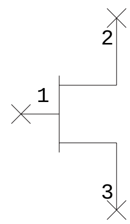
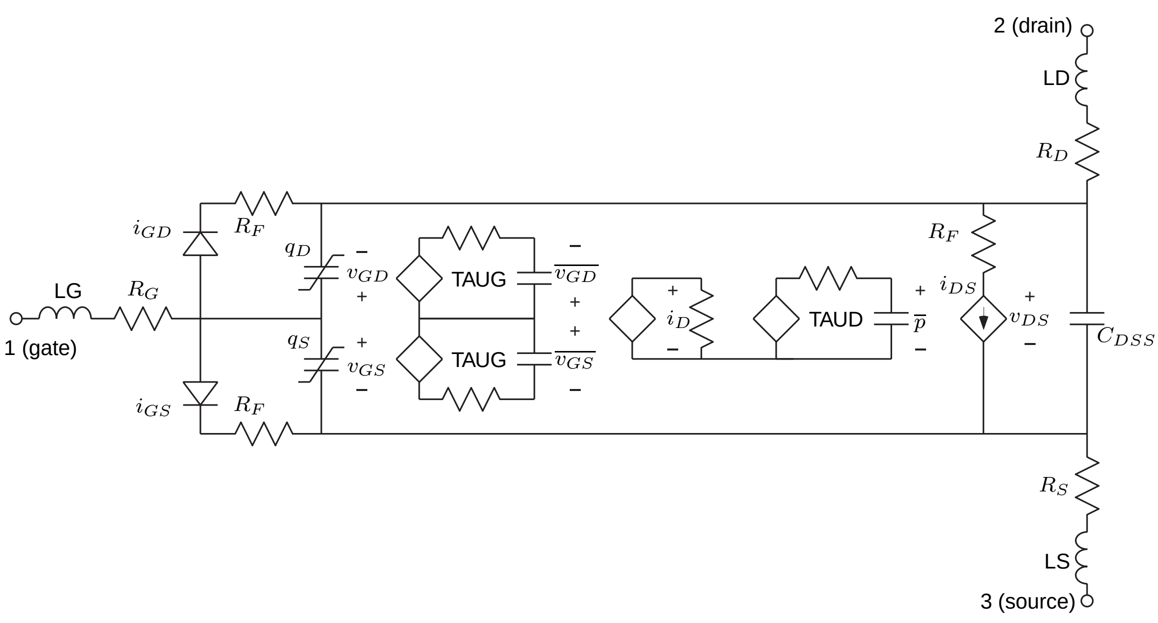
PARKER-SKELLERN FET MODEL PSFET

Symbol:



Topology:



Parameters:

Name	Description	Unit Type	Default
ID	Device IDText	Text	PF1
ACGAM	Capacitance modulation	None	0
BETA	Linear-region transconductance scale	None	10^{-4}
CGD	Zero-bias gate-source capacitance	Capacitance	0 F
CGS	Zero-bias gate-drain capacitance	Capacitance	0 F
DELTA	Thermal reduction coefficient	None	0 W^{-1}
FC	Forward bias capacitance parameter	None	0.5
HFETA	High-frequency VGS feedback parameter	None	0
HFE1	HFGAM modulation by V_{GD}	None	0 V^{-1}
HFE2	HFGAM modulation by V_{GS}	None	0 V^{-1}
HFGAM	High-frequency VGD feedback parameter	None	0
HFG1	HFGAM modulation by V_{SG}	None	0 V^{-1}
HFG2	HFGAM modulation by V_{DG}	None	0 V^{-1}
IBD	Gate-junction breakdown current	Current	0 A
IS	Gate-junction saturation current	Current	10^{-14}A
LFGAM	Low-frequency feedback parameter	None	0
LFG1	LFGAM modulation by V_{SG}	None	0 V^{-1}
LFG2	LFGAM modulation by V_{DG}	None	0 V^{-1}
MVST	Subthreshold modulation	None	0 V^{-1}
N	Gate-junction ideality factor	None	1
P	Linear-region power-law exponent	None	2
Q	Saturated-region power-law exponent	None	2
RS	Source ohmic resistance	Resistance	0 Ohm
RD	Drain ohmic resistance	Resistance	0 Ohm
TAUD	Relaxation time for thermal reduction	Time	0 s
TAUG	Relaxation time for gamma feedback	Time	0 s
VBD	Gate-junction breakdown potential	Voltage	1 V
VBI	Gate-junction potential	Voltage	1 V
VST	Subthreshold potential	Voltage	0 V
VTO	Threshold voltage	Voltage	– 2.0 V
XC	Capacitance pinch-off reduction factor	None	0
XI	Saturation-knee potential factor	None	10 00
Z	Knee transition parameter	None	0. 5
RG	Gate ohmic resistance	Resistance	0 Ohm
LG	Gate inductance	Inductance	0 H
LS	Source inductance	Inductance	0 H
LD	Drain inductance	Inductance	0 H
CDSS	Fixed Drain-source capacitance	Capacitance	0 F
AFAC	Gate-width scale factor	None	1
NFING	Number of gate fingers scale factor	None	1
TNOM	Nominal Temperature (Not implemented)	Temperature	300 K
TEMP	Temperature	Temperature	300 K

