

18 Juncap

18.1 JUNCAP Model

18.1.1 Introduction

References

[28] Sze, S.M., *Physics of semiconductor devices*, 2nd edition, John Wiley & Sons, Inc., New York, 1981

18.1.2 Physics

In this section the elementary physics of a junction diode is summarized. An extensive survey can be found in the textbooks about semiconductor devices [28], pp 74-96. Generally, the current voltage characteristics can be represented as follows:

$$J = \{J_d(n_i^2) + J_g(n_i, V)\} \cdot \left[\exp\left(\frac{qV}{kT}\right) - 1 \right] \quad (18.1)$$

$$n_i \sim T^{3/2} \cdot \exp\left(\frac{-E_g}{2kT}\right) \quad (18.2)$$

in which:

Quantity	Units	Description
J	Am^{-2}	Total reverse current density
J_d	Am^{-2}	Diffusion saturation current density
J_g	Am^{-2}	Generation current density
n_i	m^{-3}	Intrinsic carrier concentration
V	V	Voltage across the diode
E_g	J	Energy gap
k	JK^{-1}	Boltzmann constant
T	K	Temperature

For $V < V_D$ the charge of the junction capacitance is described by:

$$Q = Q_J \cdot \left[1 - \left(1 - \frac{V}{V_D} \right)^{(1-P)} \right] \quad (18.3)$$

In which:

Quantity	Units	Description
Q	C	Total diode junction charge
Q_J	C	Junction charge at built-in voltage
V	V	Voltage across the diode
V_D	V	Junction diffusion voltage
P	-	Junction grading coefficient

18.1.3 Parameters and constants

List of Electrical Variables

Variable	Programming Name	Units	Description
V_A	VA	V	Potential applied to the anode
V_K	VK	V	Potential applied to the cathode
I_A	IA	A	DC current into the anode
I_K	IK	A	DC current into the cathode
Q_A	QA	C	Charge in the device attributed to the anode
Q_K	QK	C	Charge in the device attributed to the cathode

Parameter list

Symbol	Programming Name	Units	Description
-	LEVEL	--	Level of this model. Must be set to 1
-	PARAMCHK	--	Level of clip warning info (*)
-	TYPE	--	switch (-1 or 1) to select $p - n$ or $n - p$ junction
A_B	AB	m^2	Diffusion area
L_S	LS	m	Length of the side-wall of the diffusion area AB which is not under the gate
L_G	LG	m	Length of the side-wall of the diffusion area AB which is under the gate
ΔT_A	DTA	$^{\circ}C$	Temperature offset of the JUNCAP element with respect to T_A
T_R	TR	$^{\circ}C$	Temperature at which the parameters have been determined
V_R	VR	V	Voltage at which parameters have been determined

Symbol	Programming Name	Units	Description
J_{SGBR}	JSGBR	Am^{-2}	Bottom saturation-current density due to electron-hole generation at $V = V_R$
J_{SDBR}	JSDBR	Am^{-2}	Bottom saturation-current density due to diffusion from back contact
J_{SGSR}	JSGSR	Am^{-1}	Sidewall saturation-current density due to electron-hole generation at $V = V_R$
J_{SDSR}	JSDSR	Am^{-1}	Sidewall saturation-current density due to diffusion from back contact
J_{SGGR}	JSGGR	Am^{-1}	Gate edge saturation-current density due to electron-hole generation at $V = V_R$
J_{SDGR}	JSDGR	Am^{-1}	Gate edge saturation-current density due to diffusion from back contact
N_B	NB	-	Emission coefficient of the bottom forward current
N_S	NS	-	Emission coefficient of the sidewall forward current
N_G	NG	-	Emission coefficient of the gate edge forward current
V_B	VB	V	Reverse breakdown voltage
C_{JBR}	CJBR	Fm^{-2}	Bottom junction capacitance at $V = V_R$
C_{JSR}	CJSR	Fm^{-1}	Sidewall junction capacitance at $V = V_R$
C_{JGR}	CJGR	Fm^{-1}	Gate edge junction capacitance at $V = V_R$
V_{DBR}	VDBR	V	Diffusion voltage of the bottom junction at $T = T_R$
V_{DSR}	VDSR	V	Diffusion voltage of the sidewall junction at $T = T_R$
V_{DGR}	VDGR	V	Diffusion voltage of the gate edge junction at $T = T_R$
P_B	PB	-	Bottom-junction grading coefficient
P_S	PS	-	Sidewall-junction grading coefficient

