Summary of changes from BSIM4 4.8.1 to BSIM4 4.8.2

IIT Kanpur, BSIM Group
Chetan Kumar Dabhi (chetant@iitk.ac.in)

Summary of changes done:

- **2017bug2:** IGIDL/ IGISL is arbitrary large when Vbd >= FGIDL (Vbs >= FGISL). Singularity in IGIDL/ IGISL, if Vbd = FGIDL (Vbs = FGISL) **(NXP, Synopsys)**
- **2018bug1:** Limits on BSIM4IdovVds causes unwanted noise results for noise sensitive application **(Cadence)**
- **2018enh1:** Typo, related to GIDL equation, in BSIM4 4.8.1 technical manual. **(Synopsys)**
- **2019enh1:** Discrepancy in thermal noise model description in BSIM4 4.8.1 technical manual. **(ADI)**
- **2019enh2:** Warning added to ensure GIDLCLAMP < 0 and IdovVdsc > 0 **(ADI)**
- **2019enh3:** CF is calculated based on the default value of TOXE, but not using updated value of TOXE **(ADI)**
- **2019bug1:** Parameters LK1 is initialized to zero, but value is of LKT1 is set to zero. **(ADI)**
- **2019bug2:** Sign inconsistency of parameter values: Code Vs. Technical manual **(ProPlus)**

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1) 2017bug2: IGIDL/ IGISL is arbitrary large when Vbd >= FGIDL (Vbs >= FGISL). Singularity in IGIDL/ IGISL, if Vbd = FGIDL (Vbs = FGISL) **(NXP, Synopsys)**

Arbitrary large IGIDL/ IGISL current for Vbd=FGIDL (Vbs >= FGISL). To limit the arbitrary large current, the term Vbd-FGIDL (Vbs = FGISL) is clamped to small value of -1e-5, this solution is choosen because in IGIDL/ IGISL current equation, the Vbd-FGIDL(Vbs = FGISL) term appears as follows,

$$IGIDL\ \alpha \left(\exp\left(\frac{\mathrm{KGIDL}}{\mathrm{Vbd} - \mathrm{FGIDL}} \right) \right)$$

$$IGISL\ \alpha \left(\exp\left(\frac{\mathrm{KGISL}}{\mathrm{Vbs} - \mathrm{FGISL}} \right) \right)$$

To provide tunning flexibility of clamping value, instead of hard calmping of -1e-5, new parameter with name **GIDLCLAMP** is defined.

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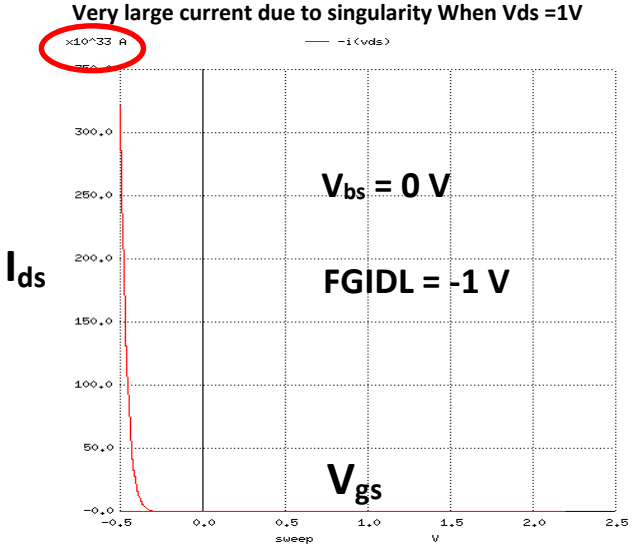
Default value of **GIDLCLAMP** is **-1e-5.**

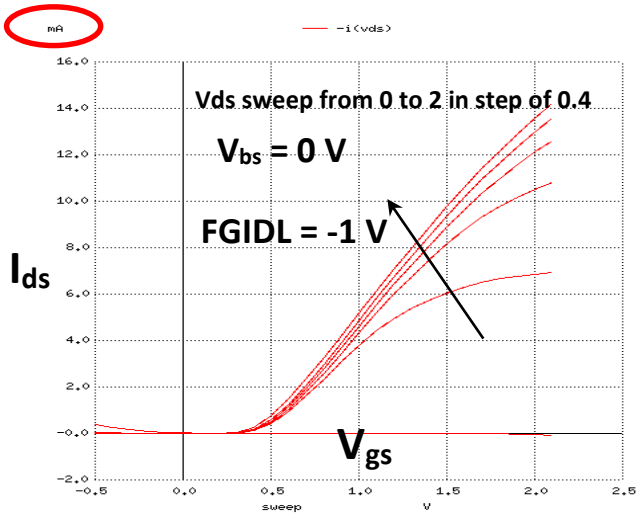
Old Code (IGIDL)	**b4ld.c** **T4 = vbd - pParam->BSIM4fgidl;**
New Code (IGIDL)	**b4ld.c** **T4 = vbd - pParam->BSIM4fgidl;** if(T4 > model->BSIM4gidlclamp) T4=model->BSIM4gidlclamp;
Old Code (IGISL)	**b4ld.c** **T4 = vbs - pParam->BSIM4fgisl;**
New Code (IGISL)	**b4ld.c** **T4 = vbs - pParam->BSIM4fgisl;** if(T4 > model->BSIM4gidlclamp) T4=model->BSIM4gidlclamp;

