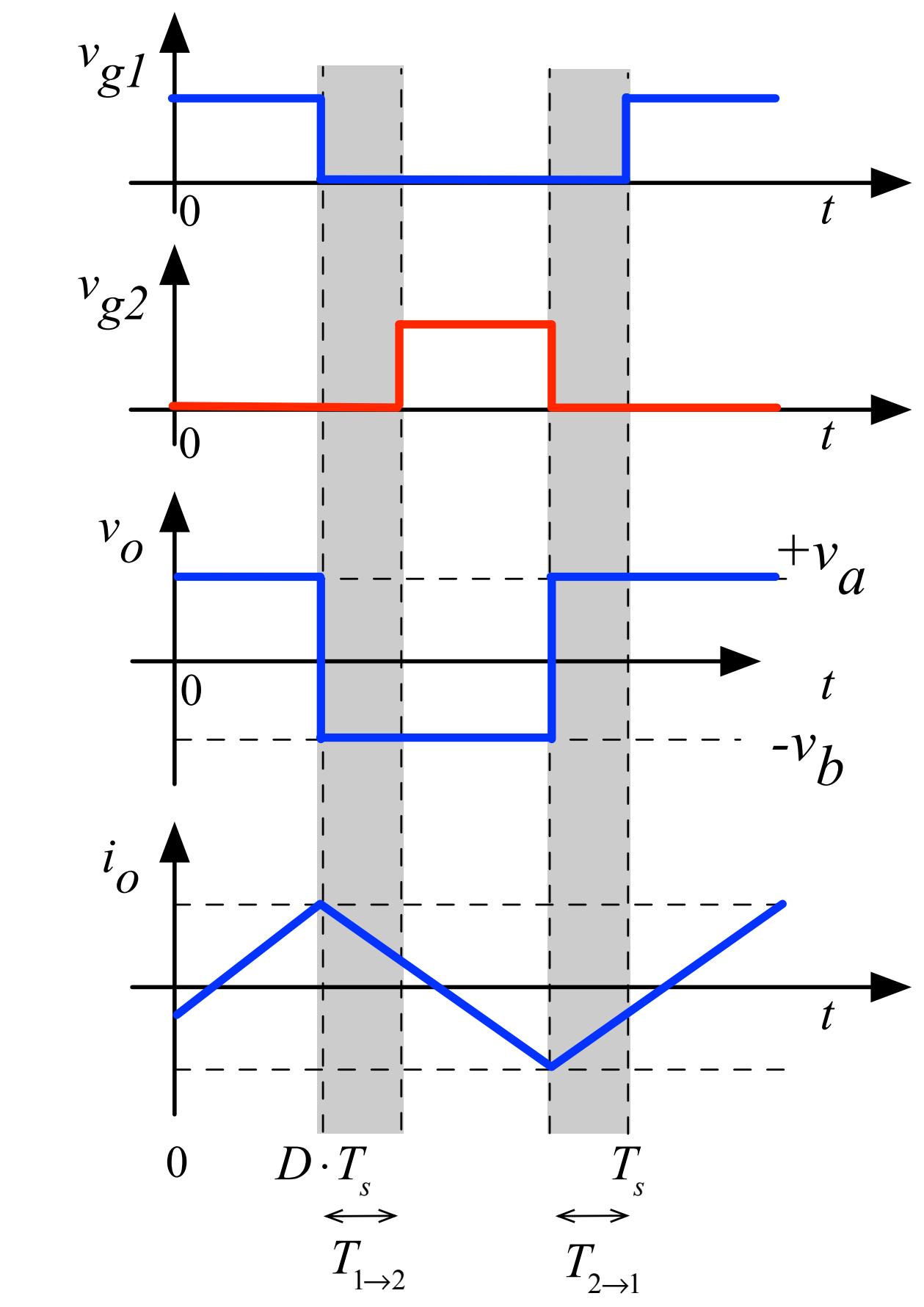
Tempo morto



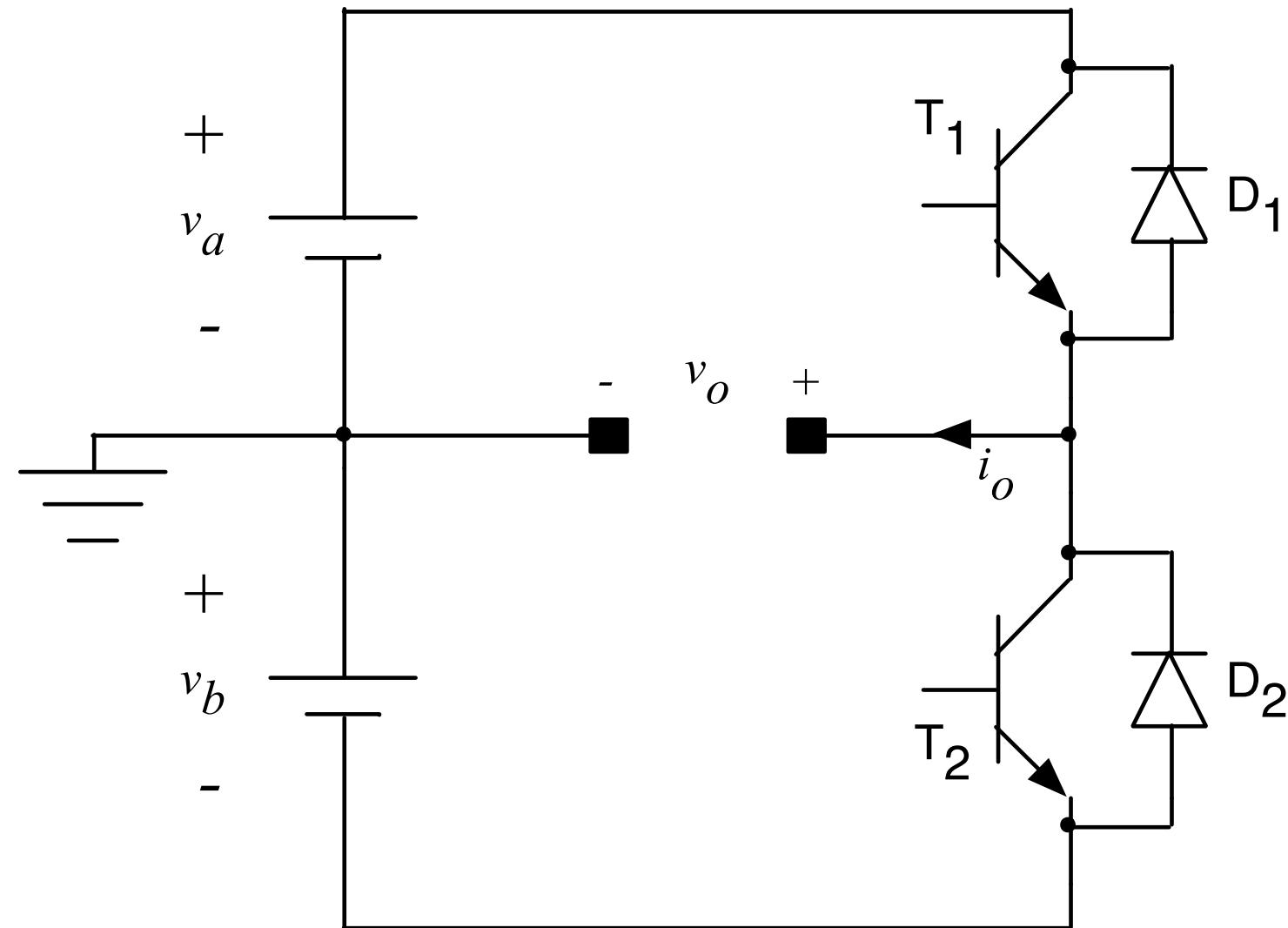
Terceira etapa



Quarta etapa