Implementation:

The model is implemented with lumped access elements between the extrinsic gate, source, and drain terminals and the intrinsic gate, source, and drain nodes.

Each terminal is connected to the intrinsic node by a series resistor and inductor. For the gate, drain, and source terminals, the respective inductor values are LG, LD, and LS and the respective access resistor values are:

$$\begin{aligned} R_G &= \frac{\mathsf{AFAC}}{\mathsf{NFING}^2} \cdot \mathsf{RG} \\ R_D &= \frac{1}{\mathsf{AFAC}} \cdot \mathsf{RD} \\ R_S &= \frac{1}{\mathsf{AFAC}} \cdot \mathsf{RS} \end{aligned}$$

The minimum value of the resistances is limited to $R_F = 10^{-6}/\mathsf{AFAC}$ ohms, to avoid a divide-by-zero.

There is a fixed drain-source capacitance between the intrinsic nodes with value $C_{DSS} = \mathsf{AFAC} \cdot \mathsf{CDSS}$.

The intrinsic node-to-node potentials are designated v_{GS}, v_{GD} and v_{DS} in the following.

Gate Junction:

The gate junction current is implemented with identical gate-source and gate-drain diodes between the intrinsic nodes. The gate-source and gate-drain currents are:

$$i_{GS} = \mathsf{AFAC} \cdot \left[\mathsf{IS} \cdot \left(e^{v_{GS}/V_T} - 1\right) - \mathsf{IBD} \cdot \left(e^{-v_{GS}/\mathsf{VBD}} - 1\right)\right]$$

$$i_{GD} = \mathsf{AFAC} \cdot \left[\mathsf{IS} \cdot \left(e^{v_{GD}/V_T} - 1\right) - \mathsf{IBD} \cdot \left(e^{-v_{GD}/\mathsf{VBD}} - 1\right)\right]$$

where $V_T = \mathsf{N} \cdot \mathsf{TEMP}/11604.4475$

Drain Current:

$$i_{DS} = \frac{i_D}{1 + \frac{\mathsf{DELTA}}{\mathsf{AFAC}} \cdot \overline{p}}$$

where

$$\overline{p} = i_D \cdot v_{DS} - \mathsf{TAUD} \cdot \frac{d\,\overline{p}}{dt}$$

and

$$i_D = \mathsf{AFAC} \cdot \mathsf{BETA} \cdot \left[{v_{gt}}^{\mathsf{Q}} - (v_{gt} - v_{DT})^{\mathsf{Q}}\right]$$

with

$$\begin{aligned} v_{GT} &= V_{ST} \cdot \ln\left[1 + \exp\left(\frac{v_{GST}}{V_{ST}}\right)\right] \\ V_{ST} &= \mathsf{VST} \cdot (1 + \mathsf{MVST} v_{DS}) \\ \\ v_{GST} &= v_{GS} - \mathsf{VTO} - \gamma_{lf}\,\overline{v_{GD}} - \gamma_{hf}\,(v_{GD} - \overline{v_{GD}}) - \eta_{hf}\,(v_{GS} - \overline{v_{GS}}) \\ \gamma_{lf} &= \mathsf{LFGAM} - \mathsf{LFG1} \cdot \overline{v_{GS}} + \mathsf{LFG2} \cdot \overline{v_{GD}} \\ \gamma_{hf} &= \mathsf{HFGAM} - \mathsf{HFG1} \cdot \overline{v_{GS}} + \mathsf{HFG2} \cdot \overline{v_{GD}} \\ \eta_{hf} &= \mathsf{HFETA} - \mathsf{HFE1} \cdot \overline{v_{GD}} + \mathsf{HFE2} \cdot \overline{v_{GS}} \\ \\ \overline{v_{GS}} &= v_{GS} - TAUG \cdot \frac{d\overline{v_{GS}}}{dt} \end{aligned}$$

