PSpice components for CAD

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The basic PSpice components for CAD circuit simulation are based on the following letters:

- **B**
- **C**
- **D**
- **E**
- **F**
- **G**
- **H**
- **I**
- **J**
- **K**
- **L**
- **M**
- **Q**
- **R**
- **S**
- **T**
- **V**
- **W**
- **X**
- **Sources**

In the next pages all these letters shall be presented and explained, giving at the end some examples of using them and the associated components in CAD projects.

B - GaAsFET

General Format:

B|name| |drain| |gate| |source| |model| {area value}

B declares a GaAsFET. PSpice models a GaAsFET as an intrinsic FET with an ohmic resistance (RD/area) in series with the drain, an ohmic resistance (RS/area) in series with the source, and an ohmic resistance (RG) in series with the gate.

{area value} is the relative device area with default 1.

Model Parameters:

Name Description

------- ---

LEVEL model type (1 = Curtiss, 2 = Raytheon)

Default value = 1

VTO threshold voltage
Default value = -2.5 ; Units = volt
ALPHA tanh constant
Default value = 2 ; Units = volt^-1
B doping tail extending parameter (level 2 only)
Default value = .3
BETA transconductance coefficient
Default value = 0.1 ; Units = amp/volt^2
LAMBDA channel-length modulation
Default value = 0 ; Units = volt^-1
RG gate ohmic resistance
Default value = 0 ; Units = ohm
RD drain ohmic resistance
Default value = 0 ; Units = ohm
RS source ohmic resistance
Default value = 0 ; Units = ohm
IS gate p-n saturation current
Default value = 1E-14 ; Units = amp
M gate p-n grading coefficient
Default value = 0.5
N gate p-n emission coefficient
Default value = 1
VBI gate p-n potential
Default value = 1 ; Units = volt
CGD gate-drain zero-bias p-n capacitance
Default value = 0 ; Units = farad
CGS gate-source zero-bias p-n capacitance
Default value = 0 ; Units = farad
CDS drain-source zero-bias p-n capacitance
Default value = 0 ; Units = farad
TAU transit time
Default value = 0 ; Units = sec
FC forward bias depletion capacitance coefficient
Default value = 0.5
VTOTC VTO temperature coefficient
Default value = 0 ; Units = volt/ĄC
BETATCE BETA exponential temperature coefficient
Default value = 0 ; Units = %/ĄC
KF flicker noise coefficient
Default value = 0
AF flicker noise exponent
Default value = 0

Examples:
B1 100 1 0 MGAAS
declares a GaAsFET B1 of model MGAAS
B2 100 10 0 MGNOM 2.0
declares a GaAsFET B2 of model MGNOM and area multiplier of 2.0

C - Capacitor

General Format:

C|name| |+ node| |- node| {model name} |value| {IC = |initial value|}

The |+ node| and |- node| define the polarity of the capacitor. Positive current flows from the |+ node| to the |- node|.

{model name} is optional and if not included then |value| is the capacitance in farads. If {model name} is specified then the capacitance is given by :

Ctot = |value|*C*(1+VC1*V+VC2*V^2)*[1+TC1*(T-Tnom))+TC2*(T-Tnom)^2]

where C, VC1, VC2, TC1, and TC2 are described below.
Ctot is the total capacitance. V is the voltage across the capacitor.
T is the simulation temperature. And Tnom is the nominal temperature (27C unless set by .OPTIONS TNOM command)

|value| can either be positive or negative.

{IC = |initial value|} gives PSPICE an initial guess for voltage across the capacitor during bias point calculation and is optional.

The capacitor does not have a noise model.

Model Parameters :

```
Name    Description
------- -----------------------------------------------------
C       capacitance multiplier
        Default value = 1
VC1     linear voltage coefficient
        Default value = 0 ; Units = volt^-1
VC2     quadratic voltage multiplier
        Default value = 0 ; Units = volt^-2
TC1     linear temperature coefficient
        Default value = 0 ; Units = ĄC^-1
TC2     quadratic temperature coefficient
        Default value = 0 ; Units = ĄC^-2
```

Example :

C1 1 0 20pF

defines a 20pF capacitor between nodes 1 and 0.

D - Diode

General Format:

D|name| |+ node| |- node| |model name| {area value}

The diode is modeled by a resistor of value RS/{area value} in series with an intrinsic diode. |+ node| is the anode and |- node|is the cathode. Positive current flows from the anode to cathode.

{area value} scales IS, RS, CJO, and IBV and is 1 by default.

IBV and BV are both positive.

