WCM-Forum

Surface potential vs. charge-based MOSFET models

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Outline:

- I-V characteristic
- Total charges

Pao-Sah current expression

$$I_{DS} = \frac{\mu W}{L} \int_{V_S}^{V_D} \left(-Q_I^{'} \right) dV_C$$

Charge Control Model

$$V_P - V_C = \frac{Q'_{IP} - Q'_I}{nC'_{ox}} + \phi_t \ln\left(\frac{Q'_I}{Q'_{IP}} \right)$$

S.I.

$$-Q_I^{'} \approx nC_{ox}^{'} \left(V_P - V_C \right)$$

W.I

$$Q_I^{'} \approx Q_{IP}^{'} e^{\frac{V_P - V_C}{\phi_t}}$$

$Q_{IP}^{'}$: pinch-off charge ϕ_t : thermal voltage

V_P : pinch-off voltage n : slope factor

I-V Compact Models

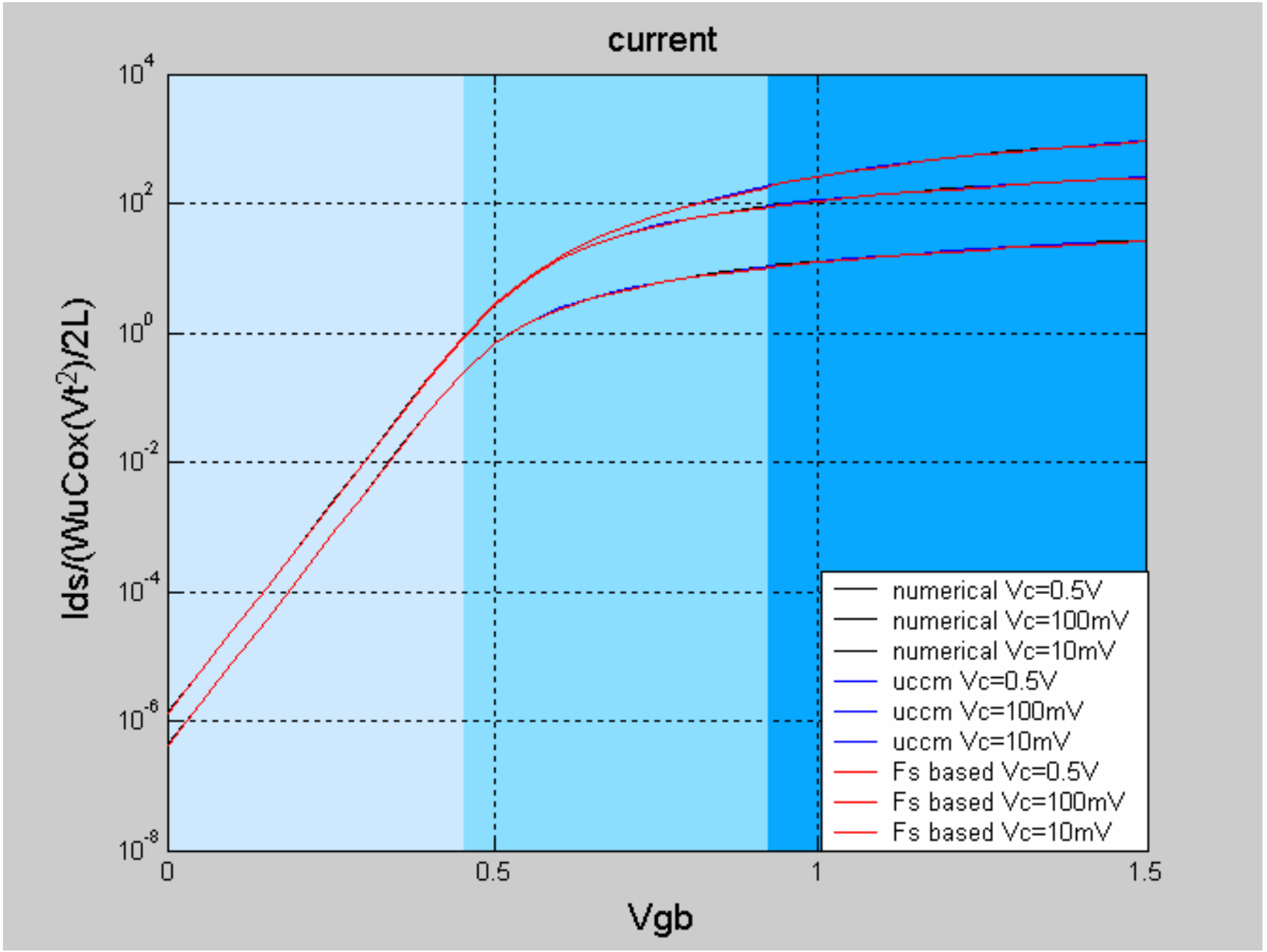
$$I_{DS} = -\mu \frac{W}{L} \int_{Q'_{IS}}^{Q'_{ID}} Q'_I \frac{dV_C}{dQ'_I} dQ'_I$$

