

# Acopladores Híbridos

de  $90^\circ$

de  $180^\circ$

SEL 369 Micro-ondas/SEL5900 Circuitos de Alta  
Frequência

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Departamento de Engenharia Elétrica da EESC-USP

# Atenção!

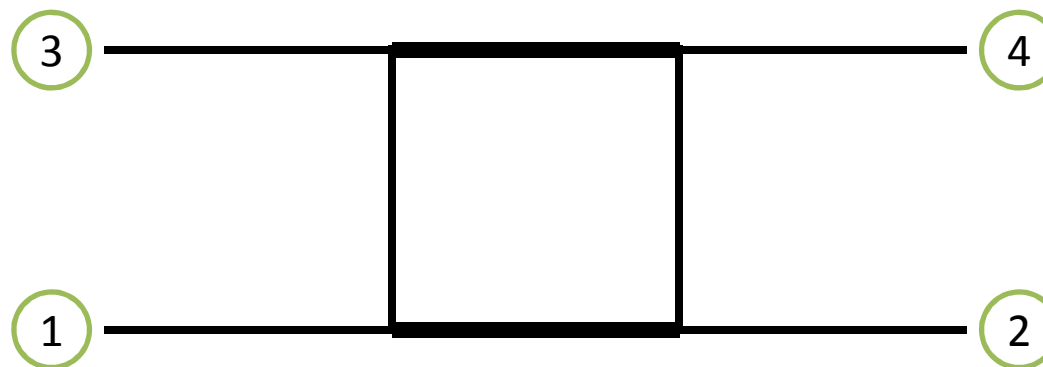
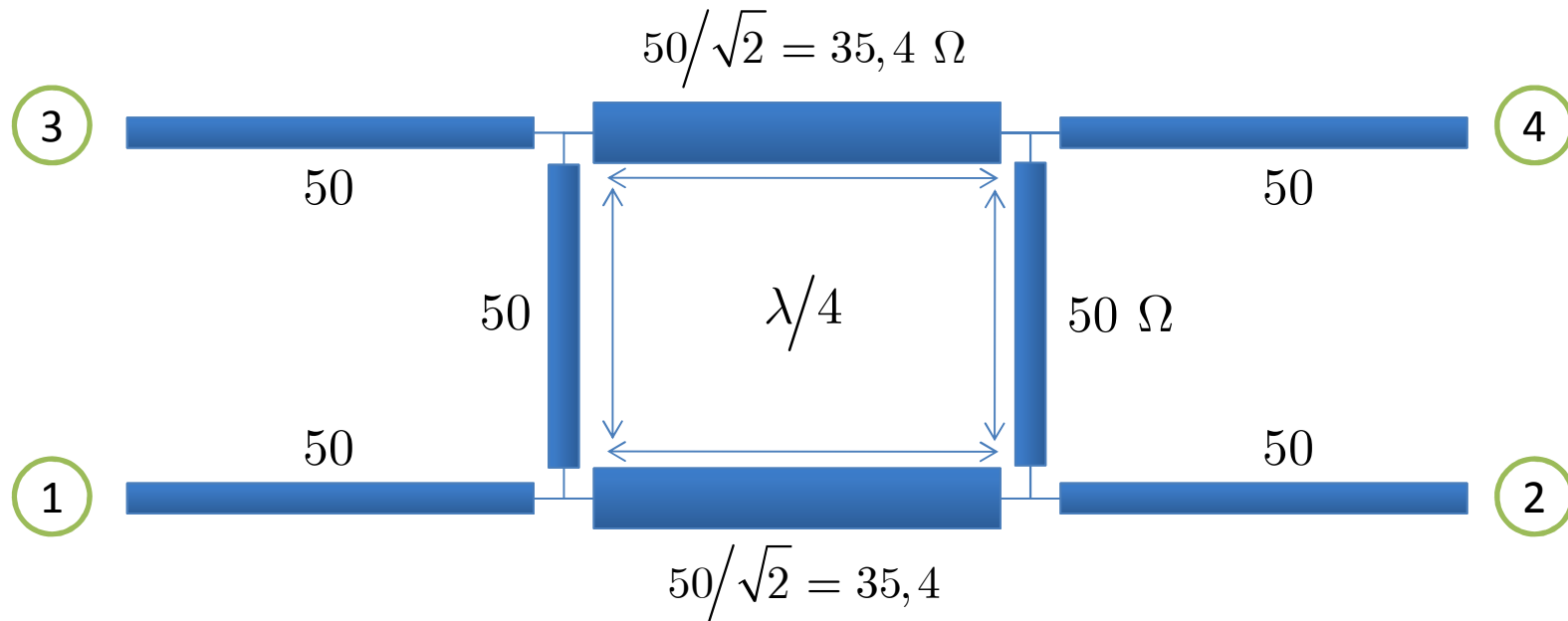
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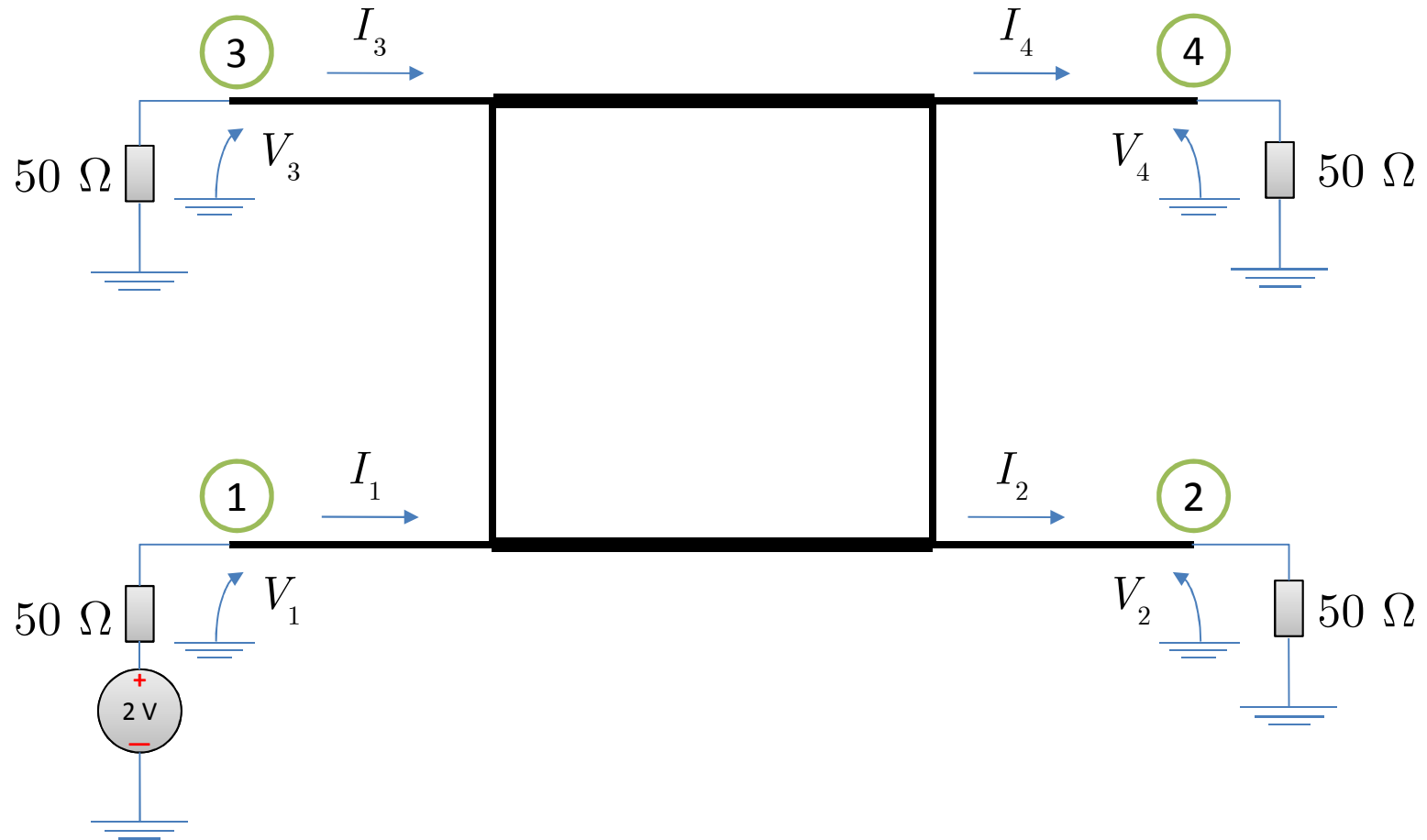
- ✓ Este material didático é planejado para servir de apoio às aulas de **SEL-369 Micro-ondas**, oferecida aos alunos regularmente matriculados no curso de engenharia elétrica/eletrônica e **SEL-5900 Circuitos de Alta Frequência**, oferecida aos alunos regularmente matriculados no curso de pós-graduação em engenharia elétrica.
- ✓ Não são permitidas a reprodução e/ou comercialização do material.
- ✓ solicitar autorização ao docente para qualquer tipo de uso distinto daquele para o qual foi planejado.