Model Parameters :

Name	Description
IS	saturation current Default value = 1E-14 ; Units = amp
N	emission coefficient Default value = 1
RS	parasitic resistance Default value = 0 ; Units = ohm
CJO	zero-bias p-n capacitance Default value = 0 ; Units = farad
VJ	p-n potential Default value = 1 ; Units = volt
M	p-n grading coefficient Default value = 0.5
FC	forward bias depletion capacitance coefficient Default value = 0.5
TT	transit time Default value = 0 ; Units = sec
BV	reverse breakdown value Default value = infinite ; Units = volt
IBV	reverse breakdown current Default value = 1E-10 ; Units = amp
EG	bandgap voltage Default value = 1.11 ; Units = eV
XTI	IS temperature exponent Default value = 3
KF	flicker noise coefficient Default value = 0
AF	flicker noise exponent Default value = 1

Example:

D1 1 2 DMOD

defines a diode having model DMOD's characteristics with node 1 as its anode and node 2 as its cathode.

E - Voltage-Controlled Voltage Source

General Formats :

E|name| |+ node| |- node| |+ control node| |- control node| |gain|

or

E|name| |+ node| |- node| POLY(|value|) (|+ control node|, |- control node| ...)
\+ |polynomial coefficient value ...|

Both formats declare a voltage source whose magnitude is related to the voltage difference between nodes |+ control node| and |- control node|.

The first form generates a linear relationship. Thus :

Vtot = |gain|*(|+control node|-|- control node|)
where Vtot is the voltage between nodes |+ node| and |- node|.

The second form generates a nonlinear response. The dimension of the polynomial is given by the |value|. The dimension means the number of pairs of controlling nodes.

In all cases positive current flows from |+ node| through the source and out |- node|.

Examples :

E1 1 2 3 4 10
gives V(1) - V(2) = 10 * (V(3) - V(4))

E2 5 6 POLY(1) (7,8) 10 20 30
gives V(5) - V(6) = 10 + 20 * (V(7) - V(8)) + 30 * (V(7) - V(8))^2

E3 1 2 POLY(2) (3,4) (5,6) 10 20 30
gives V(1) - V(2) = 10 + 20 * (V(3) - V(4)) + 30 * (V(5) - V(6))

F - Current-Controlled Current Source

General Formats :

F|name| |+ node| |- node|
\+ |controlling V source| |gain|

or

F|name| |+ node| |- node| POLY(|value|)
\+ (|controlling V source| ...)
\+ |polynomial coefficient value ...|

Both formats declare a current source whose magnitude is related to the current passing thru |controlling V source|. This means that the controlling current ***must*** flow through an independent voltage source. If it does not do so in the original circuit, then a 0-V independent voltage source must be added to the circuit in series with the branch where the controlling current exists, so that the controlling current is forced to flow through it. The orientation of this source must be such that its polarity satisfies the passive sign convention with respect to the current of interest.

The first form generates a linear relationship. Thus:
Itot = |gain|*I(|controlling V source|)
where Itot is the total current thru the declared F|name| device.

The second form generates a nonlinear response. The dimension of the polynomial is given by the |value|. The dimension means the number of |controlling V source|.
In all cases positive current flows from |+ node| through the source and out |- node|.

Examples :

F1 1 2 VIN 10
gives I(F1) = 10 * I(VIN)

F2 5 6 POLY(1) VIN 10 20 30
gives I(F2) = 10 + 20 * I(VIN) + 30 * (I(VIN)^2)

F3 1 2 POLY(2) VA VB 10 20 30
gives I(F3) = 10 + 20 * I(VA) + 30 * I(VB)

G - Voltage-Controlled Current Source

General Formats :

G|name| |+ node| |- node| |+ control node| |- control node| |transconductance|
or
G|name| |+ node| |- node| POLY(|value|) (|+ control node|, |- control node| ...)
+ |polynomial coefficient value ...|

Both formats declare a current source whose magnitude is related to the voltage difference between nodes |+ control node| and |- control node|.

The first form generates a linear relationship. Thus:
Itot = |transconductance|*(|+control node|-|- control node|)
where Itot is the current thru declared device G|name|.

The second form generates a nonlinear response. The dimension of the polynomial is given by the |value|. The dimension means the number of pairs of controlling nodes.
In all cases positive current flows from |+ node| through the source and out |- node|.

