

BSIM3v3.1 MOSFET SIMULATION

http://www.leapcad.com/Other_Tech/BSIM3V3_MOS_Simulator.mcd



University of California Berkeley MOSFET Model from BSIM Group

<http://www.eecs.berkeley.edu/Pubs/TechRpts/1998/3486.html>

<http://www-device.eecs.berkeley.edu/~bsim3/>

BSIM3v3 is the latest industry-standard MOSFET model for deep-submicron digital and analog circuit designs from the BSIM Group at the University of California at Berkeley. BSIM3v3.2 is based on its predecessor, BSIM3v3.1. Its many improvements and enhancements include

- * A new intrinsic capacitance model (the Charge Thickness Model), considering the finite charge layer thickness determined by quantum effect, is introduced as capMod 3. It is very accurate in all operating regions.
- * Modeling of C-V characteristics at the weak-to-inversion transition is improved.
- * The $T(\text{ox})$ dependence is added into the threshold voltage model.
- * The flat-band voltage is added as a new model parameter to accurately model MOSFET's with different gate materials.
- * Substrate current dependence on the channel length is improved.
- * The non-quasi-static (NQS) model is restructured to improve the model accuracy and simulation efficiency. NQS is added in the pole-zero analysis.
- * The temperature dependence is added to the diode junction capacitance model.
- * The DC junction diode model now supports a resistance-free diode model and a current-limiting feature.
- * Option of using C-V inversion charge equations of capMod 0, 1, 2 or 3 to calculate the thermal noise when noiMod == 2 or 4 is added.
- * The small negative capacitance of $C(\text{gs})$ and $C(\text{gd})$ in the accumulation-depletion regions is eliminated.
- * A separate set of length/width-dependence parameters is introduced in the C-V model to better fit the capacitance data.

P := READPRN("http://www.leapcad.com/Other_Tech/MNLPRN.prn")

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Note: Used Excel to import RMA's data file. Got records "a0=0.7," into N columns of "name=data" and then into 2N columns by removing "=" as delimiters. Fill in empty cells to get rectangular matrix. Concat "" around text. Then copy into MathCad PRN file format with Rows and 2N Columns, e.g. examine files NCH.PRN or MNLPRN.PRN.

Features:

L := 0.35·um
W := 0.6·um
L := 4·UDR
W := 4·UDR

```
F(string) := | for j ∈ 0..(cols(P)·.5) - 1
               | for i ∈ 0..rows(P) - 1
               |   if string = (P<2,j>)i
               |     | T ← (P<2,j+1>)i
               |     | break
               | T ← if[(T = 0)·(i = rows(P) - 1), T11,1}, T]
```

