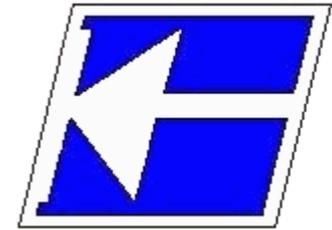


Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina

Departamento Acadêmico de Eletrônica

Eletrônica de Potência



# Conversores CC-CA Inversores

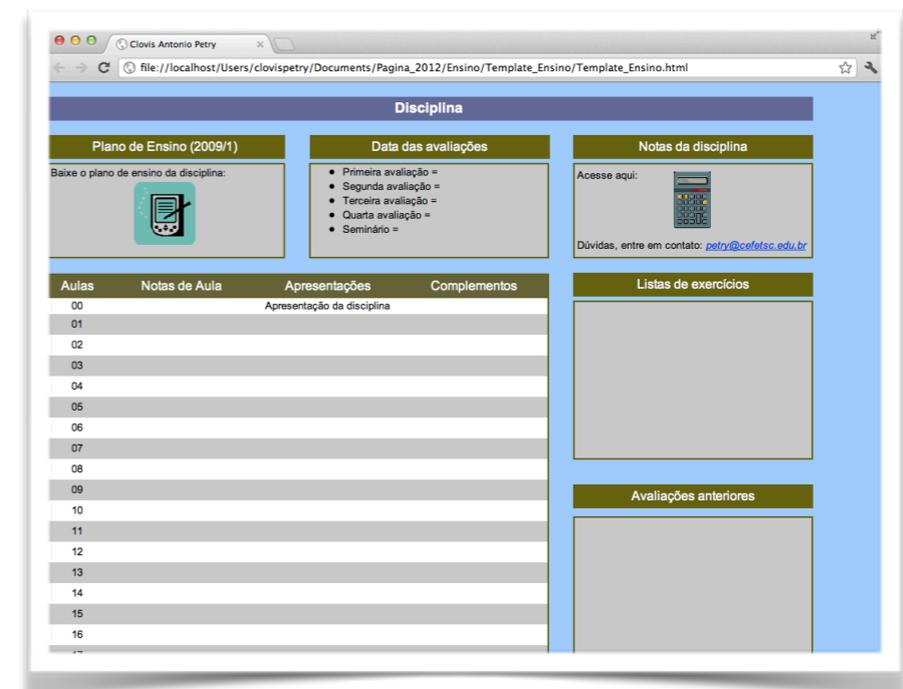
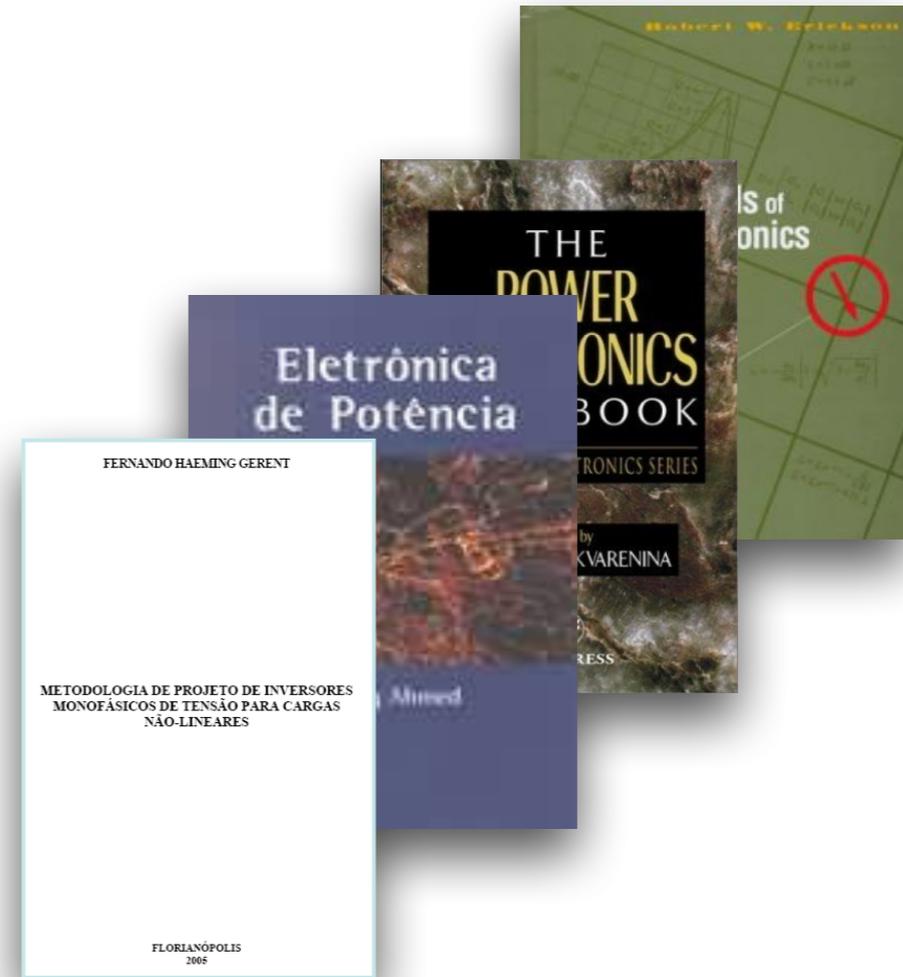
Prof. Clovis Antonio Petry.

Florianópolis, maio de 2020.

# Biografia para Esta Aula

## Capítulo 10 - Inversores:

- Introdução aos conversores CC-CA;
- Conversores CC-CA de tensão.



[www.ProfessorPetry.com.br](http://www.ProfessorPetry.com.br)



# Nesta Aula

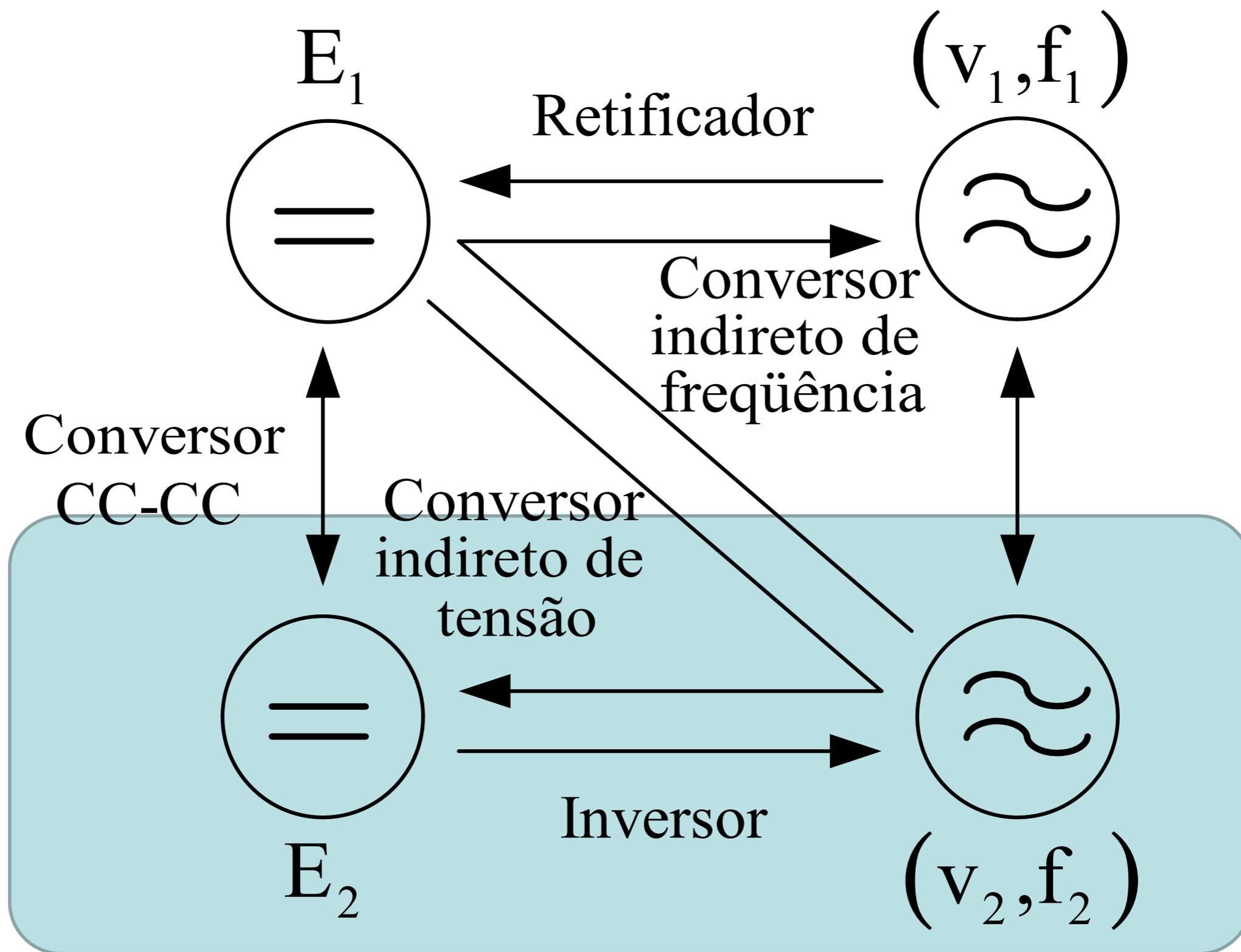
## Conversores cc-ca:

- Introdução aos conversores *CC-CA*;
- Conversores *CC-CA* de tensão.

# Inversores de Tensão ou Corrente



# Divisão da Eletrônica de Potência

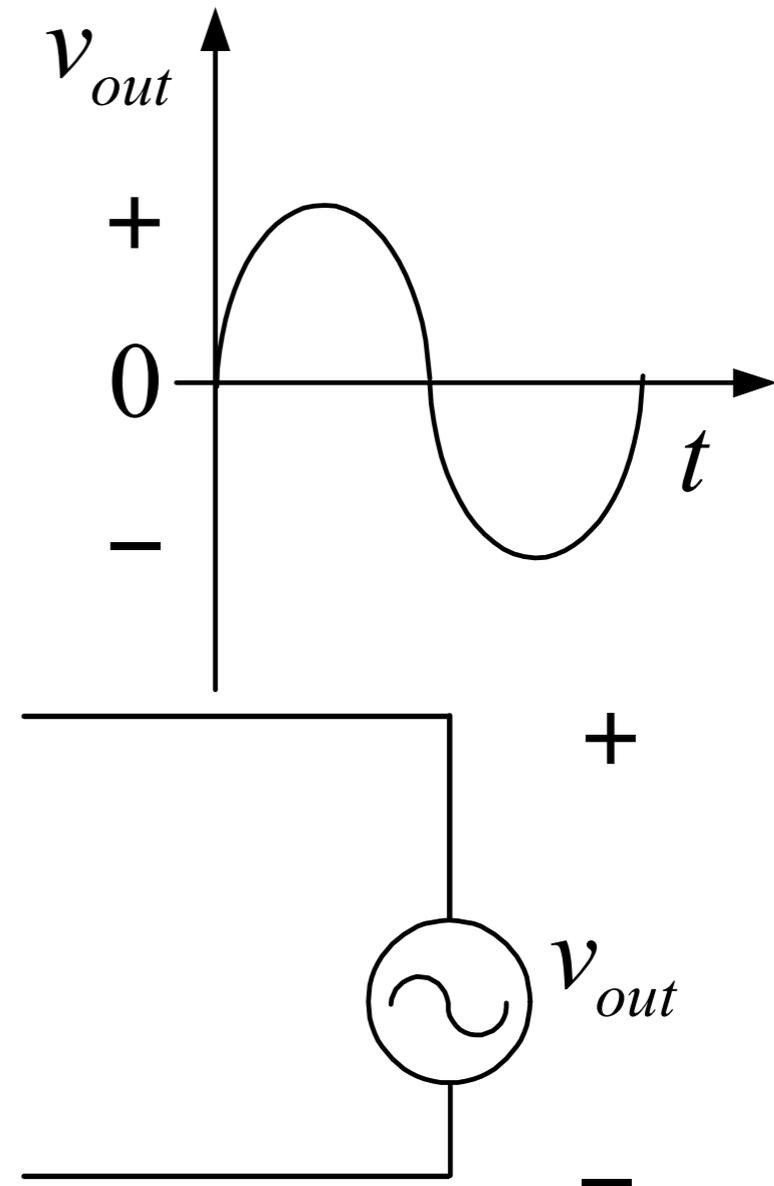
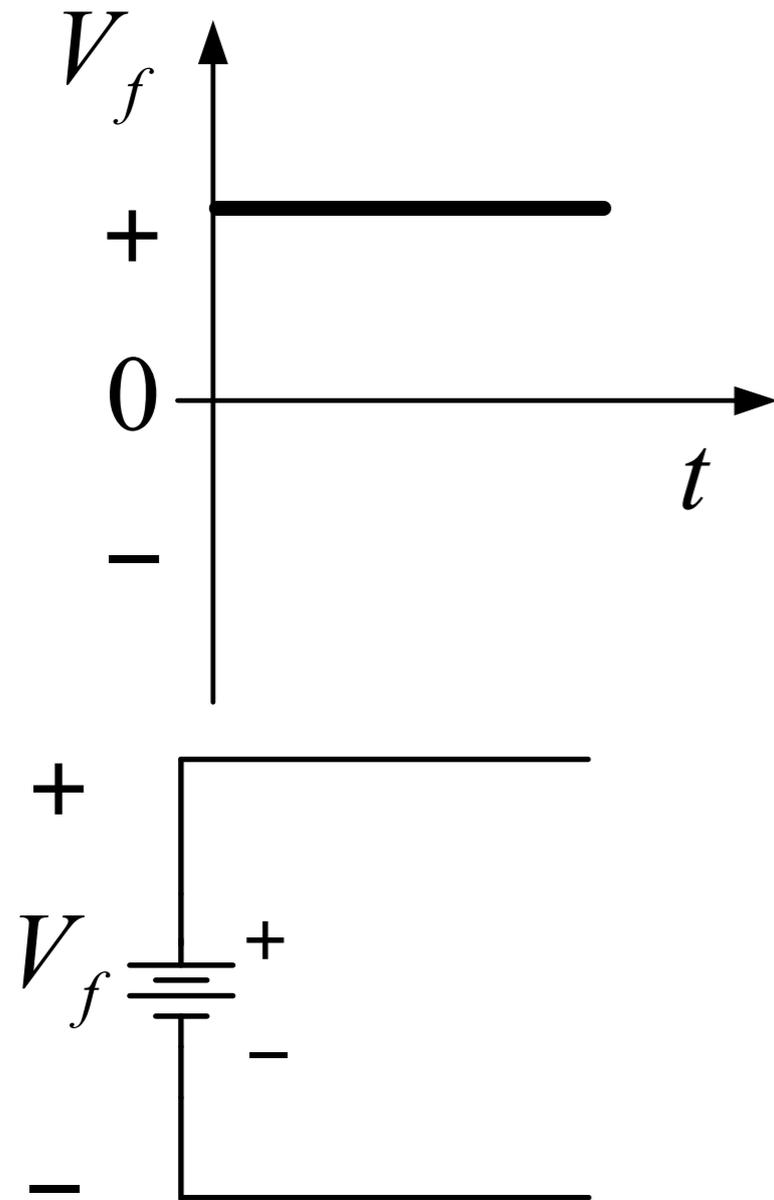


# Conversores CC-CA

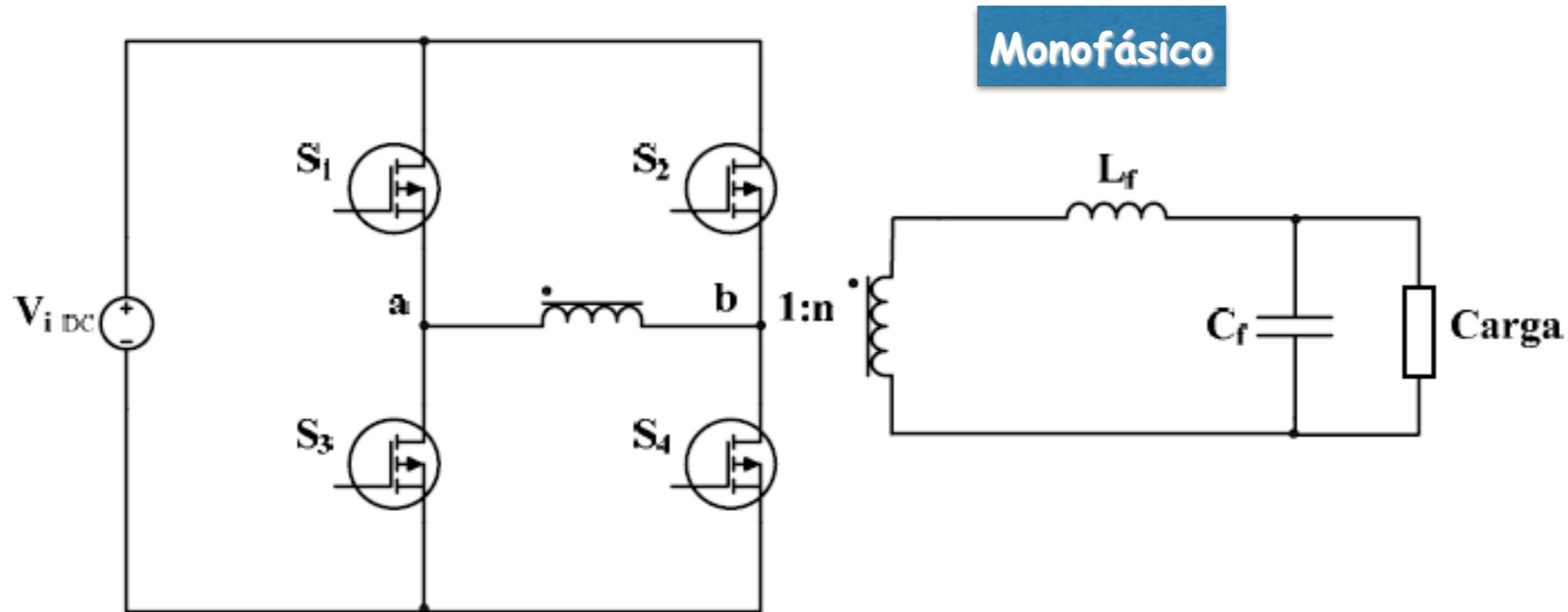
## Conversores CC-CA:

1. Denominados de inversores: convertem tensão contínua em tensões alternadas;
2. Podem ser monofásicos, trifásicos ou n-fásicos;
3. Unidirecionais ou bidirecionais;
4. Comandados em alta frequência
5. Modulação simples ou complexa;
6. Dois níveis ou multiníveis;
7. Podem ser isolados ou não-isolados;
8. Podem operar em condução contínua ou descontínua;
9. Controlados no modo tensão ou corrente;
10. Comutação normal ou suave;
11. Inversores de tensão ou corrente;
12. Aplicações dos conversores CC-CA.

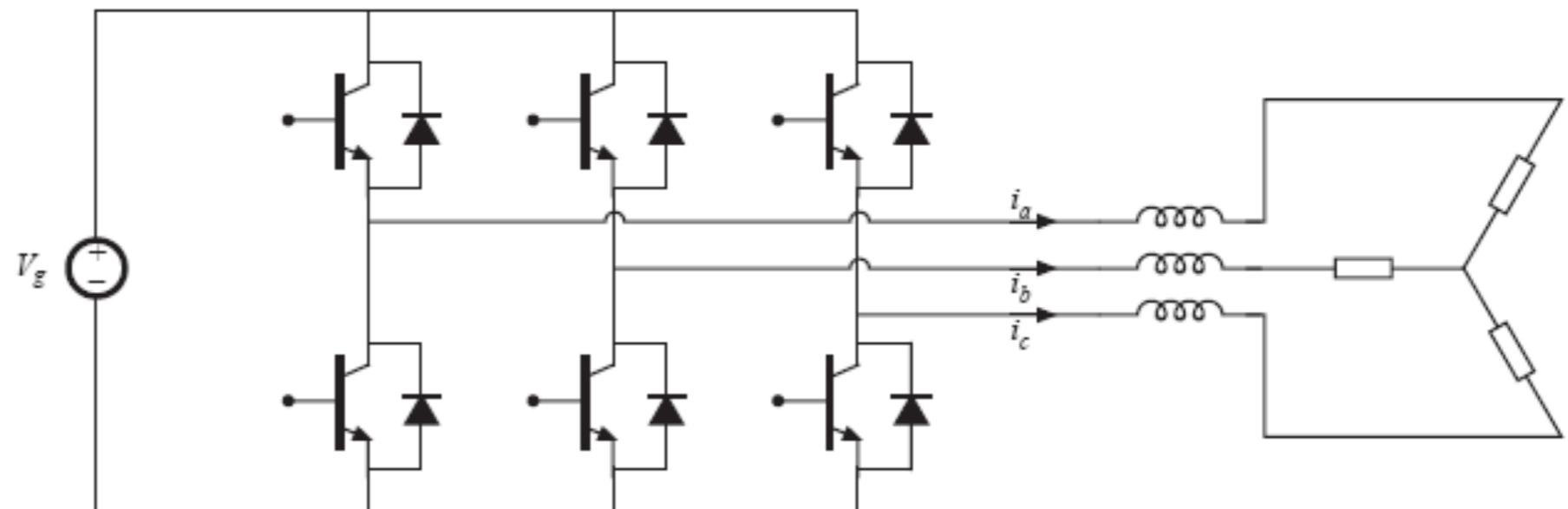
# Conversores CC-CA: Princípio Geral



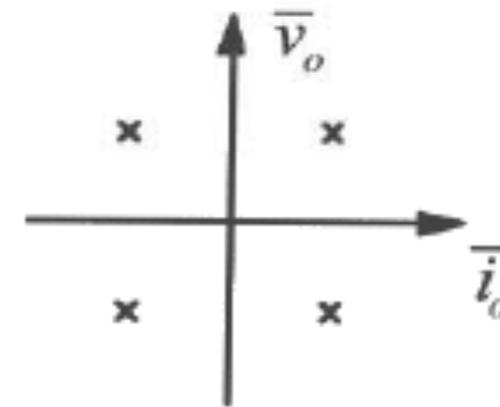
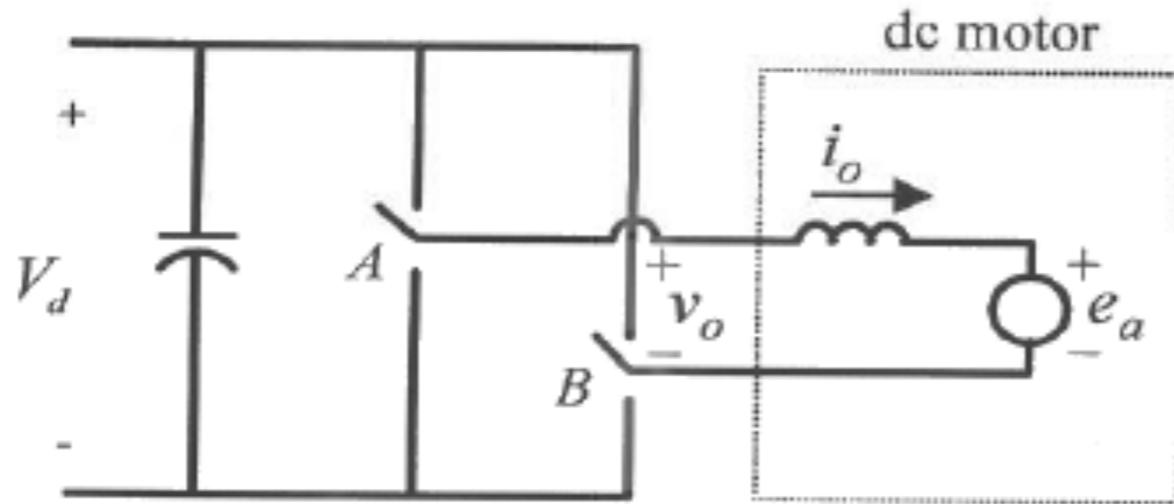
# Conversores CC-CA: Número de Fases



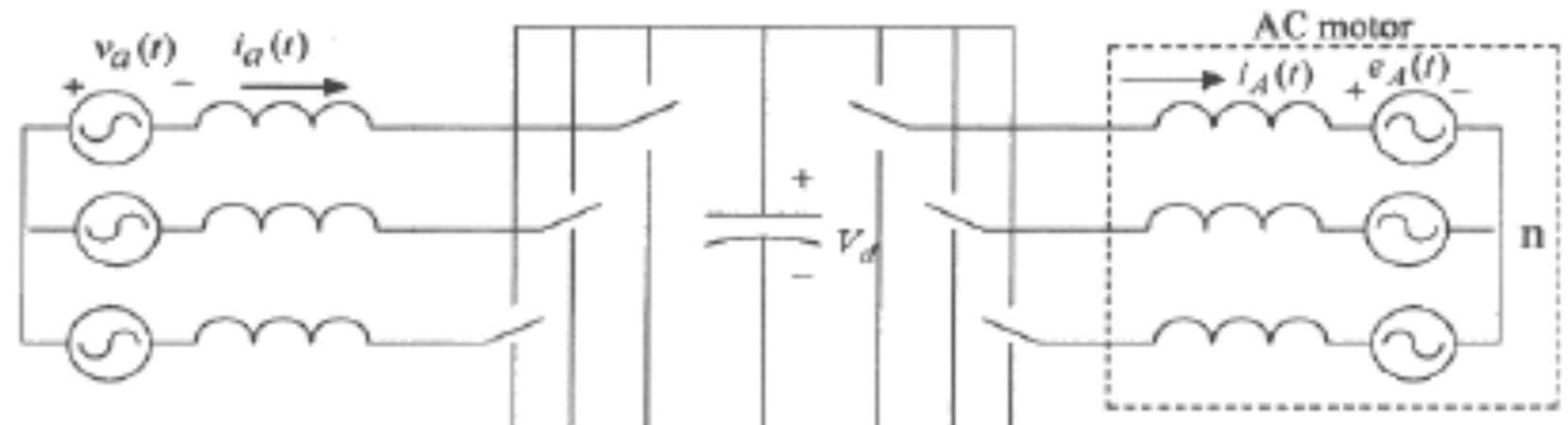
**Trifásico**



# Conversores CC-CA: Bidirecionalidade



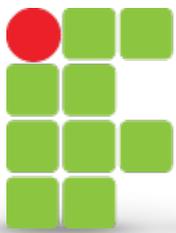
Unidirecional?