Symbol	Programming Name	Units	Description
P_G	PG	-	Gate-edge-junction grading coefficient
I_{MAX}	IMAX	A	Explosion current
$MULT$	MULT	-	Multiplication factor
-	PRINT-SCALED	-	Flag to add scaled parameters to the OP output

(*) See Appendix B for the definition of PARAMCHK.

List of Internal Variables and Parameters

Parameter	Programming Name	Units	Description
V_{DB}	VDB	V	Diffusion voltage of bottom area A_B
V_{DS}	VDS	V	Diffusion voltage of Locos-edge L_S
V_{DG}	VDG	V	Diffusion voltage of gate-edge L_G
C_{JB}	CJB	F	Capacitance of bottom area A_B
C_{JS}	CJS	F	Capacitance of Locos-edge L_S
C_{JG}	CJG	F	Capacitance of gate-edge L_G
I_{SDB}	ISDB	A	Diffusion saturation-current of bottom area A_B
I_{SDS}	ISDS	A	Diffusion saturation-current of Locos-edge L_S
I_{SDG}	ISDG	A	Diffusion saturation-current of gate-edge L_G
I_{SGB}	ISGB	A	Generation saturation-current of bottom area A_B
I_{SGS}	ISGS	A	Generation saturation-current of Locos-edge L_S
I_{SGG}	ISGG	A	Generation saturation-current of gate-edge L_G

T_A	TA	$^{\circ}\text{C}$	Ambient circuit temperature
T_{KD}	TKD	K	Absolute temperature of the junction/device
V	V	V	Diode bias voltage ($V = V_A - V_K$)
I	I	A	Total DC current from anode to cathode ($I = I_A = -I_K$)
Q	Q	C	Total junction charge ($Q = Q_A = -Q_K$)
V_{EXPL}	VEXPL	V	Explosion voltage

Default and clipping values

The default values and clipping values as used for the juncap model are listed below.

Parameter name	Units	Default	Clip low	Clip high
<i>LEVEL</i>	-	1	-	-
<i>PARAMCHK</i>	-	0	-	-
<i>AB</i>	m ²	1.00 × 10 ⁻¹²	0.00	-
<i>LS</i>	m	1.00 × 10 ⁻⁶	0.00	-
<i>LG</i>	m	1.00 × 10 ⁻⁶	0.00	-
<i>DTA</i>	°C	0.00	-	-
<i>TR</i>	°C	25.00	-273.15	-
<i>VR</i>	V	0.00	-	-
<i>JSGBR</i>	Am ⁻²	1.00 × 10 ⁻³	0.00	-
<i>JSDBR</i>	Am ⁻²	1.00 × 10 ⁻³	0.00	-
<i>JSGSR</i>	Am ⁻¹	1.00 × 10 ⁻³	0.00	-
<i>JSDSR</i>	Am ⁻¹	1.00 × 10 ⁻³	0.00	-
<i>JSGGR</i>	Am ⁻¹	1.00 × 10 ⁻³	0.00	-
<i>JSDGR</i>	Am ⁻¹	1.00 × 10 ⁻³	0.00	-
<i>NB</i>	-	1.00	0.1	-
<i>NS</i>	-	1.00	0.1	-
<i>NG</i>	-	1.00	0.1	-
<i>VB*</i>	V	0.90	-	-
<i>CJBR</i>	Fm ⁻²	1.00 × 10 ⁻¹²	0.00	-
<i>CJSR</i>	Fm ⁻¹	1.00 × 10 ⁻¹²	0.00	-
<i>CJGR</i>	Fm ⁻¹	1.00 × 10 ⁻¹²	0.00	-
<i>VDBR</i>	V	1.00	0.05	-

