Spice Name	Model Parameter	Units	Default	Example
IS	Saturation current	A	1×10^{-14}	1.0×10^{-14}
RS	Ohmic resistance	Ω	0	10
N	Emission coefficient	–	1	1.0
TT	Transit-time	sec	0	0.1 ns
CJO	Zero-bias junction capacitance	F	0	2 pF
VJ	Junction potential	V	1	0.6
M	Grading coefficient	–	0.5	0.5
EG	Activation energy	eV	1.11	1.11 Si 0.69 Sbd 0.67 Ge
XTI	Saturation-current temperature coefficient	–	3.0	3.0 pn-junction 2.0 Sbd
KF	Flicker noise coefficient	–	0	
AF	Flicker noise exponent	–	1	
FC	Coefficient for forward-bias depletion capacitance formula	–	0.5	
BV	Reverse-bias breakdown voltage	V	∞	40.0
IBV	Reverse-bias breakdown current	A	1×10^{-10}	1.0×10^{-10}

Table A.1 Semiconductor diode model parameters.

modeled by a transit time TT and a nonlinear depletion-layer capacitance. The parameters that effect the depletion layer capacitance are CJO, VJ, M and FC. The temperature dependence of the saturation current is defined by the parameters EG and XTI. The flicker noise behavior of the diode is defined by the parameters KF and AF. Reverse breakdown is modeled by an exponential increase in the reverse diode current and is determined by the parameters BV and IBV.

The parameters used to model a semiconductor diode in Spice are listed in Table A.1.

A.2 BJT Model

The bipolar junction transistor model in Spice is an adaptation of the integral charge control model of Gummel and Poon. The model will automatically simplify to the Ebers-Moll model when certain parameters are not specified.

The forward static current gain characteristic of the BJT is defined by the parameters IS, BF, NF, ISE, IKF and NE. Correspondingly, the reverse current gain characteristic of the BJT is defined by the parameters IS, BR, NR, ISC, IKR and NC. The output conductance of the forward and reverse regions of the transistor is determined by VAF and VAR, respectively. Resistors RB, RC and RE represent an ohmic resistance in series with each terminal of the

Spice Name	Model Parameter	Units	Default	Example
IS	Transport saturation current	A	1×10^{-16}	1.0×10^{-15}
BF	Ideal maximum forward beta	–	100	100
Nf	Forward current emission coefficient	–	1	1.0
VAF	Forward Early voltage	V	∞	200
IKF	Corner for forward beta high current roll-off	A	∞	0.01
ISE	B-E leakage saturation current	A	0	1.0×10^{-13}
NE	B-E leakage emission coefficient	–	1.5	2.0
BR	Ideal maximum reverse beta	–	1	0.1
NR	Reverse current emission coefficient	–	1	1.0
VAR	Reverse Early voltage	V	∞	200
IKR	Corner for reverse beta high current roll-off	A	∞	0.01
ISC	B-C leakage saturation current	A	0	1.0×10^{-13}
NC	B-C leakage emission coefficient	–	2	1.5
RB	Base ohmic resistance	Ω	0	100
IRB	Current where base resistance falls halfway to its min value	A	∞	0.1
RBM	Minimum base resistance at high currents	Ω	RB	10
RE	Emitter resistance	Ω	0	1
RC	Collector resistance	Ω	0	10
CJE	B-E zero-bias depletion capacitance	F	0	2 pF
VJE	B-E built-in potential	V	0.75	0.6
MJE	B-E junction exponential factor	–	0.33	0.33
TF	Ideal forward transit time	sec	0	0.1 ns
XTF	Coefficient for bias dependence of TF	–	0.75	0.6
VTF	Voltage describing VBC dependence of TF	V	∞	
ITF	High-current parameter for effect on TF	A	0	
PTF	Excess phase at $freq = 1/(2\pi \mathrm{TF})$	degree	0	
CJC	B-C zero-bias depletion capacitance	F	0	2 pF
VJC	B-C built-in potential	V	0.75	0.5
MJC	B-C junction exponential factor	–	0.33	0.5
XCJC	Fraction of B-C depletion capacitance connected to internal base node	–	1	
TR	Ideal reverse transit time	sec	0	10 ns
CJS	Zero-bias collector-substrate capacitance	F	0	2 pF
VJS	Substrate junction built-in potential	V	0.75	
MJS	Substrate junction exponential factor	–	0	0.5
XTB	Forward and reverse beta temperature exponent	–	0	

Table A.2 BJT model parameters .... continued next page ....

Spice Name	Model Parameter	Units	Default	Example
EG	Energy gap for temperature effect on IS	eV	1.11	
XTI	Temperature exponent for effect on IS	–	3	
KF	Flicker-noise coefficient	–	0	
AF	Flicker-noise exponent	–	1	
FC	Coefficient for forward-bias depletion capacitance formula	–	0.5	

Table A.2 BJT model parameters.

Spice Name	Model Parameter	Units	Default	Example
VTO	Threshold voltage	V	-2.0	-2.0
BETA	Transconductance parameter	A/V^2	1×10^{-4}	1×10^{-3}
LAMBDA	Channel length modulation parameter	1/V	0	1×10^{-4}
RD	Drain ohmic resistance	Ω	0	100
RS	Source ohmic resistance	Ω	0	100
CGS	Zero-bias G-S junction capacitance	F	0	5 pF
CGD	Zero-bias G-D junction capacitance	F	0	1 pF
PB	Gate junction potential	V	1	0.6
IS	Gate junction saturation current	A	1×10^{-14}	1×10^{-14}
KF	Flicker noise coefficient	–	0	
AF	Flicker noise exponent	–	1	
FC	Coefficient for forward-bias depletion capacitance formula	–	0.5	

Table A.3 JFET model parameters.

charge storage effects associated with the thin-oxide. The flag/coefficient XQC determines which of the two models will be used; a voltage-dependent or a charge-controlled capacitance model [A. Vladimirescu, 1981]. Other parameters of the MOSFET model that determine the charge storage effects are CBD, CBS, CJ, CJSW, MJ, MJSW, PB and FC. The overlap capacitances are set by the parameters CGSO, CGDO and CGBO. The flicker noise behavior of the diode is defined by the parameters KF and AF.