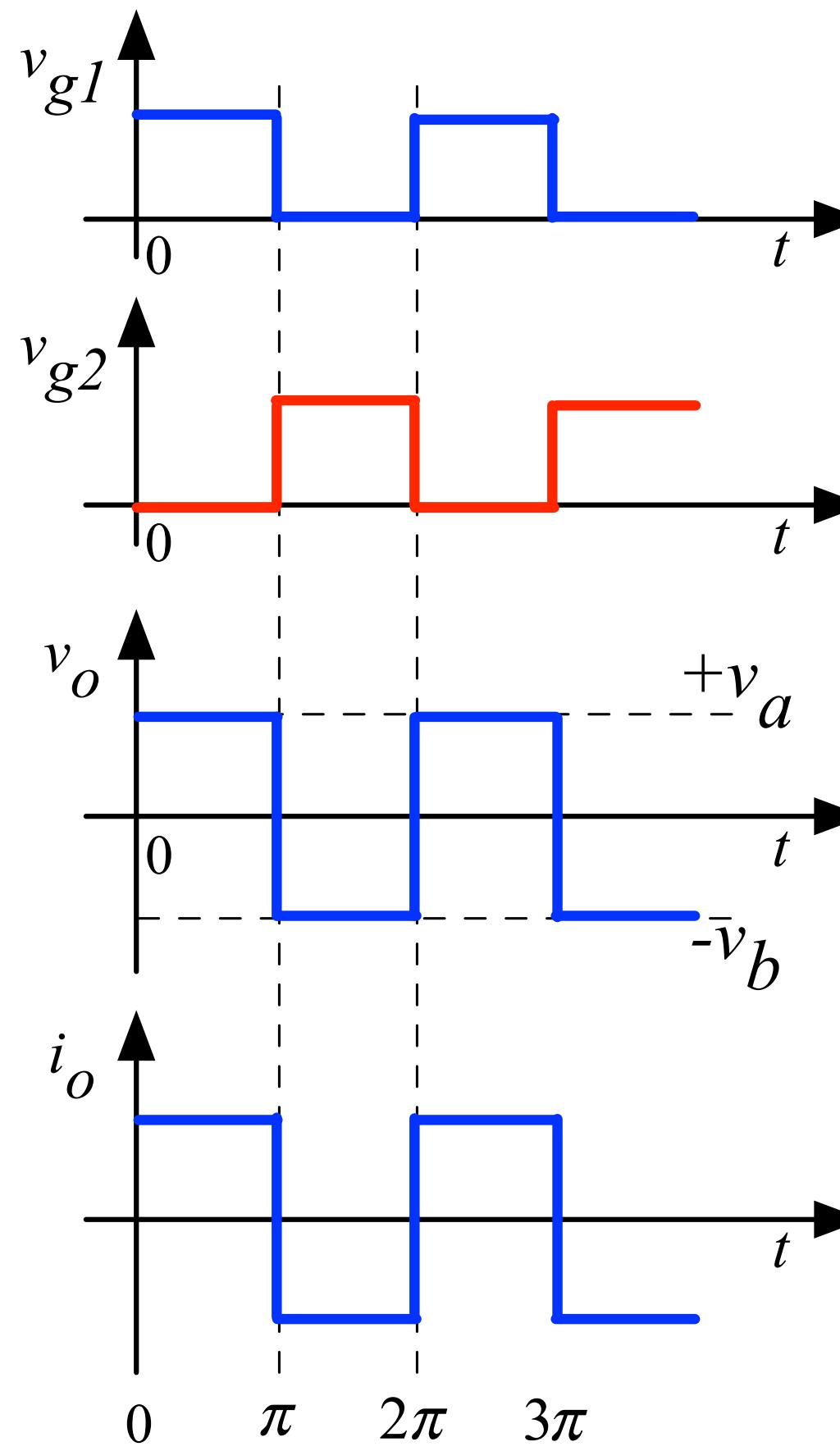


Conversor Meia Ponte

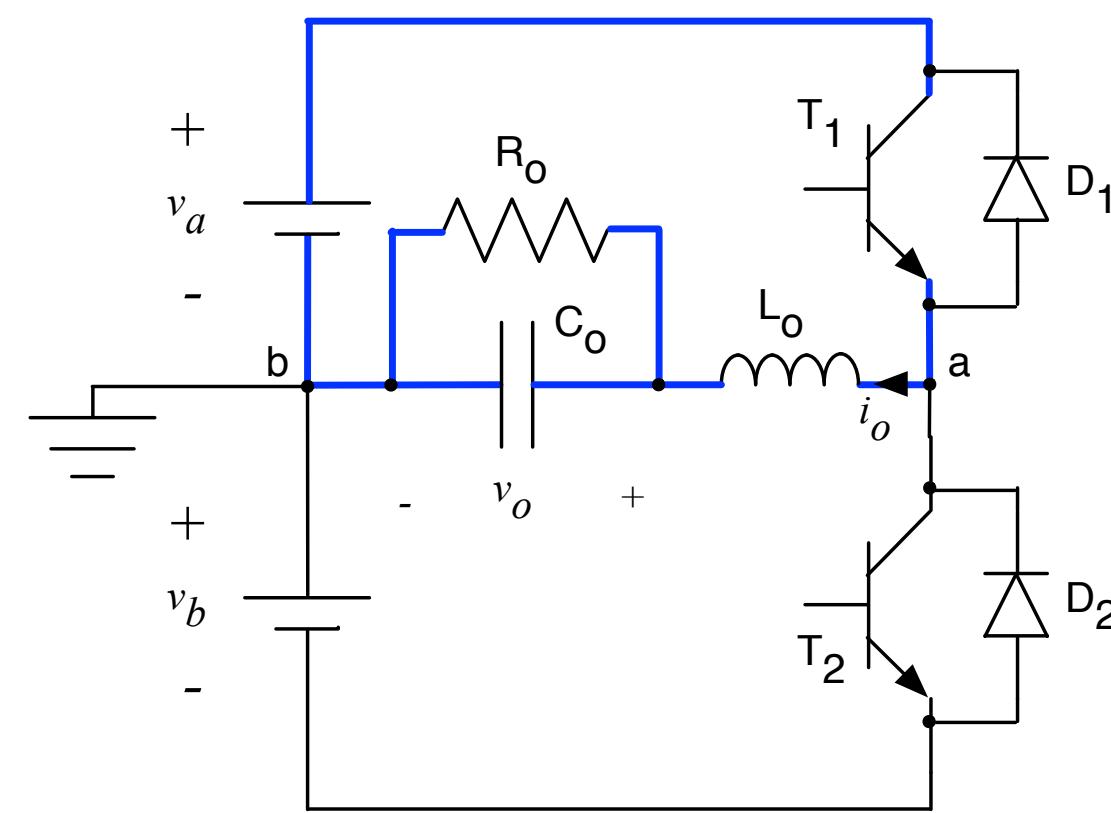
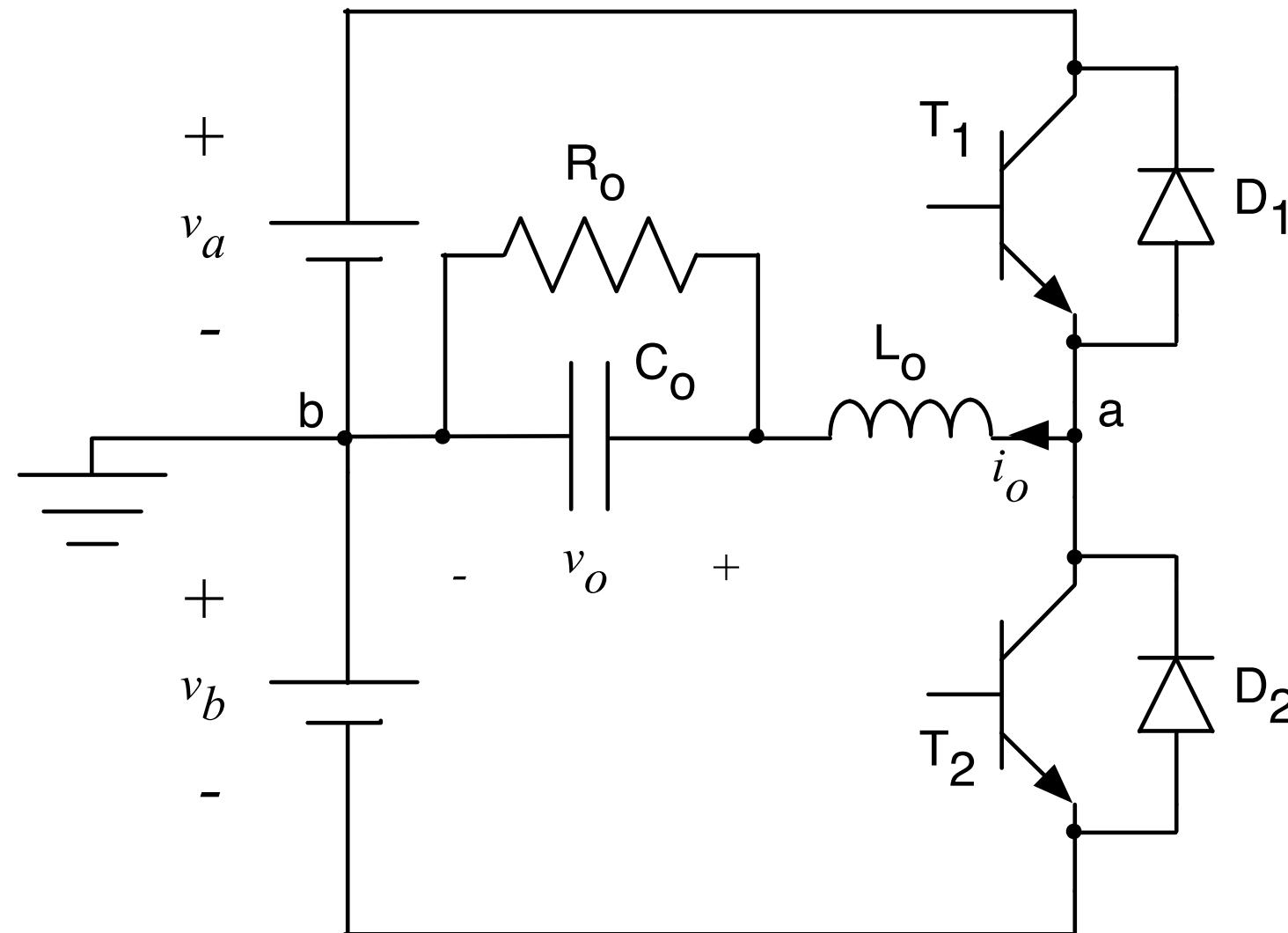


