Title of Discipline:

Computer-Aided Analysis of Electronic Circuits

Laboratory Lecture 5

Bachelor : Telecommunication Technologies and Systems

Year of Study: 2

Computer-Aided Analysis of Electronic Circuits

Laboratory 5
The description of the controlled sources supported by PSpice A/D

Analog Device Summary

Passive device	Independent sources	Controlled sources	Controlled switch	Semiconductors
R – Resistor C – Capacitor L – Inductor K – Inductor coupling T – Transmission line	V – Independent voltage source I – Independent current source	E – Voltage-controlled voltage source G – Voltage-controlled current source F – Current-controlled current source H – Current-controlled voltage source	S – Voltage-controlled switch W – Current-controlled switch	D – Diode Q – Bipolar transistor J – Junction FET M – MOSFET B – GaAsFET

The controlled sources

A controlled source is a voltage or current source whose value “depends” on the value of voltage or current elsewhere in the circuit.

Types:

Type of source	Acronym	Part name in PSpice
Voltage-Controlled Voltage Source	**VCVS**	**E**
Voltage-Controlled Current Source	**VCCS**	**G**
Current-Controlled Voltage Source	**CCVS**	**H**
Current-Controlled Current Source	**CCCS**	**F**

Voltage-Controlled Sources

General forms (standard)

[E][G]<name> <N+> <N-> <NC+> <NC-> <gain>

[E][G]<name> <N+> <N-> **POLY**(<n>) <NC1+> <NC1-> [<NC2+> <NC2-> …

+ <NCn+> <NCn->] <p0> <p1> <p2> <p3> <p4> <p5>…

Examples

GS 1 2 10 20 10 ; $I_{GS}=10*(V(10)-V(20))$

Gamp 13 0 POLY(1) 12 0 0 500 ; $I_{Gamp}=500*V(12)$

Gn 100 101 POLY(2) 1 2 3 4 0 13.6 0.2 0.005

E1 1 2 10 3 20 ; $V_{E1}=20*(V(10)-V(3))$

EAMP 13 0 POLY(1) 7 0 0 500 ; $V_{EAMP}=500*V(7)$

Enel 100 101 POLY(2) 1 2 3 4 0 13.6 0.2 0.005 ; $V_{Enel}=13.6*(V(1,2))+0.2*(V(3,4))+0.005*(V(1,2))*(V(3,4))$

Voltage-Controlled Sources

Description

Both forms declare a voltage/current source whose magnitude is related to the voltage difference between nodes NC+ and NC-.

N+, N- : Output nodes. Positive current flows from the N+ node through the source to the N- node.

NC+, NC-: Are in pairs and define a set of controlling voltages.

<p0> <p1> <p2> <p3>... : Specifies the coefficient values for the polynomial transfer function.

Voltage-Controlled Sources

Description

The first form apply to the linear case. Thus :

V_E = gain*V(<NC+>- <NC->)

where V_E is the voltage between nodes <N+> and <N-> provided by source E<name>.

or

I_G = transconductance*V(<NC+>- <NC->)

where I_G is the current thru declared current source G<name>.

The voltage-controlled voltage source (E) and the voltage-controlled current source (G) devices have the same syntax. For a voltage-controlled current source just substitute G for E.

Voltage-Controlled Sources

Description

The second form generates a nonlinear response.

POLY(<n>): Specifies the number of the dimensions of the polynomial.

The number of pairs of controlling nodes must be equal to the number of dimensions.

In all cases positive current flows from <N+> through the

source and out <N->.

Voltage-Controlled Sources

Description

Consider a voltage-controlled source with voltages V_1, V_2, …, V_n.

The coefficients are associated with the polynomial according to this convention:

$Vout\ (V_1, V_2, \ldots, V_n) = p_0 + p_1V_1 + p_2V_2 + \ldots + p_nV_n + p_{n+1}V_1^2 + p_{n+2}V_1V_2 + \ldots + p_{n+n}V_1V_n + p_{2n+1}V_2^2 + p_{2n+2}V_2V_3 + \ldots + p_{3n+1}V_2V_n + \ldots + p_{n!/(2(n-2)!+2n)}V_n^2 + p_{n!/(2(n-2)!+2n+1)}V_1^3 + \ldots$