Examples :
G1 1 2 3 4 10
gives I(G1) = 10 * (V(3) - V(4))

G2 5 6 POLY(1) (7,8) 10 20 30
gives I(G2) = 10 + 20 * (V(7) - V(8)) + 30 * (V(7) - V(8))^2

G3 1 2 POLY(2) (3,4) (5,6) 10 20 30
gives I(G3) = 10 + 20 * (V(3) - V(4)) + 30 * (V(5) - V(6))

H - Current-Controlled Voltage Source

General Formats :
H|name| |+ node| |- node| |controlling V source| |transresistance|
or
H|name| |+ node| |- node| POLY(|value|) (|controlling V source| ...)
+ |polynomial coefficient value ...|

Both formats declare a voltage source whose magnitude is related to the current passing thru |controlling V source|. This means that the controlling current ***must*** flow through an independent voltage source. If it does not do so in the original ircuit, then a 0-V independent voltage source must be added to the circuit in series with the branch where the controlling current exists, so that the controlling current is forced to flow through it. The orientation of this source must be such that its polarity satisfies the passive sign convention with respect to the current of interest.

The first form generates a linear relationship. Thus :
Vtot = |transresistance|*I(|controlling V source|)
where Vtot is the voltage across |+ node| and |- node|.

The second form generates a nonlinear response. The dimension of the polynomial is given by the |value|. The dimension means the number of |controlling V source|.

In all cases positive current flows from |+ node| through the source and out |- node|.

Examples :

H1 1 2 VIN 10
gives V(1) - V(2) = 10 * I(VIN)

H2 5 6 POLY(1) VIN 10 20 30
gives V(5) - V(6) = 10 + 20 * I(VIN) + 30 * (I(VIN)^2)

H3 1 2 POLY(2) VA VB 10 20 30
gives V(1) - V(2) = 10 + 20 * I(VA) + 30 * I(VB)

I - Independent Current Source

General Formats:

I|name| |+ node| |- node| {DC} |value|

or

I|name| |+ node| |- node| AC |magnitude| {phase}

or

I|name| |+ node| |- node| [transient specification]

I declares a current source. There are three types of current sources. DC, AC, or transient sources.

DC sources give a current source with constant magnitude current. DC sources are used for supplies or for DC analyses.

AC sources are used for the .AC analysis. The magnitude of the source is given by |magnitude|. The initial phase of the source is given by {phase}, default phase is 0.

Transient sources are sources whose output varies over the time of simulation. These are used mostly with the transient analysis, .TRAN.

Transient sources must be defined as one of the below:

EXP |parameters|
PULSE |parameters|
PWL |parameters|
SFFM |parameters|
SIN |parameters|

Positive current flows from |+ node| thru the source and out |- node|.

Examples:

I1 1 2 3mA
declares I1 as a DC source of magnitude 3mA

I2 3 4 AC 1
declares I2 an AC source of magnitude 1A (0 initial phase)

I3 5 6 SIN (1 .1 1MEG)
declares I3 a sinusoidal source with magnitude .1A peak, frequency 1 MHz, and DC offset 1A .

I4 7 8 DC 1 AC 1
declares I4 as a DC source with magnitude of 1A along with an AC component of magnitude 1A (phase angle = 0)

J - Junction FET

General Format:

J|name| |drain| |gate| |source| |model| {area}

J declares a JFET. The JFET is modeled as an intrinsic FET with an ohmic resistance (RD/{area}) in series with the drain, an ohmic resistance (RS/{area}) in series with the source, and an ohmic resistance (RG) in series with the gate.

Positive current is defined as flowing into each terminal.

{area}, optional, is the relative device area. Its default is 1.

Model Parameters :

Name	Description
VTO	threshold voltage Default value = -2.0 ; Units = volt
BETA	transconductance coefficient Default value = 1E-4 ; Units = amp/volt^2
LAMBDA	channel-length modulation Default value = 0 ; Units = volt^-1
RD	drain ohmic resistance Default value = 0 ; Units = ohm
RS	source ohmic resistance Default value = 0 ; Units = ohm
IS	gate p-n saturation current Default value = 1E-14 ; Units = amp
CGD	gate-drain zero-bias p-n capacitance Default value = 0 ; Units = farad
CGS	gate-source zero-bias p-n capacitance Default value = 0 ; Units = farad
FC	forward bias depletion capacitance coefficient Default value = 0.5

VTOTC   VTO temperature coefficient
Default value = 0 ; Units = volt/ĄC
BETATCE BETA exponential temperature coefficient
Default value = 0 ; Units = %/ĄC
KF   flicker noise coefficient
Default value = 0
AF   flicker noise exponent
Default value = 0

Example:

J1 1 2 3 MJFET

declares a JFET with drain, gate, source nodes as node 1, node 2, node 3 respectively. MJFET is the model name of the JFET and must be declared by the .MODEL command.

