UC Berkeley, BSIM Group
Sourabh Khandelwal (sourabh@berkeley.edu), Juan Pablo Duarte

Summary of Changes in BSIM-CMG108.0.0:

Corrected Bugs

- 2013bug6: Tratio dependence of nVtm removed
- 2013bug14 (was previously 2013bug7): Limits on NBODY parameter removed
- 2013bug15 (was previously 2013bug8): Double counting of Impact Ionization current corrected
- 2013bug16 (was previously 2013bug9): NQS model equation corrected for NFIN dependence
- 2013bug18: Reposition Leff range check.
- 2013bug19: devsign added in thermal noise model Gds calculation
- 2013bug20: Updated TNOIMOD=2 to correct for the different noise behavior compared to BSIM4.7 w.r.t. parameter RNOIC.
- 2014bug1: Output variable ISEFF equation corrected for typo
- 2014bug2: Removed unused variables from the code
- 2014bug3: Gate Current Igs and Igd updated for the missing Vfbsd term
- 2014bug4: Removed warning message w.r.t. initialized variable
- 2014bug5: GIDL current model update to avoid sharp transition in Igidl versus Vdb when the parameter CGIDL = 0
- 2014bug6: Vdsat calculation updated to account for RDSMOD=2

Enhancements

- 2013enh10: TEMPMOD switch introduced to switch between two types of temperature dependence of parameters
- 2013enh11: Thermal noise model TNOIMOD=1 is added from BSIM4 model
- 2013enh13: New parameter ATCV added to model temperature dependence of ATCV
- 2013enh14: Limitation imposed on parameters to avoid “divide-by-zero”
- 2013enh15: Improvement in Overlap Capacitance model
- 2013enh19: RDSMOD=2 is added to avoid additional nodes
- 2013enh21: Thermal Noise Model TNOIMOD = 2 added from BSIM4 model
- 2013enh22: Leff equation update for binning calculations
- 2013enh23: Added option to replace some pre-computed variables with parameters
- 2013enh24: Add less-than-zero check on Leff1
- 2014enh1: Less restrictive clamps on parameters modeling NFIN dependence of other parameters
- 2014enh2: Output variable to report temperature with self-heating added
- 2014enh3: Parameters added to ASYMMOD=1 model
- 2014enh4: TYPE added as a parameter to define device type for consistency with other CMC models

UC Berkeley, BSIM Group
Sourabh Khandelwal (sourabh@berkeley.edu), Juan Pablo Duarte

Description of the changes:

Corrected Bugs

- 2013bug6: Tratio dependence of nVtm removed.

- Tratio dependence of nVtm

nVtm = Vtm * ThetaSS * (1.0 + (CIT_i / TRatio + cdsc) / T1); BSIM-CMG107.0.0

where

TRatio = DevTemp / Tnom;

Technical Manual does not have TRatio term:

$$n = \begin{cases} \Theta_{SS} \cdot \left(1 + \frac{CIT_i + C_{dsc}}{(2C_{si})\|C_{ox}}\right) & \text{if } GEOMOD \neq 3 \\ \Theta_{SS} \cdot \left(1 + \frac{CIT_i + C_{dsc}}{C_{ox}}\right) & \text{if } GEOMOD = 3 \end{cases}$$

- Tratio dependence has been removed in BSIM-CMG108.0.0

- 2013bug14 (was previously 2013bug7): Limits on NBODY parameter removed

- The limits from NBODY have been removed

\- parameter real NBODY = 1e22 from [1e18:**5e24**]; BSIM-CMG107.0.0

\+ parameter real NBODY = 1e22; BSIM-CMG108.0.0

- 2013bug15 (was previously 2013bug8): Double counting of Impact Ionization current corrected

UC Berkeley, BSIM Group
Sourabh Khandelwal (sourabh@berkeley.edu), Juan Pablo Duarte

- Double-counting of the total number of fingers in impact lonization current:

BSIM-CMG107.0.0

```
NFINtotal  =  NFIN * NF;

ids  =  NFINtotal * beta * ids0 * Moc * Mob * Mnud / (Dmob * Dvsat * Dr);
ids  =  ids * IDSOMULT;

Iii  =  Ratio * ids;

Iii  =  NFINtotal * Iii;
```

- Double-counting has been removed in BSIM-CMG108.0.0

- 2013bug16 (was previously 2013bug9): NQS model equation corrected for NFIN dependence

BSIM-CMG107.0.0

$$\frac{1}{R_{ii}} = \frac{NF}{NFIN} \cdot XRCRG1_i \cdot \left(I_{dovVds} + XRCRG2 \cdot \frac{\mu_{eff} C_{oxe} WeffkT}{qL_{ef} f} \right)$$

BSIM-CMG108.0.0

$$\frac{1}{R_{ii}} = NF \cdot NFIN \cdot XRCRG1_i \cdot \left(I_{dovVds} + XRCRG2 \cdot \frac{\mu_{eff} C_{oxe} WeffkT}{qL_{ef} f} \right)$$

- 2013bug18: Reposition Leff range check.
  The position of the code to check the range of Leff has been moved in the code to lines 1214 – 1219.