DEFINE: VARIABLES = BSIM3 DATA

c2_vs := cm ² ·(volt·sec) ⁻¹	wr := F("wr")	f_m2 := farad·m ⁻²	f_m2v := farad·m ⁻² ·volt ⁻¹
a0 := F("a0")	a1 := F("a1")	ags := F("ags")·volt ⁻¹	
alpha0 := F("alpha0")·m·V ⁻¹	alpha1 := F("alpha1")·volt ⁻¹	b0 := F("b0")·m	b1 := F("b1")·m
beta0 := F("beta0")·volt	cdsc := F("cdsc")·f_m2	cdscb := F("cdscb")·f_m2v	cdscd := F("cdscd")·f_m2v
cgbo := F("cgbo")	a1 := F("a1")	a2 := F("a2")	cit := F("cit")·f_m2
cj := F("cj")	a1 := F("a1")	δ := F("delta")·volt	at := F("at")
diflens := F("diflens")	drou := F("drou")	dsub := F("dsub")	dvt0 := F("dvt0")
dvt0w := F("dvt0w")	dvt1 := F("dvt1")	dvt1w := F("dvt1w")·m ⁻¹	dvt2 := F("dvt2")·volt ⁻¹
dvt2w := F("dvt2w")·volt ⁻¹	dwb := F("dwb")·m·volt ^{-0.5}	dwg := F("dwg")·m·volt ⁻¹	eta0 := F("eta0")
etab := F("etab")·volt ⁻¹	k1 := F("k1")·volt ^{0.5}	k2 := F("k2")	js := F("js")
k3 := F("k3")	k3b := F("k3b")·volt ⁻¹	keta := F("keta")·volt ⁻¹	at := F("at")
kt11 := F("kt11")	a1 := F("a1")	lint := F("lint")·m	at := F("at")
mjsw := F("mjsw")	a1 := F("a1")	nch := F("nch")·m ⁻³	nfactor := F("nfactor")
ngate := F("ngate")	nlx := F("nlx")·m	nsub := F("nsub")·m ⁻³	at := F("at")
pbsw := F("pbsw")	pclm := F("pclm")	pdible1 := F("pdible1")	pdible2 := F("pdible2")
pdiblecb := F("pdiblecb")·volt ⁻¹	a1 := F("a1")	prwb := F("prwb")·V ^{-0.5}	prwg := F("prwg")·volt ⁻¹
pscbe1 := F("pscbe1")· $\frac{\text{volt}}{\text{m}}$	pscbe2 := F("pscbe2")· $\frac{\text{m}}{\text{volt}}$	pvag := F("pvag")	rdsw := F("rdsw")·ohm·um ^{wr}

$$\begin{array}{llll}
\text{rsh} := \text{F("rsh")} & \text{a1} := \text{F("a1")} & \text{a2} := \text{F("a2")} & \text{at} := \text{F("at")} \\
\text{tc1s} := \text{F("tc1s")} & \text{a1} := \text{F("a1")} & \text{a2} := \text{F("a2")} & \text{tnom} := \text{F("tnom")} \\
\text{tox} := \text{F("tox")} \cdot \text{m} & \text{u0} := \text{F("u0")} \cdot \text{c2_vs} & \text{ua} := \text{F("ua")} \cdot \text{m} \cdot \text{V}^{-1} & \text{ua1} := \text{F("ua1")} \cdot \text{m} \cdot \text{V}^{-1} \\
\text{ub} := \text{F("ub")} \cdot \text{m}^2 \cdot \text{V}^{-2} & \text{ub1} := \text{F("ub1")} \cdot \text{m}^2 \cdot \text{V}^{-2} & \text{uc} := \text{F("uc")} \cdot \text{m} \cdot \text{V}^{-2} & \text{uc1} := \text{F("uc1")} \cdot \text{m}^2 \cdot \text{V}^{-2} \\
\text{ute} := \text{F("ute")} & \text{vbm} := \text{F("vbm")} \cdot \text{volt} & \text{vbx} := \text{F("vbx")} \cdot \text{volt} & \text{voff} := \text{F("voff")} \cdot \text{volt} \\
\text{vsat} := \text{F("vsat")} \cdot \frac{\text{m}}{\text{sec}} & \text{vth0} := \text{F("vth0")} \cdot \text{volt} & \text{w0} := \text{F("w0")} \cdot \text{m} & \text{wint} := \text{F("wint")} \cdot \text{m} \\
\text{wln} := \text{F("wln")} & \text{wl} := \text{F("wl")} \cdot \text{m}^{\text{wln}+1} & \text{wwn} := \text{F("wwn")} & \text{ww} := \text{F("ww")} \cdot \text{m}^{\text{wwn}+1} \\
\text{wwl} := \text{F("wwl")} \cdot \text{m}^{\text{wwn}+\text{wln}+1} & \text{xj} := \text{F("xj")} \cdot \text{m} & \text{at} := \text{F("at")} & \\
\text{xt} := 1.55 \cdot 10^{-7} \cdot \text{m} & \text{fox} := 8500 \cdot 10^{-10} \cdot \text{m} & \text{dWeff} := 0.3 \cdot 10^{-6} \cdot \text{m} & \text{dLeff} := 0.25 \cdot 10^{-6} \cdot \text{m}
\end{array}$$

