Proposals for Fixes to BSIM4.4.0

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Contents

- Diode Robustness Fix
- Diode Model Discontinuity
- Gate Current Parameter Default Value Problem
- Miscellaneous Bug Fixes
- Cgs Observation

Diode Model Robustness

- **MJS,MJSWS,MJSWGS,MJD,MJSWD,MJSWGD, Factor = 1 Problem when Calculating QBS**
  - Results in divide by zero on lines 3481, 3495, 3505, 3531, 3545, and 3555 in b4ld.c. For example, lines 3479-3481 calculate Q_{bs} using MJS:

$$Q_{bs} = \phi_{bs} C_{zbs} \left(\frac{1 - a\left(\exp\left(-MJS \log(a)\right)\right)}{1 - MJS} \right) \qquad a = 1 - \frac{V_{bs}}{\phi_{bs}}$$

Diode Model Robustness (2)

– One solution: Calculate Q_{bs} from C_{bs} with MJ=1 (where MJ is MJS,MJSWS,MJSWGS,MJD,MJSWD,MJSWGD) :

$$C_{bs} = C_j\left(1-\frac{V_{bs}}{PB}\right)^{-MJ} \qquad \text{For MJ=1,} \qquad C_{bs} = C_j\left(1-\frac{V_{bs}}{PB}\right)^{-1}$$

$$\Rightarrow \quad Q_{bs} = \int C_{bs}dV_{bs} = C_j\int\left(1-\frac{V_{bs}}{PB}\right)^{-1}dV_{bs}$$

$$\Rightarrow \quad Q_{bs} = -C_j PB\left(\ln\left(\left|1-\frac{V_{bs}}{PB}\right|\right)\right)$$

– This formulation results in smooth behavior as the MJ value is varied from less than 1 to greater than 1.

Discontinuity in Diode Model

- **if() Condition Mistake: b4ld.c (From Line 850～913) causes discontinuity in the formulation.**

Line 850:

```
if ((model->BSIM4vtss - vbs) < 1e-3)
```

should be changed to

```
if((model->BSIM4vtss - vbs)/model->BSIM4vtss) < 1e-3)
```

Line 863:

```
if ((model->BSIM4vtsd - vbd) < 1e-3)
```

should be changed to

```
if((model->BSIM4vtsd - vbd)/model->BSIM4vtsd) < 1e-3)
```

Discontinuity in Diode Model (2)

Line 876:

```
if ((model->BSIM4vtssws - vbs) < 1e-3)
```

should be changed to

```
if((model->BSIM4vtssws - vbs)/model->BSIM4vtssws) < 1e-3)
```

Line 888:

```
if ((model->BSIM4vtsswd - vbd) < 1e-3)
```

should be changed to

```
if((model->BSIM4vtsswd - vbd)/model->BSIM4vtsswd) < 1e-3)
```

Discontinuity in Diode Model (3)

Line 901:

```
if ((model->BSIM4vtsswgs - vbs) < 1e-3)
```

should be changed to

```
if((model->BSIM4vtsswgs - vbs)/model->BSIM4vtsswgs) < 1e-3)
```

Line 913:

```
if ((model->BSIM4vtsswgd - vbd) < 1e-3)
```

should be changed to

```
if((model->BSIM4vtsswgd - vbd)/model->BSIM4vtsswgd) < 1e-3)
```

Gate Current Parameter Default Value Problem

Equation for Inversion

$$Igc0 = Weff \cdot Leff \cdot A \cdot ToxRatio \cdot Vgse \cdot Vaux \cdot \exp[-B \cdot TOXE(AIGBINV - BIGBINV \cdot Voxdepinv) \cdot (1 + CIGBINV \cdot Voxdepinv)]$$

$$B = \frac{8\pi\sqrt{2m_{ox}}\phi_b^{3/2}}{3hq}$$

- **Default Value Doesn't Reflect Unit Change**
  - Gate current from bulk is based on that from BSIMSOI3.2.
  - For BSIMSOI3.2, B is in units of $\sqrt{\frac{kg}{Fs^2}}$

    $$B = \frac{8\pi\sqrt{2m_{ox}}\phi_b^{3/2}}{3hq}$$

    Found by looking at hard-coded value in source code.
  - For BSIM 4.4.0, the units of B are changed to $\sqrt{\frac{g}{Fs^2}}$
  - However, default values for **AIGBINV**, **BIGBINV**, **AIGBACC**, **BIGACC** **remain the same as BSIM-SOI3.2.**