K - Inductor Coupling (Transformer Core)

General Formats:

K|name| L|inductor name| |L|inductor name|... |coupling value|

or

K|name| |L|inductor name|...| |coupling value| |model name| {size value}

K couples two or more inductors together. Using the dot convention, place a dot on the first node of each inductor. Then the coupled current will be of opposite polarity with respect to the driving current.

|coupling value| is the coefficient of mutual coupling. It must be between 0 and 1.

If |model name| is present 4 things change :

1. The mutual coupling inductor becomes a nonlinear magnetic core.
2. The core's B-H characteristics are analyzed using the Jiles-Atherton model.
3. The inductors become windings, thus the number specifying inductance now means number of turns.
4. The list of coupled inductors may just be one inductor.

{size value} scales the magnetic cross section, it's default is 1.

Model Parameters :
Name   Description
------- ---
AREA   mean magnetic cross section
Default value = 0.1 ; Units = cm^2
PATH   mean magnetic path length
Default value = 1 ; Units = cm
GAP   effective air gap length
Default value = 0 ; Units = cm
PACK   pack(stacking) factor
Default value = 1
MS   magnetization saturation

Default value = 1E6 ; Units = amp/meter
ALPHA mean field parameter
Default value = 0.001
A shape parameter
Default value = 1000 ; Units = amp/meter
C domain wall flexing coefficient
Default value = 0.2
K domain wall pinning constant
Default value = 500

Example:

K1 L1 L2 0.9

defines the mutual coupling between inductors L1 and L2 as 0.9. L1 and L2 should both be declared somewhere in the netlist.

L - Inductor

General Format:

L|name| |+ node| |- node| {model name} |value| {IC = |initial value|}

L defines an inductor. |+ node| and |- node| define the polarity of positive voltage drop. Positive current flows from the |+ node| thru the device and out the |- node|.

|value| can be positive or negative but not 0.

{model name} is optional. If left out the inductor has an inductance of |value| henries.

If {model name} is included, then the total inductance is:
Ltot=|value|*L*(1+IL1*I+IL2*I^2)*(1+TC1*(T-Tnom)+TC2*(T-Tnom)^2)
where L, IL1, IL2, TC1, and TC2 are defined in the model declaration.
T is the temperature of simulation. Tnom is the nominal temperature
(27ĄC unless specified by .OPTIONS TNOM)

{IC = |initial value|} is optional and, if used, defines the initial guess for the current thru the inductor when PSPICE attempts to find the bias point.

Model Parameters :
Name Description
------- ---
L inductance multiplier
Default value = 1
IL1 linear current coefficient
Default value = 0 ; Units = amp^-1
IL1 quadratic current coefficient
Default value = 0 ; Units = amp^-2
TC1 linear temperature coefficient
Default value = 0 ; Units = ĄC^-1
TC2 quadratic temperature coefficient
Default value = 0 ; Units = ĄC^-2

Example:

L1 1 2 10m
defines an inductor between nodes 1 and 2 with inductance of 10mH.

M - MOSFET

General Format :
M|name| |drain| |gate| |source| |substrate| |model name| {L = |value|} {W = |value|} {AD =
+ |value|} {AS = |value|} {PD = |value|} {PS = |value|} {NRD = |value|} {NRS = |value|}
+ {NRG = |value|} {NRB = |value|}

M defines a MOSFET transistor. The MOSFET is modeled as an intrinsic MOSFET with ohmic resistances in series with the drain, source, gate, and substrate(bulk). There is also a shunt resistor (RDS) in parallel with the drain-source channel. Positive current is defined to flow into each terminal.

L and W are the channel's length and width. L is decreased by 2*LD and W is decreased by 2*WD to get the effective channel length and width. L and W can be defined in the device statement, in the model, or in .OPTION command. The device statement has precedence over the model which has precedence over the .OPTIONS.

AD and AS are the drain and source diffusion areas. PD and PS are the drain and source diffusion parameters. The drain-bulk and source-bulk saturation currents can be specified by JS (which in turn is multiplied by AD and AS) or by IS (an absolute value). The zero-bias depletion capacitances can be specified by CJ, which is multiplied by AD and AS, and by CJSW, which is multiplied by PD and PS, or by CBD and CBS, which are absolute values.

NRD, NRS, NRG, and NRB are relative resistivities of their respective terminals in squares. These parasitics can be specified either by RSH (which in turn is multiplied by NRD, NRS, NRG, or NRB) or by absolute resistances RD, RG, RS, and RB.

