Star-Hspice Quick Reference Guide

Release 2001.2
June 2001

Star-Hspice Quick Reference Guide, Release 2001.2, June 2001
Previously printed December 2000, V2000.4

Contacting Avant! Corporation

Telephone:...........(510) 413-8000
Facsimile:............(510) 413-8080
Toll-Free Telephone:(800) 369-0080
URL: ....http://www.avanticorp.com

Avant! Corporation
46871 Bayside Parkway
Fremont, CA 94538

Chapter 1

Introduction

This Quick Reference Guide is a condensed version of the *Star-Hspice Manual*. For more specific details and examples refer to that manual.

The intent of this guide is to have a handy quick reference; it is not intended to replace or supplement the *Star-Hspice Manual*.

The topics covered in this chapter are:

- Syntax Notation
- Common Abbreviations
- Input and Output Files

Syntax Notation

xxx, yyy, zzz	Arbitrary alphanumeric strings
< ... >	Optional data fields are enclosed in angle brackets < >. All other symbols and punctuation are required.
UPPERCASE	Keywords, parameter names, etc. are represented in uppercase.

lowercase	Variables; should be replaced with a numeric or symbolic value.
...	Any number of parameters of the form shown can be entered.
+	Continuation of the preceding line.

Note: *The meaning of a parameter may depend on its location in the statement. Be sure that a complete set of parameters is entered in the correct sequence before running the simulation.*

Common Abbreviations

Å	Angstrom
amp	ampere
cm	centimeter
deg	degree Centigrade (unless specified as Kelvin)
ev	electron volt
F	farad
H	Henry
m	meter
s	second
V	volt

Input and Output Files

General Form	/usr/george/mydesign.tr0
/usr/george/	The design path.
mydesign	The design name.
mydesign	The design root.
tr0	The suffix.

File Name Suffix

Note: *"X" is incremenated for each .TEMP or .ALTER, 0-9, A-Z.*

Input:	
input netlist	.sp
design configuration	.cfg
Output (X is alter number, usually 0):	
graph data	.trX (transient analysis)
	.swX (dc sweep)
	.acX (ac analysis)
	.mtX (tran Measure)
	.msX (dc Measure)
	.maX (ac Measure)
hardcopy data	.grX (from .GRAPH)

Input Netlist File

For a complete description of HSPICE installation, system configuration, setup and basic operation, please refer to the *Star-Hspice Manual*, “Volume 1—Simulation and Analysis.” HSPICE now accepts input line lengths of 1024 characters.

Sample Input Netlist File Structure

.TITLE	Implicit first line; becomes input netlist file title.
* or $	Comments to describe the circuit.
.OPTIONS <.TRAN> <.AC> <.DC> <.OP>	Set conditions for simulation analysis.
.TEMPERATURE	Statements to set sweep variables.
PRINT/PLOT/ GRAPH/PROBE	Sets print, plot, graph, and probe variables.
.IC or .NODESET	Sets input state; can also be put in initial conditions.
SOURCES	Sets input stimulus.
NETLIST	Circuit description.
.MACRO libraries	.LIBRARY and .INC.
<.PROTECT>	Suppresses the printout of the text from the list file.
<.UNPROTECT>	Restores output printback.
.ALTER	Sequence for inline case analysis.

.PARAMETER	Redefinition.
.END	Terminates any ALTERs and the simulation.

Numeric Scale Factors

A number may be an integer, a floating point number, an integer or floating point number followed by an integer exponent, or an integer or floating point number followed by one of the scale factors listed below.

F	=1e-15
P	=1e-12
N	=1e-9
U	=1e-6
M	=1e-3
K	=1e3
MEG (or X)	=1e6
MI	=25.4e6
G	=1e9

Algebraic Expressions

In addition to simple arithmetic operations (+, -, *, /), the following quoted string functions may be used:

sin(x)	sinh(x)	abs(x)	cos(x)	cosh(x)
min(x,y)	tan(x)	tanh(x)	max(x,y)	atan(x)

sqrt(x)	exp(x)	db(x)	log(x)	log10(x)
pwr(x,y)	pow(x,y)	(instead of x**y)		

Algebraic Expressions as Input

General Form	'algebraic expression'

Either single (' ') or double (" ") quotes may be used.

Algebraic Expressions as Output

General Form	PAR ('algebraic expression')

The left and right parentheses are mandatory.

Equation Constants

ε_o	Vacuum permittivity=8.854e-12 F/m
εox	3.453143e-11 F/m
εsi	1.0359e-10 *F/m* dielectric constant of silicon
f	Frequency
k	1.38062e-23 - Boltzmann's constant
q	1.60212e-19 - Electron charge
t	Temperature in degrees Kelvin
Δt	t - tnom

tnom	Nominal temperature in degrees Kelvin (user-input in degrees C). Tnom = 273.15 + TNOM
vt(t)	k · t/q Thermal voltage
vt(tnom)	k · tnom/q Thermal voltage

Chapter 2

Discrete Device Library (DDL)

Star-Hspice's full Discrete Device Library is a collection of models of discrete components for use with HSPICE. Included are Diodes, FETs, s, MACROs (op-amps and comparators), Burr Brown, PMI, Signetics, and TI. See "Discrete Device Libraries" in the *Star-Hspice Manual*.

The topics covered in this chapter are:

- DDL Use
- DDL Access

DDL Use

General Form	X1 n1 n2 ... subcircuitname PAR1=val ...
n1, n2	Node names.
PAR1	User available parameter defined at top of each macro.
subcircuit name	Model name taken from DDL list.
X1	Subcircuit call.

DDL Access

HSPICE automatically looks for a file in the local directory named hspice.ini. This name can be overridden with an entry in any meta.cfg file of *default_include=<file name>*.

Example

*hspice.ini

```
* sample Automatic Include File Option
.OPTION
+ search=/usr/meta/h92/lib/pmi
+ search=/usr/meta/h92/lib/burr_brn
+ search=/usr/meta/h92/lib/linear
+ search=/usr/meta/h92/lib/signet
+ search=/usr/meta/h92/lib/ti
+ search=/usr/meta/h92/lib/bjt
+ search=/usr/meta/h92/lib/dio
+ search=/usr/meta/h92/lib/fet
+ search=/usr/meta/h92/lib/macro
****add any user options, parameters, model
*** includes, subcircuit includes or
*** libraries here
```

Chapter 3

Passive Devices and Independent Sources

The topics covered in this chapter are:

- Statements
- Resistors
- Capacitors
- Inductors
- Magnetics
- Independent Source Element
- Independent Sources

The passive devices and independent sources in Star-Hspice can use the following.

Statements

Element Statement

General Form	NAME node1,node2 … nodeN + <model reference> value + <optional parameters>

Model Statement

General Form	.MODEL mname modeltype + <keyword=value keyword=value...>

Resistors

See “Resistors” in the *Star-Hspice Manual*.

Resistor Element

General Form	Rxxx n1 n2 <mname> Rval <TC1 <TC2>> + <SCALE=val> <M=val> <AC=val> + <DTEMP=val> <L=val> <W=val> + <C=val>
Or	Rxxx n1 n2 <mname> R=val <TC1=val> + <TC2=val> <SCALE=val> <M=val> + <AC=val> <DTEMP=val> <L=val> + <W=val> <C=val>
Or	Rxxx n1 n2 R=‘users defined equation’

If mname is specified, the resistor value specification would be optional.

AC	Resistance for AC analysis
C	Capacitance
DTEMP	Element and circuit temperature difference
L	Resistor length
M	Multiplier used to simulate parallel resistors
mname	Model name

n1	Positive terminal node name
n2	Negative terminal node name
R	Resistance
Rxxx	Resistor element name
SCALE	Element scale factor for resistance and capacitance
TC1	First order temperature coefficient
TC2	Second-order temperature coefficient
user-defined equation	Can be a function of any node voltages, element currents, temperature, frequency, and time
W	Resistor width

Wire RC Model

General Form	.MODEL mname R keyname=value
keyname	Any model parameter name.
mname	Model name.
R	Specifies a wire model.

See “Wire RC Model” in the *Star-Hspice Manual*.

Capacitors

See “Capacitors” in the *Star-Hspice Manual*.

Capacitor Element

General Form	Cxxx n1 n2 <mname> capval <TC1> + <TC2>> <SCALE=val> <IC=val> + <M=val> <W=val> + <L=val> + <DTEMP=val>
Or	Cxxx n1 n2 <mname> C=val <TC1=val> + <TC2=val> <IC=val><M=val> <W=val> + <L=val> <DTEMP=val>
Or	Cxxx n1 n2 C=‘user’s defined equation’ + (CTYPE=0 or 1)

If a model is chosen for the capacitor, then the specifications of capval are optional.

Cxxx	Capacitor element name.
n1	Positive terminal node name.
n2	Negative terminal node name.
mname	Capacitance model name.
C=capacitance	Capacitance at room temperature as a numeric value or parameter in farads.
TC1	First-order temperature coefficient.
TC2	Second-order temperature coefficient.
SCALE	Element scale parameter, scales capacitance by its value.
IC	Initial voltage across the capacitor in volts.

M	Multiplier used to simulate multiple parallel capacitors.
W	Capacitor width in meters.
L	Capacitor length in meters.
DTEMP	Element temperature difference with respect to the circuit temperature in Celsius.
C='equation'	Capacitance at room temperature specified as a function of any node voltages, branch currents, or any independent variables such as time, frequency (HERTZ), or temperature.
CTYPE	Determines capacitance charge calculation for elements with capacitance equations.

If a capacitor model exists using the same name as a parameter for capval, the model name is taken to avoid syntactic conflicts.

Capacitance Model

General Form	>MODEL mname C parameter=value
C	Specifies a capacitance model.
mname	Model name.
parameter	Any model parameter name.

See "Capacitance Model" in the *Star-Hspice Manual*.

Polynomial Capacitor Elements

General Form	Cxxx n1 n2 POLY c0 c1 ... <IC=v>
c0 c1 ...	Coefficients of a polynomial described as a function of the voltage across the capacitor.
Cxxx	Capacitor element name.
IC	Initial voltage across capacitor in volts.
n1, n2	Node names.
POLY	Keyname to identify capacitor as nonlinear polynomial.

See "Capacitors" in the *Star-Hspice Manual*.

Inductors

See "Inductors" in the *Star-Hspice Manual*.

Linear Inductor Element

General Form	Lxxx n1 n2 <L=>inductance + <<TC1=>val> <<TC2=>val> + <SCALE=val> <IC=val> <M=val> + <DTEMP=val> <R=val>
Or	Lxxx n1 n2 L='equation' <LTYPE=val> + <above options...>
c0 c1...	Coefficients of a polynomial in current describing the inductor value.
DTEMP	Temperature difference between the element and the circuit in Celsius.

IC	Initial current in amperes.
L=inductance	Inductance value.
L='equation'	Inductance at room temperature.
LTYPE	Determines inductance flux calculation for elements with inductance equations.
M	Multiplier used to simulate parallel inductors.
NT=turns	Number representing the number of turns of an inductive magnetic winding.
POLY	Keyword to specify inductance given by a polynomial.
R	Resistance of inductor in ohms.
SCALE	Element scale parameter; scales inductance by its value.
TC1	First-order temperature coefficient.
TC2	Second-order temperature coefficient.

Mutual Inductor Element

General Form	Kxxx Lyyy Lzzz <K=>coupling
K=coupling	Coefficient of mutual coupling.
Kxxx	Mutual inductor element name.
Lyyy	Name of the first of two coupled inductors.
Lzzz	Name of the second of two coupled inductors.

Polynomial Inductor Element

General Form	Lxxx n1 n2 POLYc0 c1 <L=>inductance + <<TC1=>val> <<TC2=>val> + <SCALE=val> <IC=val> <M=val> + <DTEMP=val> <R=val>

See the arguments for "Linear Inductor Element" on page 3-6.

Magnetics

Magnetic Winding Element

General Form	Lxxx n1 n2 NT=turns <L=>inductance + <<TC1=>val> <<TC2=>val> + <SCALE=val> <IC=val> <M=val> + <DTEMP=val> <R=val>

See the arguments for "Linear Inductor Element" on page 3-6.
Also see "Inductors" in the *Star-Hspice Manual*.

Mutual Core Statement

General Form	Kaaa Lbbb <Lccc ... <Lddd>> mname + <MAG=magnetization>
K=coupling	Coefficient of mutual coupling.
Kaaa	Saturable core element name.
Kxxx	Mutual inductor element name.
Lbbb, Lccc, Lddd	The names of the windings about the Kaaa core.
Lyyy	Name of the first of two coupled inductors.

Lzzz	Name of the second of two coupled inductors.
MAG= magnetization	Initial magnetization of the saturable core.
mname	Saturable core model name.

See “Inductors” in the *Star-Hspice Manual*.

Magnetic Core Model

General Form	.MODEL mname L (<pname1=val1>…)
CORE	Identifies a Jiles-Atherton Ferromagnetic Core model.
L	Identifies a saturable core model
LEVEL=x	Equation selection for Jiles-Atherton model.
mname	Model name.
pname1=val1	Value of the model parameter.

See “Magnetic Core Syntax” in the *Star-Hspice Manual*.

Independent Source Element

General Form	Vxxx n+ n- <<DC=> dcval> <tranfun> + <AC=acmag, <acphase>>
Or	Iyyy n+ n- <<DC=> dcval> <tranfun> + <AC=acmag, <acphase>> + <M=val>

AC	AC source keyword for use in AC small-signal analysis.
acmag	Magnitude (RMS) of the AC source in volts.
acphase	Phase of the AC source in degrees.
DC=dcval	DC source keyword and value in volts.
Iyyy	Independent current source element name.
M	Multiplier used for simulating multiple parallel current sources.
n+	Positive node.
n-	Negative node.
tranfun	Transient source function (one or more of: AM, DC, EXP, PE, PL, PU, PULSE, PWL, SFFM, SIN).
Vxxx	Independent voltage source element name.

See “Independent Source Element” in the *Star-Hspice Manual*.

Independent Sources

All arguments for the sources in this section follow “Amplitude Modulation Source Function” on pages 3-13.

Pulse Source Function

General Form	Vxxx n+ n- PU<LSE> <(>v1 v2 <td <tr <tf + <pw <per>>>>> <)>
Or	Ixxx n+ n- PU<LSE> <(>v1 v2 <td <tr <tf + <pw <per>>>>> <)>

See “Pulse Source Function” in the *Star-Hspice Manual*.

Sinusoidal Source Function

General Form	Vxxx n+ n- SIN <(> vo va <freq <td <q + <j>>>> <)>
Or	Ixxx n+ n- SIN <(> vo va <freq <td <q + <j>>>> <)>

See “Sinusoidal Source Function” in the *Star-Hspice Manual*.

Exponential Source Function

General Form	Vxxx n+ n- EXP <(> v1 v2 <td1 <*t*1 <td2 + <*t*2>>>> <)>
Or	Ixxx n+ n- EXP <(> v1 v2 <td1 <*t*1 <td2 + <*t*2>>>> <)>

See “Exponential Source Function” in the *Star-Hspice Manual*.

Piecewise Linear Source Function

General Form	Vxxx n+ n- PWL <(> t1 v1 <t2 v2 t3 v3…> + <R <=repeat>> <TD=delay> <)>
Or	Ixxx n+ n- PWL <(> t1 v1 <t2 v2 t3 v3…> + <R <=repeat>> <TD=delay> <)>

See "Piecewise Linear (PWL) Source Function" in the *Star-Hspice Manual*.

MSINC and ASPEC

General Form	Ixxx n+ n- PL <(> v1 t1 <v2 t2 v3 t3…> +<R <=repeat>> <TD=delay> <)>

Data Driven Piecewise Linear Source Function

General Form	Vxxx n+ n- PWL (TIME, PV)
along with:	.DATA dataname TIME PV t1 v1 t2 v2 t3 v3 t4 v4 .. .. .ENDDATA .TRAN DATA=datanam
Or	Ixxx n+ n- PWL (TIME, PV)

See "Data Driven Piecewise Linear Source Function" in the *Star-Hspice Manual*.

Single-Frequency FM Source Function

General Form	`Vxxx n+ n-` SFFM <(> vo va <fc <mdi + <fs>>> <)>
Or	`Ixxx n+ n-` SFFM <(> vo va <fc <mdi + <fs>>> <)>

See “Single-Frequency FM Source Function” in the *Star-Hspice Manual*.

Amplitude Modulation Source Function

General Form	Vxxx n+ n- AM <(> so sa fm fc <td> <)>
Or	Ixxx n+ n- AM <(> so sa fm fc <td> <)>

See “Amplitude Modulation Source Function” in the *Star-Hspice Manual*.

AM	Keyword for an amplitude-modulated time-varying source.
EXP	Keyword for a exponential time-varying source.
fc	Carrier frequency in Hz.
fm	Modulation frequency in hertz.
freq	Source frequency in Hz. Default=1/TSTOP.
fs	Signal frequency in Hz.
j	Phase delay in units of degrees.
mdi	Modulation index that determines the magnitude of deviation from the carrier frequency.

oc	Offset constant, a unitless constant that determines the absolute magnitude of the modulation.
per	Pulse repetition period in seconds.
PULSE	Keyword for a pulsed time-varying source.
PV	Parameter name for amplitude value provided in a .DATA statement.
pw	Pulse width (the width of the plateau portion of the pulse) in seconds.
PWL	Keyword for a piecewise linear time-varying source.
q	Damping factor in units of 1/seconds.
sa	Signal amplitude in volts or amps.
SFFM	Keyword for a single-frequency frequency-modulated time-varying source.
SIN	Keyword for a sinusoidal time-varying source.
$\tau 1$	Rise time constant in seconds.
t1 t2 … tn	Timepoint values where the corresponding current or voltage value is valid.
$\tau 2$	Fall time constant in seconds.
td	Delay time in seconds.
tf	Duration of the recovery ramp in seconds, from the pulse plateau back to the initial value (forward transit time).

TIME	Parameter name for time value provided in a .DATA statement.
tr	Duration of the onset ramp in seconds, from the initial value to the pulse plateau value (reverse transit time).
v1 v2 … vn	Current or voltage values at corresponding timepoint.
va	Voltage or current RMS amplitude in volts or amps.
vo	Voltage or current offset in volts or amps.
Vxxx, Ixxx	Independent voltage source.

Chapter 4

Transmission Lines

Star-Hspice supports the T Element, U Element, and W Element for transmission lines. Avant! encourages users to use the W Element, however, for all transmission line needs.

The topic covered in this chapter is W Element Statement.

For detailed information about the W Element, see "W Element Statement" in the *Star-Hspice Manual*.

W Element Statement

The general syntax for including a lossy (W Element) transmission line element in a Star-Hspice netlist is:

RLGC file form	Wxxx in1 <in2 <...inx>> refin out1 <out2 + <...outx>> refout <RLGCfile = fname> + N = val L = val
U-model form	Wxxx in1 <in2 <...inx>> refin out1 <out2 + <...outx>> refout <Umodel = mname> + N = val L = val
Field Solver form	Wxxx in1 <in2 <...inx>> refin out1 <out2 + <...outx>> refout <FSmodel = mname> + N = val L = val

where the number of ports on a single transmission line are not limited. One input and output port, the ground references, a model or file reference, a number of conductors, and a length are all required.

The arguments are defined as:

Wxxx	Lossy (W Element) transmission line element name.
inx	Signal input node for the x^{th} transmission line (in1 is required).
refin	Ground reference for input signal.
outx	Signal output node for the x^{th} transmission line (each input port must have a corresponding output port).
refout	Ground reference for output signal.
RLGCfile = f name	File name reference for file containing the RLGC information for the transmission lines.
N	Number of conductors (excluding the reference conductor).
L	Physical length of the transmission line in units of meters.
U model = mname	U model lossy transmission-line model reference name.
FS model = mname	Internal field solver model name.

Chapter 5

IBIS Conventions

The topics covered in this chapter are:

- Buffer Element
- Buffers
- Differential Pins
- Scaling Buffer Strength

For detailed information about IBIS conventions, see "Understanding IBIS Conventions" in the *Star-Hspice Manual*.

Buffer Element

The general syntax of an element card for I/O buffers is:

General Form	bname node_1 node_2 ... node_N + keyword_1=value_1 ... or + [keyword_M=value_M]
bname	Buffer element name.
keyword_i = value_i	Assigns value, *value_i*, to the keyword, *keyword_i*. Optional keywords are given in square brackets.
node_1 node_2 ... node_N	List of I/O buffer external nodes. The number of nodes and corresponding rules are specific to different buffer types (see later sections in this chapter).

Limitations and Restrictions

The series, series switch, and terminator buffers are not implemented in the 00.4 version of Star-Hspice.

You can simulate the terminator by using other existing Star-Hspice elements: resistors, capacitors, and voltage dependent current sources.

For details, see "Limitations and Restrictions" in the *Star-Hspice Manual*.

Buffers

Input Buffer Syntax

```
B_input nd_pc nd_gc nd_in nd_out_of_in
+ file='filename' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
+ [buffer={1|input}]
+ [interpol={1|2}]
+ [nowarn]
+ [c_com_pc=c_com_pc_value]
+ [c_com_gc=c_com_gc_value]
```

where the total number of external nodes is equal to 4.

See "Input Buffer" in the *Star-Hspice Manual*.

Output Buffer Syntax

```
B_output nd_pu nd_pd nd_out nd_in [nd_pc nd_gc]
+ file='file_name' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
+ [buffer={2|output}]
+ [xv_pu=state_pu] [xv_pd=state_pd]
```

```
+ [interpol={1|2}]
+ [ramp_fwf={0|1|2}] [ramp_rwf={0|1|2}]
+ [fwf_tune=fwf_tune_value] [rwf_tune=rwf_tune_value]
+ [nowarn]
+ [c_com_pu=c_com_pu_value]
+ [c_com_pd=c_com_pd_value]
+ [c_com_pc=c_com_pc_value]
+ [c_com_gc=c_com_gc_value]
```

See "Output Buffer" in the *Star-Hspice Manual*.

Tristate Buffer Syntax

```
B_3state nd_pu nd_pd nd_out nd_in nd_en [nd_pc nd_gc]
+ file='file_name' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
+ [buffer={4|three_state}]
+ [xv_pu=state_pu] [xv_pd=state_pd]
+ [interpol={1|2}]
+ [ramp_fwf={0|1|2}] [ramp_rwf={0|1|2}]
+ [fwf_tune=fwf_tune_value] [rwf_tune=rwf_tune_value]
+ [nowarn]
+ [c_com_pu=c_com_pu_value]
+ [c_com_pd=c_com_pd_value]
+ [c_com_pc=c_com_pc_value]
+ [c_com_gc=c_com_gc_value]
```

See "Tristate Buffer" in the *Star-Hspice Manual*.

Input/Output Buffer Syntax

```
B_io nd_pu nd_pd nd_out nd_in nd_en V_out_of_in [nd_pc
+ nd_gc] file='file_name' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
```

```
+ [buffer={3|input_output}]
+ [xv_pu=state_pu] [xv_pd=state_pd]
+ [interpol={1|2}]
+ [ramp_fwf={0|1|2}] [ramp_rwf={0|1|2}]
+ [fwf_tune=fwf_tune_value] [rwf_tune=rwf_tune_value]
+ [nowarn]
+ [c_com_pu=c_com_pu_value]
+ [c_com_pd=c_com_pd_value]
+ [c_com_pc=c_com_pc_value]
+ [c_com_gc=c_com_gc_value]
```

See “Input/Output Buffer” in the *Star-Hspice Manual*.

Open Drain, Open Sink, Open Source Buffers

All rules given in “Output Buffer Syntax” on page 5-2 apply with the following exceptions:

- Because open drain and open sink buffers do not have pullup circuitry, do not specify the option *xv_pu=nd_state_pu*.
- Similarly, because open source buffers do not have pulldown circuitry, do not specify the option *xv_pd=nd_state_pd*.

See “Open Drain, Open Sink, Open Source Buffers” in the *Star-Hspice Manual*.

I/O Open Drain, I/O Open Sink, I/O Open Source Buffers

All rules given in “Input/Output Buffer Syntax” on page 5-3 apply with the following exceptions:

- Because I/O open drain and I/O open sink buffers do not have pullup circuitry, do not specify the option *xv_pu=nd_state_pu*.
- Similarly, because I/O open source buffers do not have pulldown circuitry, do not specify the option *xv_pd=nd_state_pd*.

See “I/O Open Drain, I/O Open Sink, I/O Open Source Buffers” in the *Star-Hspice Manual*.

Input ECL Buffer Syntax

```
B_input_ecl nd_pc nd_gc nd_in nd_out_of_in
+ file='file_name' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
+ [buffer={11|input_ecl}]
+ [interpol={1|2}]
+ [nowarn]
+ [c_com_pc=c_com_pc_value]
+ [c_com_gc=c_com_gc_value]
```

See “Input ECL Buffer” in the *Star-Hspice Manual*.

Output ECL Buffer Syntax

```
B_output_ecl nd_pu nd_out nd_in [nd_pc nd_gc]
+ file='file_name' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
```

```
+ [buffer={12|output_ecl}]
+ [xv_pu=state_pu] [xv_pd=state_pd]
+ [interpol={1|2}]
+ [ramp_fwf={0|1|2}] [ramp_rwf={0|1|2}]
+ [fwf_tune=fwf_tune_value] [rwf_tune=rwf_tune_value]
+ [nowarn]
+ [c_com_pu=c_com_pu_value]
+ [c_com_pc=c_com_pc_value]
+ [c_com_gc=c_com_gc_value]
```

See “Output ECL Buffer” in the *Star-Hspice Manual*.