# ACOPLADOR HÍBRIDO DE 90<sup>0</sup>

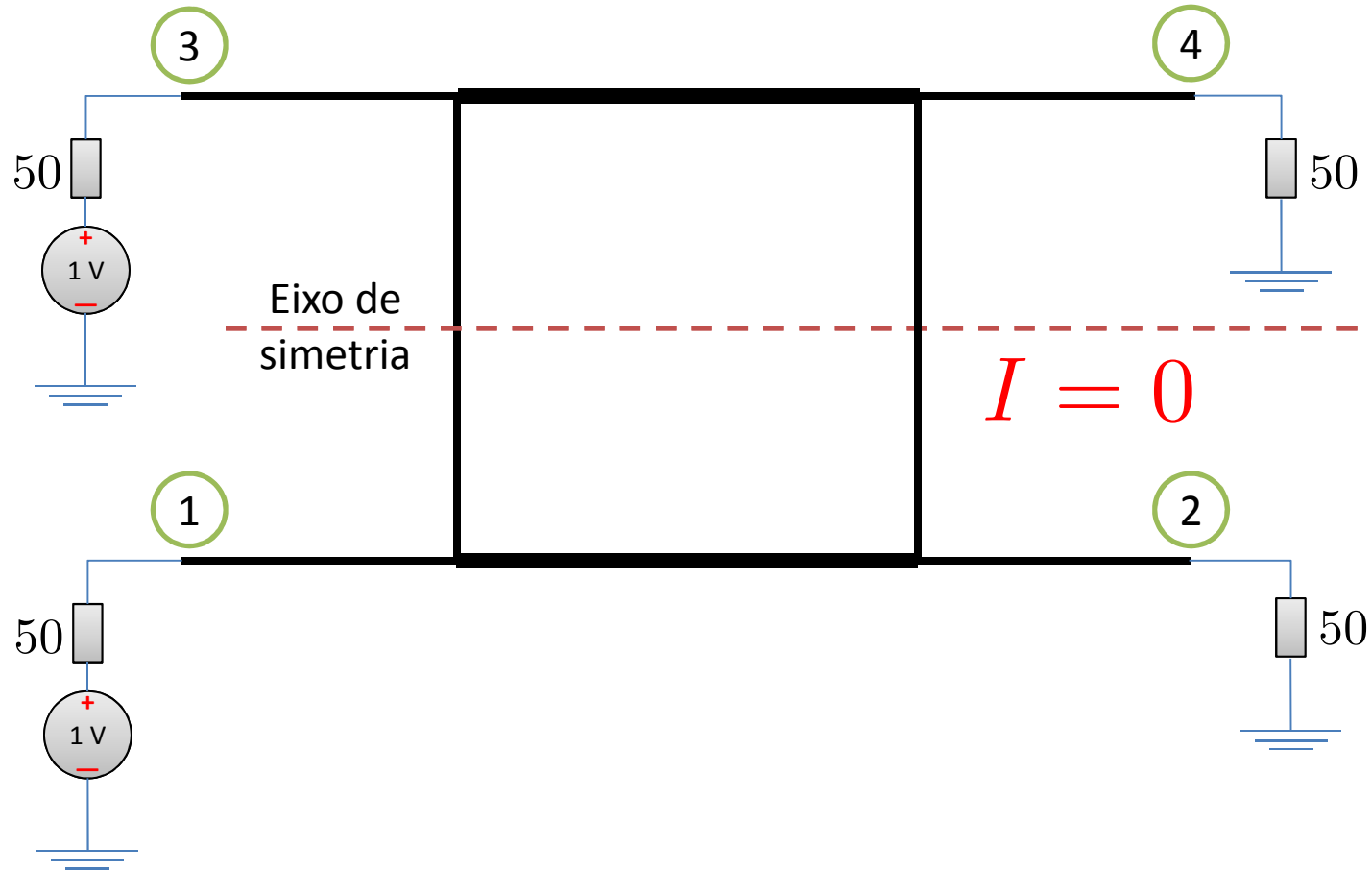
# Leiaute em microfita e esquemático



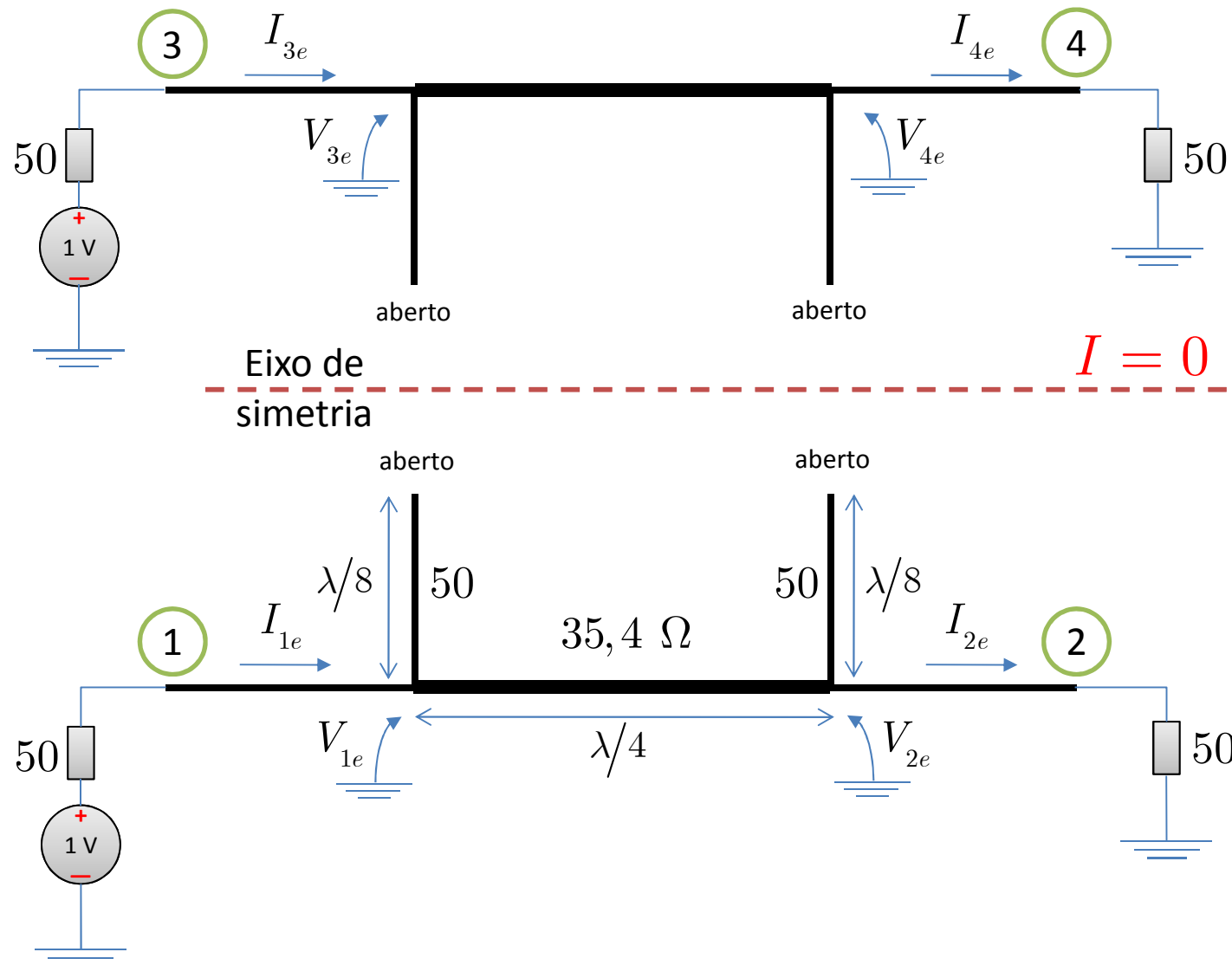
# Excitação do acoplador



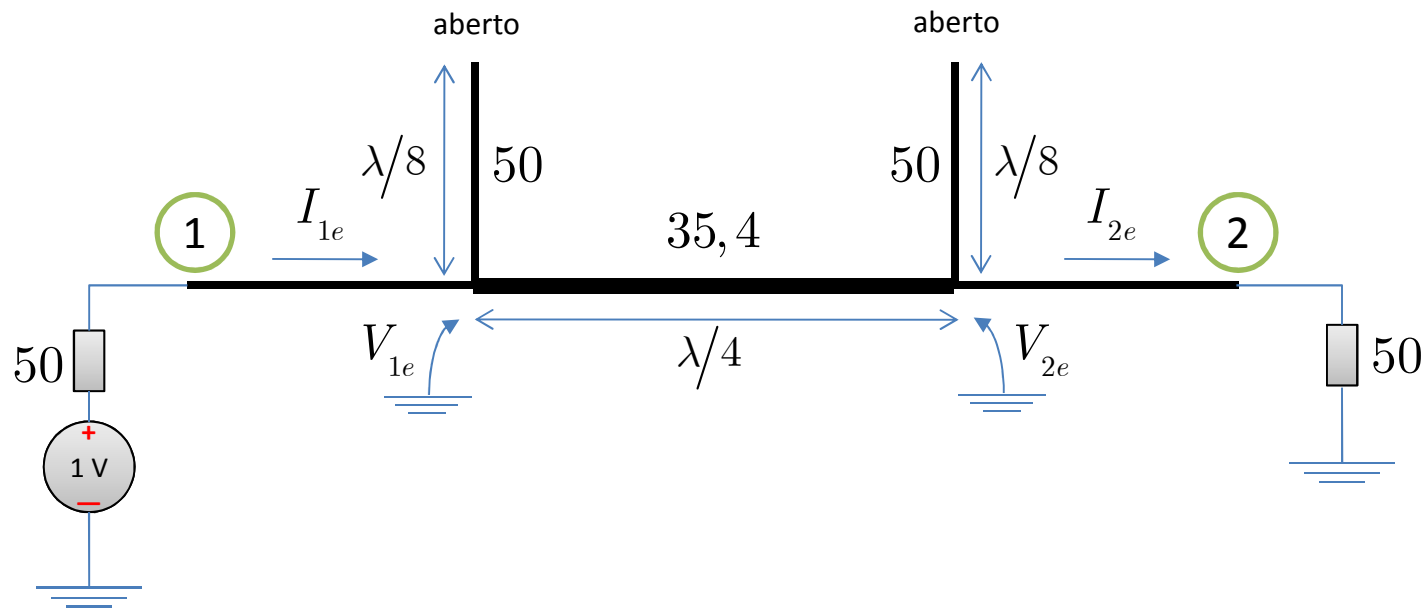
# Modo de excitação simétrica (par)-1



# Modo de excitação simétrica (par)-2



# Modo de excitação simétrica (par)-3



$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo par}} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha aberta } \lambda/8} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha } \lambda/4} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha aberta } \lambda/8}$$



# Modo de excitação simétrica (par)-4

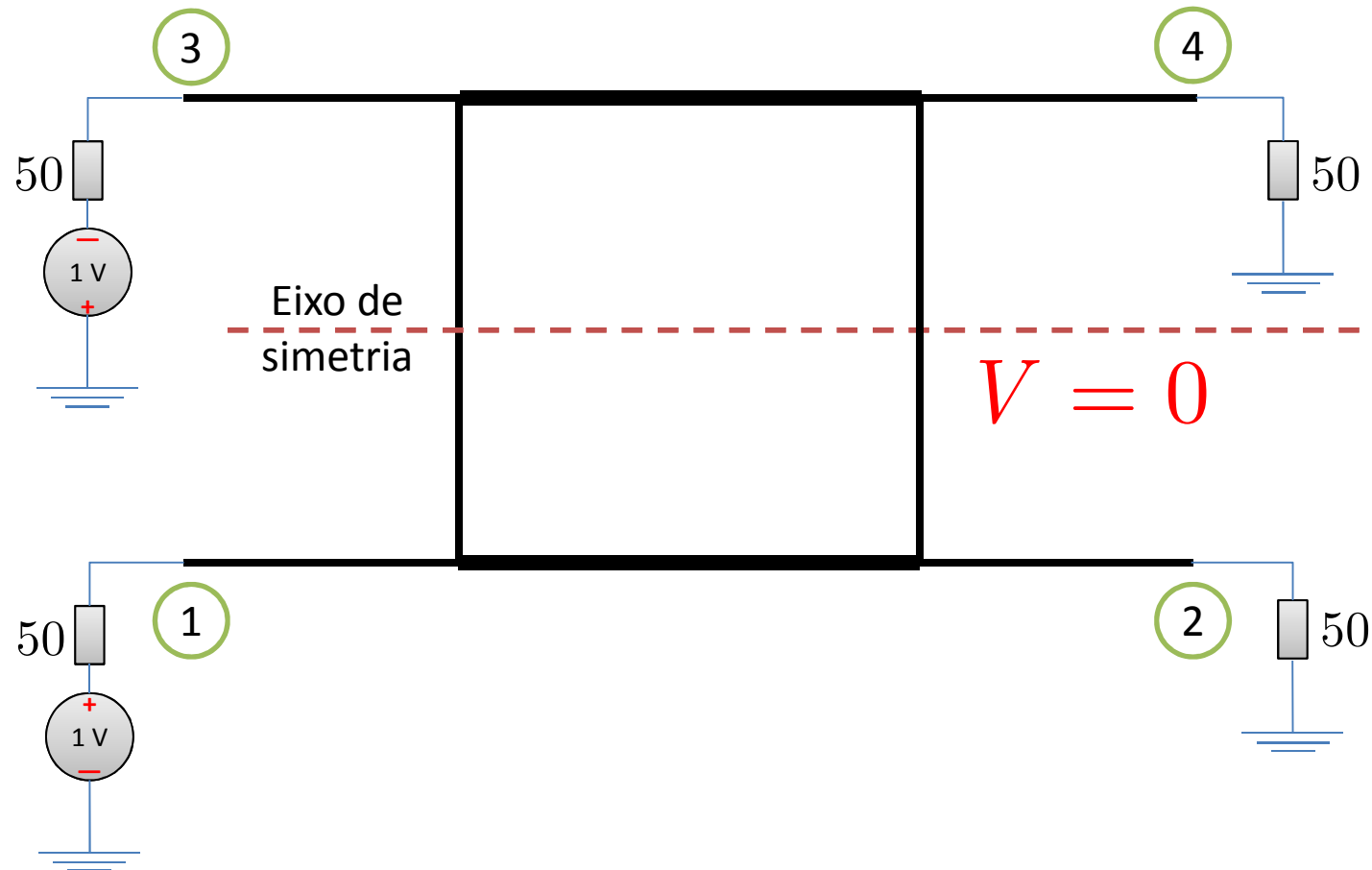
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$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo par}} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha aberto } \lambda/8} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha } \lambda/4} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha aberto } \lambda/8}$$

