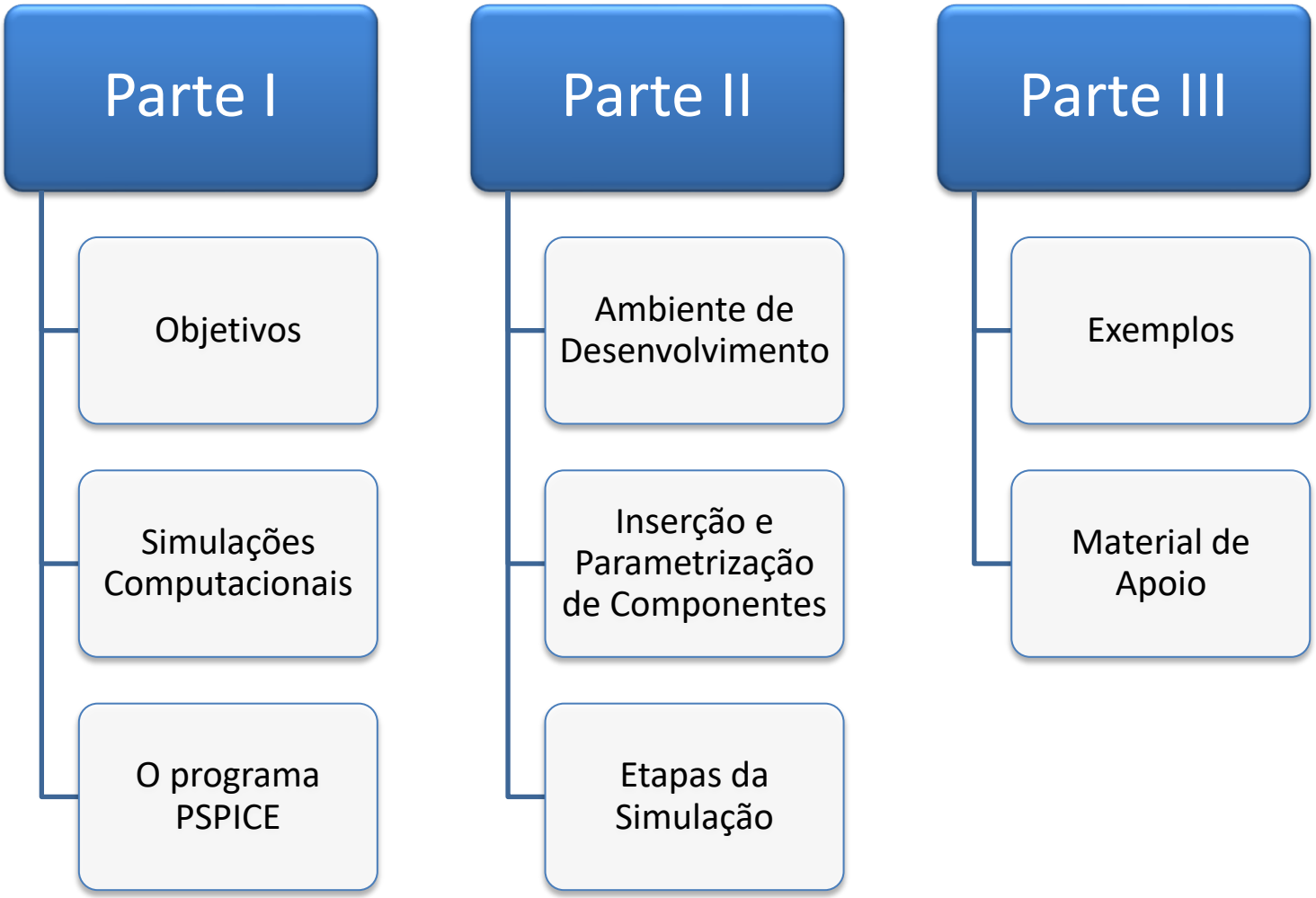
Departamento de Engenharia Elétrica e de Computação, EESC – USP
Laboratório de Sistemas de Energia Elétrica - LSEE

Introdução à Análise de Circuitos Elétricos Utilizando "PSPICE"

Disciplinas: *SEL0301 – Circuitos Elétricos I e SEL0602 – Circuitos Elétricos*
Docente: *Prof. Dr. Mário Oleskovicz*
Palestrante: *Moisés Junior Batista Borges Davi*

Organização da Apresentação



(Parte I) Objetivos

Familiarização com a ferramenta computacional para ampliação da capacidade de análise de circuitos (PSPICE)

Adquirir conhecimento mínimo necessário para solucionar os exercícios a serem repassados

- Serão 03 exercícios (solução analítica e por meio de simulação computacional)
- Nota total (1,5 ponto)

(Parte I) Simulações Computacionais

- ✓ Buscam representar matematicamente o mundo real (físico) por meio de modelos computacionais:

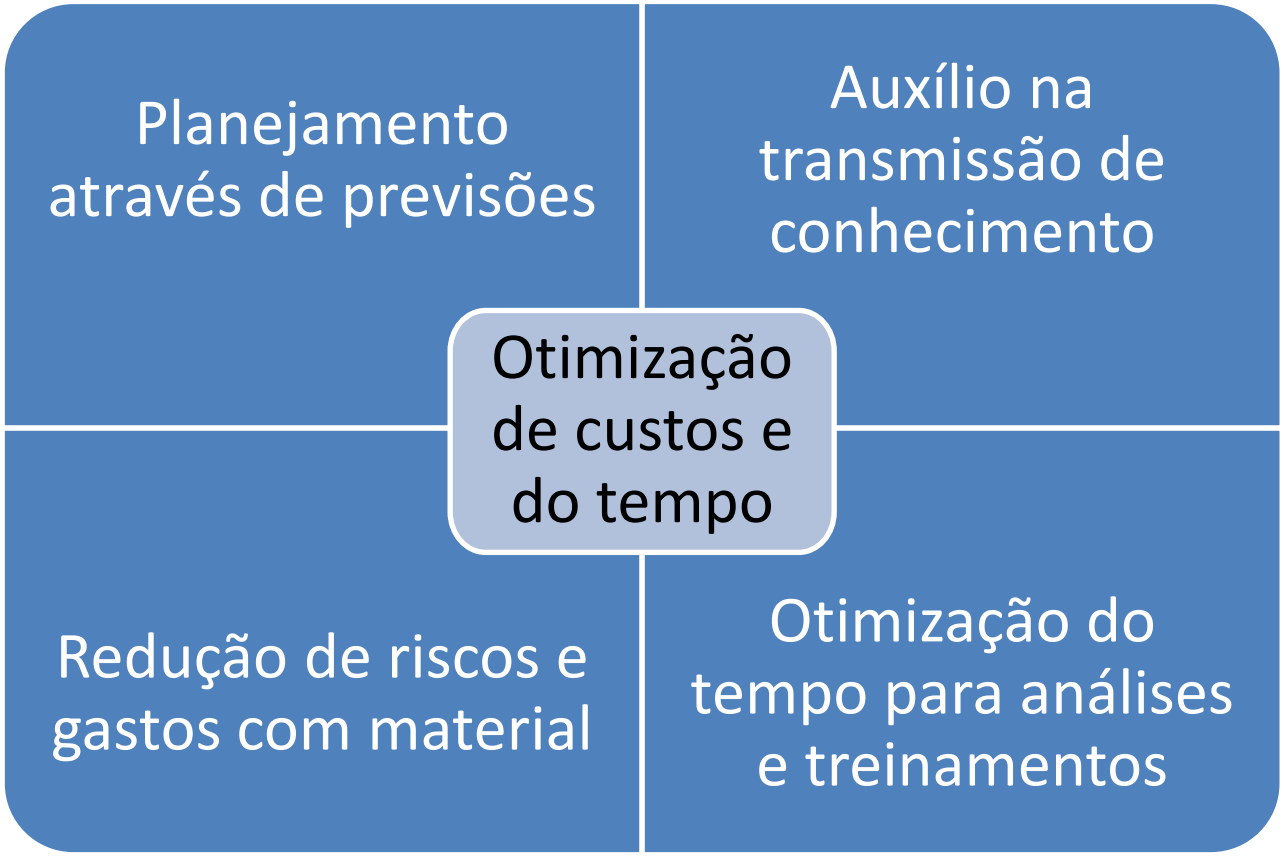
Previsões do clima

Previsões de crescimento econômico de empresas

Simulação de voo para treinamento de pilotos de avião

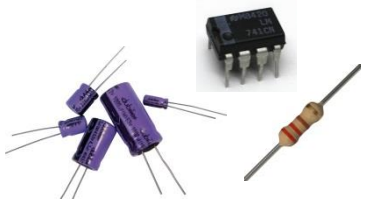
(Parte I) Simulações Computacionais

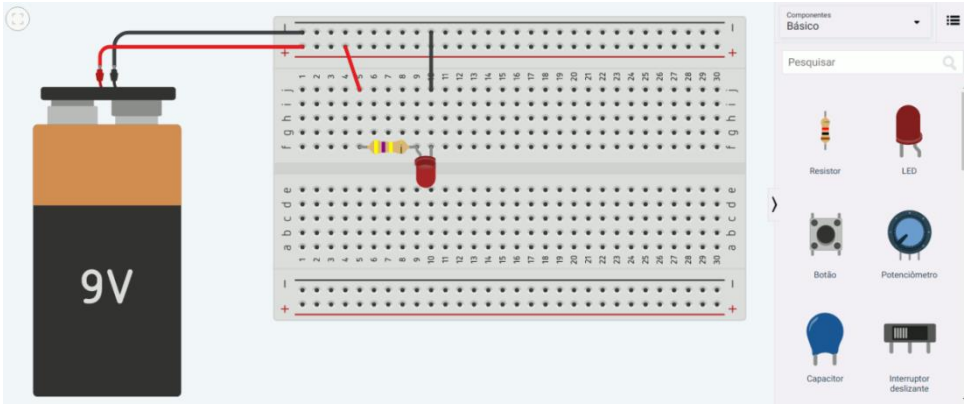
- ✓ Buscam representar matematicamente o mundo real (físico) por meio de modelos computacionais:

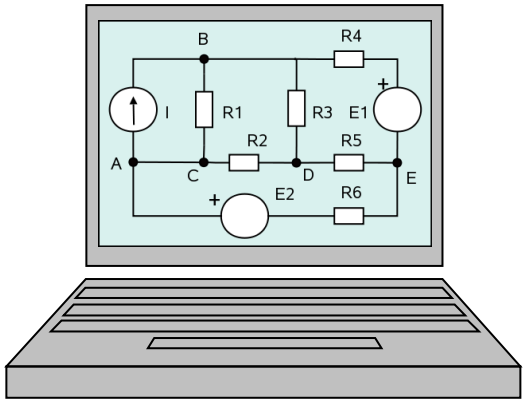


(Parte I) Simulações Computacionais

- ✓ Buscam representar matematicamente circuitos ou sistemas elétricos:
  - ✓ **Menor tempo necessário para análises de circuitos complexos;**
  - ✓ **Possibilidade de experimentos:**
    - Trocar valores dos componentes;
    - Alterar configurações e topologias do circuito;
    - Monitorar/prever o comportamento das grandezas elétricas nos testes.







(Parte I) O Programa PSPICE

- ✓ SPICE
  - ***S**imulation **P**rogram with **I**ntegrated **C**ircuit **E**mphasis*
- ✓ Prof. Donald O. Pederson;
  - SPICE 1 (1972), 2 (1975) e 3 (1989)
- ✓ Dentre as várias versões para PC que foram disponibilizadas, a mais conhecida e que será utilizada no curso, é o PSPICE (Personal SPICE);
- ✓ Ferramenta estável;
- ✓ Farta documentação e exemplos;

Berkeley
UNIVERSITY OF CALIFORNIA

(Parte I) O Programa PSPICE

Fontes DC

- Ponto de operação (***V*** *dos nós e* ***I*** *das fontes*)
- Análise de transitórios em sistemas com fonte DC

Fontes AC

- Análise de circuitos AC: levantamento de fasores de tensão e corrente

(Parte II) Ambiente de Desenvolvimento

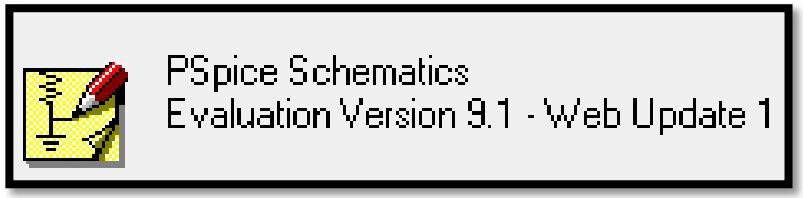
✓ PSPICE (**P**ersonal **Spice**)

✓ PSPICE 9.1 Student Version

- Algumas limitações:
  - Quantidade de componentes;
  - Biblioteca.

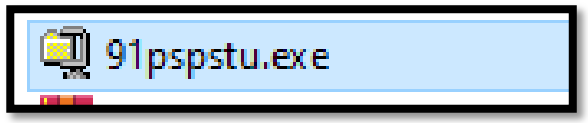
- Disponível no portal edisciplinas;

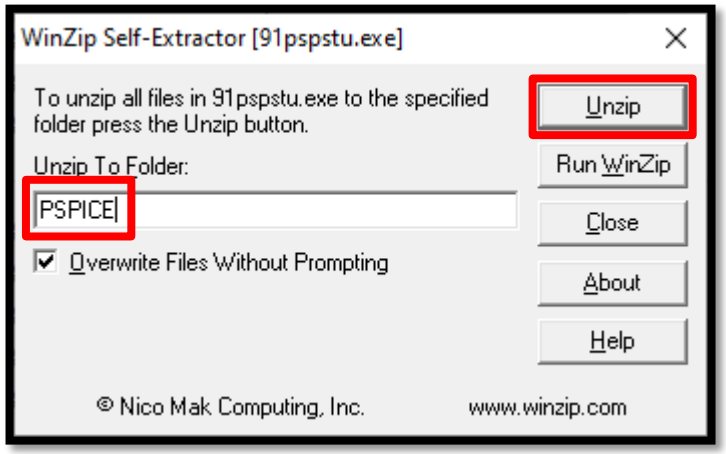
- Para modelagem e análise dos circuitos será utilizado o Pspice Schematics.

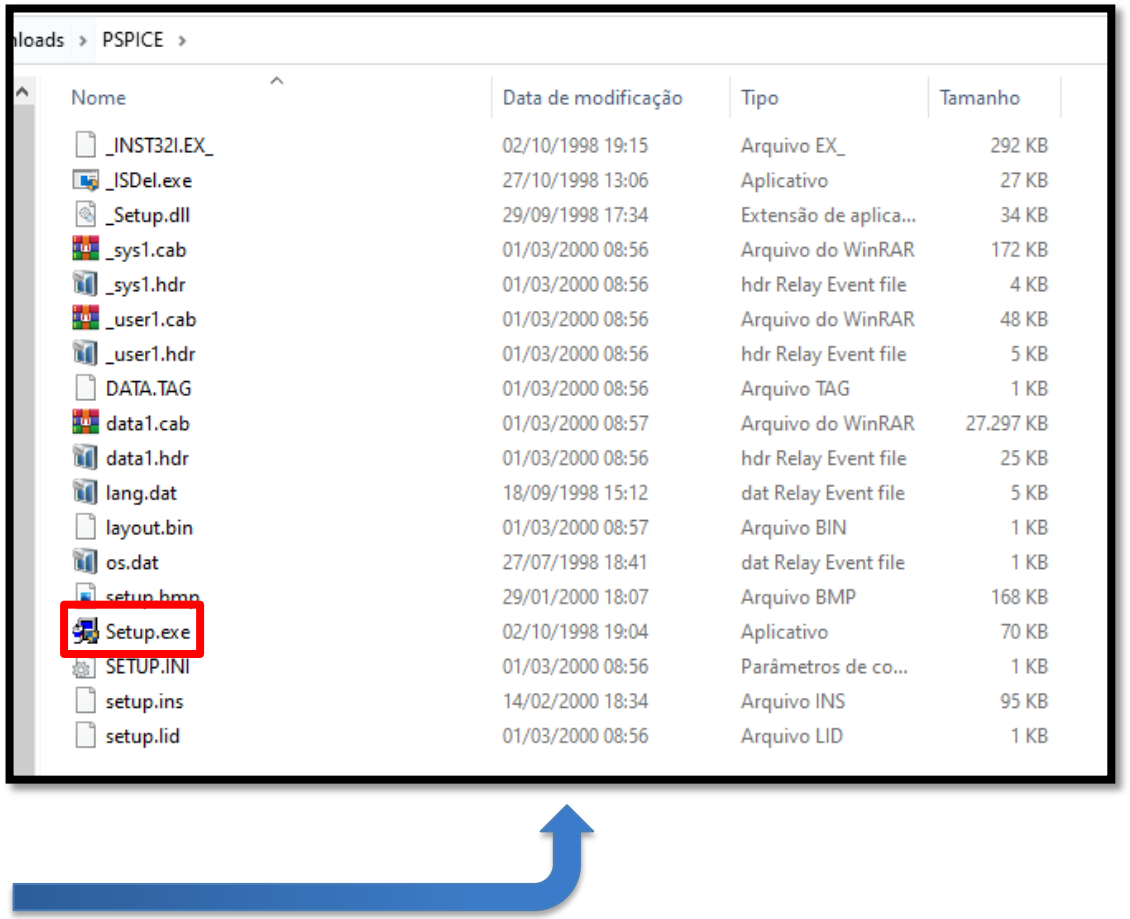


(Parte II) Ambiente de Desenvolvimento

- ✓ PSPICE (**P**ersonal **Spice**)
- ✓ Instalação!







(Parte II) Ambiente de Desenvolvimento

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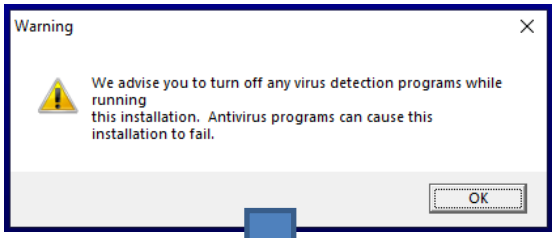