Tristate ECL Buffer Syntax

```
B_3state_ecl nd_pu nd_out nd_in nd_en [nd_pc nd_gc]
+ file='file_name' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
+ [buffer={14|three_state_ecl}]
+ [xv_pu=state_pu] [xv_pd=state_pd]
+ [interpol={1|2}]
+ [ramp_fwf={0|1|2}] [ramp_rwf={0|1|2}]
+ [fwf_tune=fwf_tune_value] [rwf_tune=rwf_tune_value]
+ [nowarn]
+ [c_com_pu=c_com_pu_value]
+ [c_com_pc=c_com_pc_value]
+ [c_com_gc=c_com_gc_value]
```

See “Tristate ECL Buffer” in the *Star-Hspice Manual*.

Input-Output ECL Buffer Syntax

```
B_io_ecl nd_pu nd_out nd_in nd_en nd_out_of_in [nd_pc
+ nd_gc] file='file_name' model='model_name'
+ [typ={typ|min|max|fast|slow}] [power={on|off}]
```

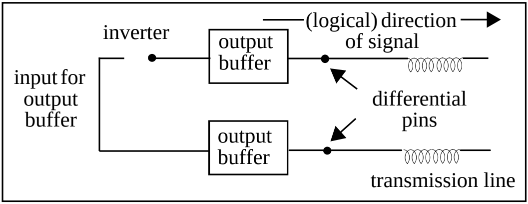
+ [buffer={13|io_ecl}]
+ [xv_pu=state_pu] [xv_pd=state_pd]
+ [interpol={1|2}]
+ [ramp_fwf={0|1|2}] [ramp_rwf={0|1|2}]
+ Input-Output ECL Buffer

See "Input-Output ECL Buffer" in the *Star-Hspice Manual*.

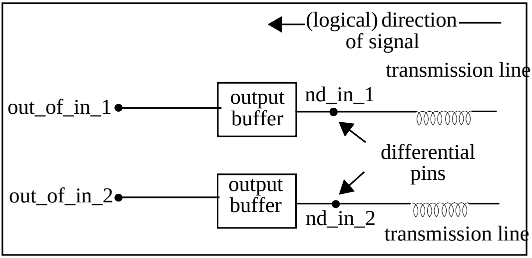
Differential Pins

For detailed information, see "Differential Pins" in the *Star-Hspice Manual*.

Output buffers:



Input buffers:



Scaling Buffer Strength

Sometimes you need to scale buffer strength to enable the same IBIS file to be used to simulate buffers of different strengths. K is the factor for current multiplication; for the original buffer, the value of K=1. This section describes how to scale using the F Element for a single output buffer and a differential output buffer. For detailed information, see "Scaling Buffer Strength" in the *Star-Hspice Manual*.

Original Circuit for a Single Output Buffer

```
Buffer nd_pu nd_pd nd_out nd_pc nd_gc
+ file=<filename> model=<modelname>
+ Rload nd_out gnd Rload_val
```

Scaled Circuit for a Single Output Buffer

```
Buffer nd_pu nd_pd nd_out nd_pc nd_gc
+ file=<filename> model=<modelname>Vsenser
+ nd_out nd_out_prime V=0 Rload nd_out_prime
+ gnd Rload_val Felement gnd nd_out_prime
+ Vsenser K-1
```

Original Circuit for a Differential Output Buffer

```
Buffer1 nd_pu1 nd_pd1 nd_out1 nd_pc1 nd_gc1
+ file=<filename1>  model=<modelname1>
Buffer2 nd_pu2 nd_pd2 nd_out2 nd_pc2 nd_gc2
+ file=<filename2>  model=<modelname2> R_load
+ n_out1  n_out2  R_load_value
```

Scaled Circuit for a Differential Output Buffer

```
Buffer1 nd_pu1 nd_pd1 nd_out1 nd_pc1 nd_gc1
+ file=<filename1> model=<modelname1>
Buffer2 nd_pu2 nd_pd2 nd_out2 nd_pc2 nd_gc2
+ file=<filename2> model=<modelname2> V_sense
+ n_out1 n_out1_prime 0V F_element n_out2
+ n_out1_prime v_sense K-1 R_load n_out1_prime
+ n_out2  R_load_value
```

Chapter 6

Diodes

The topics covered in this chapter are:

- Diode Element
- Junction Model Statement
- Junction Model Parameters
- Junction Cap Model
- Temperature Effects
- Fowler-Nordheim Diode

Diode Element

General Form	Dxxx nplus nminus mname + <<AREA = >area> <<PJ = >val> + <WP = val> <LP = val> <WM = val> + <LM = val> <OFF> <IC = vd> + <M = val> <DTEMP = val>
Or	Dxxx nplus nminus mname <W = width> + <L = length> <WP = val> <LP = val> + <WM = val> <LM = val> <OFF> + <IC = vd> <M = val> <DTEMP = val>
AREA	Area of the diode.

DTEMP	The difference between the element temperature and the circuit temperature in Celsius.
Dxxx	Diode element name.
IC = vd	Initial voltage across the diode element.
L	Length of the diode in meters (diode model LEVEL = 3 only).
LM	Width of metal capacitor in meters (for diode model LEVEL = 3 only).
LP	Length of polysilicon capacitor in meters (for diode model LEVEL = 3 only).
M	Multiplier to simulate multiple diodes in parallel.
mname	Diode model name reference.
nminus	Negative terminal (cathode) node name.
nplus	Positive terminal (anode) node name.
OFF	Sets initial condition to OFF for this element in DC analysis.
PJ	Periphery of junction.
W	Width of the diode in meters (diode model LEVEL = 3 only).
WM	Width of metal capacitor in meters (for diode model LEVEL = 3 only).

WP	Width of polysilicon capacitor in meters (for diode model LEVEL = 3 only).

See “Diode Element” in the *Star-Hspice Manual*.

Junction Model Statement

General Form	.MODEL mname D <LEVEL=val> + <keyword=val>
mname	Model name
D	Identifies a diode model
LEVEL	LEVEL=1: Junction diode LEVEL=2: Fowler-Nordheim diode LEVEL=3: Geometric processing for junction diode
keyword	Model parameter keyword, such as CJO or IS

See “Using the Junction Model Statement” in the *Star-Hspice Manual*.

Junction Model Parameters

Junction .DC Parameters LEVEL 1 and 3

Name (Alias)	Unit	Default	Description
AREA	-	1.0	Junction area.
EXPLI	amp/ AREAeff	1e15	Current explosion model parameter.

Name (Alias)	Unit	Default	Description
IB	amp	1.0e-3	Current at breakdown voltage.
IBV	amp	1.0e-3	Current at breakdown voltage.
IK (IKF, JBF)	amp/ AREAeff	0.0	Forward knee current.
IKR (JBR)	amp/ AREAeff	0.0	Reverse knee current.
IS (JS)	amp/ AREAeff	1.0e-14	Saturation current per unit area.
JSW (ISP)	amp/PJeff	0.0	Sidewall saturation current per unit junction periphery.
L	-	-	Default length of diode.
LEVEL	-	1	Diode model selector.
N	-	1.0	Emission coefficient
PJ	-	0.0	Junction periphery
RS	ohms or ohms/m^2	0.0	Ohmic series resistance.
SHRINK	-	1.0	Shrink factor.

Name (Alias)	Unit	Default	Description
VB (BV, VAR, VRB)	V	0.0	Reverse breakdown voltage.
W	-	-	Default width of diode
XW	-	-	Accounts for masking and etching effects.

See "Using Junction Model Parameters" in the *Star-Hspice Manual*.

Junction Capacitance Parameters

Name (Alias)	Unit	Default	Description
CJ (CJA, CJO)	F/ AREAeff	0.0	Zero-bias bottomwall capacitance
CJP (CJSW)	F/PJeff	0.0	Zero-bias periphery capacitance
FC	-	0.5	Coefficient for forward-bias depletion area capacitance formula
FCS	-	0.5	Coefficient for forward-bias depletion periphery capacitance formula

Name (Alias)	Unit	Default	Description
M (EXA, MJ)	-	0.5	Area junction grading coefficient
MJSW (EXP)	-	0.33	Periphery junction grading coefficient
PB (PHI, VJ, PHA)	V	0.8	Area junction contact potential
PHP	V	PB	Periphery junction contact potential
TT	s	0.0	Transit time

See “Setting Junction Capacitance Parameters” in the *Star-Hspice Manual*.

Junction Cap Model

General Syntax

General Form	Dxxx nodeplus nodeminus modelname + <<area=>val> <<peri=>val> + <<pgate>=val> <<dtemp>=val> + <<off>=val> <<IC=>val> <<m=>val>
Dxxx	Diode element name. Must begin with “D”

nodeplus	Positive terminal (anode) node name. The series resistor of the equivalent circuit is attached to this terminal
nminus	Negative terminal (cathode) node name
mname	Diode model name reference
area	Diode area. In the model card, it can be used by AB
peri	Length of the side-wall of the diffusion area AB which is not under the gate. In the model card, it is used by LS
pgate	Length of the side-wall of the diffusion area AB which is under the gate. In the model card, it is used by LG
off	Sets initial condition to OFF for this element in DC analysis. The default is ON
M	Multiplier to simulate multiple diodes in parallel. All currents, capacitances and resistances are affected by setting M. Default=1
ic	Initial voltage across the diode element. This value is used when the UIC option is present in the .tran statement and is overriden by the .ic statement
Dtemp	The difference between the element temperature and circuit temperature in celsius. Default=0.0

.option list	Prints the updated temperature parameters for juncap diode model

Junction Cap Model Statement

General Form	.MODEL modelname D level=4 <keyword=val>
modelname	Model name
D	Identifies a diode model
LEVEL	Identifies a diode model
keyword	Model parameter keyword, such as JSGBR or JSDBR

See "Using the Junction Cap Model" in the *Star-Hspice* manual.

Juncap Model Parameters

Name (Alias)	Unit	Default	Description
AB	M^2	1e-12	Diffusion area
LS	M	1.0e-6	Diffusion area side-wall length not under gate
LG	M	0.0	Diffusion area side-wall length under gate
DTA	C	0.0	Temperature offset of Juncap element

Name (Alias)	Unit	Default	Description
TR	C	25	Pre-determined temp parameters
VR	V	0.0	Pre-determined voltage parameters
JSGBR	Am^{-2}	1.0E-3	Bottom saturation-current density due to electron hole
JSDBR	Am^{-2}	1.0E-3	Bottom saturation-current density due to back contact
JSGSR	Am^{-2}	1.0E-3	Sidewall saturation-current due to electron hole
JSDSR	Am^{-2}	1.0E-3	Sidewall saturation-current due to back contact
JSGGR	Am^{-2}	1.0E-3	Gate edge saturation current due to electron hole
JSDGR	Am^{-2}	1.0E-3	Gate edge saturation current due to back contact

Name (Alias)	Unit	Default	Description
JSGGR	Am^{-2}	1.0E-3	Gate edge saturation current due to electron hole
JSDGR	Am^{-2}	1.0E-3	Gate edge saturation current due to back contact
NB		1.0	Emission coefficient of bottom forward current
NS		1.0	Emission coefficient of sidewall forward current
NG		1.0	Emission coefficient of gate edge forward current
VB	V	0.9	Reverse breakdown voltage
CJBR	Fm^{-2}	1.0E-12	Bottom junction capacitance
CJSR	Fm^{-2}	1.0E-12	Sidewall junction capacitance
CJGR	Fm^{-2}	1.0E-12	Gate edge junction capacitance
VDBR	V	1.00	Diffusion voltage of bottom junction

Name (Alias)	Unit	Default	Description
VDSR	V	1.00	Diffusion voltage of sidewall junction
VDGR	V	1.00	Diffusion voltage of gate edge junction
PB		0.40	Bottom junction grading coefficient
PS		0.40	Sidewall junction grading coefficient
PG		0.40	Gate edge junction grading coefficient

See "Juncap Model Parameters" in the *Star-Hspice* manual.

Metal and Poly Parameters Level 3

Name (Alias)	Unit	Default	Description
LM	m	0.0	Default length of metal
LP	m	0.0	Default length of polysilicon.
WM	m	0.0	Default width of metal.
WP	m	0.0	Default width of polysilicon.
XM	m	0.0	Accounts for masking and etching effects in metal layer.

Name (Alias)	Unit	Default	Description
XOI	Å	7000	Thickness of the poly to bulk oxide.
XOM	Å	10k	Thickness of the metal to bulk oxide.
XP	m	0.0	Accounts for masking and etching effects in poly layer.

See “Setting Metal and Poly Capacitor Parameters for LEVEL=3” in the *Star-Hspice Manual*.

Noise Parameters LEVEL 1 and 3

Name (Alias)	Unit	Default	Description
AF	-	1.0	Flicker noise exponent
KF	-	0.0	Flicker noise coefficient

See “Setting Noise Parameters for LEVEL=1 and 3” in the *Star-Hspice Manual*.

Temperature Effects

See “Determining Temperature Effects on Junction Diodes” in the *Star-Hspice Manual*.

Temperature Effect Parameters LEVEL 1 and 3

Name (Alias)	Unit	Default	Description
CTA (CTC)	1/°	0.0	Temperature coefficient for area junction capacitance (CJ).
CTP	1/°	0.0	Temperature coefficient for periphery junction capacitance (CJP).
EG	eV	-	Energy gap for pn junction diode.
GAP1	eV/°	7.02e-4	First bandgap correction factor. From Sze, alpha term.
GAP2		1108	Second bandgap correction factor. From Sze, beta term.
TCV	1/°	0.0	Breakdown voltage temperature coefficient.
TLEV	-	0.0	Temperature equation LEVEL selector for diode; interacts with TLEVC.

Name (Alias)	Unit	Default	Description
TLEVC	-	0.0	LEVEL selector for diode temperature, junction capacitances, and contact potentials; interacts with TLEV.
TM1	1/°	0.0	First-order temperature coefficient for MJ.
TM2	$1/°^2$	0.0	Second-order temperature coefficient for MJ.
TPB (TVJ)	V/°	0.0	Temperature coefficient for PB.
TPHP	V/°	0.0	Temperature coefficient for PHP.
TREF		25.0	Model reference temperature (LEVEL 1 or 3 only).
TRS	1/°	0.0	Resistance temperature coefficient.
TTT1	1/°	0.0	First-order temperature coefficient for TT.
TTT2	$1/°^2$	0.0	Second-order temperature coefficient for TT.

Name (Alias)	Unit	Default	Description
XTI	-	3.0	Saturation current temperature exponent.

See “Setting Temperature Effect Parameters LEVEL=1 and 3” in the *Star-Hspice Manual*.

Fowler-Nordheim Diode

See “Using the Fowler-Nordheim Diode” in the *Star-Hspice Manual*.

Fowler-Nordheim Tunnel Diode Element

LEVEL 2 Form	Dxxx nplus nminus mname <W=val + <L=val>> <WP=val><OFF> + <IC=vd> + <M=val>
Dxxx	Diode element name.
nplus	Positive terminal (anode) node name.
nminus	Negative terminal (cathode) node name.
mname	Model name.
OFF	Sets initial condition to OFF in DC analysis. Default=ON.
IC=vd	Initial voltage across this element.
M	Multiplier factor to simulate multiple diodes.

W	Width of diode in units of meter. Overrides W in the LEVEL 2 model. Default=0.0
L	Length of diode in units of meter. Overrides L in the LEVEL 2 model. Default=0.0

See “Diode Element” in the *Star-Hspice Manual*.

Diode Model Parameters LEVEL=2

Name (Alias)	Unit	Default	Description
EF	V/cm	1.0e8	Forward critical electric field
ER	V/cm	EF	Reverse critical electric field
JF	amp/V^2	1.0e-10	Forward Fowler-Nordheim current coefficient
JR	amp/V^2	JF	Reverse Fowler-Nordheim current coefficient
L	m	0.0	Length of diode for calculation of Fowler-Nordheim current
TOX	Å	100.0	Thickness of oxide layer

Name (Alias)	Unit	Default	Description
W	m	0.0	Width of diode for calculation of Fowler-Nordheim current
XW	m	0.0	Account for masking and etching effects

Chapter 7

BJT Element

The topics covered in this chapter are:

- Bipolar Junction Transistors (BJTs) Element
- BJT Model Statement
- BJT Model Parameters
- LEVEL 6 Philips Bipolar Model-503 and 504
- LEVEL 8 HiCUM Model

Bipolar Junction Transistors (BJTs) Element

General Form	Qxxx nc nb ne <ns> mname <area> <OFF> + <IC=vbeval, vceval> <DTEMP=val> + <M=val>
Or	Qxxx nc nb ne <ns> mname <AREA=val> + <AREAB=val> <AREAC=val> <OFF> + <VBE=vbeval> <VCE=vceval> <M=val> + <DTEMP=val>
area, AREA=area	Emitter area multiplying factor, which affects currents, resistances, and capacitances.

AREAB	Base AREA.
AREAC	Collector AREA.
DTEMP	The difference between element and circuit temperature.
IC=vbeval, vceval, VBE, VCE	Initial internal base-emitter voltage (vbeval) and collector-emitter voltage (vceval).
M	Multiplier factor to simulate multiple BJTs in parallel.
mname	BJT model name reference.
nb	Base terminal node name.
nc	Collector terminal node name.
ne	Emitter terminal node name.
ns	Substrate terminal node name, optional.
OFF	Sets initial condition to OFF in DC analysis.
Qxxx	BJT element name.

See "Bipolar Junction Transistors (BJTs) Element" in the *Star-Hspice Manual*.

BJT Model Statement

General Form	.MODEL mname NPN + <(> <pname1=val1> ... <)>
Or	.MODEL mname PNP <pname1=val1> ...

mname	Model name
NPN	Identifies an NPN transistor model
pname1	Several model parameters are possible
PNP	Identifies a PNP transistor model

See "Understanding the BJT Model Statement" in the *Star-Hspice Manual*.

BJT Model Parameters

Basic DC Model Parameters

Name (Alias)	Unit	Default	Definition
BF (BFM)	-	100.0	Ideal maximum forward BETA
BR (BRM)	-	1.0	Ideal maximum reverse BETA
BULK (NSUB)	-	0.0	Sets the bulk node to a global node name
IBC	amp	0.0	Reverse saturation current between base and collector
EXPLI	amp	1.e15	Current explosion model parameter
IBE	amp	0.0	Reverse saturation current between base and emitter

Name (Alias)	Unit	Default	Definition
IS	amp	1.0e-16	Transport saturation current
ISS	amp	0.0	Reverse saturation current bulk-to-collector or bulk-to-base
LEVEL	-	1.0	Model selector
NF	-	1.0	Forward current emission coefficient
NR	-	1.0	Reverse current emission coefficient
NS	-	1.0	Substrate current emission coefficient
SUBS	-	-	Substrate connection selector
UPDATE	-	0	Selects alternate base charge equation

See “Using BJT Basic DC Model Parameters” in the *Star-Hspice Manual*.

Low-Current Beta Degradation Effect Parameters

Name (Alias)	Unit	Default	Definition
ISC (C4, JLC)	amp	0.0	Base-collector leakage saturation current
ISE (C2, JLE)	amp	0.0	Base-emitter leakage saturation current
NC (NLC)	-	2.0	Base-collector leakage emission coefficient
NE (NLE)	-	1.5	Base-emitter leakage emission coefficient

See “Using Low-Current Beta Degradation Effect Parameters” in the *Star-Hspice Manual*.

Base Width Modulation Parameters

Name (Alias)	Unit	Default	Definition
VAF (VA, VBF)	V	0.0	Forward early voltage
VAR (VB, VRB, BV)	V	0.0	Reverse early voltage

See “Using Base Width Modulation Parameters” in the *Star-Hspice Manual*.

High-Current Beta Degradation Effect Parameters

Name (Alias)	Unit	Default	Definition
IKF (IK, JBF)	amp	0.0	Corner for forward Beta high-current roll-off
IKR (JBR)	amp	0.0	Corner for reverse Beta high-current roll-off
NKF	-	0.5	Exponent for high-current Beta roll-off
IKF (IK, JBF)	amp	0.0	Corner for forward Beta high-current roll-off

See “Using High-Current Beta Degradation Effect Parameters” in the *Star-Hspice Manual*.

Parasitic Resistance Parameters

Name (Alias)	Unit	Default	Definition
IRB (IRB, IOB)	amp	0.0	Base current, where base resistance falls half-way to RBM
RB	ohm	0.0	Base resistance
RBM	ohm	RB	Minimum high-current base resistance
RC	ohm	0.0	Collector resistance
RE	ohm	0.0	Emitter resistance

See “Using Parasitic Resistance Parameters” in the *Star-Hspice Manual*.

Junction Capacitor Parameters

Name (Alias)	Unit	Default	Definition
CJC	F	0.0	Base-collector zero-bias depletion capacitance
CJE	F	0.0	Base-emitter zero-bias depletion capacitance
CJS (CCS, CSUB)	F	0.0	Zero-bias collector substrate capacitance
FC	-	0.5	Coefficient for forward bias depletion capacitance
MJC (MC)	-	0.33	Base-collector junction exponent (grading factor)
MJE (ME)	-	0.33	Base-emitter junction exponent (grading factor)
MJS (ESUB)	-	0.5	Substrate junction exponent (grading factor)
VJC (PC)	V	0.75	Base-collector built-in potential

Name (Alias)	Unit	Default	Definition
VJE (PE)	V	0.75	Base-emitter built-in potential
VJS (PSUB)	V	0.75	Substrate junction built-in potential
XCJC (CDIS)	-	1.0	Internal base fraction of base-collector depletion capacitance

See “Using Junction Capacitor Parameters” in the *Star-Hspice Manual*.

Parasitic Capacitances Parameters

Name (Alias)	Unit	Default	Definition
CBCP	F	0.0	External base-collector constant capacitance
CBEP	F	0.0	External base-emitter constant capacitance
CCSP	F	0.0	External collector substrate constant capacitance (vertical) or base substrate (lateral)

See “Using Parasitic Capacitances Parameters” in the *Star-Hspice Manual*.

Transit Time Parameters

Name (Alias)	Unit	Default	Definition
ITF (JTF)	amp	0.0	TF high-current parameter
PTF	°	0.0	Frequency multiplier to determine excess phase
TF	s	0.0	Base forward transit time
TR	s	0.0	Base reverse transit time
VTF	V	0.0	TF base-collector voltage dependence on coefficient
XTF	-	0.0	TF bias dependence coefficient

See “Using Transit Time Parameters” in the *Star-Hspice Manual*.

Noise Parameters

Name (Alias)	Unit	Default	Definition
AF	-	1.0	Flicker-noise exponent
KF	-	0.0	Flicker-noise coefficient

See "Using Noise Parameters" in the *Star-Hspice Manual*.

LEVEL 6 Philips Bipolar Model

General Form	Qxxx nc nb ne <ns> mname + <AREA=val><OFF<VBE=val> + <VCE=val> <M=val><DTEMP=val>
AREA	The normalized emitter area.
DTEMP	The difference between element and circuit temperature.
M	Multiplier to simulate multiple BJTs in parallel.
mname	BJT model name reference.
nb	Base node name or number.
nc	Collector terminal node name or number.
ne	Emitter terminal node name or number.
ns	Substrate node name or number.
OFF	Sets initial condition to OFF for this element in DC analysis.
Qxxx	BJT element name.
VBE	Initial internal base to emitter voltage.
VCE	Initial internal collector to emitter voltage.

See "LEVEL 6 Element Syntax" in the *Star-Hspice Manual*.

LEVEL 6 Model Parameters

The following tables describe MEXTRAM as LEVEL 6 model parameters including parameters name, descriptions, units, default values and notes. For more detailed information, see "LEVEL 6 Model Parameters" in the *Star-Hspice Manual*.

This section describes parameters for LEVEL 503 only. See the following section for "LEVEL 6 Philips Bipolar Model (MEXTRAM LEVEL 504)" parameters.