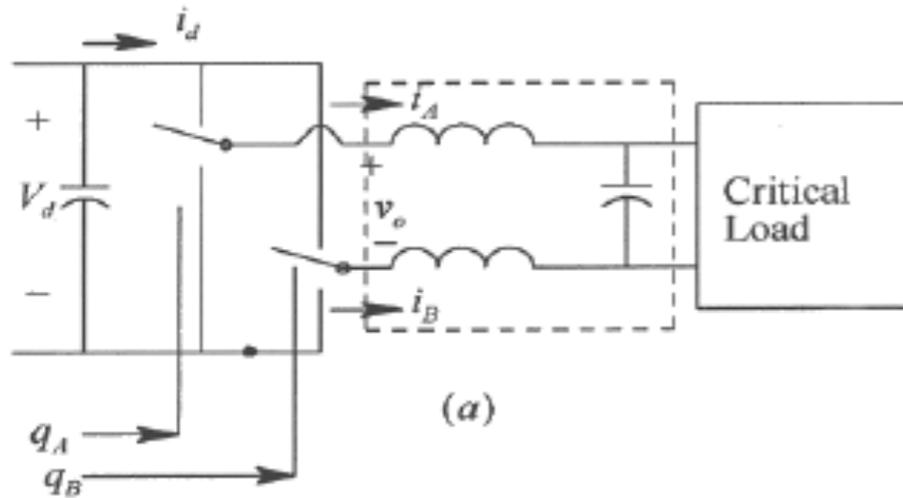
Bidirecional

$P \rightarrow$  Rectifier  $P$  motoring mode  
 $P \leftarrow$  Inverter  $P$  regenerative braking mode

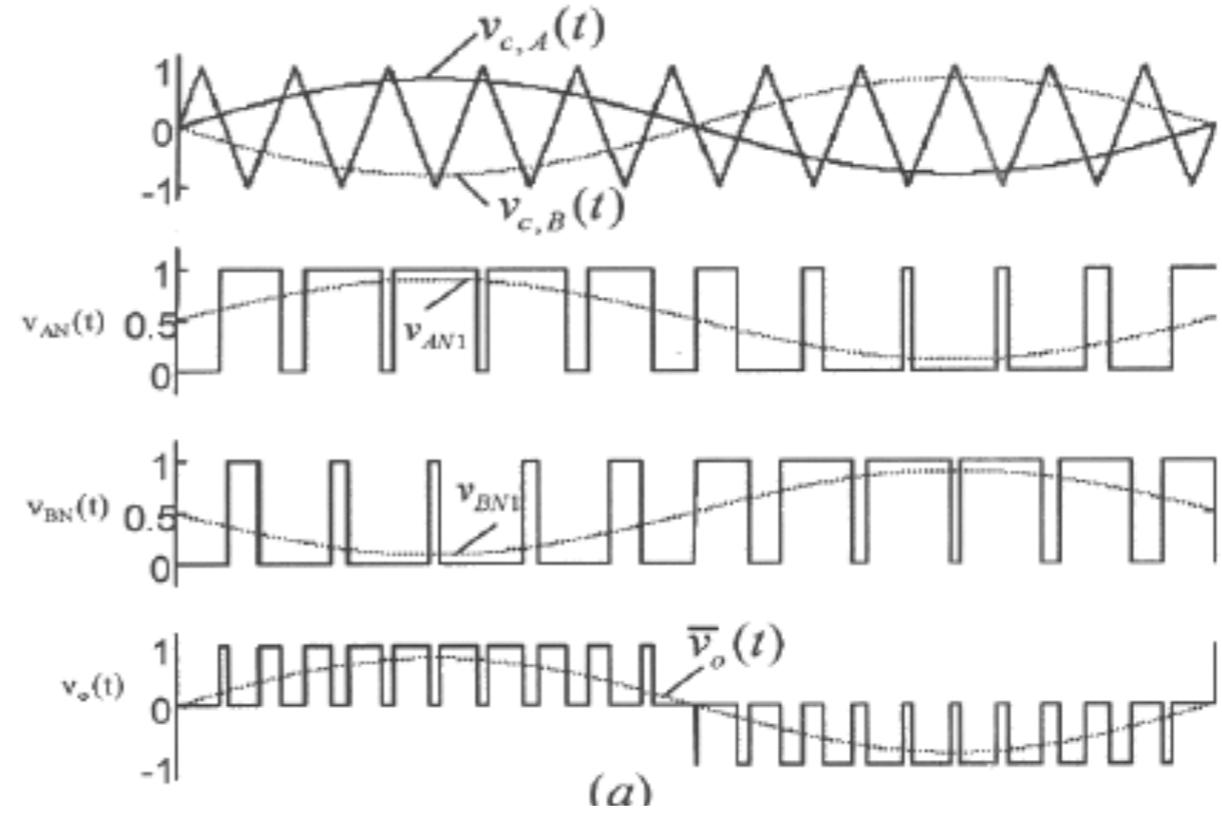




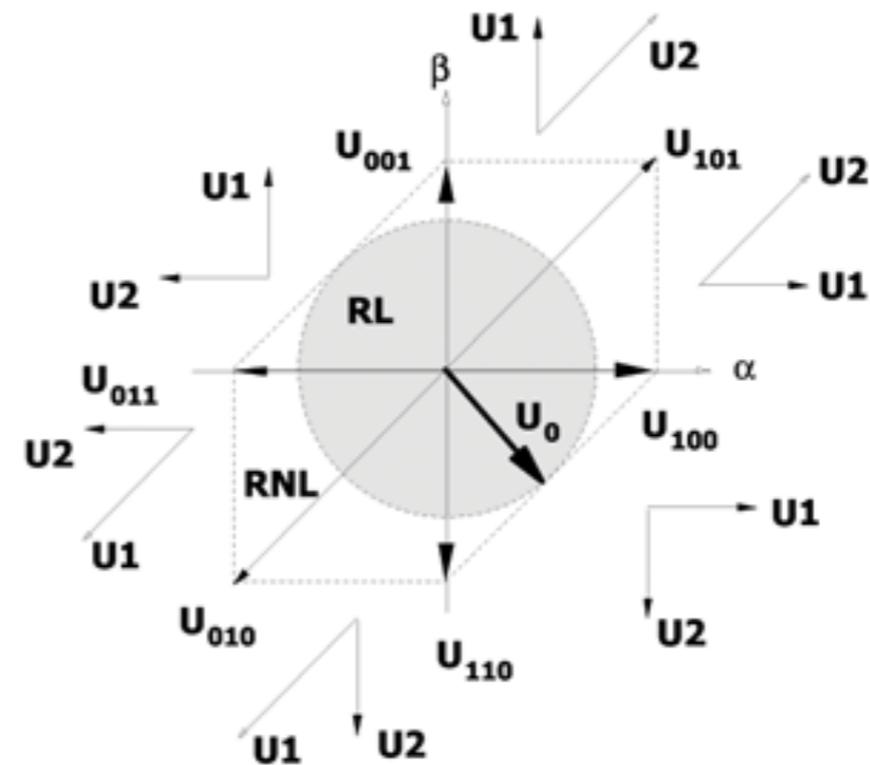
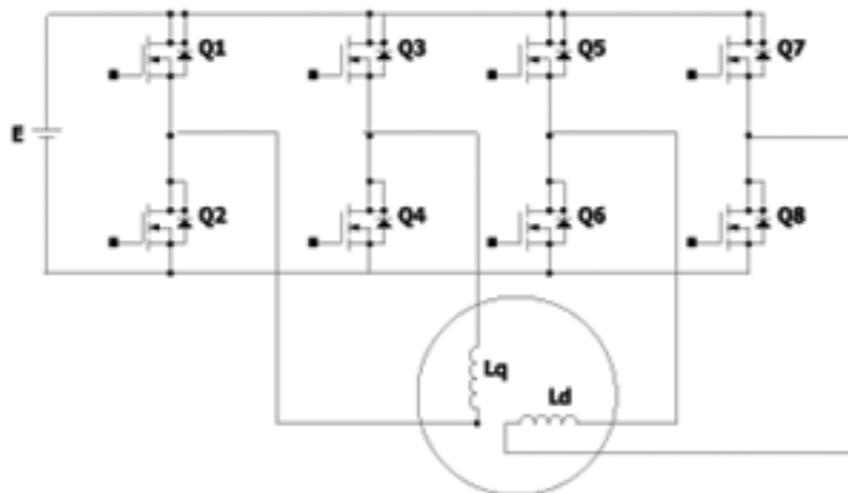
# Conversores CC-CA: Modulação