Particular cases:

n=1: $Vout\ (V) = p_0 + p_1V + p_2V^2 + p_3V^3 + \ldots$

n=2: $Vout\ (V_1, V_2) = p_0 + p_1V_1 + p_2V_2 + p_3V_1^2 + p_4V_1V_2 + p_5V_2^2 + p_6V_1^3 + \ldots$

n=3: $Vout\ (V_1, V_2, V_3) = p_0 + p_1V_1 + p_2V_2 + p_3V_3 + p_4V_1^2 + p_5V_1V_2 + p_6V_1V_3$
$+ p_7V_2^2 + p_8V_2V_3 + p_9V_3^2 + p_{10}V_1^3 + \ldots$

Current-Controlled Sources

General forms

[F][H]<name> <N+> <N-> <controlling V device name> <gain>

[F][H]<name> <N+> <N-> POLY(<n>) <controlling V device name> <p0> <p1> <p2>…

Examples

Fs 1 2 VS 10 ; $I_{Fs}=10*I(VS)$

FAMP 13 0 POLY(1) VIN 0 500 ; $I_{FAMP}=500*I(VIN)$

Fnel 100 101 POLY(2) V1 V2 0 13.6 0.2 0.005

H1 1 2 VS 10 ; V(H1)=10*I(VS)

HAMP 13 0 POLY(1) VIN 0 500 ; V(HAMP)=500*I(VIN)

Hnel 100 101 POLY(2) Vcon1 Vcon2 0 13.6 0.2 0.005

Current-Controlled Sources

Description

The current-controlled current source (F) and the current-controlled voltage source (H) devices have the same syntax. For a the current-controlled voltage source just substitute a H for the F.

Arguments and options

N+, N- Output nodes. Positive current flows from the N+ node through the source to the N- node. The controlling source must be an independent voltage source, although it need not have a zero DC value.

POLY(<n>)

Specifies the number of the dimensions of the polynomial. The number of controlling voltage sources must be equal to the number of dimensions.

<p0> <p1> <p2> ... Specifies the coefficient values for the polynomial transfer function.

The Analog Behavioral Modeling (ABM)

General form

[E]<name> <N+> <N-> <ABM_keyword>=<ABM function>

[G]<name> <N+> <N-> <ABM_keyword>=<ABM function>

Description

<N+>, <N-> - are the nodes in the circuit between which the source is connected

<ABM_keyword> - represents the type of the transfer function to be used, as one of:

- **VALUE** – arithmetical expression
- **TABLE** – lookup table
- **LAPLACE** – Laplace transform
- **FREQ**- frequency response
- **CHEBYSHEV**- Chebyshev filter characteristics

<ABM function>- specifies the transfer function as required by the specified <ABM keyword>

The analog behavioral modeling (ABM)

The description using VALUE

[E][G]<name> <N+> <N-> VALUE={<expression>}

Examples:

ESORT 5 0 VALUE={5*SQRT(V(3,2))}

GPSK 11 6 VALUE={15M*SIN(6.28*10K*TIME+V(3))}

<expression> can be constants, parameters, voltages, currents and time.

For the description of the transfer function the following operators can be used:

“+”, “-”, “*”, “/” and “(“, “)”.

Also, mathematical functions as ABS, SQRT, LOG, EXP, SIN, COS, TAN and user-defined function by .FUNC command can be used .

The analog behavioral modeling (ABM)

The description using TABLE

[E][G]<name> <N+> <N-> TABLE{<expression>} = <(<input value>, <output value>)>

Examples:

GRES 1 0 TABLE {V(1)}=(0,0) (0.1,3m) (0.25,3.5m) (0.3,2m) (0.4,2.2m) (0.6,5m)

<expression> can be constants, parameters, voltages, currents and time.

<input value>, <output value> - represents the coordinates of the corner points of the transfer characteristic.

The analog behavioral modeling (ABM)

The description using LAPLACE

[E][G]<name> <N+> <N-> LAPLACE{<expression>}={<transform>}

Examples:

ERC 5 0 LAPLACE {V(10)}={1/(1+0.001*s)} ; V(5,0) = 1/(1+0.001*s)*V(10)

<expression> - represents the input to the transform.

The output of the device depends on the type of analysis being done.

For DC and bias point, the output is simply the zero frequency gain times the value of <expression>. The zero frequency gain is the value of <transform> with s = 0.

For AC analysis, <expression> is linearized around the bias point (similar to the VALUE parts). The output is then the input times the gain of <expression> times the value of <transform>.

For transient analysis, the value of <expression> is evaluated at each time point. The output is then the convolution of the past values of < expression> with the impulse response of <transform>.