Flags - Level 503

Parameters	Unit	Default	Description
EXAVL	-	0	Flag for extended modeling of avalanche currents
EXMOD	-	0	Flag for extended modeling of the reverse current gain
EXPHI	-	1	Flag for distributed high frequency effects

Basic Parameters - Level 503

Parameters	Unit	Default	Description
TREF	^oC	0.0	Model nominal temperature
IS	A	5.E-17	Collector-emitter saturation current

Parameters	Unit	Default	Description
BF	A	140.0	Ideal forward current gain
XIBI	-	0.0	Fraction of ideal base current that belongs to the sidewall
IBF	A	2.0E-14	Saturation current of the non-ideal forward base current
VLF	V	0.5	Cross-over voltage of the non-ideal forward base current
IK	A	15.E-3	High-injection knee current
BRI	-	16.0	Ideal reverse current gain
IBR	A	8.0e-15	Saturation current of the non-ideal reverse base current
VLR	V	0.5	Cross-over voltage of the non-ideal reverse base current

Parameters	Unit	Default	Description
XEXT	-	0.5	Part of I EX ,Q EX ,Q TEX and I SUB that depends on the base-collector voltage VBC1
QBO	C	1.2e-12	Base charge at zero bias
ETA	-	4.0	Factor of the built-in field of the base
AVL	-	50.	Weak avalanche parameter
EFI	-	0.7	Electric field intercept (with EXAVL=1)
IHC	A	3.e-3	Critical current for hot carriers
RCC	ohm	25.	Constant part of the collector resistance
RCV	ohm	750.	Resistance of the unmodulated epilayer
SCRCV	ohm	1000.0	Space charge resistance of the epilayer
SFH	-	0.6	Current spreading factor epilayer

Parameters	Unit	Default	Description
RBC	ohm	50.	Constant part of the base resistance
RBV	ohm	100.	Variable part of the base resistance at zero bias
RE	ohm	2.0	Emitter series resistance
TAUNE	s	3.e-10	Minimum delay time of neutral and emitter charge
MTAU	-	1.18	Non-ideality factor of the neutral and emitter charge
CJE	F	2.5e-13	Zero bias collector-base depletion capacitance
VDE	V	0.9	Emitter-base diffusion voltage
PE	-	0.33	Emitter-base grading coefficient
XCJE	F	0.5	Fraction of the emitter-base depletion capacitance that belongs to the sidewall

Parameters	Unit	Default	Description
CJC	F	1.3e-13	Zero bias collector-base depletion capacitance
VDC	V	0.6	Collector-base diffusion voltage
PC	-	0.4	Collector-base grading coefficient variable part
XP	F	0.2	Constant part of CJC
MC	-	0.5	Collector current modulation coefficient
XCJC	-	0.1	Fraction of the collector-base depletion capacitance under the emitter area
VGE	V	1.01	Band-gap voltage of the emitter
VGB	V	1.18	Band-gap voltage of the base
VGC	V	1.205	Band-gap voltage of the collector
VGJ	V	1.1	Band-gap voltage recombination emitter-base junction

Parameters	Unit	Default	Description
VI	V	0.040	Ionization voltage base dope
NA	cm^-3	3.0E17	Maximum base dope concentration
ER	-	2.E-3	Temperature coefficient of VLF and VLR
AB	-	1.35	Temperature coefficient resistivity of the base
AEPI	-	2.15	Temperature coefficient resistivity of the epilayer
AEX	-	1.0	Temperature coefficient resistivity of the extrinsic base
AC	-	0.4	Temperature coefficient resistivity of the buried layer
KF	-	2.E-16	Flicker noise coefficient ideal base current

Parameters	Unit	Default	Description
KFN	-	2.E-16	Flicker noise coefficient non-ideal base current
AF	-	1.0	Flicker noise exponent
ISS	A	6.E-16	base-substrate saturation current
IKS	A	5.E-6	Knee current of the substrate
CJS	F	1.e-12	Zero bias collector-substrate depletion capacitance
VDS	V	0.5	Collector-substrate diffusion voltage
PS	-	0.33	Collector-substrate grading coefficient
VGS	V	1.15	Band-gap voltage of the substrate
AS	-	2.15	For a closed buried layer: AS=AC For an open buried layer: AS=AEPI

LEVEL 6 Philips Bipolar Model (MEXTRAM LEVEL 504)

The following tables describe MEXTRAM Level 504 as LEVEL 6 model parameters including parameter name, unit, default value, description and notes. For more detailed information, see "“LEVEL 6 Philips Bipolar Model (MEXTRAM LEVEL 504)”" in the *Star-Hspice Manual.*

Parameters noted with a ‘*’ are not used in the DC model.

Flags - Level 504

Parameters	Unit	Default	Description
LEVEL	-	6	Model level
VERS	-	504	Flag for choosing MEXTRAM model (level 503 or 504)
EXMOD	-	1	Flag for extended modeling of the reverse current gain
EXPHI	-	1	*Flag for distributed high frequency effects in transient
EXAVL	-	0	Flag for extended modeling of avalanche currents

Flags - Level 504

Parameters	Unit	Default	Description
TREF	^C	25.0	Reference temperature

Basic Parameters - Level 504

Parameters	Unit	Default	Description
IS	A	2.2e-17	Collector-emitter saturation current
VER		2.5	Reverse early voltage
VEF		44.0	Forward early voltage
BF	-	215.0	Ideal forward current gain
XIBI	-	0.0	Fraction of ideal base current that belongs to the sidewall
IBF	A	2.7e-15	Saturation current of the non-ideal forward base current
MLF	V	2.0	Non-ideality factor of the non-ideal forward base current

Basic Parameters - Level 504

Parameters	Unit	Default	Description
IK	A	0.1	Collector-emitter high injection knee current
BRI	-	7.0	Ideal reverse current gain
IBR	A	1.0e-15	Saturation current of the non-ideal reverse base current
VLR	V	0.2	Cross-over voltage of the non-ideal reverse base current
XEXT	-	0.63	Part of Iex, Qex, Qtex, and Isub that depends on the base-collector voltage Vbc1

Avalanche Model Parameters - Level 504

Parameters	Unit	Default	Description
WAVL	m	1.1e-6	Epilayer thickness used in weak-avalanche model

Avalanche Model Parameters - Level 504

Parameters	Unit	Default	Description
VAVL	V	3.0	Voltage determining the curvature of avalanche current
SFH	-	0.3	Current spreading factor of avalanche model (when EXAVL=1)

Resistance and Epilayer Parameters - Level 504

Parameters	Unit	Default	Description
RE	Ohm	5.0	Emitter resistance
RBC	Ohm	23.0	Constant part of the base resistance
RBV	Ohm	18.0	Zero-bias value of the variable part of the base resistance
RCC	Ohm	12.0	Constant part of the collector resistance
RCV	Ohm	150.0	Resistance of the un-modulated epilayer

Resistance and Epilayer Parameters - Level 504

Parameters	Unit	Default	Description
SCRCV	Ohm	1250.0	Space charge resistance of the epilayer
IHC	A	4.0e-3	Critical current for velocity saturation in the epilayer
AXI	-	0.3	Smoothness parameter for the onset of quasi-saturation

Base-Emitter Capacitances - Level 504

Parameters	Unit	Default	Description
CJE	F	7.3e-14	*Zero bias emitter-base depletion capacitance
VDE	V	0.95	Emitter-base diffusion voltage
PE	-	0.4	Emitter-base grading coefficient

Base-Emitter Capacitances - Level 504

Parameters	Unit	Default	Description
XCJE	-	0.4	*Fraction of the emitter-base depletion capacitance that belongs to the sidewall

Base-Collector Capacitances - Level 504

Parameters	Unit	Default	Description
CJC	F	7.8e-14	*Zero bias collector-base depletion capacitance
VDC	V	0.68	Collector-base diffusion voltage
PC	-	0.5	Collector-base grading coefficient
XP	-	0.35	Constant part of CJC
MC	-	0.5	Coefficient for the current modulation of the collector-base depletion capacitance

Base-Collector Capacitances - Level 504

Parameters	Unit	Default	Description
XCJC	-	3.2e-2	*Fraction of the collector-base depletion capacitance under the emitter

Transit Time Parameters - Level 504

Parameters	Unit	Default	Description
MTAU	-	1.0	*Non-ideality of the emitter stored charge
TAUE	S	2.0e-12	*Minimum transit time of stored emitter charge
TAUB	S	4.2e-12	*Transit time of stored base charge
TEPI	S	4.1e-11	*Transit time of stored epilayer charge
TAUR	S	5.2e-10	*Transit time of reverse extrinsic stored base charge
DEG	EV	0.0	Bandgap difference over the base

Transit Time Parameters - Level 504

Parameters	Unit	Default	Description
XREC	-	0.0	Pre-factor of the recombination part of Ib1

Temperature Parameters - Level 504

AQBO	-	0.3	Temperature coefficient of the zero-bias base charge
AE	-	0.0	Temperature coefficient of the resistivity of the emitter
AB	-	1.0	Temperature coefficient of the resistivity of the base
AEPI	-	2.5	Temperature coefficient of the resistivity of the epilayer

Temperature Parameters - Level 504

AEX	-	0.62	Temperature coefficient of the resistivity of the extrinsic base
AC	-	2.0	Temperature coefficient of the resistivity of the buried layer
DVGBF	V	5.0e-2	Bandgap voltage difference of forward current gain
CVGBR	V	4.5e-2	Bandgap voltage difference of reverse current gain
VGB	V	1.17	Bandgap voltage of the base
VGC	V	1.18	Bandgap voltage of the collector
VGJ	V	1.15	Bandgap voltage recombination emitter-base junction
DVGTE	V	0.05	*Bandgap voltage difference of emitter stored charge

Noise Parameters - Level 504

Parameters	Unit	Default	Description
AF	-	2.0	Exponent of the flicker-noise
KF	-	2.0e-11	Flicker-noise coefficient of the ideal base current
KFN	-	2.0e-11	Flicker-noise coefficient of the non-ideal base current

Substrate Parameters - Level 504

Parameters	Unit	Default	Description
ISS	A	4.8e-17	Base-substrate saturation current
IKS	A	2.5e-4	Base-substrate high injection knee current
CJS	F	3.15e-13	*Zero bias collector-substrate depletion capacitance
VDS	V	0.62	*Collector-substrate diffusion voltage

Substrate Parameters - Level 504

Parameters	Unit	Default	Description
PS	-	0.34	*Collector-substrate grading coefficient
VGS	V	1.2	Bandgap voltage of the substrate
AS	-	1.58	For a closed buried layer: AS=AC For an open buried layer: AS=AEPI

Self-Heating Parameters - Level 504

Parameters	Unit	Default	Description
RTH	^C/W	300.0	Thermal resistance
CTH	J/^C	3.0e-9	*Thermal capacitance

LEVEL 8 HiCUM Model

See “LEVEL 8 HiCUM Model” in the *Star-Hspice Manual*.

Model Parameters

Parameter	Unit	Default	Description

LEVEL	-	8	HiCUM BJT LEVEL in Hspice
TREF	C	26.85	Temperature in simulation

See “Model Parameters” in the *Star-Hspice Manual*.

Internal Transistors

See “Internal Transistors” in the *Star-Hspice Manual*.

Transfer Current Parameters

Parameter	Unit	Default	Description
C10	A^2s	3.76e-32	Constant(IS*QP0)
Qp0	As	2.78e-14	Zero-bias hole charge
ICH	A	2.09e-0z	High-current correction for 2D/3D
HFC	-	1.0	Weighting factor for Qfc(mainly for HBTs)
HFE	-	1.0	Weighting factor for Qef in HBTs
HJCI	-	1.0	Weighting factor for Qjci in HBTs
HJEI	-	0.0	Weighting factor for Qjei in HBTs
ALIT	-	0.45	Factor for additional delay time of iT

See “Transfer Current Parameters” in the *Star-Hspice Manual*.

BE Depletion Capacitance Parameters

Parameter	Unit	Default	Description
VDEI	V	0.95	Built-in voltage
CJEI0	F	8.11e-15	Zero-bias value
ZEI	-	0.5	Exponent coefficient
ALJEI	-	1.8	Ratio of max. to zero-bias value

See "BE Depletion Capacitance Parameters" in the *Star-Hspice Manual*.

BC Depletion Capacitance Parameters

Parameter	Unit	Default	Description
CJCI0	F	1.16e-15	Zero-bias value
VDCI	V	0.8	Built-in voltage
ZCI	-	0.333	Exponent coefficient
VPTCI	V	416	Punch-through voltage (=q Nci w^2ci / (2epsilion))

See "BC Depletion Capacitance Parameters" in the *Star-Hspice Manual*.

Forward Transit Time Parameters

Parameter	Unit	Default	Description
T0	s	4.75e-12	Low current transit time at $V_{B'C'}$=0
DT0H	s	2.1e-12	Time constant for base and BC SCR width modulation
TBVL	s	40e-12	Voltage for modeling carrier jam at low $V_{C'E'}$
TEF0	s	1.8e-12	Storage time in neutral emitter
GTFE	-	1.4	Exponent factor for current dep. emitter transit time
THCS	s	3.0e-11	Saturation time constant at high current densities
ALHC	-	0.75	Smoothing factor for current dep. C and B transit time
FTHC	-	0.6	Partitioning factor for base and collection portion
ALQF	-	0.225	Factor for additional delay time of Q_f

See “Forward Transit Time Parameters” in the *Star-Hspice Manual*.

Critical Current Parameters

Parameter	Unit	Default	Description
RCI0	Ohm	127.8	Low-field resistance of internal collector region
VLIM	V	0.7	Voltage separating ohmic and SCR regime
VPT	V	5.0	Epi punch-through vtg. of BC SCR
VCES	V	0.1	Internal CE sat. vtg.

See "Critical Current Parameters" in the *Star-Hspice Manual*.

Inverse Transit Time

Parameter	Unit	Default	Description
TR	s	1.0e-9	Time constant for inverse operation

See "Inverse Transit Time Parameter" in the *Star-Hspice Manual*.

Base Current Components

Parameter	Unit	Default	Description
IBEIS	A	1.16e-20	BE saturation current
MBEI	-	1.015	BE saturation current

Parameter	Unit	Default	Description
IREIS	A	1.16e-6	BE recombination saturation current
MREI	-	2.0	BE recombination non-ideality factor
IBCIS	A	1.16e-20	BC saturation current
MBCI	-	1.015	BC non-ideality factor

See "Base Current Components Parameters" in the *Star-Hspice Manual*.

Weak BC Avalanche Breakdown

Parameter	Unit	Default	Description
FAVL	1/V	1.186	Prefactor for CB avalanche effect
QAVL	As	1.11e-14	Exponent factor for CB avalanche effect

See "Weak BC Avalanche Breakdown Parameters" in the *Star-Hspice Manual*.

Internal Base Resistance

Parameter	Unit	Default	Description
RBI0	Ohm	0	Value at zero-bias

Parameter	Unit	Default	Description
FDQR0	-	0.0	Correction factor for modulation by BE abd BC SCR
FGEO	-	0.73	Geometry factor (value correspon- ding to long emitter stripe)
FQI	-	0.9055	Ratio of internal to total minority charge
FCRBI	-	0.0	Ratio of h.f. shunt to total internal capacitance

See “Internal Base Resistance Parameters” in the *Star-Hspice Manual*.

Lateral Scaling

Parameter	Unit	Default	Description
LATB	-	3.765	Scaling factor for Qfc in b_E direction
LATL	-	0.342	Scaling factor for Qfc in l_E direction

See “Lateral Scaling” in the *Star-Hspice Manual*.

Peripheral Elements

See “Peripheral Elements” in the *Star-Hspice Manual*.

BE Depletion Capacitance

Parameter	Unit	Default	Description
CJEP0	F	2.07e-15	Zero-bias value
VDEP	V	1.05	Built-in voltage
ZEP	-	0.4	Depletion coeff
ALJEP	-	2.4	Ratio of max. to zero-bias value

See “BE Depletion Capacitance” in the *Star-Hspice Manual*.

Base Current

Parameter	Unit	Default	Description
IBEPS	A	3.72e-21	Saturation current
MBEP	-	1.015	Non-ideality factor
IREPS	A	1e-30	Recombination stturation factor
MREP	-	2.0	Recombination non-ideality factor

See “Base Current” in the *Star-Hspice Manual*.

BE Tunneling

Parameter	Unit	Default	Description
IBETS	A	0	Saturation current
ABET	-	0.0	Exponent coefficient

See “BE Tunneling” in the *Star-Hspice Manual*.

External Elements

See “External Elements” in the *Star-Hspice Manual*.

BC Capacitance

Parameter	Unit	Default	Description
CJCX0	F	5.393e-15	Zero-bias depletion value
VDCX	V	0.7	Built-in voltage
ZCX	-	0.333	Exponent coefficient
VPTCX	V	100	Punch-through voltage
CCOX	F	2.97e-15	Collector oxide capacitance
FBC	-	0.1526	Partioning factor for C_BCX =C'_BCx+C"_BCx

See “BC Capacitance” in the *Star-Hspice Manual*.

BC Base Current Component

Parameter	Unit	Default	Description
IBCXS	A	4.39e-20	Saturation current
MBCX	-	1.03	Non-ideality factor

See "BC Base Current Component" in the *Star-Hspice Manual*.

Other External Elements

Parameter	Unit	Default	Description
CEOX	F	1.13e-15	Emitter-base isolation overlap cap
RBX	Ohm	0	External base series resistance
RE	Ohm	0	Emitter series resistance
RCX	Ohm	0	External collector series resistance

See "Other External Elements" in the *Star-Hspice Manual*.

Substrate Transistor

Parameter	Unit	Default	Description
ITSS	A	0.0	Transfer saturation current
MSF	-	0.0	Non-ideality factor (forward transfer current)
TSF	-	0.0	Minority charge storage transit time
ISCS	A	0.0	Saturation current of CS diode
MSC	-	0.0	Non-ideality factor of CS diode

See “Substrate Transistor Parameters” in the *Star-Hspice Manual*.

Collector-Substrate Depletion Capacitance

Parameter	Unit	Default	Description
CJS0	F	3.64e-14	Zero-bias value of CS depletion cap
VDS	V	0.6	Built-in voltage
ZS	-	0.447	Exponent coefficient
VPTS	V	1000	Punch-through voltage

See “Collector-Substrate Depletion Capacitance” in the *Star-Hspice Manual*.

Substrate Coupling Network

Parameter	Unit	Default	Description
RSU	Ohm	0	Substrate series resistance
CSU	F	0	Substrate capacitance from permittivity of bulk material

See “Substrate Coupling Network” in the *Star-Hspice Manual*.

Noise Parameters

Parameter	Unit	Default	Description
KF	-	1.43e-8	Flicker noise factor (no unit only for AF=2!)
AF	-	2.0	Flicker noise exponent factor
KRBI	-	1.17	Factor for internal base resistance

See “Noise Parameters” in the *Star-Hspice Manual*.

Temperature Dependence

Parameter	Unit	Default	Description
VGB	V	1.17	Bandgap-voltage
ALB	1/K	6.3e-3	Relative temperature coefficient of forward current gain

Parameter	Unit	Default	Description
ALT0	1/K	0	First-order relative temperature coefficient of TEF0
KT0	1/K	0	Second-order relative temperature coefficient of TEF0
ZETACI	-	1.6	Temperature exponent factor RCI0
ALVS	1/K	1e-3	Relative temperature coefficient of saturation drift velocity
ALCES	1/K	0.4e-3	Relative temperature coefficient of VCES
ZETARBI	-	.588	Temperature exponent factor of RBi0
ZETARBX	-	0.2060	Temperature exponent factor of RBX
ZETARCX	-	0.2230	Temperature exponent factor of RCX
ZETARE	-	0	Temperature exponent factor of RE
ALFAV	1/K	8.25e-5	Relative temperature coefficient for avalanche breakdown

Parameter	Unit	Default	Description
ALQAV	1/K	1.96e-4	Relative temperature coefficient for avalanche breakdown

See “Temperature Dependence Parameters” in the *Star-Hspice Manual*.

Self-Heating

Parameter	Unit	Default	Description
RTH	K/W	0	Thermal resistance (not supported in v2000.4)
CTH	Ws/K	0	Thermal resistance (not supported in v2000.4)

See “Self-Heating Parameters” in the *Star-Hspice Manual*.

Other Parameters

Parameter	Unit	Default	Description
FBCS	-	1.0	Determine external BC capacitance partitioning.
IS	1.0	A	Ideal saturation current
KRBI	-	1.0	Noise analysis of internal resistance.

Parameter	Unit	Default	Description
MCF	-	1.0	Non-ideality factor of reverse current between base and collector. VT=VT*MCF
MSR	-	1.0	Non-ideality factor of reverse current in substrate transistor. VT=VT*MSR
ZETACX	-	1.0	Temperature exponent factor (epi-layer)

Avant!

Chapter 8

Elements

This chapter provides an overview of the JFET, MESFET, and GASFET elements. The topics covered in this chapter are:

- General Form for Elements
- JFET and MESFET Model Statements
- JFET Model Parameters

For more detailed information, see “JFETs and MESFETs” in the *Star-Hspice Manual*.

General Form for Elements

General Form	Jxxx nd ng ns <nb> mname + <<<AREA> = area | <W = val> + <L = val>> <OFF> + <IC = vdsval,vgsval> <M = val> + <DTEMP = val>
Or	Jxxx nd ng ns <nb> mname + <<<AREA> = area> | <W = val> + <L = val>> <OFF> <VDS = vdsval> + <VGS = vgsval> <M = val> + <DTEMP = val>

area, AREA = area	Area multiplying factor that affects the BETA, RD, RS, IS, CGS and CGD model parameters.
DTEMP	The difference between the element temperature and the circuit temperature in Celsius.
IC = vdsval, vgsval, VDS, VGS	Initial internal drain-source voltage (vdsval) and gate-source voltage (vgsval).
Jxxx	JFET or MESFET element name.
L	FET gate length in meters.
M	Multiplier to simulate multiple JFETs or MESFETs in parallel.
mname	JFET or MESFET model name reference.
nb	Bulk terminal node name, which is optional.
nd	Drain terminal node name.
ng	Gate terminal node name.
ns	Source terminal node name.
OFF	Sets initial condition to OFF for this element in DC analysis.
W	FET gate width in meters.

JFET and MESFET Model Statements

General Form	.MODEL mname NJF <LEVEL=val> + <pname1=val1> ...
Or	.MODEL mname PJF <LEVEL=val> + <pname1=val1> ...
LEVEL	The LEVEL parameter selects different DC model equations
mname	Model name
NJF	Identifies an n-channel JFET or MESFET model
PJF	Identifies a p-channel JFET or MESFET model
pname1=val1	Can include several model parameters

See “Using JFET and MESFET Model Statements” in the *Star-Hspice Manual*.

JFET Model Parameters

See “JFET and MESFET Model Parameters” in the *Star-Hspice Manual*.

Gate Diode DC Parameters

Name (Alias)	Unit	Default	Description
ACM	-	-	Area calculation method
ALIGN	m	0	Misalignment of gate

Name (Alias)	Unit	Default	Description
AREA	-	-	The default area multiplier
HDIF	m	0	Distance of the heavily diffused or low resistance region from source or drain contact edge to lightly doped region
IS	amp	1.0e-14	Gate junction saturation current
L	m	0.0	Default length of FET
LDEL	m	0.0	Difference between drawn and actual or optical device length
LDIF	m	0	Width of the lightly doped region from heavily doped region to transistor edge
N	-	1.0	Emission coefficient for gate-drain and gate-source diodes
RD	ohm	0.0	Drain ohmic resistance
RG	ohm	0.0	Gate resistance

Name (Alias)	Unit	Default	Description
RS	ohm	0.0	Source ohmic resistance
RSH	ohm/sq	0	Heavily doped region, sheet resistance
RSHG	ohm/sq	0	Gate sheet resistance
RSHL	ohm/sq	0	Lightly doped region, sheet resistance
W	m	0.0	Default width of FET
WDEL	m	0.0	The difference between drawn & actual or optical device width

See “Gate Diode DC Parameters” in the *Star-Hspice Manual*.

Gate Capacitance LEVEL 1, 2, and 3 Parameters

Name (Alias)	Unit	Default	Description
CAPOP	-	0.0	Capacitor model selector
CALPHA	ALPHA	-	Saturation factor for capacitance model (CAPOP=2 only)

Name (Alias)	Unit	Default	Description
CAPDS	F	0	Drain to source capacitance for TriQuint model
CGAMDS	GAMDS	-	Threshold lowering factor for capacitance (CAPOP=2 only)
CGD	F	0.0	Zero-bias gate-drain junction capacitance
CGS	F	0.0	Zero-bias gate-source junction capacitance
CRAT		0.666	Source fraction of gate capacitance (used with GCAP)
GCAP	F	-	Zero-bias gate capacitance

See "Gate Capacitance LEVEL 1, 2, and 3 Parameters" in the *Star-Hspice Manual*.

DC Model LEVEL 1 Parameters

Name (Alias)	Unit	Default	Description
LEVEL	-	1.0	LEVEL=1 invokes SPICE JFET model.
BETA	amp/V^2	1.0e-4	Transconductance parameter, gain.

Name (Alias)	Unit	Default	Description
LAMBDA	1/V	0.0	Channel length modulation parameter.
ND	1/V	0.0	Drain subthreshold factor.
NG	-	0.0	Gate subthreshold factor.
VTO	V	-2.0	Threshold voltage.

See "DC Model LEVEL 1 Parameters" in the *Star-Hspice Manual*.

DC Model LEVEL 2 Parameters

Name (Alias)	Unit	Default	Description
LEVEL	-	1.0	LEVEL of FET DC model.
BETA	amp/V^2	1.0e-4	Transconductance parameter, gain.
LAMBDA	1/V	0.0	Channel length modulation parameter.
LAM1	1/V	0.0	Channel length modulation gate voltage parameter.
ND	1/V	0.0	Drain subthreshold factor.

Name (Alias)	Unit	Default	Description
NG	-	0.0	Gate subthreshold factor.
VTO	V	-2.0	Threshold voltage.

See “DC Model LEVEL 2 Parameters” in the *Star-Hspice Manual*.