<i>VDSR</i>	V	1.00	0.05	-
<i>VDGR</i>	V	1.00	0.05	-
<i>PB</i>	-	0.40	0.05	0.99
<i>PS</i>	-	0.40	0.05	0.99
<i>PG</i>	-	0.40	0.05	0.99
<i>IMAX</i>	A	1000	-	-
<i>TYPE</i>	-	-1	-1	1
<i>MULT</i>	-	1.00	0.00	-
<i>PRINTSCALED</i>	-	0.0	-	-

* The value for *VB* is **(NOT USED)**!

18.1.4 Model equations

The JUNCAP model is intended to describe the behaviour of the diodes that are formed by the source, drain or well-to-bulk junctions in MOS devices. The model is limited to the case of reverse biasing of these junctions. Similarly to the MOS model, the current equations are formulated and AC effects are modeled via charge equations using the quasi-static approximation. In order to include the effects from differences in the sidewall, bottom and gate-edge-junction profiles, these three contributions are calculated separately in the JUNCAP model. Both the diffusion and the generation currents are treated in the model, each with its own temperature and voltage dependence.

In the JUNCAP model a part of the total charge comes from the gate-edge junction very close to the surface. This charge is also included in the MOS-model charge equations, and is therefore counted twice. However this results in only a very minor error.

In the next section the model equations are presented. Correct operation of the model in a circuit-simulator environment requires some numerical additions, that are described in the section on the implementation. Finally any fixed capacitance that is present on a node - e.g. the metal-1-to-substrate capacitance - must appear in a fixed-capacitor statement or must be included in INTCAP. They no longer form a part of the JUNCAP model in contrast to the old NODCAP model.

Temperature, Geometry and Voltage Dependence

The general scaling rules, which apply to all three components of the JUNCAP model, are:

$$T_{KR} = T_0 + T_R \quad (18.4)$$

$$T_{KD} = T_0 + T_A + \Delta T_A \quad (18.5)$$

$$\phi_{TR} = \frac{k \cdot T_{KR}}{q} \quad (18.6)$$

$$\phi_{TD} = \frac{k \cdot T_{KD}}{q} \quad (18.7)$$

$$\phi_{gR} = 1.16 - \frac{7.02 \cdot 10^{-4} \cdot T_{KR}^2}{1108.0 + T_{KR}} \quad (18.8)$$

$$\phi_{gD} = 1.16 - \frac{7.02 \cdot 10^{-4} \cdot T_{KD}^2}{1108.0 + T_{KD}} \quad (18.9)$$

$$F_{TD} = \left(\frac{T_{KD}}{T_{KR}} \right)^{1.5} \cdot \exp\left(\frac{\phi_{gR}}{2\phi_{TR}} - \frac{\phi_{gD}}{2\phi_{TD}} \right) \quad (18.10)$$

The internal reference parameters for the bottom component are specified by:

$$V_{DB} = V_{DBR} \cdot \frac{T_{KD}}{T_{KR}} - 2 \cdot \phi_{TD} \cdot \ln F_{TD} \quad (18.11)$$

$$C_{JB} = C_{JBR} \cdot A_B \cdot \left(\frac{V_{DBR} - V_R}{V_{DB}} \right)^{P_B} \quad (18.12)$$

$$I_{SGB} = J_{SGBR} \cdot F_{TD} \cdot A_B \cdot \left(\frac{V_{DB}}{V_{DBR} - V_R} \right)^{P_B} \quad (18.13)$$

$$I_{SDB} = J_{SDBR} \cdot F_{TD}^2 \cdot A_B \quad (18.14)$$

Similar formulations hold for the locos-edge and the gate-edge components; one has to replace the index B by S and G , and the area A_B by L_S and L_G , so for the locos-edge:

$$V_{DS} = V_{DSR} \cdot \frac{T_{KD}}{T_{KR}} - 2 \cdot \phi_{TD} \cdot \ln F_{TD} \quad (18.15)$$

$$C_{JS} = C_{JSR} \cdot L_S \cdot \left(\frac{V_{DSR} - V_R}{V_{DS}} \right)^{P_S} \quad (18.16)$$

$$I_{SGS} = J_{SGSR} \cdot F_{TD} \cdot L_S \cdot \left(\frac{V_{DS}}{V_{DSR} - V_R} \right)^{P_S} \quad (18.17)$$

$$I_{SDS} = J_{SDSR} \cdot F_{TD}^2 \cdot L_S \quad (18.18)$$

for the gate-edge:

$$V_{DG} = V_{DGR} \cdot \frac{T_{KD}}{T_{KR}} - 2 \cdot \phi_{TD} \cdot \ln F_{TD} \quad (18.19)$$

$$C_{JG} = C_{JGR} \cdot L_G \cdot \left(\frac{V_{DGR} - V_R}{V_{DG}} \right)^{P_G} \quad (18.20)$$

$$I_{SGG} = J_{SGGR} \cdot F_{TD} \cdot L_G \cdot \left(\frac{V_{DG}}{V_{DGR} - V_R} \right)^{P_G} \quad (18.21)$$

$$I_{SDG} = J_{SDGR} \cdot F_{TD}^2 \cdot L_G \quad (18.22)$$

In subsequent sections we will show the equations only for the bottom component.

JUNCAP - Capacitor and Leakage Current Model

- Junction capacitance of the source or drain diode
In the charge description the following internal parameter is defined:

$$Q_{JDB} = \frac{C_{JB} \cdot V_{DB}}{1 - P_B} \quad (18.23)$$

In order to prevent an unlimited increase of the voltage derivative of the charge, the charge description is divided in two parts: the original power function and a supplemented quadratic function. At the cross-over point between these regions, indicated by $V_{L\dots}$, the following parameters are defined:

$$F_{CB} = 1 - \left(\frac{1 + P_B}{3} \right)^{\frac{1}{P_B}} \quad (18.24)$$

$$V_{LB} = F_{CB} \cdot V_{DB} \quad (18.25)$$

$$C_{LB} = C_{JB} (1 - F_{CB})^{-P_B} \quad (18.26)$$

$$Q_{LB} = Q_{JDB} \left\{ 1 - (1 - F_{CB})^{1 - P_B} \right\} \quad (18.27)$$

$$Q_{JBV} = \begin{cases} Q_{JDB} \cdot \left\{ 1 - \left(1 - \frac{V}{V_{DB}} \right)^{1 - P_B} \right\}, & V < V_{LB} \\ Q_{LB} + C_{LB}(V - V_{LB}) \cdot \left\{ 1 + \frac{P_B(V - V_{LB})}{2 \cdot V_{DB}(1 - F_{CB})} \right\}, & V \geq V_{LB} \end{cases} \quad (18.28)$$

and similar expressions for the locos-edge and gate-edge charges, Q_{JSV} and Q_{JGV} . The total charge characteristic can be described by:

$$Q = Q_{JBV} + Q_{JSV} + Q_{JGV}$$

Using elementary mathematics we can derive from Eqn. (18.28) simple equations for the capacitance of the bottom area:

$$C_{JBV} = \begin{cases} C_{JB} \cdot \frac{1}{\left(1 - \frac{V}{V_{DB}} \right)^{P_B}}, & V < V_{LB} \\ C_{LB} + \frac{C_{LB} \cdot P_B \cdot (V - V_{LB})}{V_{DB} \cdot (1 - F_{CB})}, & V \geq V_{LB} \end{cases} \quad (18.29)$$

and similar expressions for C_{JSV} and C_{JGV} .

