

## Description of the code changes in BSIM3v3.1 versus BSIM3v3.0

The routines B3ld.c, b3temp.c, b3noi.c, b3mpar.c, b3.c, b3mask.c, b3set.c, bsim3ext.h have been changed. A description on the changes is given in the following:

1. Code improvement to avoid any model discontinuity caused by certain parameters or unusual operation bias conditions.

(1) To avoid any problems caused by  $1+dvt2*Vbseff$  in  $V_{th}$  calculations in b3ld.c  
if  $(T1=1+dvt2*Vbseff)<0.5$

$$T1=(1+3*dvt2*Vbseff)/(3+8*dvt2*Vbseff)$$

(2) To avoid any problems caused by  $1+dvt2w*Vbseff$  in  $V_{th}$  calculations in b3ld.c  
if  $(T1=1+dvt2w*Vbseff)<0.5$

$$T1=(1+3*dvt2w*Vbseff)/(3+8*dvt2w*Vbseff)$$

(3) To avoid any problems caused by  $nfactor*esi/Xdep+theta0*(cdsc+cdscb*Vbseff+Cdsd*Vds)$  in calculating  $n$  in b3ld.c.

if  $(n=1+nfactor*esi/Xdep+theta0*(cdsc+cdscb*Vbseff+Cdsd*Vds))<-0.5$

$$n=[1+3*nfactor*esi/Xdep+theta0*(cdsc+cdscb*Vbseff+Cdsd*Vds)]/[3+8*[nfactor*esi/Xdep+theta0*(cdsc+cdscb*Vbseff+Cdsd*Vds)]]$$

(4) To avoid any problems caused by  $Abulk0$  and  $Abulk$  in b3ld.c.

if  $(Abulk0<0.1)$

$$Abulk0=(0.2-Abulk0)/(3-20*Abulk0)$$

if  $(Abulk<0.1)$

$$Abulk=(0.2-Abulk)/(3-20*Abulk)$$

(5) To avoid any problems caused by  $dwg$  and  $dwb$  in calculating  $W_{eff}$  in b3ld.c.

if  $(W_{eff}<2.e-8)$

$$W_{eff}=2.e-8(4.e-8-W_{eff})/(6.e-8-2*W_{eff})$$

(6) To avoid any problems caused by  $Prwg*Vgsteff+Prwb*(\sqrt{PHI-VBS})-\sqrt{PHI}$  in calculating  $R_{ds}$  in b3ld.c.

If  $\{T0=Prwg*Vgsteff+Prwb*(\sqrt{PHI-VBS})-\sqrt{PHI}\}<-0.9$

$$R_{ds}=R_{ds0}*(0.8+T0)/(17+20*T0)$$

(7) To avoid problems caused by  $1/(1+Keta*Vbseff)$  in calculating  $Abulk$  in b3ld.c.

if  $(T0=1/(1+Keta*Vbseff))>10$

$$T0=(17+20*Keta*Vbseff)/(0.8+Keta*Vbseff)$$

(8) To avoid problem caused by the denominator in calculating  $\mu_{eff}$  in b3ld.c.

```
Denomi=1+T5
if (T5<-0.8)
Denomi=(0.6+T5)/(7+10*T5)
```

(9) To avoid problems caused by  $A1*Vgsteff+A2$  in calculating  $\lambda$  in b3ld.c.

```
if A1>0
Lambda=1-0.5*(T1+T2)
T1=1-A2-A1*Vgsteff-1.e-4
T2=sqrt(T1*T1+0.004*(1-A2))
else
Lambda=0.5*(T1+T2)
T1=A2+A1*Vgsteff-1.e-4
T2=sqrt(T1*T1+0.004*A2)
```

(10) To avoid problems caused by  $1/(pdiblc*Vbseff)$  in calculating  $V_{dibl}$  in b3ld.c.

```
T7=pdiblc*Vbseff
T3=1/(1+T7)
if (T7<-0.9)
T3=(17+20*T7)/(0.8+T7)
```

(11) To avoid problems caused by  $1+Pvag*Vgsteff/(Esat*Leff)$  in calculating  $V_a$  in b3ld.c.

```
T9=Pvag*Vgsteff/(Esat*Leff)
T0=1+T9
if (T9<-0.9)
T0=(0.8+T9)/(17+20T9)
```

(12) To avoid problems caused by  $\eta_0+\eta_{ab}*Vbseff$  in b3ld.c.

```
if (T3= $\eta_0+\eta_{ab}*Vbseff$ )<1.e-4
T3=(2.e-4-T3)/(3.-2.e-4*T3)
```

(13) To avoid problems caused by  $V_{gs\_eff}$  in b3ld.c

```
Vgs_eff=Vgs-Vpoly
if (Vpoly>1.12)
Vgs_eff=Vgs-T5
T5=1.12-0.5*(T7+T6)
T7=1.12-Vpoly-0.05
T6=sqrt(T7*T7+0.224)
```

2. Code change to avoid Math problems such as divide by zero or sqrt root domain.

(1) introducing smooth functions to avoid any Sqrt Domain errors in calculating T1 in calculation of capacitance when capmod=1 and 2 in b3ld.c.