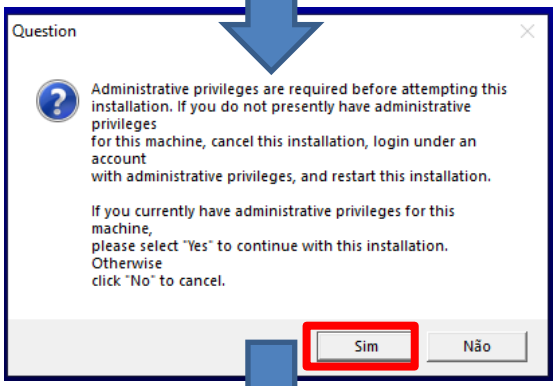

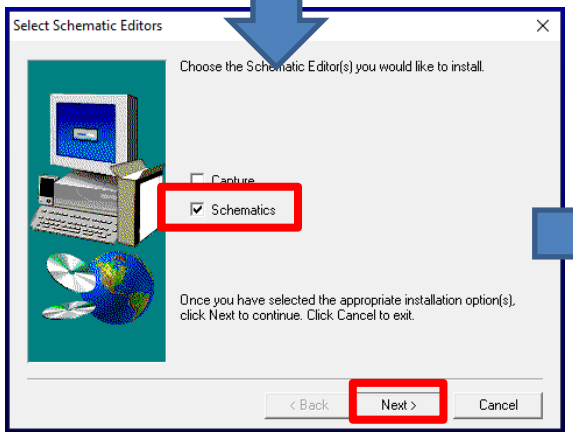

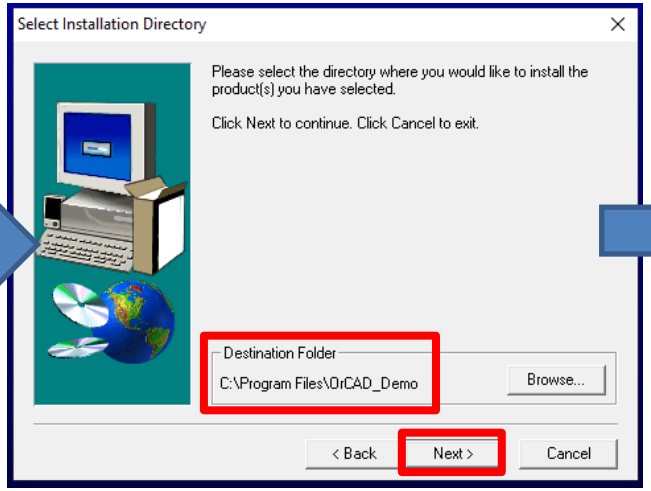

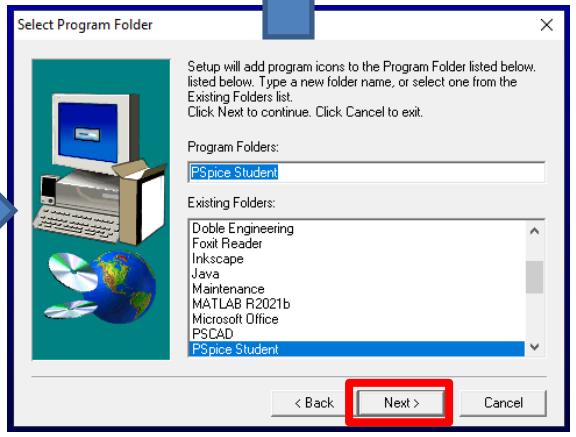

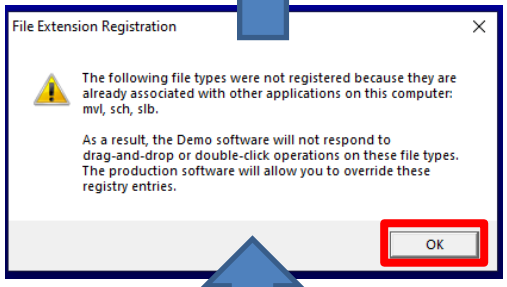

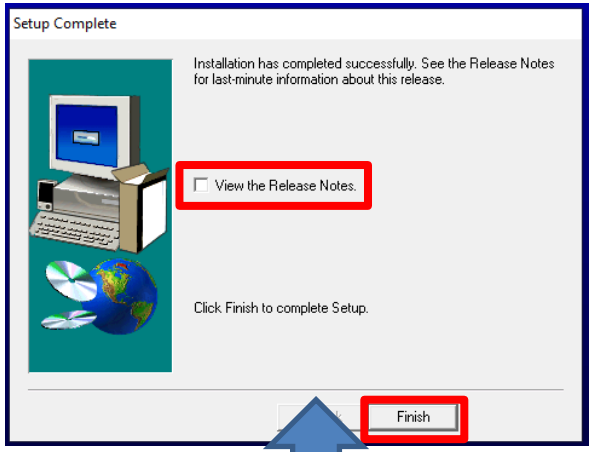

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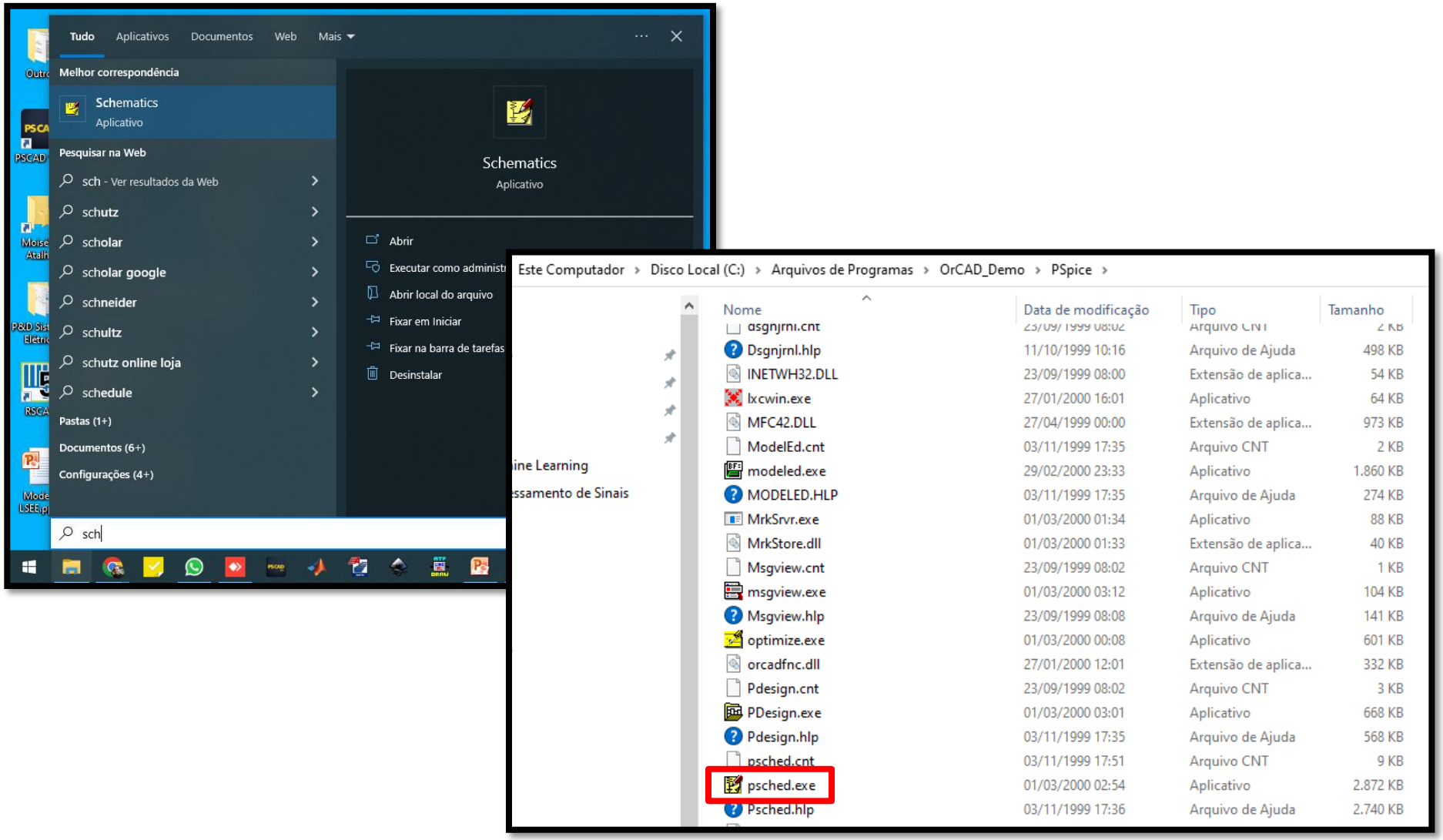
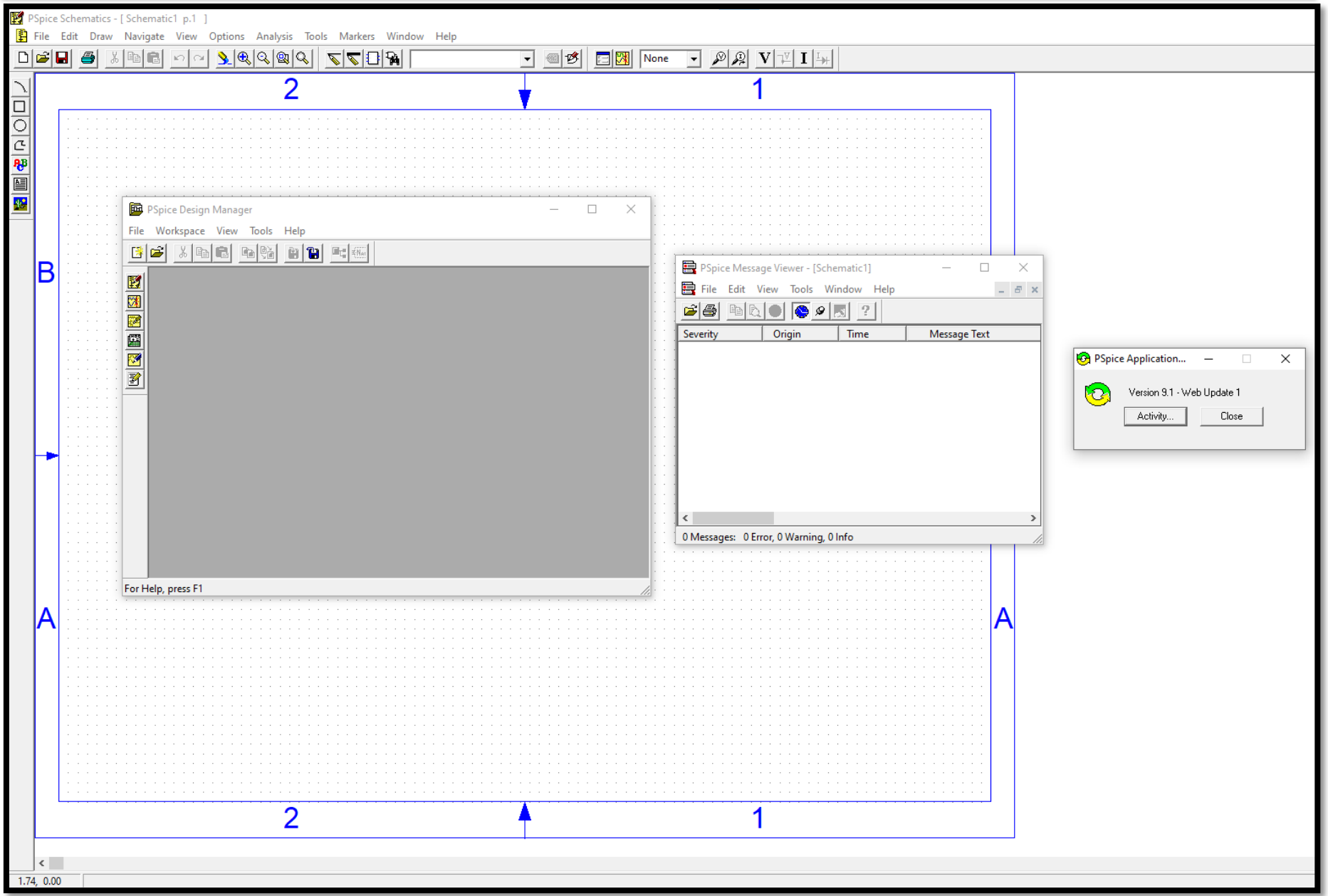


(Parte II) Ambiente de Desenvolvimento



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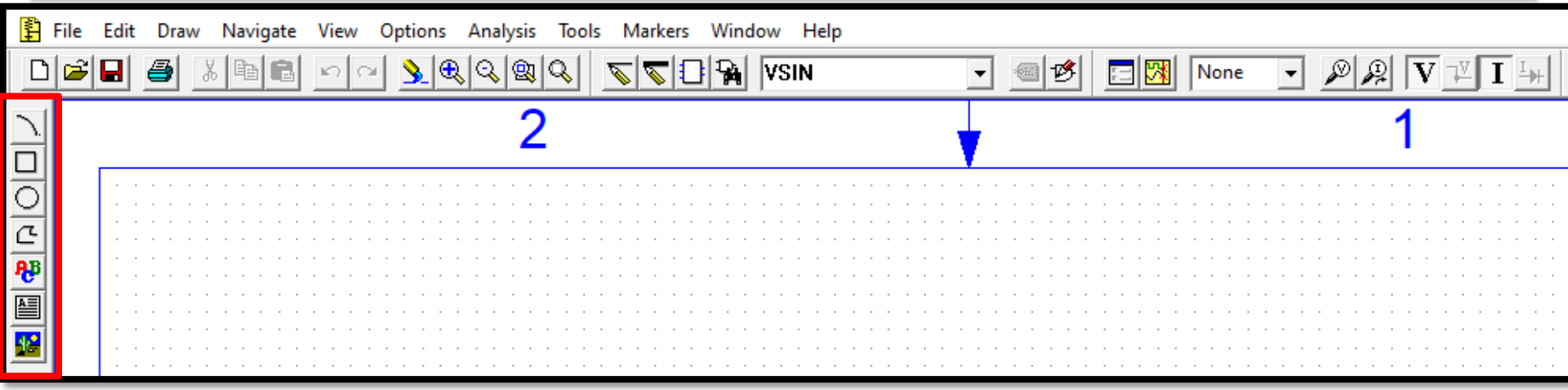
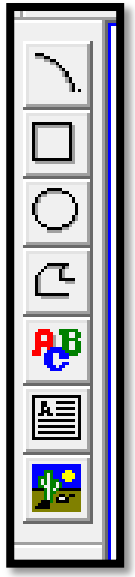
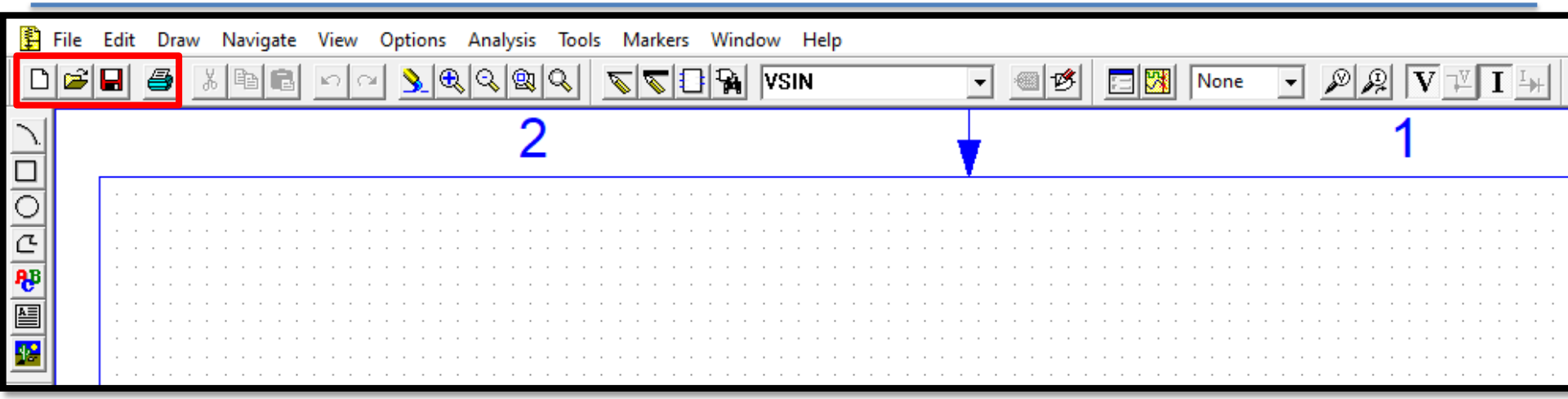
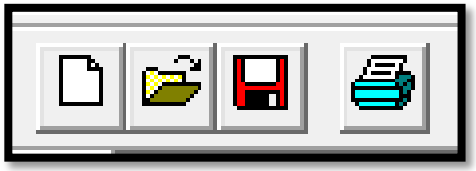




Ferramentas para desenho no ambiente PSPICE

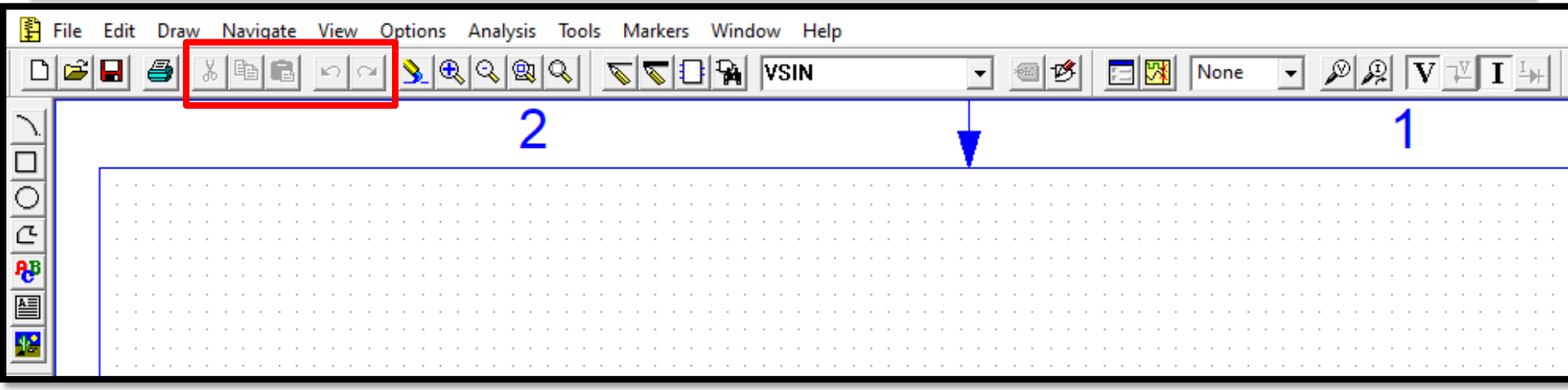
(Parte II) Ambiente de Desenvolvimento

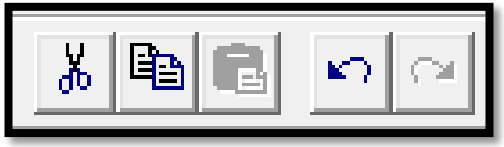




Criar novo projeto, abrir projeto existente ou salvar projeto atual

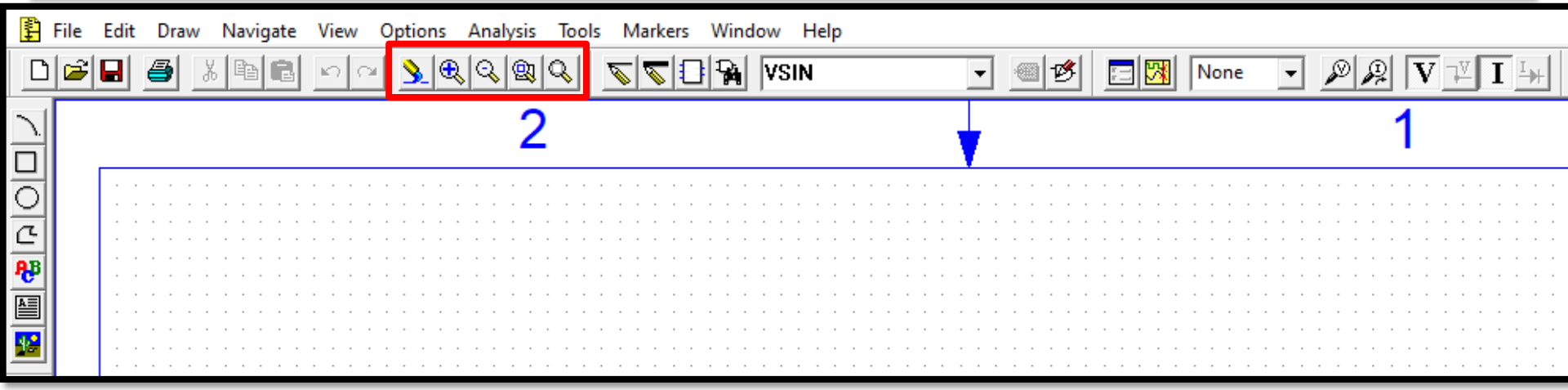
(Parte II) Ambiente de Desenvolvimento

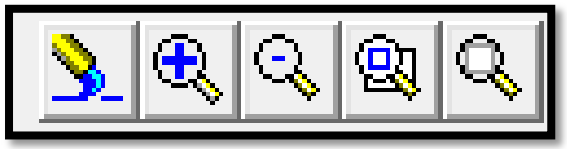




Recortar, copiar, colar, desfazer e refazer

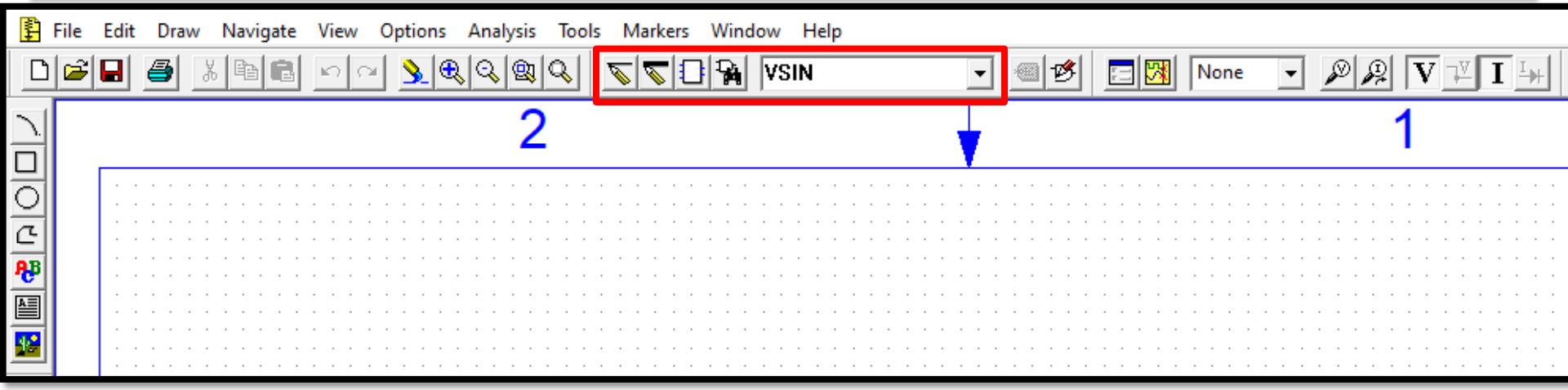
(Parte II) Ambiente de Desenvolvimento





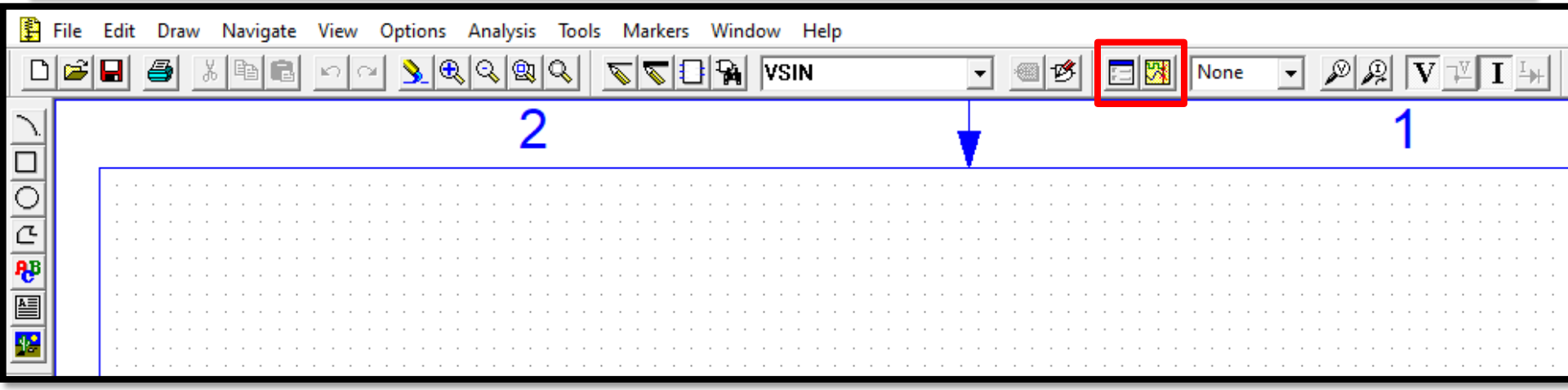
Ferramentas de zoom para o ambiente

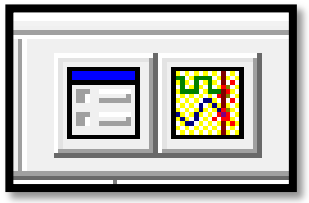
(Parte II) Ambiente de Desenvolvimento



Desenho de linhas/barras e inserção de novos componentes

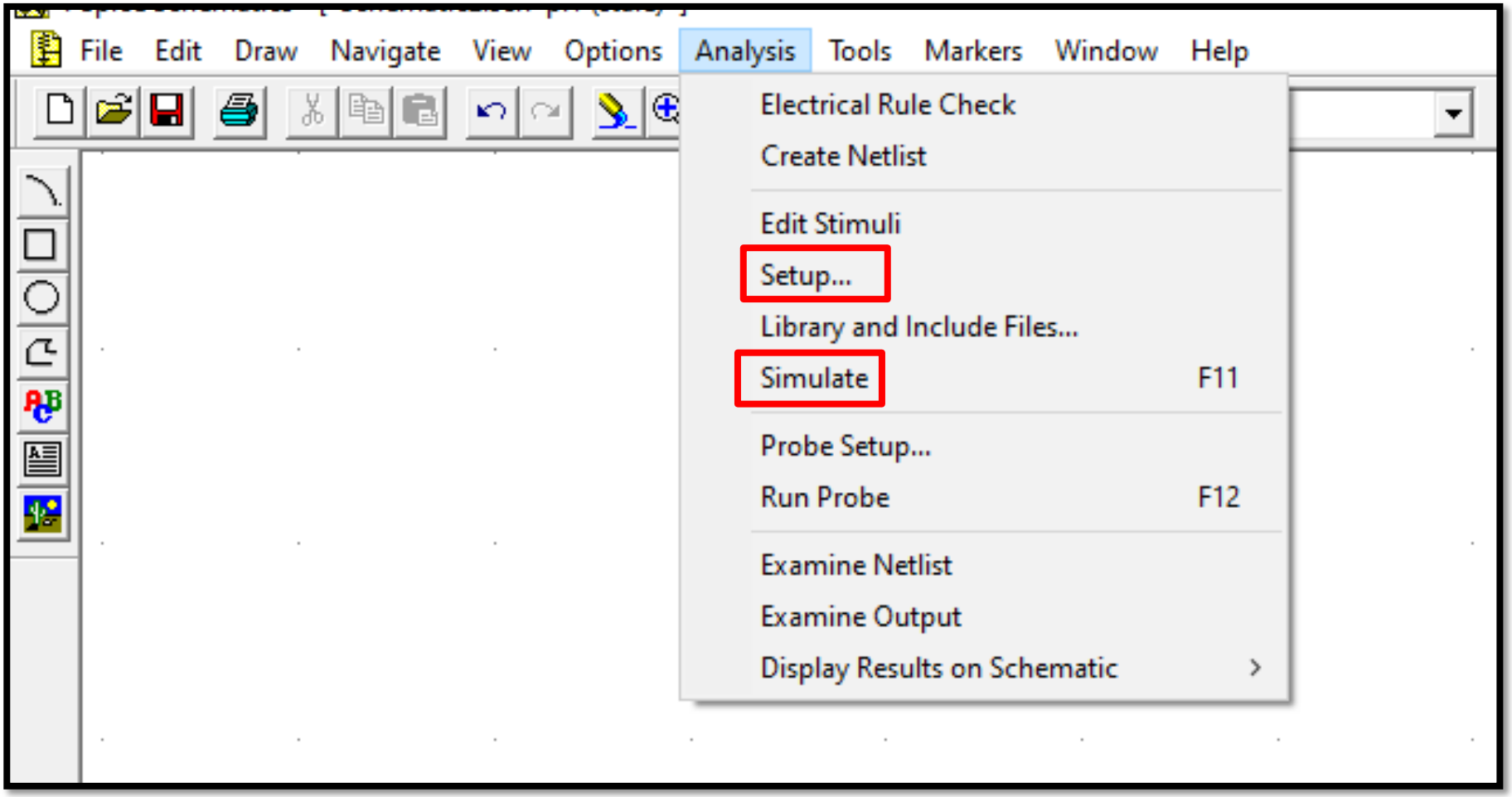
(Parte II) Ambiente de Desenvolvimento



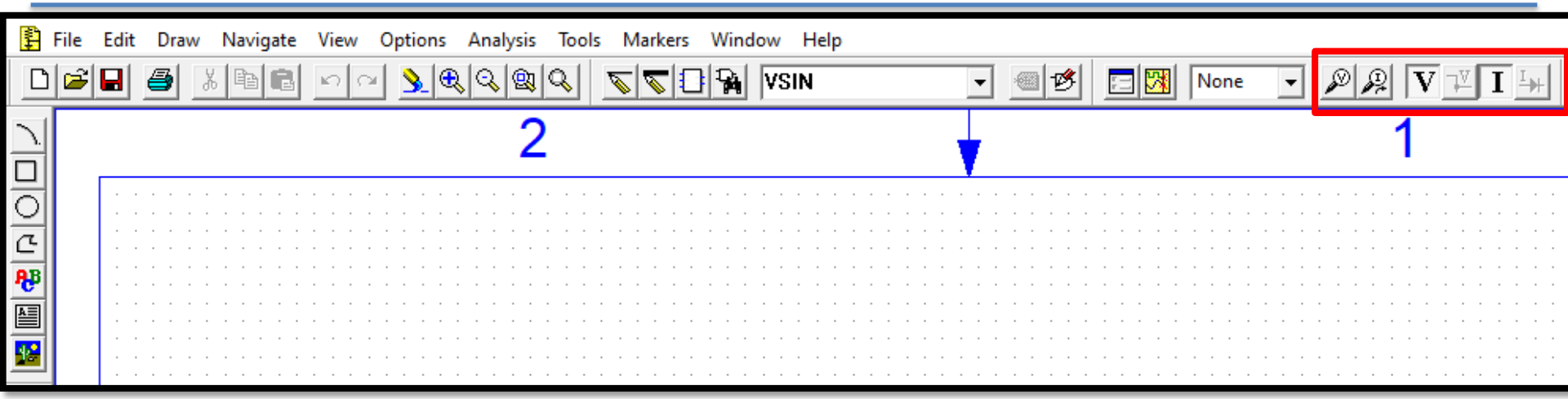


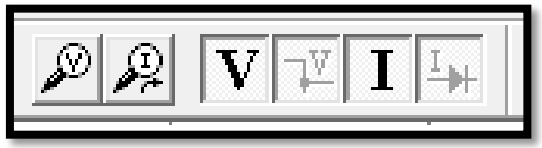
Configurações da simulação e opção de Simular...