$$V_{o(ef)} = \frac{V_i}{2} \rightarrow V_a = V_b = \frac{V_i}{2}$$

Onda Quadrada

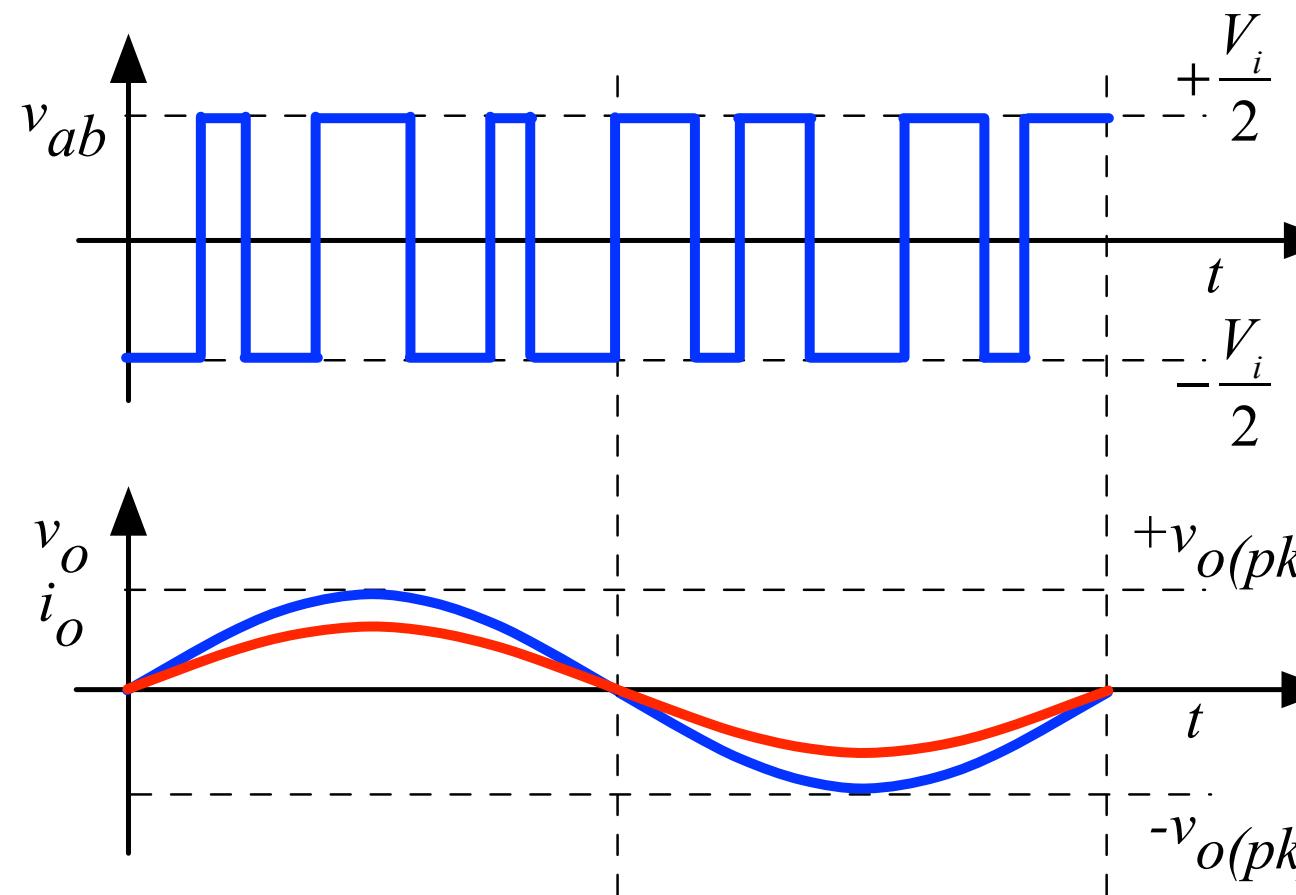


Conversor Meia Ponte



Primeira etapa

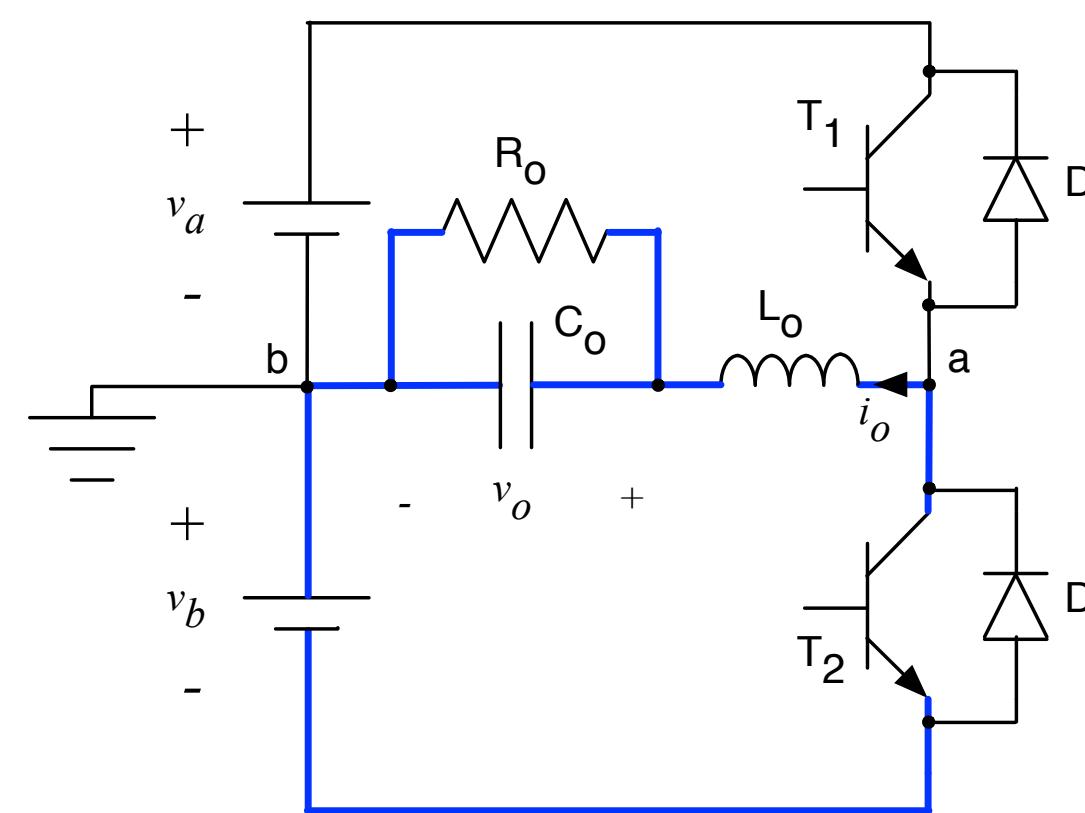
PWM Senoidal



$$V_a = V_b = \frac{V_i}{2}$$

$$V_{Lo} = 0 \rightarrow V_o = V_{ab} \rightarrow V_o = \frac{V_i}{2} \cdot (2 \cdot D - 1)$$

$$v_o(t) = V_{o(pk)} \cdot \operatorname{seno}(t)$$

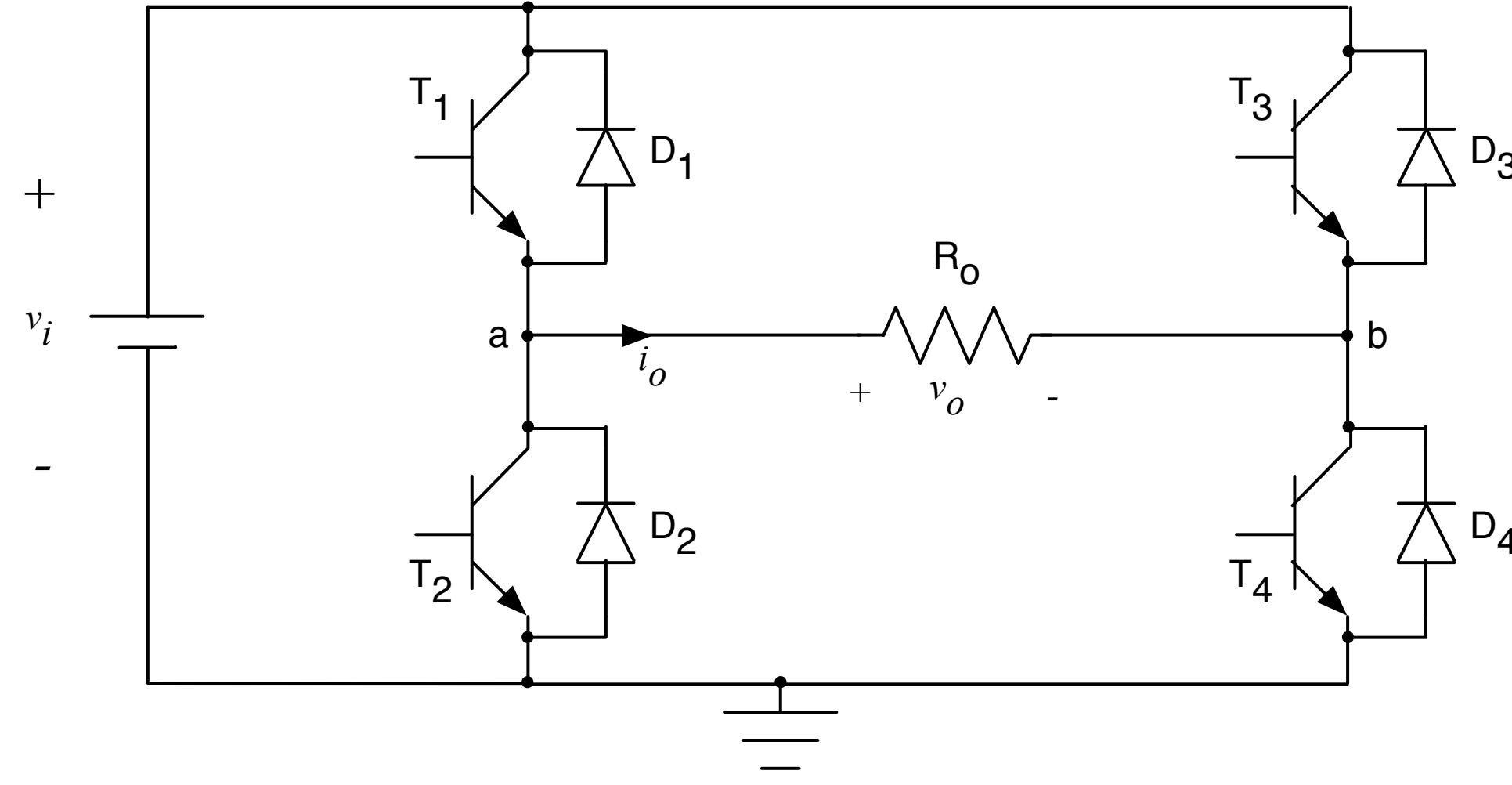


Segunda etapa

$$d(t) = \frac{1}{2} + \frac{V_{o(pk)} \cdot \operatorname{seno}(t)}{V_i} \rightarrow d(t) = \frac{1}{2} + \frac{V_{o(pk)}}{V_i} \cdot \operatorname{seno}(t)$$

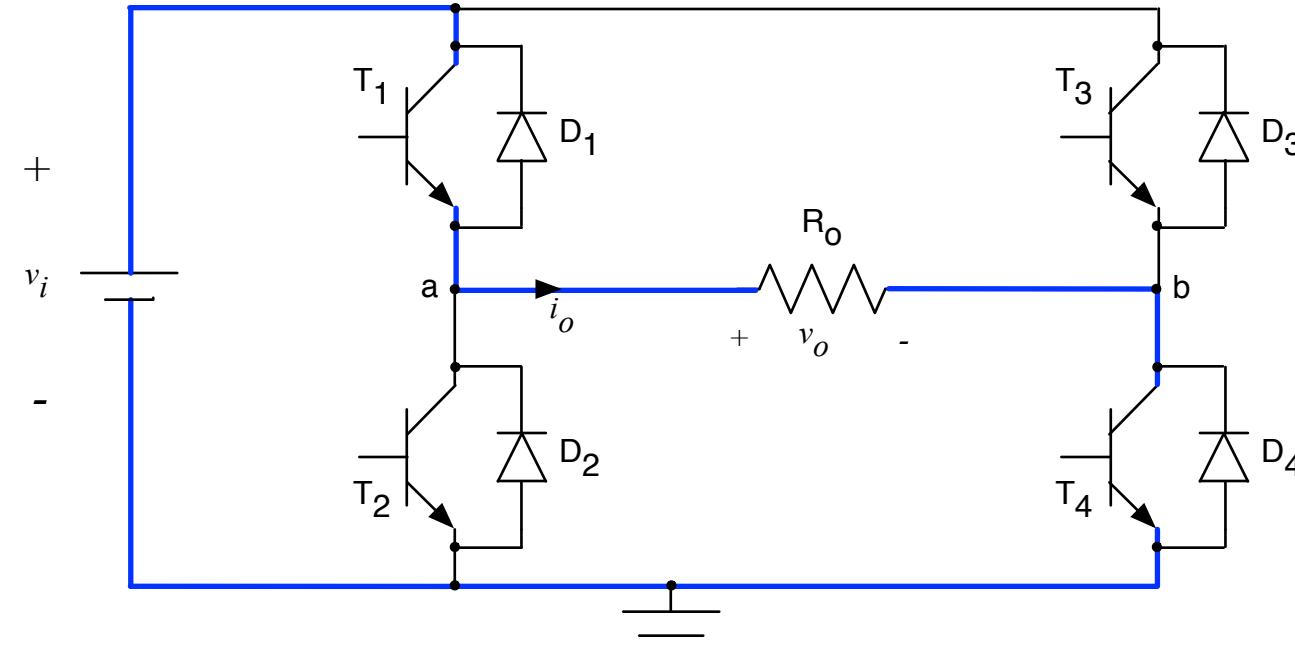
$$IM = \frac{V_{o(pk)}}{V_i} \rightarrow d(t) = \frac{1}{2} + IM \cdot \operatorname{seno}(t)$$