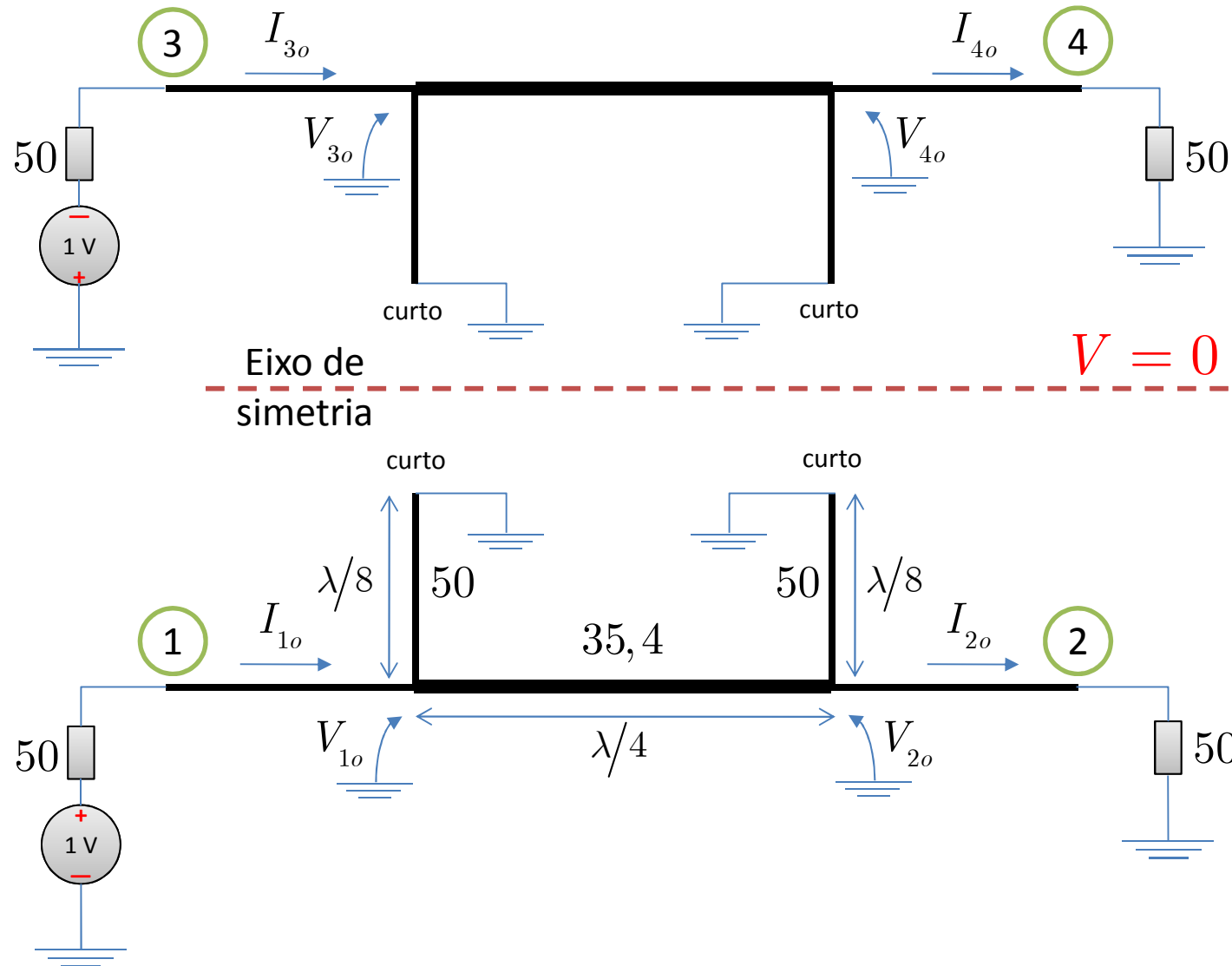
$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo par}} = \begin{bmatrix} 1 & 0 \\ jY_0 & 1 \end{bmatrix} \times \begin{bmatrix} 0 & j\frac{\sqrt{2}}{2Y_0} \\ j\sqrt{2}Y_0 & 0 \end{bmatrix} \times \begin{bmatrix} 1 & 0 \\ jY_0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo par}} = \frac{\sqrt{2}}{2} \begin{bmatrix} -1 & j\frac{1}{Y_0} \\ jY_0 & -1 \end{bmatrix}$$

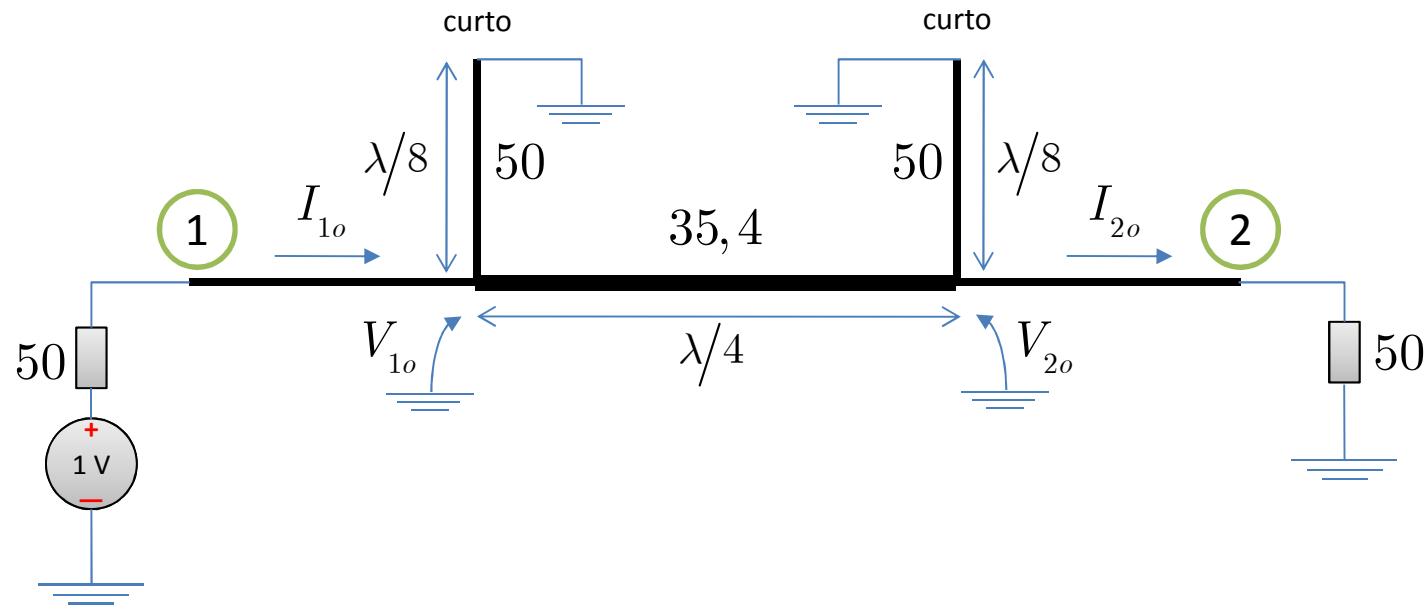
# Modo de excitação antissimétrica (ímpar)-1



# Modo de excitação antissimétrica (ímpar)-2



# Modo de excitação antissimétrica (ímpar)-3



$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo ímpar}} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha curto } \lambda/8} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha } \lambda/4} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha curto } \lambda/8}$$

# Modo de excitação antissimétrica (ímpar)-4

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$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo ímpar}} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha curto } \lambda/8} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha } \lambda/4} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{linha curto } \lambda/8}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo ímpar}} = \begin{bmatrix} 1 & 0 \\ -jY_0 & 1 \end{bmatrix} \times \begin{bmatrix} 0 & j\frac{\sqrt{2}}{2Y_0} \\ j\sqrt{2}Y_0 & 0 \end{bmatrix} \times \begin{bmatrix} 1 & 0 \\ -jY_0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{\text{modo ímpar}} = \frac{\sqrt{2}}{2} \begin{bmatrix} 1 & j\frac{1}{Y_0} \\ jY_0 & 1 \end{bmatrix}$$