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Gate Current Parameter Default Value Problem (2)

- **BSIM-SOI3.2 Default Values**
  - alphaGB1 = 0.35, betaGB1 = 0.03 (inversion)
  - alphaGB2 = 0.43, betaGB2 = 0.05 (accumulation)

- **BSIM 4.4.0 Default Values**
  - AIGBINV = 0.35, BIGBINV = 0.03 (inversion)
  - AIGBACC = 0.43, BIGACC = 0.054 (accumulation)

- **BSIM 4.4.0 Proposed Corrected Default Values**
  - AIGBINV = **1.11e-2**, BIGBINV = **9.49e-4** (inversion)
  - AIGBACC = **1.36e-2**, BIGACC = **1.71e-3** (accumulation)

Other Miscellaneous Fixes

- **Parameter Check for WLOD: b4temp.c (Line 1313)**
  - There is a parameter check for valid **WLOD** value on Line 1313, but **WLOD** is already used on line 1284. Thus the check for **WLOD** should be done before line 1284.

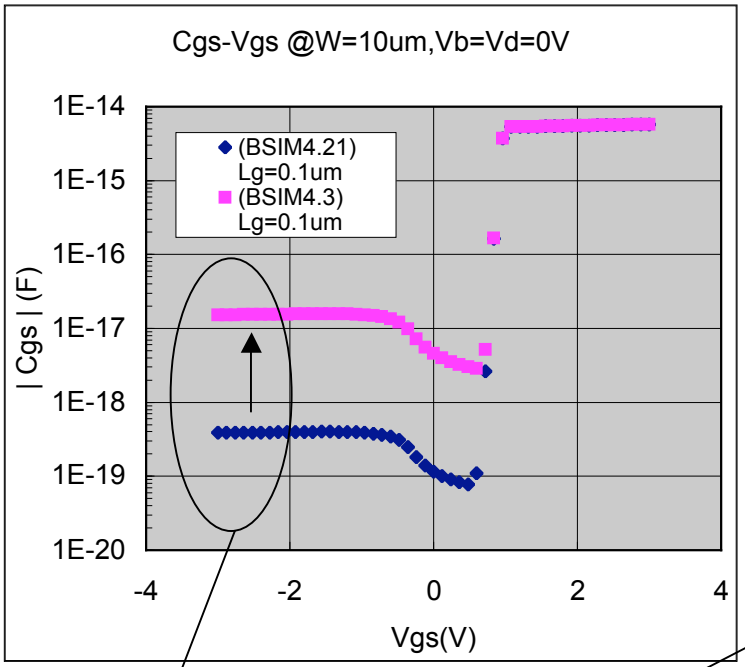
- ***(Very minor point):* MOIN parameter check: b4check.c (Line 601)only being used for CAPMOD=2, so check should be moved to CAPMOD=2 only code (Line 601)**
  - The parameter **MOIN** is being used only in CAPMOD=2, so shouldn't the check for the parameter also be moved from Line 601 to after the if(BSIM4capmod==2) on line 611?

- **BSIM 4.4.0 User's Manual Error: (Pages 12-6,12-7)**
  - For Eqs. 12.5.6, 12.5.7, and 12.5.8, Eg(TNOM)/vt -----> Eg(TNOM)/kbT, i.e. the formulation should be changed to energy/energy, as done in Eqs. 12.5.9 and onwards.