- 2013bug19: devsign added in thermal noise model Gds calculation
  Gds calculation in thermal noise model has been updated to include “devsign”. This corrects Gds calculated for PMOS devices.

UC Berkeley, BSIM Group
Sourabh Khandelwal (sourabh@berkeley.edu), Juan Pablo Duarte

BSIM-CMG107.0.0	BSIM-CMG108.0.0

if(sigvds > 0.0)
T4 = ddx(ids,V(di));// Gds
else
T4 = ddx(ids,V(si));//Gds
	if(sigvds > 0.0)
	T4 = **devsign** * ddx(ids,V(di));// Gds
	else
	T4 = **devsign** * ddx(ids,V(si));//Gds

- 2013bug20: Updated TNOIMOD=2 to correct for the different noise behavior compared to BSIM4.7 w.r.t. parameter RNOIC.
  TNOIMOD=2 thermal noise model has update for better model behavior w.r.t. the thermal noise correlation coefficient RNOIC parameter. Calculation of variable Vgst2Vtm in the thermal noise model is updated in the code for this.

- 2014bug1: Output variable ISEFF equation corrected for typo.
  A typo, two consecutive minus signs in ISEFF equation is corrected in this version of the model.

- 2014bug2 Removed unused variables from the code.
  Unused variable phipert is removed from this version of the code. The positions of a few variables are updated in the code to avoid hidden states.

- 2014bug3: Gate Current Igs and Igd updated for the missing Vfbsd term.
  Igs and Igd model equations are updated to include vfbsd term which was missing from the code in the last version. The added term in high-lighted in green below.

```
// ** Igs **
T0        =  vgs_noswap - vfbsd;
vgs_eff   =  sqrt(T0 * T0 + 1.0e-4);
T1        =  AIGS_t - BIGS_i * vgs_eff;
T2        =  1.0 + CIGS_i * vgs_eff;
T3        =  -Bechvb * TOXG * POXEDGE_i * T1 * T2;
T4        =  lexp(T3);
```

- 2014bug4: Removed warning message w.r.t. initialized variable.
  Following warning message is removed from this version of the code

```
if(!initialized) begin
    $strobe("Warning: \"initial_step\" is not triggered at the first execution of this code.
    may not be initialized.  Check your simulator for Verilog-A language compatibility.");
```

- 2014bug5: GIDL current model update to avoid sharp transition Igidl versus Vdb when CGIDL = 0.

  The constant in the equation for a variable T4a in the GIDL model is updated to avoid sharp transition in GIDL current when user sets CGIDL = 0. The highlighted constant value is changed from the old value of 1.0e-9 to 1.0e-5.

```
if(BULKMOD != 0) begin
    T4  =  - ved_jct*ved_jct*ved_jct;
    T4a =  CGIDL_i + abs(T4) + 1.0E-5;
    T5  =  hypsmooth(T4/T4a, 1.0E-6) - 1.0E-6;
    T6  =  AGIDL_i * Weff0 * T3 * lexp(-T2) * T5;
end else
    T6  =  AGIDL_i * Weff0 * T3 * lexp(-T2) * vds_noswap;
```

- 2014bug6: Vdsat calculation updated to account for RDSMOD=2.

  Rdss in the Vdsat calculation has been updated to account for RDSMOD=2 in this version. Following table shows the added code in BSIM-CMG108.0.0. RDSMOD=2 was not present in BSIM-CMG107.0.0.

BSIM-CMG108.0.0	

```
if(RDSMOD == 1)  Rdss  =  0.0;
else if (RDSMOD == 0) begin
    T4       =  1.0 + PRWGS_i * qis;
    T1       =  1.0 / T4;
    T0       =  0.5 * (T1 + sqrt(T1 * T1 + 0.01));
        Rdss     =  (RDSWMIN_i + RDSW_i * T0) * WeffWRFactor * NFINtotal * rdstemp;
end
else begin
    T4       =  1.0 + PRWGS_i * qis;
    T1       =  1.0 / T4;
    T0       =  0.5 * (T1 + sqrt(T1 * T1 + 0.01));
        Rdss     =  (RSourceGeo + RDrainGeo + RDSWMIN_i + RDSW_i * T0) * WeffWRFactor * NFINtotal * rdstemp;
end
```

Enhancements

- 2013enh10: TEMPMOD switch introduced to switch between two types of temperature dependence of parameters

  As shown below BSIM-CMG108.0.0 has two types of functional form of temperature dependence of parameters:

UC Berkeley, BSIM Group
Sourabh Khandelwal (sourabh@berkeley.edu), Juan Pablo Duarte

Type A: $PARAM(T) = PARAM(L) \times [1 \pm PARAM_T * (T - TNOM)]$

Type B: $PARAM(T) = PARAM(L) \pm PARAM_T * (T - TNOM)$

Parameter name	Type A	Type B
U0, UA		X
UC	X	
ETA0, ETA0R, ETAMOB	X	
VSAT, VSAT1, VSAT1R, VSATCV	X	
RSDR, RDDR	X	
MEXP, MEXPR	X	
PTWG, PTWGR	X	
K0, K0SI, K1SI, K1, K1SAT, A1, A2, AIGBINV, AIGBACC, AIGC, AIGS, AIGD, BGIDL, BGISL, ALPHA0, ALPHA1, ALPHAII0, ALPHAII1		X
CJS, CJD, CJSWS, CJSWD, CJSWGS, CJSWGD	X	
PBS, PBD, PBSWS, PBSWD, PBSWGS, PBSWGD		X
NJTS, NJTSD, NJTSSW, NJTSSWD, NJTSSWG, NJTSSWGD	X	

- The switch **TEMPMOD=1** (default=0) changes the reaming Type A equations into Type B.

Parameter name	Type A	Type B
U0, UA		X
UC	X	
ETA0, ETA0R, ETAMOB	X	
VSAT, VSAT1, VSAT1R, VSATCV	X	
RSDR, RDDR	X	
MEXP, MEXPR	X	
PTWG, PTWGR	X	
K0, K0SI, K1SI, K1, K1SAT, A1, A2, AIGBINV, AIGBACC, AIGC, AIGS, AIGD, BGIDL, BGISL, ALPHA0, ALPHA1, ALPHAII0, ALPHAII1		X
CJS, CJD, CJSWS, CJSWD, CJSWGS, CJSWGD	X	
PBS, PBD, PBSWS, PBSWD, PBSWGS, PBSWGD		X
NJTS, NJTSD, NJTSSW, NJTSSWD, NJTSSWG, NJTSSWGD	X	

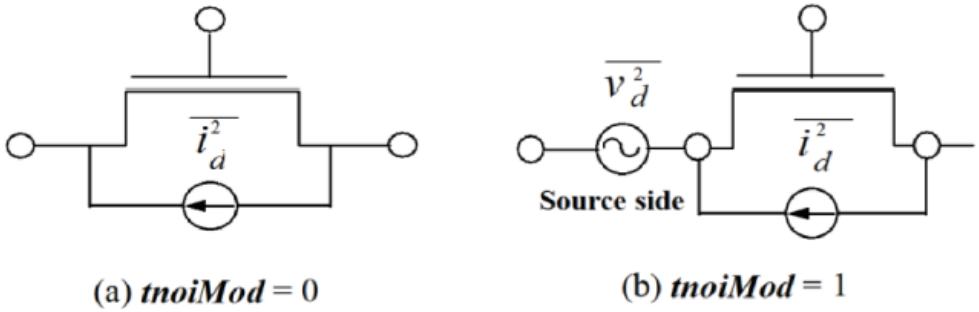
- The two white columns still do not support the switch.

- 2013enh11: Thermal noise model TNOIMOD=1 is added from BSIM4 model

UC Berkeley, BSIM Group
Sourabh Khandelwal (sourabh@berkeley.edu), Juan Pablo Duarte

- TNOIMOD=1 from BSIM4 has been added:

```
parameter real NTNOI =  1.0 from [0:inf);
parameter integer TNOIMOD  =  0 from [0:inf);
parameter real    TNOIA    = 1.5;          //
parameter real    TNOIB    = 3.5;          //
parameter real    RNOIA    = 0.577;        //
parameter real    RNOIB    = 0.37;         //
```



(a) ***tnoiMod*** = 0 (b) ***tnoiMod*** = 1

- 2013enh13: New parameter ATCV added to model temperature dependence of ATCV

BSIM-CMG108.0.0

$$VSAT(T) = VSAT[L,N] \cdot (1 - AT \cdot (T - TNOM))$$
$$VSAT1(T) = VSAT1[L,N] \cdot (1 - AT \cdot (T - TNOM))$$
$$VSAT1R(T) = VSAT1R[L,N] \cdot (1 - AT \cdot (T - TNOM))$$
$$VSATCV(T) = VSATCV[L] \cdot (1 - ATCV \cdot (T - TNOM))$$

- 2013enh14: Limitation imposed on parameters to avoid “divide-by-zero”
  Restrictions are added on parameters: BVSAT, BVSAT1, BVSATCV, BPCLM, BPTWG, BPSAT, BPSATCV, NJS, NJD, BUA, BUD, NBODYN2, PHIGN2, CDSCDN2, CDSCDRN2, BQMTCEN, VSATN2.

