Avant! HiCUM Model vs. Public HiCUM Model

Difference Highlights

To maintain flexibility, the Level 8 HiCUM model uses FBCS, IS, KRBI, MCF, MSR, and ZETACX as additional model parameters. See ‘Other Parameters” on page 4-102.

Model Implementation

Table 4-30: Model Parameters

Parameter	Unit	Default	Description
`Level`		`8`	HiCUM BJT level
`TREF`	C	`26.85`	Temperature in simulation

Internal Transistors

Table 4-31: Transfer Current Parameters

Parameter	Unit	Default	Factor	Description
C10	A^2s	3.76e-32	M^2	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

Table 4-32: BE Depletion Capacitance Parameters

Parameter	Unit	Default	Factor	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

Table 4-33: BC Depletion Capacitance Parameters

Parameter	Unit	Default	Factor	Description
CJCI0	F	1.16e-15	M^2	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))

Table 4-34: Forward Transit Time Parameters

Parameter	Unit	Default	Factor	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

Table 4-35: Critical Current Parameters

Parameter	Unit	Default	Factor	Description
RCI0	Ohm	127.8	1/M	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.

Table 4-36: Inverse Transit Time Parameter

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

Table 4-37: Base Current Components Parameters

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

Table 4-38: Weak BC Avalanche Breakdown Parameters

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

Table 4-39: Internal Base Resistance Parameters

Parameter	Unit	Default	Factor	Description
RBI0	Ohm	0	1/M	Value at zero-bias
FDQR0	-	0.0		Correction factor for modulation by BE abd BC SCR
FGEO	-	0.73		Geometry factor (value corresponding 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.

Table 4-40: Lateral Scaling

Parameter	Unit	Default	Factor	Description
LATB	-	3.765		Scaling factor for Qfc in 1_E
LATL	-	0.342		Scaling factor for Qfc in l_E direction

Peripheral Elements

Table 4-41: BE Depletion Capacitance

Parameter	Unit	Default	Factor	Description
CJEP0	F	2.07e-15	M	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

Table 4-42: Base Current

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

Table 4-43: BE Tunneling

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

External Elements

Table 4-44: BC Capacitance

Parameter	Unit	Default	Factor	Description
CJCX0	F	5.393e-15	M	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	M	Collector oxide capacitance
FBC	-	0.1526		Partitioning factor for C_BCX =C'_BCx+C"_BCx

Table 4-45: BC Base Current Component

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

Table 4-46: Other External Elements

Parameter	Unit	Default	Factor	Description
CEOX	F	1.13e-15	M	Emitter-base isolation overlap cap
RBX	Ohm	0	1/M	External base series resistance
RE	Ohm	0	1/M	Emitter series resistance
RCX	Ohm	0	1/M	External collector series resistance

Table 4-47: Substrate Transistor Parameters

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

Table 4-48: Collector-Substrate Depletion Capacitance

Parameter	Unit	Default	Factor	Description
CJS0	F	3.64e-14	M	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

Table 4-49: Substrate Coupling Network

Parameter	Unit	Default	Factor	Description
RSU	Ohm	0	1/M	Substrate series resistance
CSU	F	0		Substrate capacitance from permittivity of bulk material

Table 4-50: Noise Parameters

Parameter	Unit	Default	Factor	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

Table 4-51: Temperature Dependence Parameters

Parameter	Unit	Default	Factor	Description
VGB	V	1.17		Bandgap-voltage
ALB	1/K	6.3e-3		Relative temperature coefficient of forward current gain
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	-	0.588		Temperature exponent factor of RBI0
ZETARBX	-	0.2060		Temperature exponent factor of RBX
ZETARCX	-	0.2230		Temperature exponent factor of RCX

Table 4-51: Temperature Dependence Parameters *(Continued)*

Parameter	Unit	Default	Factor	Description
ZETARE	-	0		Temperature exponent factor of RE
ALFAV	1/K	8.25e-5		Relative temperature coefficient for avalanche breakdown
ALQAV	1/K	1.96e-4		Relative temperature coefficient for avalanche breakdown

Table 4-52: Self-Heating Parameters

Parameter	Unit	Default	Factor	Description
RTH	K/W	0	1/M	Thermal resistance (not supported)
CTH	Ws/K	0	M	Thermal resistance (not supported)

