Assignment 8
E3225
Art of Compact Modeling

Courese Instructor: Professor Santanu Mahapatra
Submitted by: Usman Ul Muazzam
Submitted to: Sirsha Guha

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1 Problem 1

Calculate Drain Current (I_D) and plot, both analytically (Eq. 4.3.16 in Tsividis) and numerically:

1.1

$I_D - V_D$ characteristic, for different V_G.

Solution:

Analytical:

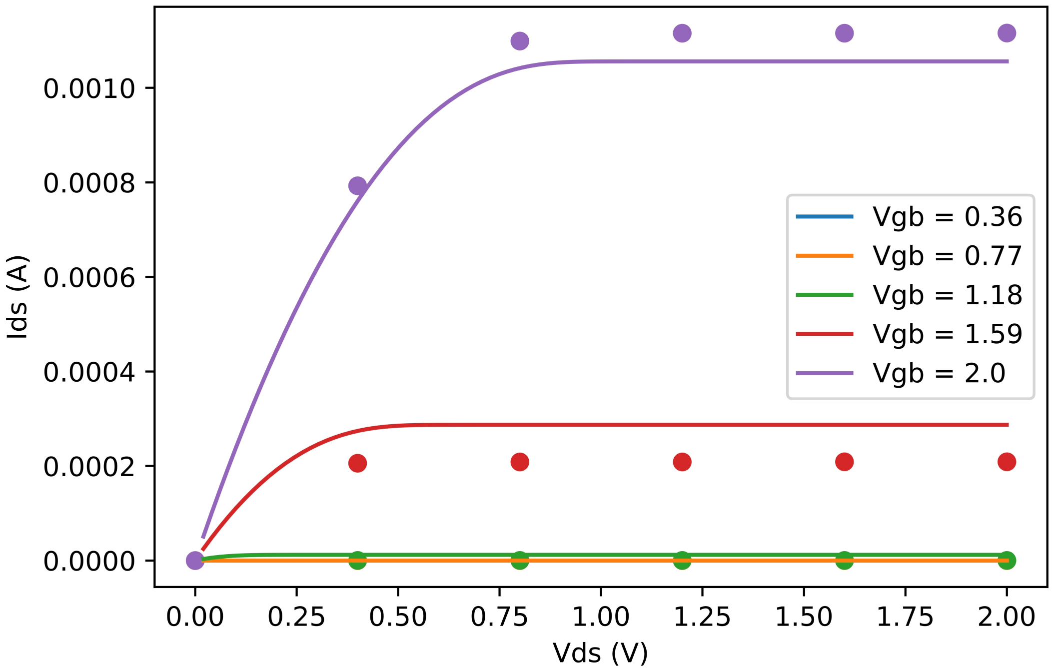
$f(\psi_s) = \mu C_{ox}^{'}[(V_{GB} - V_{FB} + \phi_t)\psi_s - \frac{1}{2}\psi_s^2 - \frac{2}{3}\gamma\psi_s^{3/2} + \phi_t\gamma\psi_s^{1/2}]$

$I_{DS} = \frac{W}{L}[f(\psi_{sL}) - f(\psi_{s0})]$

Numerical:

$I_{DS} = \mu\frac{W}{L}[\int\limits_{V_s}^{V_d}(-Q_i^{'})\ dV_{cb}\ ]$

$Q_i^{'} = \int\limits_{0}^{t_{Si}} n_i(y)\ dy$



The dot points shows Numerical one.

1.2

$I_D - V_G$ characteristic, for low and high V_D, semilog and linear . Calculate Subthreshold Slope (mV/dec) from graph by linear interpolation method and compare with 2.303ϕ_tn.
Solution:

Analytical:

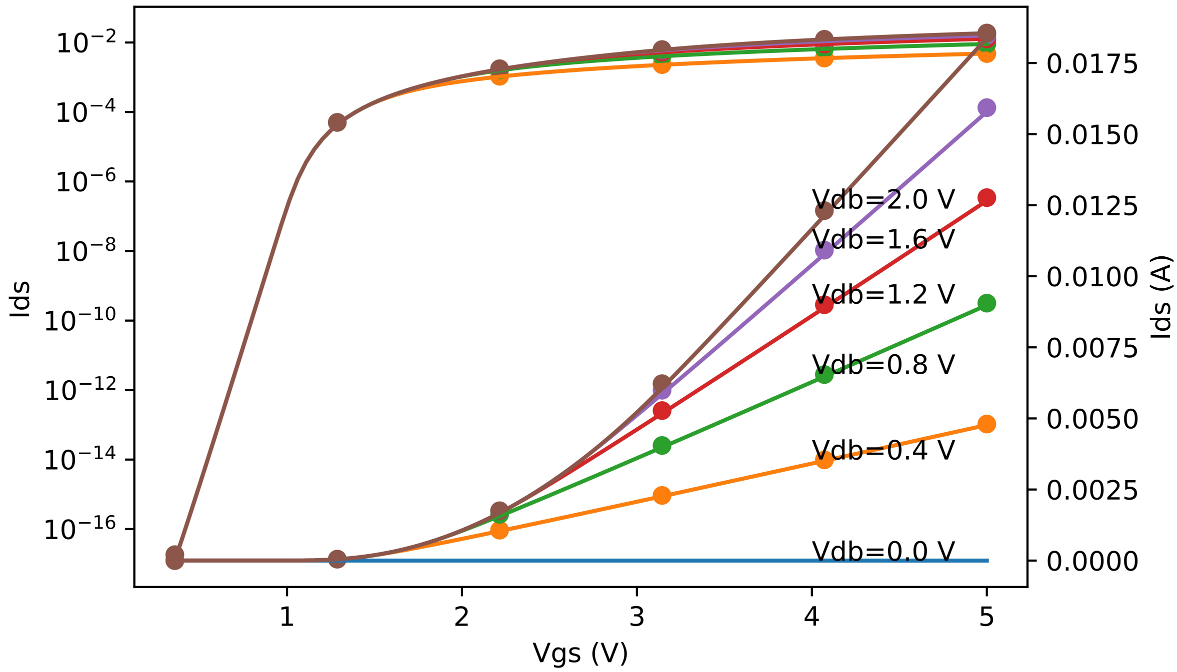
$f(\psi_s) = \mu C'_{ox}[(V_{GB} - V_{FB} + \phi_t)\psi_s - \frac{1}{2}\psi_s^2 - \frac{2}{3}\gamma\psi_s^{3/2} + \phi_t\gamma\psi_s^{1/2}]$

$I_{DS} = \frac{W}{L}[f(\psi_{sL}) - f(\psi_{s0})]$

Numerical:

$I_{DS} = \mu\frac{W}{L}[\int_{V_s}^{V_d}(-Q'_i)\ dV_{cb}\ ]$

$Q'_i = \int_0^{t_{Si}} n_i(y)\ dy$



The dot points shows Numerical one.

Subthreshold slope

Theoretical:

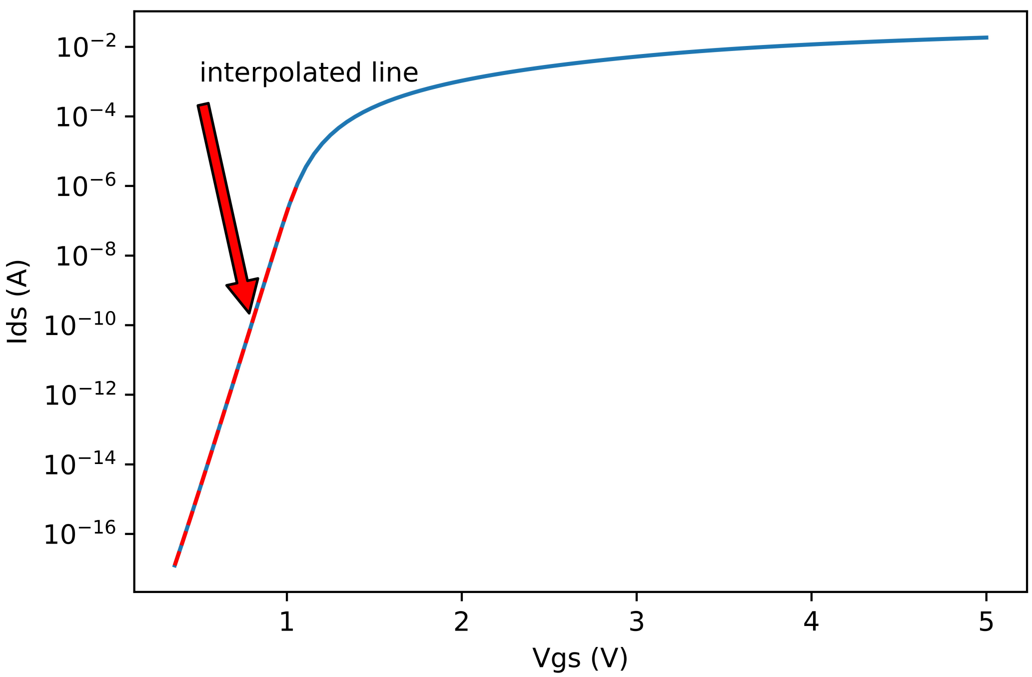
$\psi_{sa}(V_{GB}) = (-\frac{\gamma}{2} + \sqrt{\frac{\gamma^2}{4} + V_{GB} - V_{FB}}\ )$