Defaults for L, W, AD, and AS may be set using the .OPTIONS command. If .OPTIONS is not used their default values are 100u, 100u, 0, and 0 respectively

Model Parameters :
Name Description
------- ---
LEVEL model type (1, 2, or 3)
Default value = 1
L channel length
Default value = DEFL ; Units = meter
W channel width
Default value = DEFW ; Units = meter
LD lateral diffusion (length)
Default value = 0 ; Units = meter
WD lateral diffusion (width)
Default value = 0 ; Units = meter
VTO zero-bias threshold voltage
Default value = 0 ; Units = volt

KP transconductance
Default value = 2E-5 ; Units = amp/volt^2
GAMMA bulk threshold parameter
Default value = 0 ; Units = volt^0.5
PHI surface potential
Default value = 0.7 ; Units = volt
LAMBDA channel length modulation (LEVEL = 1 or 2)
Default value = 0 ; Units = volt^-1
RD drain ohmic resistance
Default value = 0 ; Units = ohm
RS source ohmic resistance
Default value = 0 ; Units = ohm
RG gate ohmic resistance
Default value = 0 ; Units = ohm
RB substrate ohmic resistance
Default value = 0 ; Units = ohm
RDS drain-source ohmic resistance
Default value = infinite ; Units = ohm
RSH drain, source diffusion sheet resistance
Default value = 0 ; Units = ohm/square
IS bulk p-n saturation current
Default value = 1E-14 ; Units = amp
JS bulk p-n saturation current/area
Default value = 0 ; Units = amp/meter^2
PB bulk p-n potential
Default value = 0.8 ; Units = volt
CBD bulk-drain zero-bias p-n capacitance
Default value = 0 ; Units = farad
CBS bulk-source zero-bias p-n capacitance
Default value = 0 ; Units = farad
CJ bulk p-n zero-bias bottom capacitance/area
Default value = 0 ; Units = farad/meter^2
CJSW bulk p-n zero-bias bottom capacitance/area
Default value = 0 ; Units = farad/meter^2
MJ bulk p-n bottom grading coefficient
Default value = 0.5
MJSW bulk p-n sidewall grading coefficient
Default value = 0.33
FC bulk p-n forward-bias capacitance coefficient
Default value = 0.5
CGSO gate-source overlap capacitance/channel width
Default value = 0 ; Units = farad/meter
CGDO gate-drain overlap capacitance/channel width
Default value = 0 ; Units = farad/meter
CGBO gate-substrate overlap capacitance/channel length
Default value = 0 ; Units = farad/meter
NSUB substrate doping density
Default value = 0 ; Units = 1/cm^3
NSS surface state density
Default value = 0 ; Units = 1/cm^2
NFS fast surface state density
Default value = 0 ; Units = 1/cm^2

TOX oxide thickness
Default value = infinite ; Units = meter
TPG gate material type :
+1 = opposite of substrate
-1 = same as substrate
0 = aluminum
Default value = +1
XJ metallurgical junction depth
Default value = 0 ; Units = meter
UO surface mobility
Default value = 600 ; Units = cm^2/(volt*sec)
UCRIT mobility degradation critical field (LEVEL = 2)
Default value = 1E4 ; Units = volt/cm
UEXP mobility degradation exponent (LEVEL =2)
Default value = 0
VMAX maximum drift velocity
Default value = 0; Units = meter/sec
NEFF channel charge coefficient (LEVEL = 2)
Default value = 1
XQC fraction of channel charge attributed to drain
Default value = 1
DELTA width effect on threshold
Default value = 0
THETA mobility modulation (LEVEL = 3)
Default value = 0 ; Units = volt^-1
ETA static feedback (LEVEL = 3)
Default value = 0
KAPPA saturation field factor (LEVEL = 3)
Default value = 0.2
KF Flicker noise coefficient
Default value = 0
AF Flicker noise exponent
Default value = 1

Examples :

M1 1 2 3 0 MNMOS L=3u W=1u

defines a MOSFET with drain node 1, gate node 2, source node 3, substrate node 0, channel length and width 3u and 1u respectively, and described further by model MNMOS (which is assumed to exist in the .MODEL statements)

M2 4 5 6 0 MNMOS

defines a MOSFET with drain node 4, gate node 5, source node 6, substrate node 0, and described further by model MNMOS (which is assumed to exist in the .MODEL statements)

Q - Bipolar Transistor

General Format :

Q|name| |collector| |base| |emitter| {substrate} |model name| {area value}

Q declares a bipolar transistor in PSpice. The transistor is modeled as an intrinsic transistor with ohmic resistances in series with the base, the collector (RC/{area value}), and with the emitter (RE/{area value}).