Conversor Ponte Completa

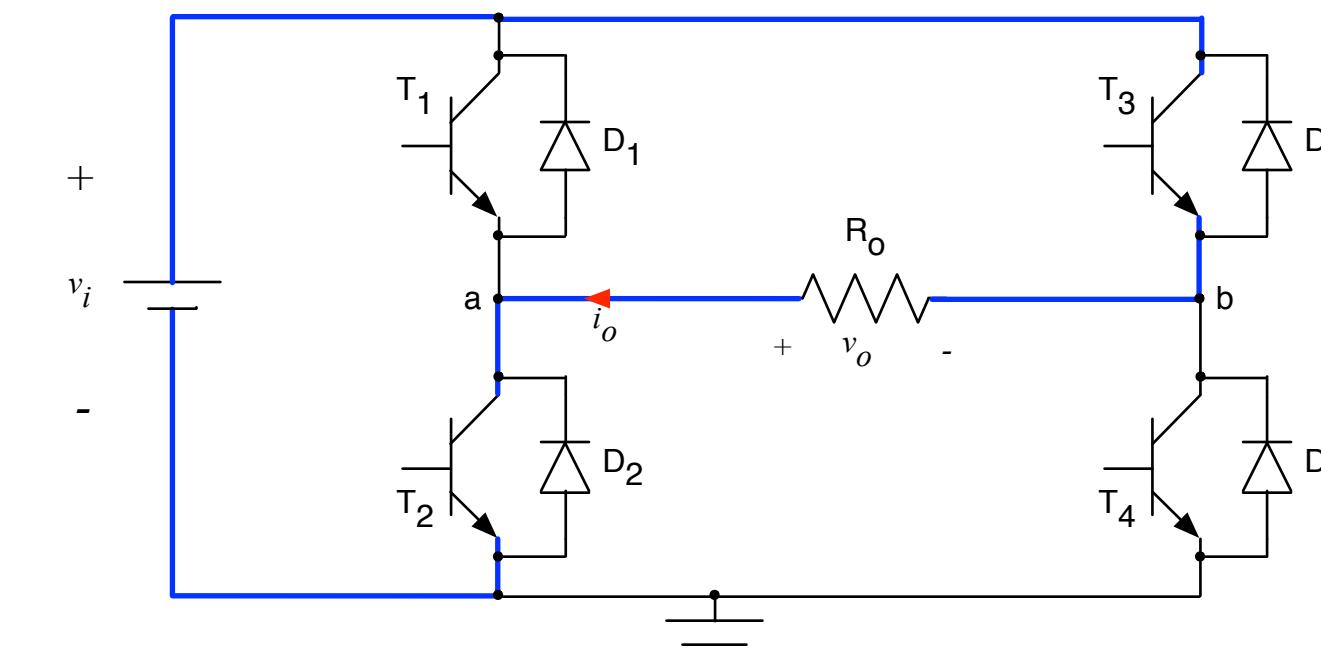


Onda Quadrada

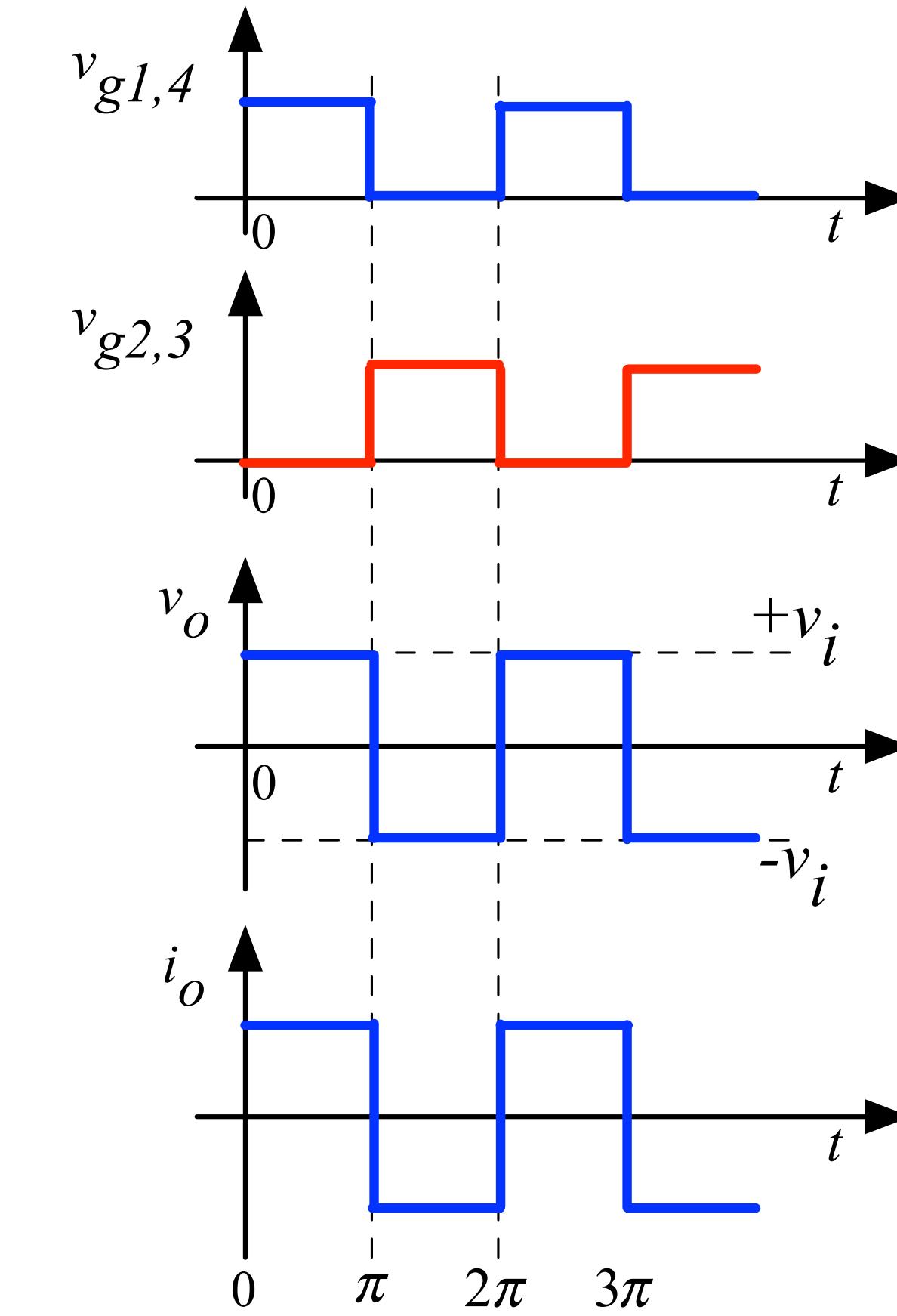
$$V_{o(ef)} = V_i$$



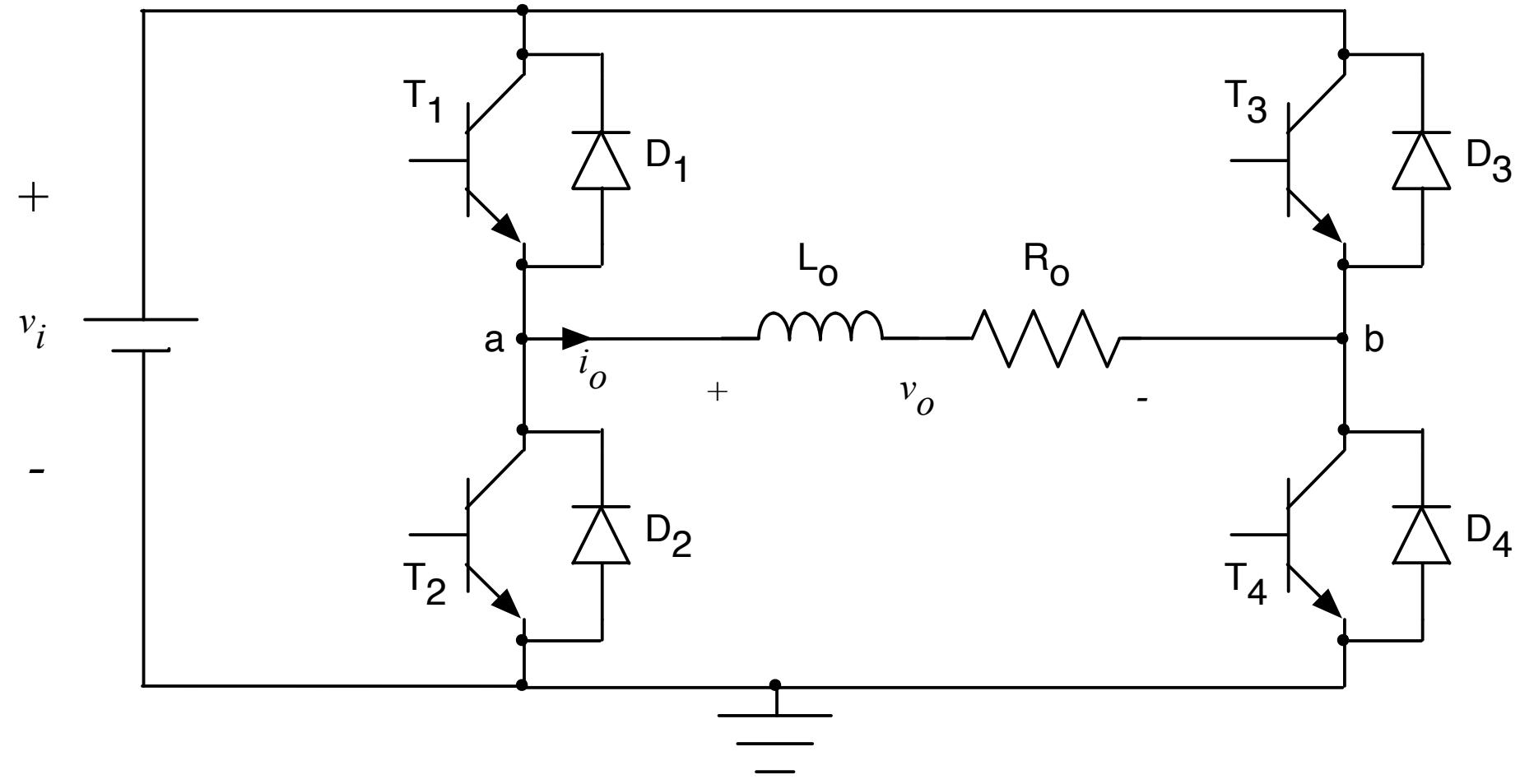
Primeira etapa



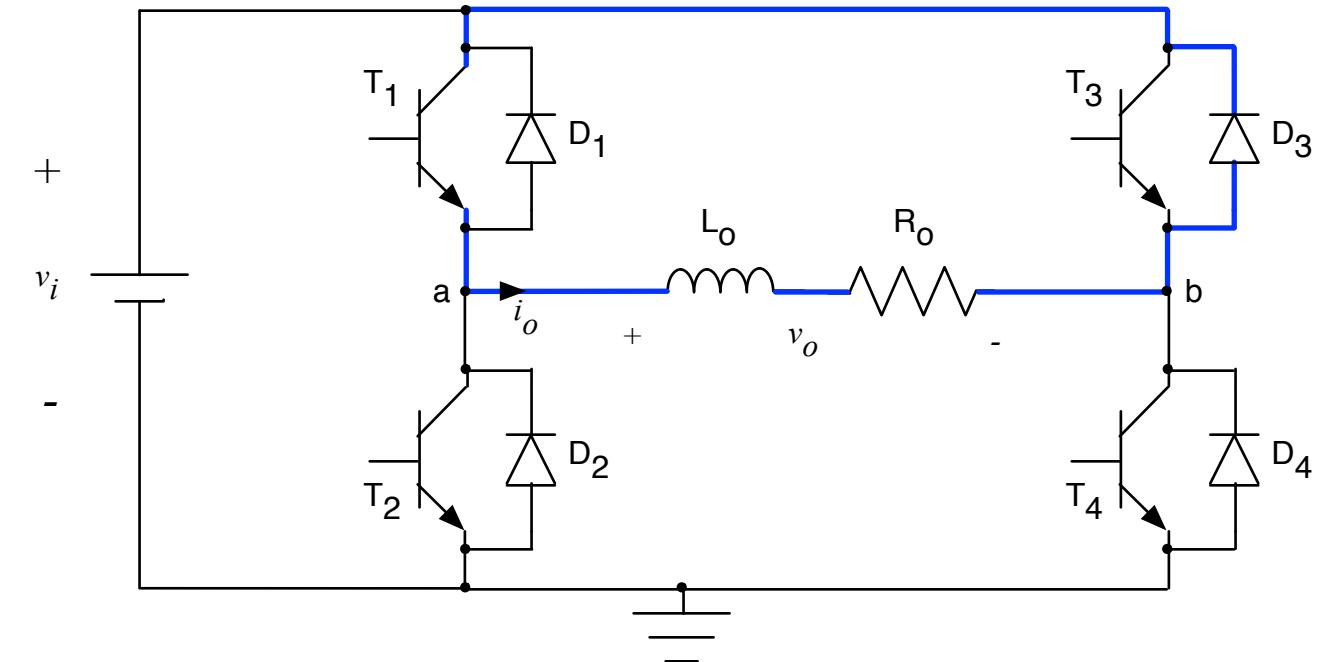
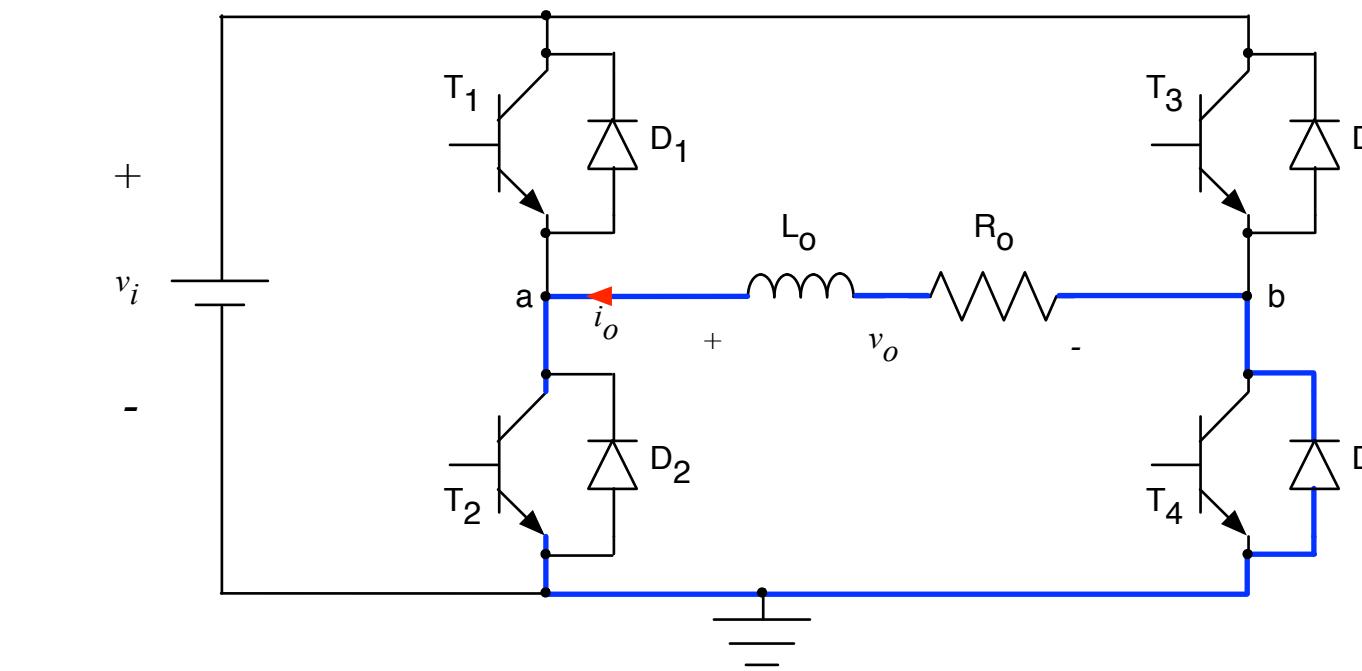
Segunda etapa