$$\overline{v_{GD}} = v_{GD} - TAUG \cdot \frac{d\overline{v_{GD}}}{dt}$$

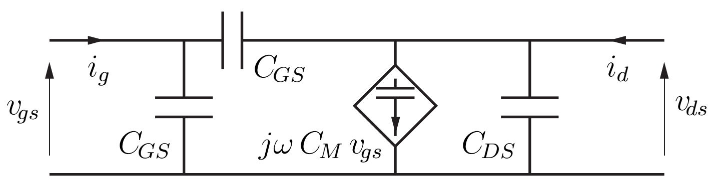
$$v_{DT} = \frac{V_{SAT}}{2} \cdot \left[\sqrt{\left[\frac{v_{DP} \cdot \sqrt{1+Z}}{{V_{SAT}}^2} + 1\right]^2 + Z} - \sqrt{\left[\frac{v_{DP} \cdot \sqrt{1+Z}}{{V_{SAT}}^2} - 1\right]^2 + Z} \right]$$

$$v_{DP} = v_{DS} \cdot \frac{\mathsf{P}}{\mathsf{Q}} \cdot \left[\frac{v_{GT}}{\mathsf{VBI} - \mathsf{VTO}}\right]^{P-Q}$$

$$V_{SAT} = \frac{\mathsf{XI} \cdot (\mathsf{VBI} - \mathsf{VTO}) \cdot v_{GT}}{\mathsf{XI} \cdot (\mathsf{VBI} - \mathsf{VTO}) + v_{GT}}$$

Charge Model:

In terms of a four-branch capacitance model and independent potentials v_{gs} and v_{ds}, a lumped element small-signal representation of the charge model is as follows:



$$\begin{bmatrix} i_g \\ i_d \end{bmatrix} = \begin{bmatrix} C_{GS} + C_{GD} & -C_{GD} \\ C_M - C_{GD} & C_{DS} + C_{GD} \end{bmatrix} \begin{bmatrix} j\omega v_{gs} \\ j\omega v_{ds} \end{bmatrix}$$

$$= \begin{bmatrix} \frac{\partial q_G}{\partial v_{gs}} & \frac{\partial q_G}{\partial v_{ds}} \\ \frac{\partial q_D}{\partial v_{gs}} & \frac{\partial q_D}{\partial v_{ds}} \end{bmatrix} \begin{bmatrix} \frac{dv_{gs}}{dt} \\ \frac{dv_{ds}}{dt} \end{bmatrix}$$

where $q_G = -(q_D + q_S)$, q_D, q_S respectively are the instantaneous, gate, drain, and source terminal charges, which are model as follows:

$$q_G = q_{GS} + q_{GD}$$
$$q_D = -q_{GD} - m \cdot (q_{GS} - q_{GD})$$
$$q_S = -q_{GS} - m \cdot (q_{GD} - q_{GS})$$

where the mode parameter, m, is

$$m = \frac{1}{2}\left[1 - \frac{v_{DS}}{\sqrt{{v_{DS}}^2 + \alpha^2}}\right]$$

with

$$\alpha = \frac{\mathsf{XI} \cdot (\mathsf{VBI} - \mathsf{VTO})}{2 \cdot (\mathsf{XI} + 1)}.$$

The mode parameter ranges from 0 for forward mode (large positive v_{DS}), through 0.5 for $v_{DS} = 0$, to 1 for reverse mode (negative v_{DS}).