PHYSICAL CONSTANTS:

$$\begin{array}{lll}
\varepsilon_0 := 8.854 \cdot 10^{-14} \frac{\text{farad}}{\text{cm}} & q := 1.602 \cdot 10^{-19} \cdot \text{coul} & k := 1.380658 \cdot 10^{-23} \cdot \text{joule} \\
\varepsilon_{\text{ox}} := 3.9 \cdot \varepsilon_0 & \varepsilon_{\text{si}} := 11.9 \cdot \varepsilon_0 & N_{\text{c}} := 2.8 \cdot 10^{19} \cdot \text{cm}^{-3} & N_{\text{v}} := 1.04 \cdot 10^{19} \cdot \text{cm}^{-3} \\
\text{lint} = 1.17 \times 10^{-7} \text{ m} & & &
\end{array}$$

DEVICE PARAMETERS:

$$\begin{array}{llll}
T := 300.15 & V_{\text{bs}} := 0 \cdot \text{volt} & n_{\text{sub}} := 10^{20} \cdot \text{m}^{-3} & \\
\text{toxm} := \text{tox} & \text{dL} := \text{lint} & n_{\text{ds}} := 10^{20} \cdot \text{m}^{-3} & \delta_1 := 0.001 \cdot \text{volt} \quad 2.2.26
\end{array}$$

CALCULATIONS:

$$v_t := k \cdot \frac{T}{q} \quad E_{\text{g0}} := \left(1.16 - \frac{7.02 \times 10^{-4} \cdot T^2}{T + 1108} \right) \cdot \text{volt} \quad n_i := 1.45 \cdot 10^{10} \cdot \left(\frac{T}{300.15} \right)^{1.5} \exp \left(21.5565981 - \frac{E_{\text{g0}} \cdot q}{2k \cdot T} \right) \cdot \text{cm}^{-3}$$

$$\text{dWp} := \text{wint} + \frac{\text{wl}}{L^{\text{wln}}} + \frac{\text{ww}}{W^{\text{wwn}}} + \frac{\text{wwl}}{L^{\text{wln}} \cdot W^{\text{wwn}}} \quad W_{\text{effp}} := W - 2 \cdot \text{dWp} \quad L_{\text{eff}} := L - 2 \cdot \text{lint}$$

$$C_{\text{ox}} := \frac{\varepsilon_{\text{ox}}}{\text{tox}} \quad \phi_s := 2 \cdot \frac{k \cdot T}{q} \cdot \ln \left(\frac{\text{nch}}{n_i} \right) \quad V_{\text{bx}} := \phi_s - \frac{q \cdot \text{nch} \cdot \text{xt}^2}{2 \cdot \varepsilon_{\text{si}}} \quad V_{\text{bi}} := \frac{k \cdot T}{q} \cdot \ln \left(\frac{\text{nch} \cdot \text{nds}}{n_i^2} \right)$$

$$\gamma_1 := \frac{\sqrt{2 \cdot q \cdot \varepsilon_{\text{si}} \cdot \text{nch}}}{C_{\text{ox}}} \quad \gamma_2 := \frac{\sqrt{2 \cdot q \cdot \varepsilon_{\text{si}} \cdot \text{nsub}}}{C_{\text{ox}}} \quad K_1 := k1 \quad K_2 := k2$$

Berkeley example defines k1 and k2

$$K_2 := \frac{(\gamma_1 - \gamma_2) \cdot (\sqrt{\phi_s - V_{bx}} - \sqrt{\phi_s})}{\left[2 \cdot \sqrt{\phi_s} \cdot (\sqrt{\phi_s - v_{bm}} - \sqrt{\phi_s}) \right] + v_{bm}}$$

$$K_1 := \gamma_2 - 2K_2 \cdot \sqrt{\phi_s - v_{bm}}$$

$$V_{bc} := 0.9 \cdot \left[\phi_s - \left(\frac{K_1}{2 \cdot K_2} \right)^2 \right]$$