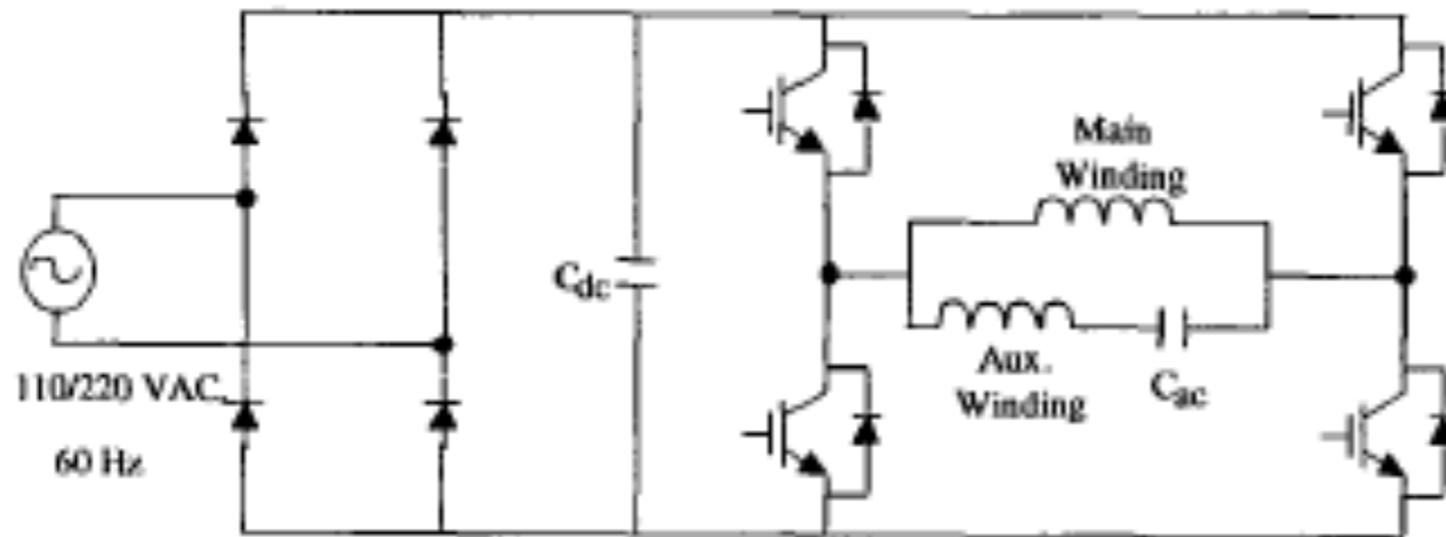
PWM Senoidal



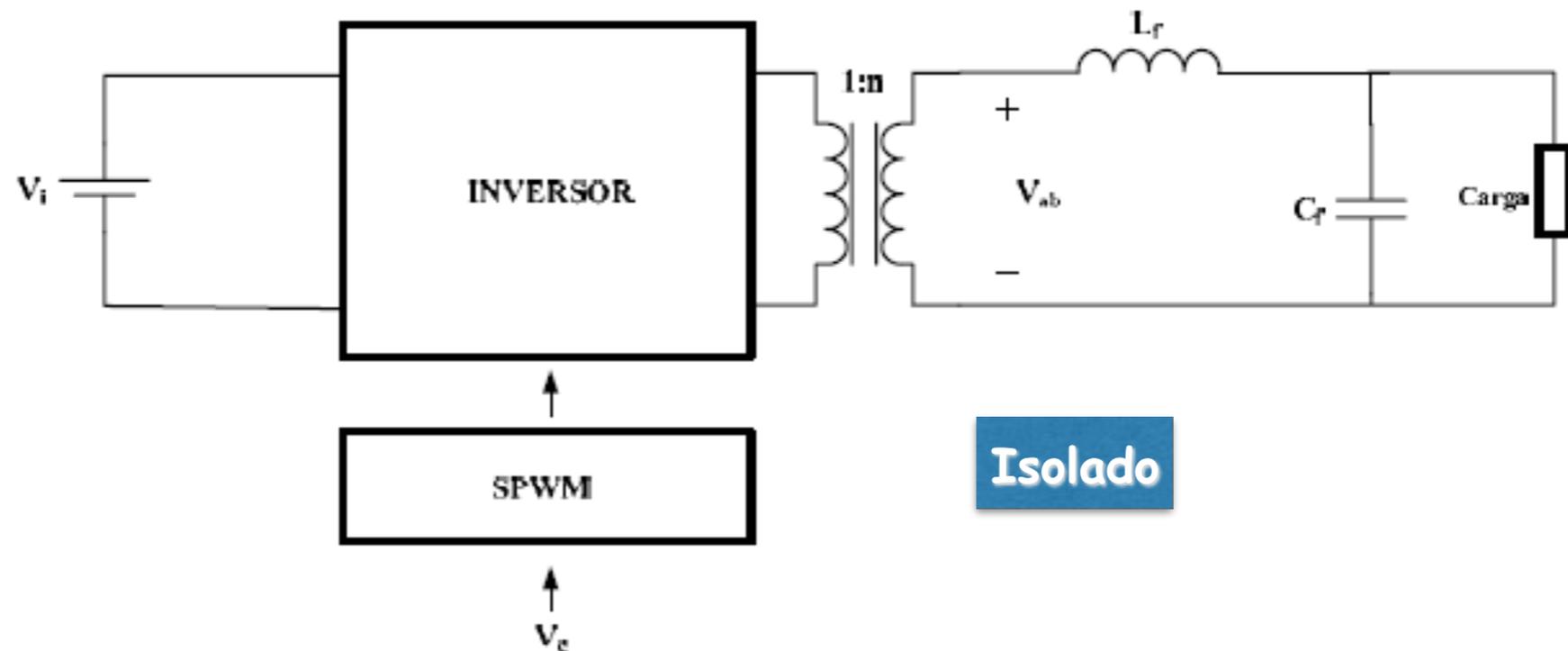
Vetorial



# Conversores CC-CA: Isolamento

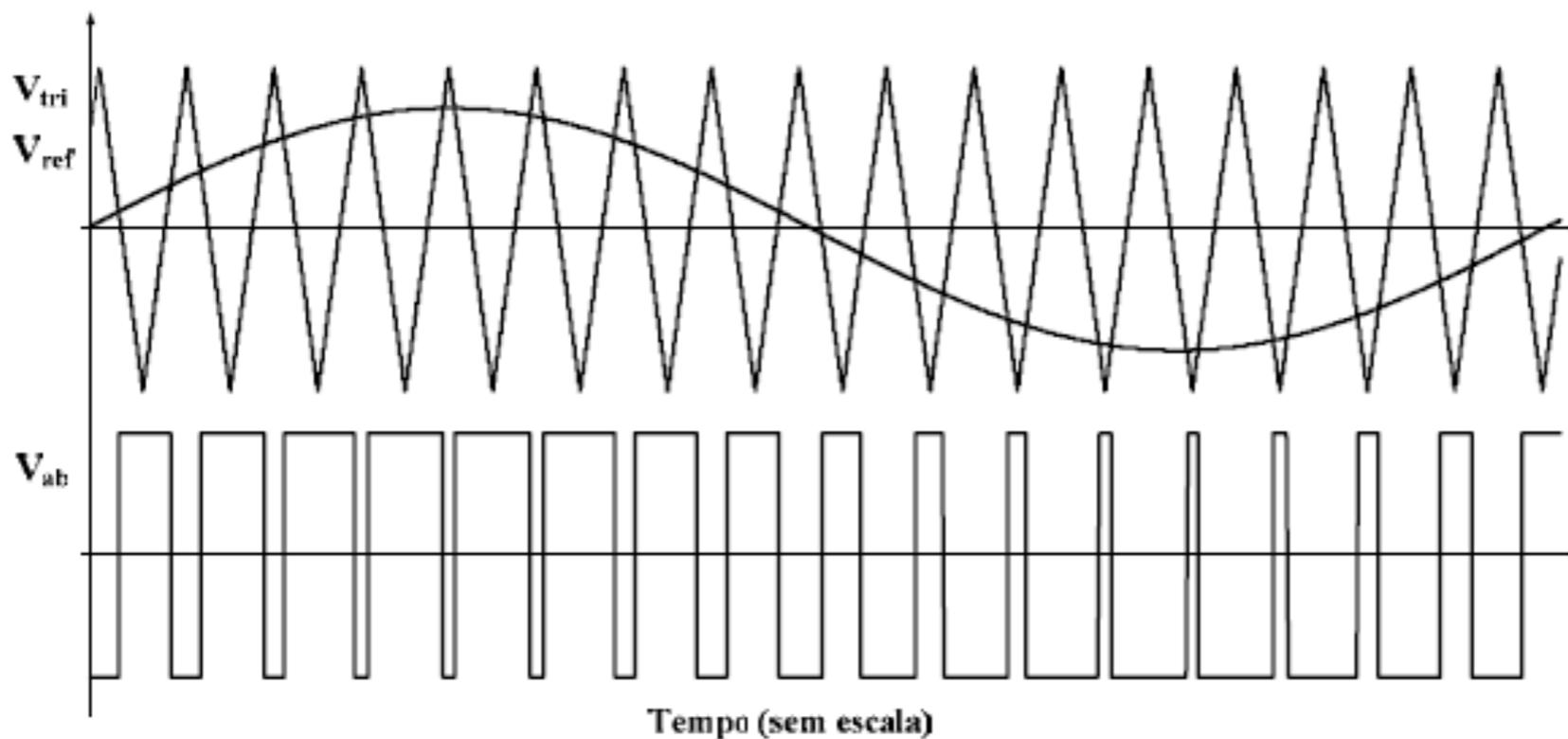


Não-isolado

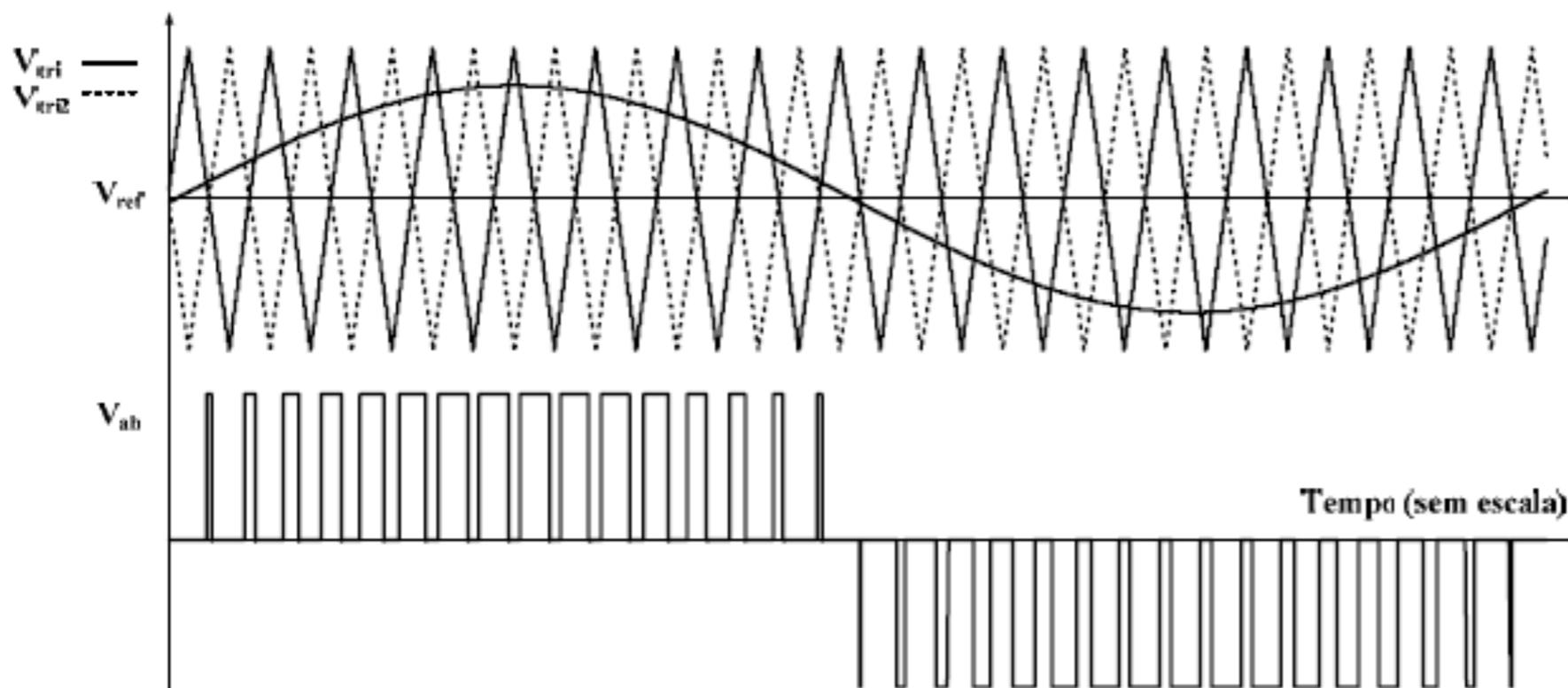


Isolado

# Conversores CC-CA: Número de Níveis

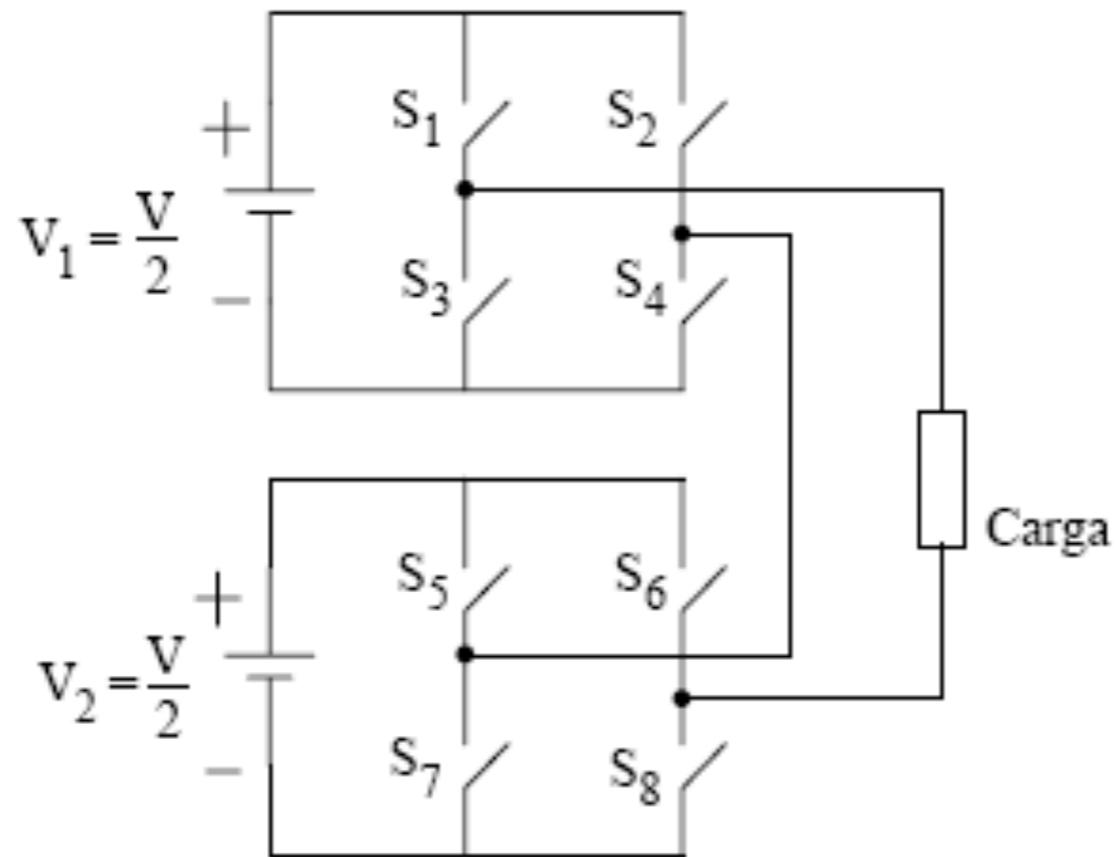


Dois níveis

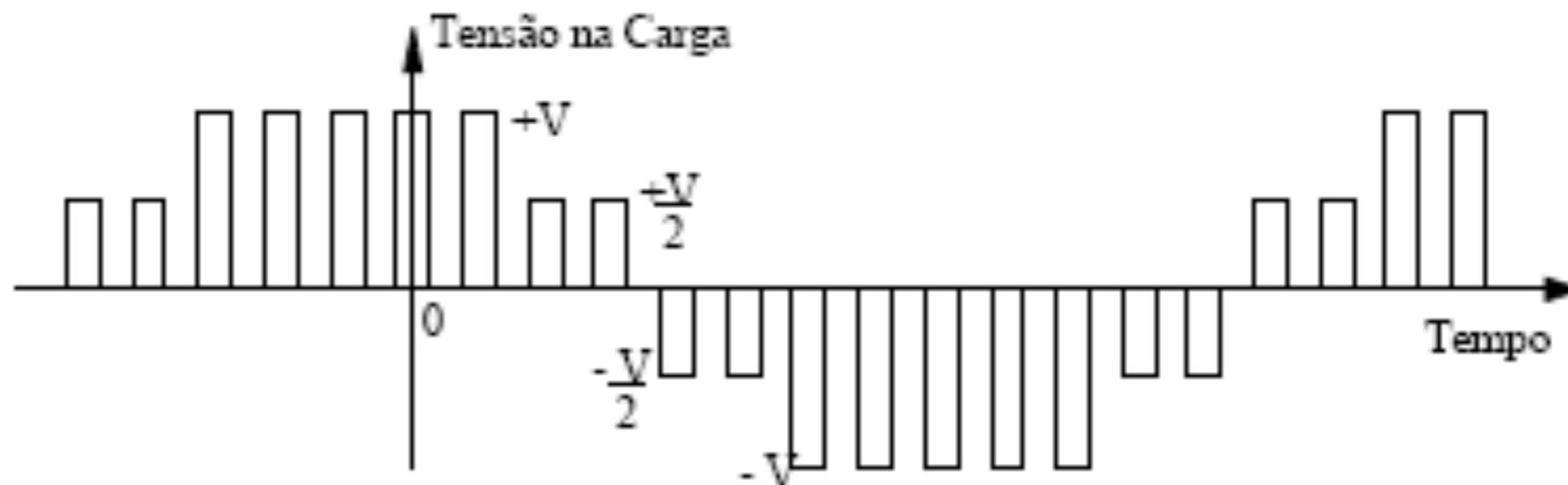


Três níveis

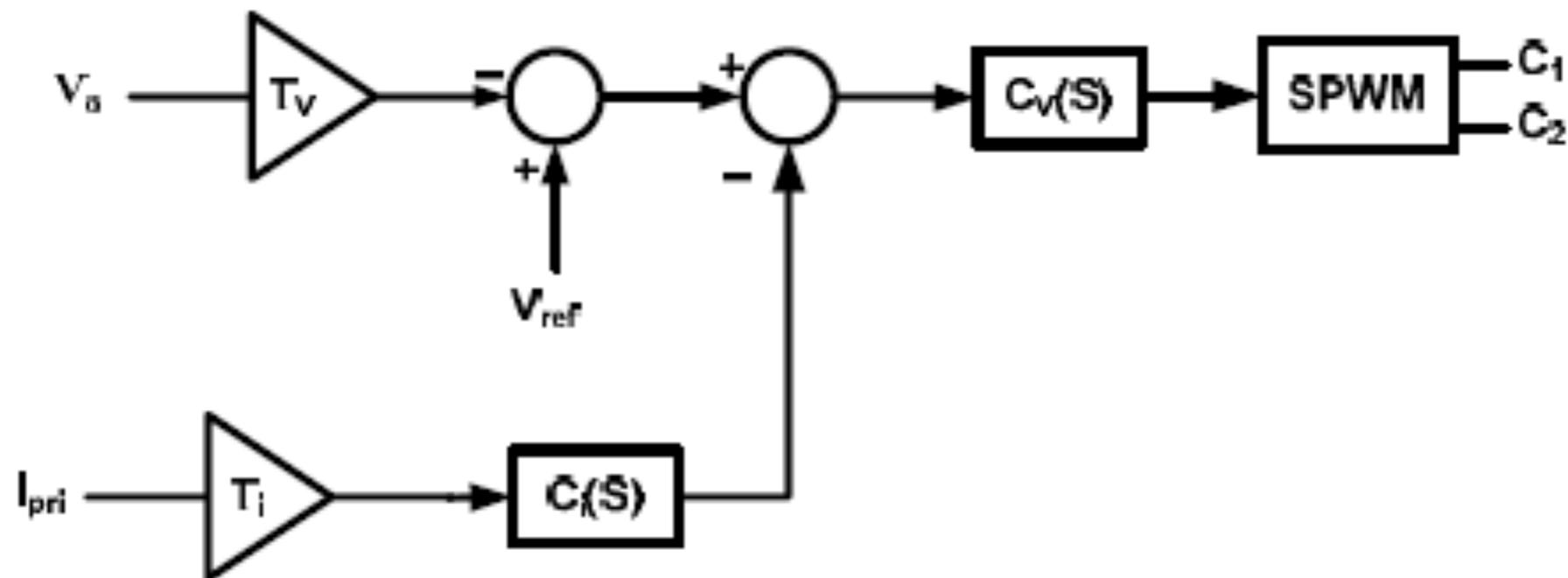
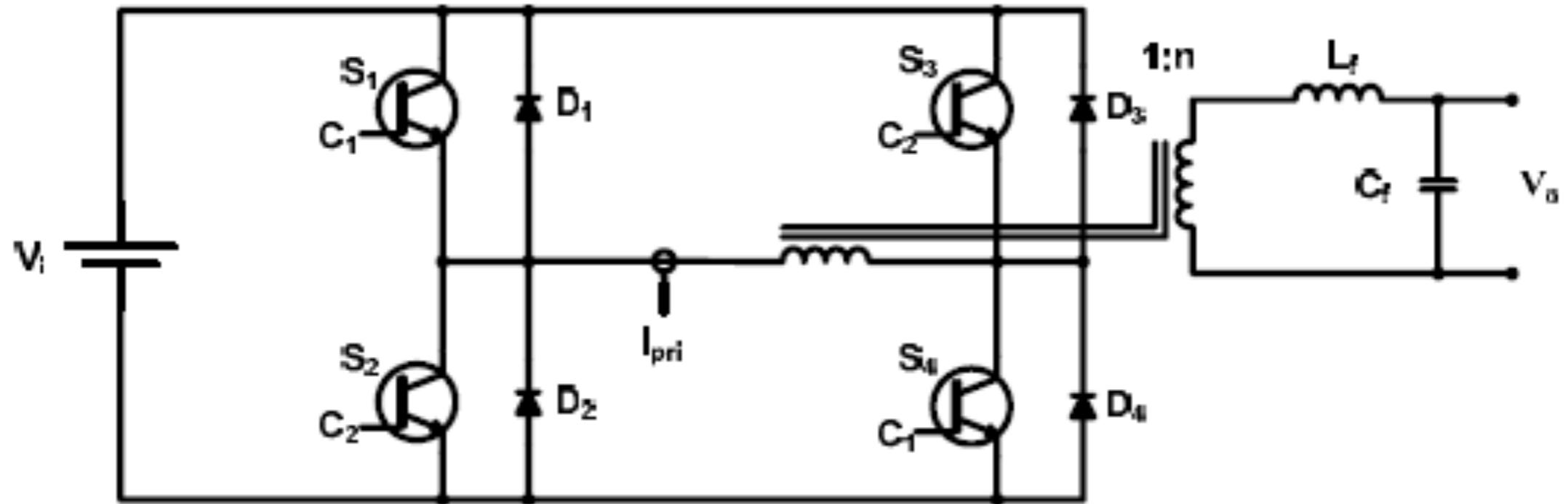
# Conversores CC-CA: Número de Níveis



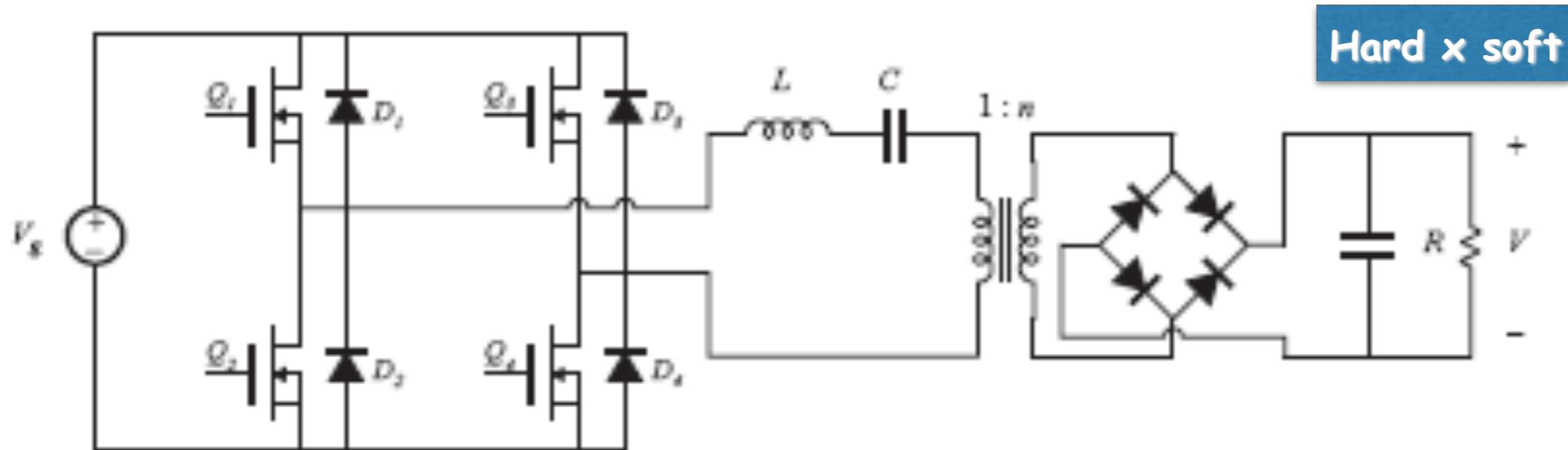
Multiníveis



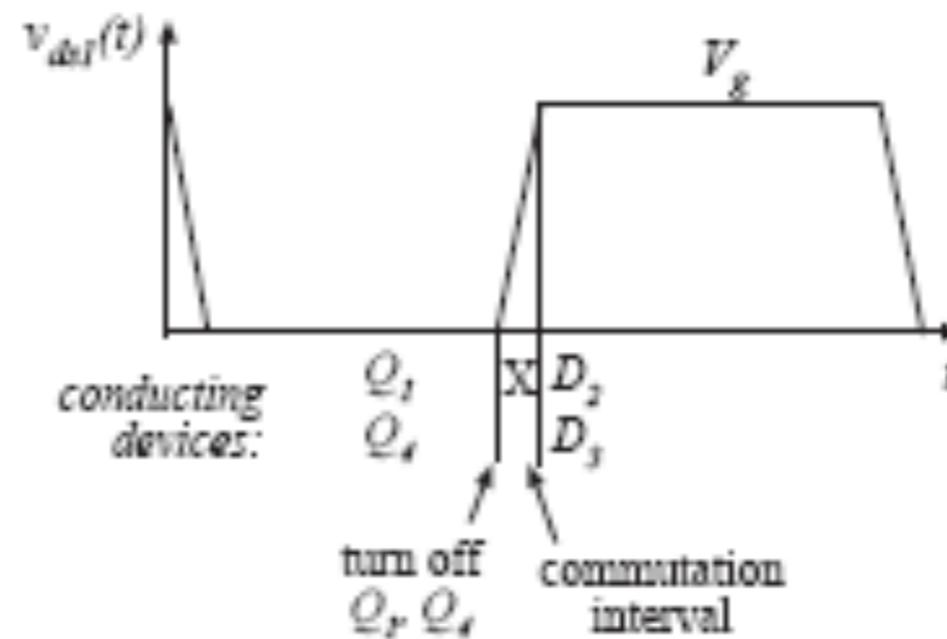
# Conversores CC-CA: Controle por V e/ou I



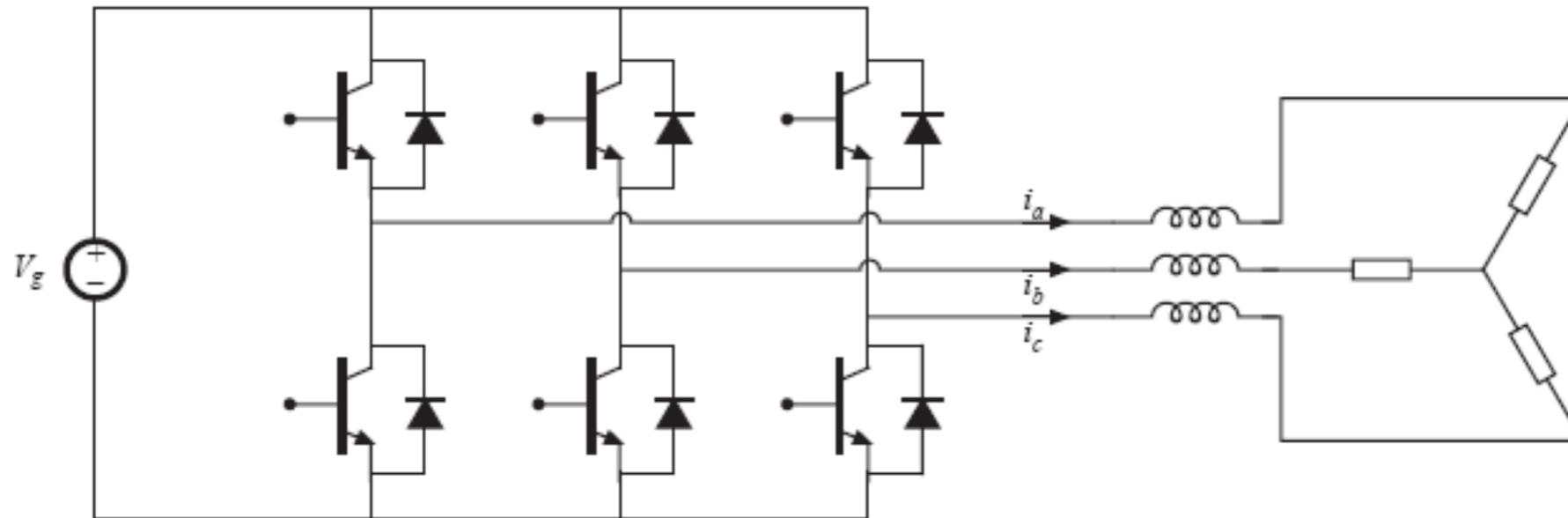
# Conversores CC-CA: Comutação



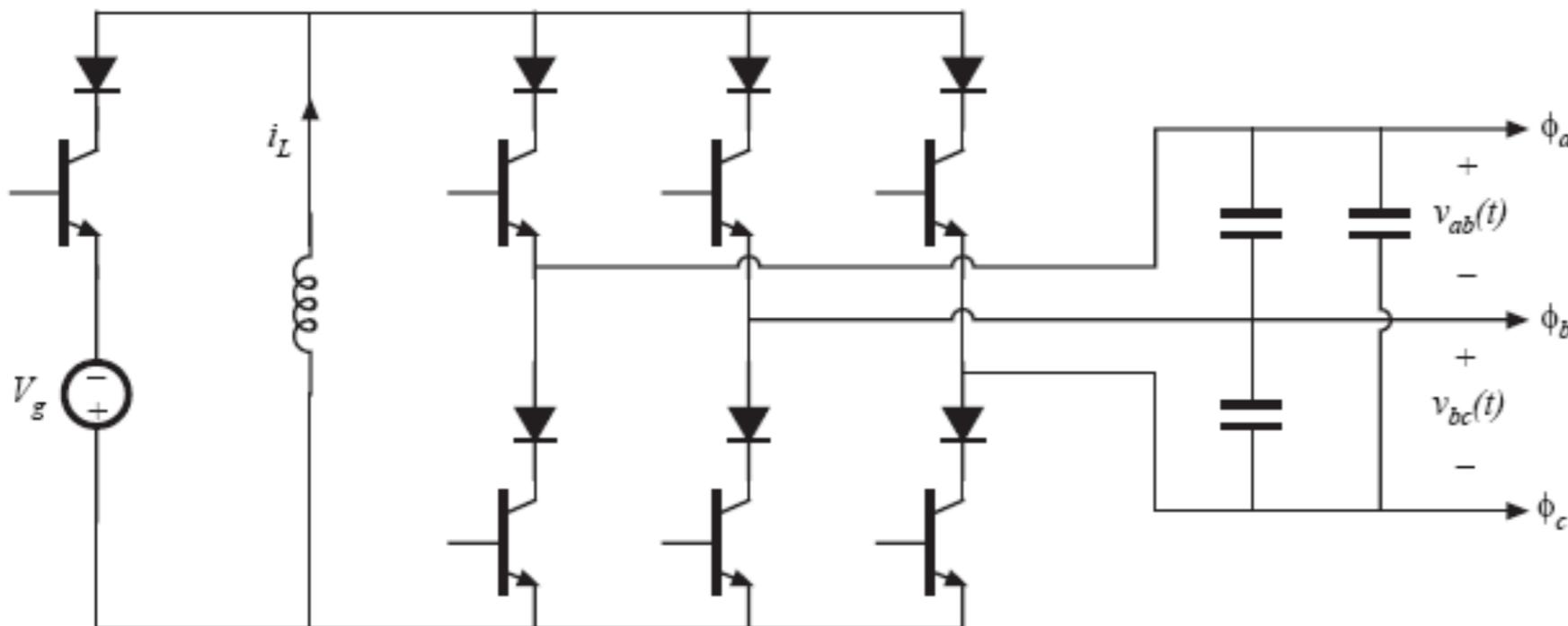
*Zero voltage  
switching*



# Conversores CC-CA: De corrente ou tensão



Tensão - VSI



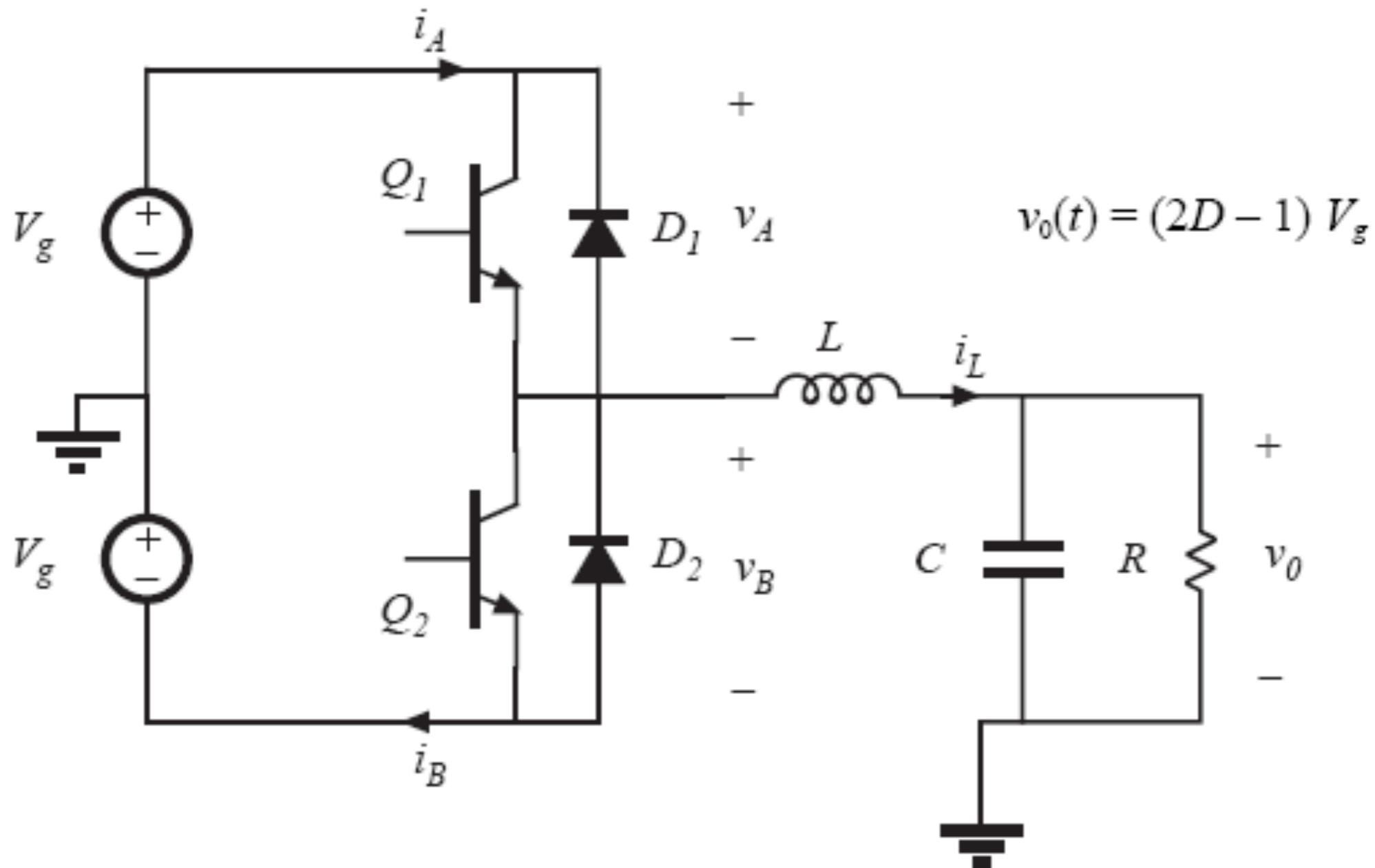
Corrente - CSI

# Aplicações de Conversores CC-CA

## Algumas aplicações:

1. Acionamento de motores de corrente contínua;
2. Acionamento de motores de corrente alternada;
3. Energias alternativas;
4. Isolamento em alta frequência;
5. Filtros ativos;
6. Estabilizadores de tensão;
7. UPS;
8. Aplicações espaciais, aeronáuticas e veiculares
9. Entre outras.