{substrate} node is optional, default value is ground.

Positive current is defined as flowing into a terminal.

{area value} is optional (used to scale devices), default is 1.

The parameters ISE and ISC may be set greater than 1. If so they become multipliers of IS (i.e. ISE*IS).

Model Parameters :
Name   Description
------- ---
IS   p-n saturation current
        Default value = 1E-16 ; Units = amp
BF   ideal maximum forward beta
        Default value = 100
NF   forward current emission coefficient
        Default value = 1
VAF   forward Early voltage
        Default value = infinite ; Units = volt
IKF   corner for forward beta high current roll off
        Default value = infinite ; Units = amp
ISE   base-emitter leakage saturation current
        Default value = 0 ; Units = amp
NE   base-emitter leakage emission coefficient
        Default value = 1.5
BR   ideal maximum reverse beta
        Default value = 1
NR   reverse current emission coefficient
        Default value = 1
VAR   reverse Early voltage
        Default value = infinite ; Units = volt
IKR   corner for reverse beta high current roll off
        Default value = infinite ; Units = amp
ISC   base-collector leakage saturation coefficient
        Default value = 0 ; Units = amp
NC   base-collector leakage emission coefficient
        Default value = 2.0
RB   zero-bias (maximum) base resistance
        Default value = 0 ; Units = ohm
RBM   minimum base resistance
        Default value = RB ; Units = ohm
IRB   current at which RB falls halfway to RBM
        Default value = infinite ; Units = amp
RE   emitter ohmic resistance
        Default value = 0 ; Units = ohm
RC   collector ohmic resistance

Default value = 0 ; Units = amp
CJE base-emitter zero-bias p-n capacitance
Default value = 0; Units = farad
VJE base-emitter built in potential
Default value = 0.75 ; Units = volt
MJE base-emitter p-n grading coefficient
Default value = 0.33
CJC base-collector zero-bias p-n capacitance
Default value = 0; Units = farad
VJC base-collector built in potential
Default value = 0.75 ; Units = volt
MJC base-collector p-n grading coefficient
Default value = 0.33
XCJC fraction of CJC connected internal to RB
Default value = 1
CJS collector-substrate zero-bias p-n capacitance
Default value = 0; Units = farad
VJS collector-substrate built in potential
Default value = 0.75 ; Units = volt
MJS collector-substrate p-n grading coefficient
Default value = 0
FC forward bias depletion capacitor coefficient
Default value = 0.5
TF ideal forward transit time
Default value = 0 ; Units = sec
XTF transit time bias dependence coefficient
Default value = 0
VTF transit time dependency on VBC
Default value = infinite ; Units = volt
ITF Transit time dependency on IC
Default value = 0 ; Units = amp
PTF excess phase at 1/(2*PI*TF) Hz.
Default value = 0 ; Units = degree
TR ideal reverse transit time
Default value = 0 ; Units = sec
EG bandgap voltage (barrier height)
Default value = 1.11 ; Units = eV
XTB forward and reverse bias temperature coefficient
Default value = 0
XTI IS temperature effect exponent
Default value = 3
KF Flicker noise coefficient
Default value = 0
AF Flicker noise exponent
Default value = 1

Example :

Q1 1 2 3 MNPN

defines a bipolar transistor of model MNPN with collector, base, and emitter nodes of 1, 2, and 3 respectively.

R - Resistor

General Format :

R|name| |+ node| |- node| {model name} |value|

The |+ node| and |- node| define the polarity of the resistor in terms of the voltage drop across it. Positive current flows from the |+ node| thru the resistor and out the |- node|.

{model name} is optional and if not included then |value| is
the resistance in ohms. If {model name} is specified and TCE is not specified then the resistance is given by :

Rtot = |value|*R*[1+TC1*(T-Tnom))+TC2*(T-Tnom)^2]

where R, TC1, and TC2 are described below.
Rtot is the total resistance, T is the simulation temperature and Tnom is the nominal temperature (27C unless set by .OPTIONS TNOM command)

If TCE is specified then the resistance is given by:

Rtot = |value|*R*1.01^(TCE*(T-Tnom))

|value| can either be positive or negative.

Noise is calculated using a 1 Hz bandwidth. The resistor generates thermal noise with the following spectral power density (per unit BW):

i^2 = 4*k*T/resistance

where k is Boltzmann's constant.