$$V_{bseff} := V_{bc} + 0.5 \cdot \left[V_{bs} - V_{bc} - \delta_1 + \sqrt{(V_{bs} - V_{bc} - \delta_1)^2 - 4 \cdot \delta_1 \cdot V_{bc}} \right]$$

$$X_{depo} := \sqrt{\frac{2 \cdot \epsilon_{si} \cdot \phi_s}{q \cdot n_{ch}}} \quad 2.1.17 \text{ B1.1}$$

$$X_{dep} := \sqrt{\frac{2 \cdot \epsilon_{si} \cdot (\phi_s - V_{bs})}{q \cdot n_{ch}}}$$

$$K_{lox} := K_1 \cdot \frac{tox}{tox_m}$$

$$I_{t0} := \sqrt{\frac{\epsilon_{si} \cdot X_{depo}}{C_{ox}}}$$

$$I_t := \sqrt{\frac{\epsilon_{si} \cdot X_{dep}}{C_{ox}}} \cdot (1 + dvt_2 \cdot V_{bseff}) \quad 2.1.16$$

$$I_{tw} := \sqrt{\frac{\epsilon_{si} \cdot X_{dep}}{C_{ox}}} \cdot (1 + dvt_{2w} \cdot V_{bseff})$$

$$C_d := \frac{\epsilon_{si}}{X_{dep}}$$

$$V_{fb} := v_{th0} - \phi_s - K_1 \cdot \sqrt{\phi_s} \quad A_{10}$$

$$V_{th0ox} := v_{th0} - K_1 \cdot \sqrt{\phi_s}$$

$$K_{1ox} := K_1$$

$$K_{2ox} := K_2$$

Note: Circular defn. Weff is function of Vgsteff(Vth). Therefore Substituted Weffp for Weff in Dvtw.

$$Dvtw := -dvt_{0w} \cdot \left(\exp\left(-dvt_{1w} \cdot \frac{W_{effp} \cdot L_{eff}}{2 \cdot I_{tw}}\right) + 2 \cdot \exp\left(-dvt_{1w} \cdot \frac{W_{effp} \cdot L_{eff}}{I_{tw}}\right) \right) \cdot (V_{bi} - \phi_s) \quad Dvtw = 7.152 \times 10^{-3} \text{ volt}$$

$$Dvt := -dvt_0 \cdot \left(\exp\left(-dvt_1 \cdot \frac{L_{eff}}{2 \cdot I_t}\right) + 2 \cdot \exp\left(-dvt_1 \cdot \frac{L_{eff}}{I_t}\right) \right) \cdot (V_{bi} - \phi_s) \quad Dvt = -0.233 \text{ volt}$$

$$\eta_{a0} = 0$$

$$D(V_{ds}) := -1 \cdot \left(\exp\left(-d_{sub} \cdot \frac{L_{eff}}{2 \cdot I_{t0}}\right) + 2 \cdot \exp\left(-d_{sub} \cdot \frac{L_{eff}}{I_{t0}}\right) \right) \cdot (\eta_{a0} + \eta_{ab} \cdot V_{bseff}) \cdot V_{ds} \quad D(6 \cdot V) = 0 \text{ V}$$

$$D_o := K_{1ox} \cdot \left(\sqrt{1 + \frac{n_{lx}}{L_{eff}}} - 1 \right) \cdot \sqrt{\phi_s} + (k_3 + k_{3b} \cdot V_{bseff}) \cdot \frac{tox}{W_{effp} + w_0} \cdot \phi_s \quad D_o = -0.012 \text{ volt}$$

$$T_o := dvt2 \cdot V_{bseff} \quad T_o = 0$$

$$V_{th0ox} = 0.85 \text{ volt}$$

$$V_{th}(V_{ds}) := V_{th0ox} + K_{1ox} \cdot \sqrt{\phi_s - V_{bseff}} - K_{2ox} \cdot V_{bseff} + D_o + Dvtw + Dvt + D(V_{ds})$$