Table 4-53: Other Parameters

Parameter	Unit	Default	Factor	Description
FBCS	-	-1.0		Determine external BC capacitance partitioning
IS	-1.0	A		Ideal saturation current
KRBI	-	1.0		Noise analysis of internal resistance
MCF	-	1.0		Non-ideal factor of reverse current between base and collector. VT=VT*MCF
MSR	-	1.0		Non-ideal factor of reverse current in substrate transistor. VT=VT*MSR
ZETACX	-	1.0		Temperature exponent factor (epi-layer)

Netlist Input and Output Formats

This section provides the syntax for Level 8 and an example of an input netlist and output format.

Syntax

```
Qxxx nc nb ne <ns> mname <area> <M=val> <DTEMP=val>
```

Table 4-54: Netlist Parameters for Level 8

Qxxx	BJT element name
nc	Collector terminal node
nb	Base terminal node, connected to 1 => 2
ne	Emitter terminal node, connected to 1 => 0
ns	Substrate terminal node
mname	BJT model name reference
area	Emitter area multiplying factor which affects currents, resistances and capacitances(default=1)
M	Multiplier to simulate multiple BJTs in parallel
DTEMP	Difference between the element temperature and the circuit temperature in Celsisu. (Default=0.0)

Example

The following is an example of a BJT `Q1` model:

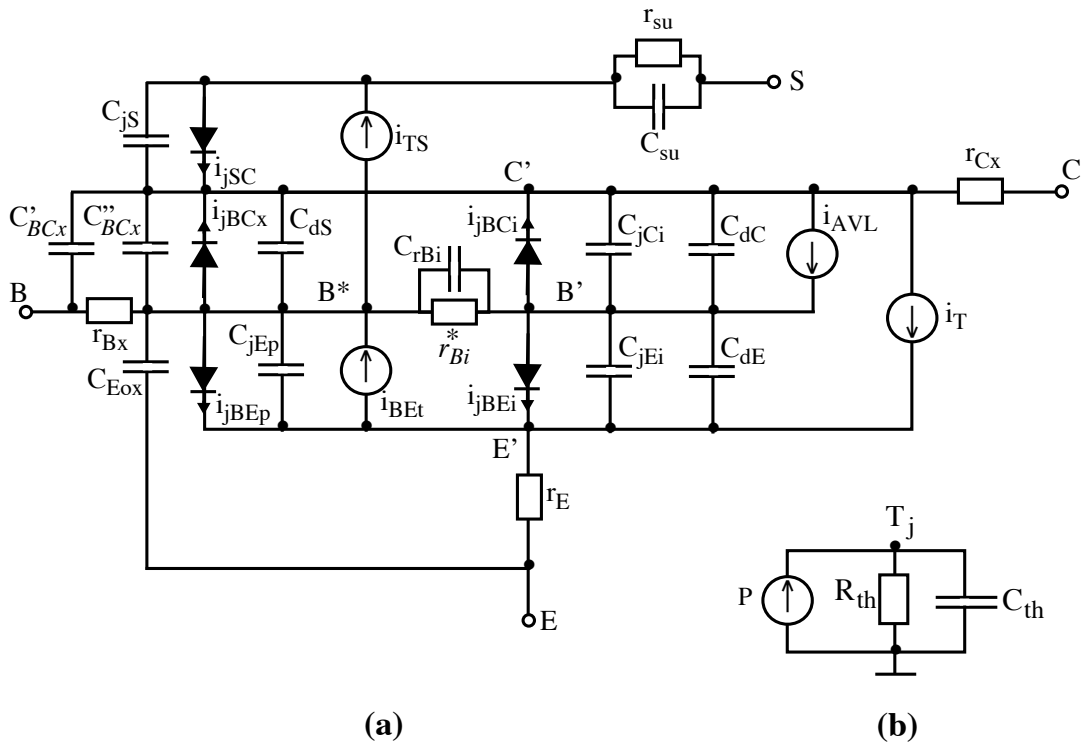
```
Q1 1 2 0 4 QM area=1*0.5*5 dtemp=0.002
```

where:

- Collector is connected to node 1.
- Base is connected to node 1.
- Emitter is connected to node 1.
- Substrate is connected to node 4.
- QM references the name of the BJT model.