# Inversor Simples

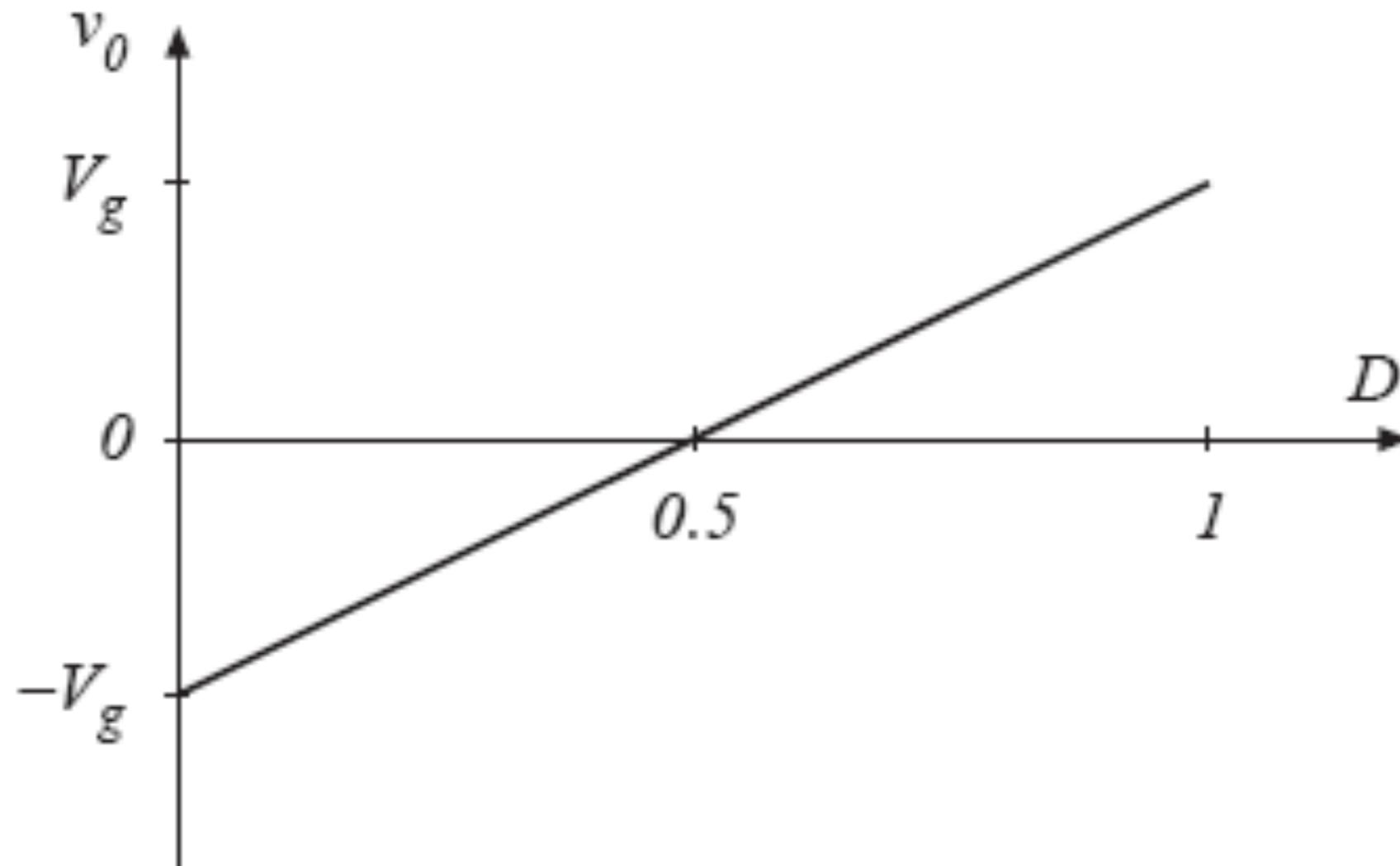


## Tarefa:

Explicar o funcionamento, etapas de operação e principais formas de onda.

# Inversor Simples

$$v_o(t) = (2D - 1) V_g$$

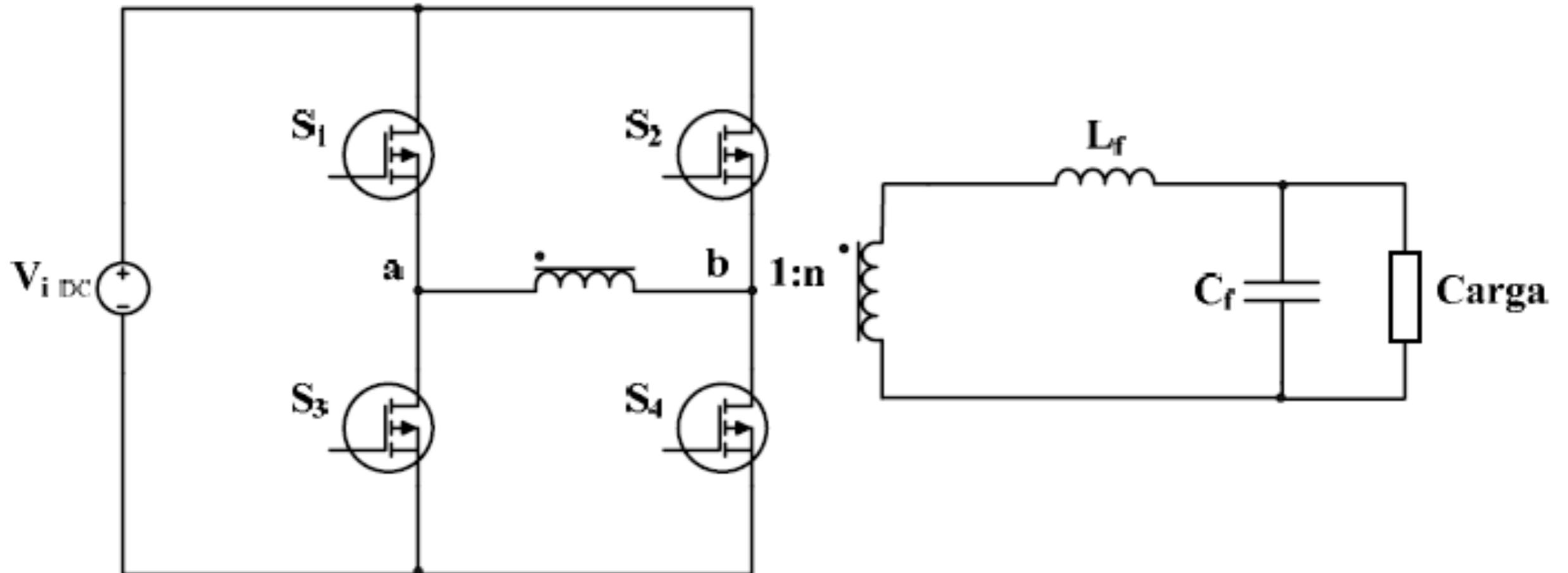


$$D(t) = 0.5 + D_m \sin(\omega t)$$

$$i_L(t) = \frac{v_o(t)}{R} = (2D - 1) \frac{V_g}{R}$$

# Inversor Ponte Completa

Estrutura do conversor:

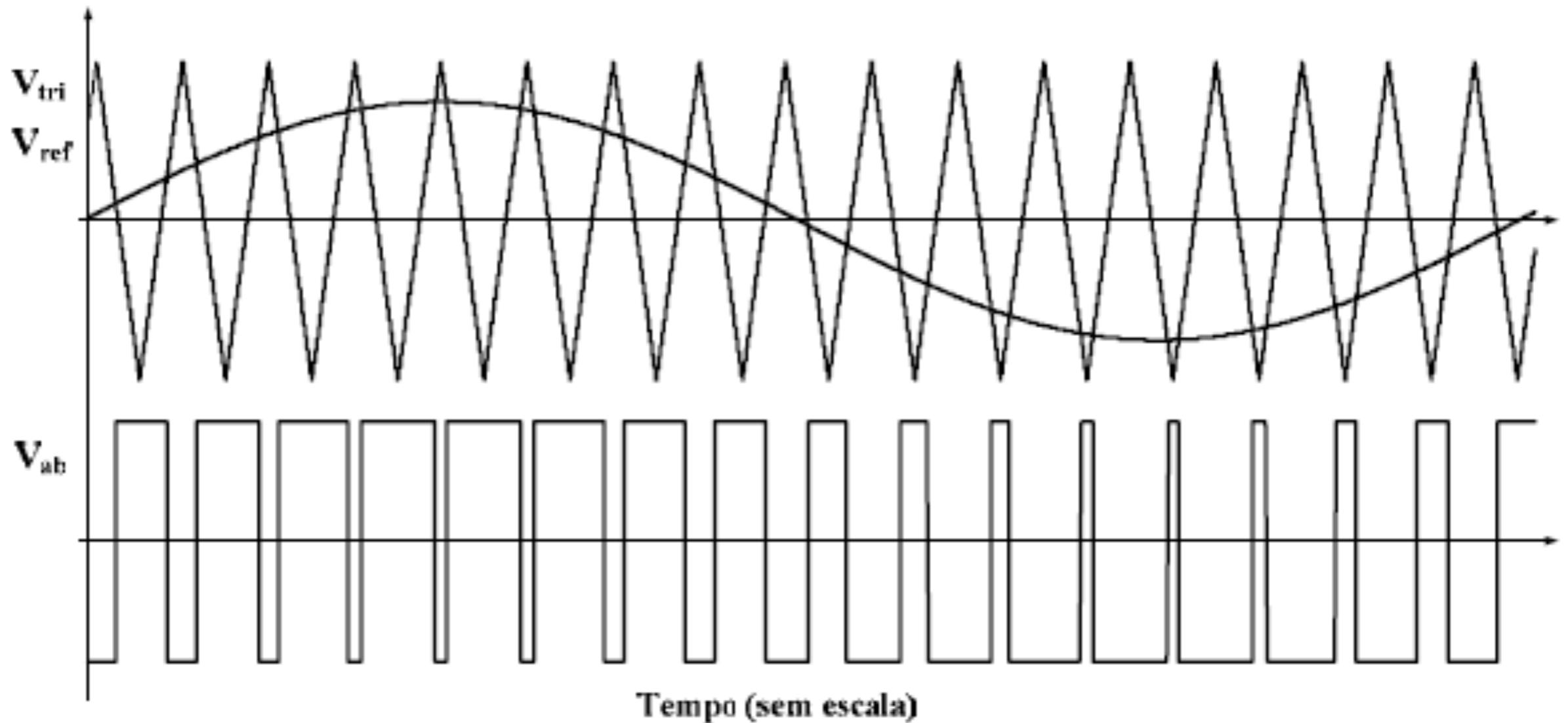


# Inversor Ponte Completa

Modulação empregada:

Tarefa:

Mostrar circuito.



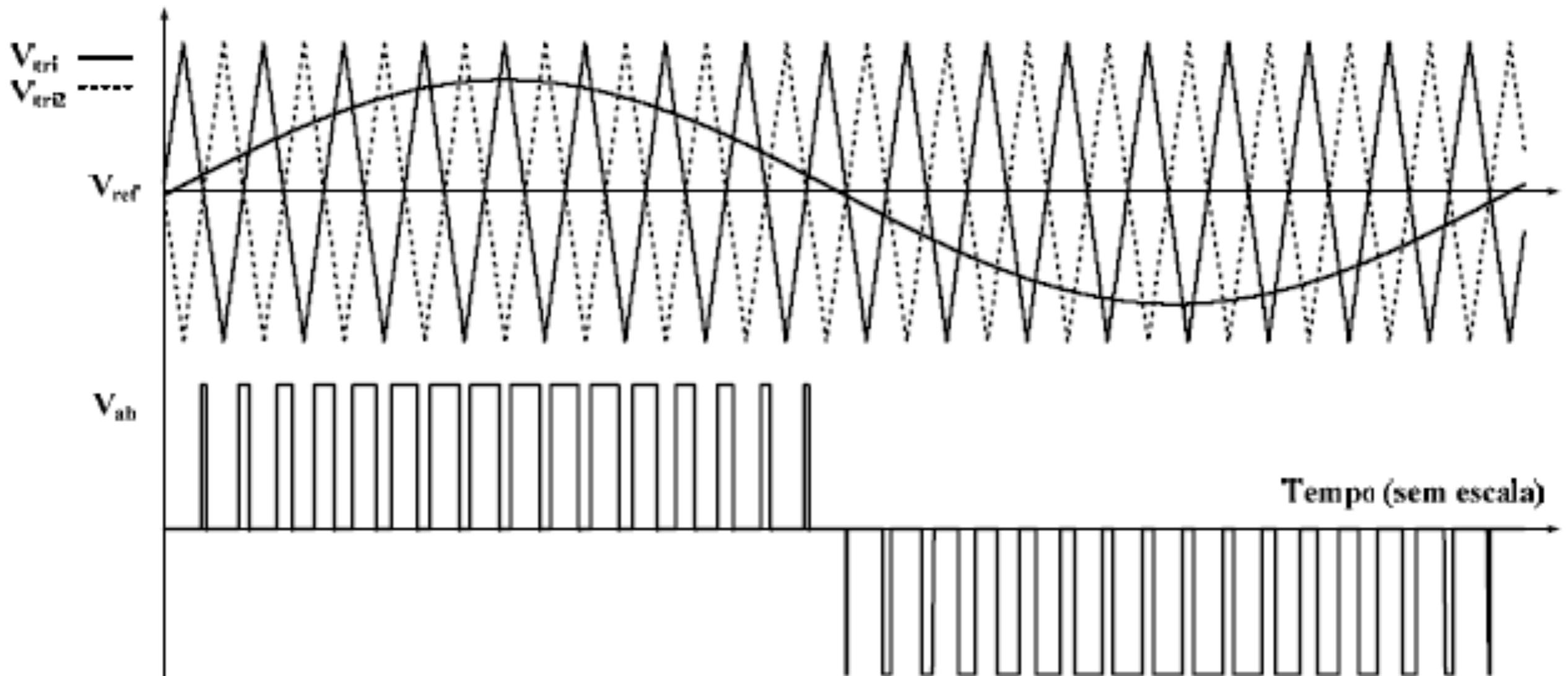
Bipolar ou dois níveis

# Inversor Ponte Completa

Modulação empregada:

Tarefa:

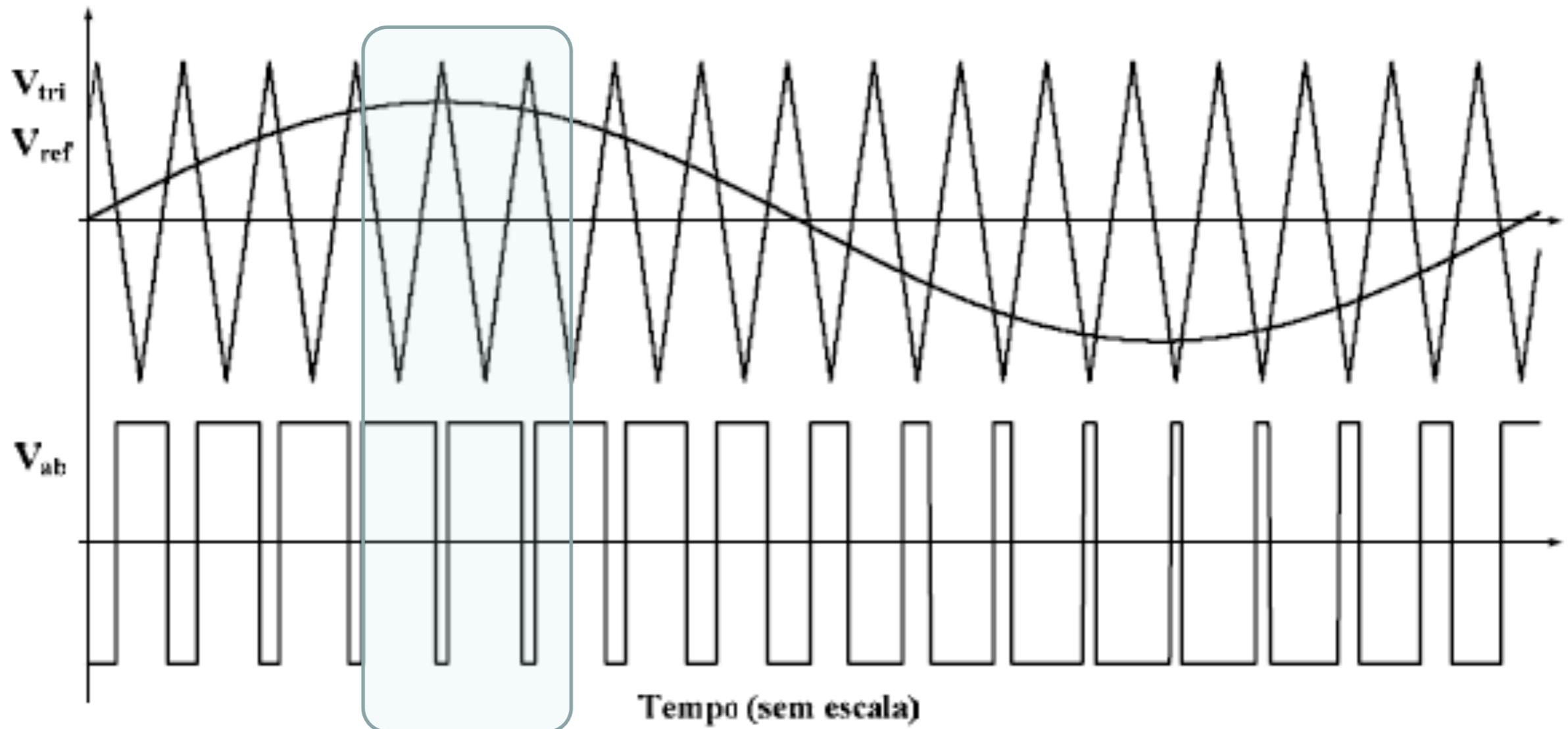
Mostrar circuito.



Unipolar ou três níveis

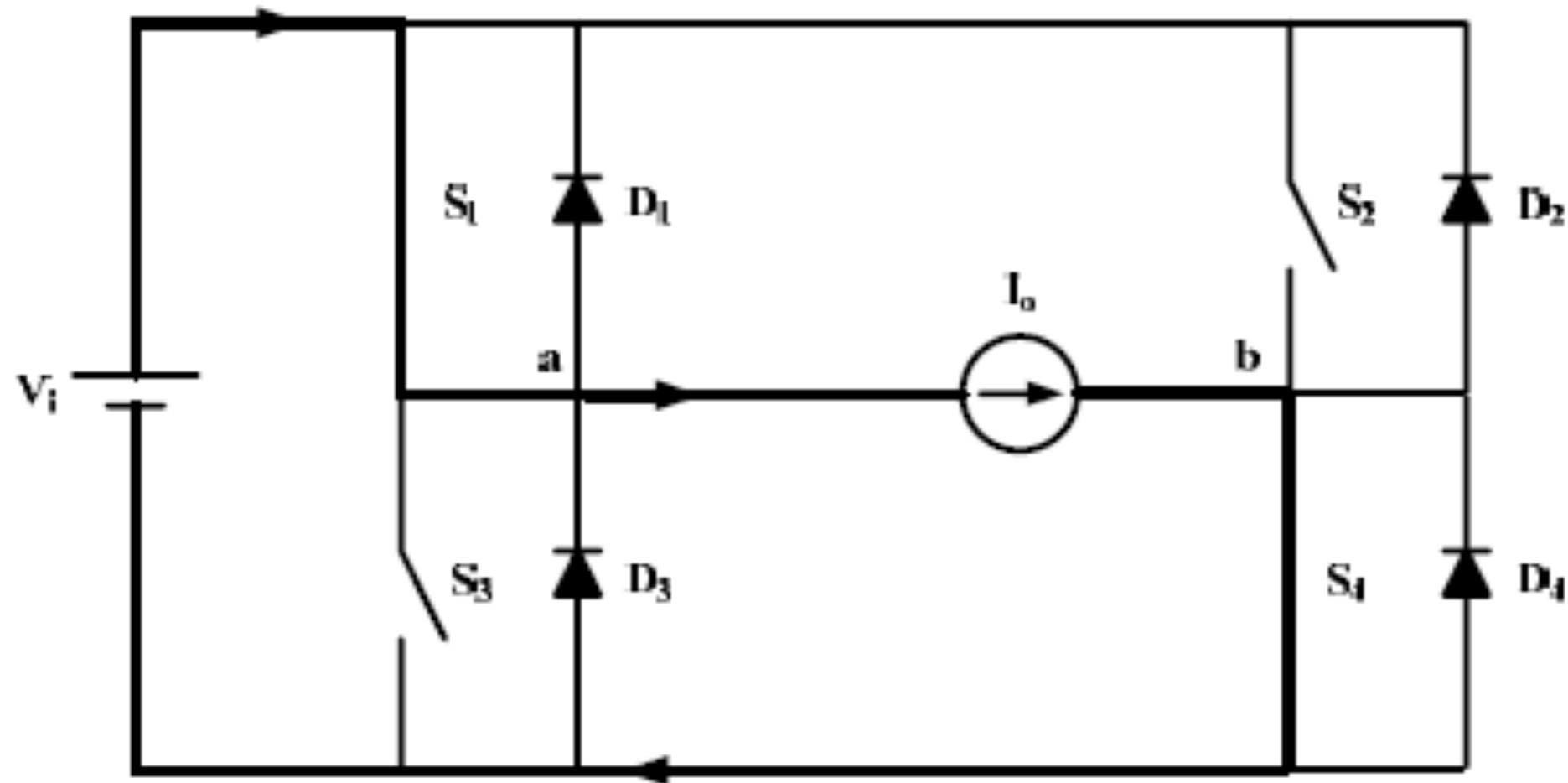
# Inversor Ponte Completa

Etapas de operação (modulação SPWM bipolar):



# Inversor Ponte Completa

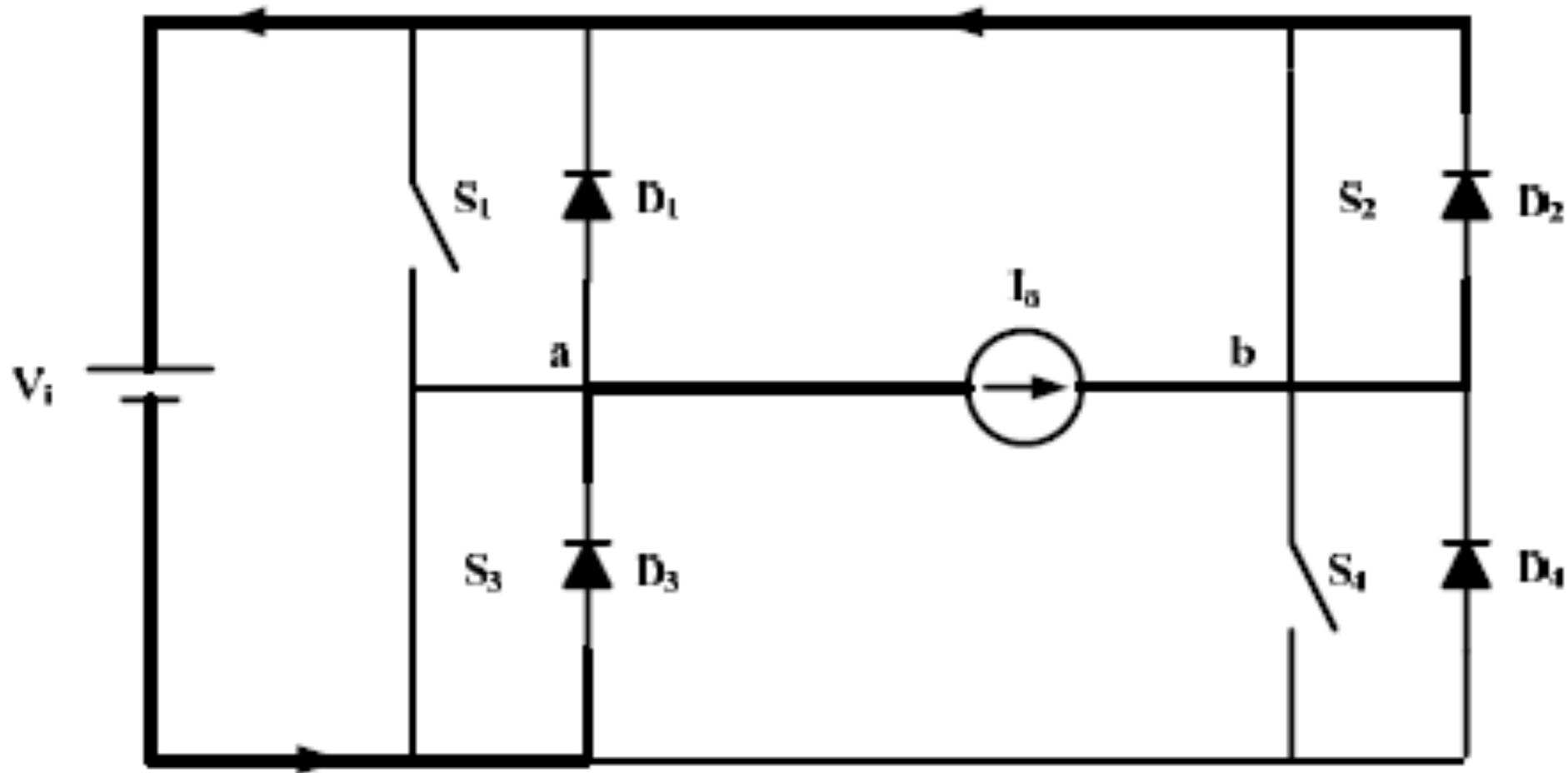
Etapas de operação (modulação SPWM bipolar):