# Matriz ABCD modos par e ímpar

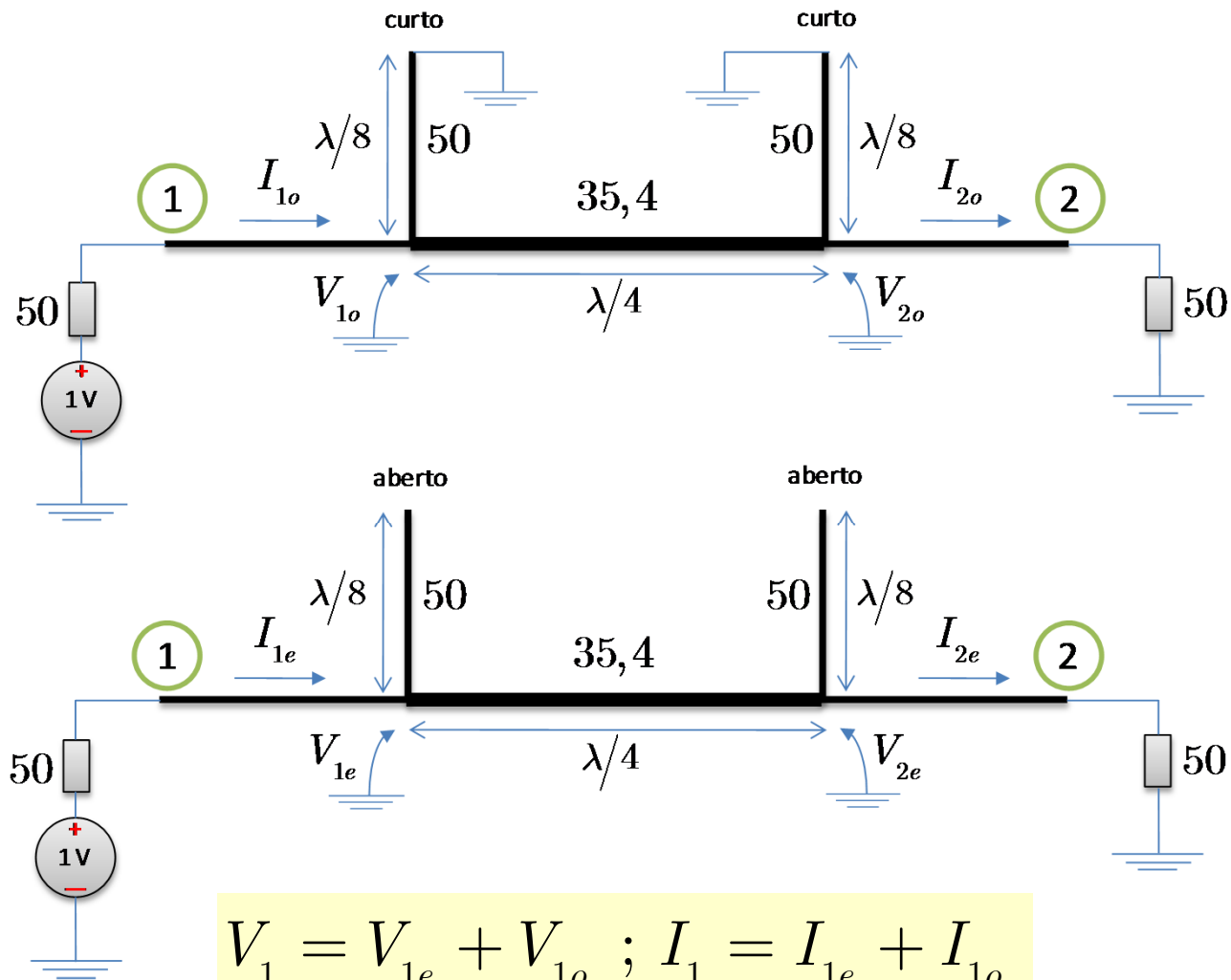
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$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \times \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

$$\begin{bmatrix} V_{1e} \\ I_{1e} \end{bmatrix} = \frac{\sqrt{2}}{2} \begin{bmatrix} -1 & j \frac{1}{Y_0} \\ jY_0 & -1 \end{bmatrix} \times \begin{bmatrix} V_{2e} \\ I_{2e} \end{bmatrix}$$

$$\begin{bmatrix} V_{1o} \\ I_{1o} \end{bmatrix} = \frac{\sqrt{2}}{2} \begin{bmatrix} 1 & j \frac{1}{Y_0} \\ jY_0 & 1 \end{bmatrix} \times \begin{bmatrix} V_{2o} \\ I_{2o} \end{bmatrix}$$

