Compact Modeling of Nonlinearities in Submicron MOSFETs

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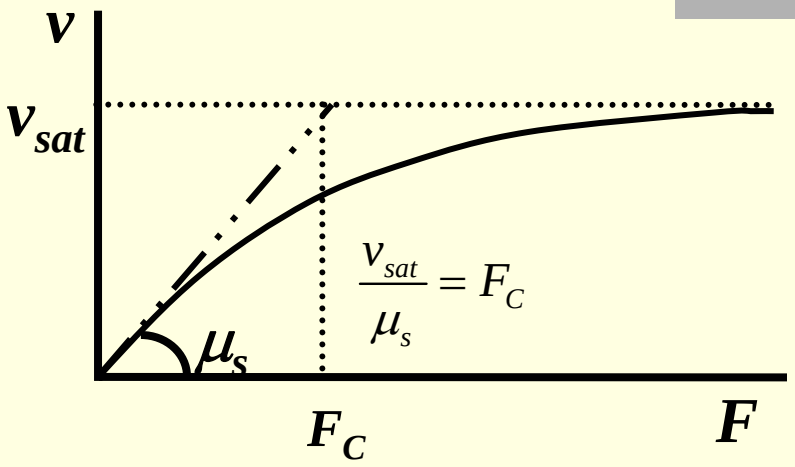
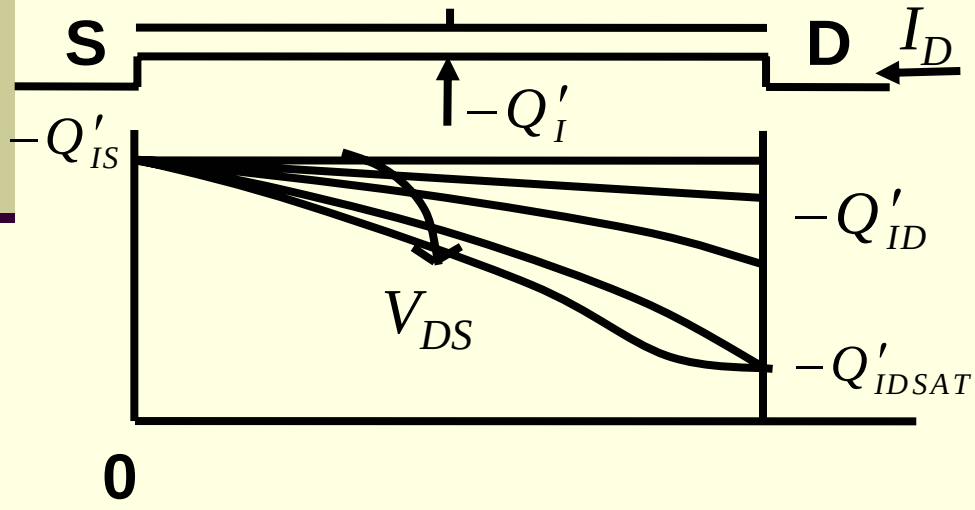
Mobility model

$$\mu = \frac{\mu_s}{1-\frac{F}{F_c}} = \frac{\mu_s}{1-\frac{\mu_s F}{v_{sat}}}$$





Saturation: The minimum amount of electron charge flowing at the saturation velocity, required to sustain the current is

$$Q'_{IDSAT} = -I_D / W v_{sat}$$

Basic dc Equations

$$\mu = \frac{\mu_s}{1-\frac{F}{F_c}} = \frac{\mu_s}{1-\frac{\mu_s F}{v_{sat}}} \qquad V_P - V_C = \phi_t\left[q'_I - 1 + \ln\left(q'_I\right)\right] \qquad dQ'_I = nC'_{ox}d\phi_s$$

$$I_D = -\mu W Q'_I \frac{dV_C}{dy}$$

$$i_{Dsat} = \frac{\left(q'_{IS} + q'_{IDsat} + 2\right)}{1+\varepsilon\left(q'_{IS} - q'_{IDsat}\right)}\left(q'_{IS} - q'_{IDsat}\right) = \frac{2}{\varepsilon}q'_{IDsat}$$

$$q'_I = \frac{Q'_I}{\left(-nC'_{ox}\phi_t\right)}, \qquad i_D = \frac{I_D}{I_S}$$

$$I_S = \frac{\mu_s C'_{ox} n\phi_t^2}{2}\frac{W}{L}, \qquad \varepsilon = \frac{\mu_s \phi_t / L}{v_{sat}}$$

ε: short-channel factor

Transconductance and 2nd order derivative

$$g_{mg} = \frac{2I_S}{n\phi t}\frac{q'_{IS}}{2+\varepsilon q'_{IS}}\left[\frac{4+\varepsilon q'_{IS}}{2+\varepsilon q'_{IS}}\right]$$

$$g''_{mg} = \frac{d^3 I_D}{dV_G{}^3} = \frac{2I_S}{\underbrace{\left(n\phi_t\right)^3\left(q'_{IS}+1\right)^3}_{g''_{mg}}}\underbrace{\frac{1-\varepsilon q'_{IS}-1.5\varepsilon q'_{IS}{}^2}{\left(1+\varepsilon q'_{IS}/2\right)^4}}$$