(Parte II) Ambiente de Desenvolvimento



(Parte II) Ambiente de Desenvolvimento





Inserção de medidores e opção de mostrar tensões e correntes nos nós do circuito

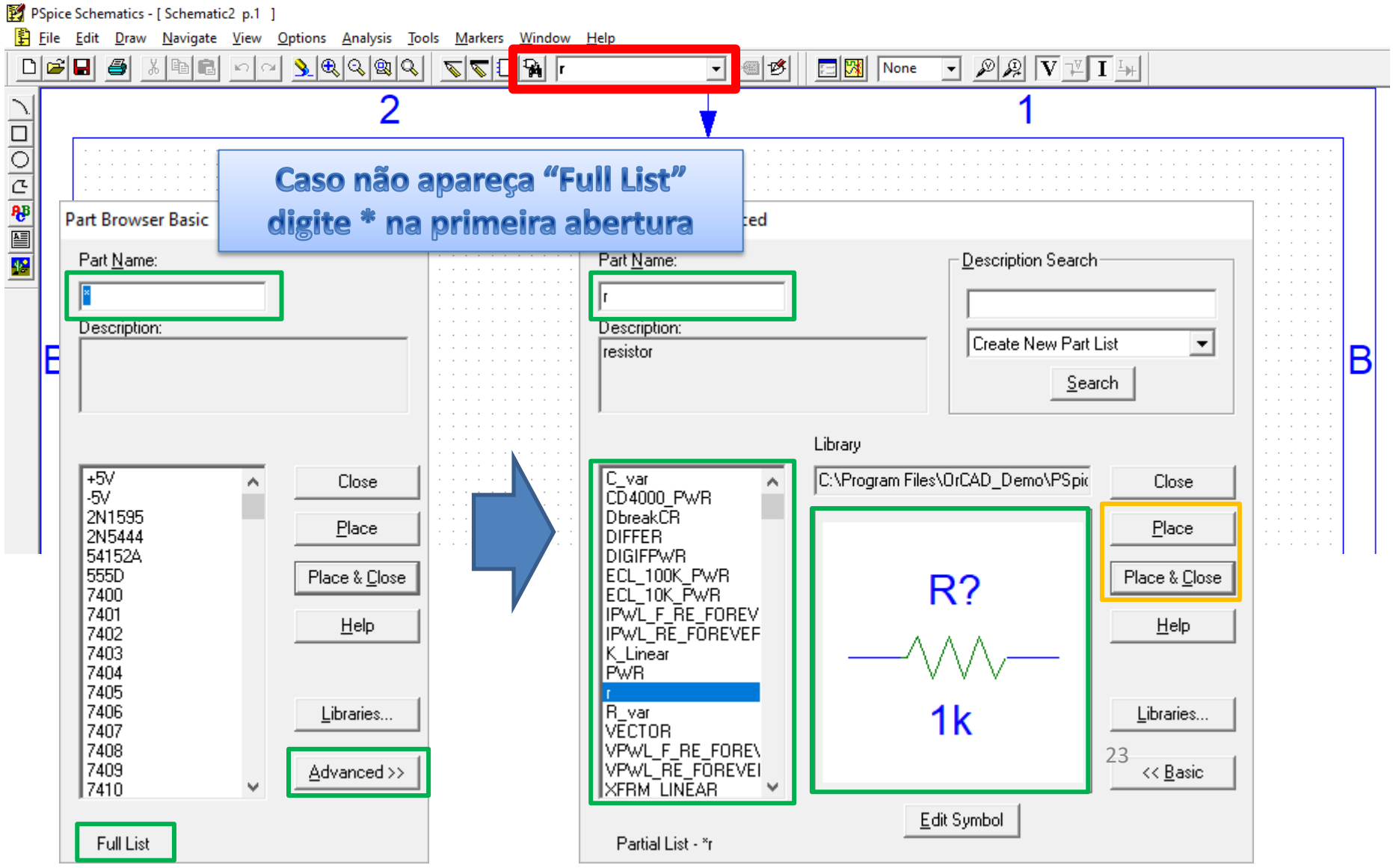
(Parte II) Regras para Inserção/Parametrização

- ✓ O PSPICE não é *case sensitive*
- ✓ É obrigatória a definição de um nó de referência (*ground*);
- ✓ O valor do elemento é dado em unidades do SI
- ✓ Valores fracionários fornecidos com **ponto decimal**
- ✓ Valor Exponencial: E3, E-3, E6, etc

Potencia de dez	Nome no SI	Sufixo do SPICE
-15	femto	f ou F
-12	pico	p ou P
-9	nano	n ou N
-6	micro	u ou U
-3	mili	m ou M
3	kilo	k ou K
6	mega	meg ou MEG
9	giga	g ou G
12	tera	t ou T

Unidade	Abreviatura
Volt	V
Ampére	A
Hertz	HZ
ohm (Ω)	OHM
Henry	H
Farad	F
graus	DEG

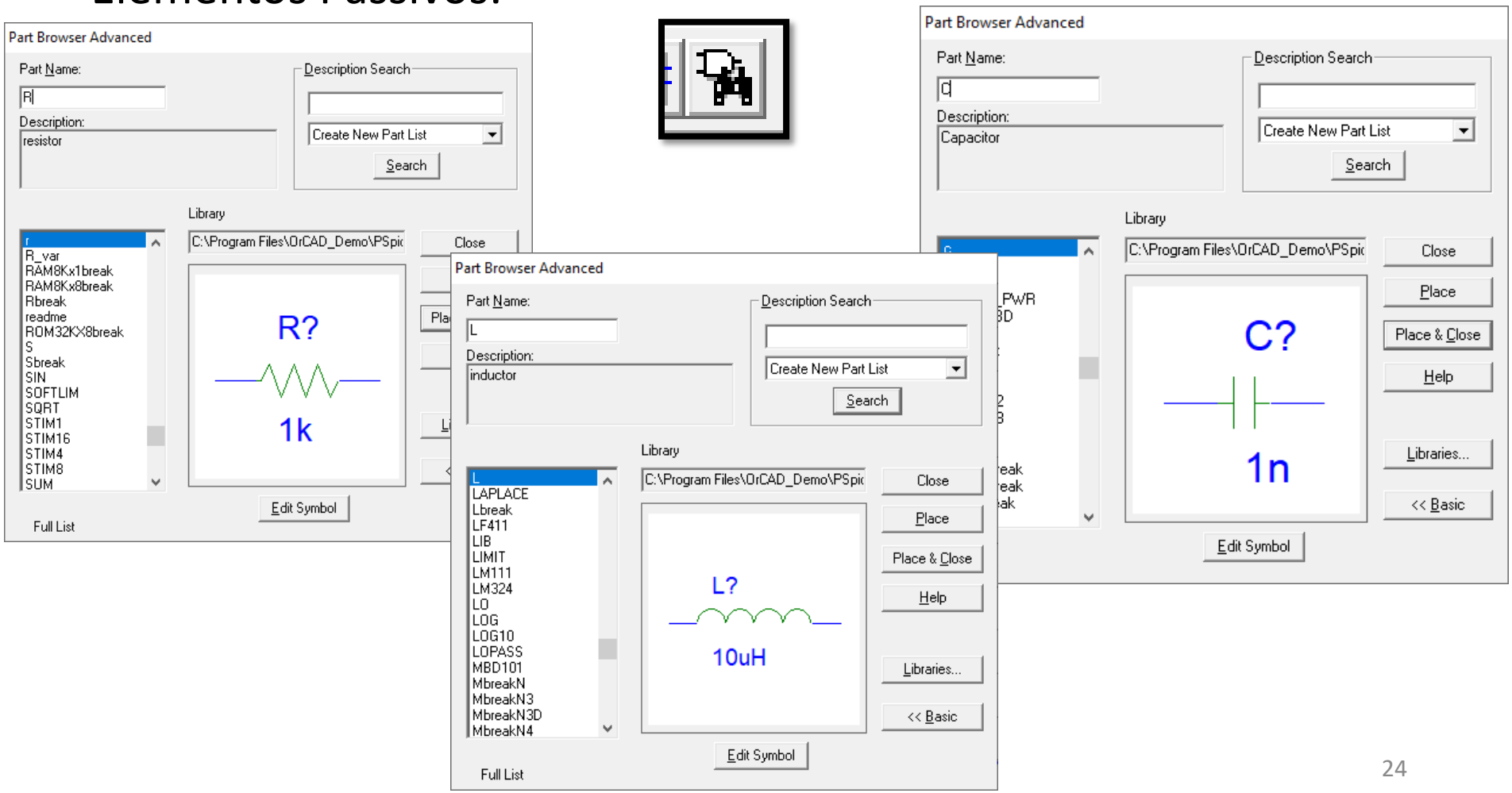
(Parte II) Inserção dos Elementos



(Parte II) Código e Parametrização dos Elementos

- ✓ Cada elemento do circuito possui nome/termo único;

- ✓ Elementos Passivos:



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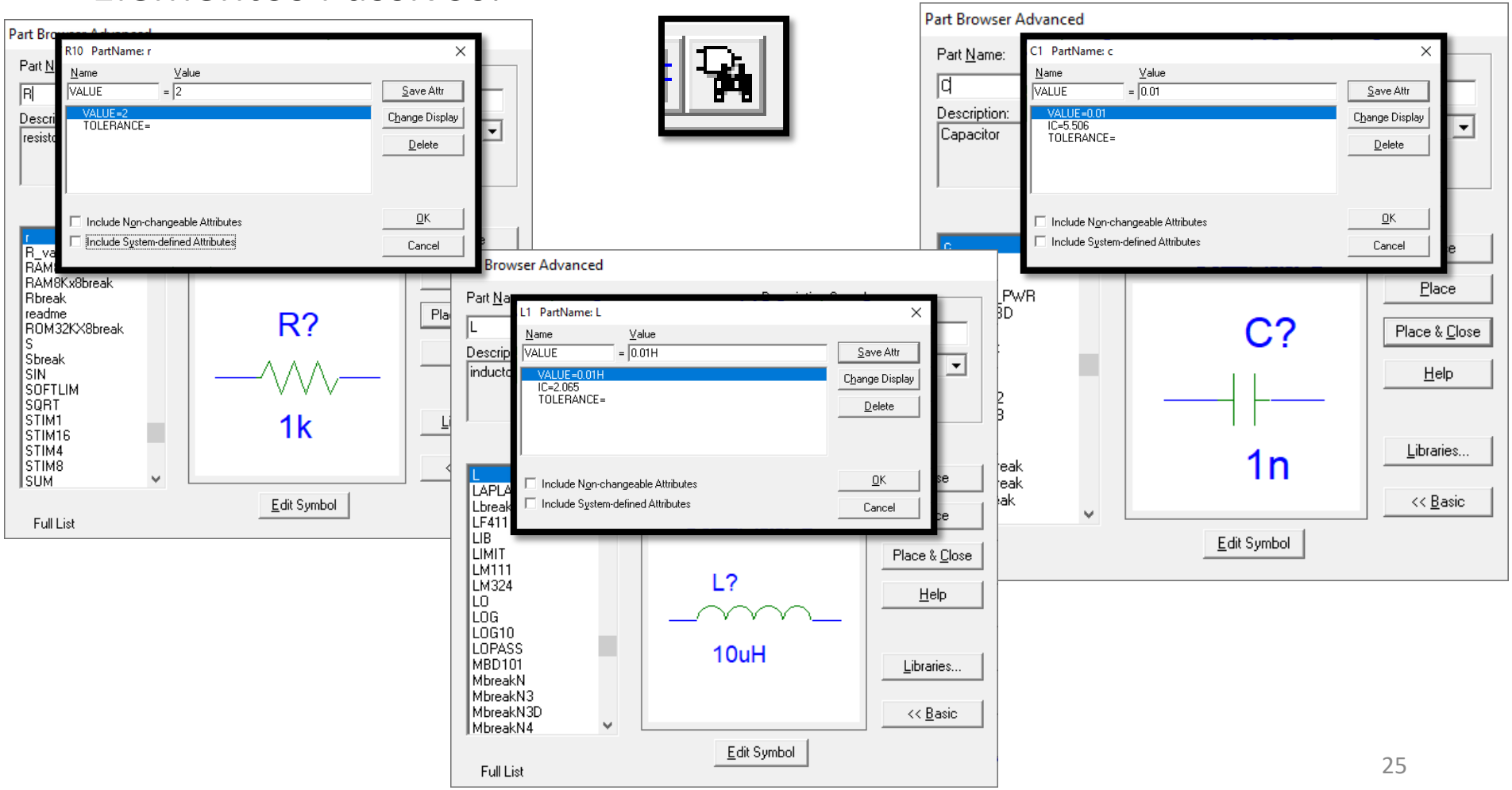

(Parte II) Código e Parametrização dos Elementos

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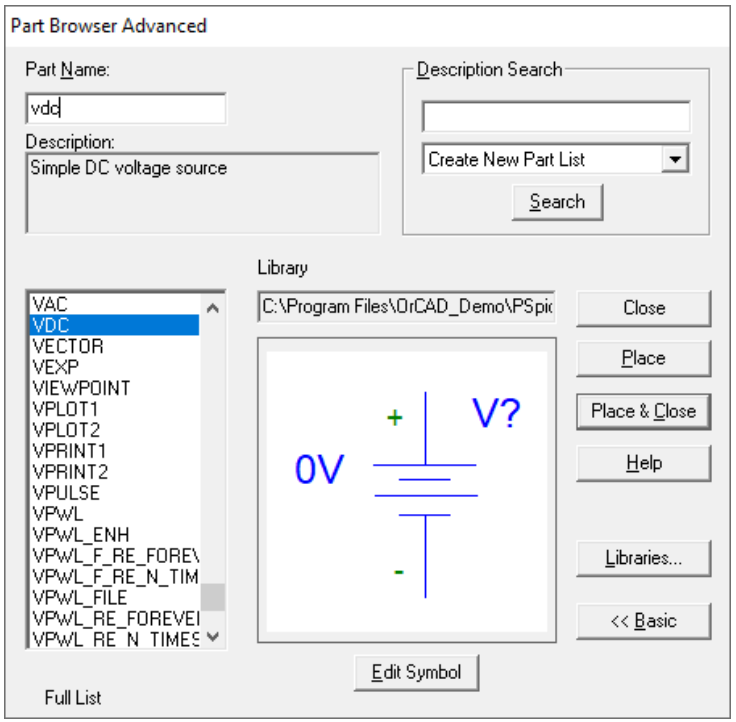
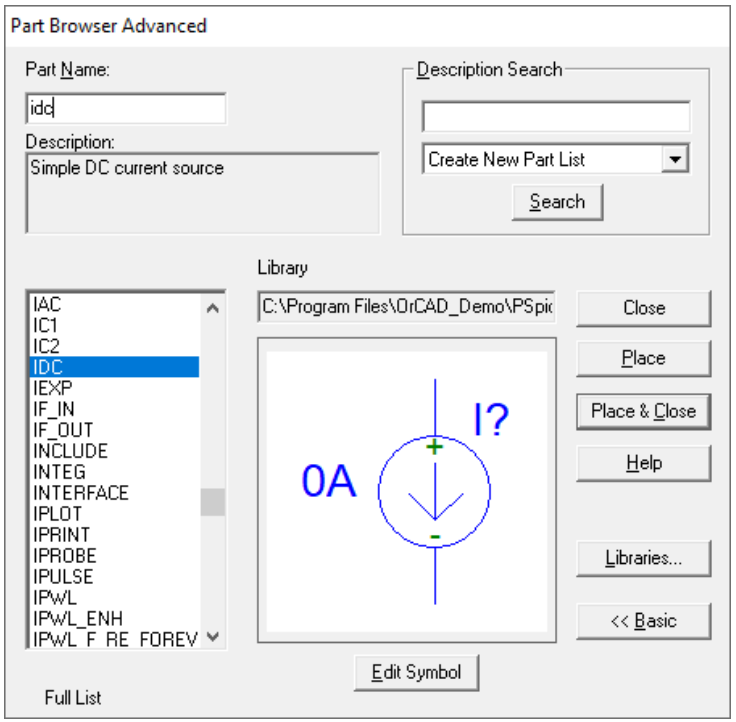
- ✓ Fontes DC Independentes:





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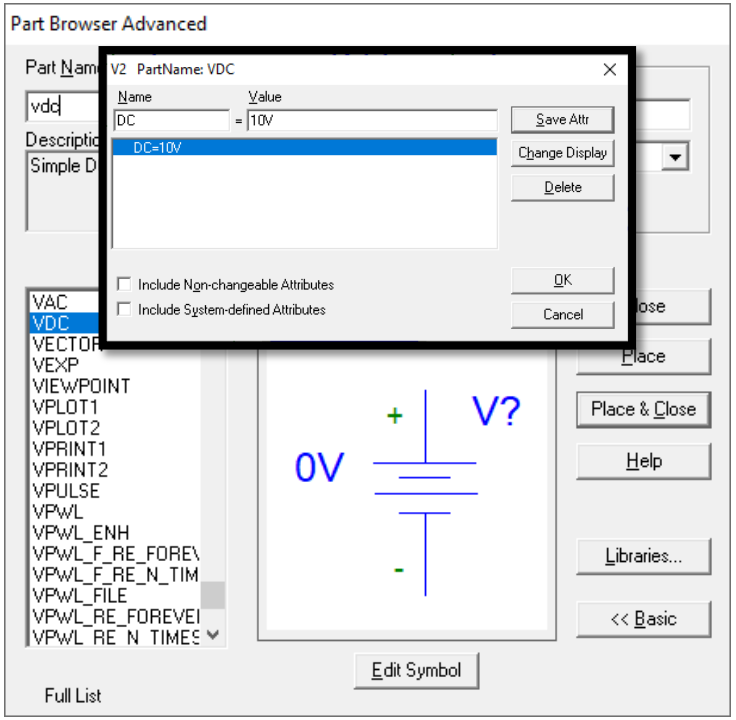
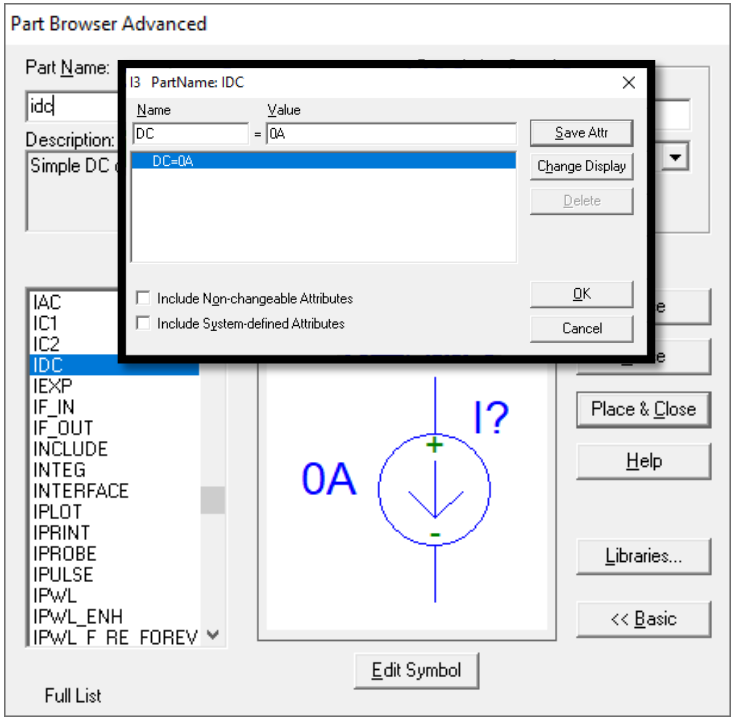
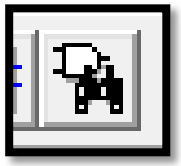
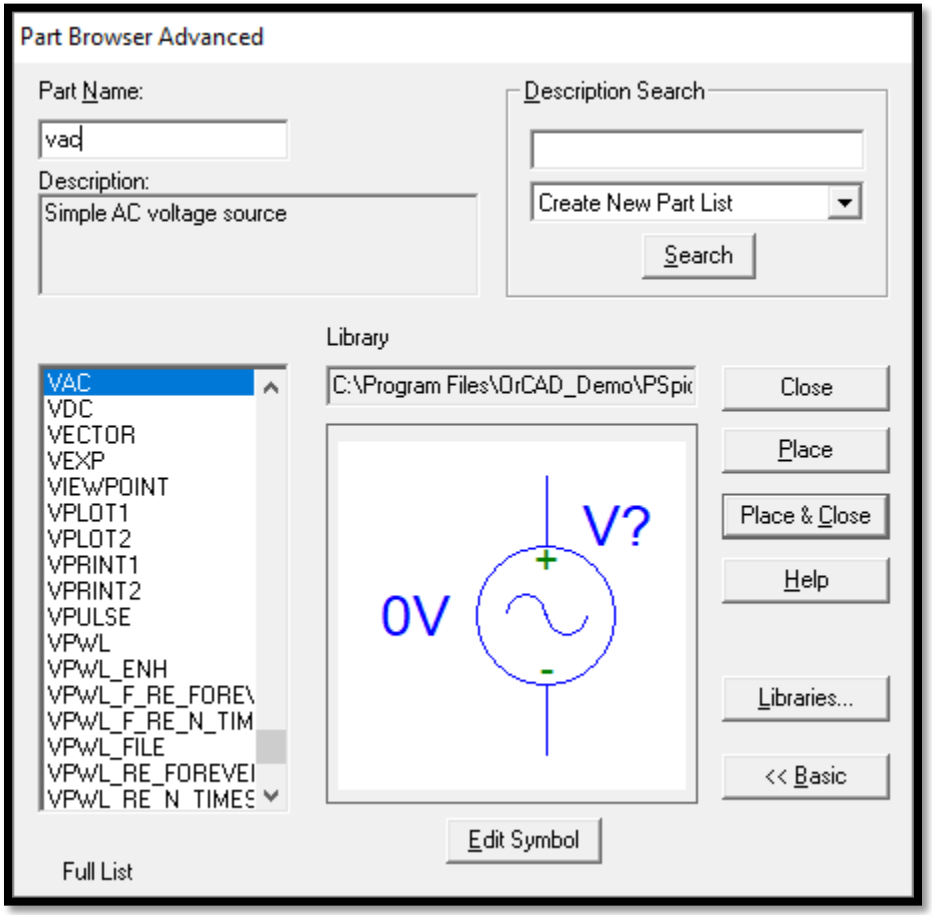


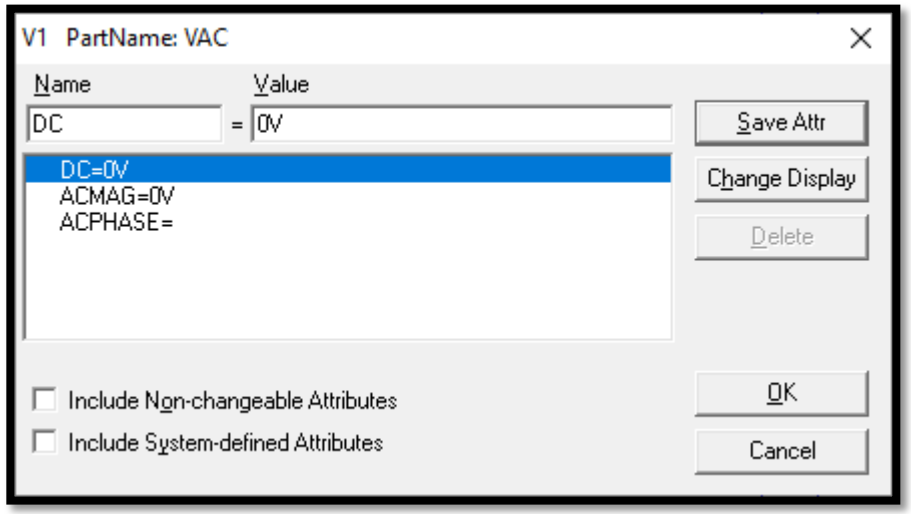


(Parte II) Código e Parametrização dos Elementos

- ✓ Cada elemento do circuito possui nome/termo único;
- ✓ Fonte AC para Análise Fasorial do Circuito:

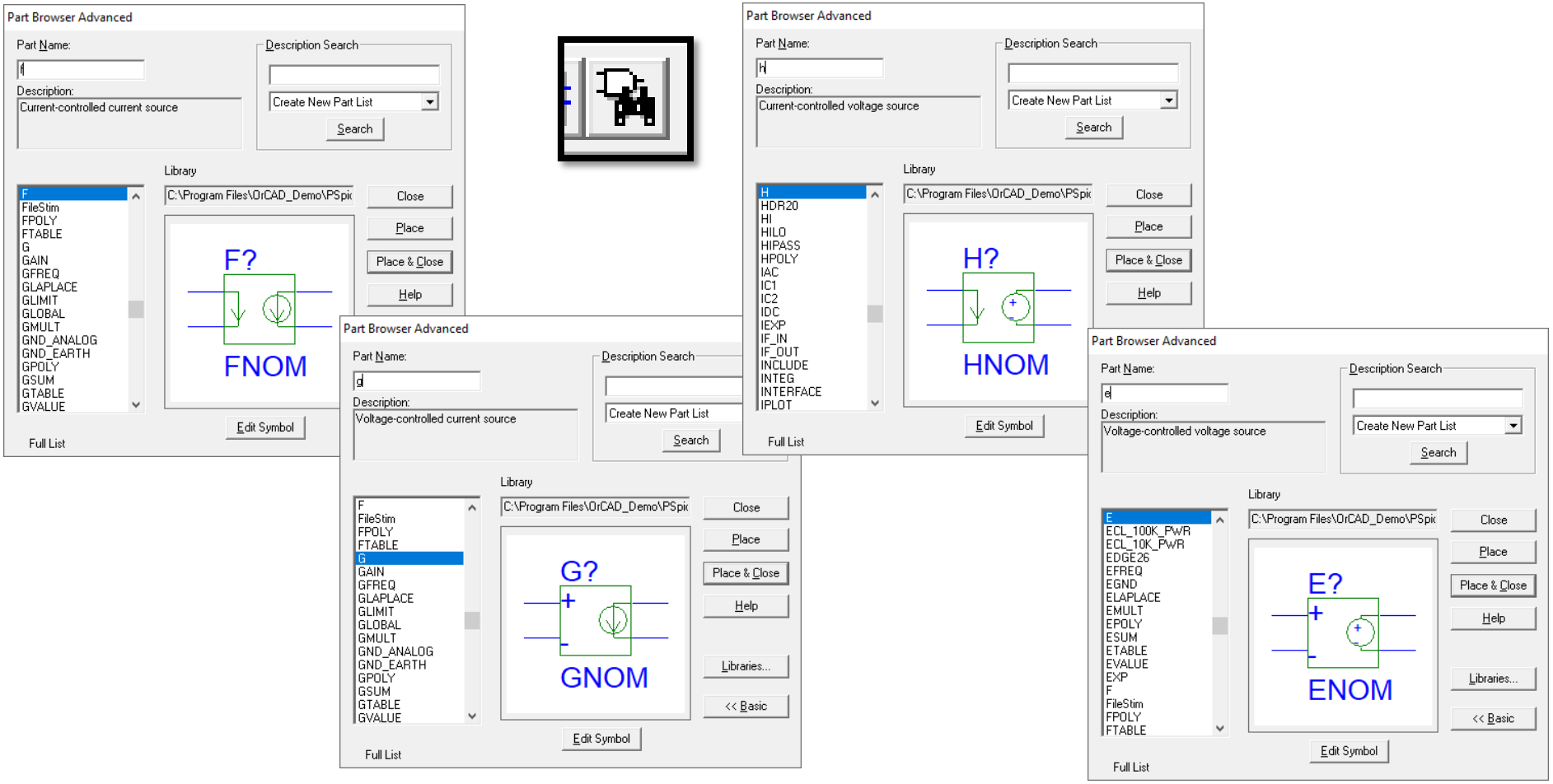






(Parte II) Código e Parametrização dos Elementos

- ✓ Cada elemento do circuito possui nome/termo único;
- ✓ Fontes Dependentes/Controladas:



(Parte II) Código e Parametrização dos Elementos

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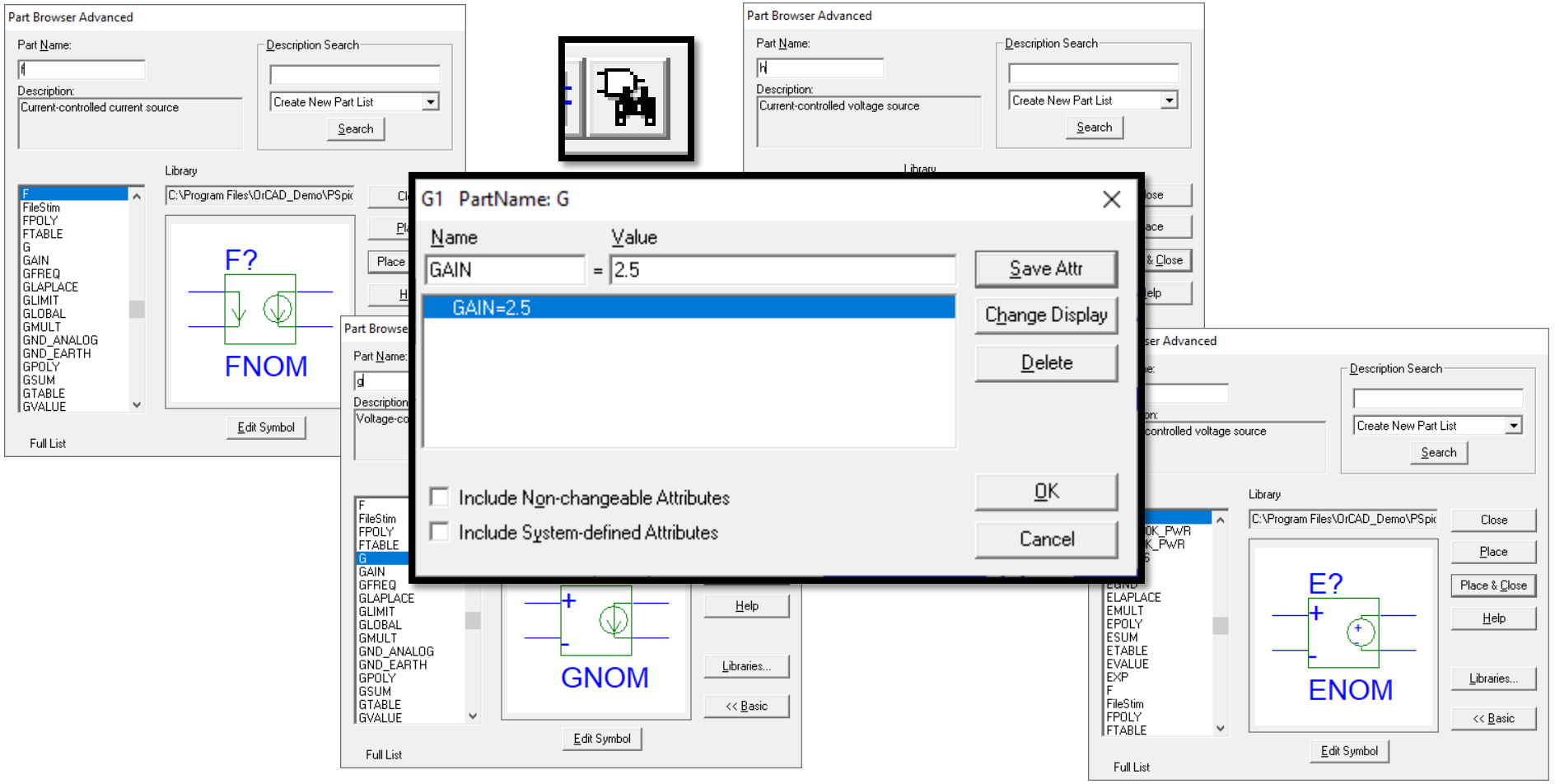
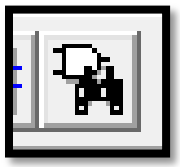
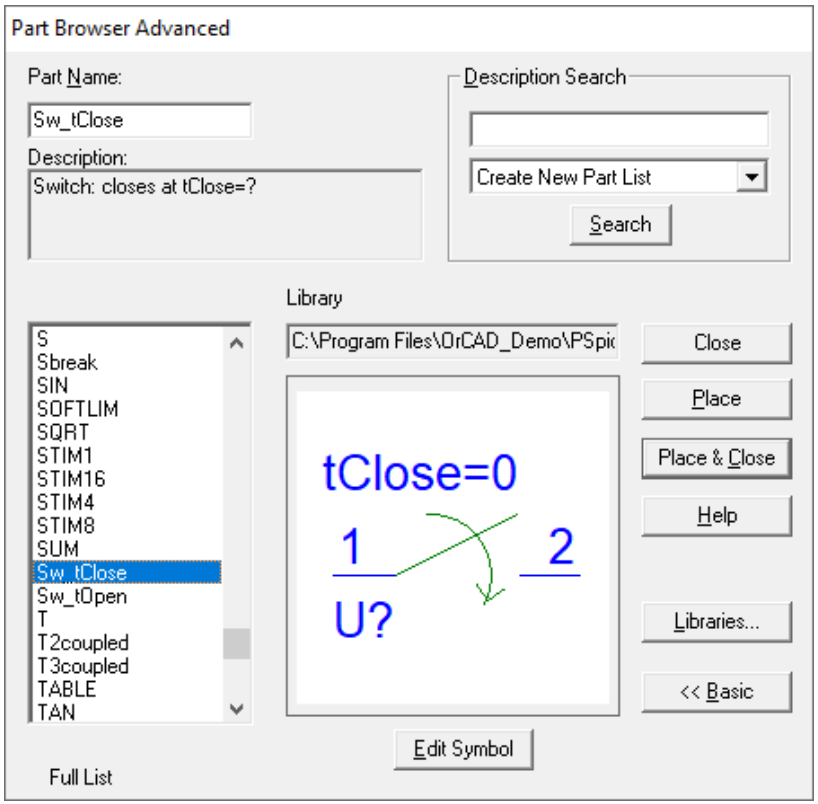
- ✓ Fontes Dependentes:

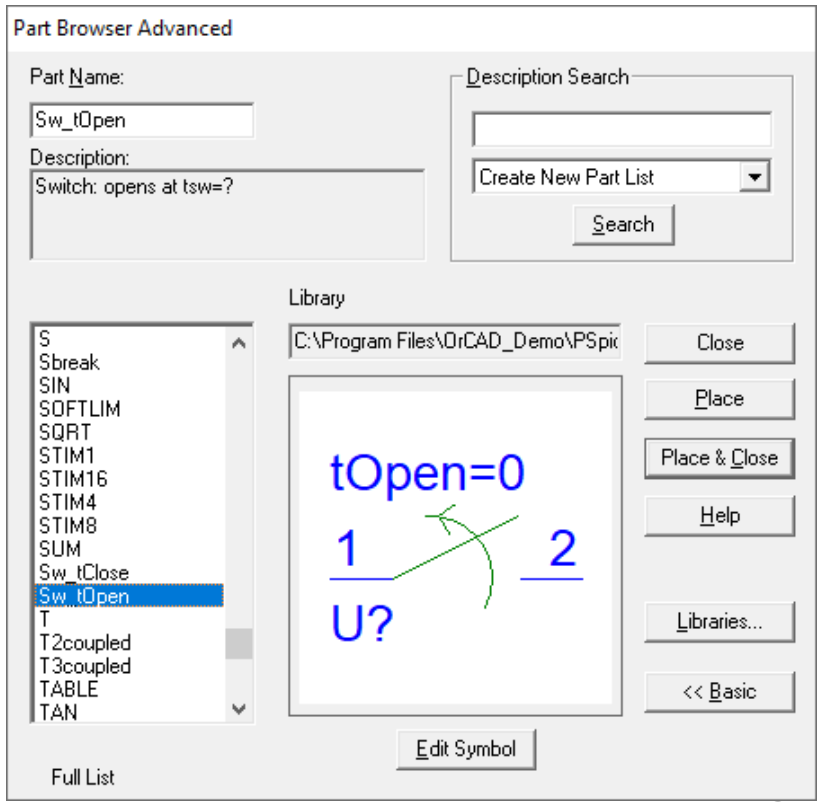


(Parte II) Código e Parametrização dos Elementos

- ✓ Cada elemento do circuito possui nome/termo único;
- ✓ Chaves:

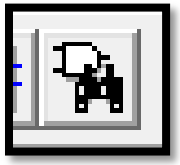


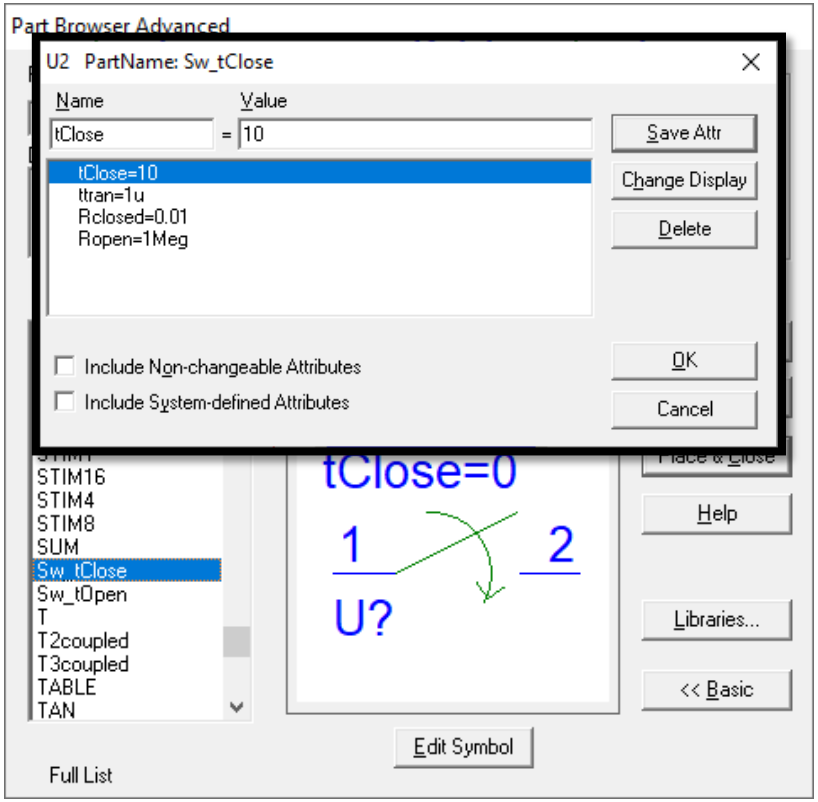


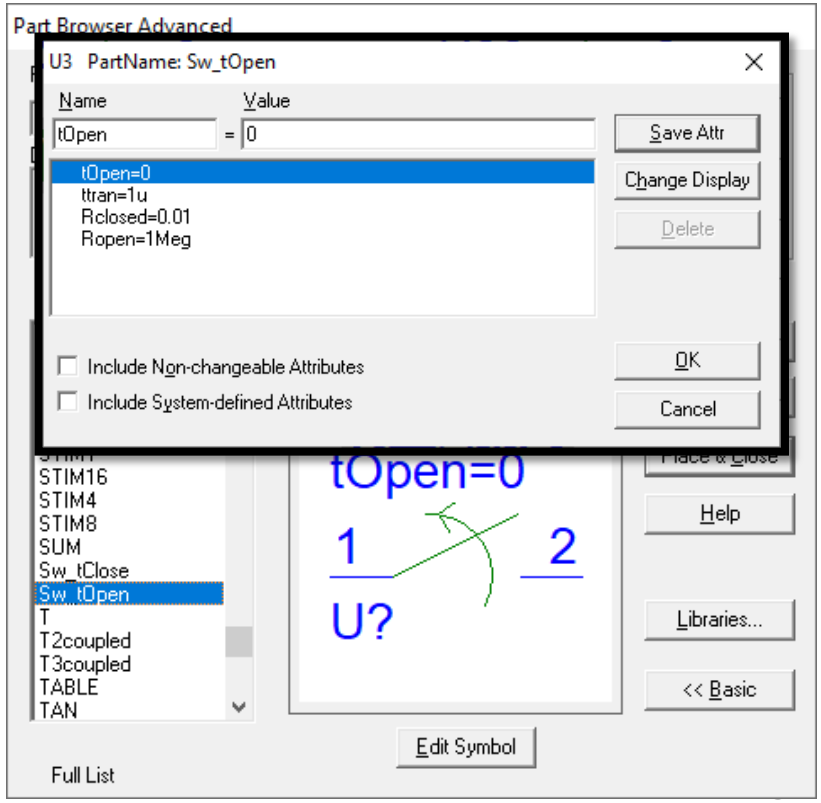


(Parte II) Código e Parametrização dos Elementos

- ✓ Cada elemento do circuito possui nome/termo único;
- ✓ Chaves:

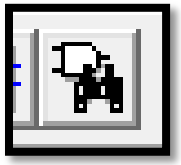


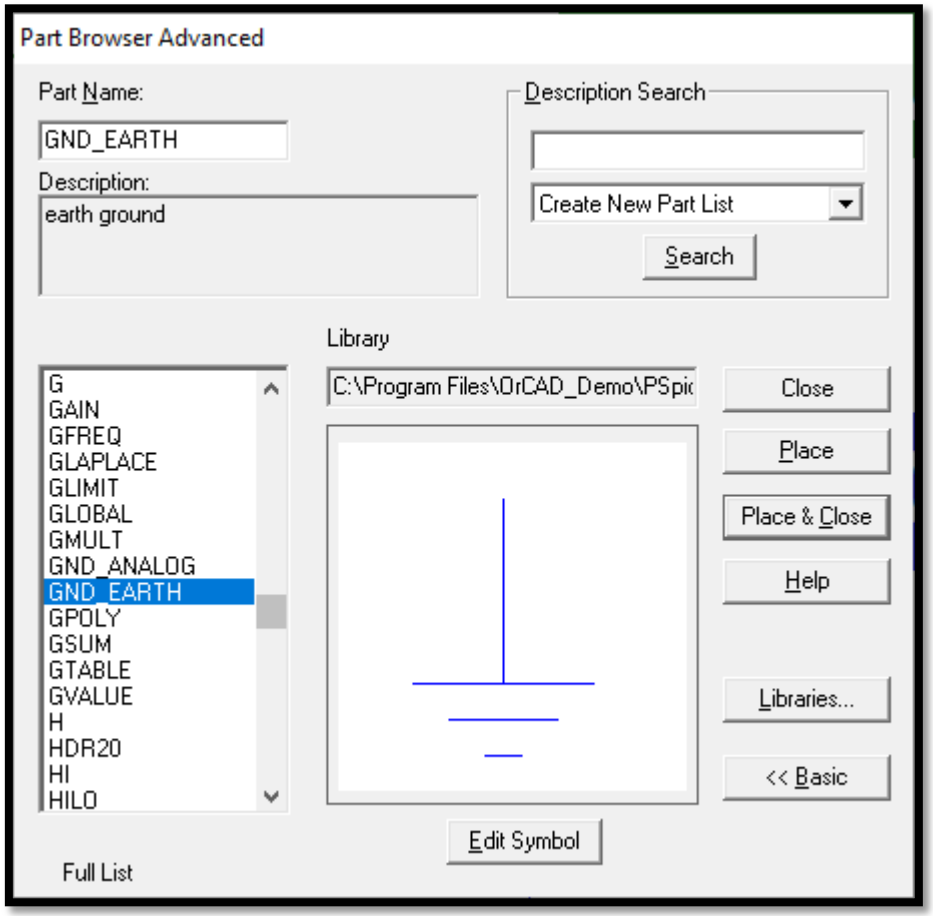




(Parte II) Código e Parametrização dos Elementos

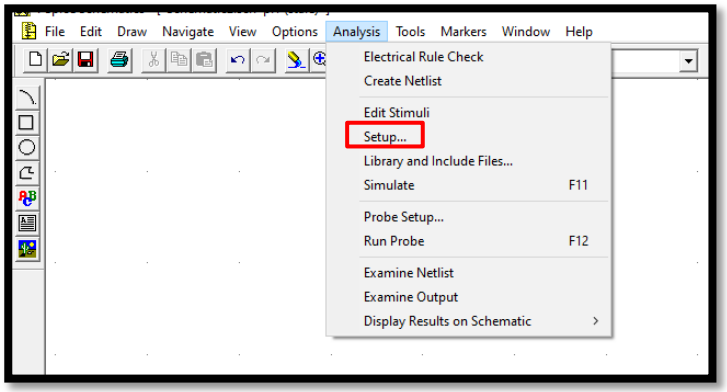
- ✓ Cada elemento do circuito possui nome/termo único;
- ✓ Nó de referência do circuito:

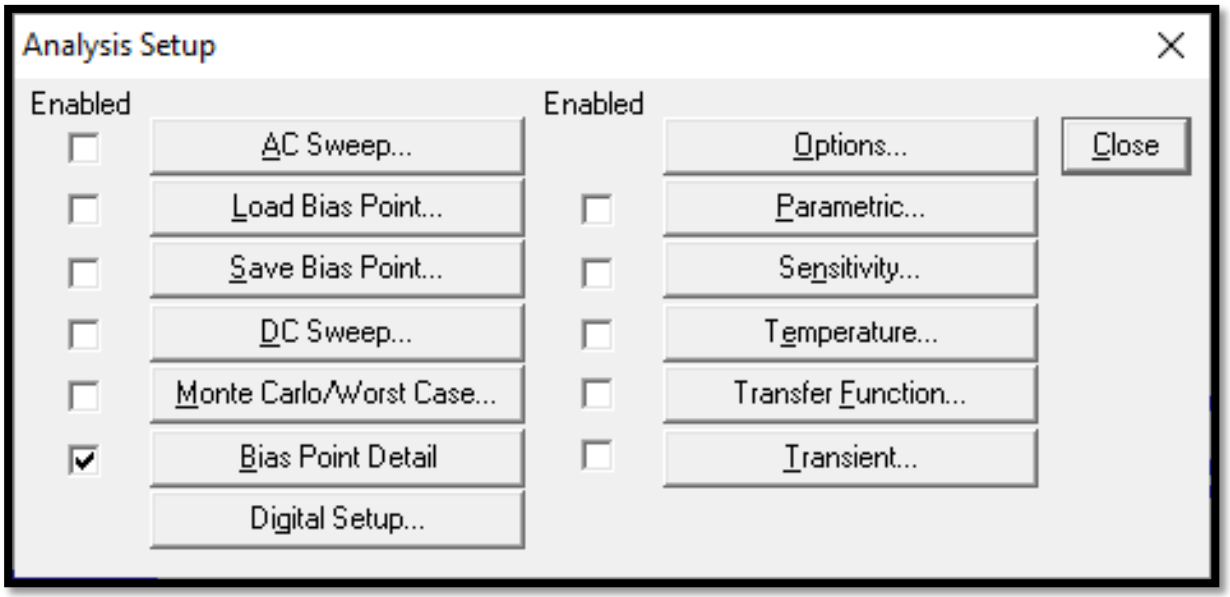




(Parte II) Tipos de Análises

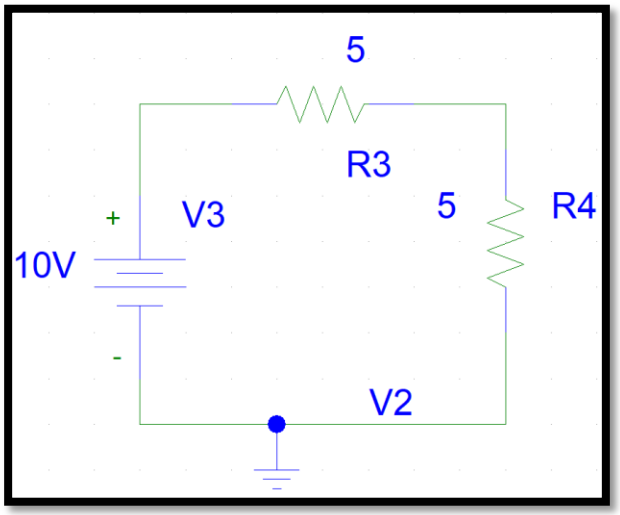
- ✓ **Ponto de operação (*V dos nós e I das fontes*)**
- ✓ Chamada pelo PSPICE de “Bias Point Detail”

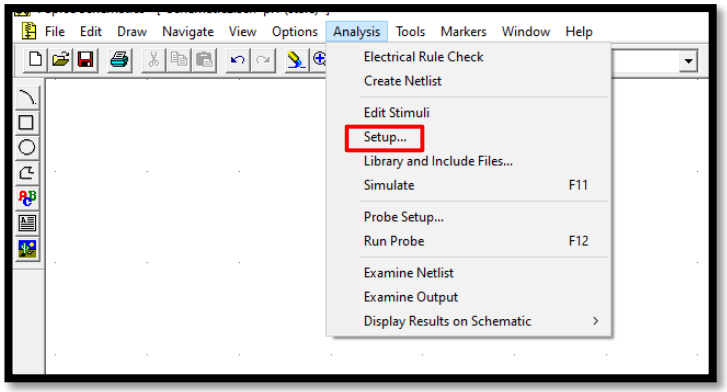


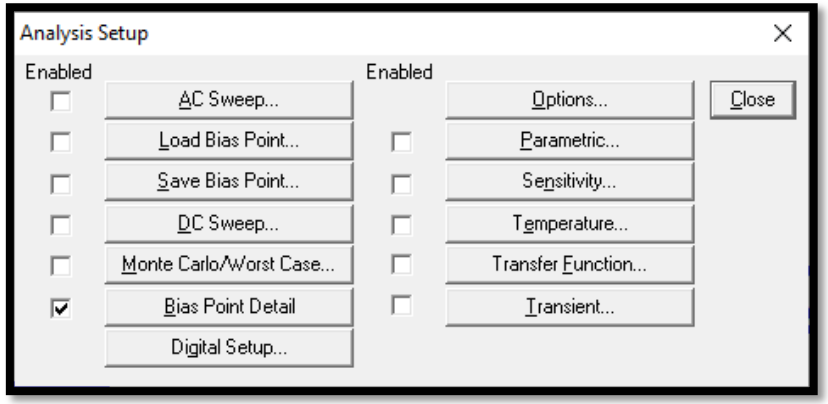


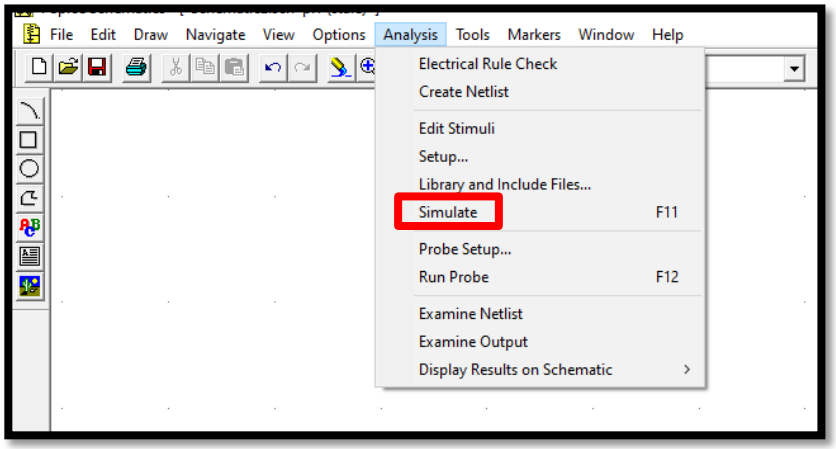
(Parte II) Tipos de Análises

- ✓ **Ponto de operação (*V dos nós e I das fontes*)**
- ✓ Chamada pelo PSPICE de “Bias Point Detail”