The branch charges are:

$$q_{GD} = \mathsf{AFAC} \cdot \mathsf{CGD} \cdot \left(v_{GD} - m \cdot \sqrt{{v_{DS}}^2 + \alpha^2} + \mathsf{ACGAM} \cdot v_{DS}\right)$$

and for $v_N \leq \mathsf{FC} \cdot \mathsf{VBI}$

$$q_{GS} = 2 \cdot \mathsf{AFAC} \cdot \mathsf{CGS} \cdot \mathsf{VBI} \cdot \left[1 - \sqrt{1 - \frac{v_N}{\mathsf{VBI}}}\right]$$

or for $v_N > \mathsf{FC} \cdot \mathsf{VBI}$

$$q_{GS} = \mathsf{AFAC} \cdot \mathsf{CGS} \cdot \mathsf{VBI} \cdot \left[2 \cdot (1 - \sqrt{1 - \mathsf{FC}}) + \frac{V_N/\mathsf{VBI} - \mathsf{FC}}{\sqrt{1 - \mathsf{FC}}} + \frac{(V_N/\mathsf{VBI} - \mathsf{FC})^2}{4 \cdot (1 - \mathsf{FC})^{3/2}} \right]$$

where

$$v_N = v_E + \frac{(v_E - \mathsf{VTO}) \cdot (\mathsf{XC} - 1) + \sqrt{(v_E - \mathsf{VTO})^2 \cdot (\mathsf{XC} - 1)^2 + 0.2^2}}{2}$$

and

$$v_E = v_{GS} + m \cdot \sqrt{{v_{DS}}^2 + \alpha^2} + \mathsf{ACGAM} \cdot v_{DS}$$

The branch capacitances are thus:

$$\begin{aligned}
C_{GD} &= -\frac{dq_G}{dv_{DS}} \\
&= C_{GD} + m \cdot (C_{GSO} - C_{GD}) - \mathsf{ACGAM} \cdot (C_{GSO} + C_{GD}) \\
C_{GS} &= \frac{d}{dv_{GS}} (q_S + q_D) - C_{GD} \\
&= C_{GSO} + m \cdot (C_{GD} - C_{GSO}) + \mathsf{ACGAM} \cdot (C_{GSO} + C_{GD}) \\
C_{DS} &= \frac{dq_D}{dv_{DS}} - C_{GD} \\
&= \mathsf{ACGAM} \cdot [(1 - m) \cdot C_{GSO} + m \cdot C_{GD}] + m \cdot (m - 1) \cdot \left[C_{GSO} + C_{GD} + 2 \cdot \frac{q_{GD} - q_{GS}}{\sqrt{{v_{DS}}^2 + \alpha^2}} \right] \\
C_M &= \frac{dq_D}{dv_{GS}} + C_{GD} \\
&= -\mathsf{ACGAM} \cdot (C_{GSO} + C_{GD})
\end{aligned}$$

where

$$C_{GD} = \mathsf{AFAC} \cdot \mathsf{CGD}$$

and for $v_N \leq \mathsf{FC} \cdot \mathsf{VBI}$

$$C_{GSO} = \frac{\mathsf{AFAC} \cdot \mathsf{CGS}}{\sqrt{1 - v_N/\mathsf{VBI}}} \cdot \frac{dv_N}{dv_E}$$

or for $v_N > \mathsf{FC} \cdot \mathsf{VBI}$

$$C_{GSO} = \frac{\mathsf{AFAC} \cdot \mathsf{CGS}}{\sqrt{1 - \mathsf{FC}}} \cdot \left(1 + \frac{1}{2} \cdot \frac{v_N/\mathsf{VBI} - \mathsf{FC}}{1 - \mathsf{FC}} \right) \cdot \frac{dv_N}{dv_E}$$

where

$$\frac{dv_N}{dv_E} = \frac{1}{2} \cdot \left(\mathsf{XC} + 1 + \frac{(1 - \mathsf{XC})^2 \cdot (v_E - \mathsf{VTO})}{\sqrt{(1 - \mathsf{XC})^2 \cdot (v_E - \mathsf{VTO})^2 + 0.2^2}} \right)$$

Reference:

Parker, A. E. and Skellern, D. J., "A Realistic Large-signal MESFET Model for SPICE," *IEEE Trans. on Microwave Theory and Techniques*, vol. MTT-45, no. 9, Sep. 1997, pp. 1563-1571