The analog behavioral modeling (ABM)

The description using FREQ

[E][G]<name> <N+> <N-> FREQ {<expression>}= [KEYWORD]

+ <<frequency value>, <magnitude value>, <phase value>> [DELAY = <delay value>]

The description using CHEBYSHEV

[E][G]<name> <N+> <N-> **CHEBYSHEV** {<expression>}=

+ <[LP] [HP] [BP] [BR]>, <cutoff frequencies>, <attenuation>

Examples:

ELP 5 0 FREQ {V(10)} = (0,0,0) (5kHz,0,0) (6kHz , 60,0) DELAY = 3.2ms

ELP 5 0 CHEBYSHEV {V(10)} = LP 800 1.2k .1dB 50dB

Chebyshev filters have two attenuation values, given in dB, which specify the pass band ripple and the stop band attenuation. Low pass (LP) and high pass (HP) have two cutoff frequencies, specifying the pass band and stop band edges, while band pass (BP) and band reject (BR) filters have four.

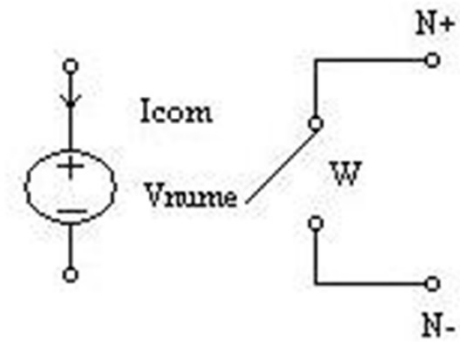
The current-controlled switch

General form

[W]<name> <N+> <N-> <controlling V device name> <model name>

Model form

.MODEL <model name> ISWITCH [model parameters]



Examples:

W12 13 17 VC WMOD

WRESET 5 0 VRESET RELAY

Description

The current-controlled switch is a special kind of current-controlled resistor.

The current-controlled switch

Arguments and options

<controlling V device name>

The current that the resistance between the <N+> and <N-> depends on.

Ideal switches

The ISWITCH model defines the on/off resistance and the on/off control voltage or current thresholds. This switch has a finite on resistance and off resistance, and it changes smoothly between the two as its control voltage (or current) changes.

The current-controlled switch

Current-controlled switch model parameters

Model parameters	Description	Units	Default
IOFF	Control current for off state	Amp	0.0
ION	Control current for on state	Amp	1E-3
ROFF	Off resistance	Ohm	1E+6
RON	On resistance	ohm	1.0

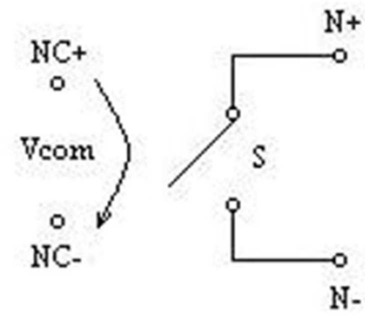
The voltage-controlled switch

General form

[S]<name> <N+> <N-> < NC+> <NC-> <model name>

Model form

.MODEL <model name> VSWITCH [model parameters]



Examples:

S12 13 17 V 2 0 SMOD

SRESET 5 0 15 3 RELAY

Description

The voltage-controlled switch is a special kind of voltage-controlled resistor.

The voltage-controlled switch

Comments

The resistance between the <N=> and <N-> depends on the voltage between the <NC+> and <NC->. The resistance varies continuously between the RON and ROFF model parameters.

Ideal switches

The VSWITCH model defines the on/off resistance and the on/off control voltage or current thresholds. This switch has a finite on resistance and off resistance, and it changes smoothly between the two as its control voltage (or current) changes.

The voltage-controlled switch

Voltage-controlled switch model parameters

Model parameters	Description	Units	Default
VOFF	Control voltage for off state	volt	0.0
VON	Control voltage for on state	volt	1.0
ROFF	Off resistance	ohm	1E+6
RON	On resistance	ohm	1.0

Applications

Application 1 *– description and analysis of a circuit with different controlled sources*

Activities:

• Let consider the circuit having 3 independent sources and 6 controlled sources, as shown on next slide.

• Describe the circuit into the SPICE circuit file (.cir). For each source specify the type waveform and its parameters corresponding to the given waveform.

• Add .TRAN command to perform a transient analysis.