DC Model LEVEL 3 Parameters

Name (Alias)	Unit	Default	Description
LEVEL	-	1.0	LEVEL of FET DC model; LEVEL=3 is the Curtice MESFET model
A	m	0.5μ	Active layer thickness
ALPHA	1/V	2.0	Saturation factor
BETA	amp /V ^{2}	1.0e-4	Transconductance parameter, gain $BETAeff = BETA \cdot \frac{Weff \cdot M}{Leff}$
D	-	11.7	Semiconductor dielectric constant: Si=11.7, GaAs=10.9
DELTA	-	0	Ids feedback parameter of TriQuint model

Name (Alias)	Unit	Default	Description
GAMDS (*GAMMA*)	-	0	Drain voltage, induced threshold voltage lowering coefficient
LAMBDA	1/V	0.0	Channel length modulation parameter
K1	$V^{1/2}$	0.0	Threshold voltage sensitivity to bulk node
NCHAN	$atom/cm^3$	1.552e16	Effective dopant concentration in the channel
ND	1/V	0.0	Drain subthreshold factor
NG	-	0.0	Gate subthreshold factor
SAT	-	0.0	Saturation factor
SATEXP	-	3	Drain voltage exponent
UCRIT	V/cm	0	Critical field for mobility degradation
VBI	-	1.0	Gate diode built-in voltage
VGEXP (Q)	-	2.0	Gate voltage exponent
VP	-	-	Dinch-off voltage (default is calculated)

See “DC Model LEVEL 3 Parameters” in the *Star-Hspice Manual*.

TOM Model Parameters

Name (Alias)	Unit	Default	Description
BETATCE	-	-	Temperature coefficient for BETA
DELTA	-	-	IDS feedback parameter
CAPDS	-	-	Drain-to-source capacitance

See “TOM Model Parameters” in the *Star-Hspice Manual*.

Noise Parameters

Name (Alias)	Unit	Default	Description
AF	-	1.0	Flicker noise exponent
KF	-	0.0	Flicker noise coefficient
GDSNOI	-	1.0	Channel noise coefficient
NLEV	-	2.0	Noise equation selector

See “Noise Parameters” in the *Star-Hspice Manual*.

Chapter 9

MOSFET Introduction

The topic covered in this chapter is MOSFET Element Statement.

MOSFET Element Statement

General Form	Mxxx nd ng ns <nb> mname + <<L = >length> <<W = >width> + <AD = val> <AS = val> <PD = val> + <PS = val> <NRD = val> <NRS = val> + <RDC = val> <RSC = val> <OFF> + <IC = vds,vgs,vbs> <M = val> + <DTEMP = val> <GEO = val> + <DELVTO = val>
Or	.OPTION WL
Or	Mxxx nd ng ns <nb> mname <width> + <length> <other options...>
AD	Drain diffusion area.
AS	Source diffusion area.
DELVTO	Zero-bias threshold voltage shift.
DTEMP	The difference between the element temperature and the circuit temperature in Celsius.

GEO	Source/drain sharing selector for MOSFET model parameter value ACM = 3.
IC = vds, vgs, vbs	Initial voltage across the external drain and source (vds), gate and source (vgs), and bulk and source terminals (vbs).
L	MOSFET channel length in meters.
M	Multiplier to simulate multiple MOSFETs in parallel.
mname	MOSFET model name reference.
Mxxx	MOSFET element name.
nb	Bulk terminal node name, which is optional.
nd	Drain terminal node name.
ng	Gate terminal node name.
NRD	Number of squares of drain diffusion for resistance calculations.
NRS	Number of squares of source diffusion for resistance calculations.
ns	Source terminal node name.
OFF	Sets initial condition to OFF for this element in DC analysis.
PD	Perimeter of the drain junction.
PS	Perimeter of the source junction.

RDC	Additional drain resistance due to contact resistance with units of ohms.
RSC	Additional source resistance due to contact resistance with units of ohms.
W	MOSFET channel width in meters.

See “MOSFETs” in the *Star-Hspice Manual*.

MOSFET Model Statement

General Form	.MODEL mname [PMOS | NMOS] + (<LEVEL=val> <keyname1=val1> + <keyname2=val2>…) + <VERSION=version_number>
Or	.MODEL mname NMOS(<LEVEL = val> + <keyname1 = val1> + <keyname2=val2>…)<VERSION = + version_number> …)

LEVEL	The MOSFET model includes several device model types.
mname	Model name.
NMOS	Identifies an N-channel MOSFET model.
PMOS	Identifies a P-channel MOSFET model.

See “Using the General MOSFET Model Statement” in the *Star-Hspice Manual*.

Diode Model Parameters

See “Using MOSFET Diode Model Parameters” in the *Star-Hspice Manual*.

DC Model Parameters

Name (Alias)	Unit	Default	Description
ACM	-	0	Area calculation method
JS	amp/m^2	0	Bulk junction saturation current
JSW	amp/m	0	Sidewall bulk junction saturation current
IS	amp	1e-14	Bulk junction saturation current
N	-	1	Emission coefficient
NDS	-	1	Reverse bias slope coefficient
VNDS	V	-1	Reverse diode current transition point

See “DC Model Parameters” in the *Star-Hspice Manual*.

Capacitance Model Parameters

Name (Alias)	Unit	Default	Description
CBD	F	0	Zero bias bulk-drain junction capacitance
CBS	F	0	Zero bias bulk-source junction capacitance
CJ (CDB, CSB, CJA)	F/m^2	579.11 $\mu F/m^2$	Zero-bias bulk junction capacitance
CJSW (CJP)	F/m	0	Zero-bias sidewall bulk junction capacitance
CJGATE	F/m	CJSW	Only for ACM=3, sidewall facing gate
FC	-	0.5	Forward-bias depletion capacitance coefficient (not used)
MJ (EXA, EXJ, EXS, EXD)	-	0.5	Bulk junction grading coefficient
MJSW (EXP)	-	0.33	Bulk sidewall junction grading coefficient
NSUB (DNB, NB)	$1/cm^3$	1e15	Substrate doping
PB (PHA, PHS, PHD)	V	0.8	Bulk junction contact potential

Name (Alias)	Unit	Default	Description
PHP	V	PB	Bulk sidewall junction contact potential
TT	s	0	Transit time

See “Using Capacitance Model Parameters” in the *Star-Hspice Manual*.

Drain and Source Resistance Model Parameters

Name (Alias)	Unit	Default	Description
RD	ohm/sq	0.0	Drain ohmic resistance
RDC	ohm	0.0	Additional drain resistance due to contact resistance
LRD	ohm/m	0	Drain resistance length sensitivity
WRD	ohm/m	0	Drain resistance length sensitivity
PRD	ohm/m^2	0	Drain resistance product (area) sensitivity
RS	ohm/sq	0.0	Source ohmic resistance
LRS	ohm/m	0	Source resistance length sensitivity

Name (Alias)	Unit	Default	Description
WRS	ohm/m	0	Source resistance width sensitivity
PRS	ohm/m^2	0	Source resistance product (area) sensitivity
RSC	ohm	0.0	Additional source resistance due to contact resistance
RSH (RL)	ohm/sq	0.0	Drain and source diffusion sheet resistance

See "Using Drain and Source Resistance Model Parameters" in the *Star-Hspice Manual*.

MOS Common Geometry Model Parameters

Name (Alias)	Unit	Default	Description
HDIF	m	0	Length of heavily doped diffusion
LD (DLAT, LATD)	m	-	Lateral diffusion into channel from source and drain diffusion
LDIF	m	0	Length of lightly doped diffusion adjacent to gate

Name (Alias)	Unit	Default	Description
WMLT	-	1	Width diffusion layer shrink reduction factor
XJ	m	0	Metallurgical junction depth
XW (WDEL, DW)	m	0	Accounts for masking and etching effects

See "Using MOS Geometry Model Parameters" in the *Star-Hspice Manual*.

Common Threshold Voltage Parameters

Name (Alias)	Unit	Default	Description
DELVTO	V	0.0	Zero-bias threshold voltage shift
GAMMA	$V^{1/2}$	0.527625	Body effect factor
NGATE	$1/cm^3$	-	Polysilicon gate doping, used for analytical model only
NSS	$1/cm^2$	1.0	Surface state density
NSUB (DNB, NB)	$1/cm^3$	1e15	Substrate doping
PHI	V	0.576036	Surface potential

Name (Alias)	Unit	Default	Description
TPG (TPS)	-	1.0	Type of gate material, used for analytical model only
VTO (VT)	V	-	Zero-bias threshold voltage

See “Common Threshold Voltage Parameters” in the *Star-Hspice Manual*.

Impact Ionization Model Parameters

Name (Alias)	Unit	Default	Description
ALPHA	1/V	0.0	Impact ionization current coefficient
LALPHA	μm/V	0.0	ALPHA length sensitivity
WALPHA	μm/V	0.0	ALPHA width sensitivity
VCR	V	0.0	Critical voltage
LVCR	μm · V	0.0	VCR length sensitivity
WVCR	μm · V	0.0	VCR width sensitivity
IIRAT	-	0.0	Portion of impact ionization current that goes to source.

See “Using Impact Ionization Model Parameters” in the *Star-Hspice Manual*.

Gate Capacitance Model Parameters

See "Using MOS Gate Capacitance Model Parameters" in the *Star-Hspice Manual*.

Basic Gate Capacitance Parameters

Name (Alias)	Unit	Default	Description
CAPOP	-	2.0	Capacitance model selector
COX (CO)	F/m^2	3.453e-4	Oxide capacitance
TOX	m	1e-7	Represents the Oxide thickness, calculated from COX, when COX is input

See "Using Basic Gate Capacitance Parameters" in the *Star-Hspice Manual*.

Gate Overlap Capacitance Model Parameters

Name (Alias)	Unit	Default	Description
CGBO (CGB)	F/m	0.0	Gate-bulk overlap capacitance per meter channel length
CGDO (CGD, C2)	F/m	0.0	Gate-drain overlap capacitance per meter channel width

Name (Alias)	Unit	Default	Description
CGSO (CGS, C1)	F/m	0.0	Gate-source overlap capacitance per meter channel width
LD (LATD, DLAT)	m	-	Lateral diffusion into channel from source and drain diffusion
METO	m	0.0	Fringing field factor for gate-to-source and gate-to-drain overlap capacitance calculation
WD	m	0.0	Lateral diffusion into channel from bulk along width

See "Using Gate Overlap Capacitance Model Parameters" in the *Star-Hspice Manual*.

Meyer Capacitance Parameters CAPOP=0, 1, 2

Name (Alias)	Unit	Default	Description
CF1	V	0.0	Transition of cgs from depletion to weak inversion for CGSO
CF2	V	0.1	Transition of cgs from weak to strong inversion region

Name (Alias)	Unit	Default	Description
CF3	-	1.0	Transition of cgs and cgd from saturation to linear region as a function of vds
CF4	-	50.0	Contour of cgb and cgs smoothing factors
CF5	-	0.667	Capacitance multiplier for cgs in saturation region
CF6	-	500.0	Contour of cgd smoothing factor
CGBEX	-	0.5	Cgb exponent

See "Using Meyer Capacitance Parameters CAPOP=0, 1, 2" in the *Star-Hspice Manual*.

Gate Capacitances (Simpson Integration) CAPOP=3

The CAPOP=3 model is the same set of equations and parameters as the CAPOP=2 model. The charges are obtained by Simpson numeric integration instead of the box integration found in CAPOP models 1, 2, and 6. For detailed information, see "Defining CAPOP=3 — Gate Capacitances (Simpson Integration)" in the *Star-Hspice Manual*.

Charge Conservation Parameters (CAPOP=4)

Name (Alias)	Unit	Default	Description
XQC	-	0.5	Coefficient of channel charge share attributed to drain

See “Using Charge Conservation Parameters (CAPOP=4)” in the *Star-Hspice Manual*.

Gate Capacitance CAPOP=5

Use CAPOP=5 for no capacitors and HSPICE will not calculate gate capacitance. For detailed information, see “Defining CAPOP=5 — Gate Capacitance” in the *Star-Hspice Manual*.

Noise Parameters

Name (Alias)	Unit	Default	Description
AF	-	1.0	Flicker noise exponent
KF	-	0.0	Flicker noise coefficient
GDSNOI	-	1.0	Channel thermal noise coefficient
NLEV	-	2.0	Noise equation selector

See “Using Noise Parameters” in the *Star-Hspice Manual*.

Temperature Effects Parameters

Name (Alias)	Unit	Default	Description
BEX	-	-1.5	Low field mobility, UO, temperature exponent
CTA	1/°K	0.0	Junction capacitance CJ temperature coefficient
CTP	1/°K	0.0	Junction sidewall capacitance CJSW temperature coefficient
EG	eV	-	Energy gap for pn junction diode
F1EX	-	0	Bulk junction bottom grading coefficient
GAP1	eV/°K	7.02e-4	First bandgap correction factor
GAP2	°K	1108	Second bandgap correction factor
LAMEX	1/°K	0	LAMBDA temperature coefficient
N	-	1.0	Emission coefficient
MJ	-	0.5	Bulk junction bottom grading coefficient

Name (Alias)	Unit	Default	Description
MJSW	-	0.33	Bulk junction sidewall grading coefficient
PTA	V/°K	0.0	Junction potential PB temperature coefficient
PTC	V/°K	0.0	Fermi potential PHI temperature coefficient
PTP	V/°K	0.0	Junction potential PHP temperature coefficient
TCV	V/°K	0.0	Threshold voltage temperature coefficient
TLEV	-	0.0	Temperature equation LEVEL selector
TLEVC	-	0.0	Temperature equation LEVEL selector
TRD	1/°K	0.0	Temperature coefficient for drain resistor
TRS	1/°K	0.0	Temperature coefficient for source resistor
XTI	-	0.0	Saturation current temperature exponent

See "Temperature Effects Parameters" in the *Star-Hspice Manual*.

Chapter 10

MOSFET Models

This chapter briefly introduces MOSFET usage and concisely describes the commonly used models. The topics covered in this chapter are:

- Model Table
- LEVEL 47 BSIM3 Version 2 MOS Model
- LEVELs 49 and 53 BSIM3v3 MOS Models
- LEVEL 50 Philips MOS9 Model
- LEVEL 54 BSIM 4.0 Model
- LEVEL 55 EPFL-EKV MOSFET Model
- LEVEL 57 UC Berkeley BSIM3-SOI Model
- LEVEL 58 University of Florida SOI Model
- LEVEL 59 UC Berkeley BSIM3-SOI FD Model
- LEVEL 60 UC Berkeley BSIM3-SOI DD Model
- LEVEL 61 RPI a-Si TFT Model
- LEVEL 62 RPI Poli-Si TFT Model

For more information about these and other models, see Chapters 21 and 22 in the *Star-Hspice Manual*.

Model Table

LEVEL	MOSFET Model Description	All Platforms including PC	All Platforms except PC
1	Schichman-Hodges	X	
2	MOS2 Grove-Frohman (SPICE 2G)	X	
3	MOS3 empirical (SPICE 2G)	X	
4	Grove-Frohman: LEVEL 2 model derived from SPICE 2E.3	X	
5	AMI-ASPEC depletion and enhancement (Taylor-Huang)	X	
6	Lattin-Jenkins-Grove (ASPEC style parasitics)	X	
7	Lattin-Jenkins-Grove (SPICE style parasitics)	X	
8	Advanced LEVEL 2	X	
9 **	AMD		X
10 **	AMD		X
11	Fluke-Mosaid		X
12 **	CASMOS (GTE style)		X

LEVEL	MOSFET Model Description	All Platforms including PC	All Platforms except PC
13	BSIM	X	
14 **	Siemens LEVEL=4		X
15	User-defined based on LEVEL 3		X
16	Not used	–	–
17	Cypress		X
18 **	Sierra 1		X
19 ***	Dallas Semiconductor		X
20 **	GE-CRD FRANZ		X
21 **	STC-ITT		X
22 **	CASMOS (GEC style)		X
23	Siliconix		X
24 **	GE-Intersil advanced		X
25 **	CASMOS (Rutherford)		X
26 **	Sierra 2		X
27	SOSFET		X
28	Modified BSIM; Avant! proprietary model	X	

LEVEL	MOSFET Model Description	All Platforms including PC	All Platforms except PC
29 ***	Not used	–	–
30 ***	VTI		X
31***	Motorola		X
32 ***	AMD		X
33 ***	National Semiconductor		X
34*	(EPFL) not used		X
35 **	Siemens		X
36 ***	Sharp		X
37 ***	TI		X
38	IDS: Cypress Depletion		X
39	BSIM2	X	
40	HP a-Si TFT	X	
41	TI Analog	X	
46 ***	SGS-Thomson MOS LEVEL 3		X
47	BSIM3 Version 2.0 MOS		X
49	BSIM3 Version 3 (Enhanced) MOS	X	

LEVEL	MOSFET Model Description	All Platforms including PC	All Platforms except PC
50	Philips MOS9	X	
53	BSIM3 Version 3 (Berkeley) MOS	X	
54	BSIM4 (Berkeley)	X	
55	EPFL-EKV Version 2.6, R 11	X	
57	UC Berkeley BSIM3-SOI MOSFET Version 2.0.1	X	
58	University of Florida SOI Version 4.5	X	
59	UC Berkeley BSIM3-SOI-FD	X	
61	RPT Amorphous Silicon TFT	X	
62	RPT PolySilicon TFT	X	

* not officially released

** equations are proprietary – documentation not provided

*** requires a license and equations are proprietary – documentation not provided

For detailed information, see “Selecting MOSFET Model LEVELs” in the *Star-Hspice Manual*.

The remainder of this section provides the general syntax for and basic description of the commonly used MOSFET models (LEVEL 47 and higher).

LEVEL 47 BSIM3 Version 2 MOS Model

The Star-Hspice LEVEL 47 model uses the general model statement described in "MOSFET Model Statement" on page 9-3. It also uses the same:

- Model parameters for source/drain diode current, capacitance, and resistance (ACM controls the choice of source/drain equations)
- Noise equations as the other LEVELs (NLEV controls the choice of noise equations)

as do the other Star-Hspice MOS LEVELs. Like all models in Star-Hspice, LEVEL 47 can be parameterized. This is useful for modeling process skew, either by worst-case corners or by Monte Carlo. For detailed information, see "LEVEL 47 BSIM3 Version 2 MOS Model" in the *Star-Hspice Manual*.

Using BSIM3 Version 2 with Star-Hspice

- Set LEVEL=47 to identify the model as a BSIM3 model.
- The default setting is CAPOP=13 (BSIM1 charge-conserving capacitance model).
- The *TNOM* model parameter is an alias for *TREF* (for compatibility with SPICE3).

- The default room temperature is 25°C in Star-Hspice, but 27°C in SPICE3; if BSIM3 model parameters are specified at 27°C, use TREF=27.
- The default of *DERIV* is zero (analytical method); if set to 1 (finite difference method), it gives more accurate derivatives but consumes more CPU time.
- Three ways for the BSIM3 model to calculate V_{th}:
  - User-specified *K1* and *K2* values.
  - *GAMMA1*, *GAMMA2*, *VBM*, and *VBX* values entered in the .MODEL statement.
  - User-specified *NPEAK*, *NSUB*, *XT*, and *VBM* values.
- *NPEAK* and *U0* can be in meters or centimeters. You must enter the parameter *NSUB* in cm^{-3} units.
- *VTH0* for P-channel in the .MODEL statement is negative.
- The default value of *KT1* is -0.11.
- *LITL* may not go below a minimum value of 1.0e-9 m.
- *VSAT*, after temperature adjustment, is not allowed to go below a minimum value of 1.0e4 m/sec, to assure that it is positive after temperature compensation.
- The model parameters that accommodate temperature dependencies are *KT1* and *KT2* for *VTH*, *UTE* for *U0*, *AT* for *VSAT*, *UA1* for *UA*, *UB1* for *UB*, and *UC1* for *UC*.

- Set up the conversion of temperature between Star-Hspice and SPICE3 as follows:

```
  SPICE3:.OPTIONS TEMP=125
    .MODEL NCH NMOS LEVEL=8
    +TNOM =27 ...
HSPICE:.TEMP 125
    .MODEL NCH NMOS LEVEL=47
    +TREF =27 ...
```

- SCALM affects the common MOS parameters, such as *XL*, *LD*, *XW*, *WD*, *CJ*, *CJSW*, *JS*, and *JSW*.
- LEVEL 47 uses MOS parasitic models, specified by ACM.
- LEVEL 47 uses MOS noise models, specified by NLEV.
- *DELVTO* and *DTEMP* on the element line can be used with LEVEL 47.
- The impact ionization current set by PSCBE1 and PSCBE2 contributes to the drain-source current; not bulk current.

For more information about this model, see "Using the BSIM3 Version 2 MOS Model in Star-Hspice" in the *Star-Hspice Manual*.

LEVELs 49 and 53 BSIM3v3 MOS Models

LEVELs 49 and 53 use the general model statement described in "MOSFET Model Statement" on page 9-3. They also maintain compliance with the UC Berkeley release of BSIM3v3. The basic differences between LEVEL 49 and 53 are:

- LEVEL 49 was designed to be compliant with Berkeley BSIM3v3, but enhanced for higher speed. To achieve this, ACM defaults to 0 in LEVEL 49; compliance with Berkeley BSIM3v3 requires ACM=10.
- LEVEL 53, on the other hand, is completely compliant with Berkeley BSIM3v3; all Hspice-specific parameters default to OFF.

For more information about this model, see "LEVELs 49 and 53 BSIM3v3 MOS Models" in the *Star-Hspice Manual*.

Selecting Model Versions

The recommended BSIM3v3 model specification is LEVEL=49, VERSION=3.22. See "Selecting Model Versions" in the *Star-Hspice Manual*.

LEVEL 50 Philips MOS9 Model

The Philips MOS9 model, available in Star-Hspice as LEVEL 50, uses the general model statement described in "MOSFET Model Statement" on page 9-3. Specific changes include:

- The ACM Parasitic Diode Model, using parameters JS, JSW, N, CJ, CJSW, CJGATE, MJ, MJSW, PB, PHP, ACM, and HDIF was added.

- The Philips JUNCAP Parasitic Diode Model were added.
- The model parameter JUNCAP=1 selects the JUNCAP Model, JUNCAP=0 (default) selects the Hspice ACM Model.
- Gate noise current is not available.

For more information, see

http://www.us.semiconductors.com/Philips_Models.

Also, see "LEVEL 50 Philips MOS9 Model" in the *Star-Hspice Manual*.

Using the Philips MOS9 Model in Star-Hspice

- Set LEVEL=50 to identify the model as Philips MOS Model 9.
- The default room temperature is 25°C in Star-Hspice, but 27°C in SPICE3.
- Always include TR, which corresponds to TREF in other LEVELs in Star-Hspice. The default for TR is 21.0°C, to match the Philips simulator.
- The model has its own charge-based capacitance model; CAPOP is ignored for this model.
- The model uses analytical derivatives for the conductances; DERIV is ignored for this model.
- DTEMP can be used with this model.

- Since defaults are non-zero, every model parameter listed in LEVEL 50 Model Parameters table should be set in the .MODEL statement.
- Select one of two available parasitic junction diode models, ACM and JUNCAP. JUNCAP=1 selects the Philips JUNCAP model, JUNCAP=0 (default) selects the Star-Hspice ACM model.

See "Using the Philips MOS9 Model in Star-Hspice" in the *Star-Hspice Manual*.

LEVEL 54 BSIM 4.0 Model

The UC Berkeley BSIM 4.0.0 MOS model is the LEVEL 54 Star-Hspice model; it is designed for modeling sub-0.13 micron CMOS technology and RF high-speed CMOS circuit simulation. LEVEL 54 uses the general model statement described in "MOSFET Model Statement" on page 9-3.

BSIM4.0.0 has major improvements and additions over BSIM3v3, including:

- A model of the intrinsic input resistance (Rii) for both RF, high-frequency analog, and high-speed digital applications
- Flexible substrate resistance network for RF modeling
- A channel thermal noise model and a noise partition model for the induced gate noise
- A non-quasi-static (NQS) model consistent with the Rii-based RF model and an AC model that accounts for the NQS effect in both transconductances and capacitances

- A gate-direct tunneling model
- A geometry-dependent parasitics model for various source/drain connections and multi-finger devices
- A model for steep vertical retrograde doping profiles
- A model for pocket-implanted devices in Vth, bulk charge effect model, and Rout
- Asymmetrical and bias-dependent source/drain resistance, either internal or external to the intrinsic MOSFET at the user's discretion
- Acceptance of either the electrical or physical gate oxide thickness as the model input at the user's choice
- The quantum mechanical charge-layer-thickness model for both IV and CV
- A mobility model for predictive modeling
- A gate-induced drain leakage (GIDL) current model
- An unified flicker (1/f) noise model, which is smooth over all bias regions and considers the bulk charge effect
- Different diode IV and CV characteristics for source and drain junctions
- Junction diode breakdown with or without current limiting
- Dielectric constant of the gate dielectric as a model parameter

For more information about this model, see "LEVEL 54 BSIM4.0 Model" in the *Star-Hspice Manual*.

LEVEL 55 EPFL-EKV MOSFET Model

The EPFL-EKV MOSFET model is a scalable and compact simulation model built on fundamental physical properties of the MOS structure. LEVEL 55 uses the general model statement described in “MOSFET Model Statement” on page 9-3. This model is for the design and simulation of low-voltage, low-current analog, and mixed analog-digital circuits using submicron CMOS technologies.

For more information about this model, see “LEVEL 55 EPFL-EKV MOSFET Model” in the *Star-Hspice Manual*.

Single Equation Model

The EPFL-EKV MOSFET model is formulated as a “single expression” which preserves continuity of first- and higher-order derivatives with respect to any terminal voltage, in the entire range of validity of the model. The analytical expressions of first-order derivatives as transconductances and transcapacitances are available for computer simulation.