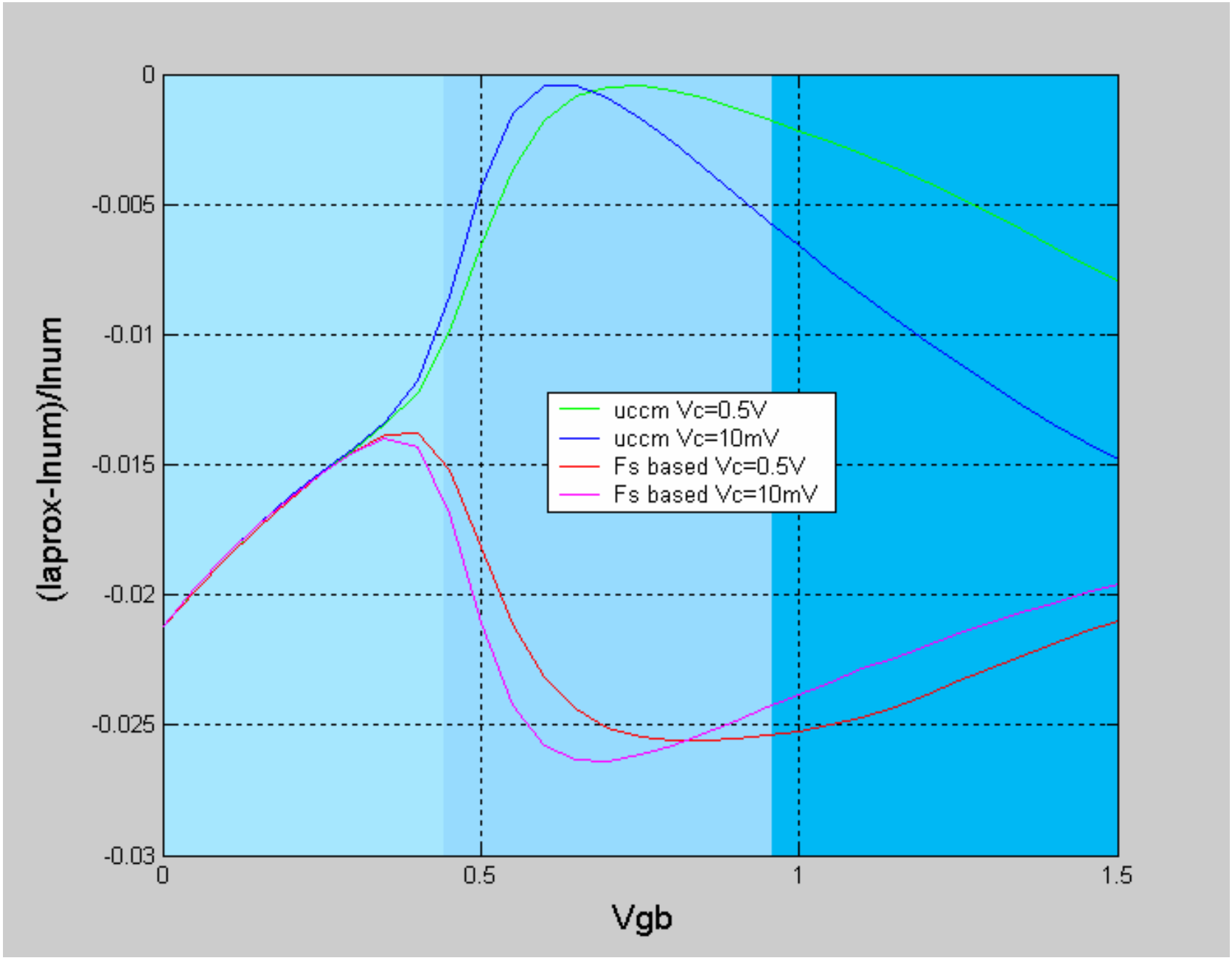
Charge-based model

$$I_{DS} = \frac{\mu W}{L} \int_{V_S}^{V_D} \left(-Q'_I\right) dV_C$$

$$I_{DS} = -\mu \frac{W}{L} \int_{\phi_{s0}}^{\phi_{sL}} Q'_I(\phi_s) \frac{dV_C}{d\phi_s} d\phi_s$$

Surface potential model


current
Ids/(WuCox(Vt^2)/2L)
Vgb
10^4
10^2
10^0
10^-2
10^-4
10^-6
10^-8
0
0.5
1
1.5
numerical Vc=0.5V
numerical Vc=100mV
numerical Vc=10mV
uccm Vc=0.5V
uccm Vc=100mV
uccm Vc=10mV
Fs based Vc=0.5V
Fs based Vc=100mV
Fs based Vc=10mV


0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
0
0.5
1
1.5
(Iaprox-Inum)/Inum
Vgb
uccm Vc=0.5V
uccm Vc=10mV
Fs based Vc=0.5V
Fs based Vc=10mV