Issue

Very large current due to singularity When Vds =1V



Resolved singularity issue



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2) 2018bug1: limiting on BSIM4IdovVds causes unwanted noise results for noise sensitive application **(Cadence)**

For noise sensitive application, BSIM4IdovVDS needs more tuning flexibility. To provide more tunning flexibility, instead of hard clamping of 1e-9, new parameter is defined, and named as "**IdovVdsc",** with default value of **1e-9.**

Old Code	**b4ld.c** here->BSIM4gds = Gds; here->BSIM4gm = Gm; here->BSIM4gmbs = Gmb; here->BSIM4IdovVds = Ids; if(here->BSIM4IdovVds <= 1e-9) here->BSIM4IdovVds = 1e-9;
New Code	**b4ld.c** here->BSIM4gds = Gds; here->BSIM4gm = Gm; here->BSIM4gmbs = Gmb; here->BSIM4IdovVds = Ids; if(here->BSIM4IdovVds <= **pParam->BSIM4IdovVdsc**) here->BSIM4IdovVds = **pParam->BSIM4IdovVdsc**;

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3) **2018enh1:** Typo, related to GIDL equation, in BSIM4 4.8.1 technical manual. **(Synopsys)**

Old

$$I_{GIDL} = AGIDL \cdot W_{diod} \cdot Nf \cdot \frac{V_{ds} - RGIDL \cdot V_{gse} - EGIDL + V_{fbsd}}{3 \cdot T_{oxe}} \times \exp\left(-\frac{3 \cdot T_{oxe} \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL}\right) \cdot \exp\left(\frac{KGIDL}{V_{ds} - FGIDL}\right) \quad (6.8)$$

New

$$I_{GIDL} = AGIDL \cdot W_{diod} \cdot Nf \cdot \frac{V_{ds} - RGIDL \cdot V_{gse} - EGIDL + V_{fbsd}}{3 \cdot T_{oxe}} * exp\left(-\frac{3 \cdot T_{oxe} \cdot BGIDL}{V_{ds} - V_{gse} - EGIDL}\right) exp\left(\frac{KGIDL}{V_{bd} - FGIDL}\right) \quad (6.8)$$

4) **2019enh1:** Discrepancy in thermal noise model description in BSIM4 4.8.1 technical manual. **(ADI)**

Page 2: technical manual: Old

The new thermal noise model shows much better physical behavior in all bias conditions **(tnoiMod=3)**

Page 2: technical manual : New

The new thermal noise model shows much better physical behavior in all bias conditions **(tnoiMod=2)**

Summary of changes from BSIM4 4.8.1 to BSIM4 4.8.2

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Page 87: 10.2 Channel Thermal Noise: Old

There **are two channel thermal noise models** in BSIM4. One is a charge-based model (default model) similar to that used in BSIM3v3.2.
The other is the holistic model.
These two models can be selected through the model selector ***tnoiMod***.

Page 87: 10.2 Channel Thermal Noise: New

There are three channel thermal noise models in BSIM4. **First is a charge-based model** (default model) similar to that used in BSIM3v3.2,
the second noise model is the holistic model
and **the third noise model** includes both the gate and the drain noise.
These three models can be selected through the model selector ***tnoiMod***.

5) 2019enh2: Warning added to ensure GIDLCLAMP < 0 and IdovVdsc > 0. **(ADI)**

Warning is added to ensure GIDLCLAMP < 0

```
/* Check GIDL parameters */
if (model->BSIM4gidlclamp >= 0.0)
{   fprintf(fplog, "Warning: gidlclamp = %g is zero or positive.\n",
        model->BSIM4gidlclamp);
    printf("Warning: gidlclamp = %g is zero or positive.\n", model->BSIM4gidlclamp);
}
```

Warning is added to ensure IdsovVdsc > 0

```
if (model->BSIM4idovvdsc <= 0.0)
{   fprintf(fplog, "Warning: idovvdsc = %g is zero or negative.\n", model->BSIM4idovvdsc);
    printf("Warning: idovvdsc = %g is zero or negative.\n", model->BSIM4idovvdsc);
}
```

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Chetan Kumar Dabhi (chetant@iitk.ac.in)

6) **2019enh3:** CF is calculated based on the default value of TOXE, but not using updated value of TOXE. **(ADI)**

Solution: Calculation of CF is moved to b4temp.c file to calculate CF based on the updated value of TOXE.