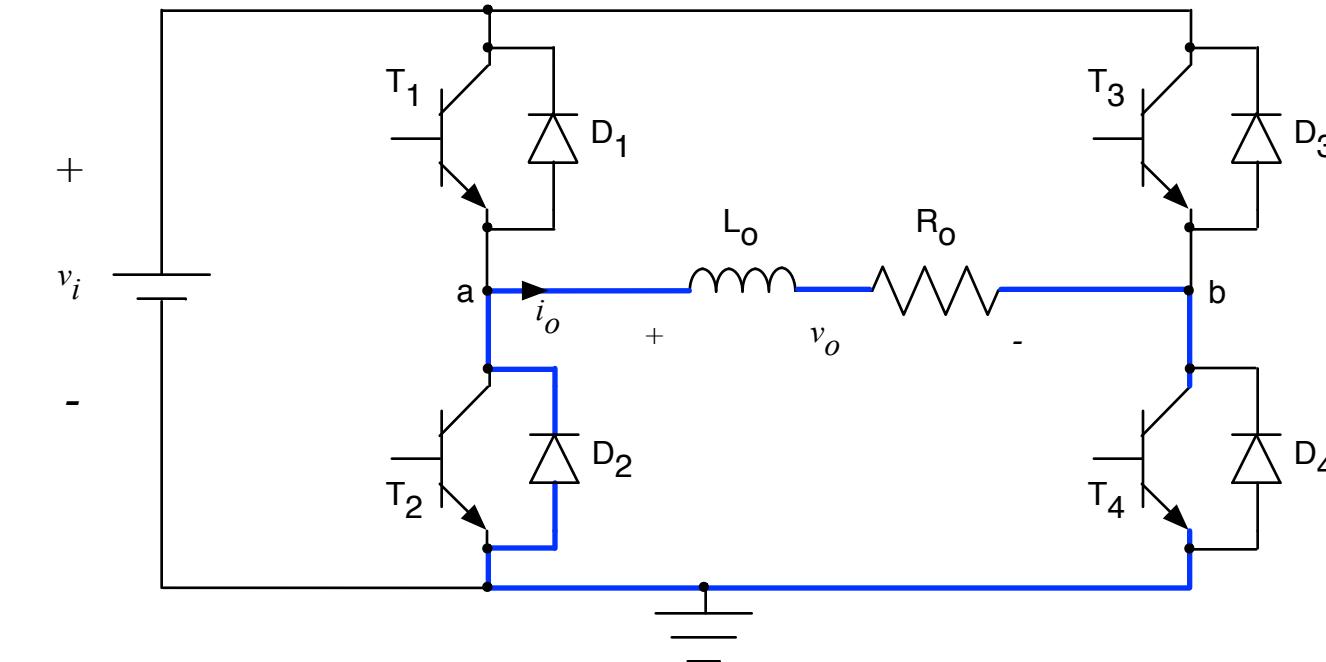
Conversor Ponte Completa



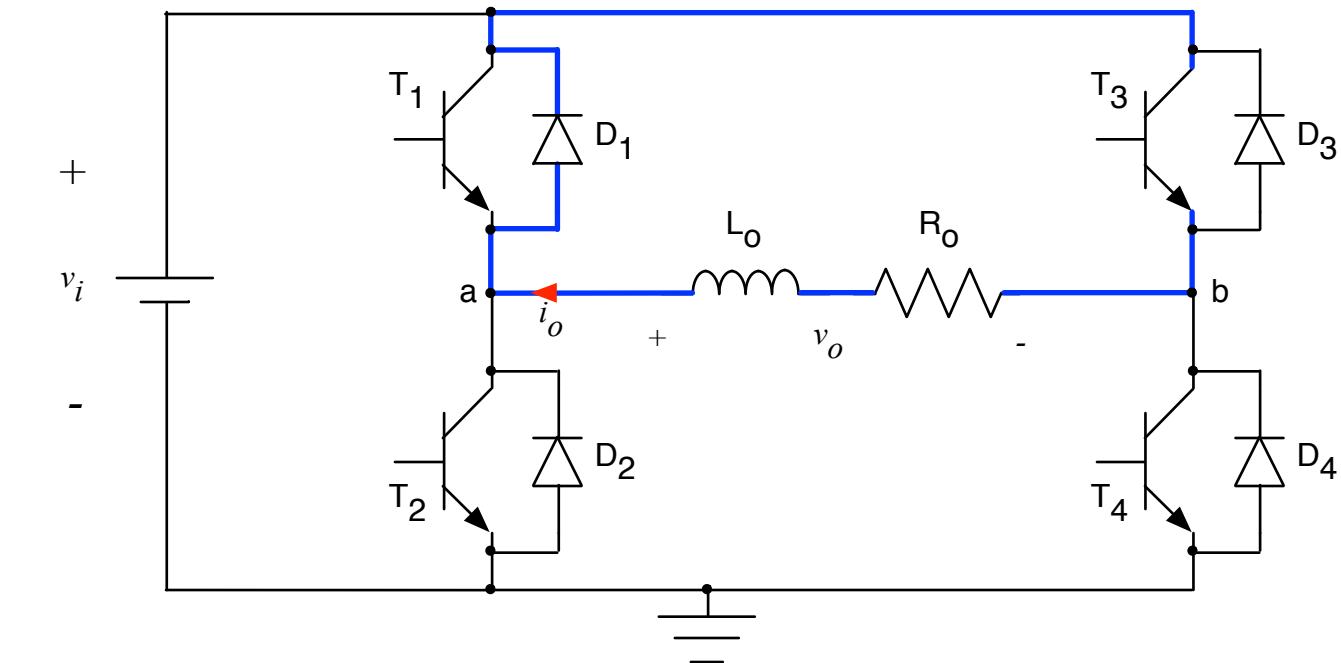
Três níveis



Semiciclo positivo

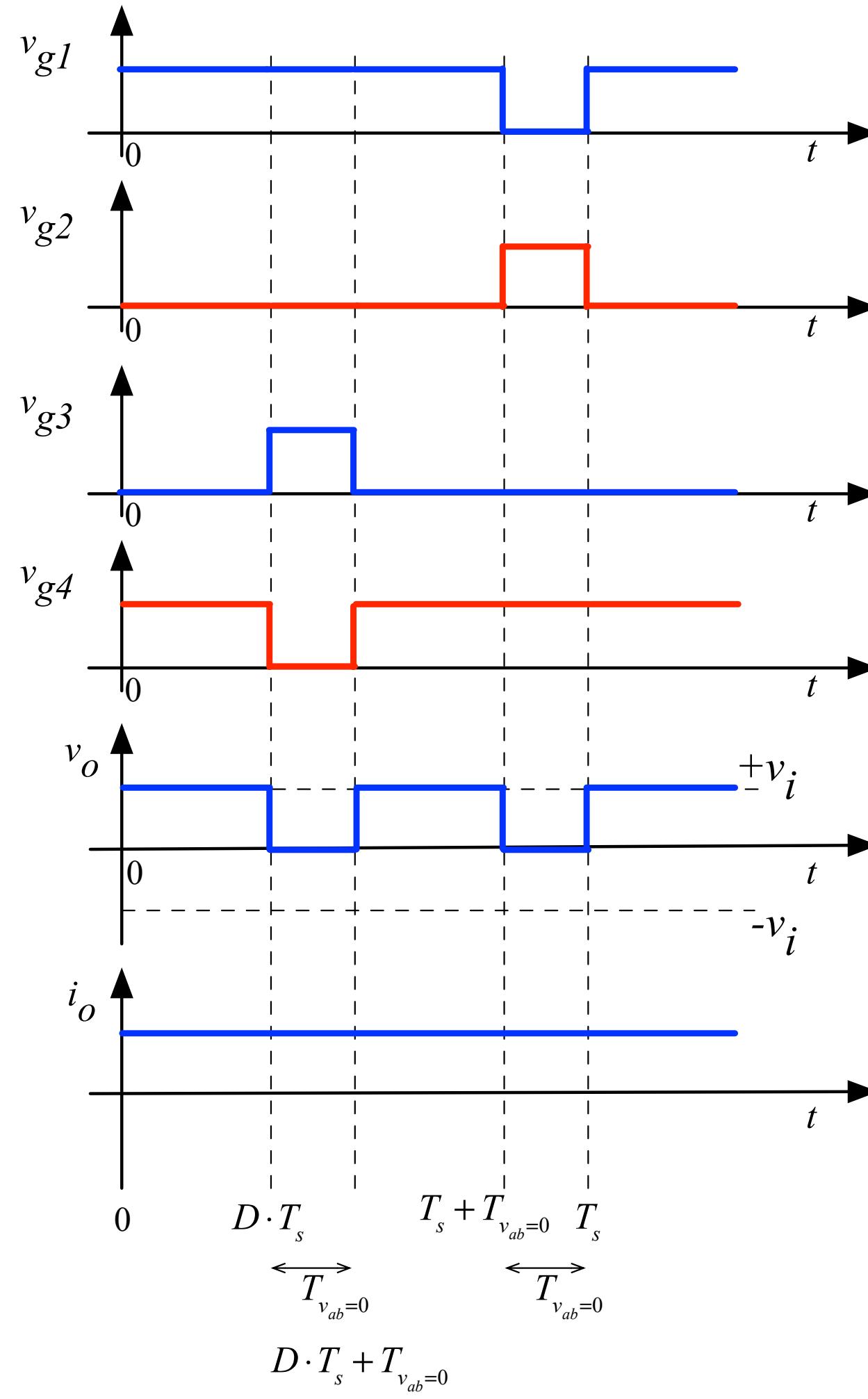


Semiciclo negativo

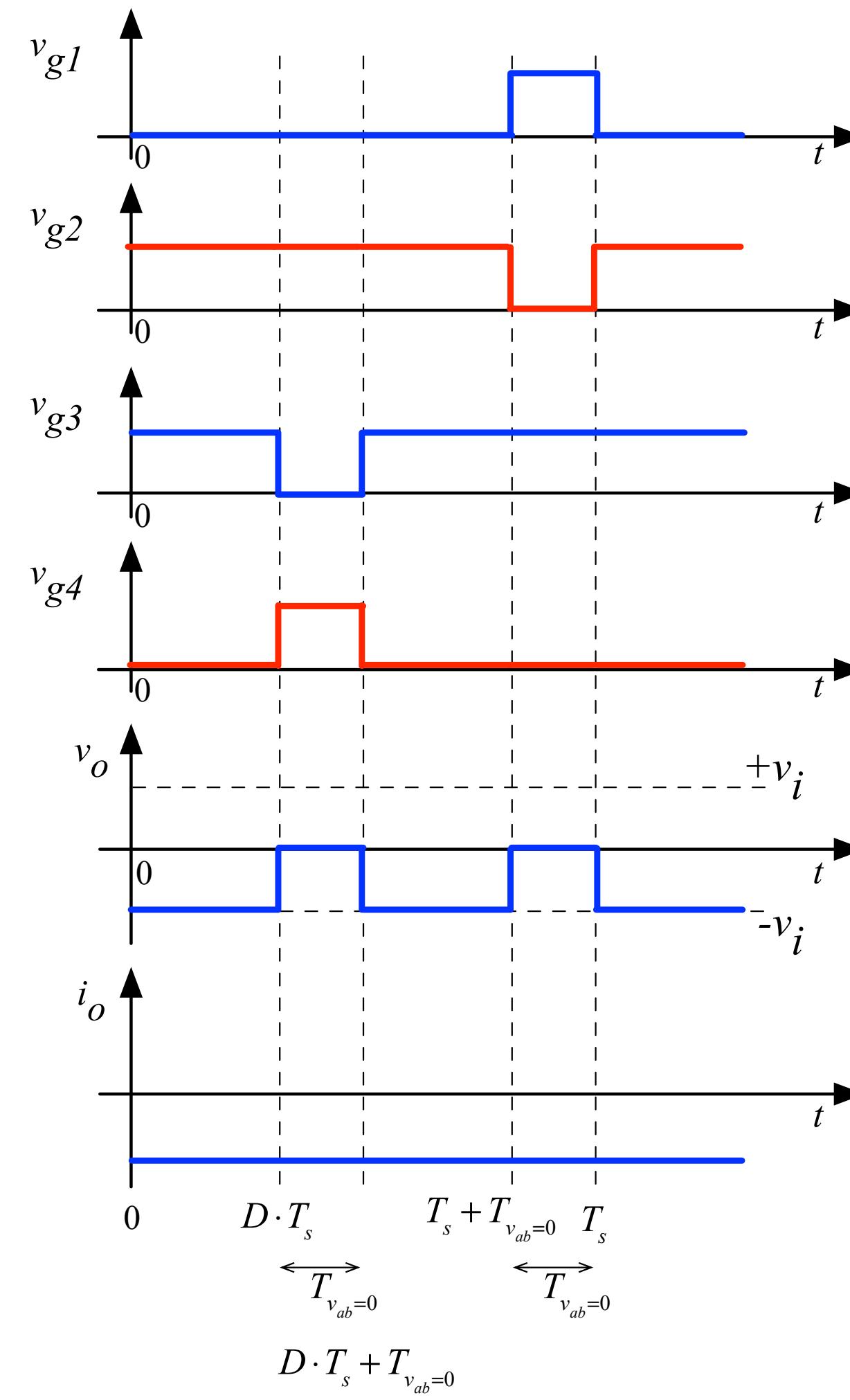


Conversor Ponte Completa

Três níveis

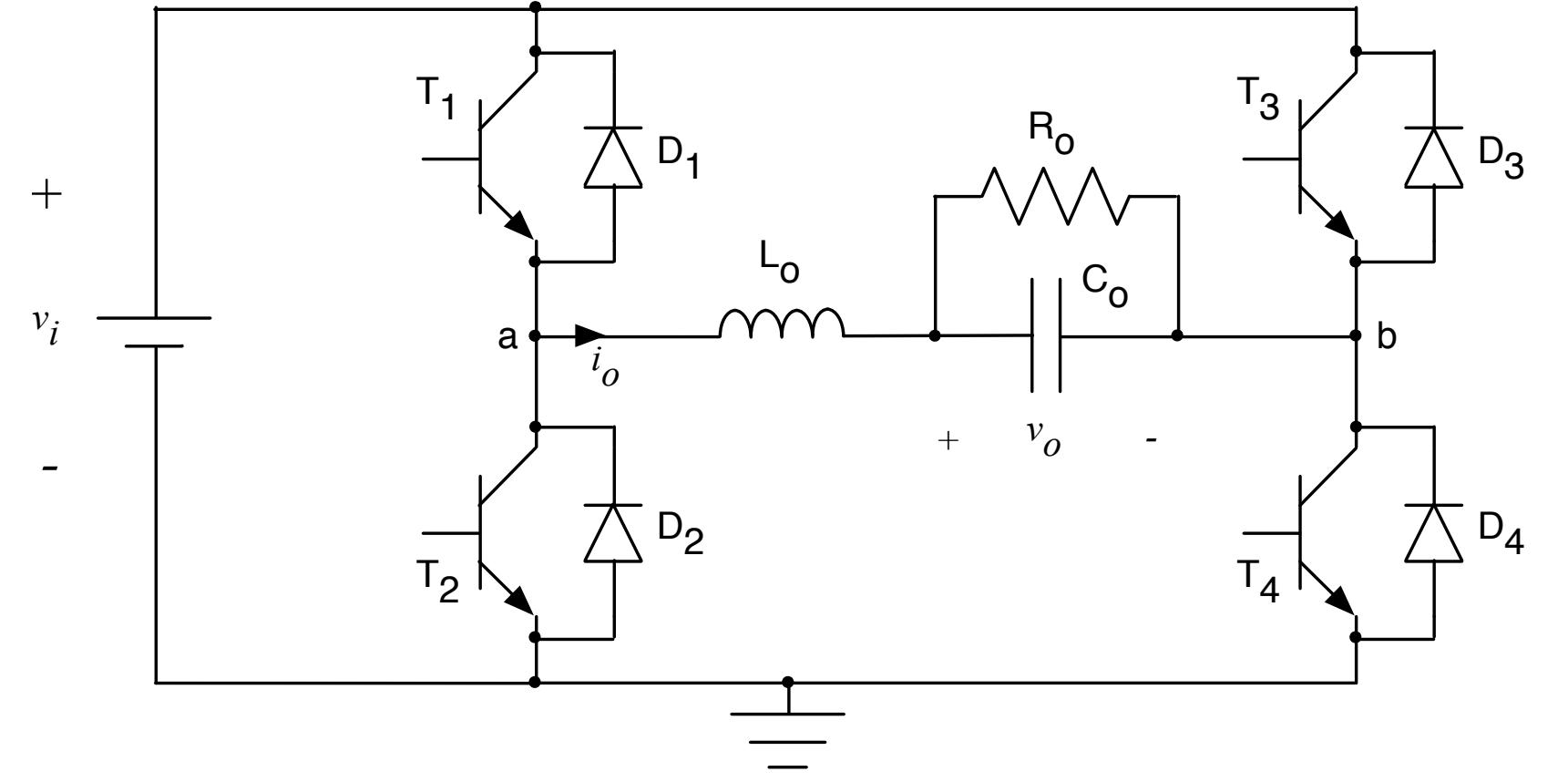


Semiciclo positivo



Semiciclo negativo

Conversor Ponte Completa



PWM Senoidal

V_i = definida