LEVEL 55 includes modeling of these physical effects:

- Basic geometrical and process-related aspects as oxide thickness, junction depth, effective channel length, and width
- Effects of doping profile, substrate effect
- Modeling of weak, moderate, and strong inversion behavior
- Modeling of mobility effects due to vertical and lateral fields, velocity saturation

- Short-channel effects as channel-length modulation (CLM), source and drain charge-sharing, reverse short channel effect (RSCE)
- Modeling of substrate current due to impact ionization
- Quasi-static charge-based dynamic model
- Thermal and flicker noise modeling
- First-order NQS model for the transadmittances
- Short-distance geometry- and bias-dependent device matching.

See “Single Equation Model” in the *Star-Hspice Manual*.

Coherence of Static and Dynamic Models

All aspects regarding the static, the quasi-static and NQS dynamic and noise models are derived from the normalized transconductance-to-current ratio. Symmetric normalized forward and reverse currents are used throughout these expressions. For quasi-static dynamic operation, both a charge-based model for the node charges and trans-capacitances, and a simpler capacitances model are available. The dynamic model, including the time constant for the NQS model, is described in symmetrical terms of the forward and reverse normalized currents. The charge formulation is further used to express effective mobility dependence of local field.

See “Coherence of Static and Dynamic Models” in the *Star-Hspice Manual*.

LEVEL 57 UC Berkeley BSIM3-SOI Model

General Form	Mxxx nd ng ns ne <np> <nb> <nT> mname + <L=val> <W=val> <M=val> <AD=val> + <AS=val> <PD=val> <PS=val> + <NRD=val> <NRS=val> <NRB=val> + <RTH0=val> <CTH0=val> <NBC=val> + <NSEG=val> <PDBCP=val> + <PSBCP=val> <AGBCP=val> + <AEBCP=val> <VBSUSR=val> + <TNODEOUT> <off> <BJToff=val> + <IC=Vds, Vgs, Vbs, Ves, Vps>
AD	Drain diffusion area
AEBCP	Parasitic body-to-substrate overlap area for body contact
AGBCP	Parasitic gate-to-body overlap area for body contact
AS	Source diffusion area
BJTOFF	Turning off BJT if equal to 1
CTH0	Thermal capacitance per unit width
IC	Initial guess in the order
L	SOI MOSFET channel length in meters
M	Multiplier to simulate multiple SOI MOSFETs in parallel
mname	MOSFET model name reference
Mxxx	SOI MOSFET element name

nb	Internal body node name or number
NBC	Number of body contact isolation edge
nd	Drain terminal node name or number
ne	Back gate (or substrate) node name or number
ng	Front gate node name or number
np	External body contact node name or number
NRB	Number of squares for body series resistance
NRD	Number of squares of drain diffusion for drain series resistance
NRS	Number of squares of source diffusion for source series resistance
ns	Source terminal node name or number
NSEG	Number of segments for channel width partitioning
nT	Temperature node name or number
OFF	Sets initial condition to OFF in DC analysis
PD	Perimeter of the drain junction, including the channel edge
PDBCP	Parasitic perimeter length for body contact at drain side
PS	Perimeter of the source junction, including the channel edge

PSBCP	Parasitic perimeter length for body contact at source side
RDC	Additional drain resistance due to contact resistance with units of ohms
RSC	Additional source resistance due to contact resistance with units of ohms
RTH0	Thermal resistance per unit width
TNODEOUT	Temperature node flag indicating the use of T node
VBSUSR	Optional initial value of Vbs specified by user for transient analysis
W	MOSFET channel width in meters

The UC Berkeley SOI model (BSIM3 SOI) supports Fully Depleted (FD), Partially Depleted (PD), and Dynamically Depleted (DD) SOI devices, of which BSIM3PD2.0.1 for PD SOI devices is Star-Hspice LEVEL 57. This model is described in the “BSIM3PD2.0 MOSFET MODEL User’s Manual,” which can be found at “http://www-device.eecs.berkeley.edu/~bsim3soi”. Also see “LEVEL 57 UC Berkeley BSIM3-SOI Model” in the *Star-Hspice Manual*.

Using BSIM3-SOI PD in Star-HSPICE

- To use PD versions 2.0, 2.2, and 2.21 in Star-Hspice, apply VERSION. For example:
  - PD2.0 is invoked when VERSION=2.0
  - PD2.2 and PD2.21 are invoked when VERSION=2.2

- For gate-body tunneling, set IGMOD=1.
- BSIMPD2.01 supports capmod=2 and 3 only; capmod=0 and 1 are not supported.
- By default, if Xj (source/drain junction depth) is not given, it is set to Tsi (silicon film thickness). Xj is not allowed to be greater than Tsi.
- BSIMPD refers substrate to the silicon below buried oxide, not the well region in BSIM3. It is used to calculate backgate flatband voltage (Vfbb) and parameters related to source/ drain diffusion bottom capacitance (Vsdth, Vsdfb, Csdmin). Positive NSUB means the same type of doping as the body and negative NSUB means opposite type of doping.

For more information about this model, see “Using BSIM3-SOI PD in Star-HSPICE” in the *Star-Hspice Manual*.

LEVEL 57 Template Output

Name	Alias	Description
L	LV1	Channel length (L)
W	LV2	Channel width (W)
AD	LV3	Area of the drain diode (AD)
AS	LV4	Area of the source diode (AS)
ICVDS	LV5	Initial condition for drain-source voltage (VDS)
ICVGS	LV6	Initial condition for gate-source voltage (VGS)

Name	Alias	Description
ICVES	LV7	Initial condition for Substrate-source voltage (VES)
VTH	LV9	Threshold voltage (bias dependent)
VDSAT	LV10	Saturation voltage (VDSAT)
PD	LV11	Drain diode periphery (PD)
PS	LV12	Source diode periphery (PS)
RDS	LV13	Drain resistance (squares) (RDS)
RSS	LV14	Source resistance (squares) (RSS)
GDEFF	LV16	Effective drain conductance (1/RDeff)
GSEFF	LV17	Effective source conductance (1/ RSeff)
COVLGS	LV36	Gate-source overlap capacitance
COVLGD	LV37	Gate-drain overlap capacitance
COVLGE	LV38	Gate-substrate overlap capacitance
VES	LX1	Substrate-source voltage (VES)
VGS	LX2	Gate-source voltage (VGS)
VDS	LX3	Drain-source voltage (VDS)
CDO	LX4	DC drain current (CDO)
CBSO	LX5	DC source-body diode current (CBSO)
CBDO	LX6	DC drain-body diode current (CBDO)

Name	Alias	Description
GMO	LX7	DC gate transconductance (GMO)
GDSO	LX8	DC drain-source conductance (GDSO)
GMESO	LX9	DC substrate transconductance (GMBSO)
GBDO	LX10	Conductance of the drain diode (GBDO)
GBSO	LX11	Conductance of the source diode (GBSO)

See "LEVEL 57 Template Output" in the *Star-Hspice Manual*.

Meyer and Charge Conservation Model Parameters

Name	Alias	Description
QB	LX12	Body charge (QB)
CQB	LX13	Body charge current (CQB)
QG	LX14	Gate charge (QG)
CQG	LX15	Gate charge current (CQG)
QD	LX16	Channel charge (QD)
CQD	LX17	Channel charge current (CQD)
CGGBO	LX18	$CGGBO = \partial Qg / \partial Vgb$ = CGS + CGD + CGB

Name	Alias	Description
CGDBO	LX19	$CGDBO = \partial Qg / \partial Vdb$, (for Meyer CGD=-CGDBO)
CGSBO	LX20	$CGSBO = \partial Qg / \partial Vsb$, (for Meyer CGS=-CGSBO)
CBGBO	LX21	$CBGBO = \partial Qb / \partial Vgb$, (for Meyer CGB=-CBGBO)
CBDBO	LX22	$CBDBO = \partial Qb / \partial Vdb$
CBSBO	LX23	$CBSBO = \partial Qb / \partial Vsb$
CDGBO	LX32	$CDGBO = \partial Qd / \partial Vgb$
CDDBO	LX33	$CDDBO = \partial Qd / \partial Vdb$
CDSBO	LX34	$CDSBO = \partial Qd / \partial Vsb$
QE	LX35	Substrate charge (QE)
CQE	LX36	Substrate charge current (CQE)
CDEBO	LX37	$CDEBO = \partial Qd / \partial Veb$
CBEBO	LX38	$CBEBO = \partial Qb / \partial Veb$
CEEBO	LX39	$CEEBO = \partial Qe / \partial Veb$
CEGBO	LX40	$CEGBO = \partial Qe / \partial Vgb$
CEDBO	LX41	$CEDBO = \partial Qe / \partial Vdb$

Name	Alias	Description
CESBO	LX42	$CESBO = \partial Qe / \partial Vsb$
VBS	LX43	Body-source voltage (VBS)
ICH	LX44	Channel current
IBJT	LX45	Parasitic BJT collector current
III	LX46	Impact Ionization current
IGIDL	LX47	GIDL current
ITUN	LX48	Tunneling current

See “Meyer and Charge Conservation Model Parameters” in the *Star-Hspice Manual*.

LEVEL 58 University of Florida SOI Model

General Form	Mxxx nd ngf ns <ngb> mname <L=val> + <W=val> <M=val> <AD=val> <AS=val> + <PD=val> <PS=val> <NRD=val> + <NRS=val> <NRB=val> <RTH=val> + <CTH=val> <off> <IC=Vds,Vgfs,VGbs>

UFSOI has non-fully depleted (NFD) and fully depleted (FD) SOI models (no dynamic mode operating between NFD and FD allowed) that separately describe two main types of SOI devices. The UFSOI version 4.5F model has been installed in Star-Hspice as LEVEL 58. This model is described in the “UFSOI Model User’s Manual,” which can be found at “http://www.soi.tec.ufl.edu/”. LEVEL 58 uses the same arguments described in "LEVEL 57 Template Output" on page 10-18.

In some processes, there is an external body contact to the device. Star-Hspice only supports a 4-terminal device, which includes drain, front gate, source and back gate (or substrate). Additional body contact is not supported and is floated.

The effects of parasitic diodes in SOI are different from those in bulk MOSFET. The Star-Hspice junction model (ACM), developed for bulk MOSFETs, is not included in the SOI model. For more information about this model, see "LEVEL 58 University of Florida SOI Model" in the *Star-Hspice Manual*.

Using the UFSOI Model in Star-Hspice

- Default value for channel length L and width W is 1.0e-6.
- LEVEL 58 supports only 4 nodes (only floating-body devices). AB is usually zero and should be specified.
- When the self-heating option is activated, RTH and CTH define the thermal impedance of the device.
- For M > 1, W, AD, AS, NRD, NRS, NRB, PDJ, PSJ, RTH, and CTH must be specified per gate finger.
- The initial condition IC is in the order: drain voltage Vds, front gate voltage Vgfs, and back gate voltage Vbgs.
- The model line must include LEVEL=58 and NFDMOD=0 for FD or NFDMOD=1 for NFD devices.
- Specifying VFBF turns off the narrow-width effect defined by NQFSW (positive or negative) and the reverse short-

channel effect defined by LRSCE (and NBH or NHALO); the latter effect is also turned off when WKF is specified.

- For floating-body devices, set CGFBO=0.
- JRO and SEFF influence the gain of the BJT, but LDIFF affects only bipolar charge storage in the source/drain. The BJT gain is influenced by NBH and NHALO (if THALO is specified) as well.
- The (non-local) impact-ionization model is physical, and its parameters should not be varied arbitrarily.
- The LDD option intensifies the model; set LLDD=0 for large-scale circuit simulation, and add the unbiased LDD resistance to RD. This simplification will stop if NLDD > 1e19.

LEVEL 59 UC Berkeley BSIM3-SOI FD Model

General Form	Mxxx nd ng ns ne <np> mname <L=val> + <W=val> <M=val> <AD=val> <AS=val> + <PD=val> <PS=val> <NRD=val> + <NRS=val> <NRB=val> <RTH0=val> + <CTH0=val> <off> <BJToff=val> + <IC=Vds, Vgs, Vbs, Ves, Vps>
AD	Drain diffusion area
AS	Source diffusion area
BJTOFF	Turning off BJT if equal to 1
CTH0	Thermal capacitance per unit width
IC	Initial guess in the order

L	SOI MOSFET channel length in meters
M	Multiplier to simulate multiple SOI MOSFETs in parallel
mname	MOSFET model name reference
Mxxx	SOI MOSFET element name
nd	Drain terminal node name or number
ne	Back gate (or substrate) node name or number
ng	Front gate node name or number
np	Optional external body contact node name or number
NRB	Number of squares for body series resistance
NRD	Number of squares of drain diffusion for drain series resistance
NRS	Number of squares of source diffusion for source series resistance
ns	Source terminal node name or number
OFF	Sets initial condition to OFF in DC analysis
PD	Perimeter of drain junction, including the channel edge
PS	Perimeter of source junction, including the channel edge

RTH0	Thermal resistance per unit width
W	MOSFET channel width in meters

The UC Berkeley SOI (BSIM3 SOI) Fully Depleted (FD) model is now installed in Star-Hspice as LEVEL 59. This model is described in the "BSIM3SOI FD2.1 MOSFET MODEL User Manual," which can be found at "http://www-device.eecs.berkeley.edu/~bsim3soi". LEVEL 59 uses the same arguments described in "LEVEL 57 Template Output" on page 10-18.

For more information about this model, see "LEVEL 59 UC Berkeley BSIM3-SOI FD Model" in the *Star-Hspice Manual*.

LEVEL 60 UC Berkeley BSIM3-SOI DD Model

General Form	Mxxx nd ng ns ne <np> mname + <L=val> <W=val> <M=val> <AD=val> + <AS=val><PD=val> <PS=val> + <NRD=val> <NRS=val> <RHT0=val> + <NRB=val> <CTH0=val> + <off> <BJToff=val> + <IC=Vds, Vgs, Vbs, Ves, Vps>
Mxxx	SOI MOSFET element name
nd	Drain terminal node name or number
ng	Front gate node name or number

ns	Source terminal node name or number
ne	Back gate (or substrate) node name or number
np	External body contact node name or number
mname	MOSFET model name reference
L	SOI MOSFET channel length in meters
W	SOI MOSFET channel width in meters
M	Mulitplier to simulate multiple SOI MOSFETs
AD	Drain diffusion area
AS	Source diffusion area
PD	Drain junction perimeter, including channel edge
PS	Source junction perimeter, including channel edge
NRD	Number of squares of drain diffusion for drain series resistance
NRS	Number of squares of source diffusion for source series diffusion
NRB	Number of squares for body series resistance
RDC	Additional drain resistance due to contact resistance with units of ohms

RSC	Additional source resistance due to contact resistance with units of ohms
RTH0	Thermal resistance per unit width
CTH0	Thermal capacitance per unit width
OFF	Sets initial condition to OFF
BJTOFF	Turning off BJT if equal to 1
IC	Initial guess in order (drain, front gate, internal body, back gate, external voltage)

The UC Berkeley SOI (BSIM3 SOI) Dynamically Depleted (DD) model is now installed in Star-Hspice as LEVEL 60.

For more information about this model, see LEVEL 60 UC Berkeley BSIM3-SOI DD Model in the *Star-Hspice Manual*.

LEVEL 61 RPI a-Si TFT Model

Star-Hspice LEVEL 61 is AIM-SPICE MOS15 amorphous silicon (a-Si) thin-film transistor (TFT) model. LEVEL 61, developed by Renssalear Polytechnic Institute, uses the general model statement described in “MOSFET Model Statement” on page 9-3.

For more information about this model, see “LEVEL 61 RPI a-Si TFT Model” in the *Star-Hspice Manual*.

Using LEVEL 61 with Star-Hspice

- Set LEVEL=61 to use the AIM-SPICE MOS15 a-Si TFT model.
- Default value for L is 100 ; default value for W is 100 m.

- LEVEL 61 model is a 3-terminal model. A fourth node can be specified, but does not affect simulation results.
- The default room temperature is 25°C in Star-Hspice, but 27°C in SPICE3; if LEVEL 61 model parameters are specified at 27°C, use .OPTION TNOM=27.

See "Using LEVEL 61 with Star-Hspice" in the *Star-Hspice Manual*.

LEVEL 62 RPI Poli-Si TFT Model

Star-Hspice LEVEL 62 is an AIM-SPICE MOS16 poly-silicon (Poli-Si) thin-film transistor (TFT) model developed by Renssalear Polytechnic Institute. (LEVEL 54 uses the general model statement described in "MOSFET Model Statement" on page 9-3.) For more information about this model, see "LEVEL 62 RPI Poli-Si TFT Model" in the *Star-Hspice Manual*.

Using LEVEL 62 with Star-Hspice

- Set LEVEL=62 to use the AIM-SPICE MOS16 Poli-Si TFT model.
- Default value for L is 100 m; default value for W is 100 m.
- The LEVEL 62 model is a 3-terminal model. A fourth node can be specified, but does not affect simulation results.
- The default room temperature is 25°C in Star-Hspice, but 27°C in SPICE3; if LEVEL 62 model parameters are specified at 27°C, use .OPTION TNOM=27.

See "Using LEVEL 62 with Star-Hspice" in the *Star-Hspice Manual*.

Chapter 11

Behavior Macromodeling

The topics covered in this chapter are:

- Subcircuit/Macros
- Voltage and Current Controlled Elements

Star-Hspice performs the following types of behavioral modeling.

Subcircuit/Macros

.SUBCKT or .MACRO Statement

General Form	.SUBCKT subnam n1 <n2 n3 …> + <parnam=val …>
Or	.MACRO subnam n1 <n2 n3 …> + <parnam=val …>
n1 …	Node name for external reference
parnam	A parameter name set to a value or another parameter
subnam	Reference name for the subcircuit model call

See ".SUBCKT or .MACRO Statement" in the *Star-Hspice Manual*.

.ENDS or .EOM Statement

General Form	.ENDS <SUBNAM>
Or	.EOM <SUBNAM>

See ".ENDS or .EOM Statement" in the *Star-Hspice Manual*.

Subcircuit Calls

General Form	Xyyy n1 <n2 n3 …> subnam + <parnam=val …> <M=val>
M	Multiplier
n1 …	Node names for external reference
parnam	A parameter name set to a value for use only in the subcircuit
subnam	Subcircuit model reference name
Xyyy	Subcircuit element name

See "Subcircuit Call Statement" in the *Star-Hspice Manual*.

Voltage and Current Controlled Elements

Star-Hspice supports the following voltage and current controlled elements. For detailed information, see "Using Voltage and Current Controlled Elements" in the *Star-Hspice Manual*.

G Elements

Voltage Controlled Current Source—VCCS

Linear

General Form	Gxxx n+ n- <VCCS> in+ in- + transconductance <MAX=val> + <MIN=val> <TC1=val> <TC2=val> + <M=val> <SCALE=val> <ABS=1> + <IC=val>

Polynomial

General Form	Gxxx n+ n- <VCCS> POLY(ndim) in1 + in1- ... <inndim+ inndim-> <MAX=val> + <MIN=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> <ABS=1> p0 + <p1…> <IC=vals>

Piecewise Linear

General Form	Gxxx n+ n- <VCCS> PWL(1) in+ in- + <DELTA=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> x1,y1 x2,y2 ... + x100,y100 <IC=val> <SMOOTH=val>
Or	Gxxx n+ n- <VCCS> NPWL(1) in+ in- + <DELTA=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> x1,y1 x2,y2 ... + x100,y100 <IC=val> <SMOOTH=val>
Or	Gxxx n+ n- <VCCS> PPWL(1) in+ in- + <DELTA=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> x1,y1 x2,y2 ... + x100,y100 <IC=val> <SMOOTH=val>

Multi-Input Gates

General Form	Gxxx n+ n- <VCCS> gatetype(k) in1+ in1- + ... ink+ ink- <DELTA=val> <TC1=val> + <TC2=val> <SCALE=val> <M=val> + x1,y1 ... x100,y100<IC=val>

Delay Element

General Form	Gxxx n+ n- <VCCS> DELAY in+ in- + TD=val <SCALE=val> <TC1=val> + <TC2=val> NPDELAY=val

See “Voltage Controlled Current Source (VCCS)” in the *Star-Hspice Manual*.

Behavioral Current Source

General Form	Gxxx n+ n- CUR=‘equation’ <MAX>=val> + <MIN=val>

See “Behavioral Current Source” in the *Star-Hspice Manual*.

Voltage Controlled Resistor—VCR

Linear

General Form	Gxxx n+ n- VCR in+ in- transfactor + <MAX=val> <MIN=val> <SCALE=val> + <M=val> <TC1=val> <TC2=val> + <IC=val>

Polynomial

General Form	Gxxx n+ n- VCR POLY(ndim) in1+ in1- ... + <inndim+ inndim-> <MAX=val> + <MIN=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> p0 <p1…> + <IC=vals>

Piecewise Linear

General Form	Gxxx n+ n- VCR PWL(1) in+ in- + <DELTA=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> x1,y1 x2,y2 ... + x100,y100 <IC=val> <SMOOTH=val>
Or	Gxxx n+ n- VCR NPWL(1) in+ in- + <DELTA=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> x1,y1 x2,y2 ... + x100,y100 <IC=val> <SMOOTH=val>
Or	Gxxx n+ n- VCR PPWL(1) in+ in- + <DELTA=val> <SCALE=val> <M=val> + <TC1=val> <TC2=val> x1,y1 x2,y2 ... + x100,y100 <IC=val> <SMOOTH=val>

Multi-Input Gates

General Form	Gxxx n+ n- VCR gatetype(k) in1+ in1- ... + ink+ ink- <DELTA=val> <TC1=val> + <TC2=val> <SCALE=val> <M=val> + x1,y1 ... x100,y100 <IC=val>

See “Voltage Controlled Resistor (VCR)” in the *Star-Hspice Manual*.

Voltage Controlled Capacitors—VCCAP

General Form	Gxxx n+ n- VCCAP PWL(1) in+ in- + <DELTA=val> <SCALE=val> + <M=val> <TC1=val> <TC2=val> + x1,y1 x2,y2 ... x100,y100 <IC=val > + <SMOOTH=val>

See “Voltage Controlled Capacitor (VCCAP)” in the *Star-Hspice Manual*.

G Element Parameters

Parameter	Description
ABS	Output is absolute value if ABS=1.
CUR= equation	Current output which flows from n+ to n-.
DELAY	Keyword for the delay element.
DELTA	Used to control the curvature of the piecewise linear corners.
Gxxx	Voltage controlled element name.
gatetype(k)	May be AND, NAND, OR, or NOR.
IC	Initial condition.
in +/-	Positive or negative controlling nodes.
M	Number of replications of the element in parallel.
MAX	Maximum current or resistance value.
MIN	Minimum current or resistance value.

Parameter	Description
n+/-	Positive or negative node of controlled element.
NPDELAY	Sets the number of data points to be used in delay simulations.
NPWL	Models the symmetrical bidirectional switch or transfer gate, NMOS.
p0, p1 …	Polynomial coefficients.
POLY	Polynomial dimension.
PWL	Piecewise linear function keyword.
PPWL	Models the symmetrical bidirectional switch or transfer gate, PMOS.
SCALE	Element value multiplier.
SMOOTH	For piecewise linear dependent source elements, SMOOTH selects the curve smoothing method.
TC1,TC2	First-order and second-order temperature coefficients.
TD	Time delay keyword.
transconductance	Voltage to current conversion factor.
transfactor	Voltage to resistance conversion factor.
VCCAP	Keyword for voltage controlled capacitance element.

Parameter	Description
VCCS	Keyword for voltage controlled current source.

See “Parameter Definitions” in the *Star-Hspice Manual*.

E Elements

Voltage Controlled Voltage Source—VCVS

Linear

General Form	Exxx n+ n- <VCVS> in+ in- gain + <MAX=val> <MIN=val> <SCALE=val> + <TC1=val> <TC2=val><ABS=1> + <IC=val>

Polynomial

General Form	Exxx n+ n- <VCVS> POLY(ndim) in1 + in1- ... inndim+ inndim-<TC1=val> + <TC2=val> <SCALE=val> <MAX=val> + <MIN=val> <ABS=1> p0 <p1…> + <IC=vals>

Piecewise Linear

General Form	Exxx n+ n- <VCVS> PWL(1) in+ in- + <DELTA=val> <SCALE=val> + <TC1=val> <TC2=val> x1,y1 x2,y2 ... + x100,y100 <IC=val>

Multi-Input Gates

General Form	Exxx n+ n- <VCVS> gatetype(k) in1+ in1- + ... inj+ inj- <DELTA=val> <TC1=val> + <TC2=val> <SCALE=val> x1,y1 ... + x100,y100 <IC=val>

Delay Element

General Form	Exxx n+ n- <VCVS> DELAY in+ in- + TD=val <SCALE=val> <TC1=val> + <TC2=val> <NPDELAY=val>

See “Voltage Controlled Voltage Source (VCVS)” in the *Star-Hspice Manual*.

Behavioral Voltage Source

General Form	Exxx n+ n- VOL=’equation’ <MAX>=val> + <MIN=val>

See “Behavioral Voltage Source” in the *Star-Hspice Manual*.

Ideal Op-Amp

General Form	Exxx n+ n- OPAMP in+ in-

See “Ideal Op-Amp” in the *Star-Hspice Manual*.