Circuit Diagram

Figure 4-15: Large-signal HiCUM/Level2 equivalent circuit



(a) The external BC capacitance consists of a depletion and a bias independent (e.g., oxide) capacitance with the ratio C'_{BCx} / C''_{BCx} being adjusted with respect to proper modelling of the h.f. behavior.
(b) Thermal network used for self-heating calculation.

Input Netlist

```
.DATA test_data vbe vce vsub
0.0 0.0 0.0
0.1 0.0 0.0
0.2 0.0 0.0
0.3 0.0 0.0
0.4 0.0 0.0
0.5 0.0 0.0
0.6 0.0 0.0
0.7 0.0 0.0
0.8 0.0 0.0
0.9 0.0 0.0
1.0 0.0 0.0
.ENDDATA

.OPTIONS
.TEMP 26.85
VIN 2 0 vbe
VC 1 0 vce
VS 4 0 vsub
VE 3 0 0

Q1 1 2 3 4 hicum
.DC data= test_data
.PRINT DC I(VIN) i2(q1) I(VC) i1(q1) I(VCS) i4(q1)

.MODEL hicum NPN Level=8
+        tref = 26.85
+        c10=.3760000E-31 qp0=.2780000E-13 ich=.2090000E-01
+        hfc=.1000000E+01
+        hfe=1.0000000E+00 hjei=.000000E+00
+        hjci=.100000E+01 tr=1.00000000E-9
+        cjei0=.81100E-14 vdei=.950000E+00 zei=.5000000E+00
+        aljei=.18000E+01
+        cjci0=.11600E-14 vdci=.800000E+00 zci=.3330000E+00
+        vptci=.41600E+03
+        rci0=.127800E+03 vlim=.700000E+00 vpt=.5000000E+01
+        vces=.100000E+00
+        t0=.47500000E-11 dt0h=.210000E-11 tbvl=.400000E-11
+        tef0=.180000E-11 gtfe=.140000E+01 thcs=.300000E-10
+        alhc=.750000E+00
+        fthc=.600000E+00
+        latb=.376500E+01 latl=.342000E+00 fqi=.9055000E+00
```

```
+        alit=.450000E+00 alqf=.225000E+00
+        favl=.118600E+01 qavl=.111000E-13 alfav=.82500E-04
+        alqav=.19600E-03
+        ibeis=.11600E-19 mbei=.101500E+01 ibeps=.10000E-29
+        mbep=.200000E+01
+        ireis=.11600E-15 mrei=.200000E+01 ireps=.10000E-29
+        mrep=.200000E+01
+        rbi0=.000000E+00 fdqr0=.00000E+00 fgeo=.730000E+00
+        fcrbi=.00000E+00
+        cjep0=.00000E+00 vdep=.105000E+01 zep=.4000000E+00
+        aljep=.24000E+01
+        ceox=.000000E+00
+        cjcx0=.00000E+00 vdcx=.700000E+00 zcx=.3330000E+00
+        vptcx=.10000E+03
+        ccox=.000000E+00 fbc=.1526000E+00
+        ibcxs=.10000E-29 mbcx=.200000E+01 ibcis=.11600E-19
+        mbci=.101500E+01
+        cjs0=.000000E+00 vds=.6000000E+00 zs=.44700000E+00
+        vpts=.100000E+04
+        rcx=.0000000E+00 rbx=.0000000E+00 re=.00000000E+00
+        kf=.00000000E+00 af=.00000000E+00
+        vgb=.1170000E+01 alb=.6300000E-02 alt0=.000000E+00
+        kt0=.0000000E+00
+        zetaci=.1600E+01 alvs=.100000E-02 alces=.40000E-03
+        zetarbi=0.5880E+00              zetarcx=0.2230E+00
+        zetarbx=0.2060E+00               zetare=0.0000E+00
+        rth=0.0 cth=0.0
+        ibets=.00000E+00 abet=.000000E+00
+        itss=.000000E+00 msf=.0000000E+00 tsf=0.000000E+00
+        iscs=.000000E+00
+        msc=.0000000E+00
+        rsu=.0000000E+00 csu=.0000000E+00
.END
```