(Parte II) Tipos de Análises

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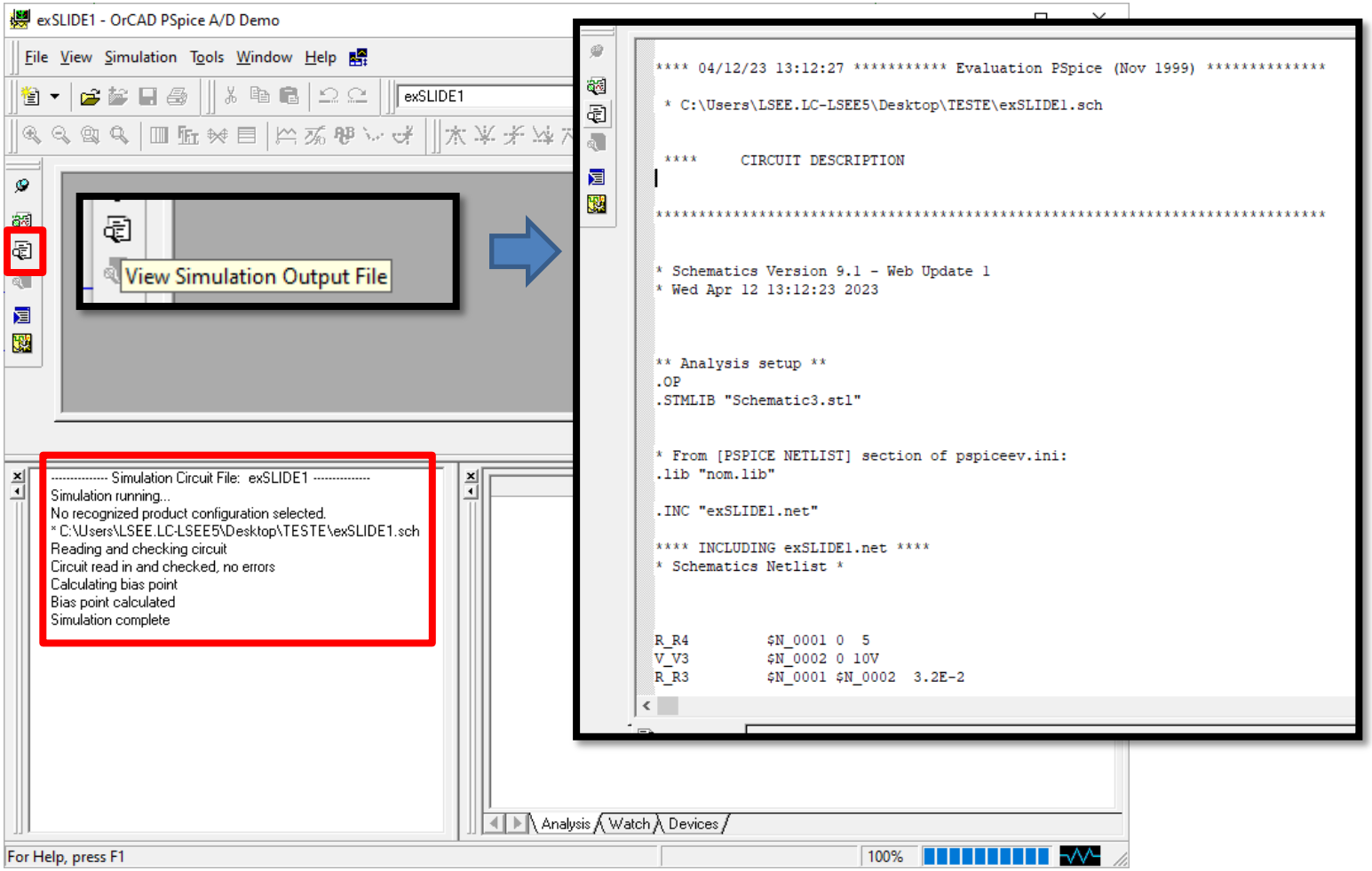
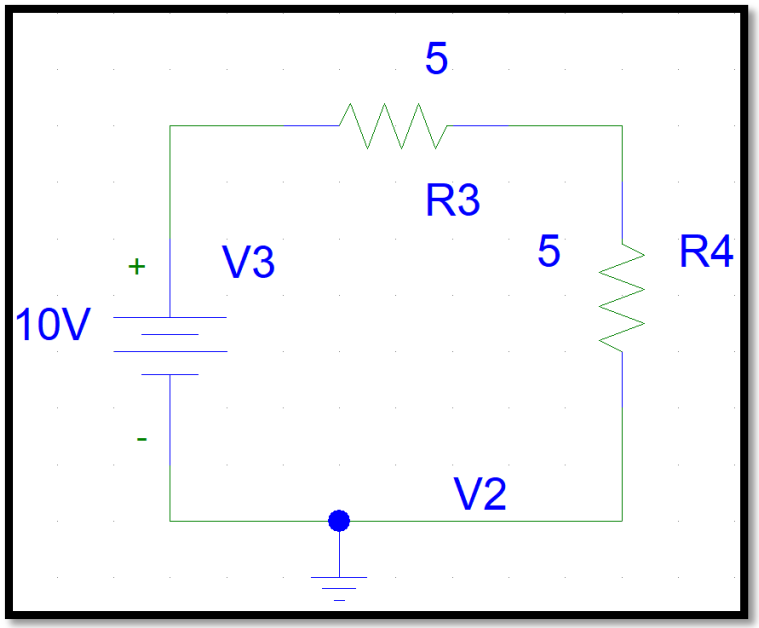
- ✓ Chamada pelo PSPICE de “Bias Point Detail”

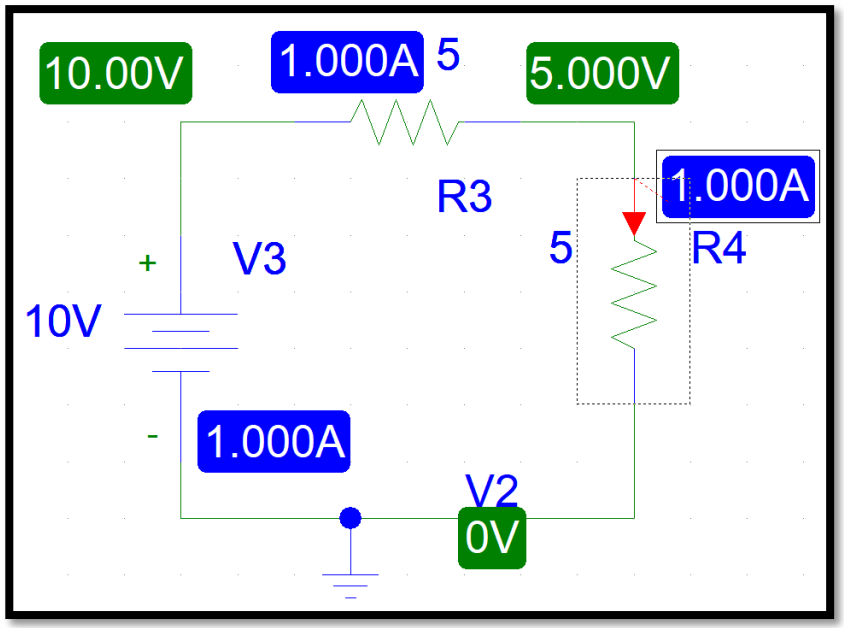


(Parte II) Tipos de Análises

- ✓ **Ponto de operação (*V dos nós e I das fontes*)**
- ✓ Chamada pelo PSPICE de “Bias Point Detail”

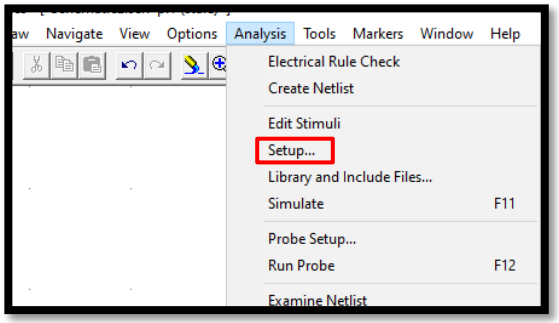
??? Exercício 01 ???

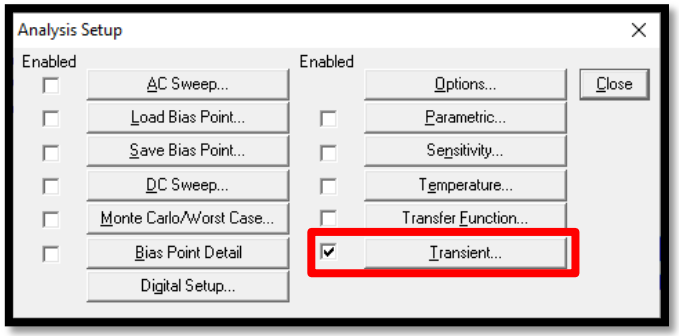


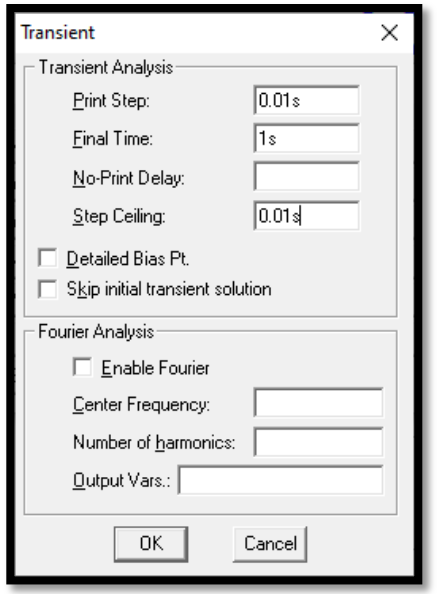


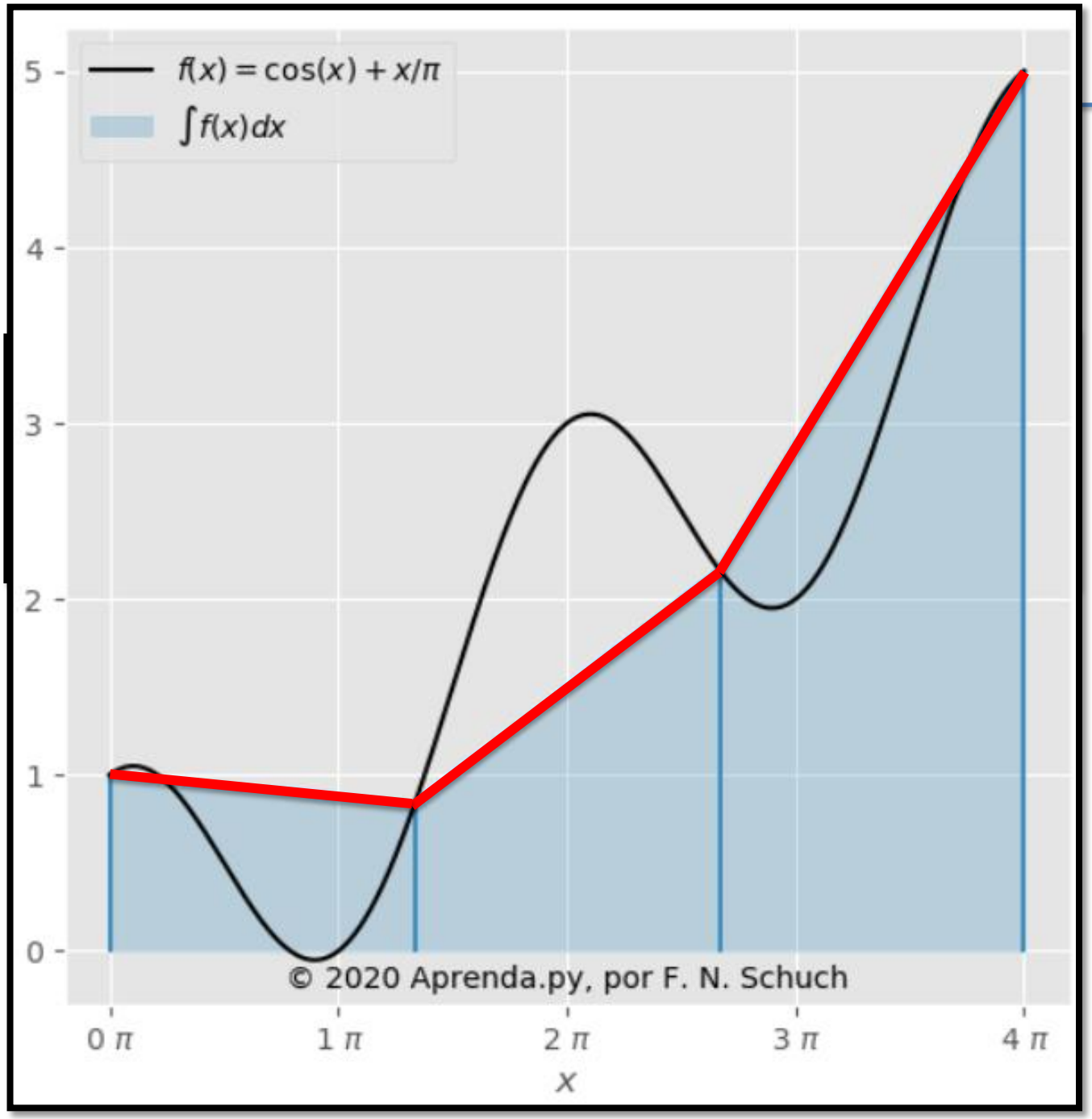
(Parte II) Tipos de Análises

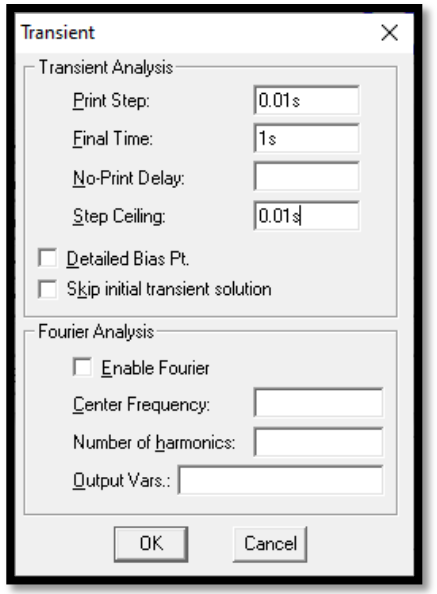
- ✓ **Análises de Transitórios**
- ✓ **Análises onde verificar as oscilografias é importante.**
- ✓ Chamada pelo PSPICE de “Transient...”

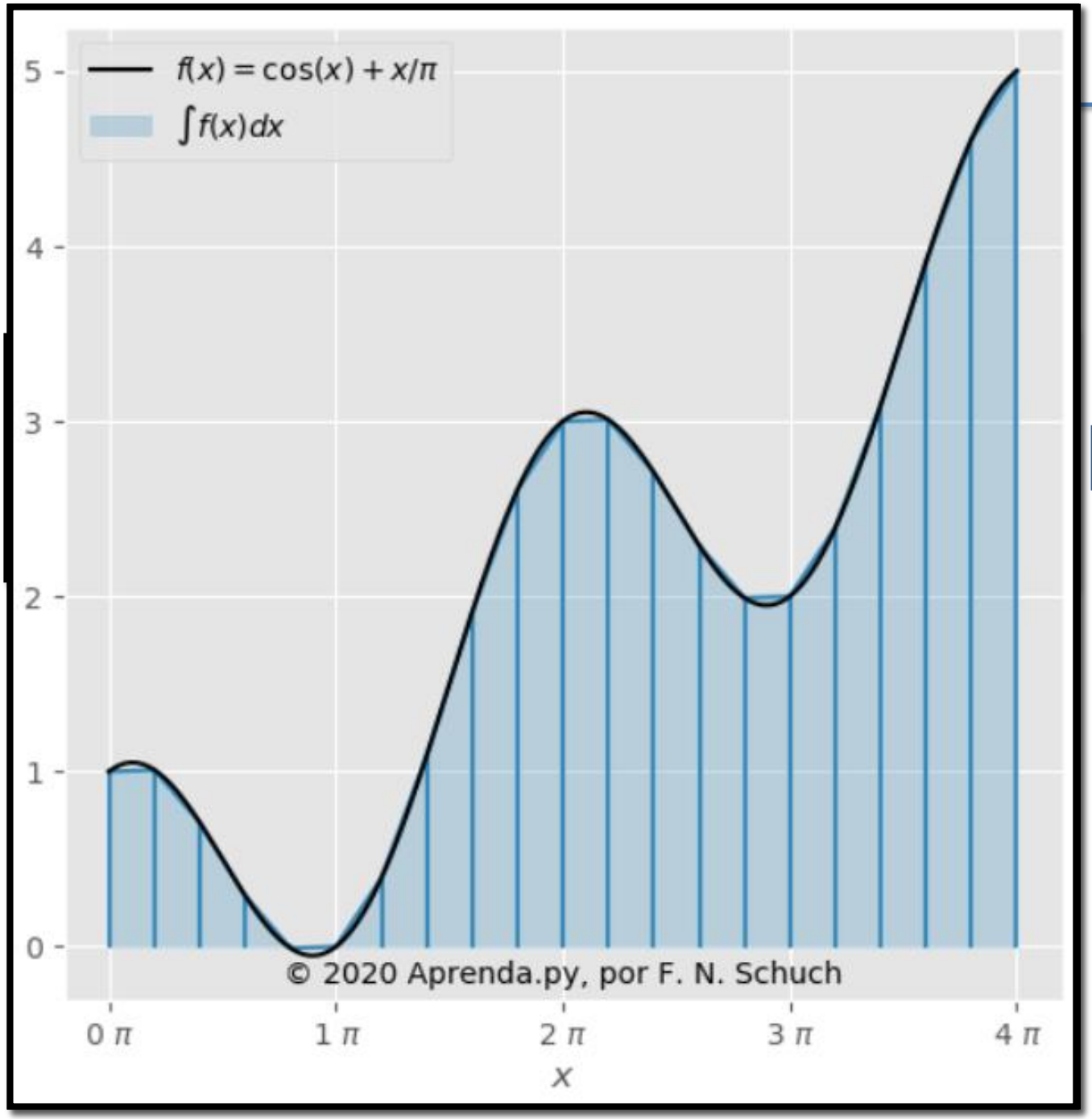


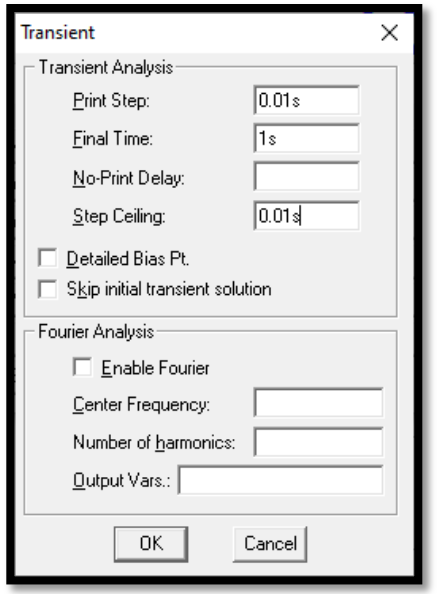


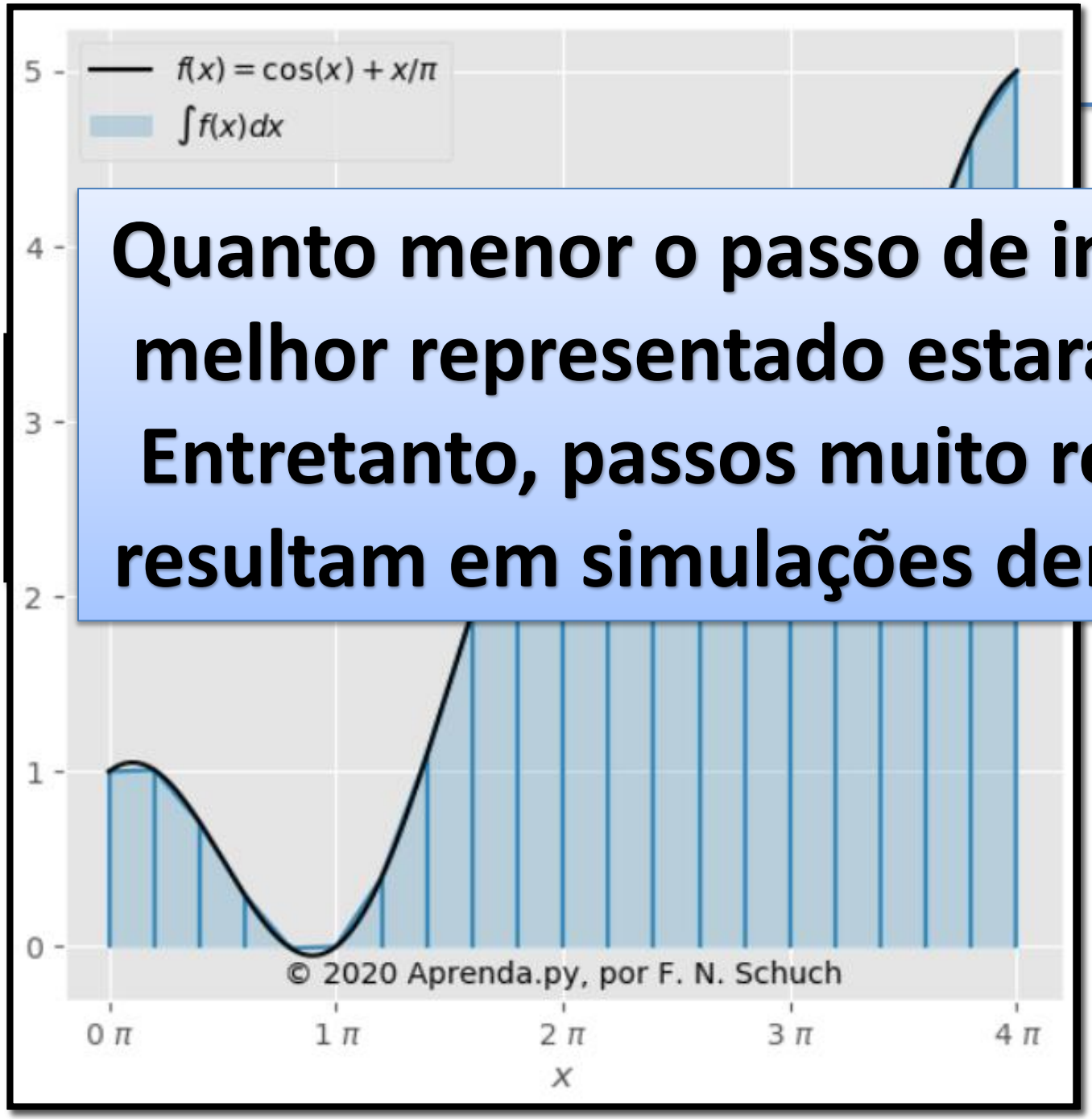



$f(x) = \cos(x) + x/\pi$
$\int f(x)dx$
5
4
3
2
1
0
© 2020 Aprenda.py, por F. N. Schuch
0 π
1 π
2 π
3 π
4 π
x

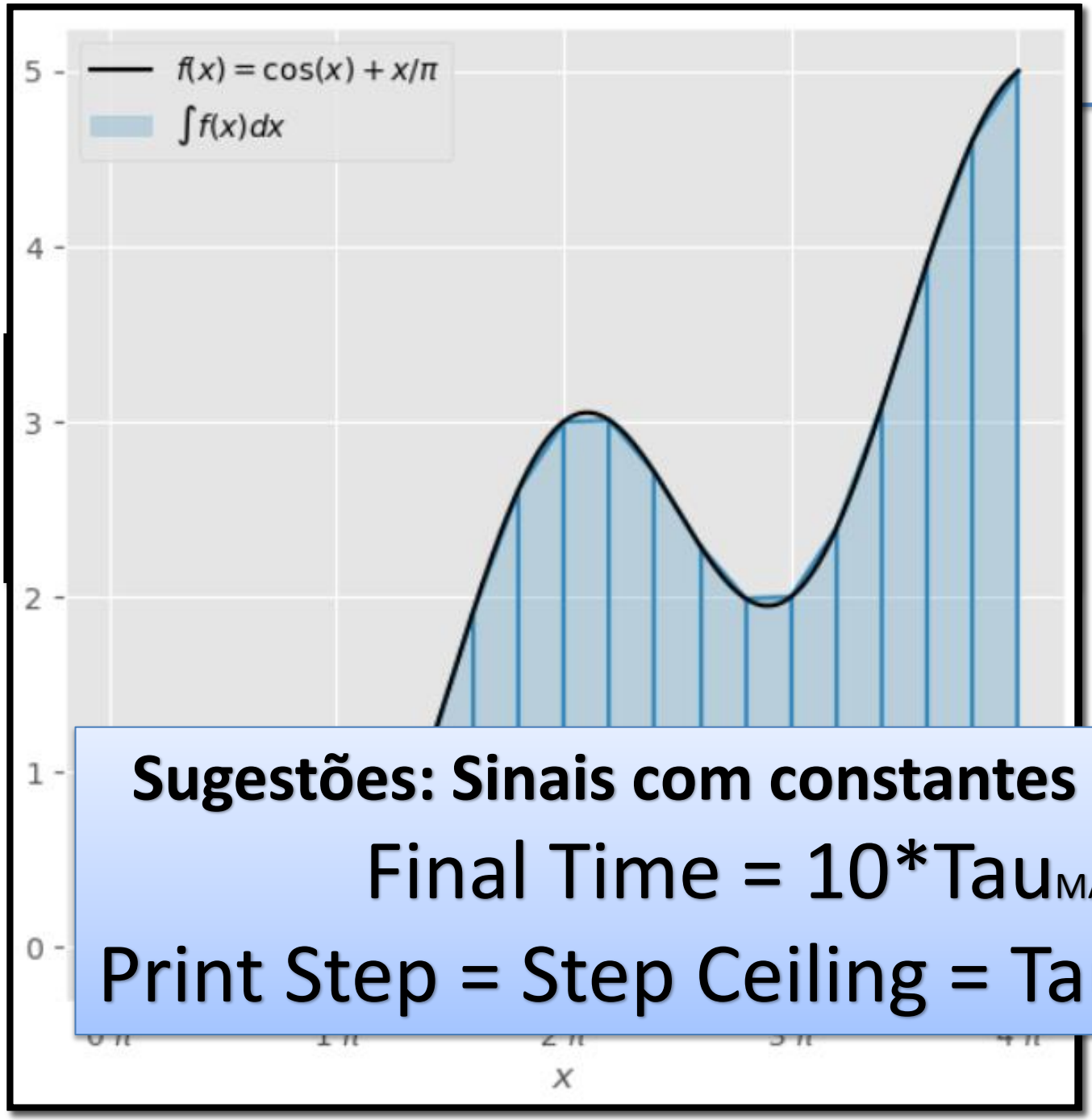

Transient
Transient Analysis
Print Step:
0.01s
Final Time:
1s
No-Print Delay:
Step Ceiling:
0.01s
Detailed Bias Pt.
Skip initial transient solution
Fourier Analysis
Enable Fourier
Center Frequency:
Number of harmonics:
Output Vars.:
OK
Cancel

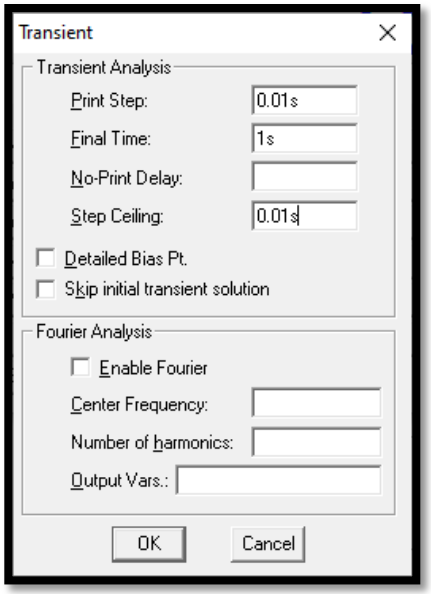

$f(x) = \cos(x) + x/\pi$
$\int f(x)dx$
5
4
3
2
1
0
© 2020 Aprenda.py, por F. N. Schuch
0 π
1 π
2 π
3 π
4 π
x


Transient
Transient Analysis
Print Step:
0.01s
Final Time:
1s
No-Print Delay:
Step Ceiling:
0.01s
Detailed Bias Pt.
Skip initial transient solution
Fourier Analysis
Enable Fourier
Center Frequency:
Number of harmonics:
Output Vars.:
OK
Cancel



Quanto menor o passo de integração melhor representado estará o sinal! Entretanto, passos muito reduzidos resultam em simulações demoradas!