Primeira etapa de operação

# Inversor Ponte Completa

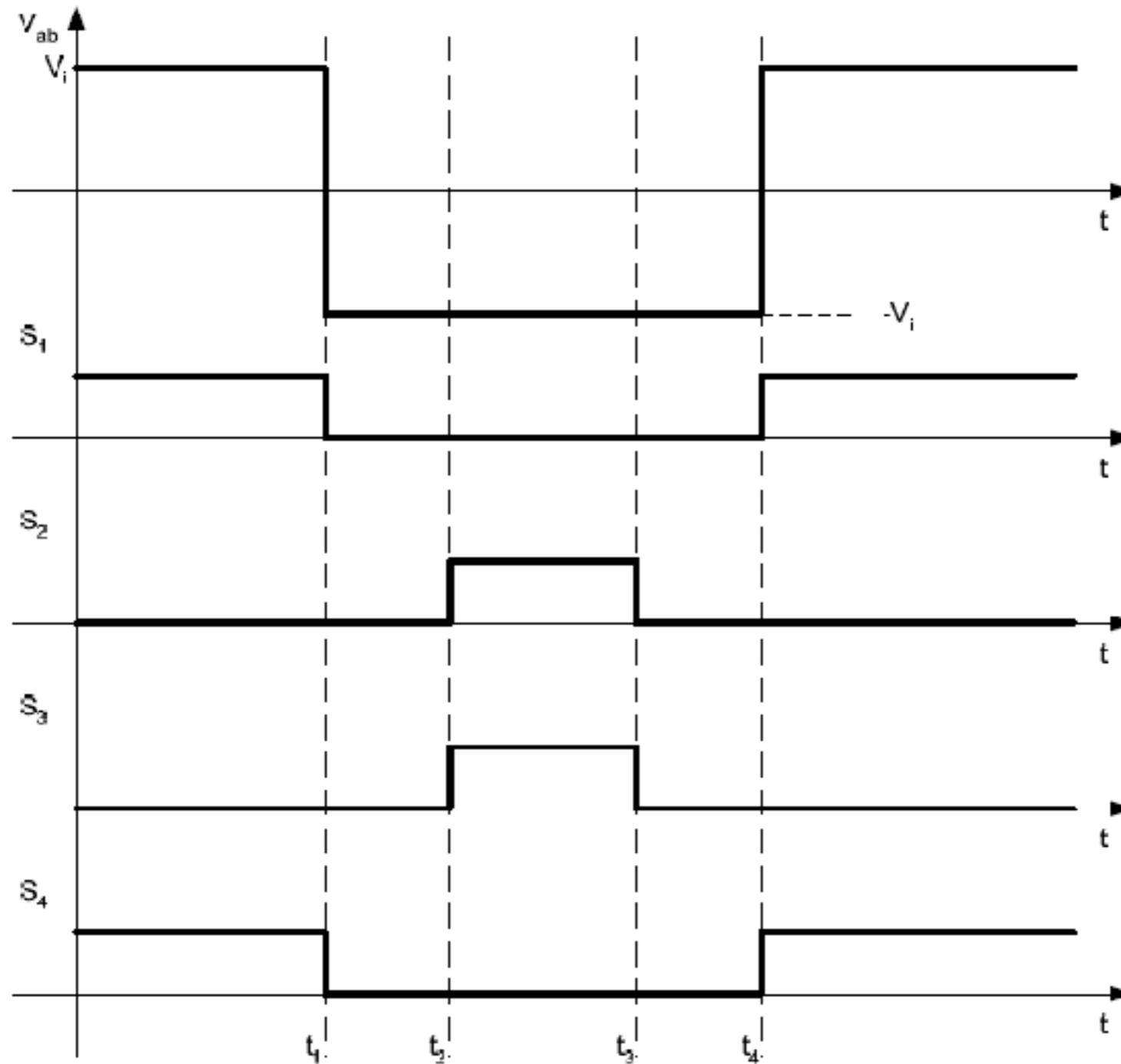
Etapas de operação (modulação SPWM bipolar):



Segunda etapa de operação

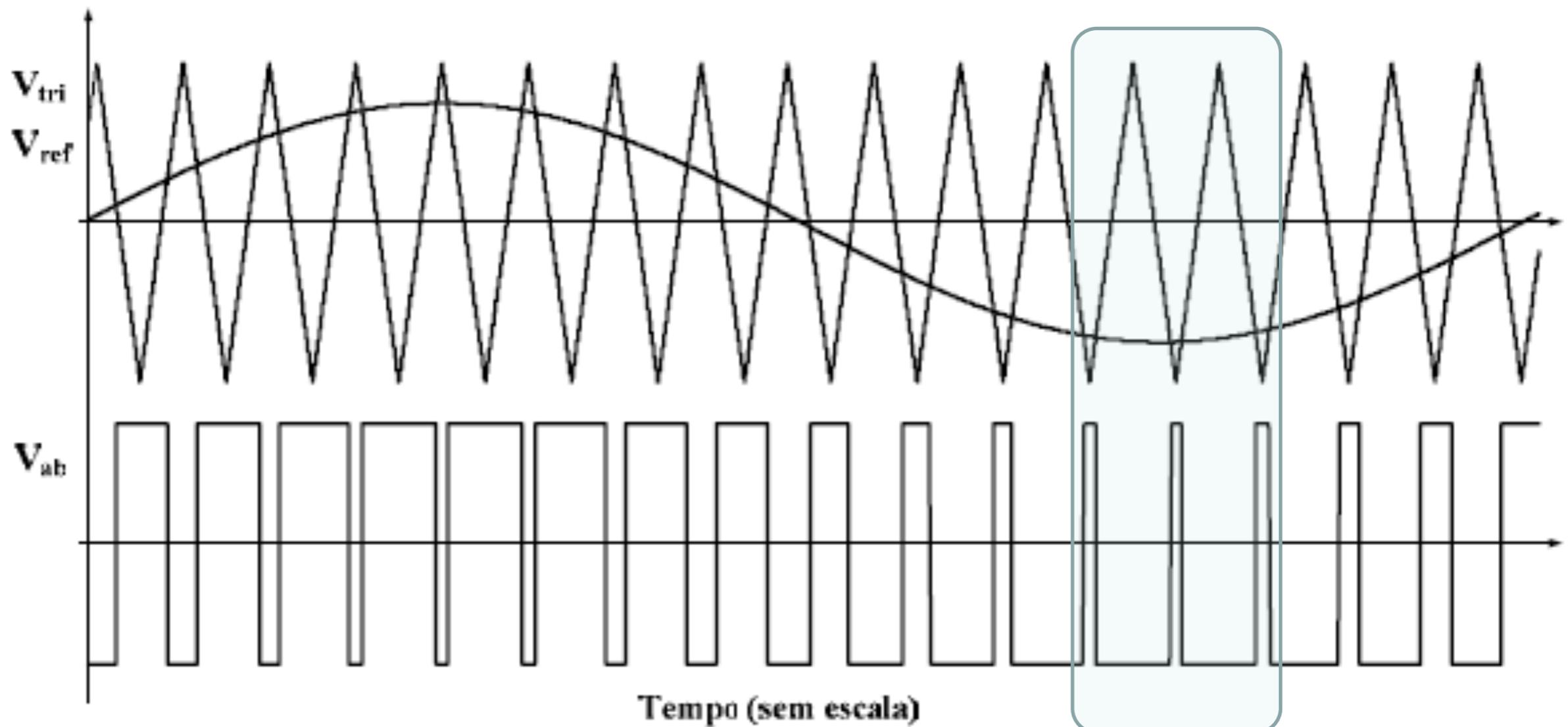
# Inversor Ponte Completa

Principais formas de onda (modulação SPWM bipolar):



# Inversor Ponte Completa

Etapas de operação (modulação SPWM bipolar):

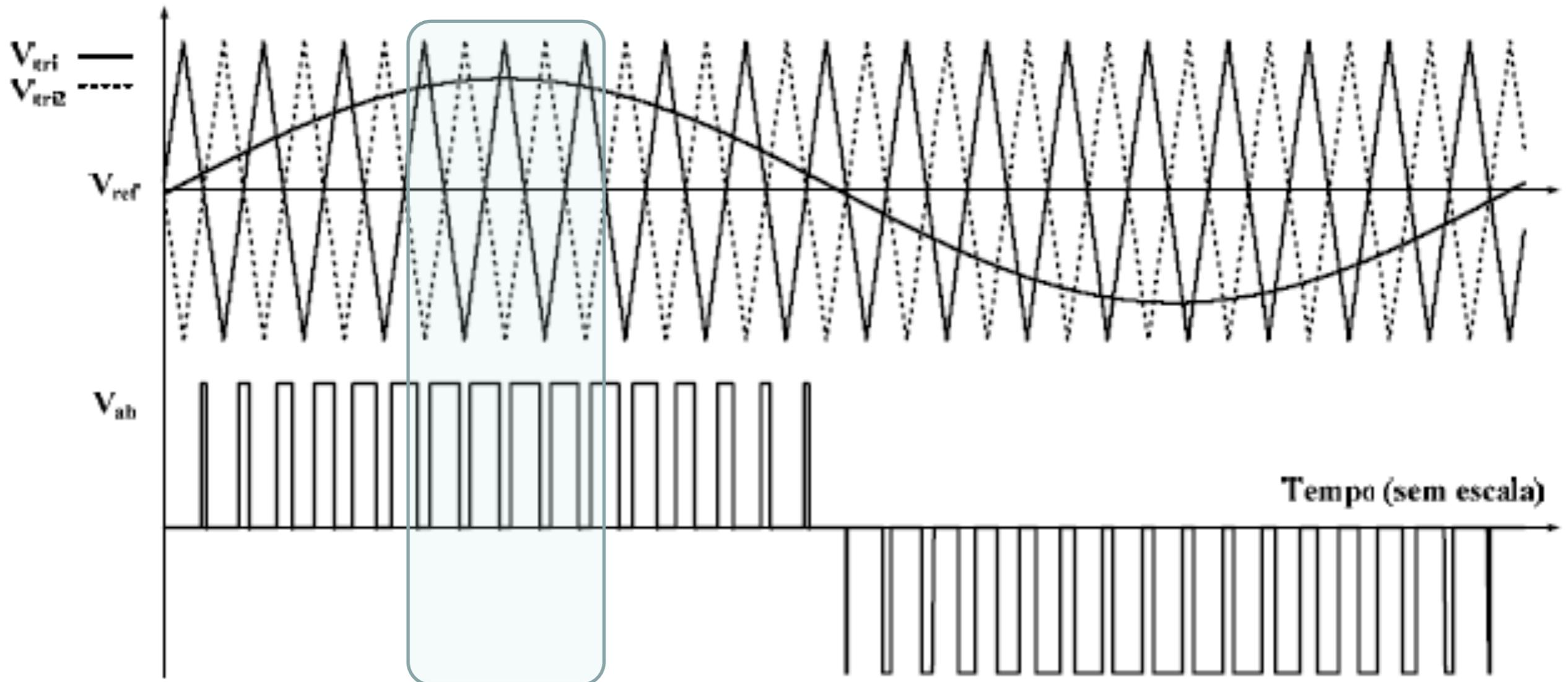


Tarefa:

Repetir para o semiciclo negativo.

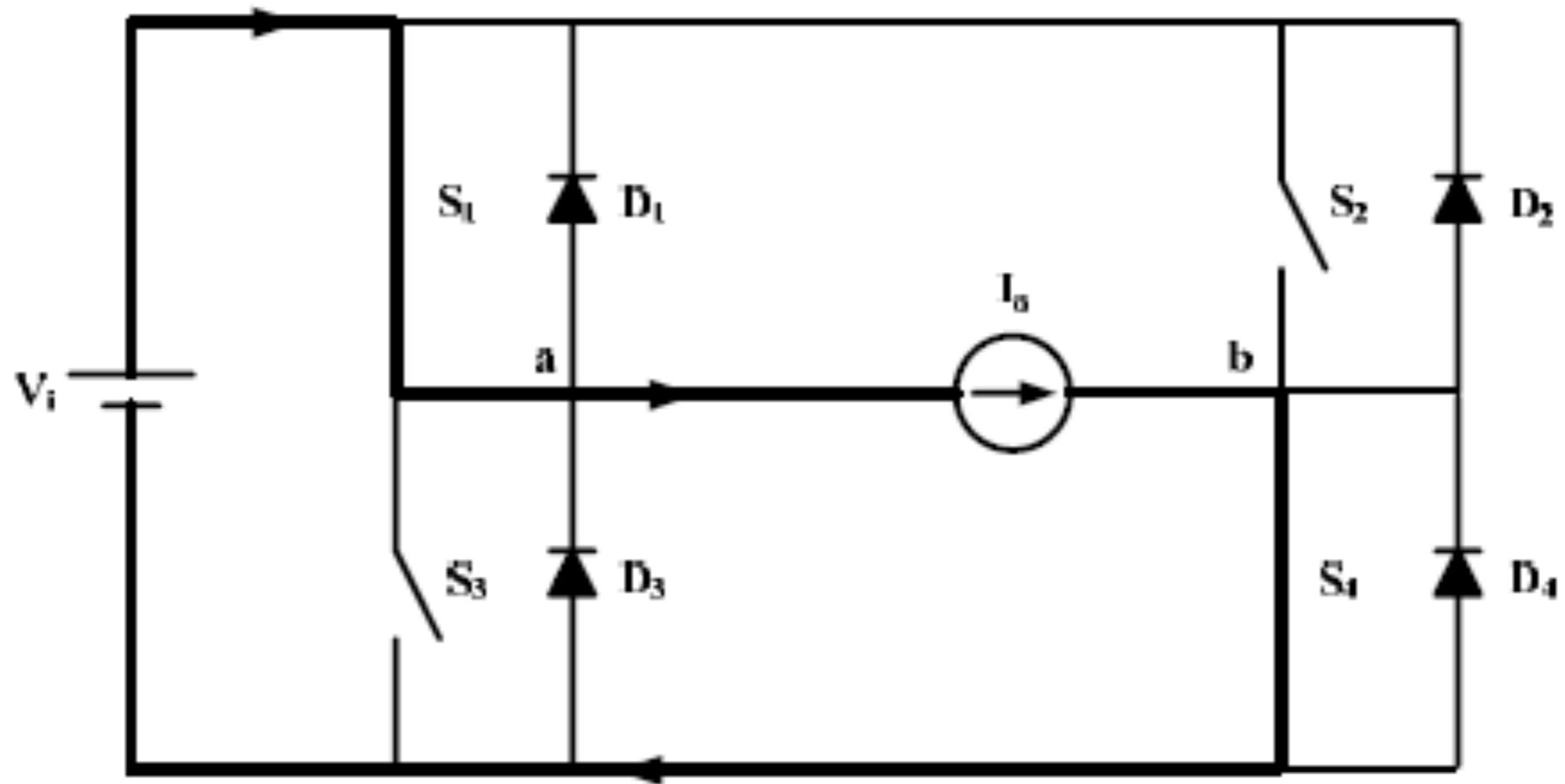
# Inversor Ponte Completa

Etapas de operação (modulação SPWM unipolar):



# Inversor Ponte Completa

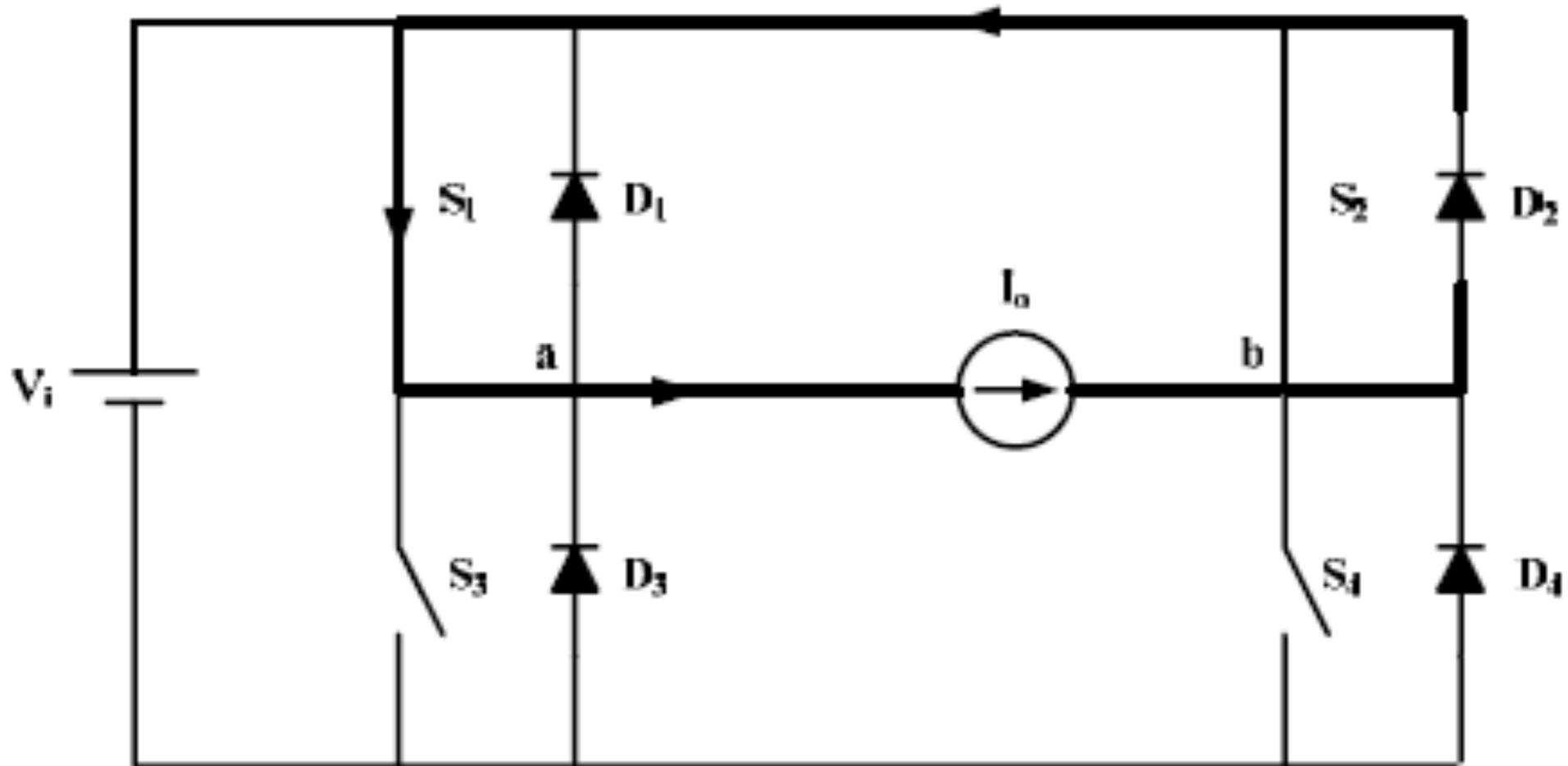
Etapas de operação (modulação SPWM unipolar):



Primeira etapa de operação

# Inversor Ponte Completa

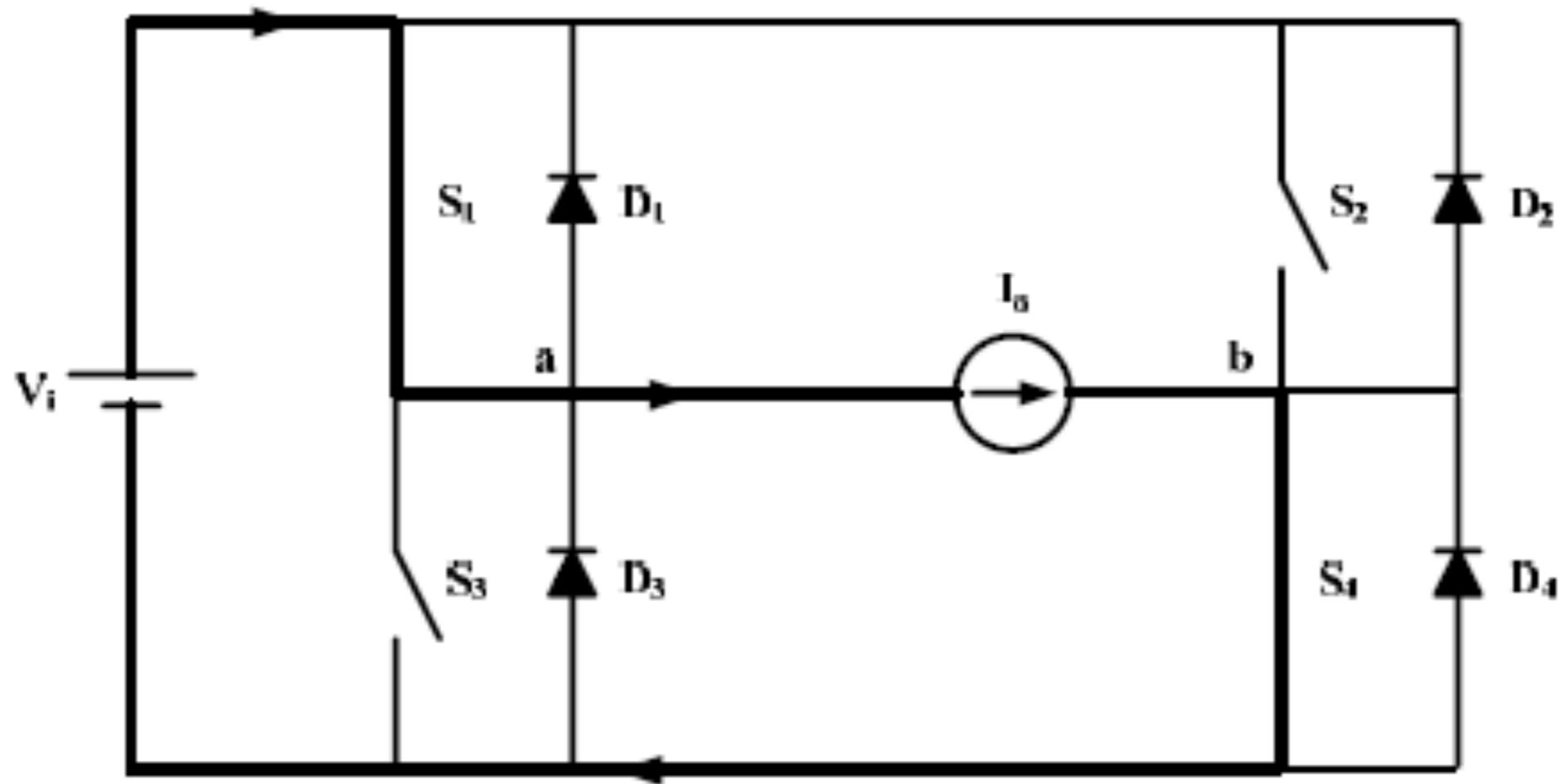
Etapas de operação (modulação SPWM unipolar):