.TRAN 30u 2m 0 10u

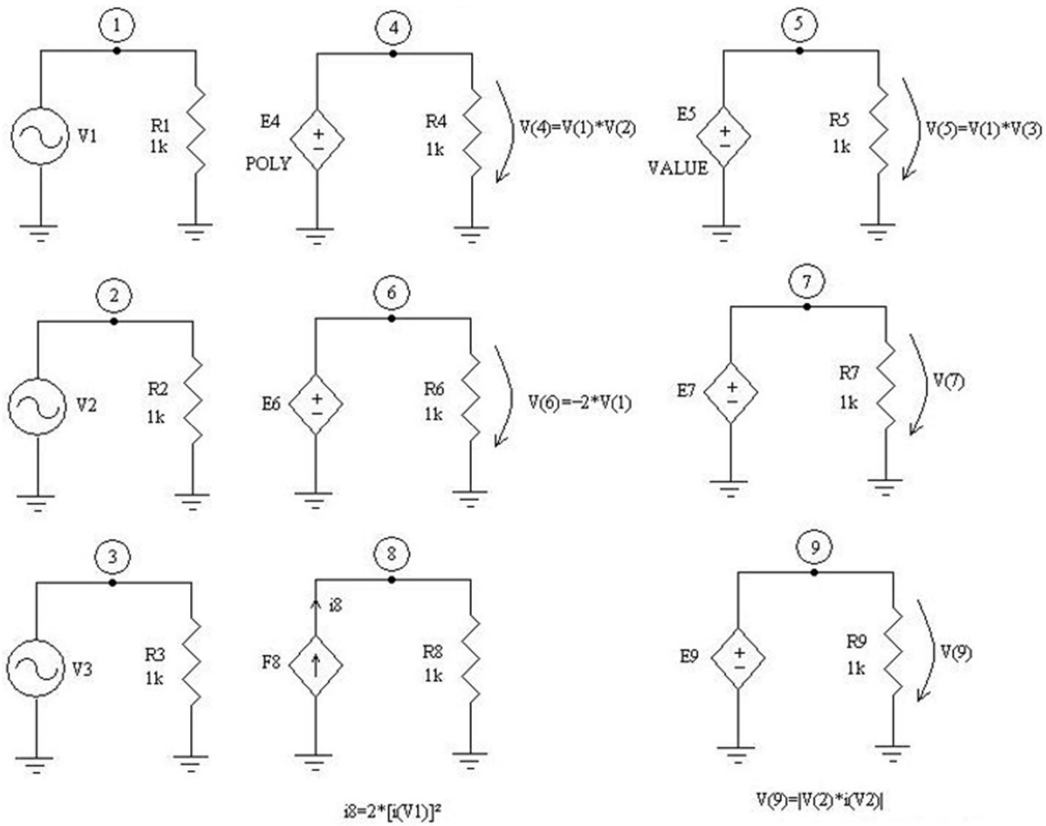
• Perform the simulation

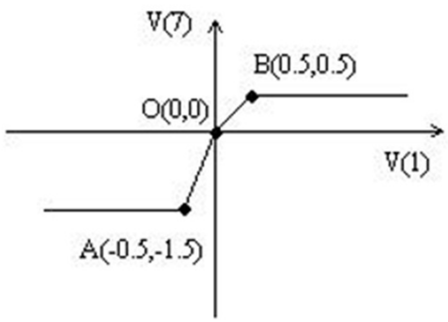
• In the *Probe* graphic analyzer plot the nodal voltages V(1), V(2), V(3) and check if the resulting waveforms are identical with given waveforms.

•In the *Probe* graphic analyzer plot the nodal voltages V(4), V(5),…,V(9) and check if the resulting waveforms are according to the given dependency.