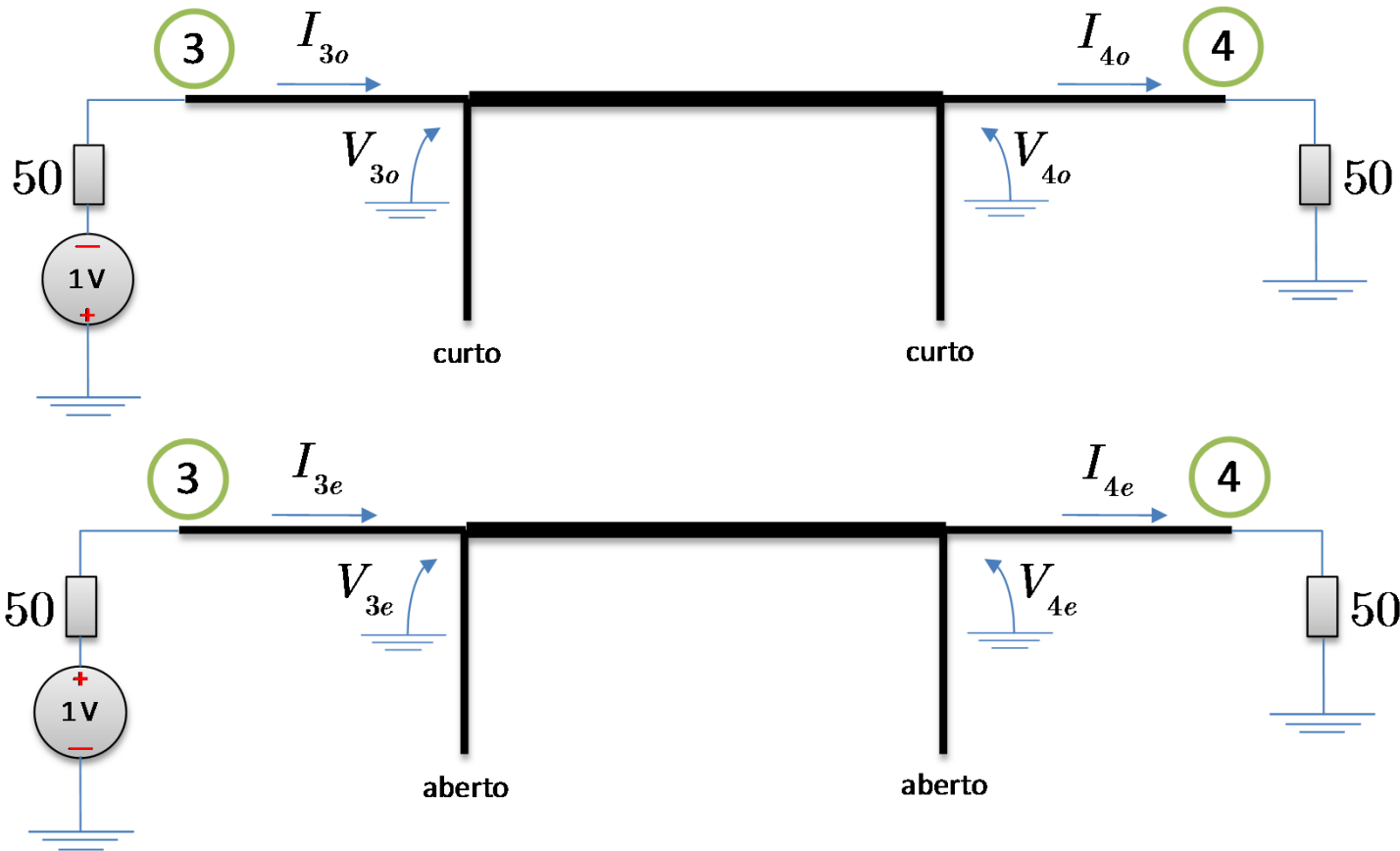
# Superposição-1



$$V_1 = V_{1e} + V_{1o} ; I_1 = I_{1e} + I_{1o}$$

$$V_2 = V_{2e} + V_{2o} ; I_2 = I_{2e} + I_{2o}$$

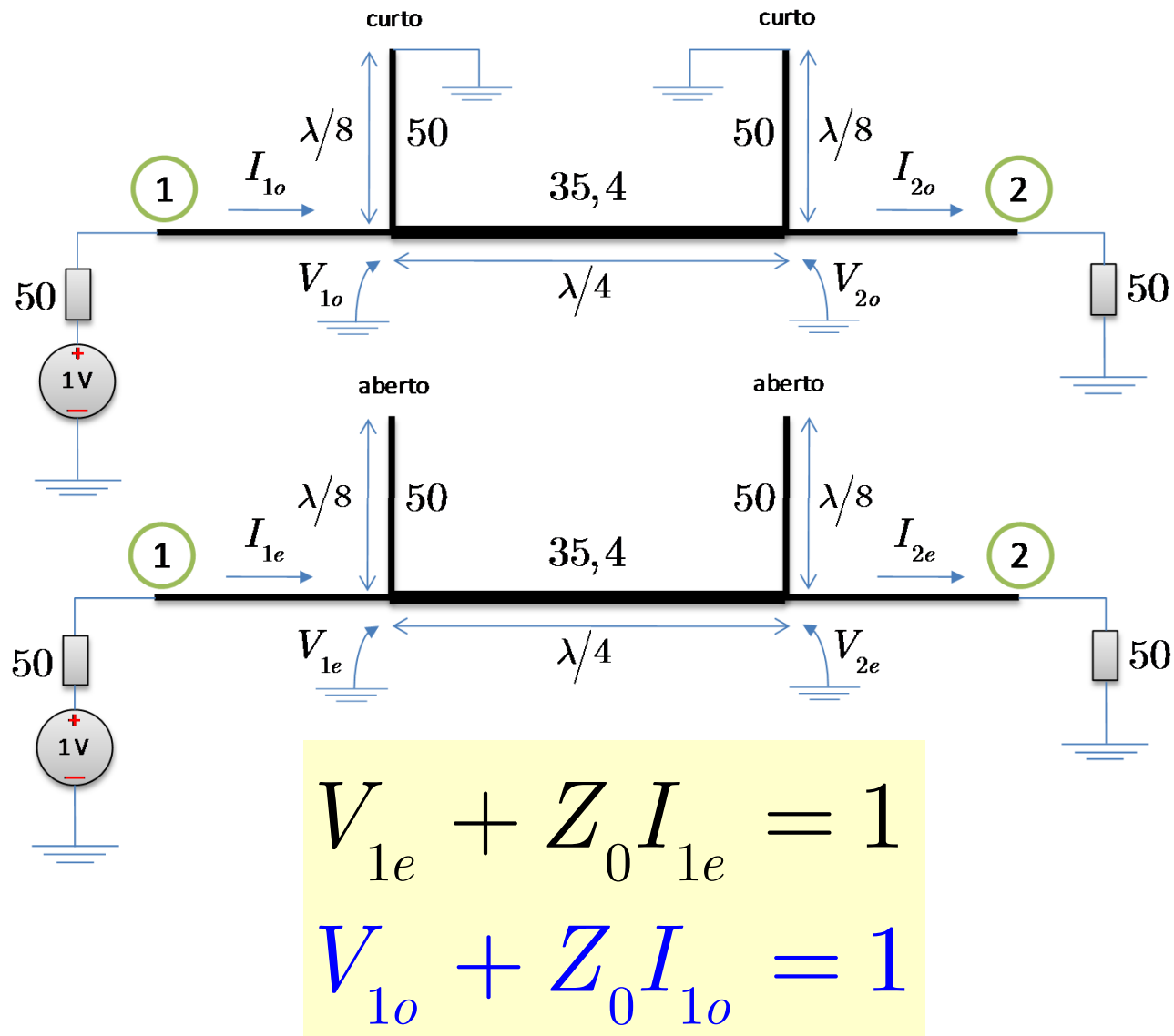
# Superposição-2



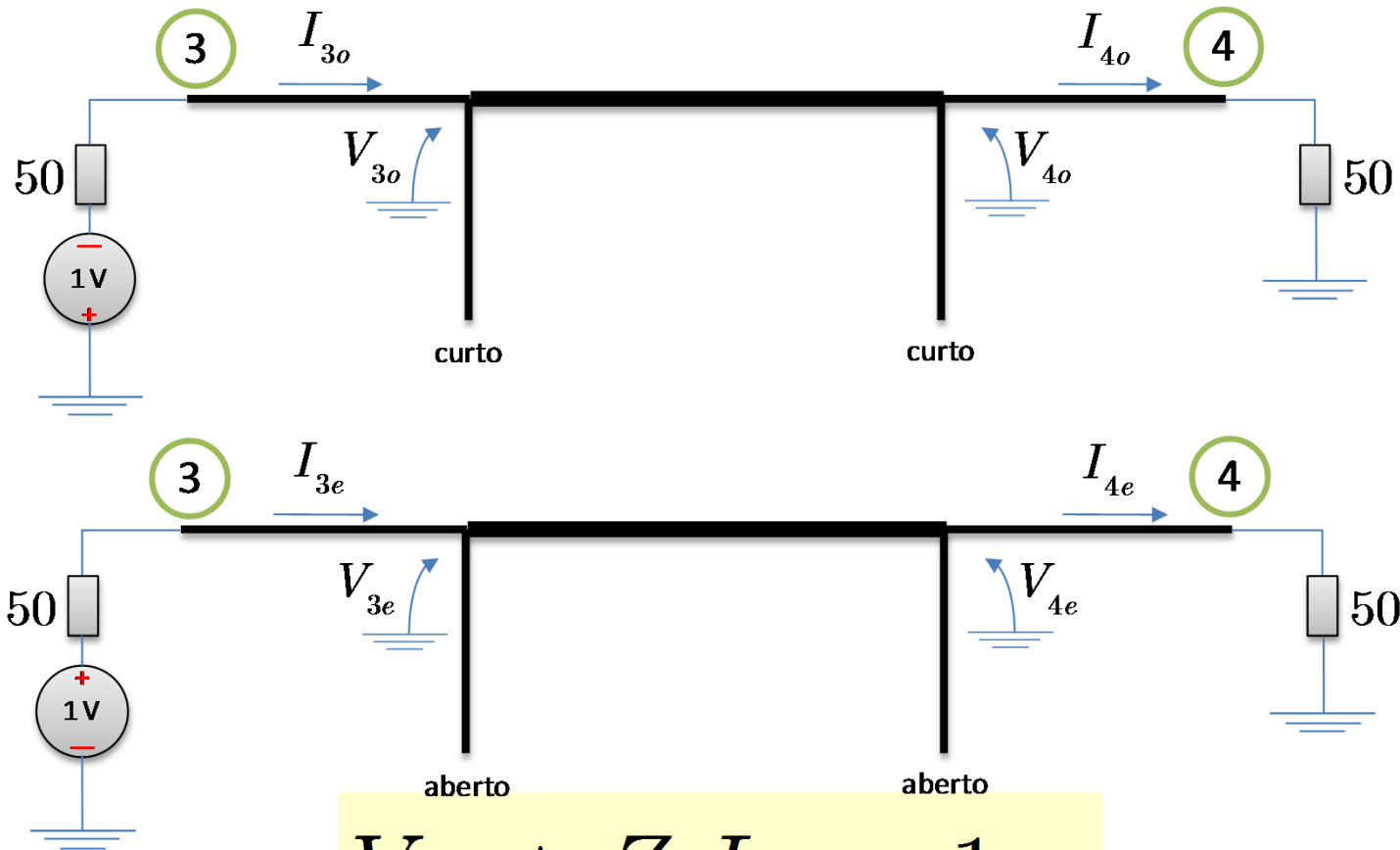
$$V_3 = V_{3e} + V_{3o} ; I_3 = I_{3e} + I_{3o}$$
$$V_4 = V_{4e} + V_{4o} ; I_4 = I_{4e} + I_{4o}$$