long-channel

short-channel effect

Experimental results

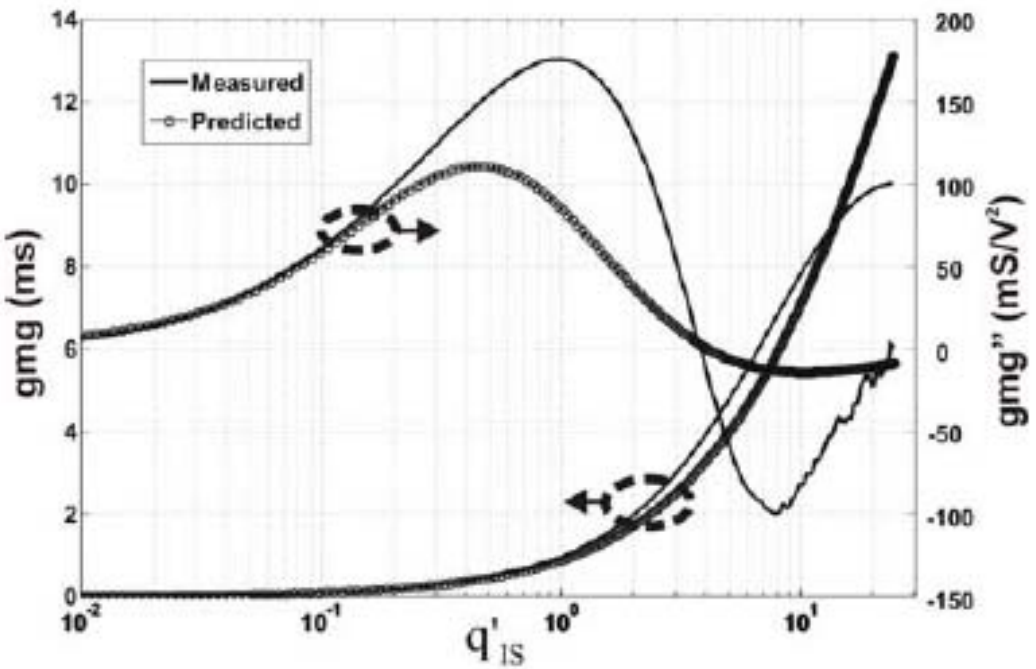


Figure 3: Predicted and measured gmg and gmg'' for a $W(20\mu m)/L(0.2\mu m)$ transistor in the TSMC 0.18 process.

Experimental results

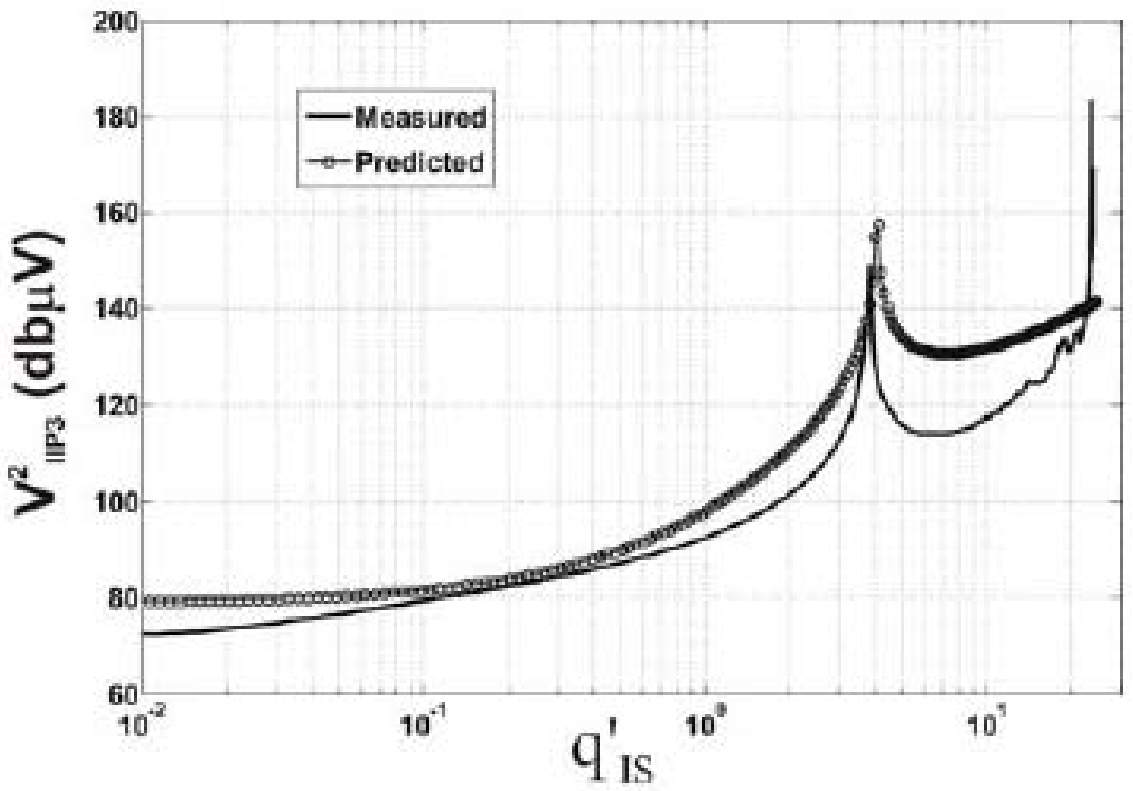


Figure 4: Predicted and measured V^2_{IIP3} as a function of the normalized charge density in the source

- Velocity saturation degrades transconductance but reduces third order harmonic distortion
- Simple equations derived using charge-based model
- Approximations allow first order calculation of IP3