Old Code	**b4set.c** if (!model->BSIM4toxeGiven) model->BSIM4toxe = 30.0e-10; . . if (!model->BSIM4cfGiven) model->BSIM4cf = 2.0 * model->BSIM4epsrox * EPS0 / PI * log(1.0 + 0.4e-6 / model->BSIM4toxe);
New Code	**b4set.c** if (!model->BSIM4toxeGiven) model->BSIM4toxe = 30.0e-10; **CF calcutation is moved to b4temp.c**
Old Code	**b4temp.c** if(model->BSIM4mtrlMod == 0) { if ((model->BSIM4toxeGiven) && (model->BSIM4toxpGiven) && (model->BSIM4dtoxGiven) && (model->BSIM4toxe != (model->BSIM4toxp + model->BSIM4dtox))) { printf("Warning: toxe, toxp and dtox all given and toxe != toxp + dtox; dtox ignored.\n"); } else if ((model->BSIM4toxeGiven) && (!model->BSIM4toxpGiven)) { model->BSIM4toxp = model->BSIM4toxe - model->BSIM4dtox; } else if ((!model->BSIM4toxeGiven) && (model->BSIM4toxpGiven))

IIT Kanpur, BSIM Group
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	{ model->BSIM4toxe = model->BSIM4toxp + model->BSIM4dtox; if (!model->BSIM4toxmGiven) /* v4.7 */ model->BSIM4toxm = model->BSIM4toxe; } }
New Code	**b4temp.c** if(model->BSIM4mtrlMod == 0) { if ((model->BSIM4toxeGiven) && (model->BSIM4toxpGiven) && (model->BSIM4dtoxGiven) && (model->BSIM4toxe != (model->BSIM4toxp + model->BSIM4dtox))) { printf("Warning: toxe, toxp and dtox all given and toxe != toxp + dtox; dtox ignored.\n"); } else if ((model->BSIM4toxeGiven) && (!model->BSIM4toxpGiven)) { model->BSIM4toxp = model->BSIM4toxe - model->BSIM4dtox; } else if ((!model->BSIM4toxeGiven) && (model->BSIM4toxpGiven)) { model->BSIM4toxe = model->BSIM4toxp + model->BSIM4dtox; if (!model->BSIM4toxmGiven) /* v4.7 */ model->BSIM4toxm = model->BSIM4toxe; } **if (!model->BSIM4cfGiven) /* v4.8.2 */** **model->BSIM4cf = 2.0 * model->BSIM4epsrox * EPS0 / P * log(1.0 + 0.4e-6 / model->BSIM4toxe);** **}**

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Chetan Kumar Dabhi (chetant@iitk.ac.in)

Table indicates the updated CF value based on the updated TOXE value:

Cases		Values (b4temp.c)
CASE 1 All given TOXE = = 3.5e-9, TOXP = 10e-10, DTOX = 8e-10 **TOXE != TOXP + DTOX**		toxe = 3.5e-09 cf = 1.04364e-10
CASE 2 TOXE = 4e-8 **TOXP not given**		toxe = 4e-08 cf = 5.27137e-11 toxp = 3.92e-08 calculated
CASE 3 TOXP = 4.5e-9, **TOXE not given**		toxp = 4.5e-09 cf = 9.53399e-11 toxe = 5.3e-09 calculated
Case 4 Nothing given TOXE, TOXP, DTOX	**Default Case**	toxe = 3e-09 cf = 1.07725e-10

7) **2019bug1:** parameters LK1 is initialized to zero, but value is of LKT1 is set to zero. **(ADI)**

Issue:

b4set.c

if (!model->BSIM4lk1Given)

model->BSIM4lkt1 = 0.0;

If LK1 is not given, then LKT1 is set to zero!

Solution:

if (!model->BSIM4lk1Given)

model->BSIM4lk1 = 0.0; **(LK1 is set to zero)**

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8) **2019bug2:** Sign inconsistency of parameter values: Code Vs. Technical manual.

(ProPlus)

Bug:

Technical manual

UC1	Temperature coefficient for UC	0.056V-1 for MOBMOD=1 and 5; 0.056e-9m/ V^2 for MOBMOD=0, and 2

Solution:

Code B4set.c

```
if(model->BSIM4version<=4.80)
{
        if (!model->BSIM4uaGiven)
        model->BSIM4ua = ((model->BSIM4mobMod == 2)) ? 1.0e-15 : 1.0e-9; /* unit m/V */
        /*printf("warning:ua=%g",model->BSIM4ua);*/
        if (!model->BSIM4ucGiven)
        model->BSIM4uc = (model->BSIM4mobMod == 1) ? -0.0465 : -0.0465e-9;
        if (!model->BSIM4uc1Given)
        model->BSIM4uc1 = (model->BSIM4mobMod == 1) ? -0.056 : -0.056e-9;
}
```

Technical manual is updated according to the parameter values in the code