The total capacitance can be described by:

$$C = C_{JBV} + C_{JSV} + C_{JGV}$$

- Bulk to source or bulk to drain diode current

With the scaled parameters of the preceding section, the diffusion and generation current components can be expressed as:

$$I_{DB} = I_{SDB} \cdot \left\{ \exp\left(\frac{V}{N_B \cdot \Phi_{TD}}\right) - 1 \right\} \quad (18.30)$$

$$I_{GB} = \begin{cases} I_{SGB} \cdot \left(\frac{V_{DB} - V}{V_{DB}}\right)^{P_B} \cdot \left\{ \exp\left(\frac{V}{N_B \cdot \Phi_{TD}}\right) - 1 \right\}, & V \leq V_{DB} \\ 0, & V > V_{DB} \end{cases} \quad (18.31)$$

The first relation concerning the diffusion component, is valid over the whole operating range.

The exponential formula for I_{DB} in (18.30) is used until I_{DB} reaches a maximum (explosion) current I_{MAX} . The explosion voltage for which this happens is called V_{EXPL}^{DB} . From (18.30)

the value of V_{EXPL}^{DB} can be derived:

$$V_{EXPL}^{DB} = N_B \Phi_{TD} \log\left(\frac{I_{MAX}}{I_{SDB}} + 1\right). \quad (18.32)$$

For $V > V_{EXPL}^{DB}$ the following linear expression is used for I_{DB} :

$$I_{DB} = I_{MAX} + \left(V - V_{EXPL}^{DB}\right) \frac{I_{SDB}}{N_B \Phi_{TD}} \exp\left(\frac{V_{EXPL}^{DB}}{N_B \Phi_{TD}}\right) \quad (18.33)$$

The second relation, describing the generation current, shows an unlimited increase in the derivative of this function at $V = V_{DB}$. Therefore the power function is merged at $V = 0.0$ with a hyperbolic function in the forward bias range and the exponential part is divided by $\exp\left(\frac{V}{N_B \cdot \phi_{TD}}\right)$. This enables a gradual decrease in the generation current component.

The hyperbolic function: $I_{HYP} = F_{SB} (V + V_{AB})^{-B}$ is used. The parameter B controls the decrease of the current for voltages $V > 0.0$ for all generation components. The value of B is fixed and set to 2 in the model. The continuity constraints of function and derivative in the merge point lead to the following relations for F_{SB} and V_{AB} :

$$V_{AB} = \frac{B \cdot V_{DB}}{P_B} \quad (18.34)$$

$$F_{SB} = I_{SGB} \cdot V_{AB}^B \quad (18.35)$$

Now the generation current voltage characteristic in the forward region becomes:

$$I_{GB} = \frac{F_{SB}}{(V + V_{AB})^B} \cdot \left\{ 1 - \exp\left(\frac{-V}{N_B \cdot \phi_{TD}}\right) \right\} \quad (18.36)$$

and the final model equations for the currents of the bottom area are:

$$I_{DB} = \begin{cases} I_{SDB} \left(\exp\left(\frac{V}{N_B \cdot \phi_{TD}}\right) - 1 \right), & V \leq V_{EXPL}^{DB} \\ I_{MAX} + \left(V - V_{EXPL}^{DB} \right) \frac{I_{SDB}}{N_B \phi_{TD}} \exp\left(\frac{V - V_{EXPL}^{DB}}{N_B \phi_{TD}}\right), & V > V_{EXPL}^{DB} \end{cases} \quad (18.37)$$

$$I_{GB} = \begin{cases} I_{SGB} \cdot \left(\frac{V_{DB} - V}{V_{DB}}\right)^{P_B} \cdot \left\{ \exp\left(\frac{V}{N_B \cdot \phi_{TD}}\right) - 1 \right\}, & V \leq 0.0 \\ I_{SGB} \cdot \left(\frac{V_{AB}}{V + V_{AB}}\right)^B \cdot \left\{ 1 - \exp\left(\frac{-V}{N_B \cdot \phi_{TD}}\right) \right\}, & V > 0.0 \end{cases} \quad (18.38)$$