Segunda etapa de operação

# Inversor Ponte Completa

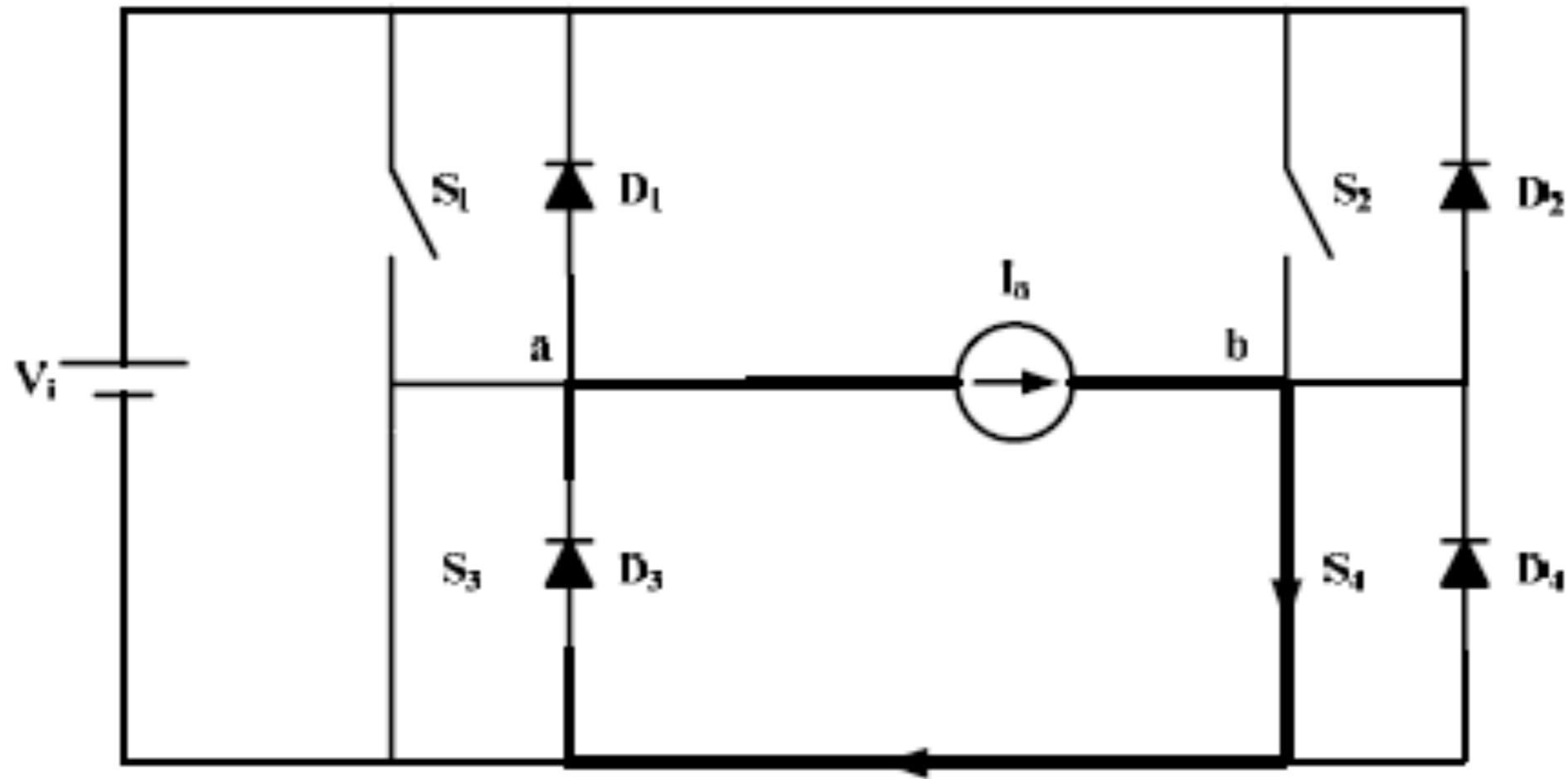
Etapas de operação (modulação SPWM unipolar):



Terceira etapa de operação

# Inversor Ponte Completa

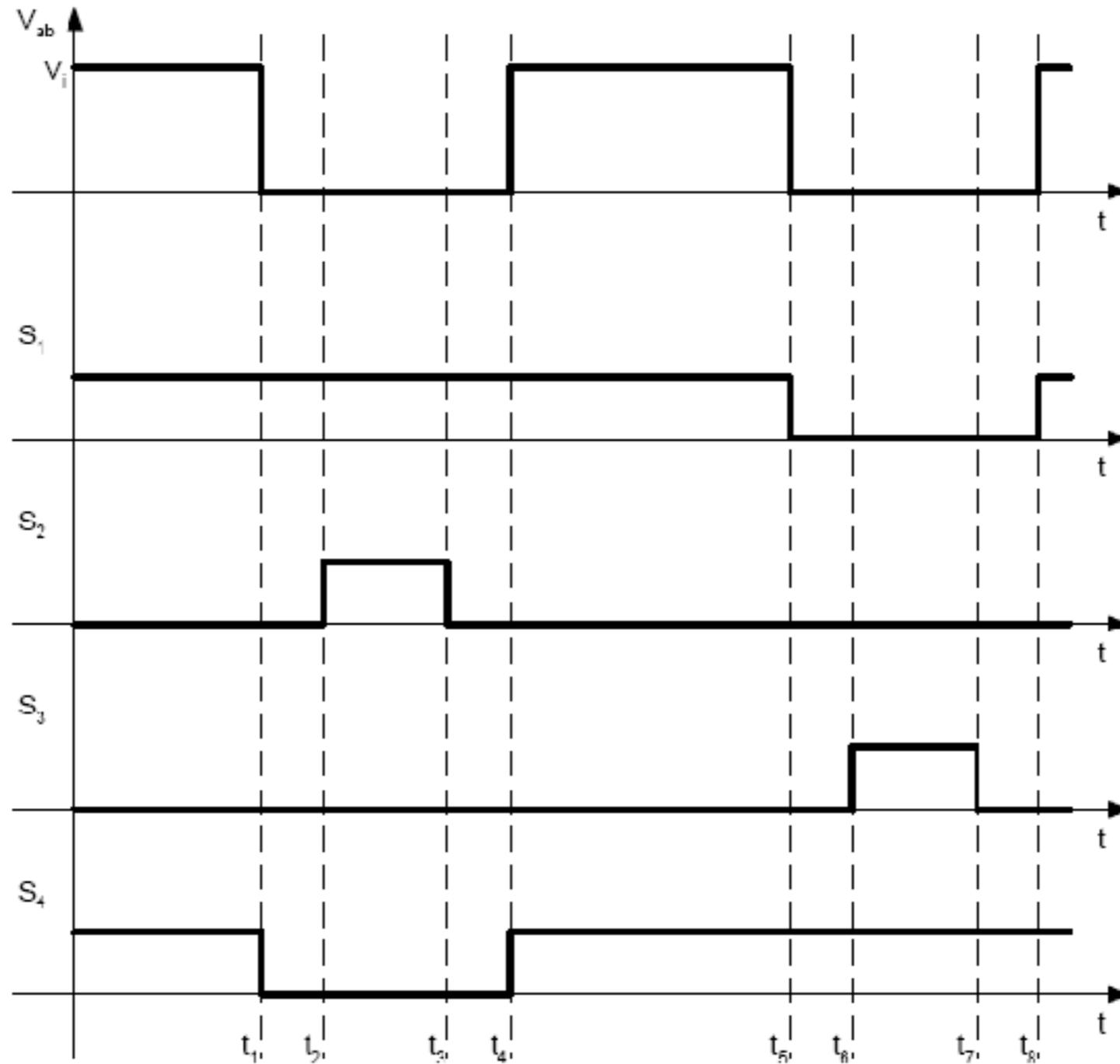
Etapas de operação (modulação SPWM unipolar):



Quarta etapa de operação

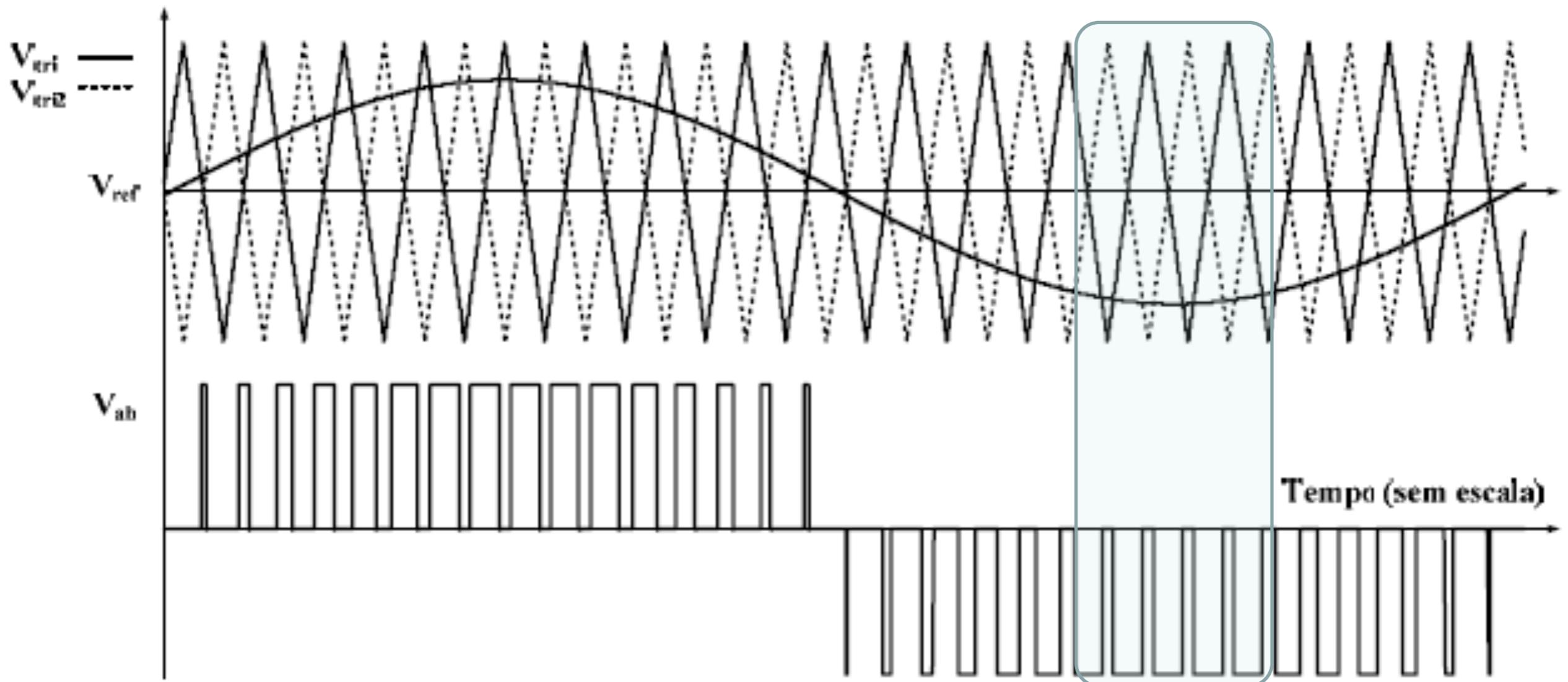
# Inversor Ponte Completa

Principais formas de onda (modulação SPWM unipolar):



# Inversor Ponte Completa

Etapas de operação (modulação SPWM unipolar):

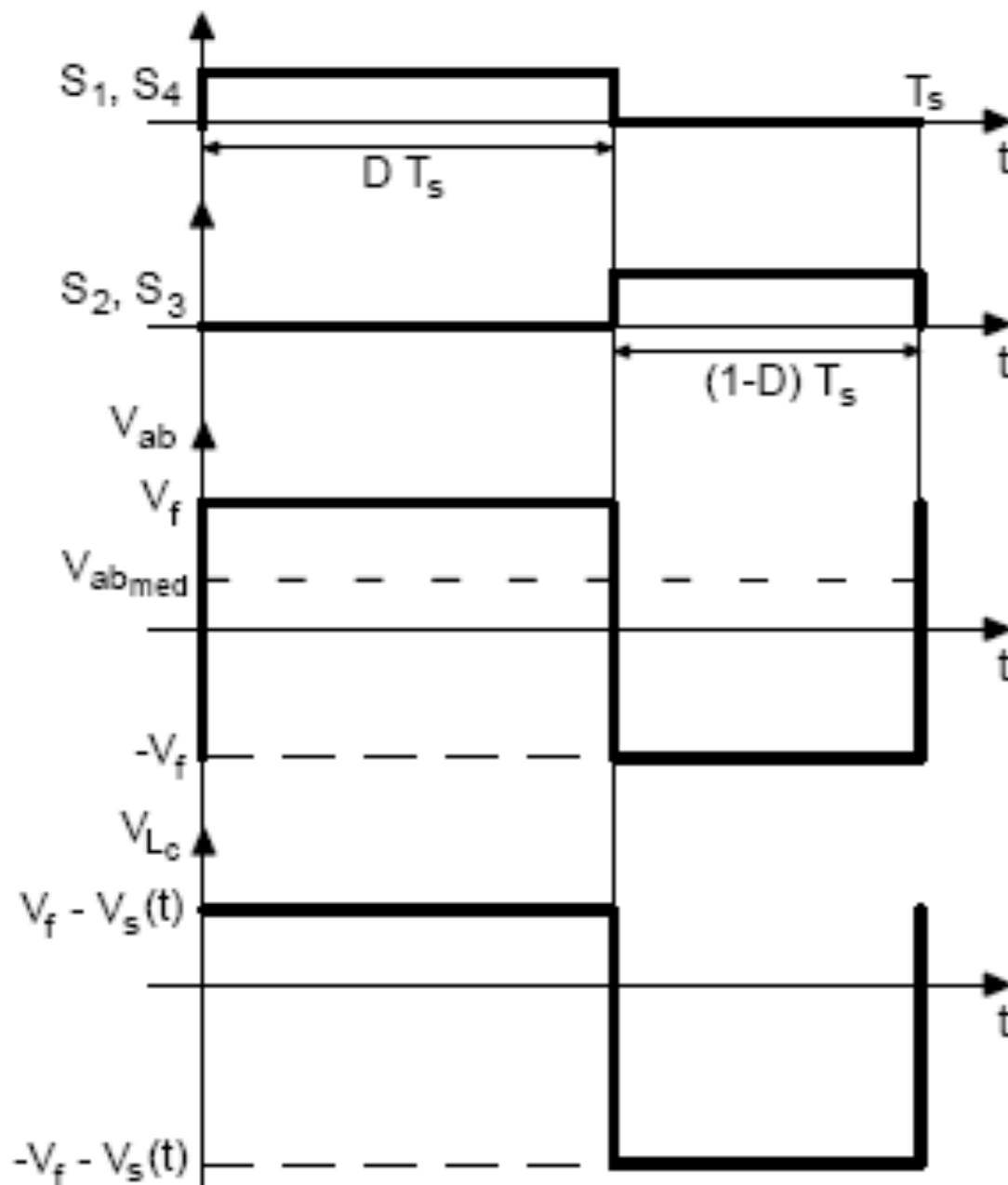


Tarefa:

Repetir para o semiciclo negativo.

# Inversor Ponte Completa

Tensão de saída (modulação SPWM bipolar):



$$V_{ab} = V_f \cdot (2 \cdot D - 1)$$

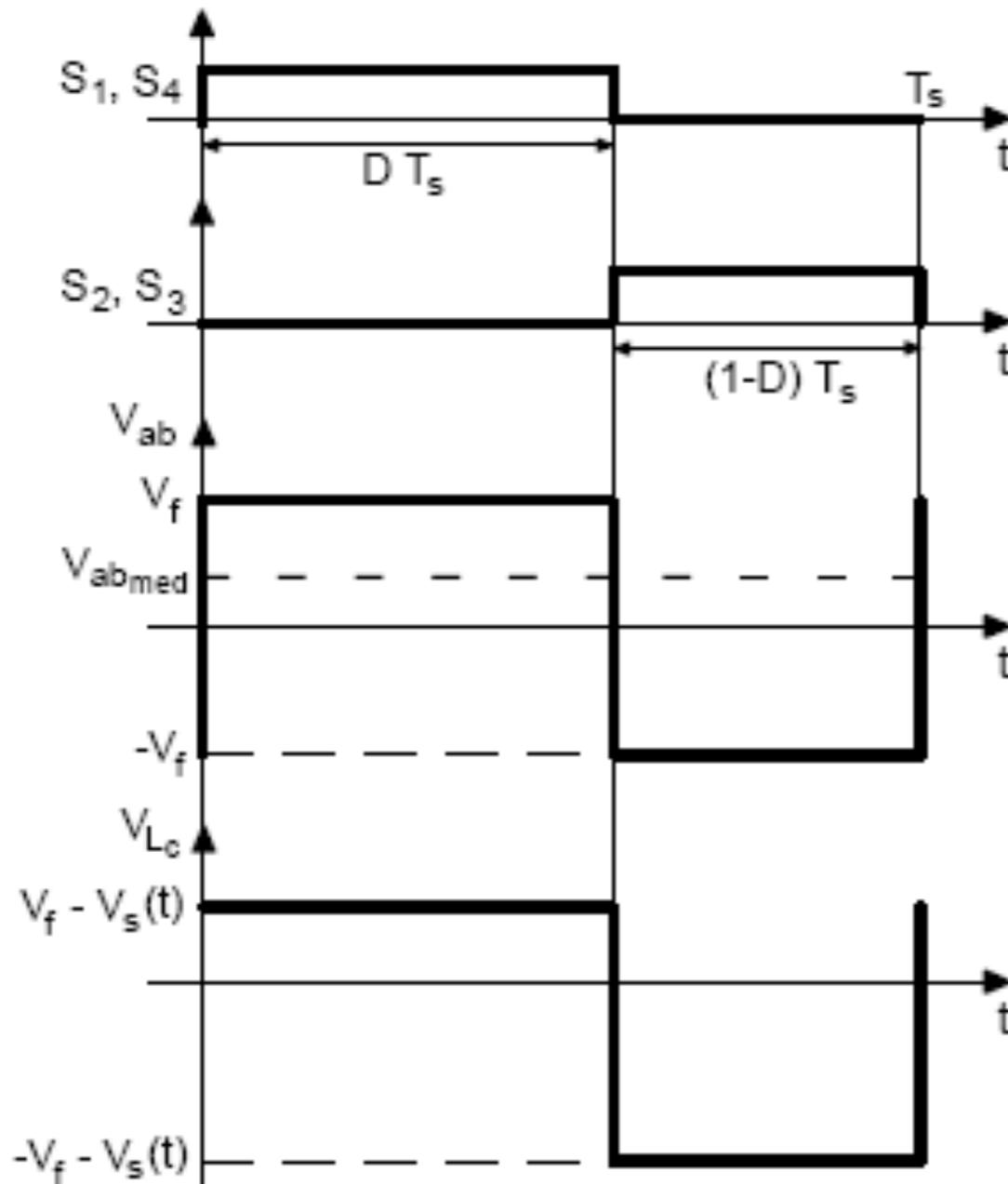
$$d(t) = \frac{1}{2} + \frac{1}{2} \cdot \frac{V_{ab\_pk}}{V_f} \cdot \text{sen}(\omega \cdot t)$$

Índice de modulação:

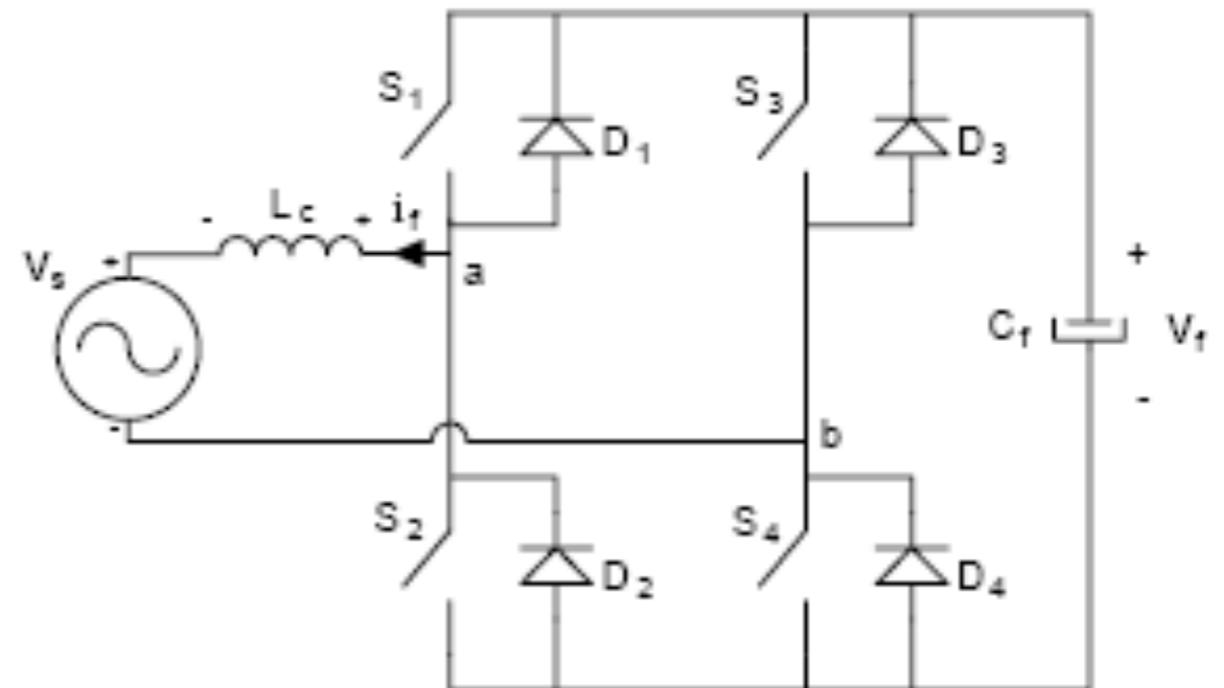
$$MI = \frac{V_{ab\_pk}}{V_f}$$

# Inversor Ponte Completa

Determinando o indutor (modulação SPWM bipolar):

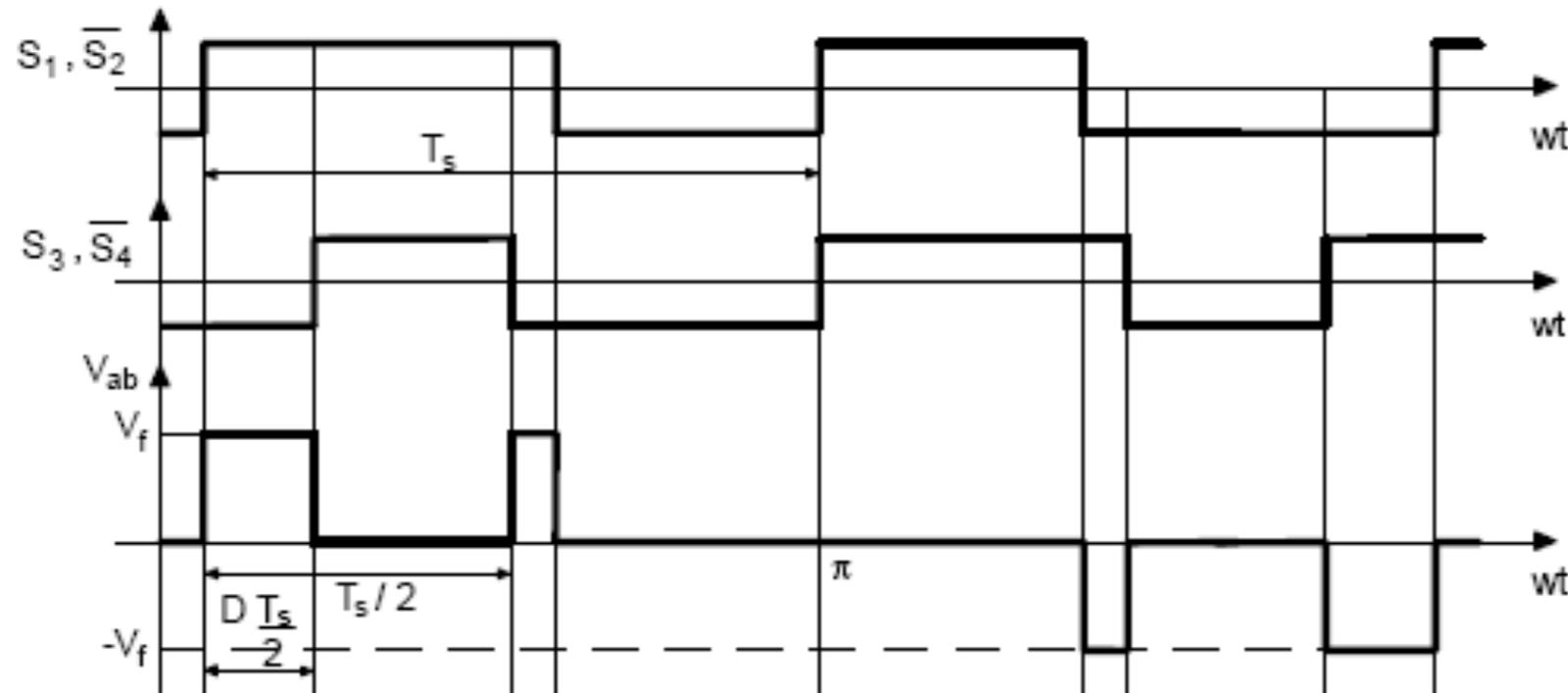


$$L = \frac{V_f}{2 \cdot \Delta I L_{o\max} \cdot F_s}$$



# Inversor Ponte Completa

Tensão de saída (modulação SPWM bipolar):