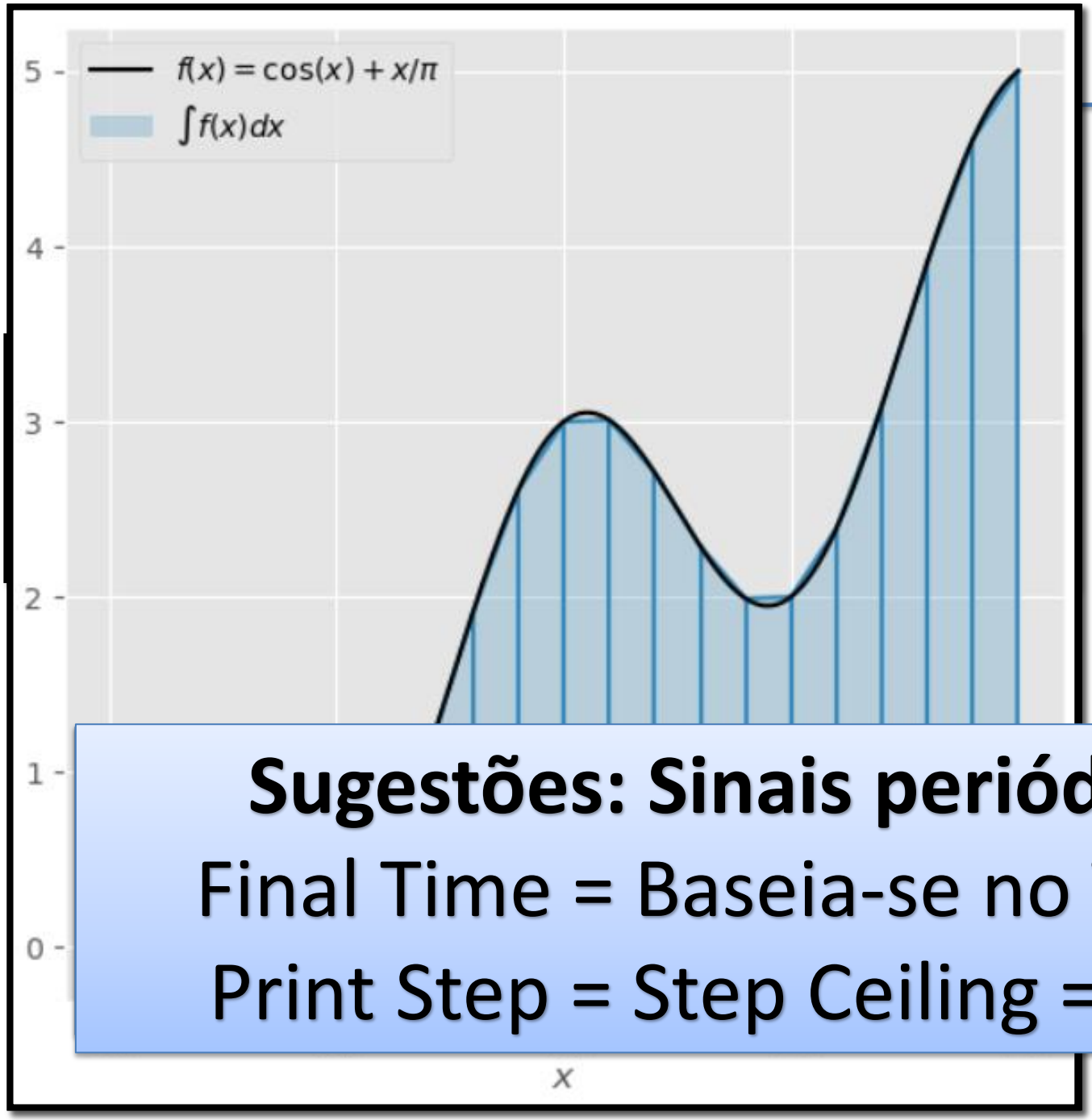


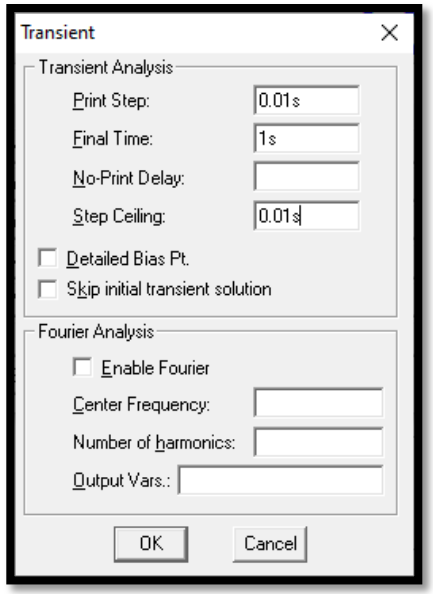


Sugestões: Sinais com constantes de tempo?

Final Time = $10 * Tau_{MAIOR}$

Print Step = Step Ceiling = $Tau_{MENOR}/100$



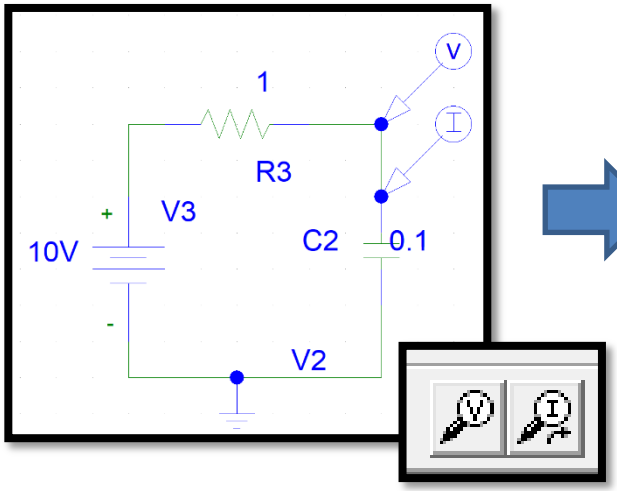


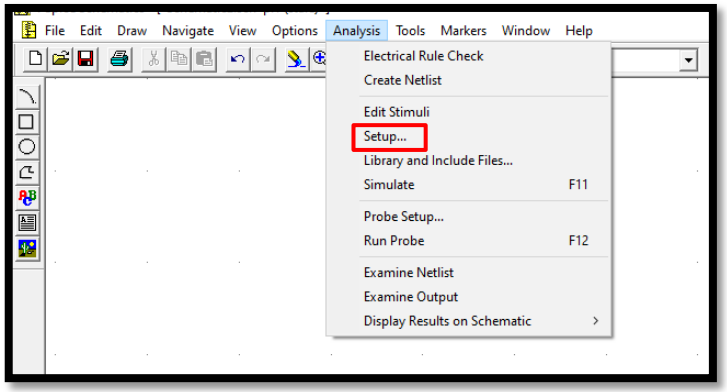
Sugestões: Sinais periódicos?