Model Parameters :

Name	Description
R	resistance multiplier Default value = 1
TC1	linear temperature coefficient Default value = 0 ; Units = ĄC^-1
TC2	quadratic temperature coefficient Default value = 0 ; Units = ĄC^-2
TCE	exponential temperature coefficient Default value = 0 ; Units = %/ĄC

Example :

R1 1 0 20

defines a 20 ohm resistor between nodes 1 and 0.

S - Voltage-Controlled Switch

General Format :

S|name| |+ switch node| |- switch node| |+ control node| |- control node| |model name|

S denotes a voltage controlled switch. The resistance between |+ switch node| and |- switch node| depends on the voltage difference between |+ control node| and |- control node|. The resistance varies continuously between RON and ROFF.

RON and ROFF must be greater than zero and less than GMIN (set in the .OPTIONS command). A resistor of value 1/GMIN is connected between the controlling nodes to prevent them from floating.

Model Parameters :

Name	Description
RON	on resistance Default value = 1 ; Units = ohm
ROFF	off resistance Default value = 1E6 ; Units = ohm
VON	control voltage for on state Default value = 1 ; Units = volt
VOFF	control voltage for off state Default value = 0 ; Units = volt

Example :

S1 1 2 3 4 MSW

defines a current controlled switch. The resistance between nodes 1 and 2 varies with the voltage difference between nodes 3 and 4. The switch model is MSW.

T - Transmission Line

General Format :

T|name| |+ A port| |- A port| |+ B port| |- B port| Z0 = |value| {TD = |TD value|} {F = |F value|{NL = |NL value|}}

T defines a 2 port transmission line. The device is a bidirectional, ideal delay line. The two ports are A and B with their polarities given by the + or - sign.

Z0 is the characteristic impedance of the line.

The length of the transmission line can either be defined by TD, the delay in seconds, or by F and NL a frequency and relative wavelength.

Example :

T1 1 0 2 0 Z0=50 F=1E9 NL=0.25

declares a two port transmission line. The two ports are given as nodes 1 and 2. The line has a characteristic impedance of 50 ohms and a length of 0.25 wavelengths at 1 GHz.

V - Independent Voltage Source

General Formats :

V|name| |+ node| |- node| {DC} |value|

or

V|name| |+ node| |- node| AC |magnitude| {phase}

or

V|name| |+ node| |- node| [transient specification]

V declares a voltage source. There are three types of voltage sources. DC, AC, or transient sources.

DC sources give a voltage source with constant magnitude voltage. DC sources are used for supplies or for DC analyses.

AC sources are used for the .AC analysis. The magnitude of the source is given by |magnitude|. The initial phase of the source is given by {phase}, default phase is 0.

Transient sources are sources whose output varies over the time of simulation. These are used mostly with the transient analysis, .TRAN.

Transient sources must be defined as one of the below:
EXP |parameters|
PULSE |parameters|
PWL |parameters|
SFFM |parameters|
SIN |parameters|

Positive current flows from |+ node| thru the source and out |- node|.

Examples :

V1 1 2 1
declares V1 as a DC source of magnitude 1 V.

V2 3 4 AC 1
declares V2 an AC source of magnitude 1 V (phase angle = 0)

V3 5 6 SIN (1 .1 1MEG)
declares V3 a sinusoidal source with magnitude .1 V peak, frequency 1 MHz, and DC offset 1 V .

V4 7 8 DC 1 AC 1
declares V4 as a DC source with magnitude of 1 V along with an AC component of magnitude 1 V (phase angle = 0)

W - Current-Controlled Switch

General Format :

W|name| |+ switch node| |- switch node| |controlling V source| |model name|

W denotes a current controlled switch. The resistance between |+ switch node| and |- switch node| depends on the current flowing thru the control source |controlling V source|. The resistance varies continuously between RON and ROFF.

RON and ROFF must be greater than zero and less than GMIN (set in the .OPTIONS command). A resistor of value 1/GMIN is connected between the controlling nodes to prevent them from floating.

Model Parameters :

```
Name    Description
------- -----------------------------------------------------
RON     on resistance
        Default value = 1 ; Units = ohm
ROFF    off resistance
        Default value = 1E6 ; Units = ohm
ION     control voltage for on state
        Default value = 0.001 ; Units = amp
IOFF    control voltage for off state
        Default value = 0 ; Units = amp
```

Example :

W1 1 2 VCONT MSW

defines a current controlled switch. The resistance between nodes 1 and 2 varies with the current flowing thru the control source VCONT. The switch model is MSW.