$$V_{ab} = \frac{1}{T_s} \cdot V_i \cdot D \cdot T_s$$

$$V_{ab} = V_i \cdot D$$

$$V_{Lo} = 0 \rightarrow V_o = V_{ab} \rightarrow V_o = V_i \cdot D$$

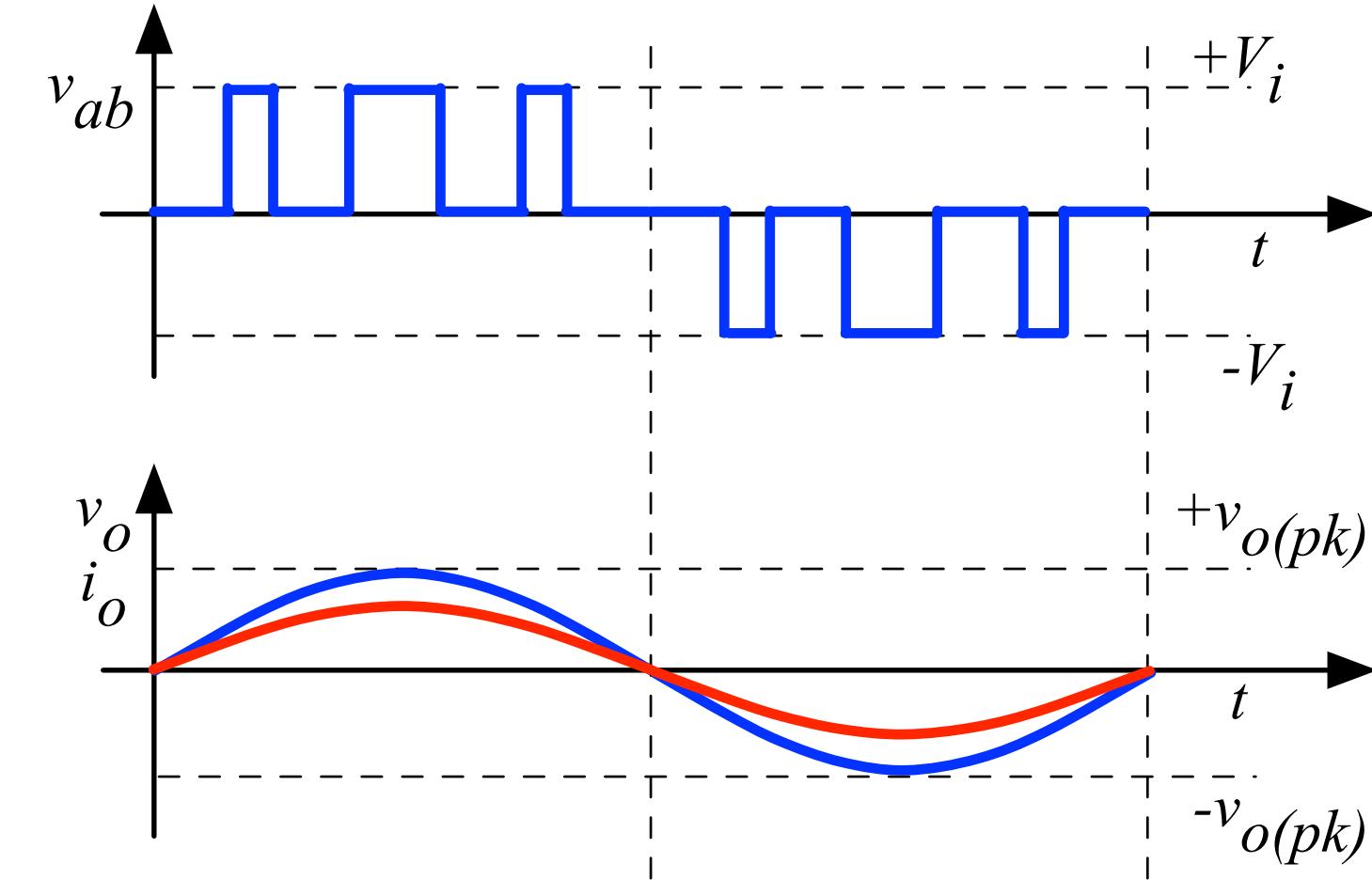
$$V_{o(ef)} = \frac{V_{o(pk)}}{\sqrt{2}}$$

$$v_o(t) = V_{o(pk)} \cdot \operatorname{seno}(t)$$

$$V_{o(pk)} \cdot \operatorname{seno}(t) = V_i \cdot d(t)$$

$$d(t) = \frac{V_{o(pk)} \cdot \operatorname{seno}(t)}{V_i} \rightarrow d(t) = \frac{V_{o(pk)}}{V_i} \cdot \operatorname{seno}(t)$$