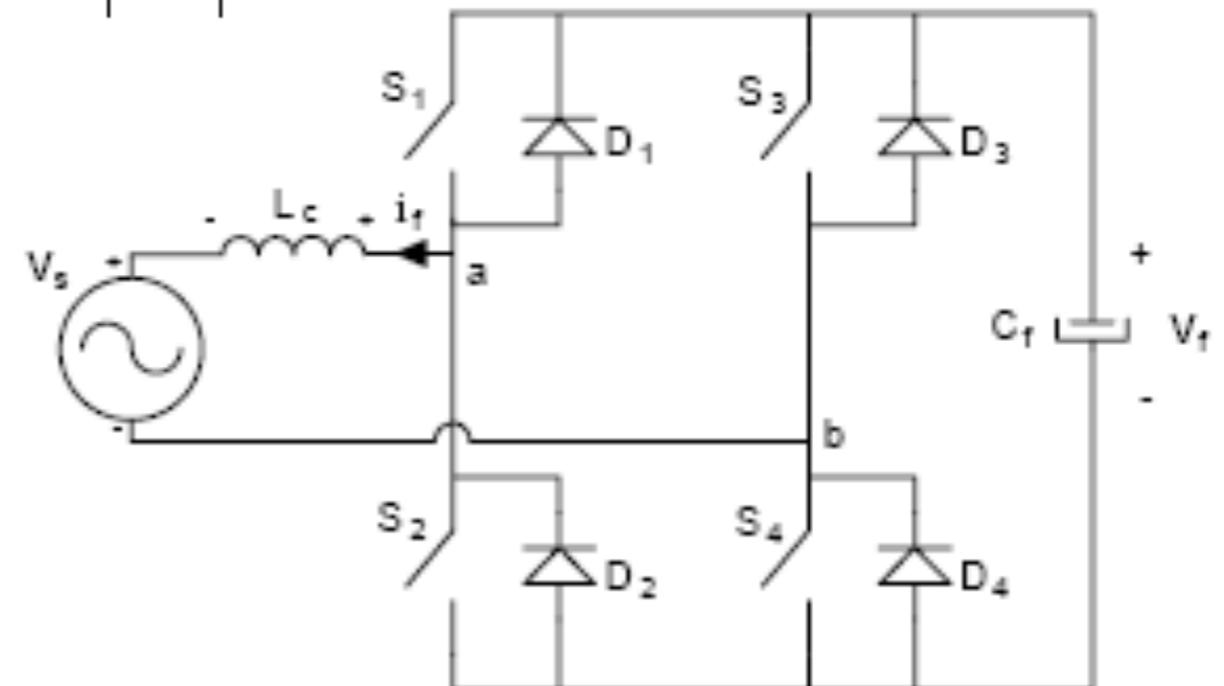


Índice de modulação:

$$MI = \frac{V_{ab\_pk}}{V_f}$$

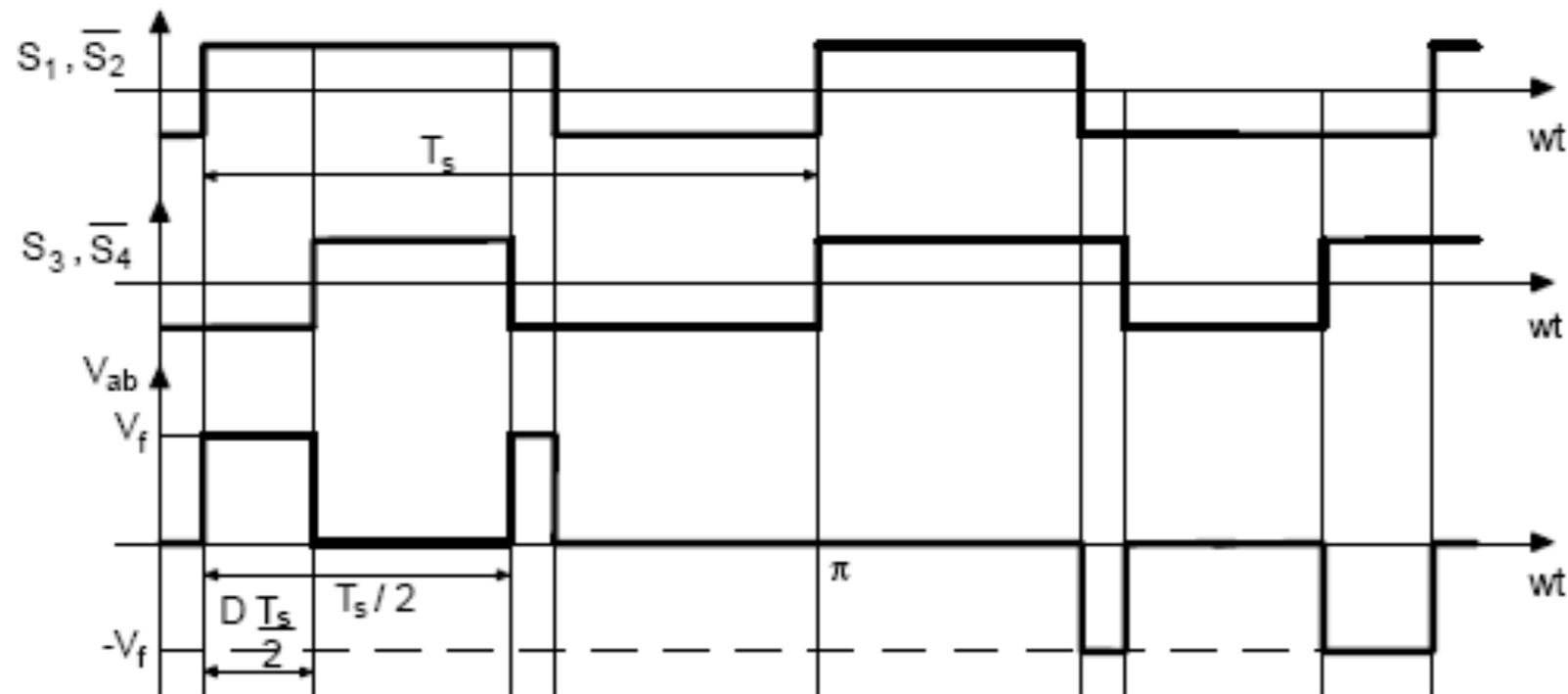
$$V_{ab} = V_f \cdot D$$

$$d(t) = \frac{V_{ab\_pk}}{V_f} \cdot \text{sen}(\omega \cdot t)$$

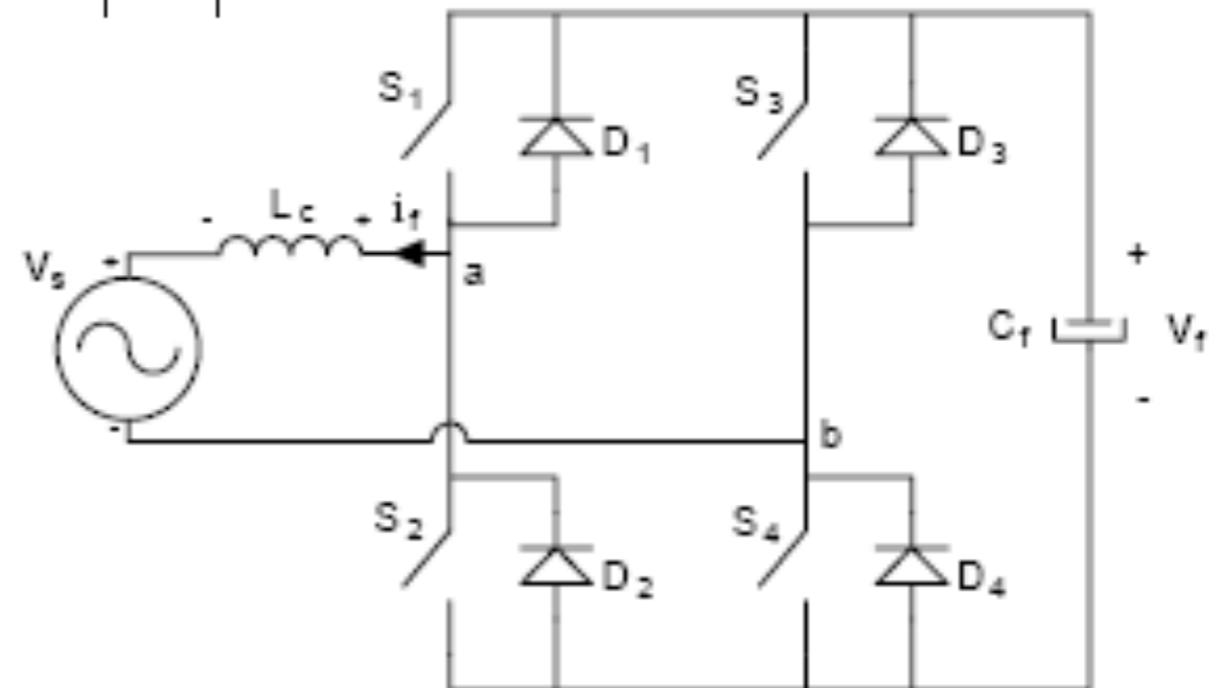


# Inversor Ponte Completa

Determinando o indutor (modulação SPWM bipolar):



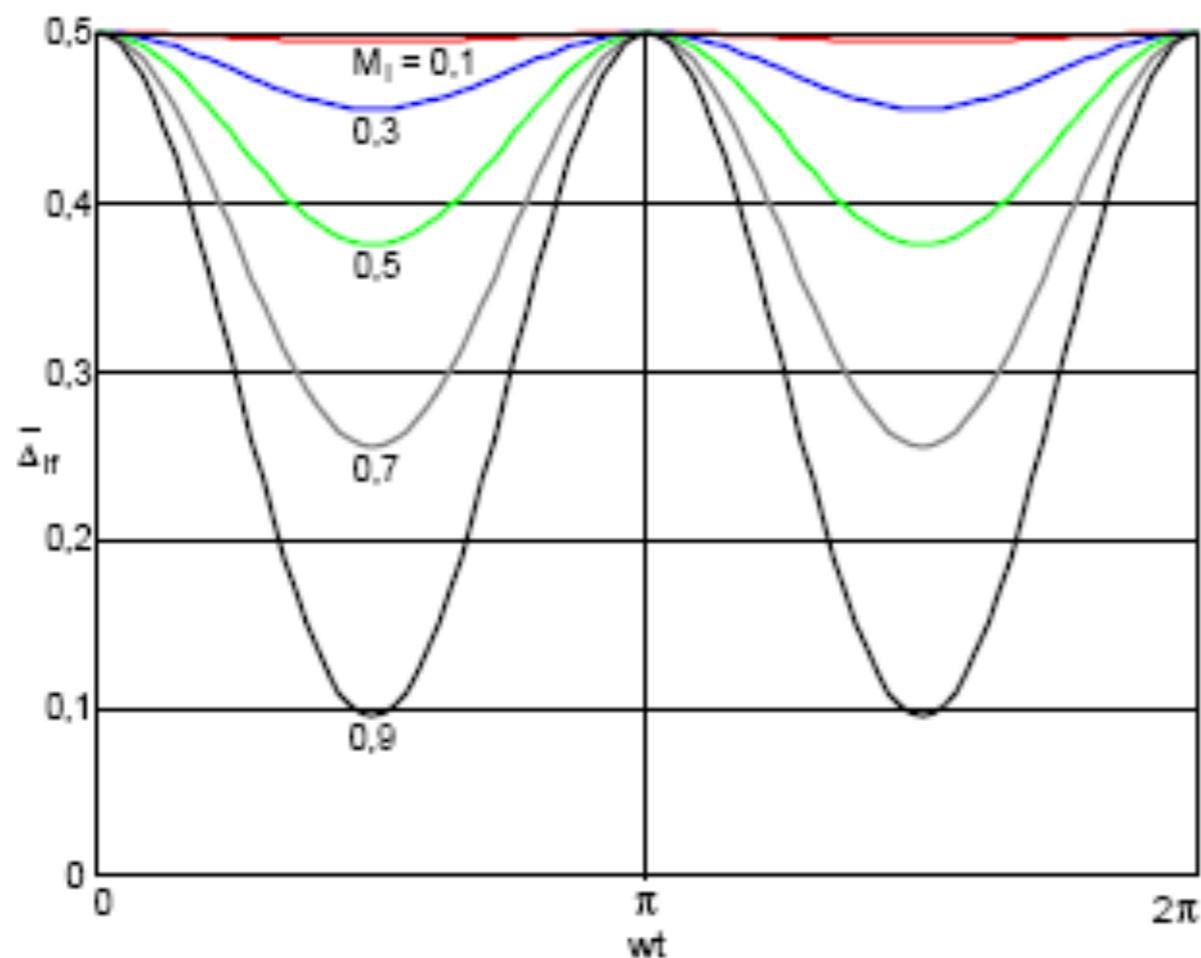
$$L = \frac{V_f}{4 \cdot \Delta I L_{o \max} \cdot F_s}$$



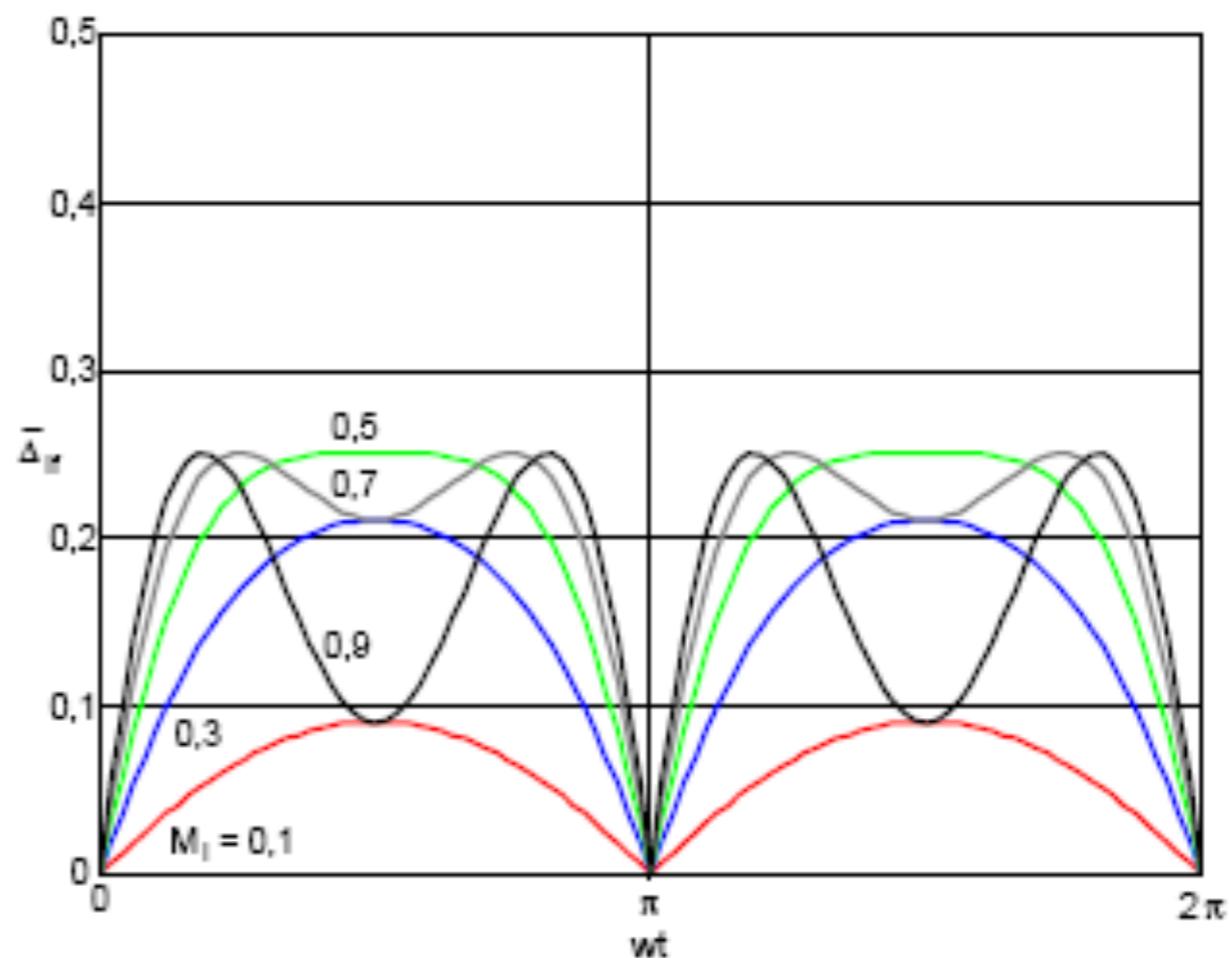
# Inversor Ponte Completa

Indutor (modulação SPWM bipolar x SPWM unipolar):

2 níveis

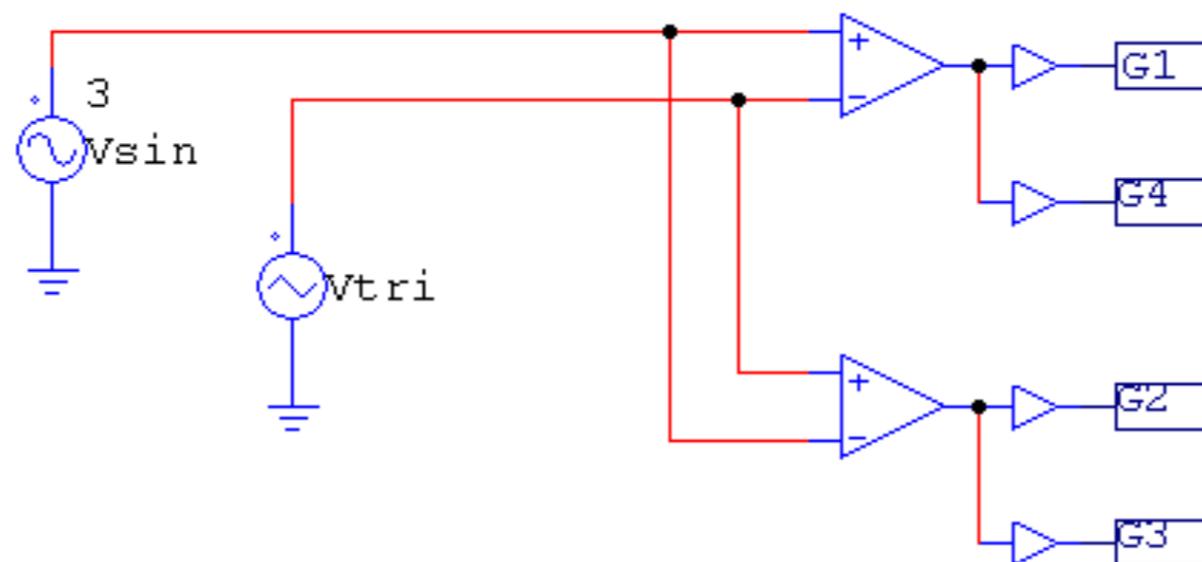
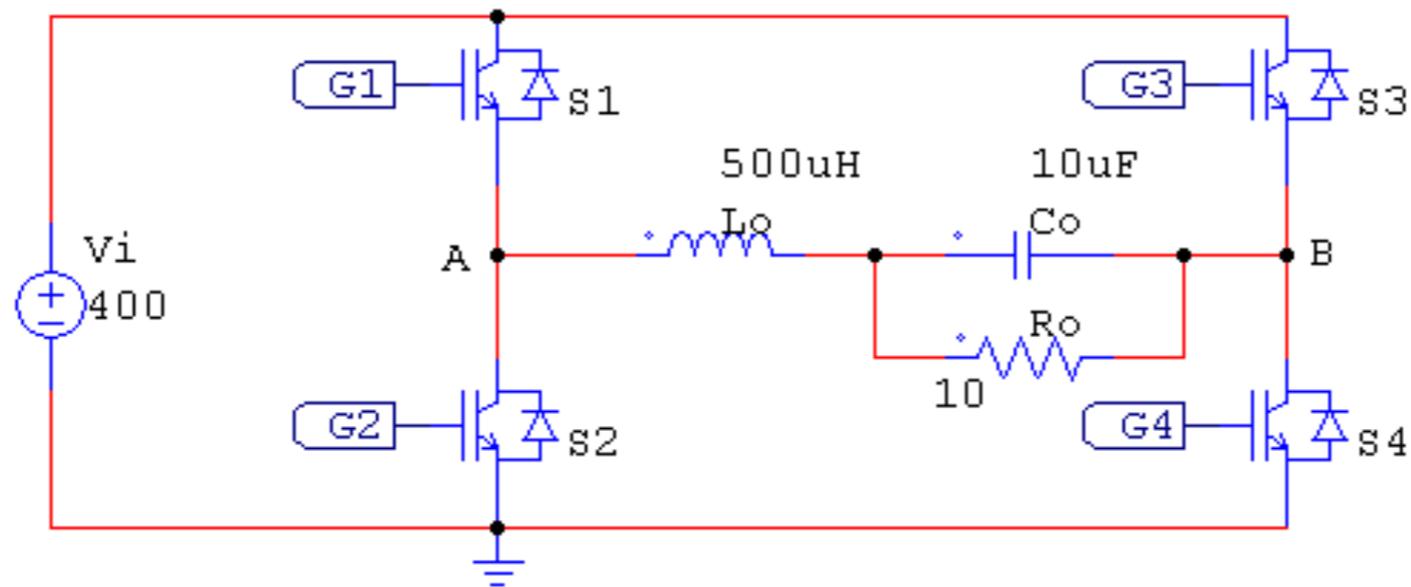


3 níveis



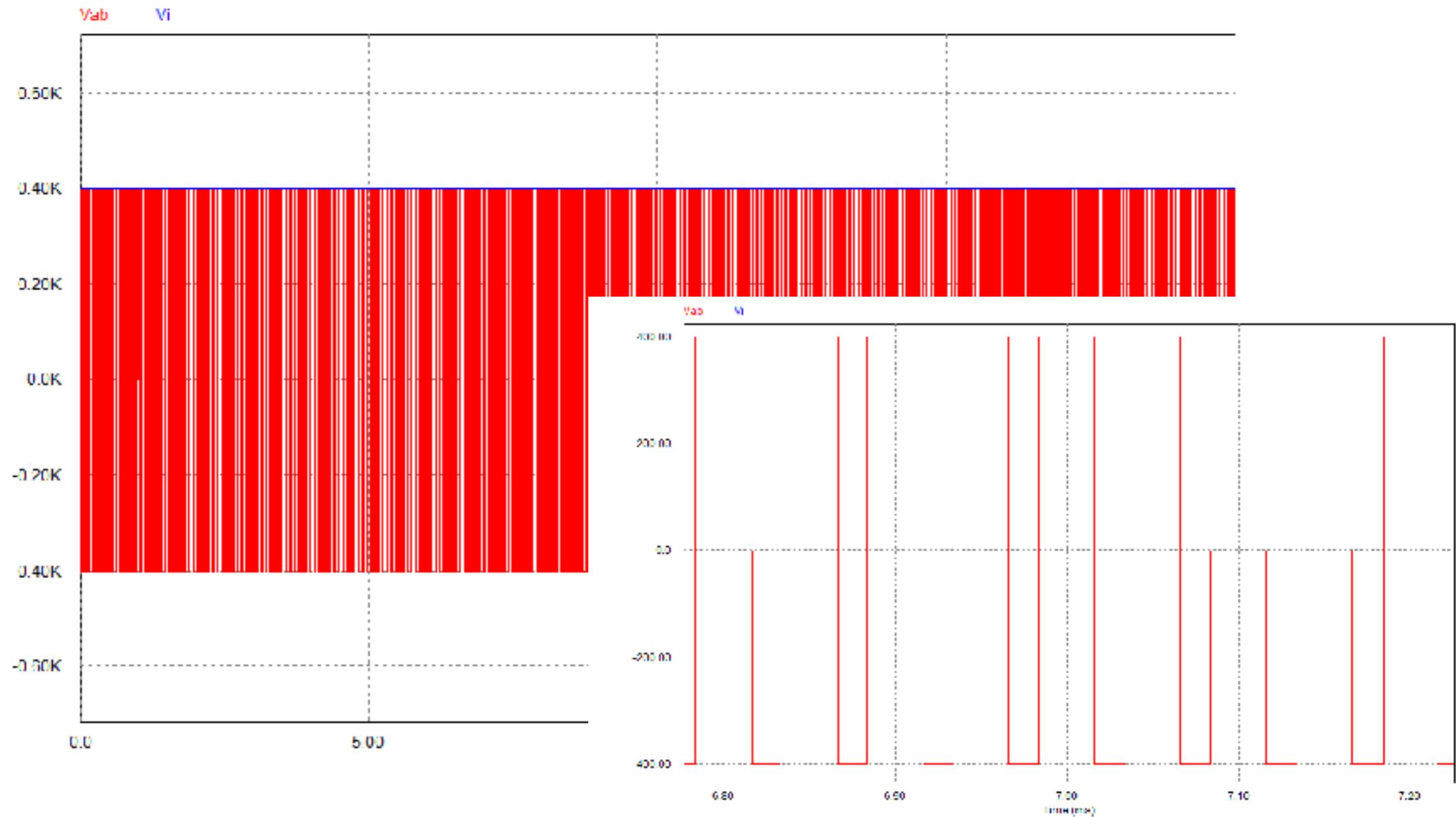
# Inversor Ponte Completa

Simulação (modulação SPWM bipolar):