X - Subcircuit Call

General Format :

X|name| {node ...} |subcircuit name|

X calls the subcircuit |subcircuit name|. |subcircuit name| must somewhere be defined by the .SUBCKT and .ENDS command. The number of nodes (given by {node ...}) must be consistent. The referenced subcircuit is inserted into the given circuit with the given nodes replacing the argument nodes in the definition. Subcircuit calls may be nested but cannot be recursive.

Example :

X1 1 2 OPAMP

calls the subcircuit OPAMP.

SOURCES - Transient Source Descriptions

There are several types of available sources for transient declarations. Each kind, its description, and an example is given below:

1. EXP - Exponential Source

General Format :
    EXP (|v1| |v2| |td1| |td2| |tau1| |tau2|)

The EXP form causes the voltage to be |v1| for the first |td1| seconds. Then it grows exponentially from |v1| to |v2| with time constant |tau1|. The growth lasts |td2| - |td1| seconds. Then the voltage decays from |v2| to |v1| with time constant |tau2|.

Parameter Listing :

Name	Description
v1	initial voltage Default value = none ; Units = volt
v2	peak voltage Default value = none ; Units = volt
td1	rise delay time Default value = 0 ; Units = second
tau1	rise time constant Default value = TSTEP ; Units = second
td2	fall delay time Default value = td1 + TSTEP ; Units = second
tau2	fall time constant Default value = TSTEP ; Units = second

Example :
    V1 1 0 EXP(0 1 2u 10u 50u 10u)

2. PULSE - Pulse source

General Format :
    PULSE(|v1| |v2| |td| |tr| |tf| |pw| |per|)

Pulse generates a voltage to start at |v1| and hold there for |td| seconds. Then the voltage goes linearly from |v1| to |v2| for the next |tr| seconds. The voltage is then held at |v2| for |pw| seconds. Afterwards, it changes linearly from |v2| to |v1| in |tf| seconds. It stays at |v1| for the remainder of the period given by |per|.

Parameter Listing :

Name	Description
v1	initial voltage Default value = none ; Units = volt
v2	pulsed voltage Default value = none ; Units = volt
td	delay time Default value = 0 ; Units = second
tr	rise time Default value = TSTEP ; Units = second
tf	fall time Default value = TSTEP ; Units = second
pw	pulse width

Default value = TSTOP ; Units = second
per   period
        Default value = TSTOP ; Units = second

Example :
    V1 1 0 PULSE(0 5 2u 10u 10u 100u 300u)

3. PWL - Piecewise Linear Source

General Format:
    PWL(|t1| |v1| |t2| |v2| .... |ti| |vi|)

PWL describes a piecewise linear format. Each pair of time/voltage (i.e. |t1|, |v1|) specifies a corner of the waveform. The voltage between corners is the linear interpolation of the voltages at the corners.

Parameter Listing :
Name   Description
----   ---
ti   corner time
         Default value = none ; Units = second
vi   corner voltage
         Default value = none ; Units = volt

Example :
    V1 1 0 PWL(0 0 1u 0 1.01u 5 10m 5)

4. SFFM - Single Frequency FM Source

General Format :
    SFFM(|vo| |va| |fc| |mdi| |fs|)

SFFM causes the voltage signal to follow :
    v=vo+va*sin(2*PI*fc*t+mdi*sin(2*PI*fs*t))
where vo, va, fc, mdi, and fs are defined below. t is time.

Parameter Listing :
Name   Description
----   ---
vo   offset voltage
         Default value = none ; Units = volt
va   peak amplitude voltage
         Default value = none ; Units = volt
fc   carrier frequency
         Default value = 1/TSTOP ; Units = Hz
mdi   modulation index
         Default value = 0
fs   signal frequency
         Default value = 1/TSTOP ; Units = Hz

Example:

V1 1 0 SFFM(3 1 88MEG 0.5 20k)

5. SIN - Sinusoidal Source

General Format :
SIN(|vo| |va| |freq| |td| |df| |phase|)

SIN creates a sinusoidal source. The signal holds at |vo| for |td| seconds. Then the voltage becomes an exponentially damped sine wave described by :
v=vo+va*sin(2*PI*(freq*(t-td)+phase/360))*e^-((t-td)*df)

Parameter Listing :

Name	Description
vo	offset voltage Default value = none ; Units = volt
va	peak amplitude voltage Default value = none ; Units = volt
freq	carrier frequency Default value = 1/TSTOP ; Units = Hz
td	delay Default value = 0 ; Units = second
df	damping factor Default value = 0 ; Units = second^-1
phase	phase Default value = 0 ; Units = degree

Example :
V1 1 0 SIN(2 1 20k 1m 0 90)

Note that the above functions can also be used to describe time varying current sources, just interchanging current for voltage.