$$IM = \frac{V_{o(pk)}}{V_i} \rightarrow d(t) = IM \cdot \operatorname{seno}(t)$$



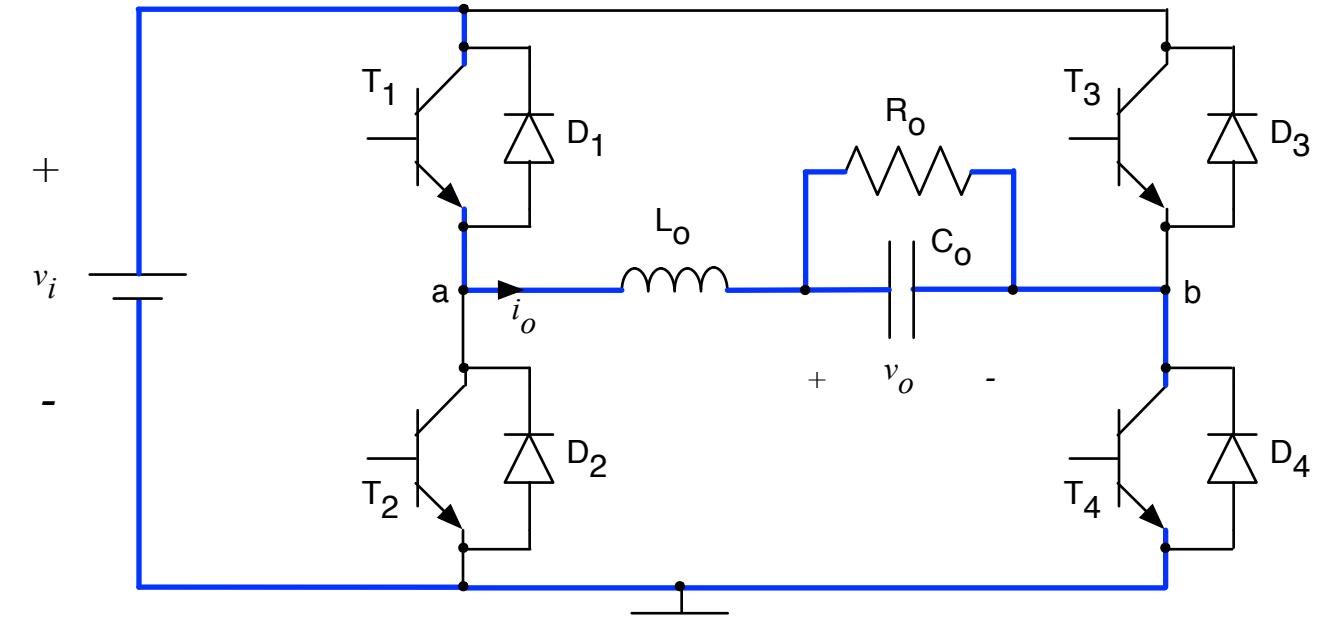
$$\Delta i = \% \cdot I_o [A]$$

$$\Delta v = \% \cdot V_o [V]$$

$$L_o = \frac{V_i}{2 \cdot \Delta i \cdot F_s} \cdot D \cdot (1 - D)$$

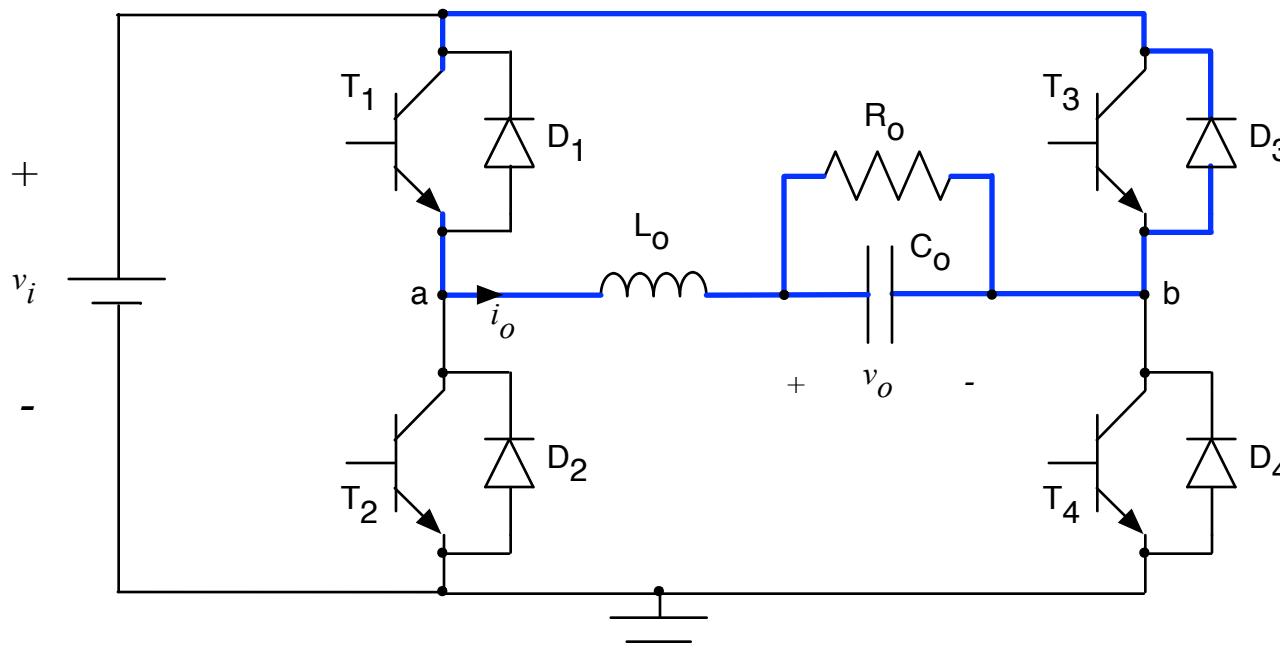
$$C_o = \frac{V_i}{4 \cdot \pi^3 \cdot \Delta v \cdot L_o \cdot F_s^2}$$