# Malha porta 1 (par e ímpar)



# Malha porta 3 (par e ímpar)



$$V_{3e} + Z_0 I_{3e} = 1$$

$$V_{3o} + Z_0 I_{3o} = -1$$

# Tensões e correntes

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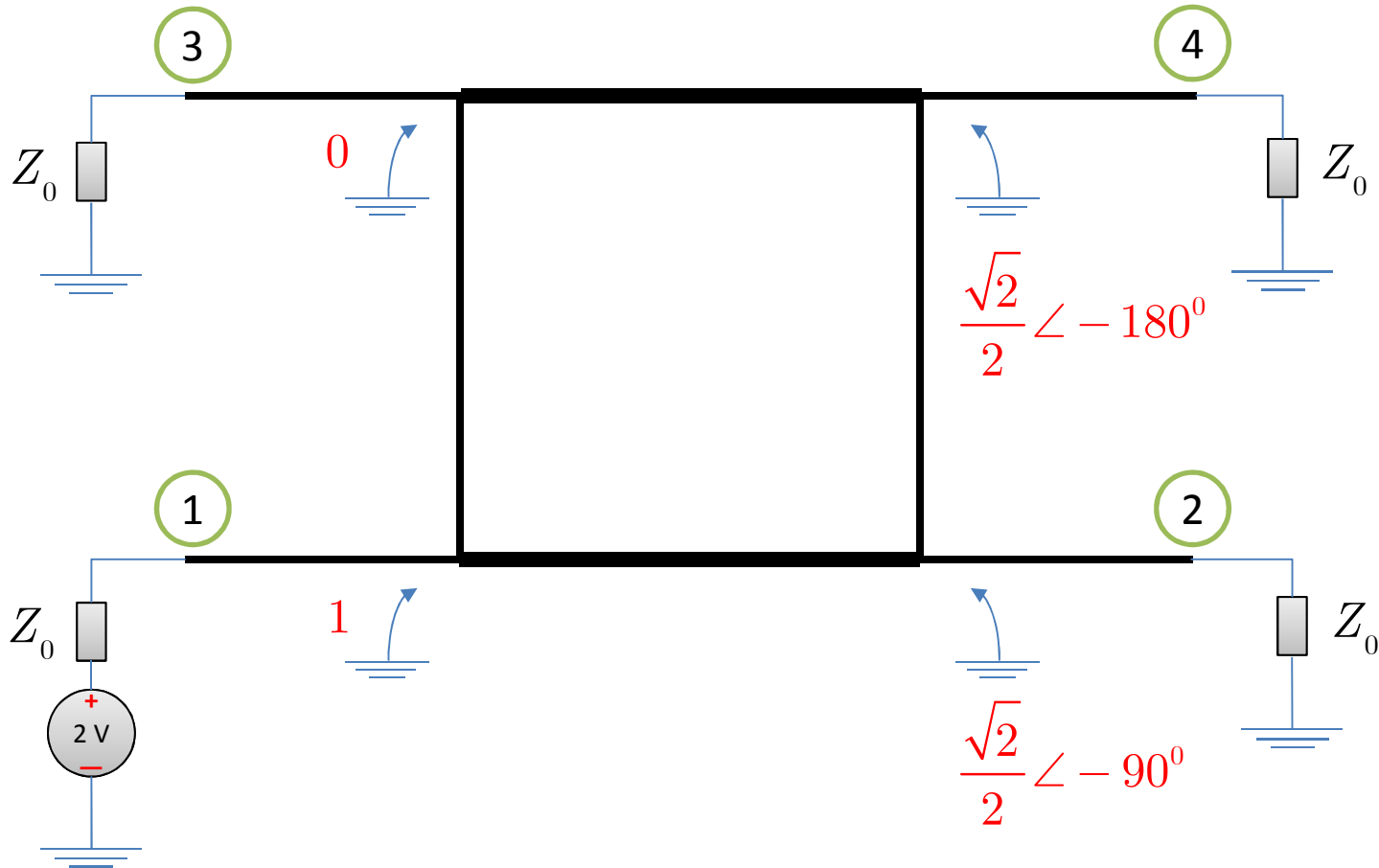
$$V_1 = 1 \text{ V}; I_1 = \frac{1}{Z_0} \text{ A}$$

$$V_2 = -j \frac{\sqrt{2}}{2} \text{ V}; I_2 = -j \frac{\sqrt{2}}{2Z_0} \text{ A}$$

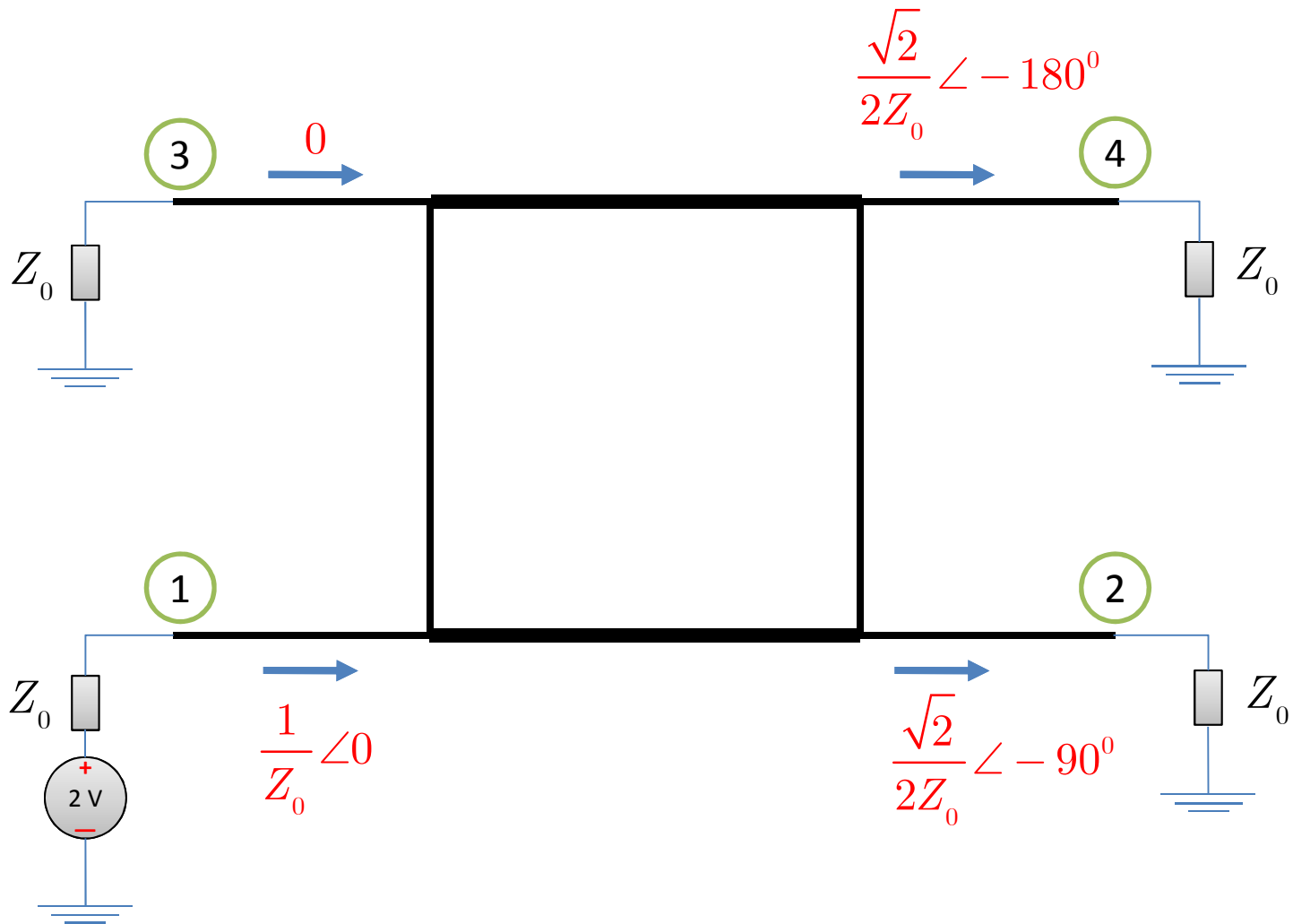
$$V_3 = 0 \text{ V}; I_3 = 0 \text{ A}$$