$$V_{th}(0 \cdot V) = 0.638 \text{ V}$$

2.2.11

$$V_{thx}(V_{ds}) := \left[v_{th0} + K_1 \cdot (\sqrt{\phi_s - V_{bs}} - \sqrt{\phi_s}) \right] - \left[K_2 \cdot V_{bs} + K_1 \cdot \left(\sqrt{1 + \frac{nI_x}{L_{eff}}} - 1 \right) \cdot \sqrt{\phi_s} \right]$$

$$V_{thx}(0 \cdot V) = 0.876 \text{ V}$$

$$temp4(V_{ds}) := nfactor \cdot \frac{C_d}{C_{ox}} + \frac{(cdsc + cdscl \cdot V_{ds} + cdsclb \cdot V_{bseff}) \cdot \left(\exp\left(\frac{-dvt1 \cdot L_{eff}}{2l_t}\right) + 2 \cdot \exp\left(\frac{-dvt1 \cdot L_{eff}}{l_t}\right) \right)}{C_{ox}} + \frac{cit}{C_{ox}}$$

$$T_o(V_{ds}) := (3 + 8 \cdot temp4(V_{ds}))^{-1} \quad n2(V_{ds}) := (1 + 3 \cdot temp4(V_{ds})) \cdot T_o(V_{ds})$$

$$n(V_{ds}) := \text{if}(temp4(V_{ds}) > -0.5, 1 - temp4(V_{ds}), n2(V_{ds}))$$

$$n(3 \cdot \text{volt}) = 0.384$$

$$V_{gsteff}(V_{gs}, V_{ds}) := \frac{2 \cdot n(V_{ds}) \cdot v_t \cdot \ln\left(1 + \exp\left(\frac{V_{gs} - V_{th}(V_{ds})}{2 \cdot n(V_{ds}) \cdot v_t}\right)\right)}{1 + 2 \cdot n(V_{ds}) \cdot C_{ox} \cdot \sqrt{\frac{2 \cdot \phi_s}{q \cdot \epsilon_{si} \cdot nch}} \cdot \exp\left(\frac{-V_{gs} - V_{th}(V_{ds}) - 2 \cdot v_{off}}{2 \cdot n(V_{ds}) \cdot v_t}\right)}$$

$$dW(V_{gs}, V_{ds}) := dW_p + dwg \cdot V_{gsteff}(V_{gs}, V_{ds}) + dwb \cdot (\sqrt{\phi_s - V_{bseff}} - \sqrt{\phi_s})$$

$$W_{eff}(V_{gs}, V_{ds}) := W - 2 \cdot dW(V_{gs}, V_{ds})$$

$$\mu_{eff}(V_{gs}, V_{ds}) := \frac{u_0}{1 + (ua + uc \cdot V_{bseff}) \cdot \left(\frac{V_{gs} + V_{th}(V_{ds})}{tox}\right) + ub \cdot \left(\frac{V_{gs} + V_{th}(V_{ds})}{tox}\right)^2}$$

$$\sigma(V_{gs}, V_{ds}) := \frac{W}{L} \cdot \mu_{eff}(V_{gs}, V_{ds}) \cdot C_{ox}$$

$$\theta_{th}(L) := \exp\left(\frac{-L}{2 \cdot l_t}\right) + 2 \cdot \exp\left(\frac{-L}{l_t}\right)$$

Velocity, v , is not used explicitly in model

$$E_{\text{sat}}(V_{\text{gs}}, V_{\text{ds}}) := \frac{2 \cdot v_{\text{sat}}}{\mu_{\text{eff}}(V_{\text{gs}}, V_{\text{ds}})}$$

$$E_{\text{eff}}(V_{\text{gs}}, V_{\text{ds}}) := \frac{V_{\text{gs}} + V_{\text{th}}(V_{\text{ds}})}{6 \cdot t_{\text{ox}}}$$

$$v := \text{if} \left[\frac{\mu_{\text{eff}} \cdot E_{\text{eff}}}{1 + \left(\frac{E_{\text{eff}}}{E_{\text{sat}}} \right)} > v_{\text{sat}}, v_{\text{sat}}, \frac{\mu_{\text{eff}} \cdot E_{\text{eff}}}{1 + \left(\frac{E_{\text{eff}}}{E_{\text{sat}}} \right)} \right]$$