Ideal Transformer

General Form	Exxx n+ n- TRANSFORMER in+ in- k

See “Ideal Transformer” in the *Star-Hspice Manual*.

E Element Parameters

Parameter	Description
ABS	Output is absolute value if ABS=1.
DELAY	Keyword for the delay element.
DELTA	Used to control the curvature of the piecewise linear corners.
Exxx	Voltage controlled element name.
gain	Voltage gain.
gatetype(k)	May be AND, NAND, OR, or NOR.
IC	Initial condition.
in +/-	Positive or negative controlling nodes.
j	Ideal transformer turn ratio.
MAX	Maximum output voltage value.
MIN	Minimum output voltage value.
n+/-	Positive or negative node of controlled element.
NPDELAY	Sets the number of data points to be used in delay simulations.
OPAMP	Keyword for ideal op-amp element.
P0, P1…	Polynomial coefficients.
POLY	Polynomial dimension.
PWL	Piecewise linear function keyword.

Parameter	Description
SCALE	Element value multiplier.
TC1, TC2	First-order and second-order temperature coefficients.
TD	Time delay keyword.
TRANS-FORMER	Keyword for ideal transformer.
VCVS	Keyword for voltage controlled voltage source.
x1,…	Controlling voltage across nodes in+ and in-.
y1,…	Corresponding element values of x.

See "Parameter Definitions" in the *Star-Hspice Manual*.

F Elements

Current Controlled Current Sources—CCCS

Linear

General Form	Fxxx n+ n- <CCCS> vn1 gain + <MAX=val> <MIN=val> <SCALE=val> + <TC1=val> <TC2=val> <M=val> + <ABS=1> <IC=val>

Polynomial

General Form	Fxxx n+ n- <CCCS> POLY(ndim) vn1 + <... vnndim> <MAX=val> <MIN=val> + <TC1=val> <TC2=val> <SCALE=vals> + <M=val> <ABS=1> p0 <p1…> + <IC=vals>

Piecewise Linear

General Form	Fxxx n+ n- <CCCS> PWL(1) vn1 + <DELTA=val> <SCALE=val> + <TC1=val> <TC2=val> <M=val> x1,y1 + ... x100,y100 <IC=val>

Multi-Input Gates

General Form	Fxxx n+ n- <CCCS> gatetype(k) vn1, ... + vnk <DELTA=val> <SCALE=val> + <TC1=val> <TC2=val> <M=val> + <ABS=1> x1,y1 ... x100,y100 + <IC=val>

Delay Element

General Form	Fxxx n+ n- <CCCS> DELAY vn1 + TD=val <SCALE=val> <TC1=val> + <TC2=val> NPDELAY=val

See “Current Controlled Current Source (CCCS)” in the *Star-Hspice Manual*.

F Element Parameters

Parameter	Heading
ABS	Output is absolute value if ABS=1.
CCCS	Keyword for current controlled current source.
DELAY	Keyword for the delay element.
DELTA	Used to control the curvature of the piecewise linear corners.
Fxxx	Current controlled current source element name.
gain	Current gain.
gatetype(k)	May be AND, NAND, OR, or NOR.
IC	Initial condition.
M	Number of replications of the element in parallel.
MAX	Maximum output current value.
MIN	Minimum output current value.
n+/-	Positive or negative controlled source connecting nodes.
NPDELAY	Sets the number of data points to be used in delay simulations.
P0, P1…	The polynomial coefficients.
POLY	Polynomial dimension.

Parameter	Heading
PWL	Piecewise linear function keyword.
SCALE	Element value multiplier.
TC1, TC2	First and second order temperature coefficients.
TD	Time delay keyword.
vn1…	Names of voltage sources through which the controlling current flows.
x1,…	Controlling current through vn1 source.
y1,…	Corresponding output current values of x.

See “Parameter Definitions” in the *Star-Hspice Manual*.

H Elements

Current Controlled Voltage Source—CCVS

Linear

General Form	Hxxx n+ n- <CCVS> vn1 transresistance + <MAX=val> <MIN=val> <SCALE=val> + <TC1=val> <TC2=val> <ABS=1> + <IC=val>

Polynomial

General Form	Hxxx n+ n- <CCVS> POLY(ndim) vn1 + <... vnndim> <MAX=val>MIN=val> + <TC1=val> <TC2=val> <SCALE=val> + <ABS=1> p0 <p1…> <IC=vals>

Piecewise Linear

General Form	Hxxx n+ n- <CCVS> PWL(1) vn1 + <DELTA=val> <SCALE=val> + <TC1=val> <TC2=val> x1,y1 ... + x100,y100 <IC=val>

Multi-Input Gates

General Form	Hxxx n+ n- gatetype(k) vn1, ... vnk + <DELTA=val> <SCALE=val> + <TC1=val> <TC2=val> x1,y1 ... + x100,y100 <IC=val>

Delay Element

General Form	Hxxx n+ n- <CCVS> DELAY vn1 + TD=val <SCALE=val> <TC1=val> + <TC2=val> <NPDELAY=val>

See "Current Controlled Voltage Source — (CCVS)" in the *Star-Hspice Manual*.

H Element Parameters

Parameter	Description
ABS	Output is absolute value if ABS=1.
CCVS	Keyword for current controlled voltage source.
DELAY	Keyword for the delay element.
DELTA	Used to control the curvature of the piecewise linear corners.

Parameter	Description
gatetype(k)	May be AND, NAND, OR, or NOR.
Hxxx	Current controlled voltage source element name.
IC	Initial condition.
MAX	Maximum voltage value.
MIN	Minimum voltage value.
n+/-	Positive or negative controlled source connecting nodes.
NPDELAY	Sets the number of data points to be used in delay simulations.
P0, P1…	The polynomial coefficients.
POLY	Polynomial dimension.
PWL	Piecewise linear function keyword.
SCALE	Element value multiplier.
TC1, TC2	First-order and second-order temperature coefficients.
TD	Time delay keyword.
transresis-tance	Current to voltage conversion factor.
vn1…	Names of voltage sources through which the controlling current flows.
x1,…	Controlling current through vn1 source.

Parameter	Description
y1,…	Corresponding output voltage values of x.

See “Parameter Definitions” in the *Star-Hspice Manual*.

Op-Amp Element Statement

COMP=0	xa1 in- in+ out vcc vee modelname AV=val
Or	
COMP=1	xa1 in- in+ out comp1 comp2 vcc vee modelname AV=val
in+	Noninverting input
in-	Inverting input
modelname	Subcircuit reference name
out	Output, single ended
vcc	Positive supply
vee	Negative supply

See “Op-Amp Element Statement Format” in the *Star-Hspice Manual*.

Op-Amp .MODEL Statement

General Form	.MODEL mname AMP parameter=value …
AMP	Identifies an amplifier model
mname	Model name. Elements reference the model by this name.

parameter	Any model parameter described below
value	Value assigned to a parameter

See “Op-Amp .MODEL Statement Format” in the *Star-Hspice Manual*.

Chapter 12

Controlling Input

This chapter contains abbreviated definitions. The topics covered in this chapter are:

- .OPTIONS Statement
- General Control Options
- Model Analysis Options
- Statements

For complete definitions, see the *Star-Hspice Manual*, Chapter 3, “Specifying Simulation Input and Controls.”

.OPTIONS Statement

General Form	.OPTIONS opt1 <opt2 opt3 …>
opt1 …	Specifies any of the input control options.

See “.OPTIONS Statement” in the *Star-Hspice Manual*.

General Control Options

Option	**Description**
ACCT	Reports job accounting and runtime statistics at the end of the output listing.

Option	Description
ACOUT	AC output calculation method for the difference in values of magnitude, phase and decibels for prints and plots.
ALT999, ALT9999	This option generates up to 1000 (ALT999) or 10,000 (ALT9999) unique output files from .ALTER runs.
BRIEF, NXX	Stops printback of the data file until an .OPTIONS BRIEF = 0 or the .END statement is encountered.
CO = x	Sets the number of columns for printout: x can be either 80 (for narrow printout) or 132 (for wide carriage printouts).
INGOLD = x	Specifies the printout data format.
LENNAM = x	Specifies the maximum length of names in the operating point analysis results printout.
LIST, VERIFY	Produces an element summary listing of the input data to be printed.
MEASDGT = x	Used for formatting of the .MEASURE statement output in both the listing file and the .MEASURE output files (*.ma0*, *.mt0*, *.ms0*, and so on).
NODE	Causes a node cross reference table to be printed.

Option	Description
NOELCK	No element check; bypasses element checking to reduce preprocessing time for very large files.
NOMOD	Suppresses the printout of model parameters
NOPAGE	Suppresses page ejects for title headings
NOTOP	Suppresses topology check resulting in increased speed for preprocessing very large files
NUMDGT = x	Sets the number of significant digits printed for output variable values.
NXX	Same as BRIEF. See BRIEF.
OPTLST = x	Outputs additional optimization information:
OPTS	Prints the current settings of all control options.
PATHNUM	Prints subcircuit path numbers instead of path names
PLIM = x	Specifies plot size limits for printer plots of current and voltage
POST_VERSION = x	Sets the post-processing output version with values x = 9601 or 9007.

Option	Description
SEARCH	Sets the search path for libraries and included files.
VERIFY	Same as LIST. See LIST.

See “General Control Options” in the *Star-Hspice Manual*.

CPU Options

Option	Description
CPTIME = x	Sets the maximum CPU time, in seconds, allotted for this job.
EPSMIN = x	Specifies the smallest number that can be added or subtracted on a computer, a constant value.
EXPMAX = x	Specifies the largest exponent you can use for an exponential before overflow occurs.
LIMTIM = x	Sets the amount of CPU time reserved for generating prints and plots in case a CPU time limit (CPTIME = x) causes termination.

See “CPU Options” in the *Star-Hspice Manual*.

Interface Options

Option	Description
ARTIST = x	ARTIST = 2 enables the Cadence Analog Artist interface. Requires a specific license.
CDS, SDA	CDS = 2 produces a Cadence WSF ASCII format post-analysis file for Opus™. Requires a specific license.
CSDF	Selects Common Simulation Data Format (Viewlogic-compatible graph data file format).
MEASOUT	Outputs .MEASURE statement values and sweep parameters into an ASCII file for post-analysis processing by AvanWaves or other analysis tools.
MENTOR = x	MENTOR = 2 enables the Mentor MSPICE-compatible ASCII interface. Requires a specific license.
POST = x	Enables storing of simulation results for analysis using the AvanWaves graphical interface or other methods.
PROBE	Limits the post-analysis output to just the variables designated in .PROBE, .PRINT, .PLOT, and .GRAPH statements.

Option	Description
PSF = x	Specifies whether Star-Hspice outputs binary or ASCII when Star-Hspice is run from Cadence Analog Artist.
SDA	Same as CDS. See CDS.
ZUKEN = x	If x is 2, enables the Zuken interactive interface.

See “Interface Options” in the *Star-Hspice Manual*.

Analysis Options

Option	Description
ASPEC	Sets Star-Hspice into ASPEC compatibility mode.
LIMPTS = x	Sets the total number of points that you can print or plot in AC analysis.
PARHIER	Selects the parameter passing rules that control the evaluation order of subcircuit parameters.
SPICE	Makes Star-Hspice compatible with Berkeley SPICE.
SEED	User-specified random number generator starting seed for Monte Carlo analysis.

See “Analysis Options” in the *Star-Hspice Manual*.

Error Options

Option	Description
BADCHR	Generates a warning when a nonprintable character is found in an input file.
DIAGNOSTIC	Logs the occurrence of negative model conductances.
NOWARN	Suppresses all warning messages except those generated from statements in .ALTER blocks.
WARNLIMIT = x	Limits the number of times that certain warnings appear in the output listing, thus reducing output listing file size.

See “Error Options” in the *Star-Hspice Manual*.

Version Options

Option	Description
H9007	Sets general control option default values to correspond to the values for Star-Hspice Release H9007D.

See “Version Options” in the *Star-Hspice Manual*.

Model Analysis Options

See "Model Analysis Options" in the *Star-Hspice Manual*.

General Options

Option	Description
DCAP	The DCAP option selects the equations used in calculating the depletion capacitance for LEVEL 1 and 3 diodes and BJTs.
SCALE	Element scaling factor.
TNOM	The reference temperature for the simulation.

See "General Options" in the *Star-Hspice Manual*.

MOSFET Control Options

Option	Description
CVTOL	Changes the number of numerical integration steps in the calculation of the gate capacitor charge for a MOSFET using CAPOP = 3.
DEFAD	Default value for MOSFET drain diode area.
DEFAS	Default value for MOSFET source diode area.
DEFL	Default value for MOSFET channel length.

Option	Description
DEFNRD	Default value for the number of squares for the drain resistor on a MOSFET.
DEFNRS	Default value for the number of squares for the source resistor on a MOSFET.
DEFPD	Default value for MOSFET drain diode perimeter.
DEFPS	Default value for MOSFET source diode perimeter.
DEFW	Default value for MOSFET channel width.
SCALM	Model scaling factor.
WL	This option changes the order of specifying MOS element VSIZE from the default order length-width to width-length.

See “MOSFET Control Options” in the *Star-Hspice Manual*.

DC Solution Control Options

Option	Description
ABSH = x	Sets the absolute current change through voltage defined branches (voltage sources and inductors).
ABSI = x	Sets the absolute branch current error tolerance in diodes, BJTs, and JFETs during DC and transient analysis.

Option	Description
ABSMOS = x	Current error tolerance used for MOSFET devices in both DC and transient analysis.
ABSTOL = x	Sets the absolute node voltage error tolerance for DC and transient analysis.
ABSVDC = x	Sets the absolute minimum voltage for DC and transient analysis.
DI = x	Sets the maximum iteration-to-iteration current change through voltage defined branches (voltage sources and inductors).
KCLTEST	Activates the KCL test (Kirchhoff's Current Law) function.
MAXAMP = x	Sets the maximum current through voltage defined branches (voltage sources and inductors).
RELH = x	Sets relative current tolerance through voltage defined branches (voltage sources and inductors).
RELI = x	Sets the relative error/tolerance change from iteration to iteration to determine convergence for all currents in diode, BJT, and JFET devices.

Option	Description
RELMOS = x	Sets the relative drain-to-source current error tolerance percent from iteration to iteration to determine convergence for currents in MOSFET devices.
RELV = x	Sets the relative error tolerance for voltages
RELVDC = x	Sets the relative error tolerance for voltages.
ITL1 = x	Sets the maximum DC iteration limit.
ITL2 = x	Sets the DC transfer curve iteration limit.
NOPIV	Prevents Star-Hspice from switching automatically to pivoting matrix factorization when a nodal conductance is less than PIVTOL. NOPIV inhibits pivoting. Also see PIVOT.
PIVOT = x	Provides different pivoting algorithm selections.
PIVREF	Pivot reference.
PIVREL = x	Sets the maximum/minimum row/matrix ratio.
PIVTOL = x	Sets the absolute minimum value for which a matrix entry is accepted as a pivot.
SPARSE = x	Same as PIVOT.

Option	Description
CAPTAB	Prints table of single plate nodal capacitance for diodes, BJTs, MOSFETs, JFETs and passive capacitors at each operating point.
DCCAP	Used to generate C-V plots and to print out the capacitance values of a circuit (both model and element) during a DC analysis.
VFLOOR = x	Sets a lower limit for the voltages that are printed in the output listing.
CONVERGE	Invokes different methods for solving nonconvergence problems
CSHDC	The same option as CSHUNT, but is used only with option CONVERGE.
DCFOR = x	Used in conjunction with the DCHOLD option and the .NODESET statement to enhance the DC convergence properties of a simulation
DCHOLD = x	DCFOR and DCHOLD are used together for the initialization process of a DC analysis.
DCON = X	In the case of convergence problems, Star-Hspice automatically sets DCON = 1

Option	Description
DCSTEP = x	Used to convert DC model and element capacitors to a conductance to enhance DC convergence properties.
DCTRAN	DCTRAN is an alias for CONVERGE. See CONVERGE.
DV = x	The maximum iteration-to-iteration voltage change for all circuit nodes in both DC and transient analysis.
GMAX = x	The conductance in parallel with the current source used for .IC and .NODESET initialization conditions circuitry.
GMINDC = x	A conductance that is placed in parallel with all pn junctions and all MOSFET nodes for DC analysis.
GRAMP = x	Value is set by Star-Hspice during the autoconvergence procedure.
GSHUNT	Conductance added from each node to ground.
ICSWEEP	For a parameter or temperature sweep, saves the results of the current analysis for use as the starting point in the next analysis in the sweep.

Option	Description
NEWTOL	Calculates one more iterations past convergence for every DC solution and timepoint circuit solution calculated.
OFF	Initializes the terminal voltages of all active devices to zero if they are not initialized to other values.
RESMIN = x	Specifies the minimum resistance value for all resistors, including parasitic and inductive resistances.

See "DC Operating Point, DC Sweep, and Pole/Zero" in the *Star-Hspice Manual*.

Pole/Zero Control Options

Option	Description
CSCAL	Sets the capacitance scale. Capacitances are multiplied by CSCAL.
FMAX	Sets the limit for maximum pole and zero angular frequency value.
FSCAL	Sets the frequency scale. Frequency is multiplied by FSCAL.
GSCAL	Sets the conductance scale.
LSCAL	Sets inductance scale.
PZABS	Sets absolute tolerances for poles and zeros.

Option	Description
PZTOL	Sets the relative error tolerance for poles or zeros.
RITOL	Sets the minimum ratio value for (real/ imaginary) or (imaginary/real) parts of the poles or zeros.
(X0R,X0I), (X1R,X1I), (X2R,X2I)	The three complex starting points in the Muller pole/zero analysis algorithm

See “Pole/Zero Control Options” in the *Star-Hspice Manual*.

Transient Control Options

Option	Description
ABSH = x	Sets the absolute current change through voltage defined branches (voltage sources and inductors).
ABSV = x	Same as VNTOL. See VNTOL.
ACCURATE	Selects a time algorithm that uses LVLTIM = 3 and DVDT = 2 for circuits such as high-gain comparators.
ACOUT	AC output calculation method for the difference in values of magnitude, phase and decibels for prints and plots.

Option	Description
CHGTOL = x	Sets the charge error tolerance when LVLTIM = 2 is set.
CSHUNT	Capacitance added from each node to ground.
DI = x	Sets the maximum iteration-to-iteration current change through voltage defined branches (voltage sources and inductors).
GMIN = x	Sets the minimum conductance allowed for in a transient analysis time sweep.
GSHUNT	Conductance added from each node to ground.
MAXAMP = x	Sets the maximum current through voltage defined branches (voltage sources and inductors).
RELH = x	Sets relative current tolerance through voltage defined branches (voltage sources and inductors).
RELI = x	Sets the relative error/tolerance change from iteration to iteration to determine convergence for all currents in diode, BJT, and JFET devices.
RELQ = x	Used in the local truncation error timestep algorithm (LVLTIM = 2).

Option	Description
RELTOL, RELV	Sets the relative error tolerance for voltages
RISETIME	Specifies the smallest risetime of the signal, .OPTION RISETIME = x.
TRTOL = x	Used in the local truncation error timestep algorithm (LVLTIM = 2)
VNTOL = x, ABSV	Sets the absolute minimum voltage for DC and transient analysis.
AUTOSTOP	Stops the transient analysis when all TRIG-TARG and FIND-WHEN measure functions are calculated.
BKPSIZ = x	Sets the size of the breakpoint table.
BYPASS	Speeds up simulation by not updating the status of latent devices.
BYTOL = x	Specifies the tolerance for the voltage at which a MOSFET, MESFET, JFET, BJT, or diode is considered latent.
FAST	Speeds up simulation by not updating the status of latent devices.
ITLPZ	Sets the pole/zero analysis iteration limit.
MBYPASS = x	Used to compute the default value for the BYTOL control option

Option	Description
ABSVAR = x	Sets the limit on the maximum voltage change from one time point to the next.
DELMAX = x	Sets the maximum value for the internal timestep Delta.
DVDT	Allows the timestep to be adjusted based on node voltage rates of change.
FS = x	Sets the fraction of a timestep (TSTEP) that Delta (the internal timestep) is decreased for the first time point of a transient.
FT = x	Sets the fraction of a timestep (TSTEP) by which Delta (the internal timestep) is decreased for an iteration set that does not converge.
IMIN = x, ITL3 = x	Determines the timestep in the algorithms used for transient analysis siimulations.
IMAX = x, ITL4 = x	Determines the maximum timestep in the timestep algorithms used for transient analysis simulations.
ITL3 = x	Same as IMIN. See IMIN.
ITL4 = x	Same as IMAX. See IMAX.
ITL5 = x	Sets the transient analysis total iteration limit.

Option	Description
RELVAR = x	Used with ABSVAR and the timestep algorithm option DVDT. RELVAR sets the relative voltage change for LVLTIM = 1 or 3.
RMAX = x	Sets the TSTEP multiplier, which determines the maximum value, DELMAX, that can be used for the internal timestep Delta.
RMIN = x	Sets the minimum value of Delta (internal timestep)
SLOPETOL = x	Sets a lower limit for breakpoint table entries in a piecewise linear (PWL) analysis.
TIMERES = x	Sets a minimum separation between breakpoint values for the breakpoint table.
DVTR	Allows the use of voltage limiting in transient analysis.
IMAX = x, ITL4 = x	Determines the maximum timestep in the timestep algorithms used for transient analysis simulations.
IMIN = x, ITL3 = x	Determines the timestep in the algorithms used for transient analysis simulations.

Option	Description
LVLTIM = x	Selects the timestep algorithm used for transient analysis.
MAXORD = x	Sets the maximum order of integration when the GEAR method is used (see METHOD)
METHOD = na me	Sets the numerical integration method used for a transient analysis to either GEAR or TRAP.
MU = x, XMU = x	The coefficient for trapezoidal integration. Same as MU. See MU.
INTERP	Limits output to post-analysis tools, such as Cadence or Zuken, to only the .TRAN timestep intervals.
ITRPRT	Prints output variables at their internal timepoint values.
MEASFAIL	Writes out “0” or “1” to .mt#, .ms# or .ma# file and “failed” to listing file when .measure statement fails.
PUTMEAS	Allows user to control the output variables listed in the .measure statement.
UNWRAP	Displays phase results in AC analysis in unwrapped form (with a continuous phase plot).

See “Transient and AC Small Signal Analysis” in the *Star-Hspice Manual*.

Statements

Star-Hspice supports the following statements.

.ALTER Statement

General Form	.ALTER <title_string>

See ".ALTER Statement" in the *Star-Hspice Manual*.

Comments

General Form	*<Comment on a line by itself>
Or	<HSPICE statement> $<comment following HSPICE input>

See "Comments" in the *Star-Hspice Manual*.

.DATA Statement

See ".DATA Statement" in the *Star-Hspice Manual*.

Inline .DATA Statement

General Form	.DATA datanm pnam1 <pnam2 pnam3 … + pnamxxx > pval1<pval2 pval3 … + pvalxxx> pval1' <pval2' pval3' … + pvalxxx'> .ENDDATA

See "Inline .DATA Statement" in the *Star-Hspice Manual*.

External File .DATA Statement

General Form	.DATA datanm MER FILE = ‘filename1’ + pname1=colnum <panme2=colnum …> + <FILE = ‘filename2’ pname1 = colnum + <pname2 = colnum …>> … + <OUT = ‘fileout’> .ENDDATA

See “External File .DATA Statement” in the *Star-Hspice Manual*.

Column Laminated .DATA Statement

General Form	.DATA datanm LAM FILE=‘filename1’ + pname1=colnum <panme2=colnum …> + <FILE=‘filename2’ pname1=colnum + <pname2=colnum …>>… + <OUT = ‘fileout’> .ENDDATA
datanm	Specifies the data name referred to in the .TRAN, .DC or .AC statement.
LAM	Specifies column laminated (parallel merging) data files to be used.
MER	Specifies concatenated (series merging) data files to be used.
filenamei	Specifies the name of the data file to be read.

pnami	Specifies the parameter names used for source value, element value, device size, model parameter value, and so on.
colnum	Specifies the column number in the data file for the parameter value.
fileout	Specifies the name of the data file to be written with all the data concatenated.
pvali	Specifies the parameter value.

See “Column Laminated .DATA Statement” in the *Star-Hspice Manual*.

.DEL LIB Statement

General Form	.DEL LIB ‘<filepath>filename’ entryname .DEL LIB libnumber entryname
entryname	Entry name used in the library call statement to be deleted.
filename	Name of a file for deletion from the data file.
filepath	Path name of a file, if the operating system supports tree-structured directories.
libnumber	Library number used in the library call statement to be deleted.

See “.DEL LIB Statement” in the *Star-Hspice Manual*.

Element Statements

General Form	elname <node1 node2 … nodeN> + <mname> <pname1 = val1> + <pname2 = val2> <M = val>
Or	elname <node1 node2 … nodeN> + <mname> <pname = ‘expression’> + <M = val>
Or	elname <node1 node2 … nodeN> + <mname> <val1 val2 … valn>

B	IBIS buffer
C	Capacitor
D	Diode
E,F,G,H	Dependent current and voltage sources
I	Current source
J	JFET or MESFET
K	Mutual inductor
L	Inductor
M	MOSFET
Q	BJT
R	Resistor
T,U,W	Transmission line
V	Voltage source
X	Subcircuit call

elname	Element name that cannot exceed 1023 characters, and must begin with a specific letter for each element type.
expression	Any mathematical expression containing values or parameters, i.e., param1 * val2.
M = val	Element multiplier.
mname	Model reference name is required for all elements except passive devices.
node1 …	Node names are identifiers of the nodes to which the element is connected.
pname1 …	Element parameter name used to identify the parameter value that follows this name.
val1…	Value assigned to the parameter pname1 or to the corresponding model node.