- 2013enh15: Improvement in Overlap Capacitance model

- L_{drawn}+ XL instead of $L_{eff,CV}$ is used in $C_{ge,overlap}$:

BSIM-CMG107.0.0

$$C_{ge,overlap} = (CGBO \cdot NF \cdot NGCON + CGBN \cdot NFIN_{total}) \cdot L_{eff,CV}$$

BSIM-CMG108.0.0

$$C_{ge,overlap} = (CGBO \cdot NF \cdot NGCON + CGBN \cdot NFIN_{total}) \cdot (L + XL)$$

- 2013enh19: RDSMOD=2 is added to avoid additional nodes.
  RDSMOD = 2 includes the effect of parasitic resistances (both bias dependent part and bias independent part) within the model and avoids addition of external nodes in the model. See technical manual for more details.

- 2013enh21: Thermal Noise Model TNOIMOD = 2 added from BSIM4 model.
  TNOIMOD = 2 is the correlated thermal noise model.

- 2013enh22: Leff equation update for binning calculations

BSIM-CMG107.0.0	BSIM-CMG108.0.0

Lg = L + XL;
deltaL = LINT + LL * pow(Lg, -LLN);
deltaLCV = DLC + LLC * pow(Lg, -LLN);
Leff = Lg - 2.0 * deltaL;
LeffCV = Lg - 2.0 * deltaLCV;
if(CAPMOD == 1 && BULKMOD != 0) LeffCV_acc = LeffCV - DLCACC;
// Total Fins
NFINtotal = NFIN * NF;
// Binning
Inv_L = 1.0e-6 / (Leff + DLBIN);
Inv_NFIN = 1.0 / NFIN;
Inv_LNFIN = 1.0e-6 / ((Leff + DLBIN) * NFIN);
	Lg = L + XL;
	deltaL = LINT + LL * pow(Lg, -LLN);
	deltaL1 = LINT + LL * pow(Lg+DLBIN, -LLN);
	deltaLCV = DLC + LLC * pow(Lg, -LLN);
	Leff = Lg - 2.0 * deltaL;
	Leff1 = Lg + DLBIN - 2.0 * deltaL1; //Used in the binning equations only
	LeffCV = Lg - 2.0 * deltaLCV;
	if(CAPMOD == 1 && BULKMOD != 0) LeffCV_acc = LeffCV - DLCACC;
	// Total Fins
	NFINtotal = NFIN * NF;
	// Binning
	Inv_L = 1.0e-6 / (Leff1);
	Inv_NFIN = 1.0 / NFIN;
	Inv_LNFIN = 1.0e-6 / (Leff1 * NFIN);

- 2013enh23: Added option to replace some pre-computed variables with parameters.
  THETASCE, THETADIBL, THETASS, NVTM are added as parameters to replace their corresponding pre-computed terms.

- 2013enh24: Add less-than-zero check on Leff1

```
if(Leff <= 0) begin
    $strobe("Fatal: Leff = %e is not positive.", Leff);
end else if(Leff <= 1e-9) begin
    $strobe("Warning: Leff = %e <= 1.0e-9.", Leff);
end
```

- 2014enh1: Less restrictive clamps on parameters which control NFIN dependence.

  The NFIN scaling equation for various parameters is:

$$PARAM_N = PARAM \times \left[1.0 + \frac{PARAMN1}{NFIN} \times ln\left(1.0 + \frac{NFIN}{PARAMN2}\right)\right]$$

  BSIM-CMG108.0.0 code removes the clamps on parameters PARAMN1 and PARAMN2. The final calculated value of parameter $PARAM_N$ is used to check if they are in appropriate range instead of the parameters PARAMN1 and PARAMN2.

- 2014enh2: Output variable to report temperature with self-heating added.

  Output variable TDEVICE to report temperature including self-heating is added to the code.

- 2014enh3: Parameters added to ASYMMOD=1 model.

  Following parameters along with their binning equations, L-dependence and Temperature dependence have been added to the ASYMMOD=1: U0, UA, UC, UD, EU, PDIBL2, KSATIV, DVTSHIFT, PCLM, VSAT.

- 2014enh4: TYPE added as a parameter to define device type for consistency with other CMC models.

  TYPE can be used as parameter to set device type NMOS/PMOS from this version of the code. In order to meet backward compatibility TYPE is added in the following way in the model:

```
parameter integer DEVTYPE  =  `ntype from [`ptype:`ntype];
parameter integer TYPE     = DEVTYPE from [`ptype:`ntype];
```

  DEVTYPE can still be used, however TYPE takes the precedence.

Sourabh Khandelwal
Juan Pablo Duarte