The MOSFET parameters used for the three different MOSFET models in Spice are listed in Table A.4. There are 42 parameters associated with the three models of the MOSFET.

Spice Name	Model Parameter	Units	Default	Example
LEVEL	Model index (eg. 1,2 or 3)	–	1	
VTO	Zero-bias threshold voltage	V	0	1.0
KP	Transconductance parameter	A/V^2	2.0×10^{-5}	3.1×10^{-5}
GAMMA	Bulk threshold parameter	$V^{1/2}$	0	0.37
PHI	Surface potential	V	0.6	0.65
LAMBDA	Channel-length modulation (LEVEL 1 and 2 only)	1/V	0	0.02
RD	Drain ohmic resistance	Ω	0	1.0
RS	Source ohmic resistance	Ω	0	1.0
CBD	Zero-bias B-D junction capacitance	F	0	20 fF
CBS	Zero-bias B-S junction capacitance	F	0	20 fF
IS	Bulk junction saturation current	A	1.0×10^{-14}	1.0×10^{-15}
PB	Bulk junction potential	V	0.8	0.87
CGSO	Gate-source overlap capacitance per meter channel width	F/m	0	4.0×10^{-11}
CGDO	Gate-drain overlap capacitance per meter channel width	F/m	0	4.0×10^{-11}
CGBO	Gate-bulk overlap capacitance per meter channel length	F/m	0	2.0×10^{-10}
RSH	Drain and source diffusion sheet resistance	Ω/sq.	0	10.0
CJ	Zero-bias bulk junction bottom cap. per sq-meter of junction area	F/m^2	0	2.0×10^{-4}
MJ	Bulk junction bottom grading coeff.	–	0.5	0.5
CJSW	Zero-bias bulk junction sidewall cap. per meter of junction perimeter	F/m	0	2.0×10^{-9}
MJSW	Bulk junction sidewall coefficient	–	0.33	
JS	Bulk junction saturation current per sq-meter of junction area	A/m^2	1.0×10^{-8}	
TOX	Oxide thickness	meter	1.0×10^{-7}	1.0×10^{-7}
NSUB	Substrate doping	$1/cm^3$	0	4.0×10^{15}
NSS	Surface state density	$1/cm^2$	0	1.0×10^{10}
NFS	Fast surface state density	$1/cm^2$	2×10^{-5}	1.0×10^{10}
TPG	Type of gate material: +1 op. to substrate; −1 same as substrate; 0 Al gate	–	1	
XJ	Metallurigical junction depth	meter	0	1.0 μm
LD	Lateral diffusion	meter	0	0.8 μm
UO	Surface mobility	$cm^2/(V \cdot s)$	600	700
UCRIT	Critical field for mobility degradation (LEVEL 2 only)	V/cm	1×10^4	1.0×10^4
UEXP	Critical field exponent in mobility degradation (LEVEL 2 only)	–	0	0.1

Table A.4 MOSFET model parameters .... continued next page ....

Spice Name	Model Parameter	Units	Default	Example
UTRA	Transverse field coefficient (mobility) (deleted for LEVEL 2)	–	0	0.3
VMAX	Maximum drift velocity of carriers	m/s	0	5.0×10^4
NEFF	Total channel charge (fixed and mobile) coefficient (LEVEL 2 only)	–	1	5.0
XQC	Thin-oxide capacitance model flag and coefficient of channel charge share attributed to drain (0-0.5)	–	1	0.4
KF	Flicker-noise coefficient	–	0	1.0×10^{-26}
AF	Flicker-noise exponent	–	1	1.2
FC	Coefficient for forward-bias depletion capacitance formula	–	0.5	
DELTA	Width effect on threshold voltage (LEVEL 2 and LEVEL 3)	–	0	1.0
THETA	Mobility modulation (LEVEL 3 only)	1/V	0	0.1
ETA	Static feedback (LEVEL 3 only)	–	0	1.0
KAPPA	Saturation field factor (LEVEL 3 only)	–	0.2	0.5

Table A.4 MOSFET model parameters

A.5 MESFET Model

The MESFET model that we describe here is that provided in the PSpice program by MicroSim Corporation. Spice version 2G6 does not have a device model for the MESFET.

PSpice provides three MESFET device models that have different large-signal *i-v* characteristics. The variable LEVEL specifics the model that is to be used to represent a particular MESFET:

LEVEL=1 => Curtice
LEVEL=2 => Raytheon
LEVEL=3 => TriQuint

The MESFET is modeled as an intrinsic JFET with resistances RD, RS and RG in series with the drain, source and gate, respectively. The DC characteristics are defined by the parameters VTO, BETA, ALPHA, LAMBDA, IS, N and M. Charge storage is modeled by a nonlinear depletion-layer capacitance for both gate junctions using parameters CGS, CGD, PB and FC. A capacitance between drain and source CDS can also be declared. The flicker noise behavior of the diode is defined by the parameters KF and AF. Effects of temperature can also be modeled using parameters EG, XTI, VTOTC, BETATCE, TRG1, TRD1 and TRS1.