With similar expressions for the locos-edge and gate-edge components, the total junction current can be expressed as:

$$I = (I_{DB} + I_{GB}) + (I_{DS} + I_{GS}) + (I_{DG} + I_{GG}) \quad (18.39)$$

The same current limiting applies to the calculation of I_{DS} and I_{DG} , leading to different explosion voltages V_{EXPL}^{DS} and V_{EXPL}^{DG} . The actual value of V_{EXPL} used for all three currents I_{DB} , I_{DS} and I_{DG} is the minimum of the three explosion voltages:

$$V_{EXPL} = \min\left(V_{EXPL}^{DB}, V_{EXPL}^{DS}, V_{EXPL}^{DG}\right).$$

Numerical Adaptation

To implement the model in a circuit simulator, care must be taken of the numerical stability of the simulation program. A small non-physical conductance, G_{min} , is connected parallel to the conductance G . The value of the conductance G_{min} is 10^{-15} [1/ Ω].

18.1.5 DC operating point output

The DC operating point output facility gives information on the state of a device at its operation point.

Quantity	Equation	Description
G		Conductance
C		Capacitance
$Lx1$		Current
$Lx3$		Charge
$Lx5$		Capacitance

Remark: The conductance G_{min} is connected parallel to the conductance G . This conductance influences the DC operating output.

Remark: The quantities $Lx1$, $Lx3$ and $Lx5$ are supplied specifically for use by some simulators (e.g. *UltraSim*) in their calculations.

When the parameter PRINTSCALED is set to 1 the following scaled parameters are added to the OP output:

Quantity	Description
DTA	Temperature offset of the juncap element with respect to T_A
TR	Reference temperature
VR	Reference voltage
$ISGB$	Bottom saturation-current due to electron-hole generation at device temperature, at $V=V_R$ (Ref. eqn. 18.13)
$ISDB$	Bottom saturation-current due to diffusion from back contact at device temperature (Ref. eqn. 18.14)
$ISGS$	Sidewall saturation-current due to electron-hole generation at $V=V_R$ at device temperature (Ref. eqn. 18.17)
$ISDS$	Sidewall saturation-current due to diffusion from back contact at device temperature (Ref. eqn. 18.18)
$ISGG$	Gate edge saturation-current due to electron-hole generation at $V=V_R$ at device temperature (Ref. eqn. 18.21)
$ISDG$	Gate edge saturation-current due to diffusion from back contact at device temperature (Ref. eqn. 18.22)
NB	Emission coefficient of the bottom forward current

Quantity	Description
<i>NS</i>	Emission coefficient of the sidewall forward current
<i>NG</i>	Emission coefficient of the gate edge forward current
<i>CJB</i>	Bottom junction capacitance at $V=V_R$ at device temperature
<i>CJS</i>	Sidewall junction capacitance at $V=V_R$ at device temperature
<i>CJG</i>	Gate edge junction capacitance at $V=V_R$ at device temperature
<i>VDB</i>	Diffusion voltage of the bottom junction at device temperature
<i>VDS</i>	Diffusion voltage of the sidewall junction at device temperature
<i>VDG</i>	Diffusion voltage of the gate edge junction at device temperature
<i>PB</i>	Bottom junction grading coefficient
<i>PS</i>	Sidewall junction grading coefficient
<i>PG</i>	Gate edge junction grading coefficient
<i>IMAX</i>	Explosion current
<i>VEXPL</i>	Explosion voltage

18.1.6 Simulator specific items

Pstar syntax

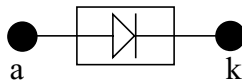
juncap_n (a,k) level=1, type=1, <parameters>
 juncap_n (a,k) level=1, type=-1, <parameters>

n : occurrence indicator
 <parameters> : list of model parameters
 a and k are anode and cathode terminals respectively.

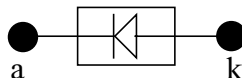
3 Note

The type parameter indicates the position of the diode.