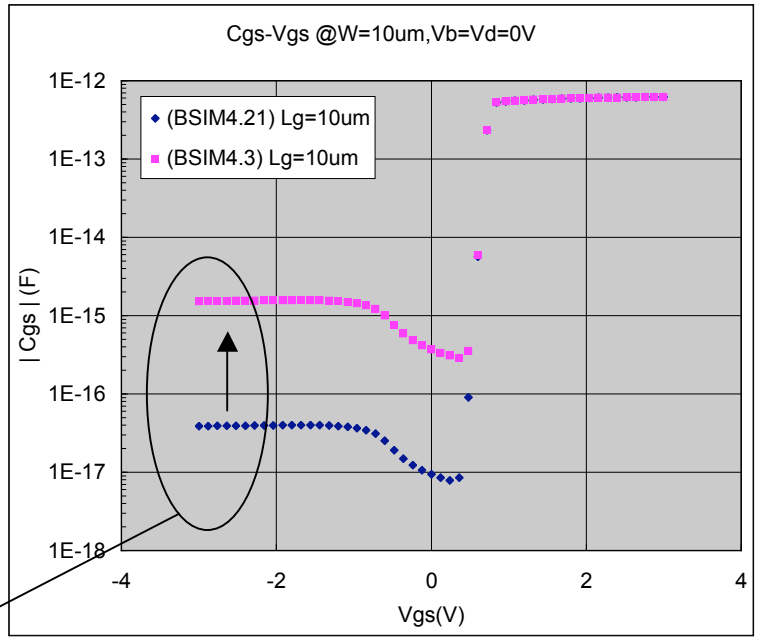
- **BSIM-SOI3.1 User's Manual: (Page B-9)**
  - Denote the correct units for alphaGB1, alphaGB2, betaGB1, betaGB2.

Cgs Observation

- **Observation: Cgs(BSIM4.3.0) > Cgs(BSIM 4.2.1) when Vgs < Vth.**
  - Seen especially for larger Lg.



(a) L=0.1um



(b) L=10um

Value increase

Parameters are at their default values.

```
+LEVEL =    54    VERSION =    4.3
+TNOM  =    25
+CF    =    0     CGDO    =    0
+CGSO  =    0
+UC    =    0     K1      =    0.5
+LPEB  =    0
+VTH0  =    0.7   VTL     =    0
```

Fig. 1 BSIM4.2.1 and BSIM4.3.0 Intrinsic C_{gs} behavior.

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Cgs Observation (2)

- **Code in BSIM 4.3.0, 4.4.0**
  - Code commented as /* JX: Correction to forward body bias */ for calculating Vbseff_dVb seems to be the problem.

BSIM4.3.0, 4.4.0 Source Code （ b4ld.c）

Line (4.3.0)	Line (4.4.0)	
858	968	/* JX: Correction to forward body bias */
859	969	T9 = 0.95 * pParam->BSIM4phi;
860	970	T0 = T9 - Vbseff - 0.001;
861	971	T1 = sqrt(T0 * T0 + 0.004 * T9);
862	972	Vbseff = T9 - 0.5 * (T0 + T1);
863	973	dVbseff_dVb *= 0.5 * (1.0 + T0 / T1);
864	974	
865	975	Phis = pParam->BSIM4phi - Vbseff;
866	976	dPhis_dVb = -1.0;
867	977	sqrtPhis = sqrt(Phis);
868	978	dsqrtPhis_dVb = -0.5 / sqrtPhis;

This code added by UCB to smooth out V_{bseff} when going to forward bias body levels.

The added calculation which seems to cause this increase.

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Cgs Observation (3)

- **Effect of Problem Limited, However**
  - Cgg remains unchanged between BSIM4.2.1 and BSIM4.3.0,4.4.0, as before the Cgs discrepancy occurs, Cgb dominates the capacitance curve.
  - Effect is seen only for long channel length L and if fixed overlap capacitance is small.
  - Effect can only be seen if Cgs actively used for Vgs < Vth where the effect of Cgb is not seen (e.g. if the source is tied to a signal line, with gate and bulk tied to ground).
- **Thus No Fix Requested**
  - No fix is requested if a simple solution is not available.