$$V_4 = -\frac{\sqrt{2}}{2} \text{ V}; I_4 = -\frac{\sqrt{2}}{2Z_0} \text{ A}$$

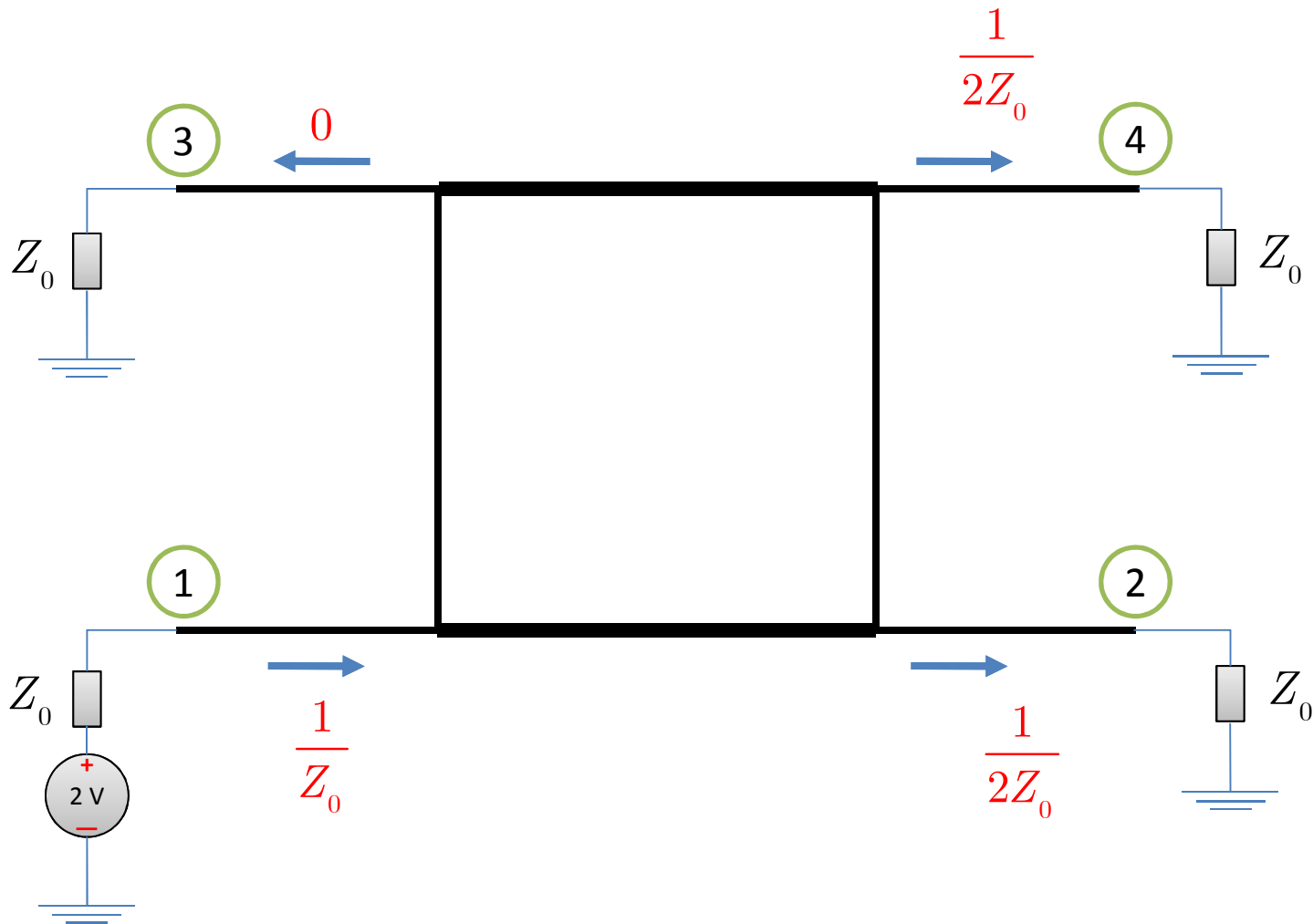
# Tensões (volt)



# Correntes (ampere)



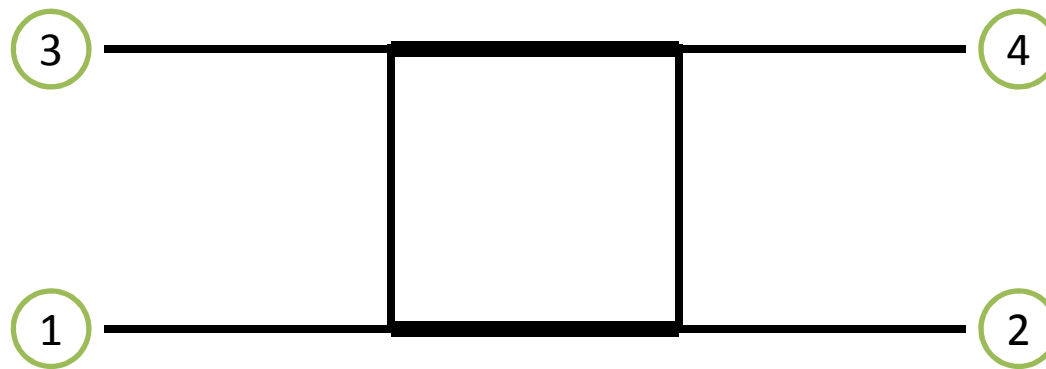
# potências (watt)



# Matriz espalhamento (S)

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$$[S]_{90^\circ} = \frac{\sqrt{2}}{2} \begin{bmatrix} 0 & -j & 0 & -1 \\ -j & 0 & -1 & 0 \\ 0 & -1 & 0 & -j \\ -1 & 0 & -j & 0 \end{bmatrix}$$

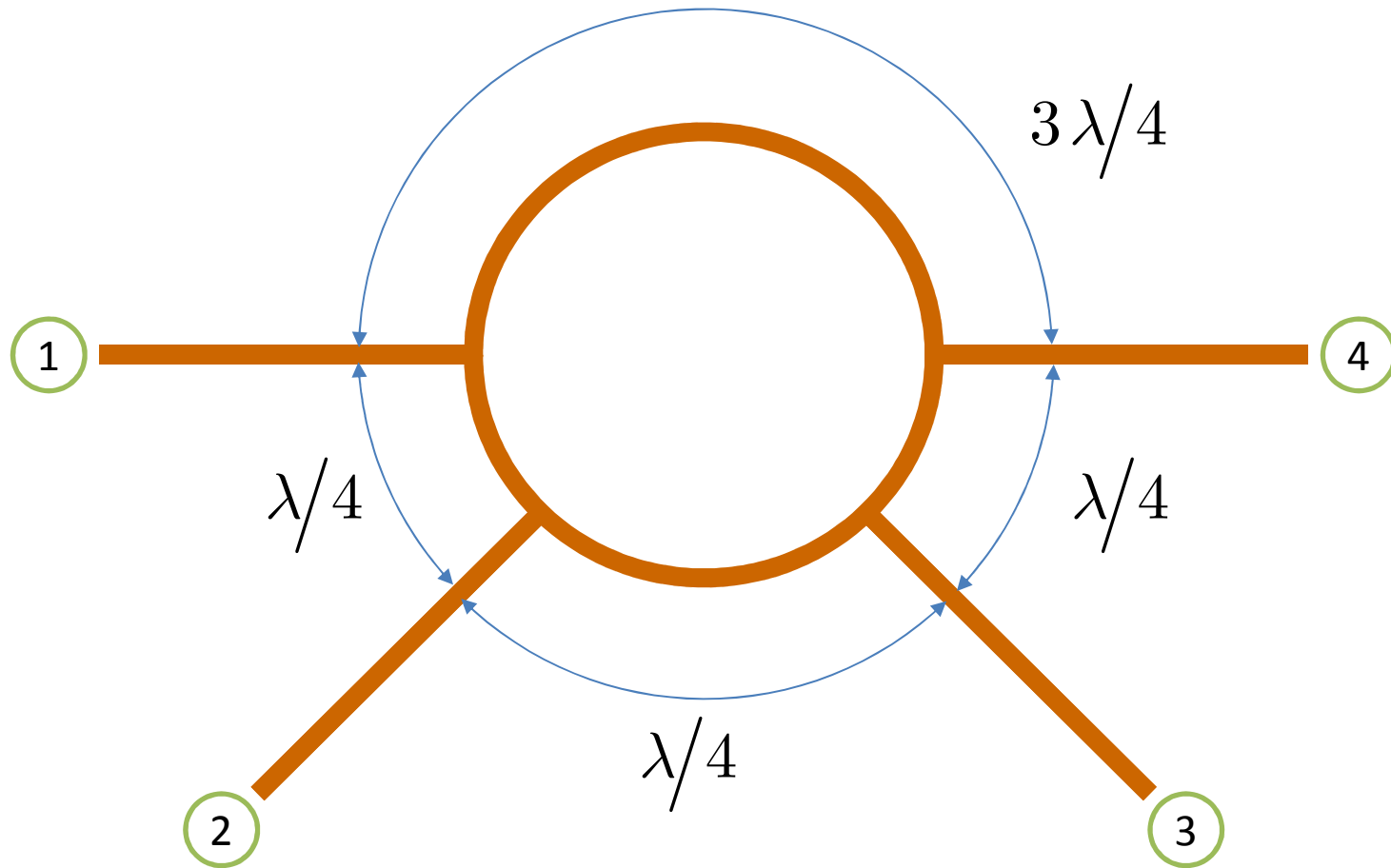


# ACOPLADOR HÍBRIDO DE 180<sup>0</sup>



# Acoplador híbrido de $180^\circ$

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# Distribuição das tensões (volt)