See “Element and Source Statements” in the *Star-Hspice Manual*.

.END Statement

General Form	.END <comment>
comment	Any comment, normally the name of the data file being terminated.

See “.END Statement” in the *Star-Hspice Manual*.

.GLOBAL Statement

General Form	.GLOBAL node1 node2 node3 …

See ".GLOBAL Statement" in the *Star-Hspice Manual*.

.IC/.DCVOLT Initial Condition Statement

General Form	.IC v(node1)=val 1 v(node2)= val 2 …
Or	.DCVOLT V(node1)=val 1 V(node2)=val 2

See ".IC and .DCVOLT Initial Condition Statements" in the *Star-Hspice Manual*.

.INCLUDE Statement

General Form	.INCLUDE '<filepath> filename'

See ".INCLUDE Statement" in the *Star-Hspice Manual*.

.LIB Library Call Statement

General Form	.LIB '<filepath> filename' entryname
entryname	Entry name for the section of the library file to include.
filename	Name of a file to include in the data file.
filepath	Path to a file.

See ".LIB Library Call Statement" in the *Star-Hspice Manual*.

.LIB Library File Definition Statement

General Form

```
.LIB entryname1
.
. $ ANY VALID SET OF Star-Hspice
+ STATEMENTS
.
.ENDL entryname1
.LIB entryname2
.
. $ ANY VALID SET OF Star-Hspice
+ STATEMENTS
.
.ENDL entryname2
.LIB entryname3
.
. $ ANY VALID SET OF Star-Hspice
+ STATEMENTS
.
.ENDL entryname3
```

The text following a library file entry name must consist of valid Star-Hspice statements. See ".LIB Library File Definition Statement" in the *Star-Hspice Manual*.

.LIB Nested Library Calls

Library calls may be nested in other libraries provided they call different files. Library calls may be nested to any depth. See ".LIB Nested Library Calls" in the *Star-Hspice Manual*.

.MODEL Statement

General Form .MODEL mname type
+ <VERSION = version_number>
+ <pname1 = val1 pname2 = val2 …>

OPT	optimization model
PJF	p-channel JFET model
PLOT	plot model for the .GRAPH statement
PMOS	p-channel MOSFET model
PNP	pnp BJT model
R	resistor model
U	lossy transmission line model (lumped)
W	lossy transmission line model
SP	S-Parameter

mname	Model name reference.
pname1 …	Parameter name.
type	Selects the model type, which must be one of the following:

AMP	operational amplifier model
C	capacitor model
CORE	magnetic core model
D	diode model
L	magnetic core mutual inductor model
NJF	n-channel JFET model
NMOS	n-channel MOSFET model
NPN	npn BJT model

VERSION	Star-Hspice version number, used to allow portability of the BSIM (LEVEL=13), BSIM2 (LEVEL = 39) models between Star-Hspice releases. Version parameter also valid for LEVEL 49, 53, 54, 57, and 59.

See ".MODEL Statement" in the *Star-Hspice Manual*.

.NODESET Statement

General Form	.NODESET V(node1) = val1 + <V(node2) = val2 …>
Or	.NODESET node1 val1 <node2 val2>
node1…	Node numbers or node names can include full path names or circuit numbers

See ".NODESET Statement" in the *Star-Hspice Manual*.

.PARAM Statement

General Form	.PARAM <ParamName>=<RealNumber>

See ".PARAM Statement" in the *Star-Hspice Manual*.

Algebraic Format

General Form	.PARAM <ParamName>='algebraic expression'
Or	.PARAM<ParamName1>=<ParamName2>

Note: *Quotes around the algebraic expression are mandatory.*

See "Algebraic Parameter" in the *Star-Hspice Manual*.

Optimization Format

General Form	OPTIMIZE=opt_pav_fun
Or (for element or model keyname assignment)	.PARAM <ParamName>=<OptParamFunc> (<Init>, <LoLim>, <Hi Lim>, <Inc>)
paramname1 …	Parameter names are assigned to values
OptParmFunc	Optimization parameter function(string)
Init	Initial value of parameter (real)
LoLim	Lower limit for parameter (real)
HiLim	Upper limit for parameter (real)
Inc	Rounds to nearest <Inc> value (real)

Note: *A parameter can be used in an expression only if it is defined.*

.PROTECT Statement

General Form	.PROTECT

The .PROTECT command suppresses the printback of text. See “.PROTECT Statement” in the *Star-Hspice Manual*.

.TITLE Statement

General Form	Any string of up to 72 characters
Or	.Title "any string"
Title	The first line of the simulation is always the title.

See "Title of Simulation and .TITLE Statement" in the *Star-Hspice Manual*.

.UNPROTECT Statement

General Form	.UNPROTECT

The .UNPROTECT command restores normal output functions from a .PROTECT command. See ".UNPROTECT Statement" in the *Star-Hspice Manual*.

.WIDTH Statement

General Form	.WIDTH OUT={80|132}
OUT	The output print width. Permissible values are 80 and 132.

See ".WIDTH Statement" in the *Star-Hspice Manual*.

Chapter 13

Analyzing Data

You can perform several types of analysis with Star-Hspice. The topics covered in this chapter are:

- DC Analysis
- AC Analysis
- Small-Signal Network Analysis
- Temperature Analysis
- Transient Analysis
- FFT Analysis
- Worst Case Analysis

DC Analysis

Star-Hspice can perform the following types of DC analysis.

.DC Statement—DC Sweep

See ".DC Statement—DC Sweeps" in the *Star-Hspice Manual*.

Sweep or Parameterized Sweep

General Form	.DC var1 START = start1 STOP = stop1 + STEP = incr1
Or	.DC var1 START = <param_expr1> + STOP = <param_expr2> + STEP = <param_expr3>

Or	.DC var1 start1 stop1 incr1 <SWEEP + var2 type np start2 stop2>
Or	.DC var1 start1 stop1 incr1 + <var2 start2 stop2 incr2 >

Data-Driven Sweep

General Form	.DC var1 type np start1 stop1 + <SWEEP DATA = datanm>
Or	.DC DATA = datanm + <SWEEP var2 start2 stop2 incr2>
Or	.DC DATA = datanm

Monte Carlo

General Form	.DC var1 type np start1 stop1 + <SWEEP MONTE = val>
Or	.DC MONTE = val >

Optimization

General Form	.DC DATA = datanm OPTIMIZE = + opt_par_fun RESULTS = + measnames MODEL = optmod
Or	.DC var1 start1 stop1 SWEEP + OPTIMIZE = OPTxxx RESULTS = + measname MODEL = optmod
DATA=datanm	Datanm is the reference name of a .DATA statement.

incr1 …	Voltage, current, element, model parameters, or temperature increment values.
MODEL	Optimization reference name used in the .MODEL OPT statement.
MONTE=val	Produces a number *val* of randomly generated values, which are used to select parameters from a distribution.
np	Number of points per decade (or depending on the preceding keyword).
OPTIMIZE	Specifies the parameter reference name used in the .PARAM statement.
RESULTS	Specifies the measure name used in the .MEASURE statement.
start1 …	Starting voltage, current, element, model parameters, or temperature values.
stop1 …	Final voltage, current, any element, model parameter, or temperature values.
SWEEP	Indicates a second sweep has different type of variation (DEC, OCT, LIN, POI, DATA statement, or MONTE = val).
TEMP	Indicates a temperature sweep.
type	Can be any of the following keywords: DEC, OCT, LIN, POI.

var1 …	Name of an independent voltage or current source, any element or model parameter, or the keyword TEMP.

.OP Statement—Operating Point

General Form	.OP <format> <time> <format> <time>
format	Any of the following keywords: ALL, BRIEF, CURRENT, DEBUG, NONE, VOLTAGE.
time	Parameter after ALL, VOLTAGE, CURRENT, or DEBUG to specify the time at which the report is printed.

See ".OP Statement — Operating Point" in the *Star-Hspice Manual*.

.SENS Statement—DC Sensitivity Analysis

General Form	.SENS ov1 <ov2 ...>
ov1 ov2 …	Branch currents or nodal voltage for DC component sensitivity analysis.

See ".SENS Statement — DC Sensitivity Analysis" in the *Star-Hspice Manual*.

.TF Statement—DC Small-Signal Transfer Function Analysis

General Form	.TF ov srcnam
ov	Small-signal output variable
srcnam	Small-signal input source

See “.TF Statement — DC Small-Signal Transfer Function Analysis” in the *Star-Hspice Manual*.

AC Analysis

.AC Statement

Single/Double Sweep

General Form	.AC type np fstart fstop
Or	.AC type np fstart fstop <SWEEP var start + stop incr>
Or	.AC var1 START = <param_expr1 STOP = + <param_expr2> STEP = <param_expr3>
Or	.AC var1 START = start1 STOP = stop1 + STEP = incr1

See “Using the .AC Statement” in the *Star-Hspice Manual*.

.PZ Statement—Pole/Zero Analysis

General Form	.PZ ov srcnam
ov	Output variable: a node voltage V(n), or branch current I(element)
srcnam	Input source: an independent voltage or current source name

See “.PZ Statement— Pole/Zero Analysis” in the *Star-Hspice Manual*.

Parameterized Sweep

General Form	.AC type np fstart fstop <SWEEP DATA = + datanm>
Or	AC DATA = datanm

Optimization

General Form	.AC DATA=datanm OPTIMIZE = + opt_par_fun RESULTS = measnames + MODEL = optmod

Random/Monte Carlo

General Form	.AC type np fstart fstop <SWEEP + MONTE = val>
DATA=datanm	Data name referenced in the .AC statement.
fstart	Starting frequency.
fstop	Final frequency.
incr	Voltage, current, element, or model parameter increment value.
MONTE = val	Produces a number *val* of randomly-generated values used to select parameters from a distribution.
np	Number of points per decade (or depending on the preceding keyword).
start	Starting voltage, current, any element, or model parameter value.

stop	Final voltage, current, any element, or model parameter value.
SWEEP	Indicates a second sweep is specified in the .AC statement.
TEMP	Indicates a temperature sweep
type	Can be any of the following keywords: DEC, OCT, LIN, POI.
var	Name of an independent voltage or current source, any element or model parameter, or the keyword TEMP.

.DISTO Statement—AC Small-Signal Distortion Analysis

General Form	.DISTO Rload <inter <skw2 <refpwr + <spwf>>>>
inter	Interval at which a distortion-measure summary is to be printed.
refpwr	Reference power LEVEL used in computing the distortion products.
Rload	The name of the output load resistor into which the output power is fed.
skw2	Ratio of the second frequency F2 to the nominal analysis frequency F1.
spwf	Amplitude of the second frequency F2.

See ".DISTO Statement — AC Small-Signal Distortion Analysis" in the *Star-Hspice Manual*.

.NOISE Statement—AC Noise Analysis

General Form	.NOISE ovv srcnam inter
inter	Interval at which a noise analysis summary is to be printed; inter specifies a number of frequency points summary in the AC sweep.
ovv	Nodal voltage output variable defining the node at which the noise is summed.
srcnam	Name of the independent voltage or current source used as the noise input reference.

See ".NOISE Statement — AC Noise Analysis" in the *Star-Hspice Manual*.

.SAMPLE Statement—Noise Folding Analysis

General Form	.SAMPLE FS = freq <TOL = val> + <NUMF = val> <MAXFLD = val> + <BETA = val>
BETA	Integrator duty cycle; specifies an optional noise integrator at the sampling node.
FS = freq	Sample frequency, in Hertz.
MAXFLD	Maximum allowed number of folding intervals.
NUMF	Maximum allowed number of user-specified frequencies.
TOL	Sampling error tolerance.

See ".SAMPLE Statement — Noise Folding Analysis" in the *Star-Hspice Manual*.

Small-Signal Network Analysis

.NET Statement—AC Network Analysis

One-port network

General Form	.NET input <RIN = val>
Or	.NET input <val >

Two-port network

General Form	.NET output input <ROUT = val> + <RIN = val>
input	AC input voltage or current source name.
output	Output port.
RIN	Input or source resistance keyword.
ROUT	Output or load resistance keyword.

See ".NET Statement - AC Network Analysis" in the *Star-Hspice Manual*.

AC Network Analysis—Output Specification

General Form	Xij(z), ZIN(z), ZOUT(z), YIN(z), YOUT(z)
ij	Identifies which matrix parameter to print.
X	Specifies Z for impedance, Y for admittance, H for hybrid, and S for scattering.
YIN	Input admittance.
YOUT	Output admittance.

z	Output type: R, I, M, P, DB, T.
ZIN	Input impedance.
ZOUT	Output impedance.

See "AC Network Analysis - Output Specification" in the *Star-Hspice Manual*.

Temperature Analysis

.TEMP Statement

General Form	.TEMP t1 <t2 <t3 ...>>
t1 t2 …	Specifies temperatures, in °C, at which the circuit is to be simulated.

See ".TEMP Statement" in the *Star-Hspice Manual*.

Transient Analysis

.TRAN Statement

See "Using the .TRAN Statement" in the *Star-Hspice Manual*.

Single-Point Analysis

General Form	.TRAN var1 START = start1 STOP = stop1 + STEP = incr1
Or	.TRAN var1 START = <param_expr1> + STOP = <param_expr2> STEP = + <param_expr3>

Double-Point Analysis

General Form	.TRAN var1 START = start1 STOP = stop1 + STEP = incr1 <SWEEP var2 type np + start2 stop2>
Or	.TRAN tincr1 tstop1 <tincr2 tstop2 + ...tincrN tstopN> <START = val> <UIC> + <SWEEP var pstart pstop pincr>

Parameterized Sweep

General Form	.TRAN tincr1 tstop1 <tincr2 tstop2 + ...tincrN tstopN> <START = val> <UIC>

Data-Driven Sweep

General Form	.TRAN DATA = datanm
Or	.TRAN var1 START = start1 STOP = stop1 + STEP = incr1 <SWEEP DATA = + datanm>
Or	.TRAN DATA = datanm <SWEEP var + pstart pstop pincr>

Monte Carlo Analysis

General Form	.TRAN tincr1 tstop1 <tincr2 tstop2 + ...tincrN tstopN> + <START = val> + <UIC><SWEEP MONTE = val> >

Optimization

General Form	.TRAN DATA = datanm OPTIMIZE = + opt_par_fun RESULTS = measnames + MODEL = optmod
DATA = datanm	Data name referenced in the .TRAN statement.
MONTE = val	Produces a number *val* of randomly-generated values used to select parameters from a distribution.
np	Number of points per decade (or depending on the preceding keyword).
param_expr...	User-specified expressions.
pincr	Voltage, current, element, or model parameter, or temperature increment value.
pstart	Starting voltage, current, temperature, any element, or model parameter value.
pstop	Final voltage, current, temperature, any element, or model parameter value.
START	Time at which printing/plotting begins.
SWEEP	Indicates a second sweep is specified on the .TRAN statement.
tincr1…	Printing/plotting increment for printer output, and the suggested computing increment for the postprocessor.

tstop1…	Time at which the transient analysis stops incrementing by tincr1.
type	Specifies any of the following keywords: DEC, OCT, LIN, POI.
UIC	Causes Star-Hspice to use the nodal voltages specified in the .IC statement (or by the “IC = ” parameters in the various element statements) to calculate the initial transient conditions, rather than solving for the quiescent operating point.
var	Name of an independent voltage or current source, any element or model parameter, or the keyword TEMP.

FFT Analysis

.FFT Statement

General Form	.FFT <output_var> <START = value> + <STOP = value> <NP = value> + <FORMAT = keyword> + <WINDOW = keyword> + <ALFA = value> <FREQ = value> + <FMIN = value> <FMAX = value>
ALFA	Parameter used in GAUSS and KAISER windows to control the highest side-lobe LEVEL, bandwidth, and so on.

FMAX	Maximum frequency for which FFT output is printed in the listing file, or which is used in THD calculations.
FMIN	Minimum frequency for which FFT output is printed in the listing file, or which is used in THD calculations.
FORMAT	Output format.
FREQ	Frequency of interest.
FROM	An alias for START.
NP	Number of points used in the FFT analysis.
output_var	Any valid output variable, such as voltage, current, or power.
START	Beginning of the output variable waveform to be analyzed.
STOP	End of the output variable waveform to be analyzed.
TO	An alias for STOP.
WINDOW	Window type to be used: RECT, BART, HANN, HAMM, BLACK, HARRIS, GAUSS, KAISER.

See ".FFT Statement" in the *Star-Hspice Manual*.

Numerical Integration Algorithm Controls

See “Numerical Integration Algorithm Controls” in the *Star-Hspice Manual*.

Gear Algorithm

General Form	.OPTION METHOD=GEAR

Backward-Euler

General Form	.OPTION METHOD=GEAR MU = 0

Trapezoidal Algorithm

General Form	.OPTION METHOD=TRAP

Worst Case Analysis

See “Performing Worst Case Analysis” in the *Star-Hspice Manual*.

Sigma Deviations

Type	Param	Slow	Fast
NMOS	XL	+	-
	RSH	+	-
	DELVTO	+	-
	TOX	+	-
	XW	-	+

Type	Param	Slow	Fast
PMOS	XL	+	-
	RSH	+	-
	DELVTO	-	+
	TOX	+	-
	XW	-	+

See “Sigma Deviations” in the *Star-Hspice Manual*.

Monte Carlo Analysis

HSPICE statements needed to set up a Monte Carlo analysis are:

- .PARAM statement.
- .DC, .AC, or .TRAN analysis—enable MONTE.
- .MEASURE statement.

See “Performing Monte Carlo Analysis” in the *Star-Hspice Manual*. For details about the syntax for these statements, see “Analysis Syntax” in the *Star-Hspice Manual*.

Operating Point

General Form	.DC MONTE=val

DC Sweep

General Form	.DC vin 1 5 .25 SWEEP MONTE=val

AC Sweep

General Form	.AC dec 10 100 10meg SWEEP + MONTE=val

TRAN Sweep

General Form	.TRAN 1n 10n SWEEP MONTE=val

.PARAM Distribution Function Syntax

General Form	.PARAM xx=UNIF(nominal_val, + rel_variation <, multiplier>)
Or	.PARAM xx=AUNIF(nominal_val, + abs_variation <,multiplier>)
Or	.PARAM xx=GAUSS(nominal_val, + rel_variation, sigma <,multiplier>)
Or	.PARAM xx=AGAUSS(nominal_val, + abs_variation, sigma <,multiplier>)
Or	.PARAM xx=LIMIT(nominal_val, + abs_variation)
abs_variation	The AUNIF and AGAUSS vary the nominal_val by +/- abs_variation.
AGAUSS	Gaussian distribution function using absolute variation.
AUNIF	Uniform distribution function using absolute variation.
GAUSS	Gaussian distribution function using relative variation.

LIMIT	Random limit distribution function using absolute variation.
multiplier	If not specified, the default is 1.
nominal_val	Nominal value for Monte Carlo analysis and default value for all other analyses.
rel_variation	The UNIF and GAUSS vary the nominal_val by +/- (nominal_val · rel_variation).
sigma	The abs_variation or rel_variation is specified at the sigma LEVEL.
UNIF	Uniform distribution function using relative variation.
xx	The parameter whose value is calculated by distribution function.

Avant!

Chapter 14

Optimizing Data

This chapter briefly describes how to optimize your design data. The topics covered in this chapter are:

- Analysis Statement (.DC, .TRAN, .AC) Syntax
- .PARAM Statement Syntax
- .MODEL Statement Syntax
- Filters and Systems
- Laplace Transforms

Analysis Statement (.DC, .TRAN, .AC) Syntax

General Form	.DC <DATA=filename> SWEEP + OPTIMIZE=OPTxxx RESULTS=ierr1 ... + ierr*n* MODEL=optmod
DATA	In-line file of parameter data to use in the optimization.
MODEL	The optimization reference name (also specified in the .MODEL optimization statement).
OPTIMIZE	Indicates the analysis is for optimization.
Or	.AC <DATA=filename> SWEEP + OPTIMIZE=OPTxxx RESULTS=ierr1 ... + ierr*n* MODEL=optmod

Or	.TRAN <DATA=filename> SWEEP + OPTIMIZE=OPTxxx RESULTS=ierr1 ... + ierr*n* MODEL=optmod
RESULTS	The measurement reference name (also specified in the .MEASURE optimization statement).

See “Analysis Statement (.DC, .TRAN, .AC)” in the *Star-Hspice Manual*.

.PARAM Statement Syntax

General Form	.PARAM parameter=OPTxxx + (initial_guess, low_limit, upper_limit)
Or	.PARAM parameter=OPTxxx + (initial_guess, low_limit, upper_limit, + delta)
delta	The final parameter value is the initial guess ± (n·delta).
OPTxxx	Optimization parameter reference name, referenced by the associated optimization analysis.
parameter	Parameter to be varied, the initial value estimate, the lower limit, and the upper limit allowed for the parameter.

See “.PARAM Statement” in the *Star-Hspice Manual*.

.MODEL Statement Syntax

General Form	.MODEL *mname* OPT <parameter = val + ...>
CENDIF	Point at which more accurate derivatives are required.
CLOSE	The initial estimate of how close the parameter initial value estimates are to the final solution.
CUT	Modifies CLOSE, depending on how successful the iterations toward the solution become.
DIFSIZ	Determines the increment change in a parameter value for gradient calculations ($\Delta x = DIFSIZ \cdot max(x, 0.1)$).
GRAD	Represents a possible convergence when the gradient of the RESULTS function is less than GRAD.
ITROPT	Sets the maximum number of iterations.
LEVEL	Selects the optimizing algorithm to use.
MAX	Sets the upper limit on CLOSE.
mname	Model name.
PARMIN	Allows better control of incremental parameter changes during error calculations.

RELIN	Relative input parameter variation for convergence.
RELOUT	Relative output RESULTS function variance for convergence.

See ".MODEL Statement" in the *Star-Hspice Manual*.

Filters and Systems

.PZ Statement—Pole/Zero Analysis

General Form	.PZ ov srcnam
ov	Output variable: a node voltage V(n), or branch current I(element)
srcnam	Input source: an independent voltage or current source name

See ".PZ Statement— Pole/Zero Analysis" in the *Star-Hspice Manual*.

Laplace Transforms

See "Laplace Transform (LAPLACE) Function" and "Laplace Transform" in the *Star-Hspice Manual*.

Transconductance H(s)

General Form	Gxxx n_+ n_- LAPLACE in_+ in_- k_0, k_1, ..., k_n + / d_0, d_1, ..., d_m <SCALE=val> <TC1=val> + <TC2=val> <M=val>

Voltage Gain H(s)

General Form	Exxx n_+ n_- LAPLACE in_+ in_- k_0, k_1, ..., k_n + / d_0, d_1, ..., d_m <SCALE=val> <TC1=val> + <TC2=val>

Chapter 15

Output Format

The topics covered in this chapter are:

- Graphing Results in AvanWaves
- AC Analysis
- Print Commands
- DC and Transient Output
- Power Output
- AC Analysis Output
- Element Template Output
- Element Template Listings

For a detailed description of graphing with HSPLOT and GSI, see the *Star-Hspice Manual*, Chapter 4, “Graphing.”

Graphing Results in AvanWaves

The .option POST must be placed in the Hspice netlist input file.

- POST or POST=1 creates a binary file.
- POST=2 creates an ascii file, portable to all supported machines.

Limiting the Size of the Graph Data File

The option PROBE limits the number of curves stored to those nodes specified in the Hspice input file's .PRINT, .PLOT, .OPTION PROBE, and .GRAPH statements. The option INTERP (for transient analysis only) limits the number of points stored. The option INTERP preinterpolates the output to the interval specified on the .TRAN statement.

Automatic Hardcopy During HSPICE Run

A .GRAPH statement will automatically produce a hardcopy plot. A .TITLE placed before each .GRAPH will set the graph title. Otherwise, the simulation title will be used. The option POST in conjunction with .GRAPH will create a graph data file.

Starting AvanWaves—Command line

AvanWaves' command line definition is:

```
awaves [[-d] <path><design-name> [-c
+ <config_name>] [-laf(windows|openlook|motif)]
```

-d	The name of the design to be opened on invoking AvanWaves
-c	Specifies that a previously saved configuration for the current design is to be used upon the initialization of AvanWaves.
-laf[windows|openlook|motif]	Specifies the window manager style to be used. The default is Motif.

Setup Commands

Cmd	Default	Description
I	--	Name input file.
XMIN, XMAX, YMIN, YMAX	X=LIM Y=AUTO	Set range defaults for all panels.
XS, YS	LIN	Set x or y scale.
P	1	Set number of panels.
F	NONE	Set the frequency of symbols.
T	ON	Set/Toggle ticks.
M	NO	Monotonic. Set/Toggle for family of curves.
XG, YG	ON	Set/Toggle x or y grids.
D	--	Reinitialize all Setup menu values.

Accessible Menus From Setup

G	Bring up the Graph window.
N	Bring up the Node window.
Q	Exit the program.