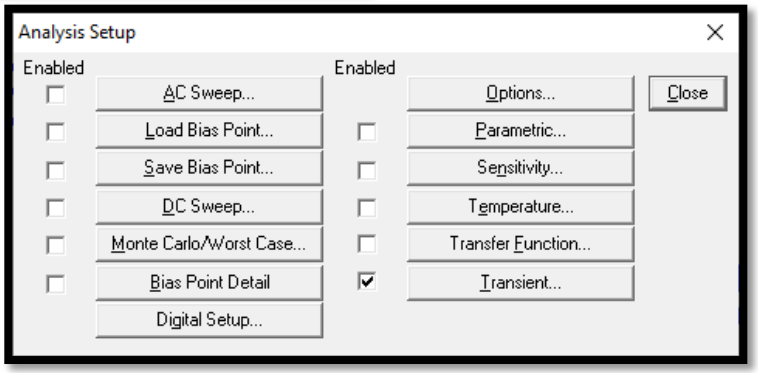
Final Time = Baseia-se no T e Tau

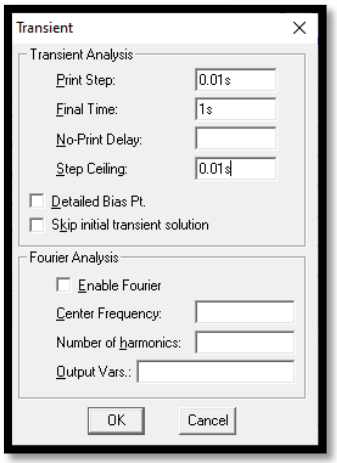
Print Step = Step Ceiling = T/100

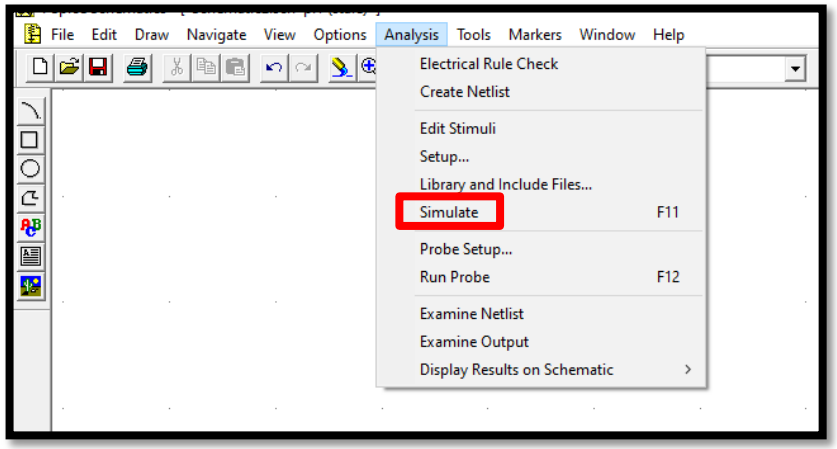
(Parte II) Tipos de Análises



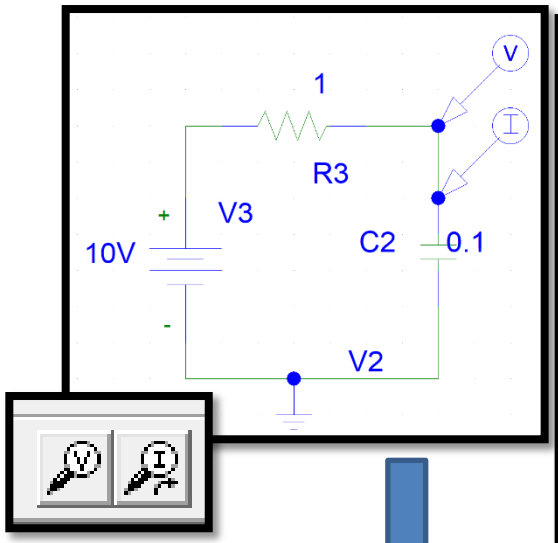


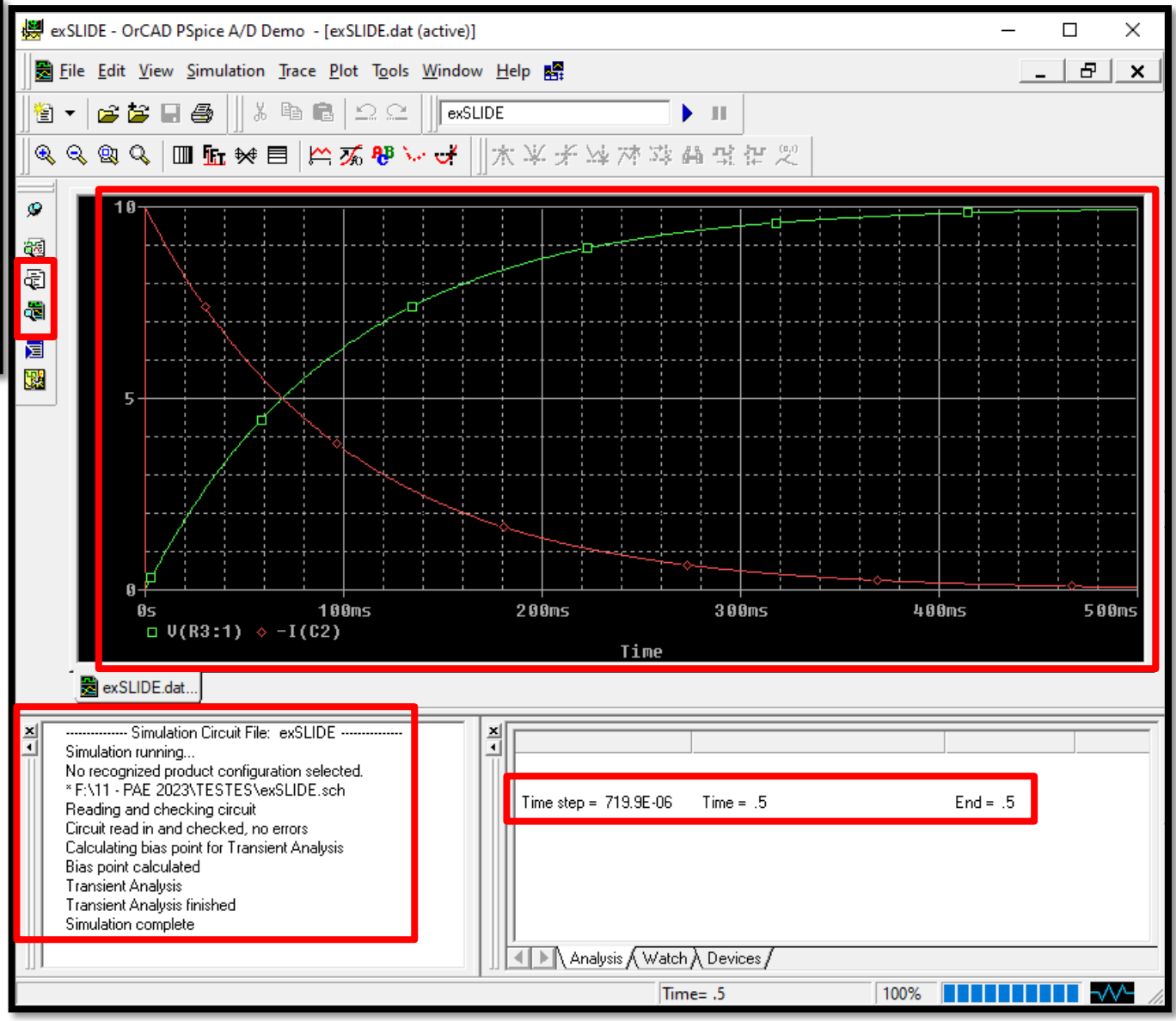




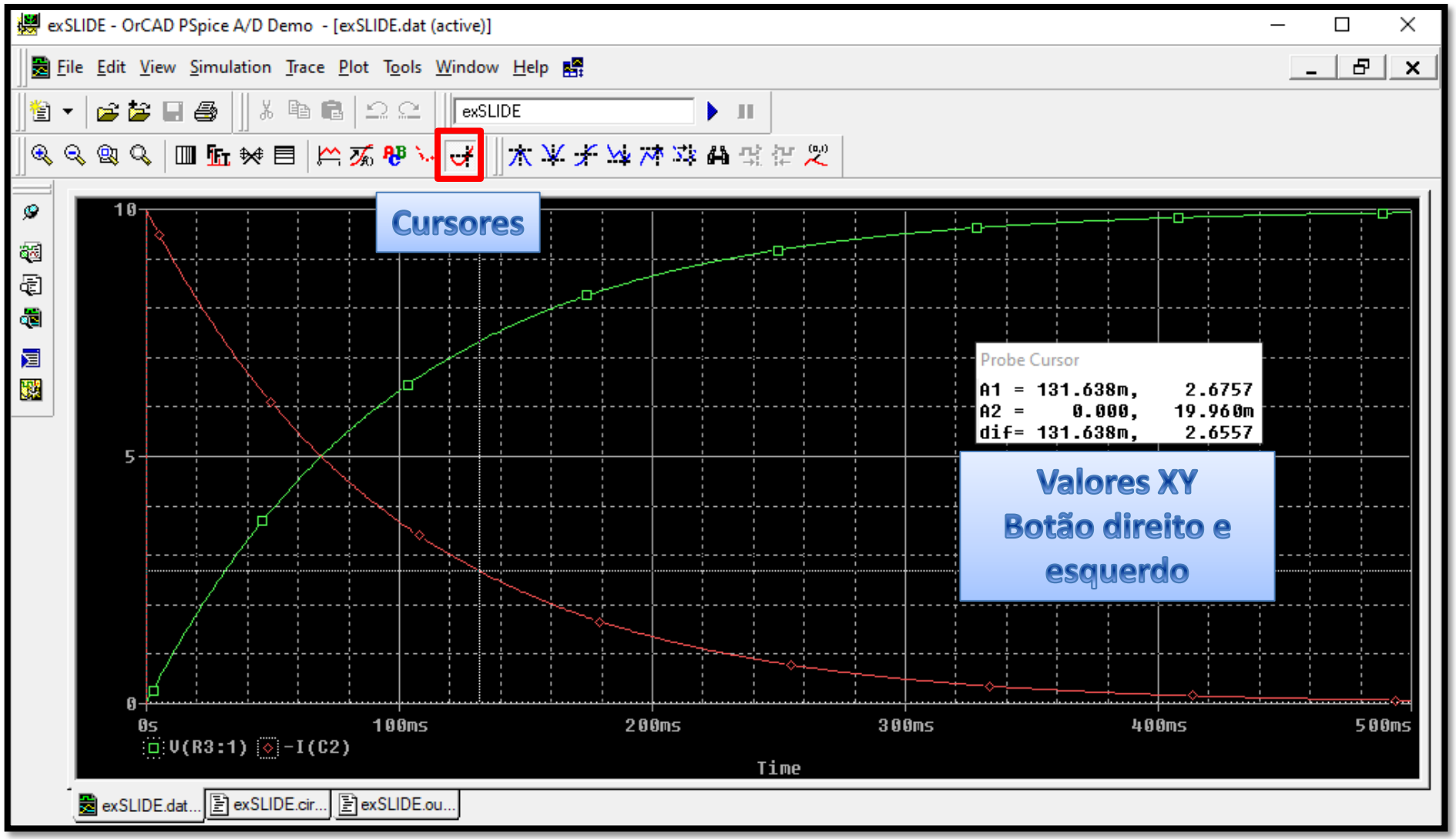


(Parte II) Tipos de Análises

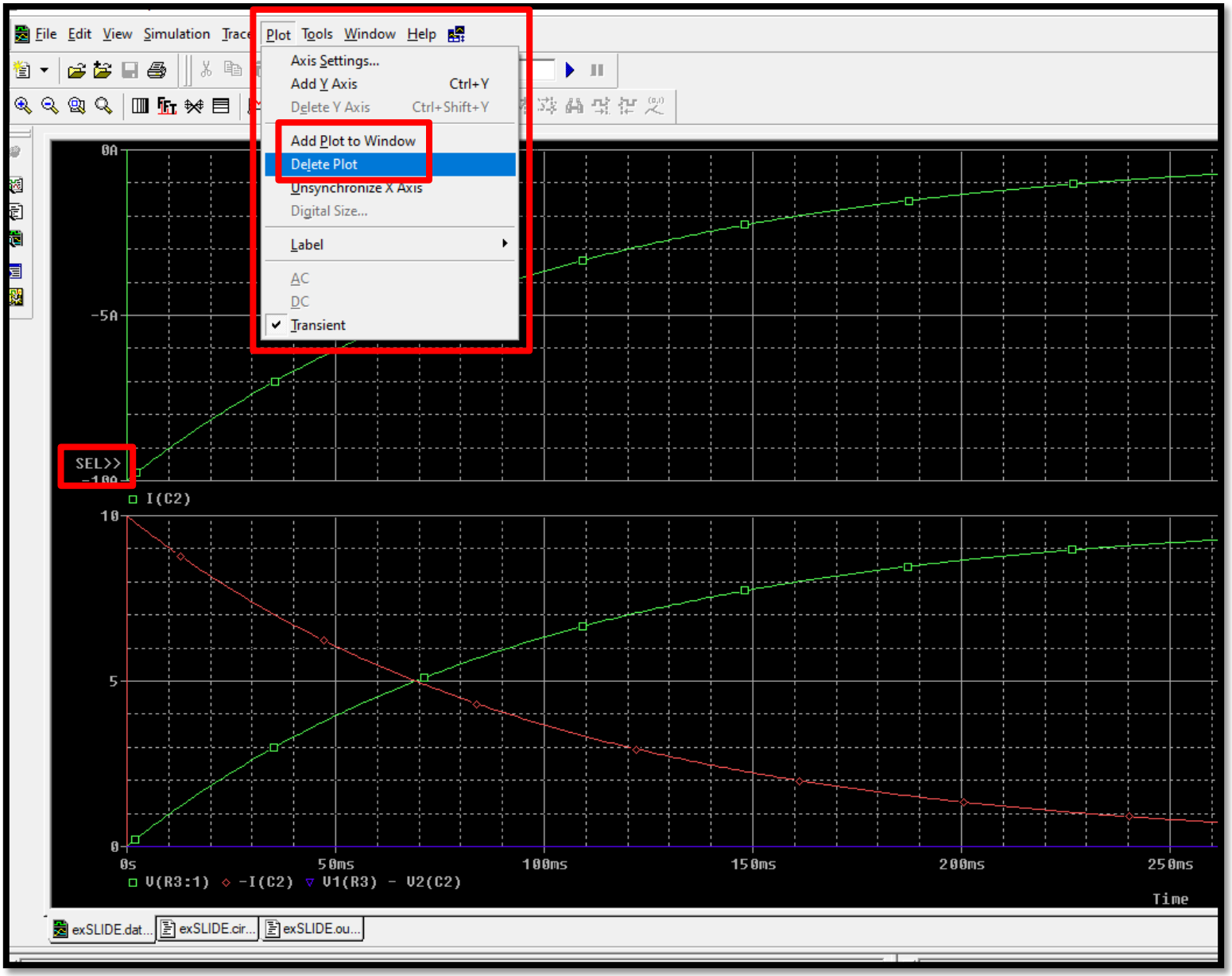




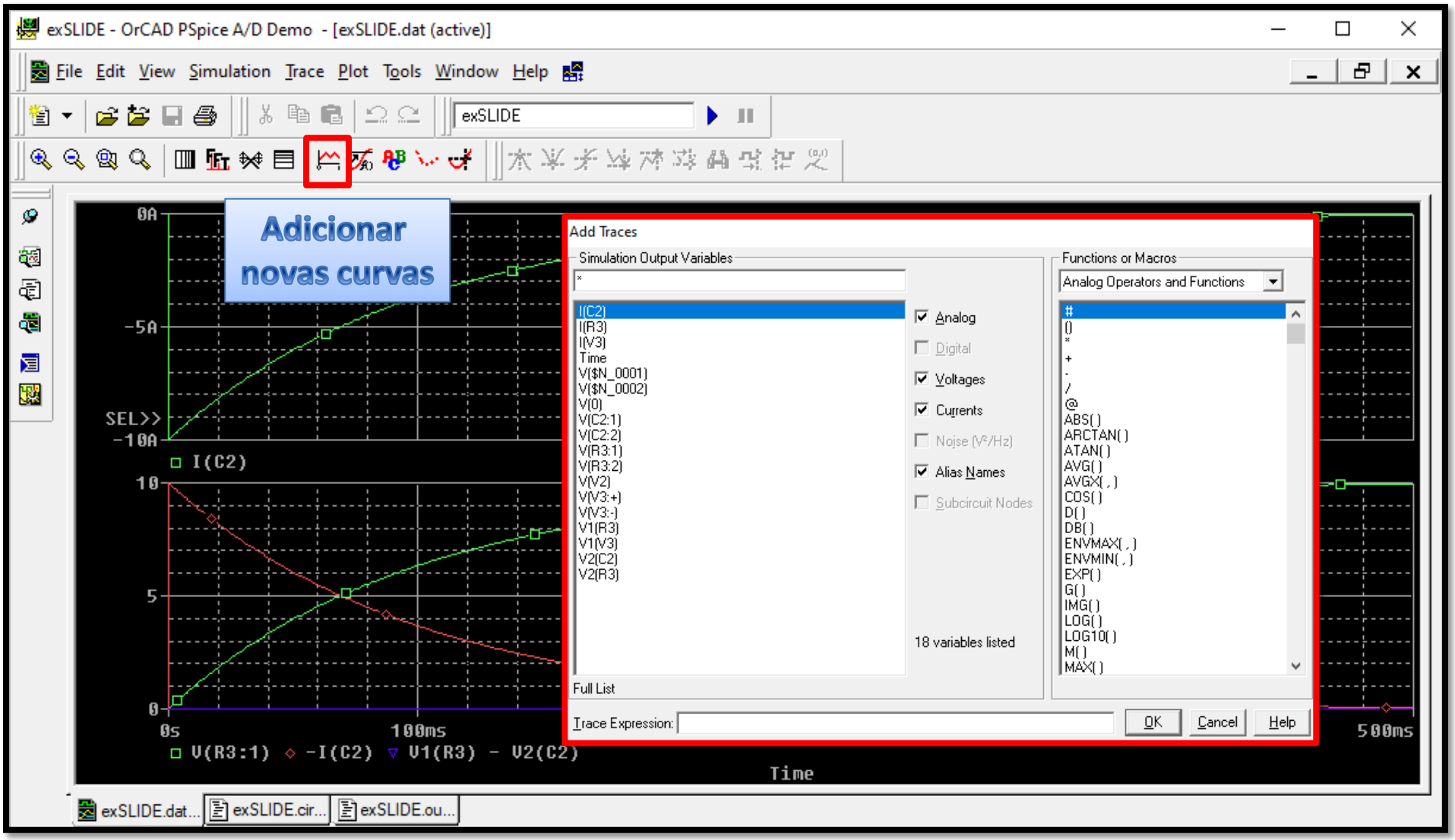
(Parte II) Tipos de Análises



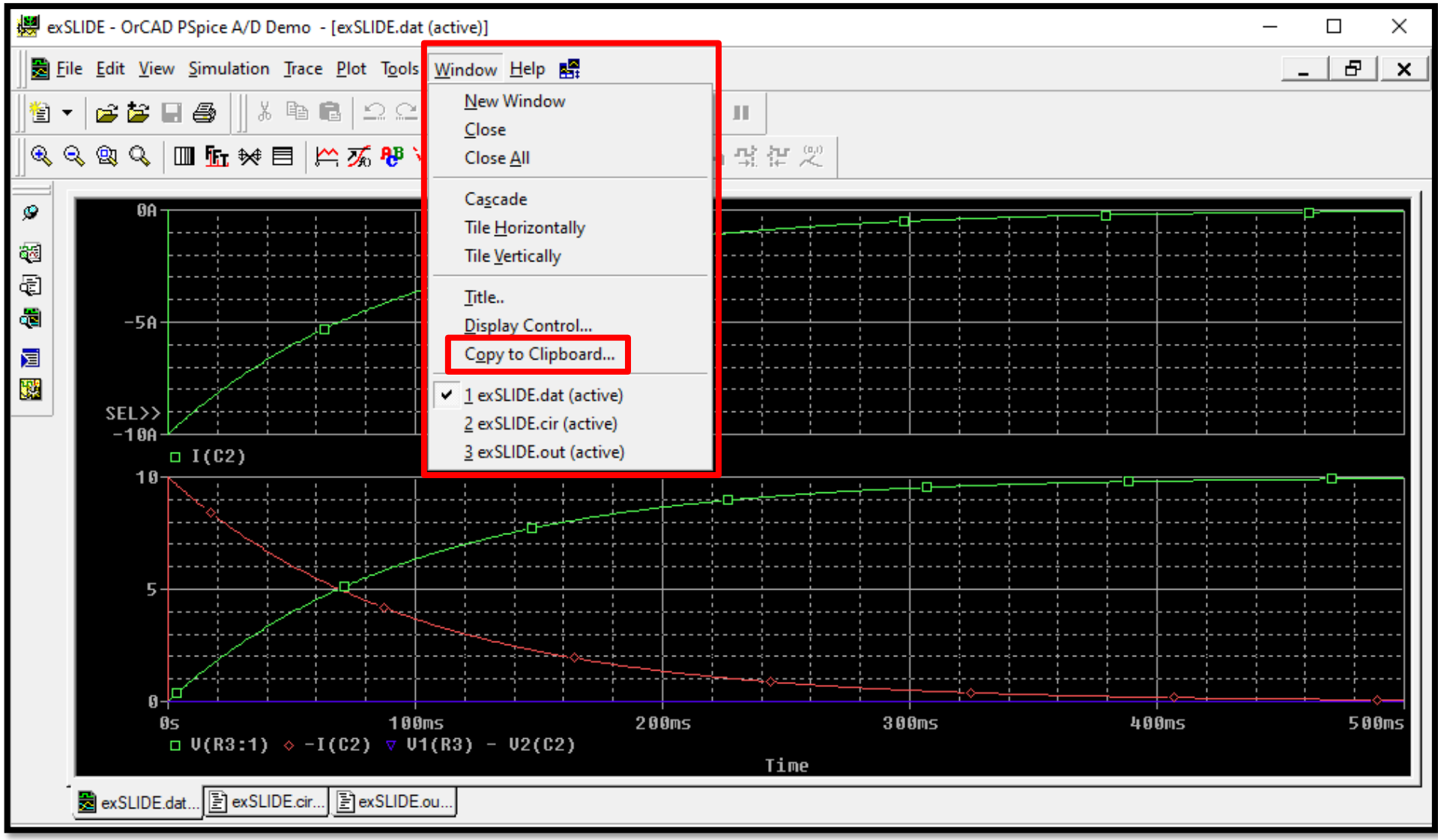
(Parte II) Tipos de Análises



(Parte II) Tipos de Análises



(Parte II) Tipos de Análises



(Parte II) Tipos de Análises

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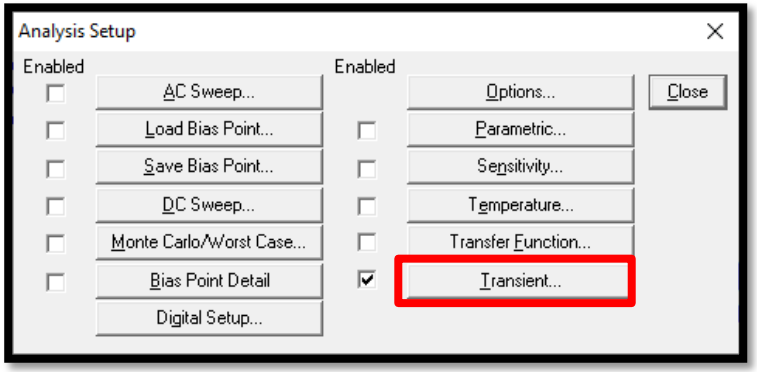

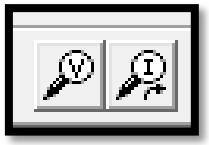

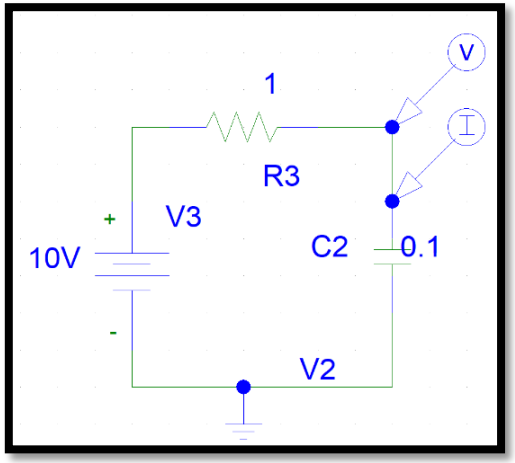

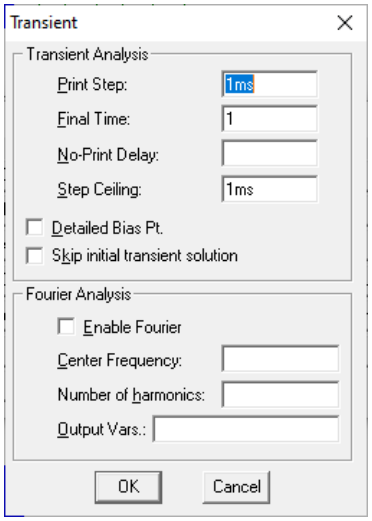

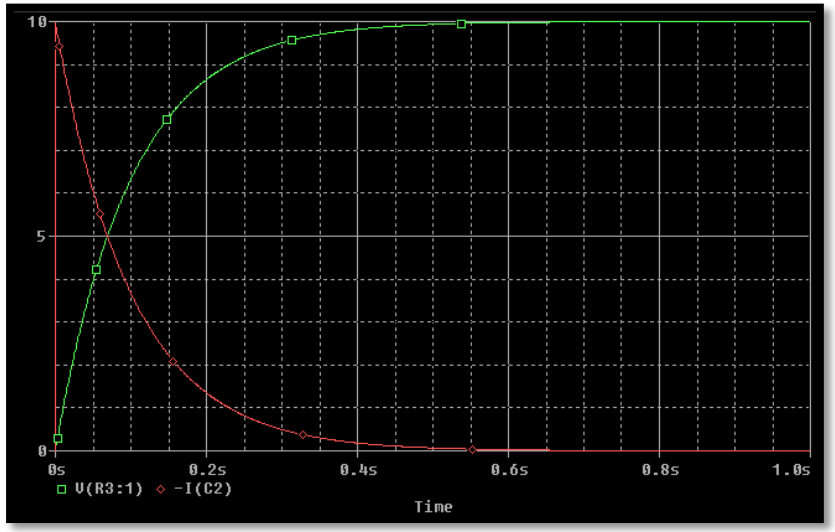

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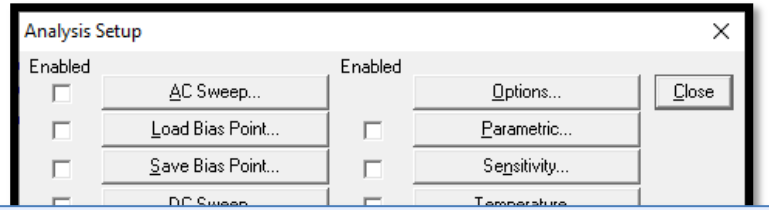
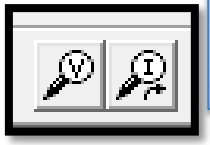
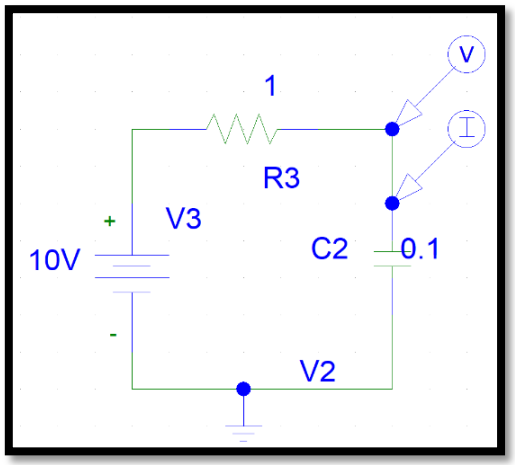
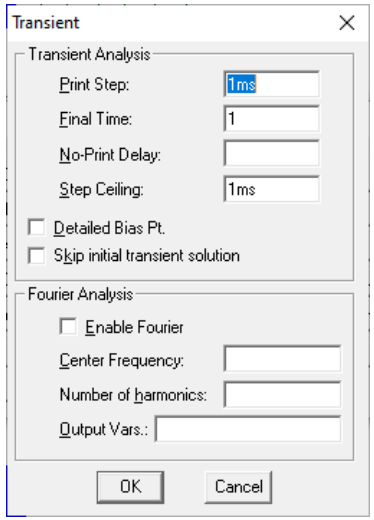
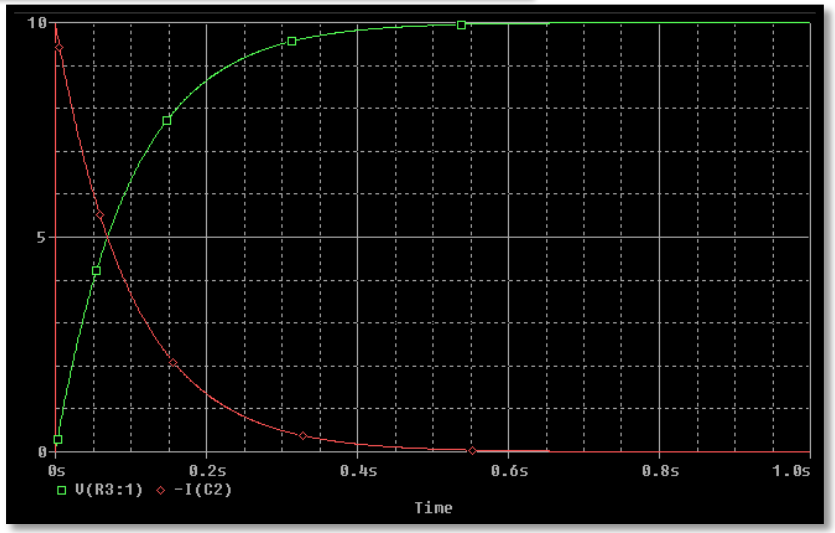




??? Exercício 02 ???

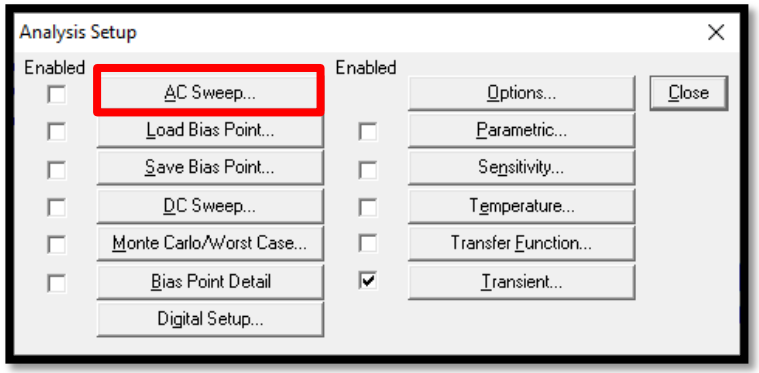


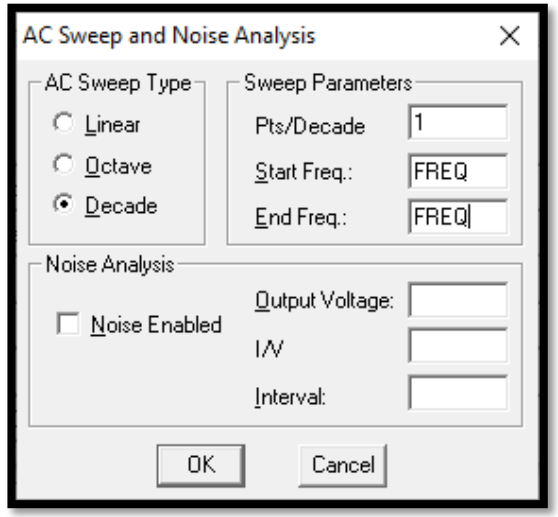


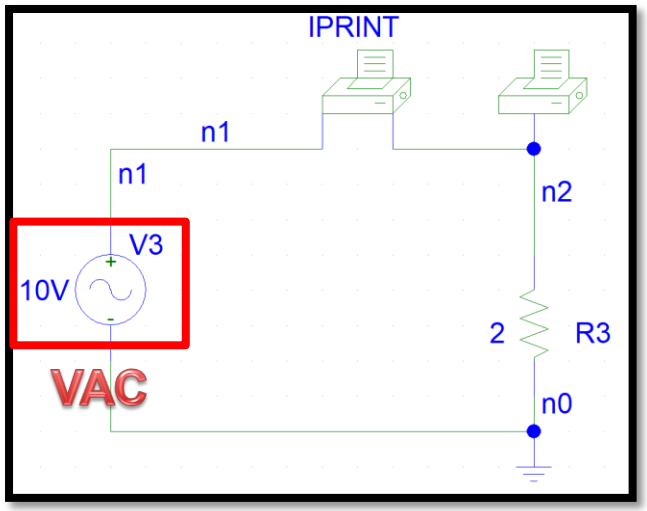


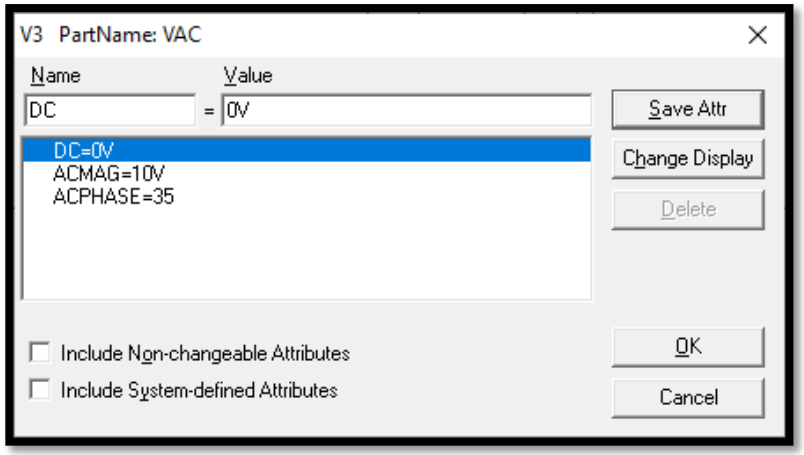
(Parte II) Tipos de Análises

- ✓ **Análises Fasorial de Circuitos com Fontes AC**
- ✓ **Análises onde a obtenção dos fasores é importante.**
- ✓ Chamada pelo PSPICE de “AC Sweep...”









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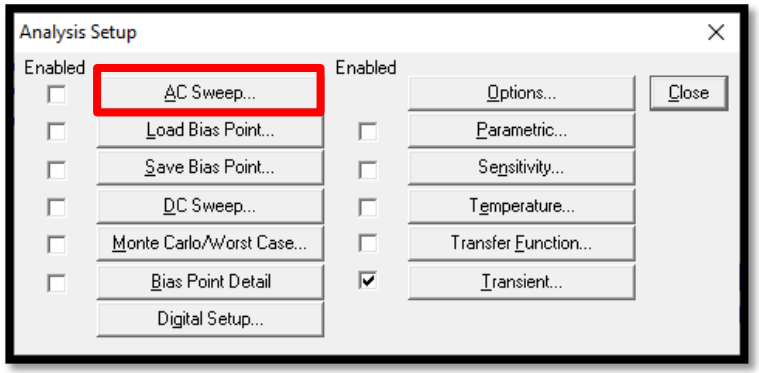

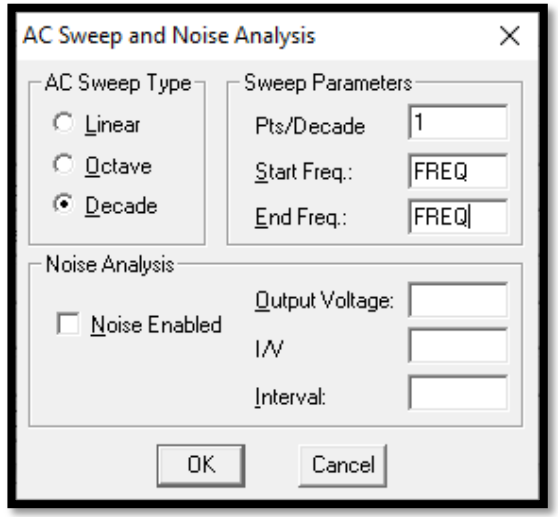

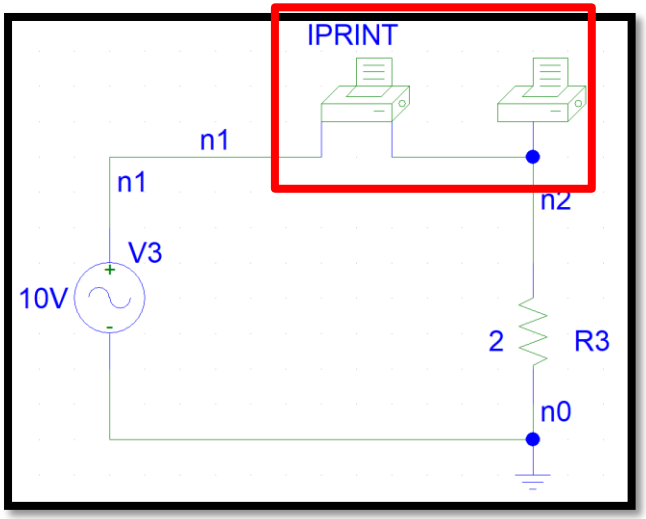

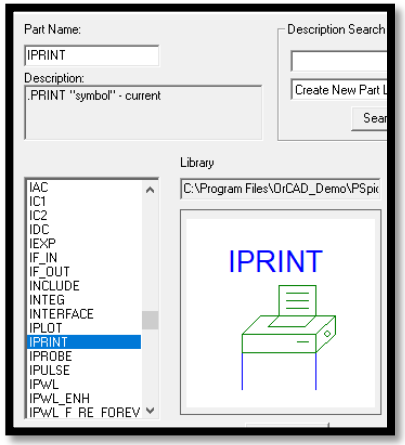

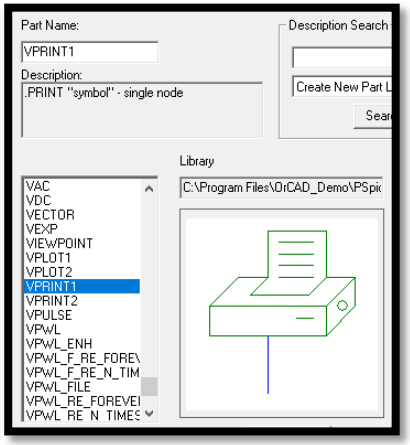

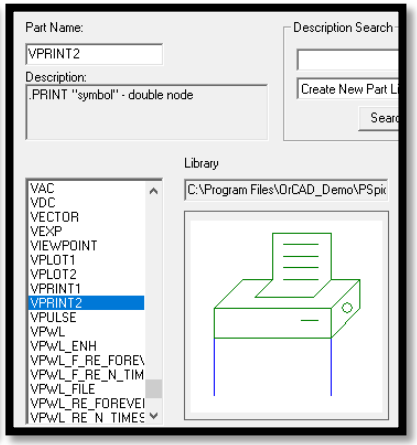

(Parte II) Tipos de Análises

- ✓ **Análises Fasorial de Circuitos com Fontes AC**
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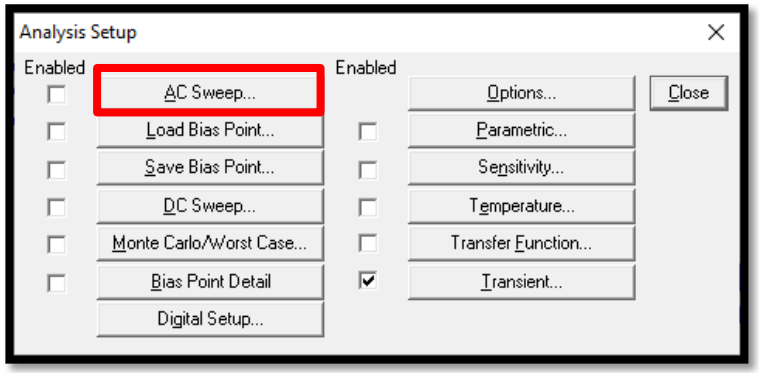
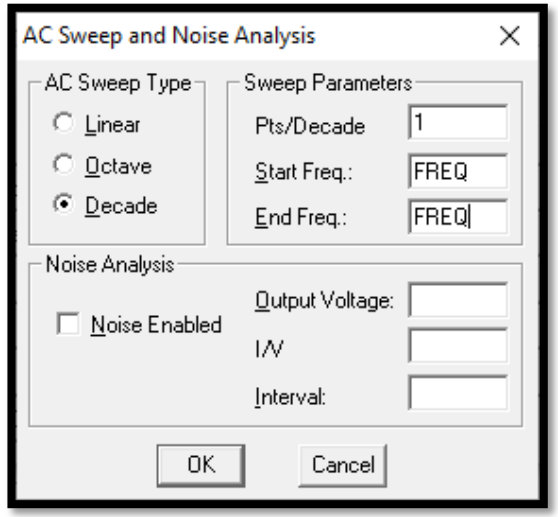
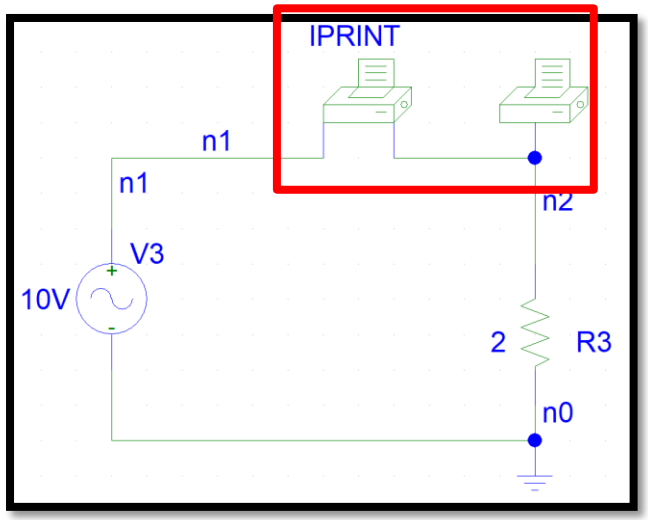
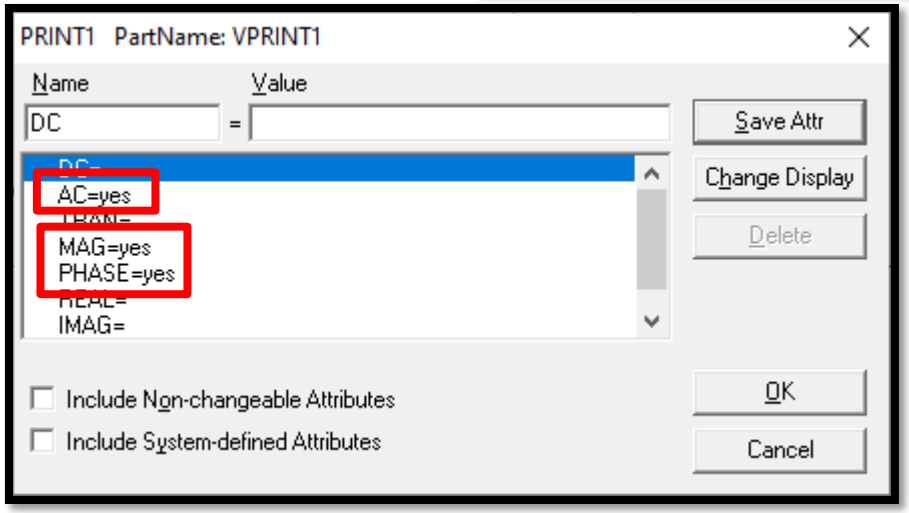
- ✓ Chamada pelo PSPICE de “AC Sweep...”