$n = 1 + \frac{\gamma}{2\sqrt{\psi_{sa}(V_{GB})}}$

$SS_{Th} = 2.303\phi_t n$

Calculated:

$SS_{cal} = [\frac{d(log_{10} I_{ds})}{dV_{gs}}]^{-1}$



Extracted value of subthreshold slope is 63.26 mV/dec

Theoretically calculated value of subthreshold slope is 60.49 mV/dec

2 Problem 2

Plot Surface Potential (ψ_s) as a function of V_G using Gildenbalt algorithm and numerical approach. Compare their efficiency, by plotting computation time of ψ_s as a function of V_G.

Solution:

Gildenbalt Algorithm:

$V_{GB} = V_{FB} + \psi_s + \psi_s \gamma \sqrt{\psi_s - \phi_t + \phi_t e^{\frac{\psi_s - 2\phi_f - \phi_n}{\phi_t}}}$

Above equation can be converted to:

$(x_g - x)^2 = G^2[x - 1 + e^{(x - x_n)}]$

with,

$x = \frac{\psi_s}{\phi_t}$

$G = \frac{\gamma}{\sqrt{\phi_t}}$

$x_g = \frac{(V_{gb} - V_{fb})}{\phi_t}$

$x_n = \frac{(2\phi_f + \phi_n)}{\phi_t}$

$x_{sub} = x_g + \frac{G^2}{2} - G\sqrt{x_g - 1 + \frac{G^2}{4}}$

create functions:

$s(a, b, c) = \frac{1}{2}[a + b - \sqrt{(a - b)^2 + c}]$

$\sigma(a, c, \tau) = \frac{a\nu}{\mu + \frac{\nu}{\mu}c(\frac{c^2}{3} - a)}$

where,

$\nu = a + c$
$\mu = \frac{\nu^2}{\tau} + \frac{c^2}{2} - a$

Steps:

1. Compute x_g, x_n and x_{sub} and then evaluate $\eta = s(x_{sub}, x_n + 3, 5)$

2. Compute

$a = (x_g - \eta)^2 - G^2\eta + G^2$
$c = 2(x_g - \eta) + G^2$
$\tau = x_n - \eta + ln(\frac{a}{G^2})$