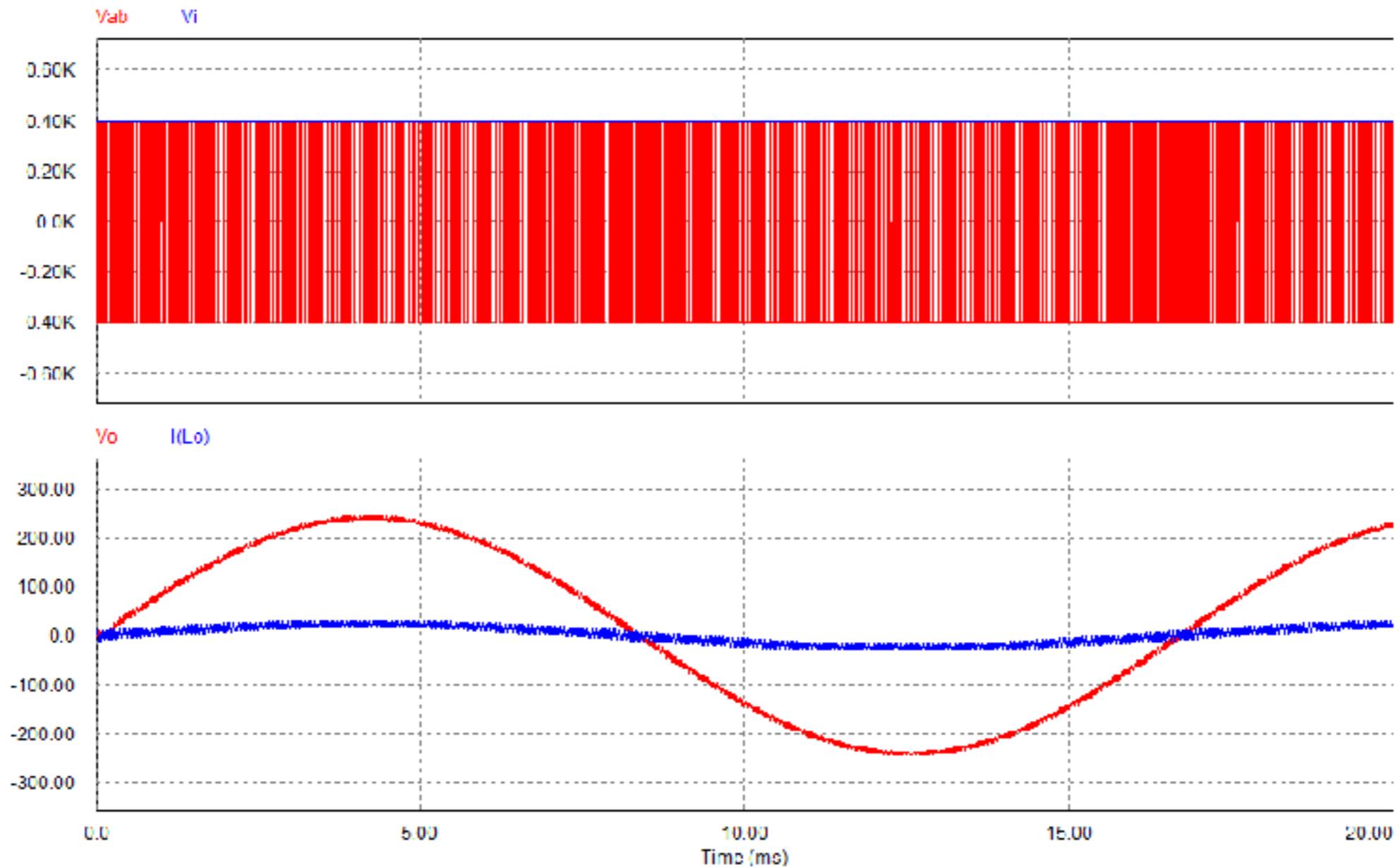
# Inversor Ponte Completa

Simulação (modulação SPWM bipolar):



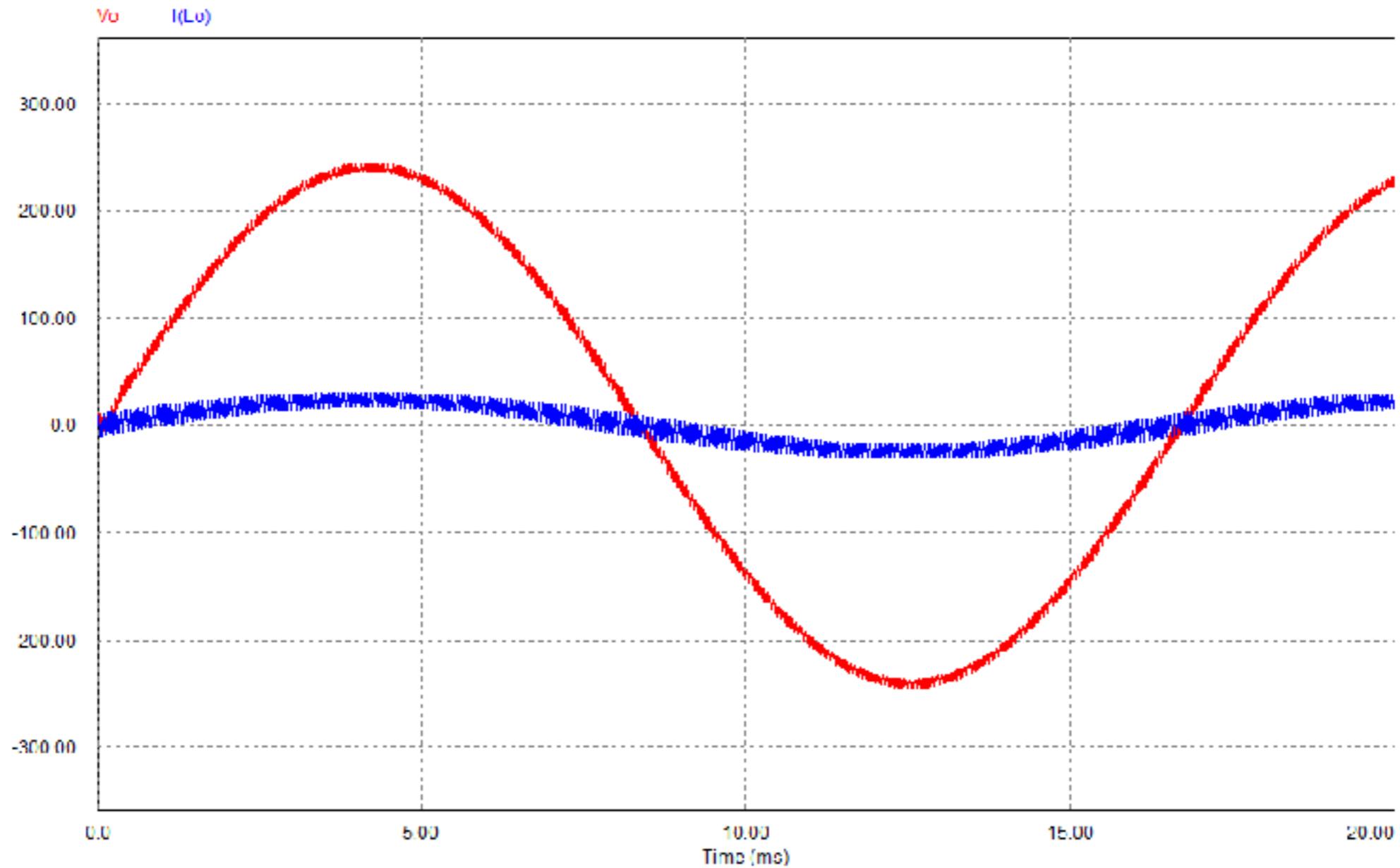
# Inversor Ponte Completa

Simulação (modulação SPWM bipolar):



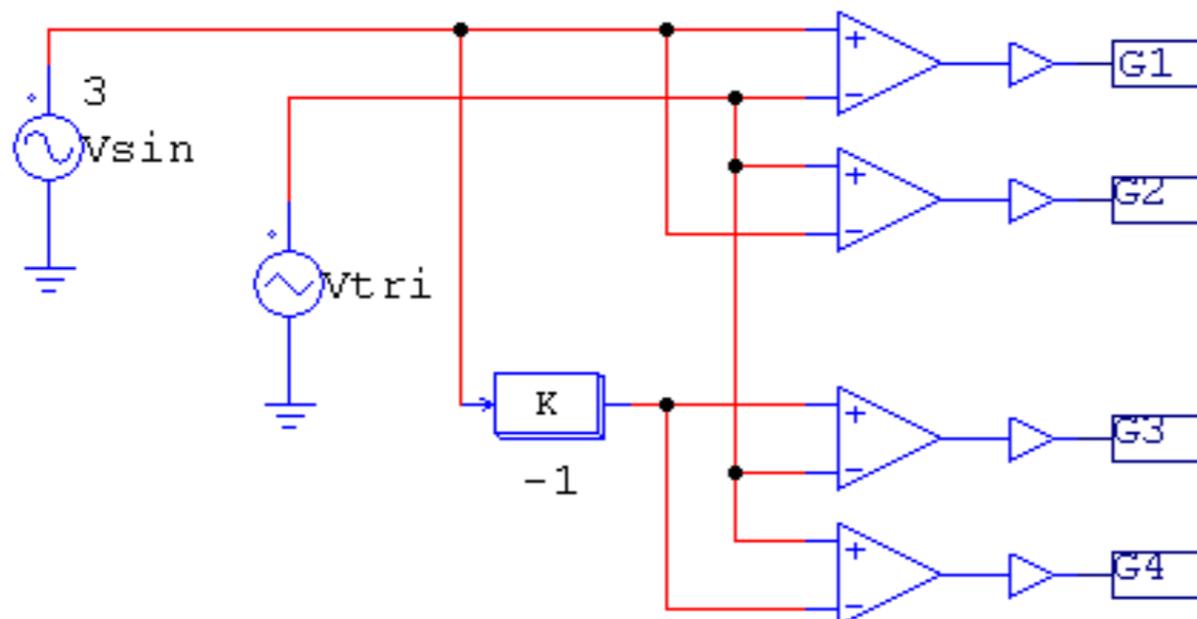
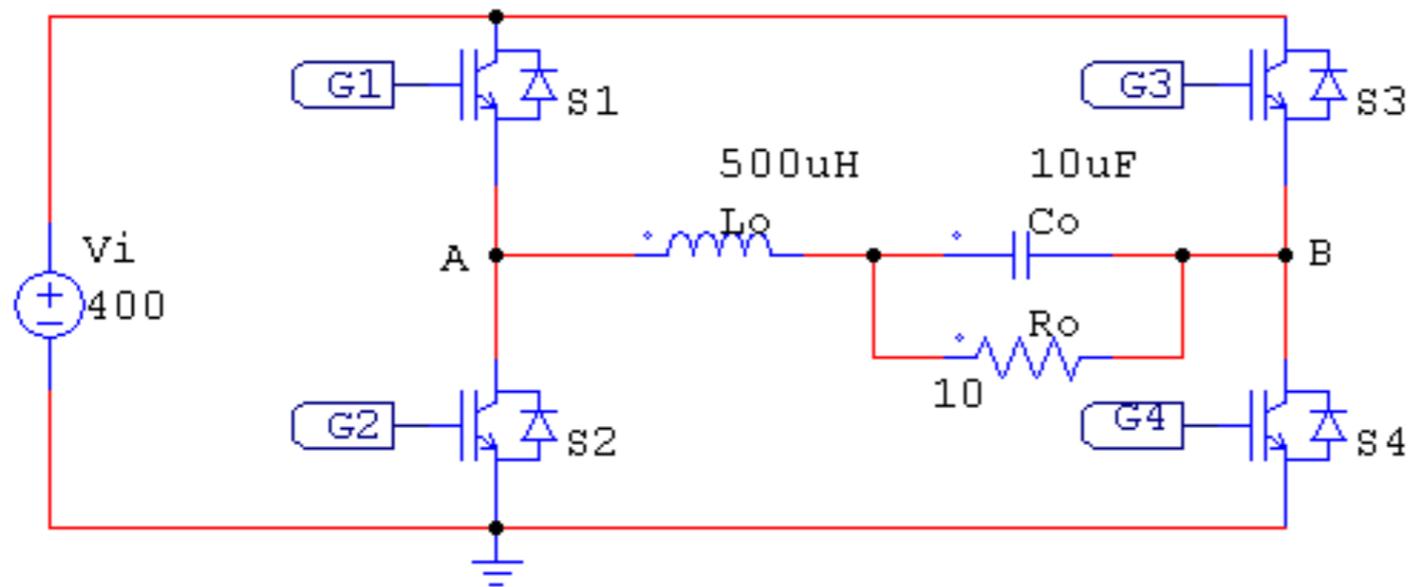
# Inversor Ponte Completa

Simulação (modulação SPWM bipolar):



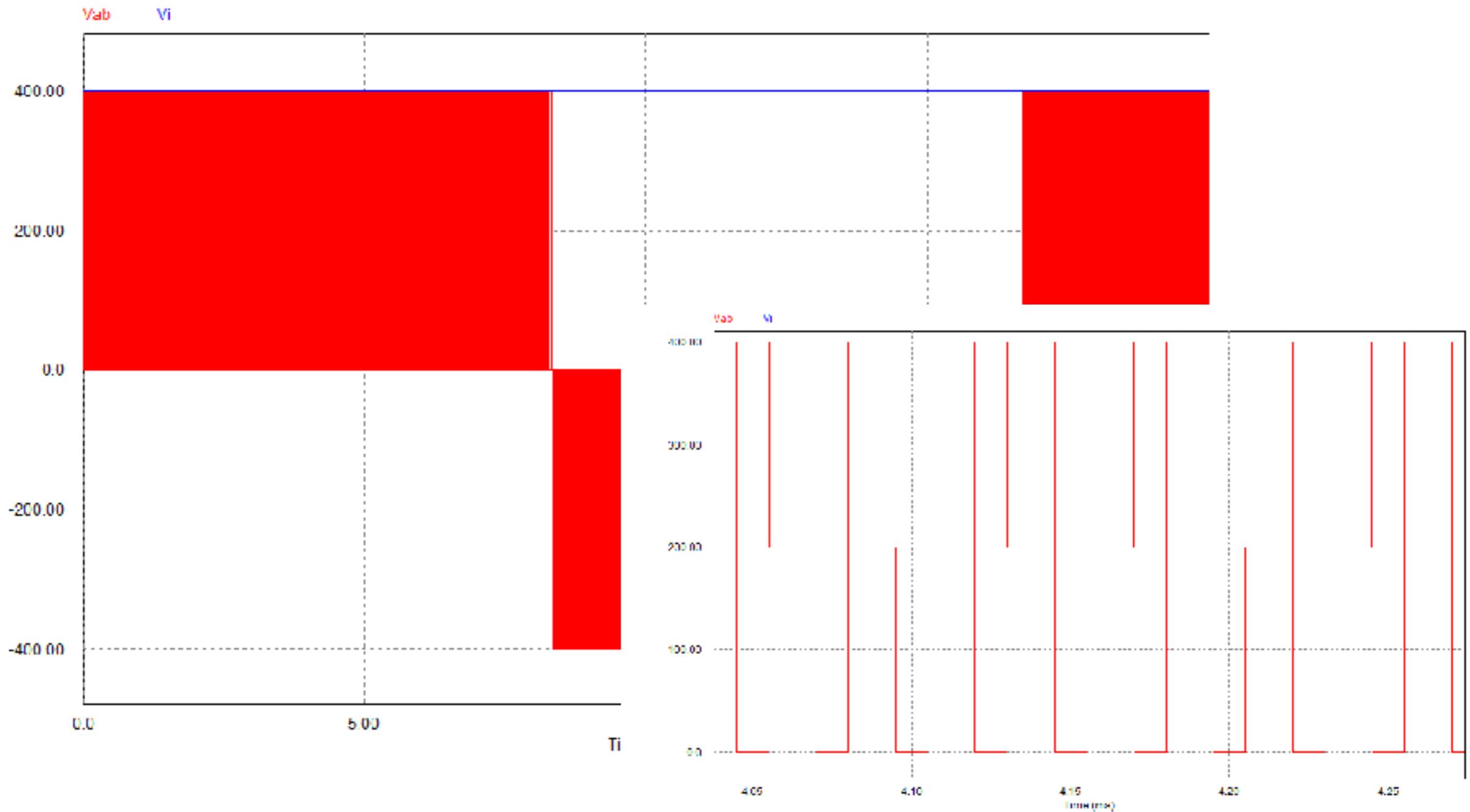
# Inversor Ponte Completa

Simulação (modulação SPWM unipolar):



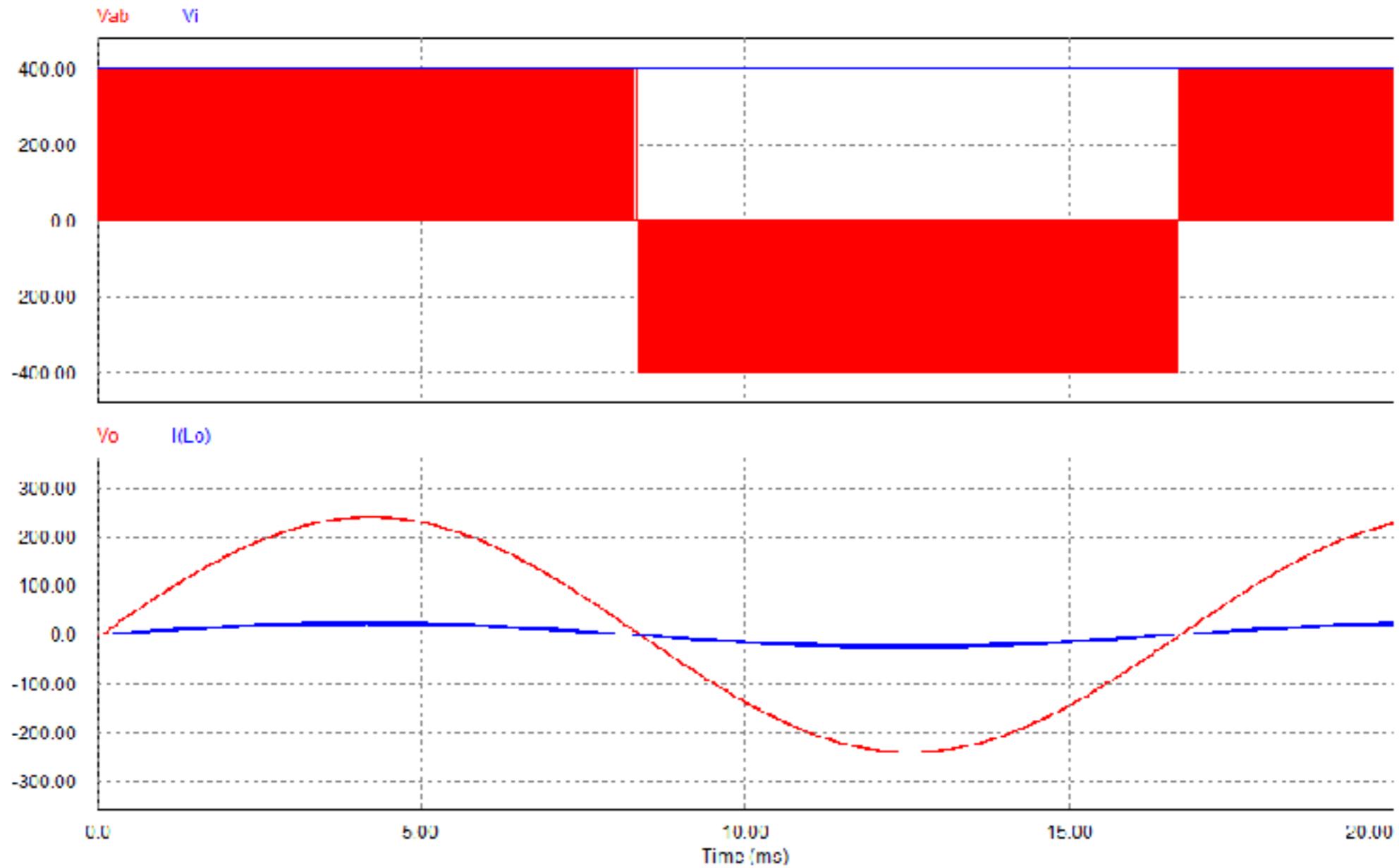
# Inversor Ponte Completa

Simulação (modulação SPWM unipolar):



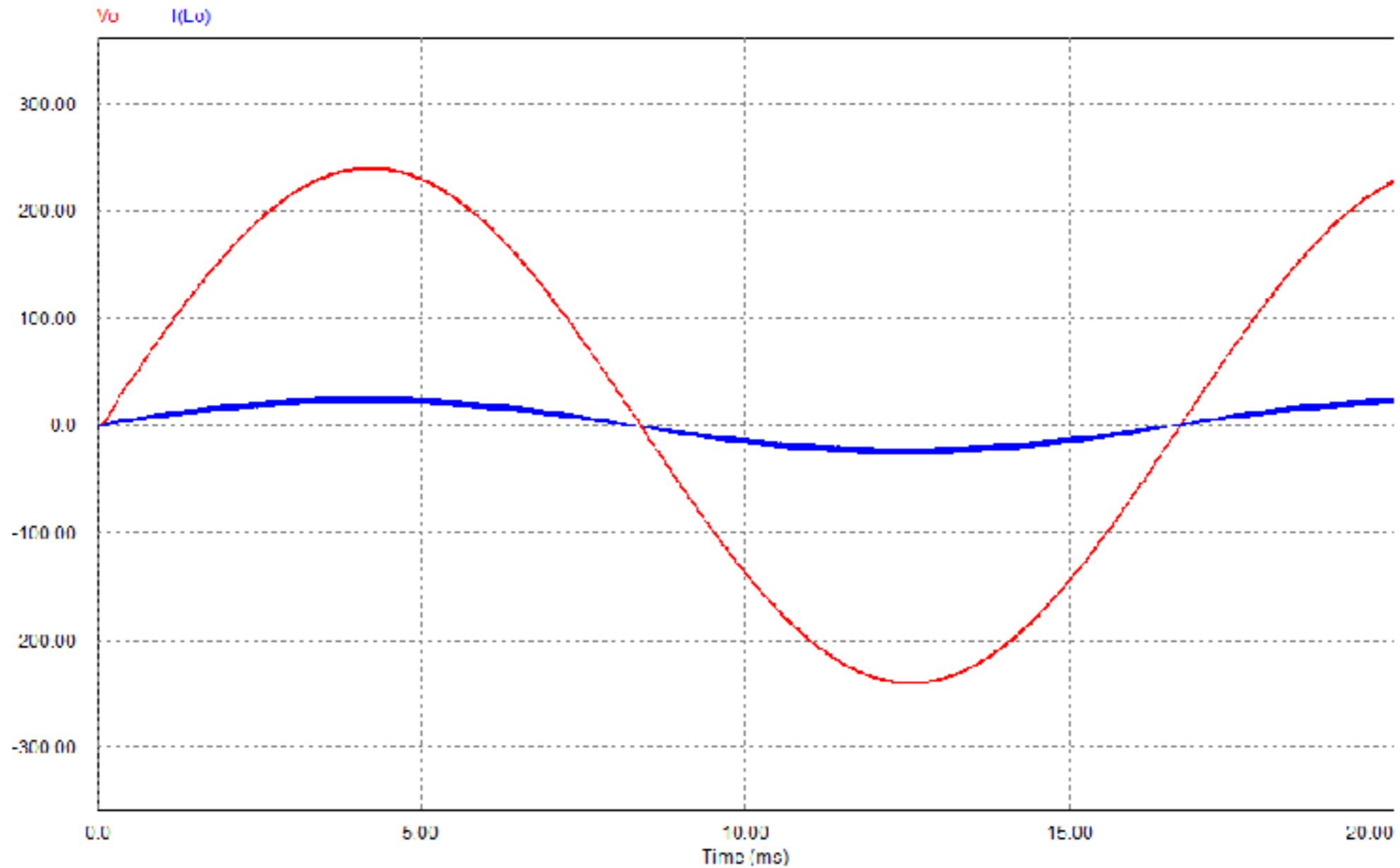
# Inversor Ponte Completa

Simulação (modulação SPWM unipolar):



# Inversor Ponte Completa

Simulação (modulação SPWM unipolar):



## Conversores cc-ca:

- Conversor ponte completa.