$$A_{\text{bulkx}}(V_{\text{gs}}, V_{\text{ds}}) := 1 - \text{ags} \cdot V_{\text{gsteff}}(V_{\text{gs}}, V_{\text{ds}}) \cdot \left(\frac{L_{\text{eff}}}{L_{\text{eff}} + 2 \cdot \sqrt{x_j} \cdot X_{\text{dep}}} \right)^2$$

$$A_{\text{bulk}}(V_{\text{gs}}, V_{\text{ds}}) := \left[1 + \frac{K_{\text{lox}}}{2 \cdot \sqrt{\phi_s - V_{\text{bseff}}}} \cdot \left[\frac{a_0 \cdot L_{\text{eff}}}{L_{\text{eff}} + 2 \cdot \sqrt{x_j} \cdot X_{\text{dep}}} \cdot (A_{\text{bulkx}}(V_{\text{gs}}, V_{\text{ds}})) + \frac{b_0}{W_{\text{effp}} + b_1} \right] \right] \cdot \frac{1}{1 + k_{\text{eta}} \cdot V_{\text{bseff}}}$$

$$V_{\text{dsat}}(V_{\text{gs}}, V_{\text{ds}}) := \frac{E_{\text{sat}}(V_{\text{gs}}, V_{\text{ds}}) \cdot L_{\text{eff}} \cdot (V_{\text{gsteff}}(V_{\text{gs}}, V_{\text{ds}}) + 2 \cdot v_t)}{A_{\text{bulk}}(V_{\text{gs}}, V_{\text{ds}}) \cdot E_{\text{sat}}(V_{\text{gs}}, V_{\text{ds}}) \cdot L_{\text{eff}} + (V_{\text{gsteff}}(V_{\text{gs}}, V_{\text{ds}}) + 2 \cdot v_t)}$$

$$V_{\text{dseff}}(V_{\text{gs}}, V_{\text{ds}}) := V_{\text{dsat}}(V_{\text{gs}}, V_{\text{ds}}) - \frac{1}{2} \cdot \left[(V_{\text{dsat}}(V_{\text{gs}}, V_{\text{ds}}) - V_{\text{ds}} - \delta) + \sqrt{(V_{\text{dsat}}(V_{\text{gs}}, V_{\text{ds}}) - V_{\text{ds}} - \delta)^2 + 4 \cdot \delta \cdot V_{\text{dsat}}(V_{\text{gs}}, V_{\text{ds}})} \right]$$

$$l_{\text{itl}} := \sqrt{3 \cdot x_j \cdot t_{\text{ox}}} \quad V_{\text{aclm}}(V_{\text{gs}}, V_{\text{ds}}) := \frac{A_{\text{bulk}}(V_{\text{gs}}, V_{\text{ds}}) \cdot E_{\text{sat}}(V_{\text{gs}}, V_{\text{ds}}) \cdot L_{\text{eff}}}{p_{\text{clm}} \cdot A_{\text{bulk}}(V_{\text{gs}}, V_{\text{ds}}) \cdot E_{\text{sat}}(V_{\text{gs}}, V_{\text{ds}}) \cdot l_{\text{itl}}} \cdot (V_{\text{ds}} - V_{\text{dseff}}(V_{\text{gs}}, V_{\text{ds}}))$$

$$\theta_{\text{rout}} := p_{\text{diblc1}} \cdot \left(\exp\left(-\text{drou} \cdot \frac{L_{\text{eff}}}{2 \cdot l_{\text{t0}}}\right) + 2 \cdot \exp\left(-\text{drou} \cdot \frac{L_{\text{eff}}}{l_{\text{t0}}}\right) \right) + p_{\text{diblc2}}$$