Total charges

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Table 1. Auxiliary functions and parameters

Quantity	Expression
Q'_F	$Q'_I(V_{SB}, V_{GB}) - nC'_{ox}\phi_t$
Q'_R	$Q'_I(V_{DB}, V_{GB}) - nC'_{ox}\phi_t$

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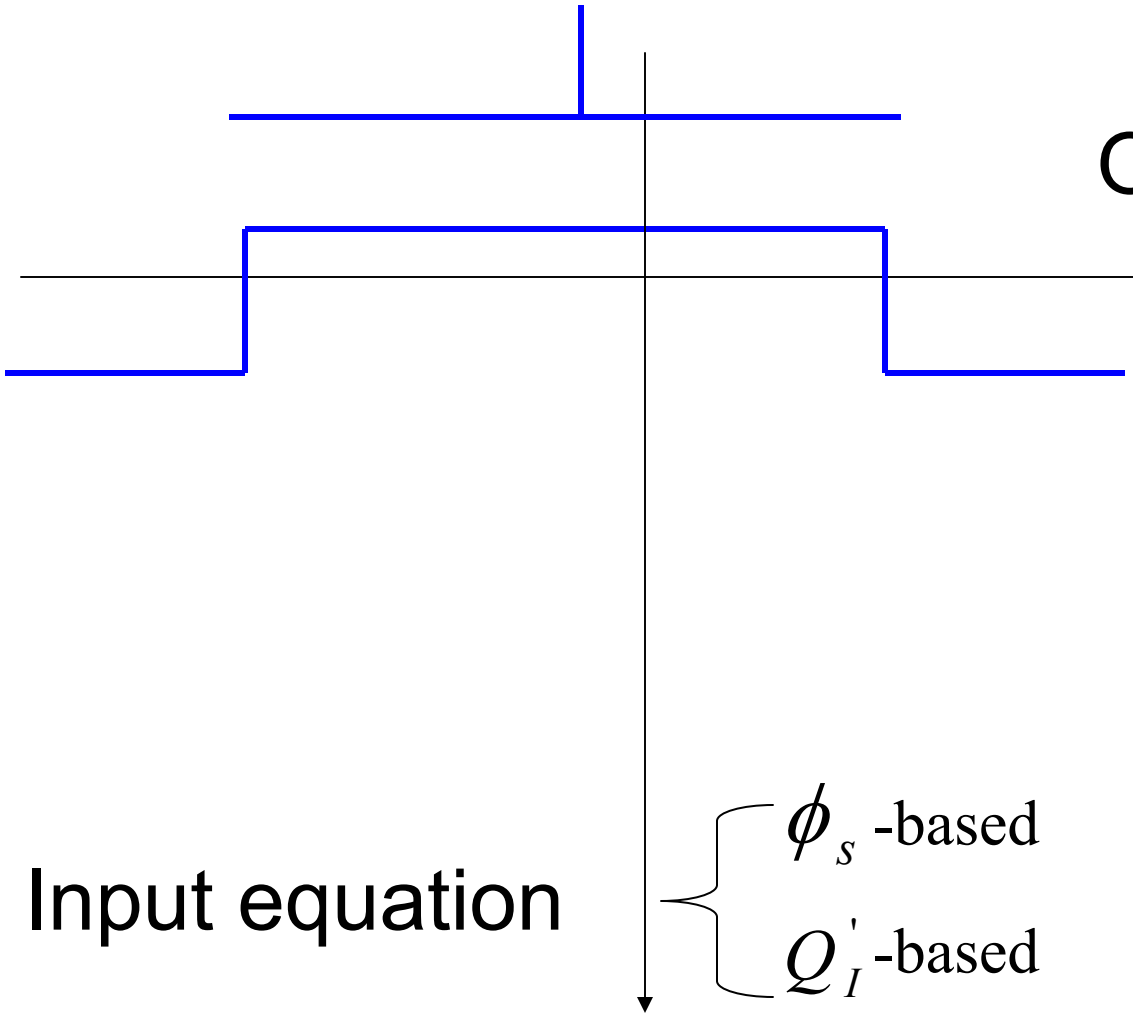
Table 2. Drain current, total charges and small signal parameters

Quantity	Expression
Q_I	$WL\left[\frac{2}{3}\frac{Q'^2_F + Q'_F Q'_R + Q'^2_R}{Q'_F + Q'_R} + nC'_{ox}\phi_t\right]$
Q_S	$WL\left[\frac{6Q'^3_F + 12Q'_R Q'^2_F + 8Q'^2_R Q'_F + 4Q'^3_R}{15(Q'_F + Q'_R)^2} + \frac{n}{2}C'_{ox}\phi_t\right]$

MOSFET compact models



Output equations

I_D ϕ_s -based

I_D Q_I' -based

$Q_S, Q_D \rightarrow Q_I'$ -based

$Noise \rightarrow Q_I'$ -based

Input equation

ϕ_s -based

Q_I' -based