When type = -1:



When type = 1:



The default type for Juncap level 1 is -1.

⚠ Care

When assignment by position is used, the order of the parameters must be equal to the order specified in the model definition. Readability is improved if assignment by name is used.

Spectre syntax

```
model modelname juncap type=p <modpar> componentname a k modelname <inpar>
model modelname juncap type=n <modpar> componentname a k modelname <inpar>
```

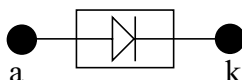
modelname : name of model, user defined
 componentname : occurrence indicator
 <modpar> : list of model parameters
 <inpar> : list of instance parameters

a and k are anode and cathode terminals respectively.

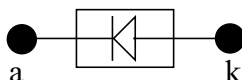
3 Note

The type parameter indicates the position of the diode.

When type = p:



When type = n:



The default type for Juncap level 1 is n.

Warning! In Spectre, use only the parameter statements type=n or type=p. Using any other string and/or numbers will result in unpredictable and possibly erroneous results.

ADS syntax

```

model modelname juncap gender=0 <modpar>
modelname: componentname a k <instpar>
model modelname juncap gender=1 <modpar>
modelname: componentname a k <instpar>

```

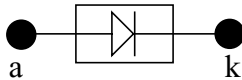
modelname	:	name of model, user defined
componentname	:	occurrence indicator
<modpar>	:	list of model parameters
<instpar>	:	list of instance parameters

a and k are anode and cathode terminals respectively.

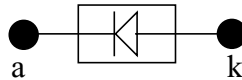
3 Note

The gender parameter indicates the position of the diode.

When gender = 0:



When gender = 1:



The default gender for Juncap level 1 is 1, which is n-type.

The ON/OFF condition for Pstar

The solution for a circuit involves a process of successive calculations. The calculations are started from a set of 'initial guesses' for the electrical quantities of the nonlinear elements. A simplified DCAPPROX mechanism for devices using ON/OFF keywords is given in [9]. By default the devices start in the default state.

JUNCAP2			
	Default	ON	OFF
V_{AK}	-0.1	0.7	-0.1

The ON/OFF condition for Spectre

JUNCAP2			
	Default	ON	OFF
V_{AK}	-0.1	0.7	0.0

The ON/OFF condition for ADS

JUNCAP2			
	Default	ON	OFF
V_{AK}	0.0	0.0	0.0

18.1.7 Parameter extraction

A Spectre Specific Information

Imax, Imelt, Jmelt parameters

Introduction

Imax, Imelt and Jmelt are Spectre-specific parameters used to help convergence and to prevent numerical problems. We refer in this text only to the use of Imax model parameter in Spectre with SiMKit devices since the other two parameters, Imelt and Jmelt, are not part of the SiMKit code. For information on Imelt and Jmelt refer to Cadence documentation.

Imax model parameter

Imax is a model parameter present in the following SiMKit models:

- juncap and juncap2
- psp and pspnqs (since they contain juncap models)

In Mextram 504 (bjt504) and Modella (bjt500) SiMKit models, Imax is an internal parameter and its value is set through the adapter via the Spectre-specific parameter Imax.

The default value of the Imax model parameter is 1000A. Imax should be set to a value which is large enough so it does not affect the extraction procedure.

In models that contain junctions, the junction current can be expressed as:

$$I = I_s \exp\left(\frac{V}{N \cdot \phi_{TD}} - 1\right) \quad (19.94)$$

The exponential formula is used until the junction current reaches a maximum (explosion) current Imax.

$$I_{max} = I_s \exp\left(\frac{V_{expl}}{N \cdot \phi_{TD}} - 1\right) \quad (19.95)$$

The corresponding voltage for which this happens is called Vexpl (explosion voltage). The voltage explosion expression can be derived from (1):

$$V_{expl} = N \cdot \phi_{TD} \log\left(\frac{I_{max}}{I_s}\right) + 1 \quad (19.96)$$