$$R_{\text{ds}}(V_{\text{gs}}, V_{\text{ds}}) := \frac{\text{rdsw} \cdot \left[1 + \text{prwg} \cdot V_{\text{gsteff}}(V_{\text{gs}}, V_{\text{ds}}) + \text{prwb} \cdot (\sqrt{\phi_s - V_{\text{bseff}}} - \sqrt{\phi_s}) \right]}{W_{\text{effp}}^{\text{wr}}}$$

$$V_{adiblc}(V_{gs}, V_{ds}) := \frac{(V_{gsteff}(V_{gs}, V_{ds}) + 2 \cdot v_t)}{\theta_{rout} \cdot (1 + pdiblc \cdot V_{bseff})} \cdot \left(1 - \frac{A_{bulk}(V_{gs}, V_{ds}) \cdot V_{dsat}(V_{gs}, V_{ds})}{A_{bulk}(V_{gs}, V_{ds}) \cdot V_{dsat}(V_{gs}, V_{ds}) + V_{gsteff}(V_{gs}, V_{ds}) + 2 \cdot v_t} \right)$$

$$V_{Asat}(V_{gs}, V_{ds}) := E_{sat}(V_{gs}, V_{ds}) \cdot L_{eff} + V_{dsat}(V_{gs}, V_{ds}) + 2 \cdot R_{ds}(V_{gs}, V_{ds}) \cdot vsat \cdot C_{ox} \cdot W_{eff}(V_{gs}, V_{ds}) \cdot V_{gsteff}(V_{gs}, V_{ds}) \cdot \left[1 - \frac{A_{bulk}(V_{gs}, V_{ds}) \cdot V_{dsat}(V_{gs}, V_{ds})}{2 \cdot (V_{gsteff}(V_{gs}, V_{ds}) + 2 \cdot v_t)} \right]$$

$$V_A(V_{gs}, V_{ds}) := V_{Asat}(V_{gs}, V_{ds}) + \left(1 + \frac{pvag \cdot V_{gsteff}(V_{gs}, V_{ds})}{E_{sat}(V_{gs}, V_{ds}) \cdot L_{eff}} \right) \cdot \left(\frac{1}{V_{aclm}(V_{gs}, V_{ds})} + \frac{1}{V_{adiblc}(V_{gs}, V_{ds})} \right)^{-1}$$

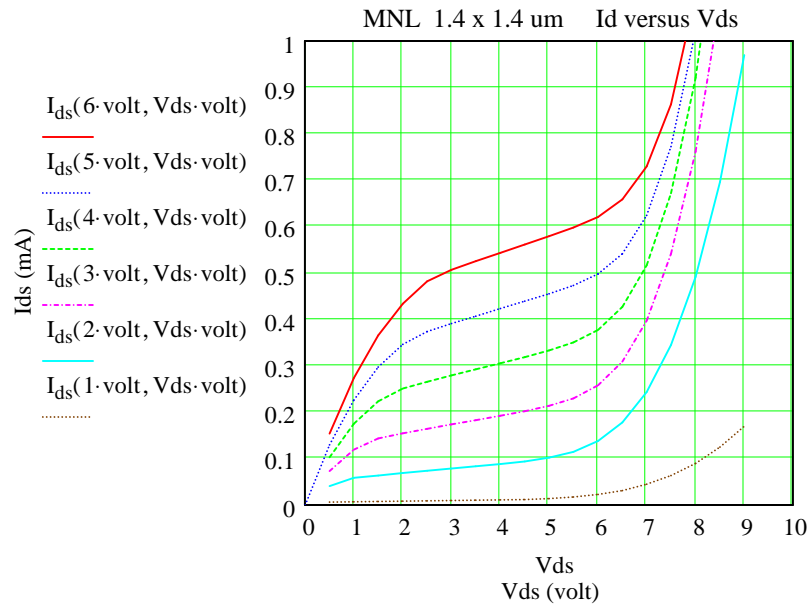
$$I_{dso}(V_{gs}, V_{ds}) := \frac{W_{eff}(V_{gs}, V_{ds}) \cdot \mu_{eff}(V_{gs}, V_{ds}) \cdot C_{ox} \cdot V_{gsteff}(V_{gs}, V_{ds}) \cdot \left[1 - A_{bulk}(V_{gs}, V_{ds}) \cdot \frac{V_{dseff}(V_{gs}, V_{ds})}{2 \cdot (V_{gsteff}(V_{gs}, V_{ds}) + 2 \cdot v_t)} \right] \cdot V_{dseff}(V_{gs}, V_{ds})}{L_{eff} \cdot \left(1 + \frac{V_{dseff}(V_{gs}, V_{ds})}{E_{sat}(V_{gs}, V_{ds}) \cdot L_{eff}} \right)}$$