(2) Code change in calculating the Vascbe in b3ld.c to avoid the problem divided by zero when pscbe2=0

3. Fixing the bugs

(1) "ldvt1w and ldvt2w missed their 'w' " at line 519 and 523 in b3mset.c

(2) "undefined vfb parameter when Vth0 is not defined" in b3temp.c

(3) "considering CONSTCtoK twice" at line 53, 69, and 232 in b3noi.c

(4) "here->BSIM3gtg should be here->gtb" in line 1905 in b3ld.c

(5) "uninitialized parameters in SizeDepend structure in b3temp.c

(6) "0.5 should be dxpart" in 1901 in b3ld.c.

4. Addition of a new routine to check the parameters:

A new routine called as b3check.c has been created to check the parameters before doing the simulation. In this routine, the following parameters are checked such as Leff, LeffCV, Weff, WeffCV, Nlx, Nch, Vbsc, Tox, Dvt0, Dvt0w, Dvt1, Dvt1w, W0, nfactor, Cdsc, Cdsd, et0, b1, u0, delta, a1, a2, rds, rds0, vsattemp, pclm, pdibl1, pdibl2, clc. For some parameters such as Tox, Xj, Nlx, the simulator outputs "Fatal error" and quit the simulation if the users input any parameters outside the bounds in the code. For some parameters such as et0, a1, a2 etc., the simulator outputs "Warning" message to let the users know that they are using some unsuitable parameters for their simulation.

(1) Values of parameters are outside the following bounds would be treated as "fatal errors":

Leff<0

Weff<0

Tox≤0

NCH ≤0

Ngate<0

NLX ≤ -Leff

W0 = -Weff

XJ ≤0

B1 = -Weff

U0 ≤ 0

DELTA ≤ 0

NSUB≤0

Dvt1<0

Dvt1w<0

Dsub<0

Vsatttemp $\leq$ 0  
Pclm $<$ 0  
Drout $<$ 0  
Clc $<$ 0

(2) Values of parameters are within the following regions would be treated as “warning errors”:

NLX $>$ -Leff but  $<$ 0  
Nch  $<1e15\text{ cm}^{-3}$  or  $>1E21\text{ cm}^{-3}$   
Nsub  $<1e14\text{ cm}^{-3}$  or  $>1E21\text{ cm}^{-3}$   
TOX  $<10\text{\AA}$   
Leff  $<0.05\mu\text{m}$   
LeffCV $<0.05\mu\text{m}$   
Weff  $<0.1\mu\text{m}$   
WeffC  $<0.1\mu\text{m}$   
Ngate $>$ 0 but  $<1e18\text{ cm}^{-3}$   
Dvt0 $<$ 0  
ABS(1e-6/(Weff+W0))  $>10$   
ABS(B0/(Weff + B1))  $>10$   
nfactor $<$ 0  
Cdsc $<$ 0  
Cdsd $<$ 0  
Eta0 $<$ 0  
A2 $<0.01$  or A2 $>1$   
Rdsw  $>$ 0 but  $<0.001$   
Vsatttemp  $>$ 0 but  $<1e3$   
Pdlblc1 $<$ 0  
Pdlblc2 $<$ 0  
Cgdo $<$ 0  
Cgso $<$ 0  
Cgbo $<$ 0  
Ps and Pd  $<$ Weff (when Cj or Cjsw is given)

## 5. Changes in noise routine:

(1) Adding two more options (noiMod= 1, 2, 3, 4, ) for users to use different combinations of thermal and flicker noise models. noiMod=1: Spice2 flicker noise model + Spice2 thermal noise model ; noiMob=2: BSIM3 flicker noise model + BSIM3 thermal noise model; noiMod=3: Spice2 thermal noise model + BSIM3 flicker noise model; noiMod=4: Spice2 flicker noise model + BSIM3 thermal noise model.

(2) Adding the Gmb term in the calculation of Spice2 thermal noise model equation.

## 6. Modify the S/B and D/B diode model.

- (1) Modifying the code for the calculation of source/bulk and drain/bulk diode currents (One new parameter, Jssw, is introduced for the parasitic side junction current).
  - (2) Modifying the code for the calculation of source/bulk and drain/bulk diode parasitic side capacitances (Three new parameters, Cjswg, Pbswg and Mjswg, are introduced for the sidewall parasitic capacitances at gate side) .
  - (3) Adding the code to account for the temperature effect of S/B and D/B diode (Two more parameters, XTI and NJ, are introduced).
- Please see manual for details on the above.

7. Add capmod=0 for capacitance model compatible with that in BSIM1

8. Other code change and clean-ups:

- (1) Change the code in b3set.c to calculate Cf according to the equation in the manual as the default value instead of zero when it is not given by the user.

- (2) Add an option for users to use high Vbc value in the simulation when parameter K2>0  
If K2<0

$$Vbc = 0.9 * [PHI - (0.5 * K1 / K2)^2]$$

else

$$Vbc = -30 \text{ if } (Vbm \geq -30)$$

$$Vbc = Vbm \text{ if } (Vbm < -30)$$

- (3) Changing judgment condition for poly gate depletion effect in b3ld.c.  
Polygate depletion effect is calculated if (Ngate>Nch and Vgs>Vfb+PHI)

- (4) Code change for the calculation of Vgsteff function in b3ld.c.

- (5) One parameter, version, was added for the version control of the code. The default value is 3.1.

- (6) One flag parameter, paramchk, was added for users to have the option to turn on or off the parameter checking for warning error.

- (7) Code clean-ups to improve the calculation efficiency.