For $V > V_{expl}$ the following linear expression is used for the junction current:

$$I = I_{max} + (V - V_{expl}) \frac{I_s}{N \cdot \phi_{TD}} \exp\left(\frac{V_{expl}}{N \cdot \phi_{TD}}\right) \quad (19.97)$$

Region parameter

Region is an Spectre-specific model parameter used as a convergence aid and gives an estimated DC operating region. The possible values of region depend on the model:

- For Bipolar models:
 - subth: Cut-off or sub-threshold mode
 - fwd: Forward
 - rev: Reverse
 - sat: Saturation.
 - off¹
 -
- For MOS models:
 - subth: Cut-off or sub-threshold mode;
 - triode: Triode or linear region;
 - sat: Saturation
 - off¹

For PSP and PSPNQS all regions are allowed, as the PSP(NQS) models both have a MOS part and a juncap (diode). Not all regions are valid for each part, but when e.g. region=fwd is set, the initial guesses for the MOS will be set to zero. The same holds for setting a region that is not valid for the JUNCAP.

- For diode models:
 - fwd: Forward
 - rev: Reverse
 - brk: Breakdown
 - off¹

Model parameters for device reference temperature in Spectre

This text describes the use of the tnom, tref and tr model parameters in Spectre with SiMKit devices to set the device reference temperature.

¹.Off is not an electrical region, it just states that the user does not know in what state the device is operating

A Simkit device in Spectre has three model parameter aliases for the model reference temperature, `tnom`, `tref` and `tr`. These three parameters can only be used in a model definition, not as instance parameters.

There is no difference in setting `tnom`, `tref` or `tr`. All three parameters have exactly the same effect. The following three lines are therefore completely equivalent:

```
model nmos11020 mos11020 type=n tnom=30
model nmos11020 mos11020 type=n tref=30
model nmos11020 mos11020 type=n tr=30
```

All three lines set the reference temperature for the `mos11020` device to 30 C.

Specifying combinations of `tnom`, `tref` and `tr` in the model definition has no use, only the value of the last parameter in the model definition will be used. E.g.:

```
model nmos11020 mos11020 type=n tnom=30 tref=34
```

will result in the reference temperature for the `mos11020` device being set to 34 C, `tnom=30` will be overridden by `tref=34` which comes after it.

When there is no reference temperature set in the model definition (so no `tnom`, `tref` or `tr` is set), the reference temperature of the model will be set to the value of `tnom` in the options statement in the Spectre input file. So setting:

```
options1 options tnom=23 gmin=1e-15 reltol=1e-12 \
  vabstol=1e-12 iabstol=1e-16
model nmos11020 mos11020 type=n
```

will set the reference temperature of the `mos11020` device to 23 C.

When no `tnom` is specified in the options statement and no reference temperature is set in the model definition, the default reference temperature is set to 27 C.

So the lines:

```
options1 options gmin=1e-15 reltol=1e-12 vabstol=1e-12 \
  iabstol=1e-16
model nmos11020 mos11020 type=n
```

will set the reference temperature of the `mos11020` device to 27 C.

The default reference temperature set in the SiMKit device itself is in the Spectre simulator never used. It will always be overwritten by either the default "options tnom", an explicitly set option tnom or by a tnom, tref or tr parameter in the model definition.

B Parameter PARAMCHK

Parameter PARAMCHK

Introduction

All models have the parameter PARAMCHK. It is not related to the model behavior, but has been introduced control the clip warning messages. Various situations may call for various levels of warnings. This is made possible by setting this parameter.

PARAMCHK model parameter

This model parameter has been added to control the amount of clip warnings.

PARAMCHK	<	0	No clip warnings
PARAMCHK	≥	0	Clip warnings for instance parameters (default)
PARAMCHK	≥	1	Clip warnings for model parameters
PARAMCHK	≥	2	Clip warnings for electrical parameters at initialisation
PARAMCHK	≥	3	Clip warnings for electrical parameters during evaluation. This highest level is of interest only for selfheating jobs, where electrical parameters may change dependent on temperature.