$$\frac{1}{V_{ascbe}} = \frac{pscbe2}{L_{eff}} \cdot \exp\left(\frac{-pscbe1 \cdot l_{itl}}{V_{ds} - V_{dseff}}\right) \quad \alpha_{11} := 0 \cdot \text{volt}^{-1} \quad \alpha_{11} \text{ added in BSIM3V3.2. Rouchoz has not yet extracted.}$$

$$I_{sub}(V_{gs}, V_{ds}) := \frac{\alpha_{10} + \alpha_{11} \cdot L_{eff}}{L_{eff}} \cdot (V_{ds} - V_{dseff}(V_{gs}, V_{ds})) \cdot \exp\left(\frac{-\beta_{10}}{V_{ds} - V_{dseff}(V_{gs}, V_{ds})}\right) \cdot \frac{I_{dso}(V_{gs}, V_{ds})}{1 + R_{ds}(V_{gs}, V_{ds}) \cdot \frac{I_{dso}(V_{gs}, V_{ds})}{V_{dseff}(V_{gs}, V_{ds})}} \cdot \left(1 + \frac{V_{ds} - V_{dseff}(V_{gs}, V_{ds})}{V_A(V_{gs}, V_{ds})} \right)$$

$$I_{ds}(V_{gs}, V_{ds}) := \frac{I_{dso}(V_{gs}, V_{ds})}{1 + \frac{R_{ds}(V_{gs}, V_{ds}) \cdot I_{dso}(V_{gs}, V_{ds})}{V_{dseff}(V_{gs}, V_{ds})}} \cdot \left(1 + \frac{V_{ds} - V_{dseff}(V_{gs}, V_{ds})}{V_A(V_{gs}, V_{ds})} \right) \cdot \left[1 + (V_{ds} - V_{dseff}(V_{gs}, V_{ds})) \cdot \left(\frac{pscbe2}{L_{eff}} \cdot \exp\left(\frac{-pscbe1 \cdot l_{itl}}{V_{ds} - V_{dseff}(V_{gs}, V_{ds})}\right) \right) \right] \cdot \frac{1}{a}$$

$$V_{gs} := 0..6 \quad V_{ds} := 0,0.5..9 \quad R_{ds}(3 \cdot \text{volt}, 4 \cdot \text{volt}) = 601.46 \Omega \quad I_{sub}(14 \cdot V, 10 \cdot V) = 2.407 \times 10^{-4} \text{ A}$$



$\mu\text{m} \equiv 10^{-6} \cdot \text{m}$
 $\text{\AA} \equiv 10^{-8} \cdot \text{cm}$
 millihenry $\equiv 10^{-3} \cdot \text{henry}$
 $\Omega \equiv \text{ohm}$
 mamp $\equiv 0.001 \cdot \text{amp}$

$eV \equiv q \cdot \text{volt}$
 $\text{UDR} \equiv \frac{1.4 \cdot \mu\text{m}}{4}$

$$\text{Idds} := \begin{cases} \text{for } Vd \in 0..6 \\ \text{for } Vg \in 0..6 \\ \text{ID}_{Vd, Vg} \leftarrow I_{ds}(Vg \cdot \text{volt}, Vd \cdot \text{volt}) \text{ on error 100} \\ \text{ID} \end{cases}$$

$\text{Idds} = 0$