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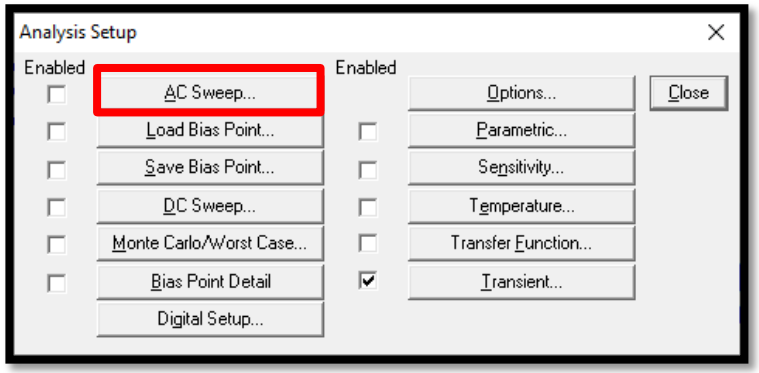

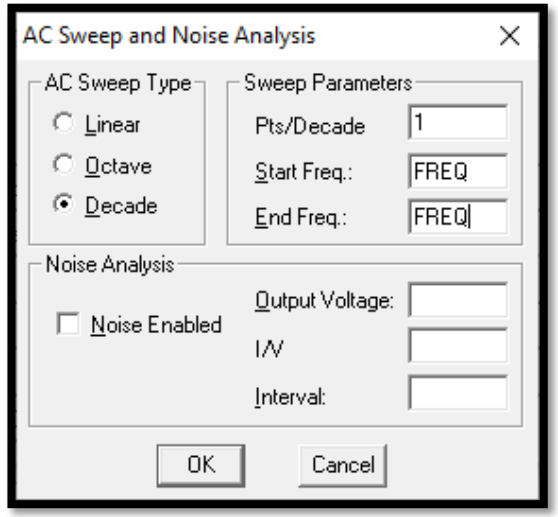

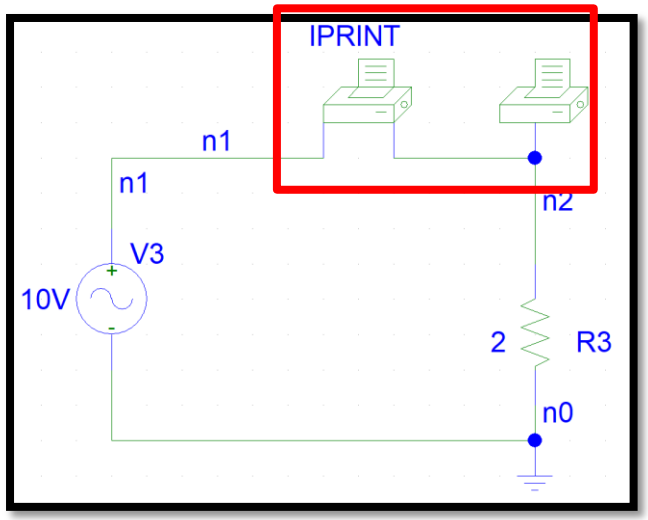

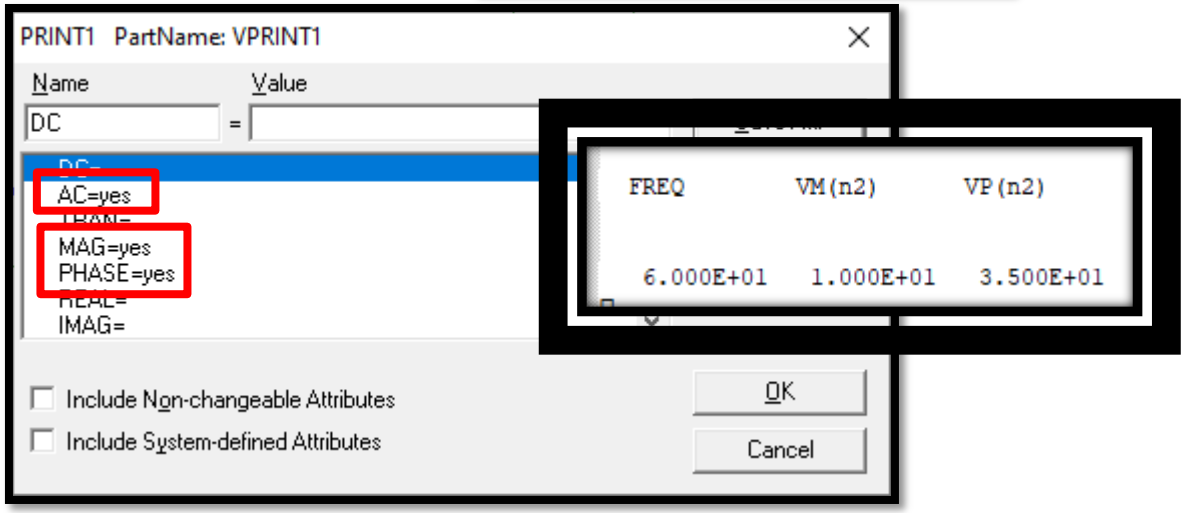

(Parte II) Tipos de Análises

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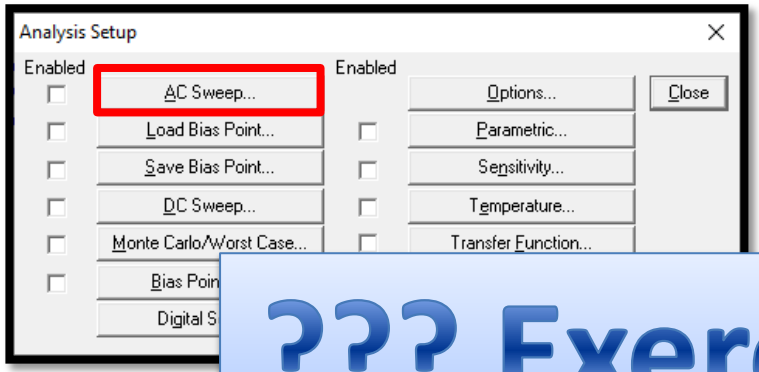
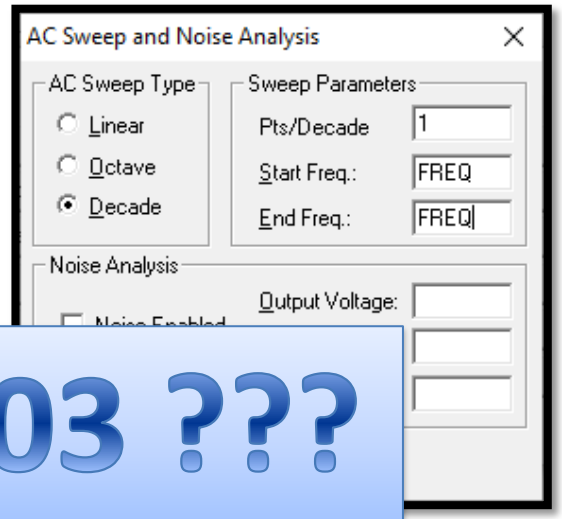
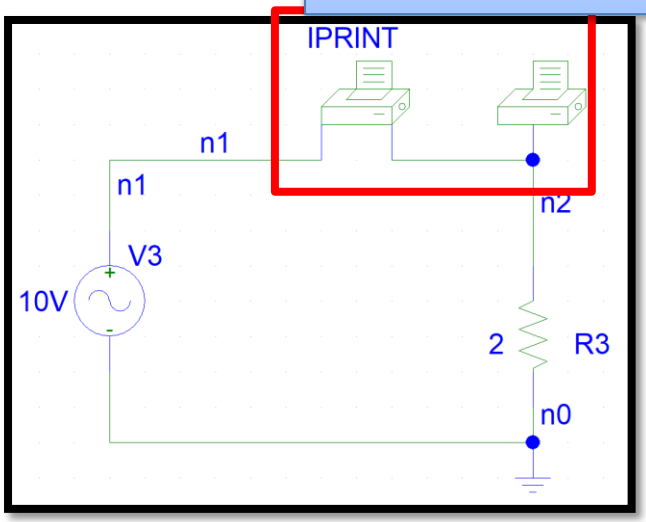
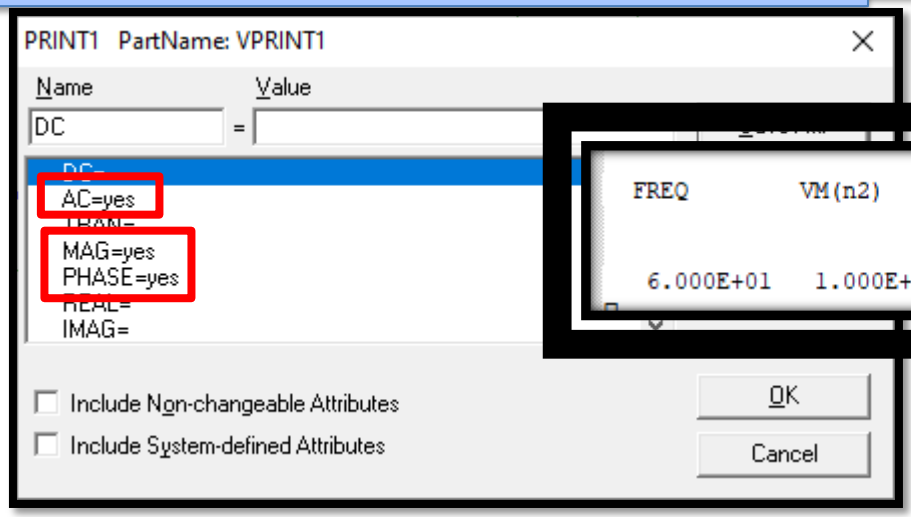


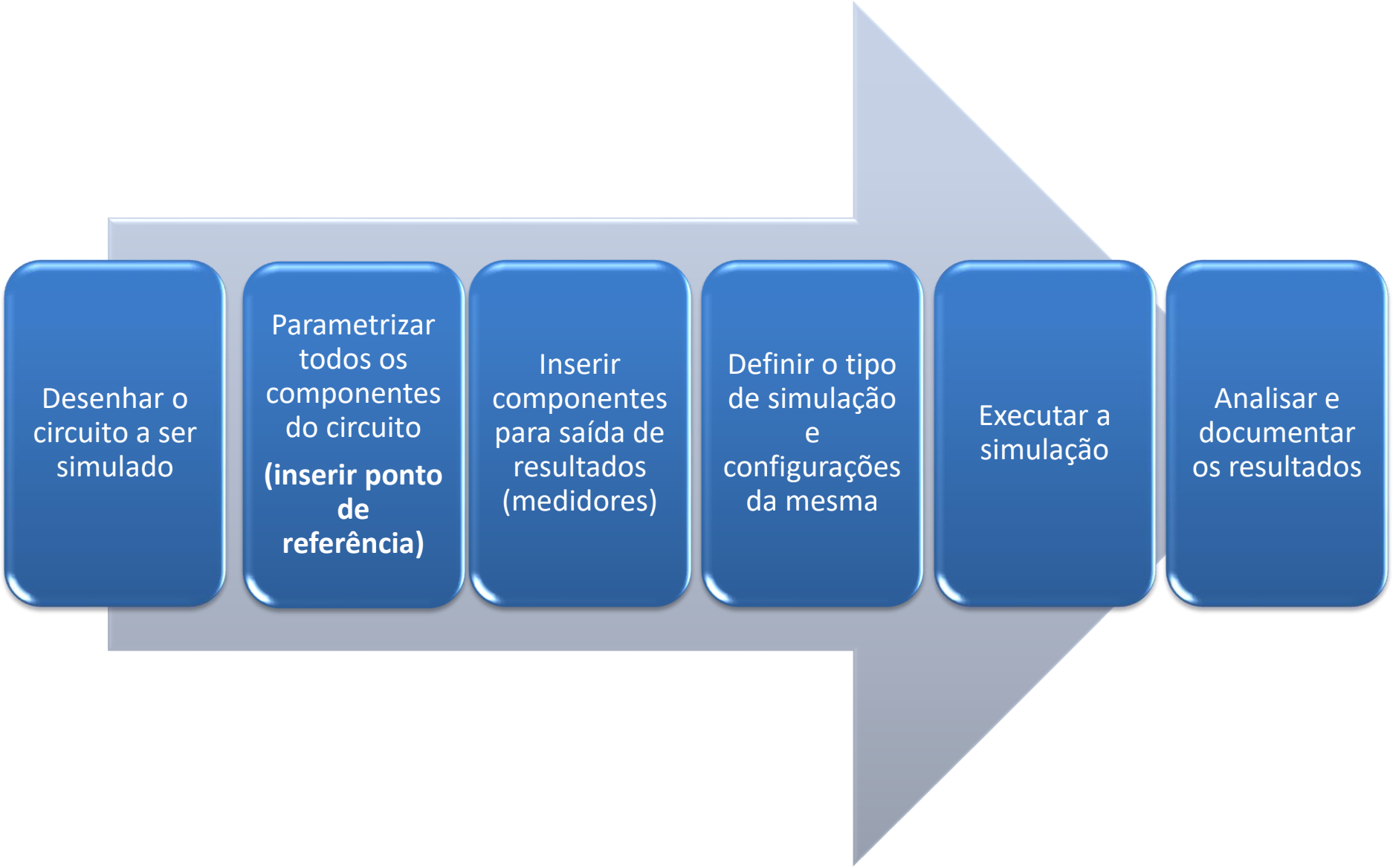


??? Exercício 03 ???





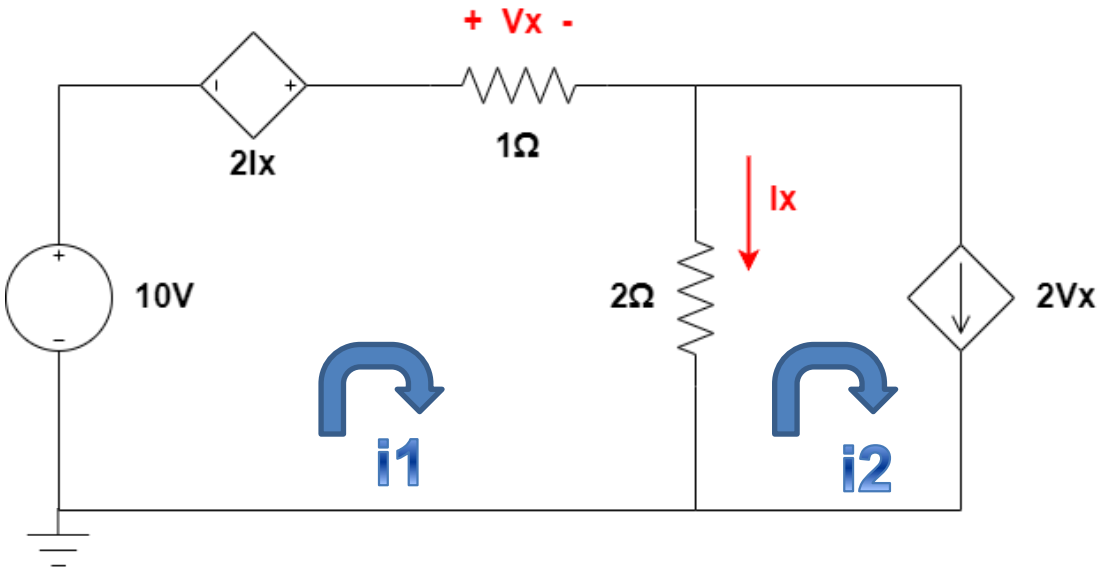
(Parte II) Etapas da Simulação



(Parte III) Exemplos

Exemplo 1:

Para o circuito abaixo, determine a tensão **Vx** e a corrente **Ix**.



$$10 + 2Ix - Vx - 2Ix = 0 \rightarrow \boldsymbol{Vx = 10V}$$

$$i2 = 2Vx = 20A$$

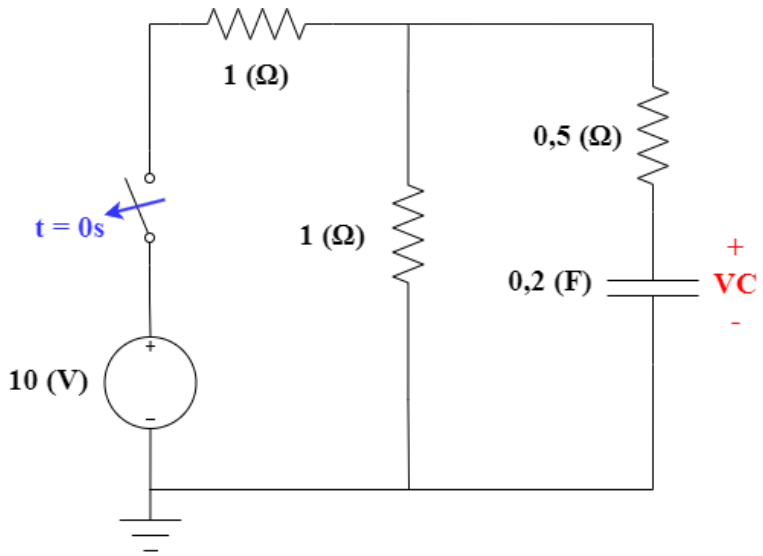
$$i1 * 1 = Vx = 10A$$

$$Ix = i1 - i2 \rightarrow \boldsymbol{Ix = -10A}$$

(Parte III) Exemplos

Exemplo 2:

Para o circuito abaixo calcule e VC(t) para t > 0, considerando as condições iniciais do circuito.



$Para\ t = 0^{-}s$:

$VC(0) = 5V$

$Para\ t > 0\ s$:

$Constante\ RC = 0{,}2 * 1{,}5 = 0{,}3\ s$

$Logo:\ VC(t) = VC(0)e^{-t/RC}$

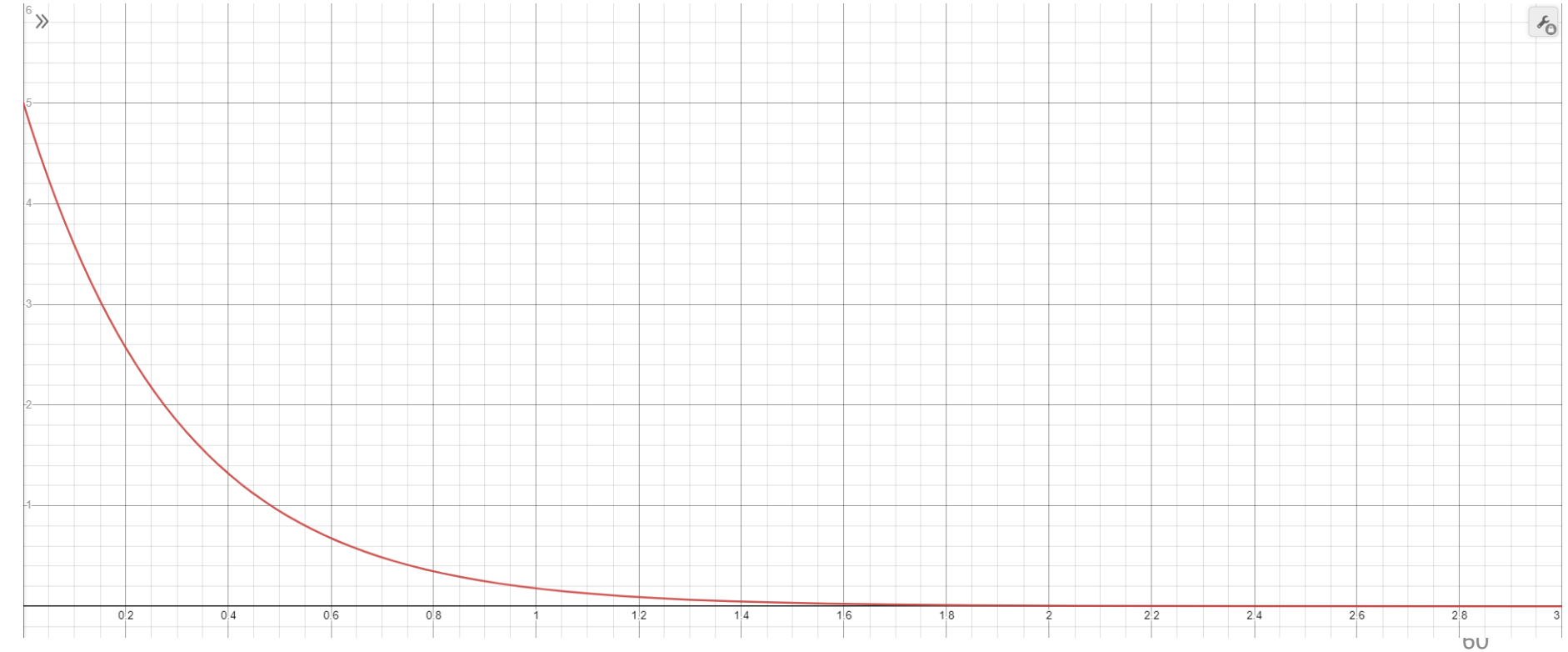
$Logo:\ VC(t) = 5e^{-t/0{,}3}$

(Parte III) Exemplos

Exemplo 2:

Para o circuito abaixo calcule VC(t) para t > 0, considerando as condições iniciais do circuito.

$$\boldsymbol{Logo}:\ \boldsymbol{VC(t) = 5e^{-t/0,3}}$$



(Parte III) Material de Apoio

JOHNSON, David E., *et. al*. *Fundamentos de Análise de Circuitos Elétricos*, 4a ed. Editora LTC. Rio de Janeiro, 2000.

PSPICE User's Guide:
https://www.electronics-lab.com/wp-content/uploads/2015/08/PSPICE.pdf

PSPICE Schematics User's Guide:
http://orion.ipt.pt/~jorge/Electronica1/PSPICE/Manuais/scug.pdf

Vídeo tutoriais:
https://www.youtube.com/watch?v=eBGepKS18L0&list=PL0lfaY4kueVrZLGUuqzBTQHD1he87kwyu

Departamento de Engenharia Elétrica e de Computação, EESC – USP
Laboratório de Sistemas de Energia Elétrica - LSEE

Introdução à Análise de Circuitos Elétricos Utilizando "PSPICE"

Atendimento:

Sexta-feira: 08:10 às 09:00h

Datas importantes:

Exercício 1 – 14/04 até 28/04

Moisés J. B. B. Davi
moisesdavi@usp.br