Node Menu Prompts

-Panel	Each panel prompts for one x-axis parameter and any number of y-axis curves.

-X-axis	Any node may be chosen as the x-axis for a panel.
-Y-axis	Any listed node name or function, or algebraic expression can be entered at the y-axis prompt.

Node Menu Commands

$P	Remove all curves in present panel.
$A	Remove all curves from all panels.
$Q	Exit the program.
MORE	Display next/previous page of nodes.
/BACK	These commands appear only when the node list spans more than one page.
$S	Bring up the Setup menu.

AC Analysis

*R	Draw the Real component of the data.
*I	Draw the Imaginary component of the data.
*M	Calculate and draw the Magnitude
*P	Calculate and draw the Phase.

Graph Commands

A, D	Add or Delete curves or expressions.
X, Y	Change the view on some panels or all panels.
Q	Exit the program.

Accessible Menus from Graph Menu

N	Bring up the Node window
P	Bring up the Print menu
S	Bring up the Setup menu

Print Menu

The Print menu lists printers and /or plotters at your site on which you may create a hardcopy plot.

Screensave Option

The SCREENSAVE function produces a file that can later be displayed on the terminal. The function is useful for making video slides.

Print Commands

<CR>	Print with the default printer.
1…n-1	Print with one of printer options.
n	Save the screen into a preview file.

.PRINT Statement

General Form	.PRINT antype ov1 <ov2 … ov32>

See “.PRINT Statement” in the *Star-Hspice Manual*.

.PLOT Statement

General Form	.PLOT antype ov1 <(plo1,phi1)> … + <ov32> <(plo32,phi32)>

See “.PLOT Statement” in the *Star-Hspice Manual*.

.PROBE Statement

General Form	.PROBE antype ov1 … <ov32>

See “.PROBE Statement” in the *Star-Hspice Manual*.

.GRAPH Statement

General Form	.GRAPH antype <MODEL = mname> + <unam1 = > ov1, <unam2 = >ov2, … + <unam32 = > ov32 (plo,phi)
antype	Type of analysis for outputs: DC, AC, TRAN, NOISE, or DISTO.
mname	Plot model name referenced by the .GRAPH statement.
ov1 …ov2	Output variables to be printed/plotted; 32 maximum.
plo, phi …	Lower and upper plot limits.
unam1…	User-defined output names.

See “.GRAPH Statement” in the *Star-Hspice Manual*.

.MODEL Statement for .GRAPH

General Form	.MODEL mname PLOT (pnam1 = val1 + pnam2 = val2….)
mname	Plot model name referenced by the .GRAPH statement.
PLOT	Keyword for a .GRAPH statement model.
pnam1=val1…	Each .GRAPH statement model includes a variety of model parameters.

See “.MODEL Statement for .GRAPH” in the *Star-Hspice Manual*.

.MEASURE Statement: Rise, Fall, and Delay

<table>
<tr><th>General Form</th><th>.MEASURE <DC|AC|TRAN> result
+ TRIG … TARG … <GOAL=val>
+ <MINVAL=val> <WEIGHT=val></th></tr>
<tr><td><DC|AC|TRAN></td><td>Analysis type of the measurement. If omitted, the last analysis mode requested is assumed.</td></tr>
<tr><td>GOAL</td><td>Desired measure value in optimization.</td></tr>
<tr><td>MEASURE</td><td>Specifies measurements.</td></tr>
</table>

MINVAL	If the absolute value of GOAL is less than MINVAL, the GOAL value is replaced by MINVAL in the denominator of the ERRfun expression.
result	Name associated with the measured value in the Star-Hspice output.
TRIG…, TARG …	Identifies the beginning of trigger and target specifications, respectively.
WEIGHT	The calculated error is multiplied by the weight value.

See ".MEASURE Statement: Rise, Fall, and Delay" in the *Star-Hspice Manual*.

Trigger

General Form	TRIG trig_var VAL=trig_val + <TD=time_delay> <CROSS=c> + <RISE=r> <FALL=f>
Or	TRIG AT=val
result	Name associated with the measured value in the Star-Hspice output.

See "Trigger" in the *Star-Hspice Manual*.

Target

General Form	TARG targ_var VAL = targ_val + <TD = time_delay> <CROSS = c | LAST> + <RISE = r | LAST> <FALL = f | LAST>
AT = val	Special case for trigger specification.
CROSS = c RISE = r FALL = f	The numbers indicate which occurrence of a CROSS, FALL, or RISE event causes a measurement to be performed.
LAST	Measurement is performed when the last CROSS, FALL, or RISE event occurs.
TARG	Beginning of the target signal specification.
targ_val	Value of the *targ_var* at which the counter for crossing, rises, or falls is incremented by one.
targ_var	Name of the output variable whose propagation delay is determined with respect to the *trig_var*.
time_delay	Amount of simulation time that must elapse before the measurement is enabled.
TRIG	Beginning of the trigger specification.
trig_val	Value of *trig_var* at which the counter for crossing, rises, or falls is incremented by one.
trig_var	Name of the output variable, that determines the logical beginning of measurement.

See “Target” in the *Star-Hspice Manual*.

Average, RMS, MIN, MAX, and Peak to Peak

General Form	.MEASURE <DC|AC|TRAN> result + func out_var <FROM = val> + <TO = val> <GOAL = val> + <MINVAL = val> <WEIGHT = val>
<DC|AC|TRAN>	Analysis type of the measurement. If omitted, the last analysis mode requested is assumed.
FROM	Initial value for the “func” calculation.
func	Type of the measure statement: • AVG (average) • MAX (maximum) • MIN (minimum) • PP (peak-to-peak) • RMS (root mean squared)
GOAL	Desired .MEASURE value.
MINVAL	If the absolute value of GOAL is less than MINVAL, the GOAL value is replaced by MINVAL in the denominator of the ERRfun expression.

out_var	Name of any output variable whose function is to be measured in the simulation.
result	Name associated with the measured value in the Star-Hspice output.
TO	End of the “func” calculation.
WEIGHT	The calculated error is multiplied by the weight value.

See “Average, RMS, MIN, MAX, INTEG, and Peak-To-Peak” in the *Star-Hspice Manual*.

Equation Evaluation

General Form	.MEASURE <DC|TRAN|AC> result + PARAM = ‘equation’ <GOAL = val> + <MINVAL = val>

See “Equation Evaluation” in the *Star-Hspice Manual*.

ERROR Function

General Form	.MEASURE <DC|AC|TRAN> result + ERRfun meas_var calc_var + <MINVAL = val> < IGNORE | + YMIN = val> <YMAX = val> + <WEIGHT = val> <FROM = val> + <TO = val>

<DC|AC|TRAN>	Analysis type of the measurement. If omitted, the last analysis mode requested is assumed.
calc_var	Name of the simulated output variable or parameter in the .MEASURE statement to be compared with *meas_var*.
ERRfun	ERRfun indicates which error function to use: ERR, ERR1, ERR2, or ERR3.
FROM	Beginning of the ERRfun calculation.
IGNOR|YMIN	If the absolute value of *meas_var* is less than IGNOR value, then this point is not considered in the ERRfun calculation.
meas_var	Name of any output variable or parameter in the data statement.
MINVAL	If the absolute value of *meas_var* is less than MINVAL, the *meas_var* value is replaced by MINVAL in the denominator of the ERRfun expression.
result	Name associated with the measured result in the output.
TO	End of the ERRfun calculation.
WEIGHT	The calculated error is multiplied by the weight value.

YMAX — If the absolute value of *meas_var* is greater than the YMAX value, then this point is not considered in the ERRfun calculation.

See “ERROR Function” in the *Star-Hspice Manual*.

Find and When Functions

General Form

```
.MEASURE <DC|TRAN| AC> result
+ WHEN out_var = val <TD = val>
+ < RISE = r | LAST > <FALL = f |
+ LAST > <CROSS = c | LAST >
+ <GOAL = val> <MINVAL = val>
+ <WEIGHT = val>
```

Or

```
.MEASURE <DC|TRAN|AC> result
+ WHEN out_var1 = out_var2
+ < TD = val > < RISE = r | LAST >
+ <FALL = f | LAST > < CROSS = c|
+ LAST > <GOAL = val>
+ <MINVAL = val> <WEIGHT = val>
```

Or

```
.MEASURE <DC|TRAN|AC> result
+ FIND out_var1 WHEN out_var2 = val
+ < TD = val > < RISE = r | LAST >
+ <FALL = f | LAST > < CROSS = c|
+ LAST > <GOAL = val>
+ <MINVAL = val> <WEIGHT = val>
```

Or

```
.MEASURE <DC|TRAN|AC> result
+ FIND out_var1 WHEN
+ out_var2 = out_var3 <TD = val >
+ < RISE = r | LAST > <FALL = f |
+ LAST ><CROSS = c | LAST>
+ <GOAL = val> <MINVAL = val>
+ <WEIGHT = val>
```

Or

```
.MEASURE <DC|TRAN|AC> result
+ FIND out_var1 AT = val
+ <GOAL = val> <MINVAL = val>
+ <WEIGHT = val>
```

<DC|AC|TRAN> — Analysis type of the measurement. If omitted, the last analysis type requested is assumed.

CROSS = c
RISE = r
FALL = f — The numbers indicate which occurrence of a CROSS, FALL, or RISE event causes a measurement to be performed.

FIND — Selects the FIND function.

GOAL — Desired .MEASURE value.

LAST — Measurement is performed when the last CROSS, FALL, or RISE event occurs.

MINVAL — If the absolute value of GOAL is less than MINVAL, the GOAL value is replaced by MINVAL in the denominator of the ERRfun expression.

out_var(1,2,3)	Variables used to establish conditions at which measurement is to take place.
result	Name associated with the measured value in the Star-Hspice output.
TD	Time at which measurement is to start.
WEIGHT	Calculated error is multiplied by the weight value.
WHEN	Selects the WHEN function.

See “FIND and WHEN Functions” in the *Star-Hspice Manual*.

DC and Transient Output

See “DC and Transient Output Variables” in the *Star-Hspice Manual*.

Nodal Voltage

General Form	V (n1<,n2>)
n1, n2	Defines nodes between which the voltage difference (n1-n2) is to be printed/plotted.

See “Nodal Voltage” in the *Star-Hspice Manual*.

Current: Voltage Sources

General Form	I (Vxxx)
Vxxx	Voltage source element name.

See “Current: Voltage Sources” in the *Star-Hspice Manual*.

Current: Element Branches

General Form	In (Wwww)
n	Node position number in the element statement.
Wwww	Element name.

See “Current: Element Branches” in the *Star-Hspice Manual*.

Power Output

See “Power Output” in the *Star-Hspice Manual*.

Print/Plot Power

General Form	.PRINT antype ov1 <ov2 … ov32>
Or	.PLOT antype ov1 <(plo1,phi1)> … + <ov32> <(plo32,phi32)>
antype	Type of analysis for the specified plots: DC, AC, TRAN, NOISE, or DISTO.
ov1 …	Output variables to plot.
plo1,phi1 …	Lower and upper plot limits.

Power calculation is associated only with transient and DC sweep analyses. The .MEASURE statement may be used to compute the average, rms, minimum, maximum, and peak to peak value of the power. POWER invokes the total power dissipation output. See “Print or Plot Power” in the *Star-Hspice Manual*.

AC Analysis Output

See “AC Analysis Output Variables” in the *Star-Hspice Manual*.

Nodal Voltage

General Form	Vz (n1,<,n2>)
z	Voltage output type.
DB	Decibel
I	Imaginary Part
M	Magnitude
P	Phase
R	Real Part
T	Group Delay
n1, n2	Node names. If n2 is omitted, ground (node 0) is assumed.

See “Nodal Voltage” in the *Star-Hspice Manual*.

Current: Independent Voltage Sources

General Form	Iz (Vxxx)
Vxxx	Voltage source element name.
z	Current output type. See nodal voltage for specific output types.

See “Current: Independent Voltage Sources” in the *Star-Hspice Manual*.

Current: Element Branches

General Form	Izn (Wwww)
n	Node position number in the element statement.
Wwww	Element name.
z	Current output type. See nodal voltage for specific output types.

See “Current: Element Branches” in the *Star-Hspice Manual*.

Group Time Delay

General Form	.PRINT AC VT(10) VT(2,25) IT(RL) .PLOT AC IT1(Q1) IT3(M15) IT(D1)

Note: *Since there is discontinuity in phase each 360 degrees, the same discontinuity is noticed in the Td, even though Td is not discontinued.*

See “Group Time Delay” in the *Star-Hspice Manual*.

Network Output

General Form	Xij (z), ZIN(z), ZOUT(z), YIN(z), YOUT(z)
ij	i and j can be 1 or 2.
X	Specifies Z for impedance, Y for admittance, H for hybrid, or S for scattering parameters.
YIN	Input admittance.
YOUT	Output admittance.
z	Output type.

ZIN	Input impedance.
ZOUT	Output impedance.

See “Network” in the *Star-Hspice Manual*.

Noise and Distortion

General Form	ovar <(z)>

Note: *See “Nodal Voltage” on page 15-17 for specific output types.*

ovar	Noise and distortion analysis parameter.
z	Output type (only for distortion).

See “Noise and Distortion” in the *Star-Hspice Manual*.

Element Template Output

Use for DC, AC, or Transient Analysis.

General Form	Elname:Property
Elname	Name of the element.
Property	Property name of an element, such as a user-input parameter, state variable, stored charge, capacitance current, capacitance, or derivative of a variable.

See “Element Template Output” in the *Star-Hspice Manual*.

Element Template Listings

Resistor

Name	Alias	Description
G	LV1	Conductance at analysis temperature
R	LV2	Resistance at reference temperature
TC1	LV3	First temperature coefficient
TC2	LV4	Second temperature coefficient

Capacitor

Name	Alias	Description
CEFF	LV1	Computed effective capacitance
IC	LV2	Initial condition
Q	LX0	Charge stored in capacitor
CURR	LX1	Current flowing through capacitor
VOLT	LX2	Voltage across capacitor
–	LX3	Capacitance (not used in Star-Hspice releases after 95.3)

Inductor

Name	Alias	Description
LEFF	LV1	Computed effective inductance
IC	LV2	Initial condition

Name	Alias	Description
FLUX	LX0	Flux in the inductor
VOLT	LX1	Voltage across inductor
CURR	LX2	Current flowing through inductor
–	LX4	Inductance (not used in Star-Hspice releases after 95.3)

Mutual Inductor

Name	Alias	Description
K	LV1	Mutual inductance

Voltage-Controlled Current Source

Name	Alias	Description
CURR	LX0	Current through the source, if VCCS
R	LX0	Resistance value, if VCR
C	LX0	Capacitance value, if VCCAP
CV	LX1	Controlling voltage
CQ	LX1	Capacitance charge, if VCCAP
DI	LX2	Derivative of source current with respect to control voltage
ICAP	LX2	Capacitance current, if VCCAP
VCAP	LX3	Voltage across capacitance, if VCCAP

Voltage-Controlled Voltage Source

Name	Alias	Description
VOLT	LX0	Source voltage
CURR	LX1	Current through source
CV	LX2	Controlling voltage
DV	LX3	Derivative of source voltage with respect to control current

Current-Controlled Current Source

Name	Alias	Description
CURR	LX0	Current through source
CI	LX1	Controlling current
DI	LX2	Derivative of source current with respect to control current

Current-Controlled Voltage Source

Name	Alias	Description
VOLT	LX0	Source voltage
CURR	LX1	Source current
CI	LX2	Controlling current
DV	LX3	Derivative of source voltage with respect to control current

Independent Voltage Source

Name	Alias	Description
VOLT	LV1	DC/transient voltage
VOLTM	LV2	AC voltage magnitude
VOLTP	LV3	AC voltage phase

Independent Current Source

Name	Alias	Description
CURR	LV1	DC/transient current
CURRM	LV2	AC current magnitude
CURRP	LV3	AC current phase

Diode

Name	Alias	Description
AREA	LV1	Diode area factor
AREAX	LV23	Area after scaling
IC	LV2	Initial voltage across diode
VD	LX0	Voltage across diode (VD), excluding RS (series resistance)
IDC	LX1	DC current through diode (ID), excluding RS. Total diode current is the sum of IDC and ICAP

Name	Alias	Description
GD	LX2	Equivalent conductance (GD)
QD	LX3	Charge of diode capacitor (QD)
ICAP	LX4	Current through diode capacitor.
		Total diode current is the sum of IDC and ICAP.
C	LX5	Total diode capacitance
PID	LX7	Photo current in diode

BJT

Name	Alias	Description
AREA	LV1	Area factor
ICVBE	LV2	Initial condition for base-emitter voltage (VBE)
ICVCE	LV3	Initial condition for collector-emitter voltage (VCE)
MULT	LV4	Number of multiple BJTs
FT	LV5	FT (Unity gain bandwidth)
ISUB	LV6	Substrate current
GSUB	LV7	Substrate conductance
LOGIC	LV8	LOG 10 (IC)
LOGIB	LV9	LOG 10 (IB)

Name	Alias	Description
BETA	LV10	BETA
LOGBETAI	LV11	LOG 10 (BETA) current
ICTOL	LV12	Collector current tolerance
IBTOL	LV13	Base current tolerance
RB	LV14	Base resistance
GRE	LV15	Emitter conductance, 1/RE
GRC	LV16	Collector conductance, 1/RC
PIBC	LV18	Photo current, base-collector
PIBE	LV19	Photo current, base-emitter
VBE	LX0	VBE
VBC	LX1	Base-collector voltage (VBC)
CCO	LX2	Collector current (CCO)
CBO	LX3	Base current (CBO)
GPI	LX4	g_{π} = ib / vbe, constant vbc
GU	LX5	$g\mu$ = ib / vbc, constant vbe
GM	LX6	g_m = ic / vbe+ ic / vbe, constant vce
G0	LX7	g_0 = ic / vce, constant vbe
QBE	LX8	Base-emitter charge (QBE)

Name	Alias	Description
CQBE	LX9	Base-emitter charge current (CQBE)
QBC	LX10	Base-collector charge (QBC)
CQBC	LX11	Base-collector charge current (CQBC)
QCS	LX12	Current-substrate charge (QCS)
CQCS	LX13	Current-substrate charge current (CQCS)
QBX	LX14	Base-internal base charge (QBX)
CQBX	LX15	Base-internal base charge current (CQBX)
GXO	LX16	1/Rbeff Internal conductance (GXO)
CEXBC	LX17	Base-collector equivalent current (CEXBC)
–	LX18	Base-collector conductance (GEQCBO) (not used in Star-Hspice releases after 95.3)
CAP_BE	LX19	cbe capacitance ($C\Pi$)
CAP_IBC	LX20	cbc internal base-collector capacitance ($C\mu$)

Name	Alias	Description
CAP_SCB	LX21	csc substrate-collector capacitance for vertical transistors csb substrate-base capacitance for lateral transistors
CAP_XBC	LX22	cbcx external base-collector capacitance
CMCMO	LX23	(TF*IBE) / vbc
VSUB	LX24	Substrate voltage

JFET

Name	Alias	Description
AREA	LV1	JFET area factor
VDS	LV2	Initial condition for drain-source voltage
VGS	LV3	Initial condition for gate-source voltage
PIGD	LV16	Photo current, gate-drain in JFET
PIGS	LV17	Photo current, gate-source in JFET
VGS	LX0	VGS
VGD	LX1	Gate-drain voltage (VGD)
CGSO	LX2	Gate-to-source (CGSO)

Name	Alias	Description
CDO	LX3	Drain current (CDO)
CGDO	LX4	Gate-to-drain current (CGDO)
GMO	LX5	Transconductance (GMO)
GDSO	LX6	Drain-source transconductance (GDSO)
GGSO	LX7	Gate-source transconductance (GGSO)
GGDO	LX8	Gate-drain transconductance (GGDO)
QGS	LX9	Gate-source charge (QGS)
CQGS	LX10	Gate-source charge current (CQGS)
QGD	LX11	Gate-drain charge (QGD)
CQGD	LX12	Gate-drain charge current (CQGD)
CAP_GS	LX13	Gate-source capacitance
CAP_GD	LX14	Gate-drain capacitance
–	LX15	Body-source voltage (not used in Star-Hspice releases after 95.3)
QDS	LX16	Drain-source charge (QDS)
CQDS	LX17	Drain-source charge current (CQDS)

Name	Alias	Description
GMBS	LX18	Drain-body (backgate) transconductance (GMBS)

MOSFET

Name	Alias	Description
L	LV1	Channel length (L)
W	LV2	Channel width (W)
AD	LV3	Area of the drain diode (AD)
AS	LV4	Area of the source diode (AS)
ICVDS	LV5	Initial condition for drain-source voltage (VDS)
ICVGS	LV6	Initial condition for gate-source voltage (VGS)
ICVBS	LV7	Initial condition for bulk-source voltage (VBS)
–	LV8	Device polarity: 1 = forward, -1 = reverse (not used in Star-Hspice releases after 95.3)
VTH	LV9	Threshold voltage (bias dependent)
VDSAT	LV10	Saturation voltage (VDSAT)
PD	LV11	Drain diode periphery (PD)

Name	Alias	Description
PS	LV12	Source diode periphery (PS)
RDS	LV13	Drain resistance (squares) (RDS)
RSS	LV14	Source resistance (squares) (RSS)
XQC	LV15	Charge sharing coefficient (XQC)
GDEFF	LV16	Effective drain conductance (1/RDeff)
GSEFF	LV17	Effective source conductance (1/RSeff)
IDBS	LV18	Drain-bulk saturation current at -1 volt bias
ISBS	LV19	Source-bulk saturation current at -1 volt bias
VDBEFF	LV20	Effective drain bulk voltage
BETAEFF	LV21	BETA effective
GAMMAEFF	LV22	GAMMA effective
DELTAL	LV23	ΔL (MOS6 amount of channel length modulation) (only valid for LEVELs 1, 2, 3 and 6)
UBEFF	LV24	UB effective (only valid for LEVELs 1, 2, 3 and 6)

Name	Alias	Description
VG	LV25	VG drive (only valid for LEVELs 1, 2, 3 and 6)
VFBEFF	LV26	VFB effective
–	LV31	Drain current tolerance (not used in Star-Hspice releases after 95.3)
IDSTOL	LV32	Source diode current tolerance
IDDTOL	LV33	Drain diode current tolerance
COVLGS	LV36	Gate-source overlap capacitance
COVLGD	LV37	Gate-drain overlap capacitance
COVLGB	LV38	Gate-bulk overlap capacitance
VBS	LX1	Bulk-source voltage (VBS)
VGS	LX2	Gate-source voltage (VGS)
VDS	LX3	Drain-source voltage (VDS)
CDO	LX4	DC drain current (CDO)
CBSO	LX5	DC source-bulk diode current (CBSO)
CBDO	LX6	DC drain-bulk diode current (CBDO)
GMO	LX7	DC gate transconductance (GMO)

Name	Alias	Description
GDSO	LX8	DC drain-source conductance (GDSO)
GMBSO	LX9	DC substrate transconductance (GMBSO)
GBDO	LX10	Conductance of the drain diode (GBDO)
GBSO	LX11	Conductance of the source diode (GBSO)
Meyer and Charge Conservation Model Parameters		
QB	LX12	Bulk charge (QB)
CQB	LX13	Bulk charge current (CQB)
QG	LX14	Gate charge (QG)
CQG	LX15	Gate charge current (CQG)
QD	LX16	Channel charge (QD)
CQD	LX17	Channel charge current (CQD)
CGGBO	LX18	$CGGBO = \partial Qg/\partial Vgb$ = CGS + CGD + CGB
CGDBO	LX19	$CGDBO = \partial Qg/\partial Vdb$, (for Meyer CGD = -CGDBO)
CGSBO	LX20	$CGSBO = \partial Qg/\partial Vsb$, (for Meyer CGS = -CGSBO)

Name	Alias	Description
CBGBO	LX21	$CBGBO = \partial Qb / \partial Vgb$, (for Meyer CGB = -CBGBO)
CBDBO	LX22	$CBDBO = \partial Qb / \partial Vdb$
CBSBO	LX23	$CBSBO = \partial Qb / \partial Vsb$
QBD	LX24	Drain-bulk charge (QBD)
–	LX25	Drain-bulk charge current (CQBD) (not used in Star-Hspice releases after 95.3)
QBS	LX26	Source-bulk charge (QBS)
–	LX27	Source-bulk charge current (CQBS) (not used in Star-Hspice releases after 95.3)
CAP_BS	LX28	Bulk-source capacitance
CAP_BD	LX29	Bulk-drain capacitance
CQS	LX31	Channel charge current (CQS)
CDGBO	LX32	$CDGBO = \partial Qd / \partial Vgb$
CDDBO	LX33	$CDDBO = \partial Qd / \partial Vdb$
CDSBO	LX34	$CDSBO = \partial Qd / \partial Vsb$

Saturable Core Element

Name	Alias	Description
MU	LX0	Dynamic permeability (mu) Weber/(amp-turn-meter)
H	LX1	Magnetizing force (H) Ampere-turns/meter
B	LX2	Magnetic flux density (B) Webers/meter^2

Saturable Core Winding

Name	Alias	Description
LEFF	LV1	Effective winding inductance (Henry)
IC	LV2	Initial condition
FLUX	LX0	Flux through winding (Weber-turn)
VOLT	LX1	Voltage across winding (Volt)