Conversor Ponte Completa

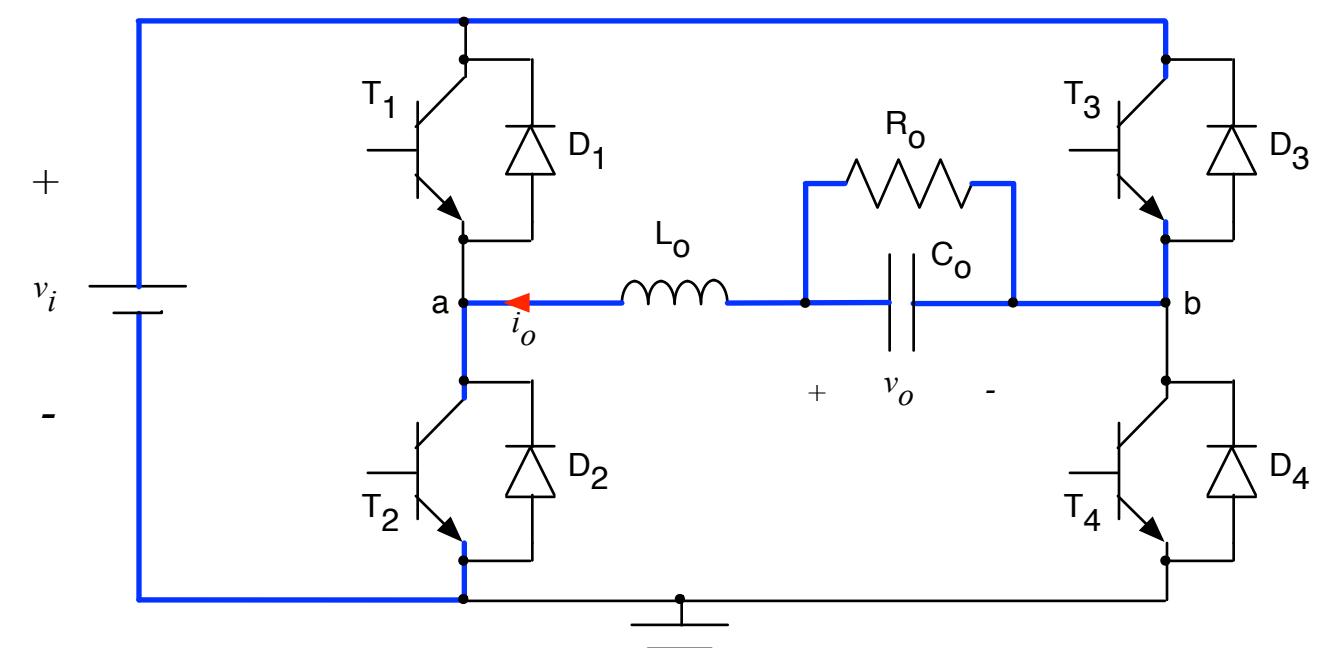


$$v_{ab} = +V_i \text{ e } i_o > 0$$

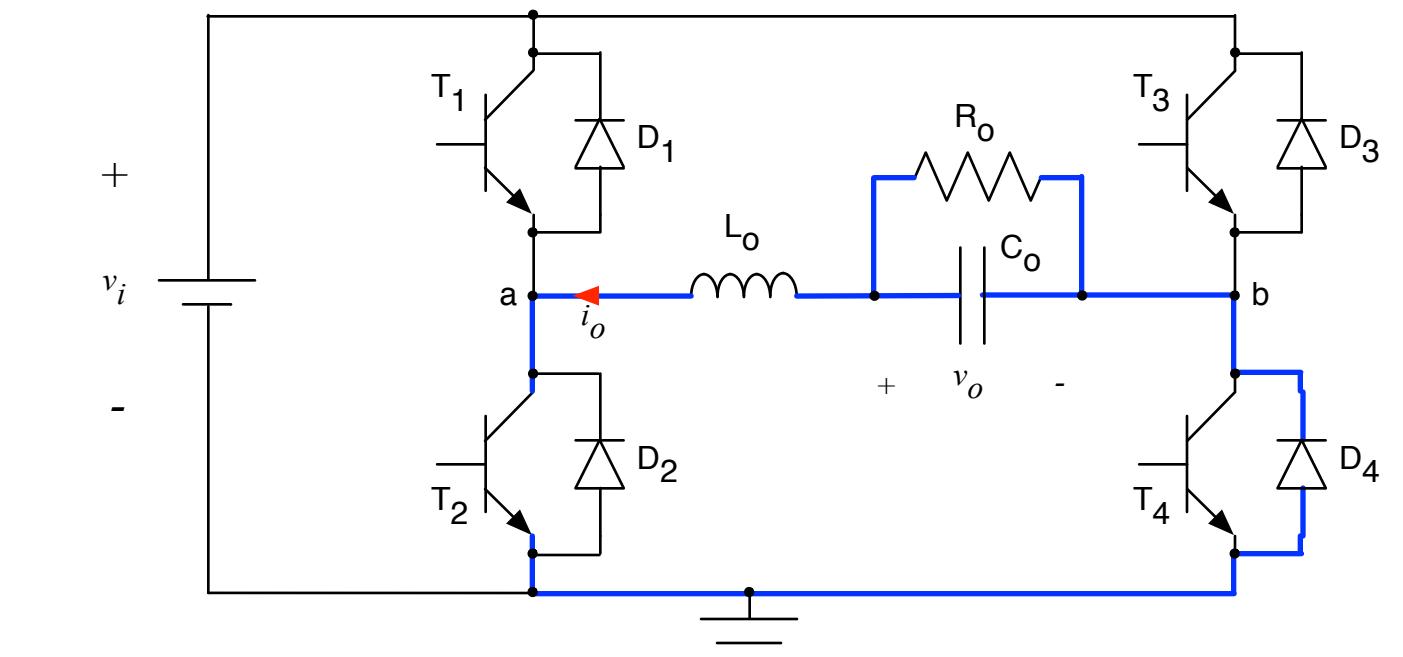
PWM Senoidal



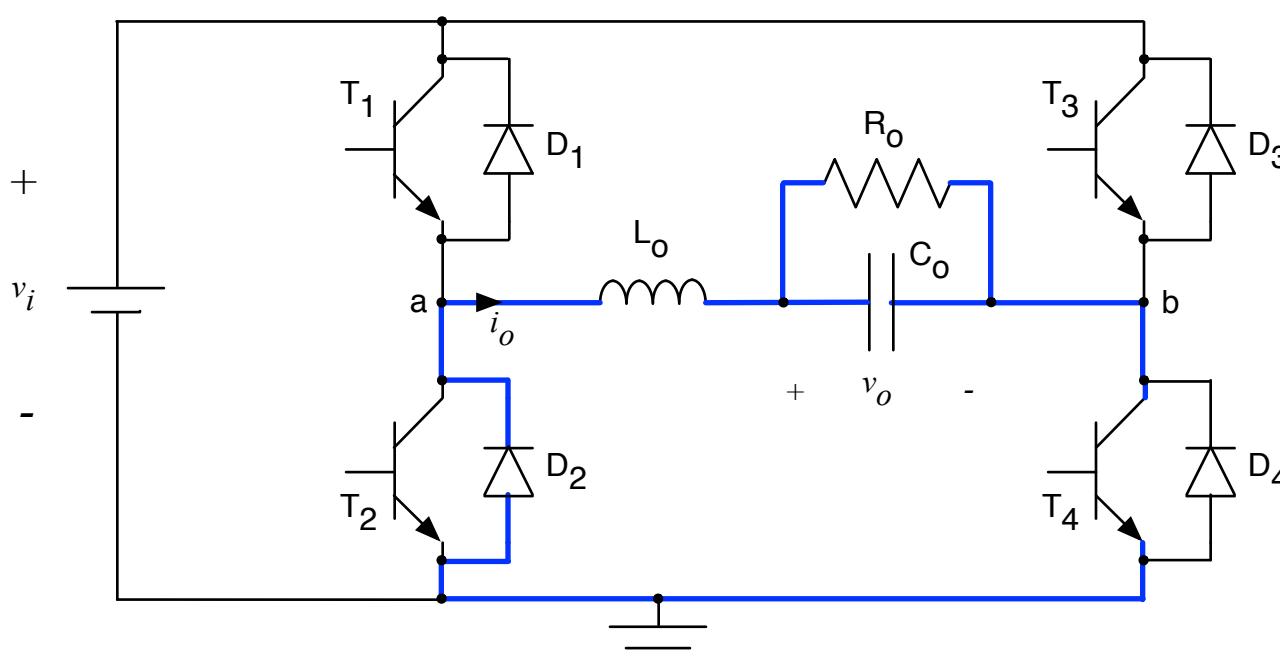
$$v_{ab} = 0 \text{ e } i_o > 0$$



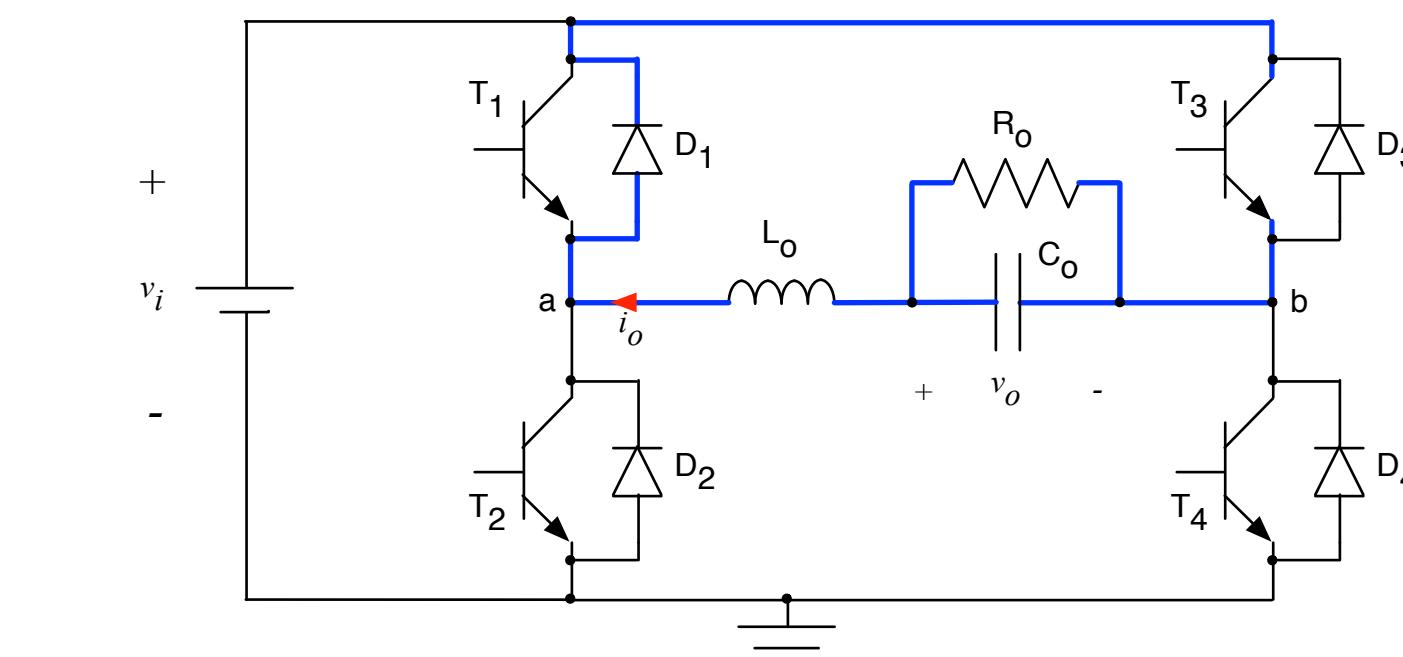
$$v_{ab} = -V_i \text{ e } i_o < 0$$



$$v_{ab} = 0 \text{ e } i_o < 0$$



$$v_{ab} = 0 \text{ e } i_o > 0$$



$$v_{ab} = 0 \text{ e } i_o < 0$$

Próxima Aula

Conversores ca-ca



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