Applications

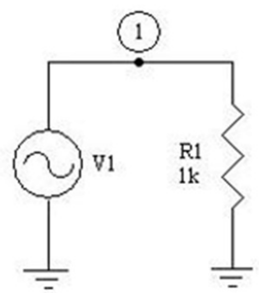
Application 1: Circuit schematic

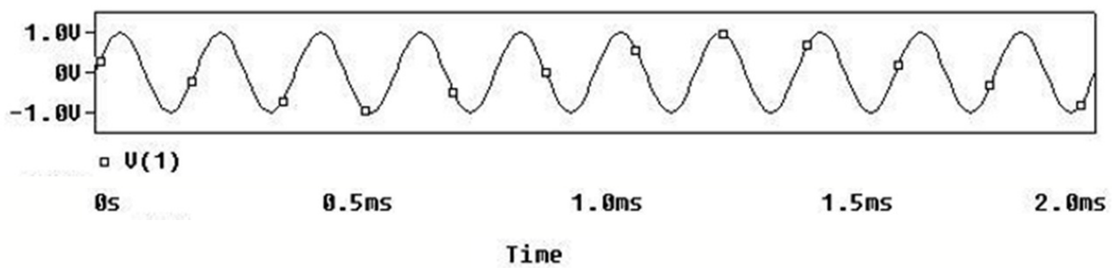




Applications

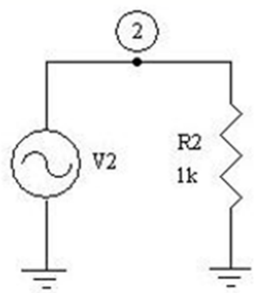
Waveform of source V1

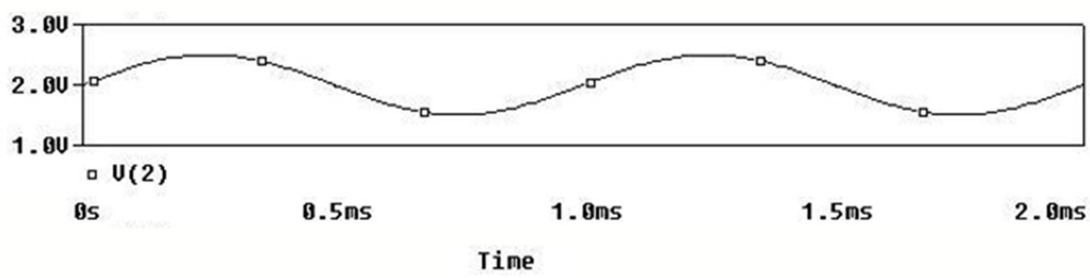




Applications

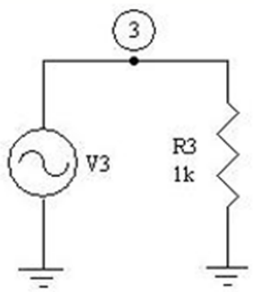
Waveform of source V1

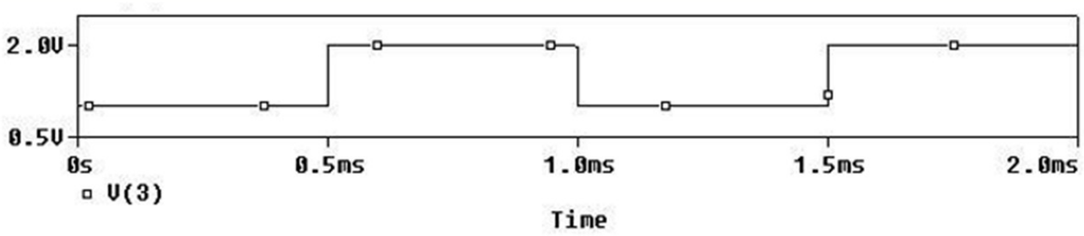




Applications

Waveform of source V1



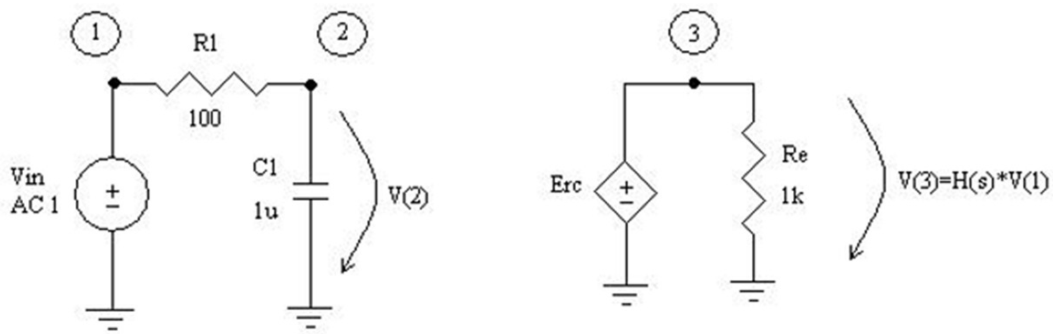


Applications

Application 2 – RC circuit

Activities:

• Describe the following circuit into the SPICE circuit file (.cir) where the Erc is a voltage-controlled voltage source controlled by Vin: VErc = H(s)*Vin



H(s) is the transfer function of the RC filter

$H(s) = \alpha / (s + \alpha)$, $\alpha = 1/ (R1*C1)$

Applications

Application 2 – RC circuit

Activities:

- Add .AC command in the SPICE circuit file to perform a frequency analysis:

  .AC DEC 10 1 10MEG

- Perform the simulation
- In the *Probe* graphic analyzer plot the transfer characteristics waveforms (Bode diagrams) of the RC filter and of Erc source:

  VDB(2), VDB(3), VP(2), VP(3).

- Check if these characteristics overlap.