$x_0 = \eta + \sigma(a, c, \tau)$

3. Compute

$\Delta_0 = e^{(x_0 - x_n)}$

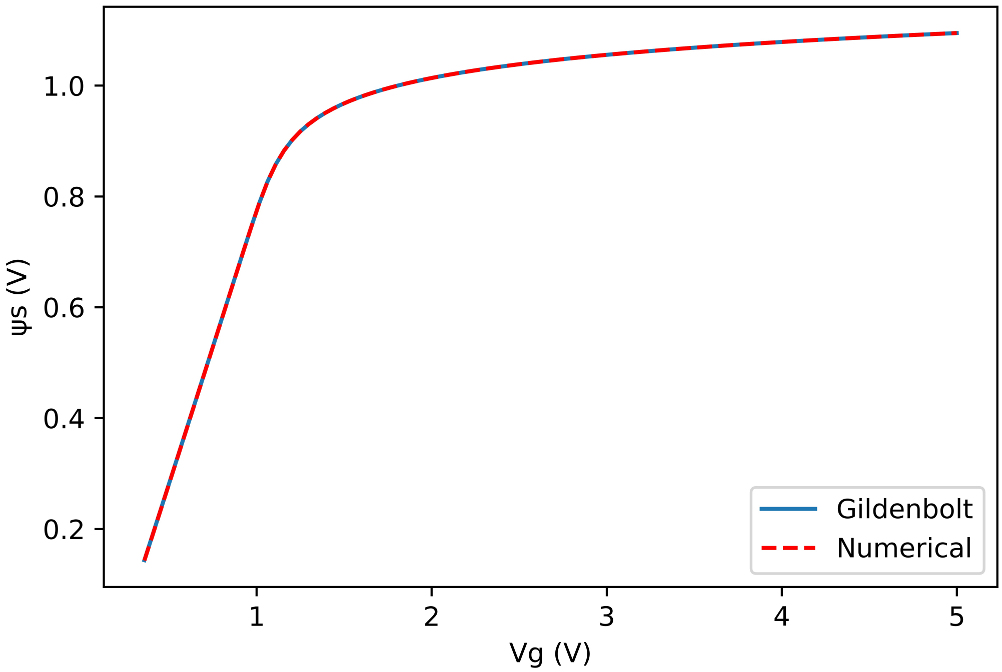
$p = 2(x_g - x_0) + G^2(1 + \Delta_0)$

$q = (x_g - x_0)^2 - G^2(x_0 + \Delta_0 - 1)$

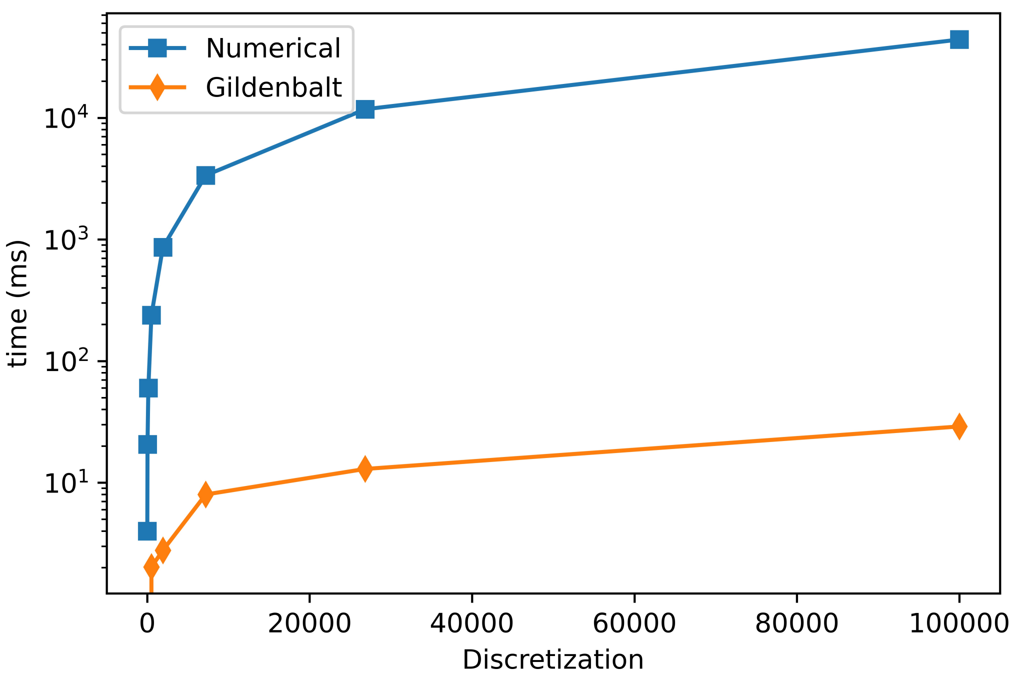
$x = x_0 + \frac{2q}{p + \sqrt{p^2 - 2(2 - G^2\Delta_0)q}}$

$\psi_s = x\phi_t$

Plotted ψ_s vs V_G for both methods on same graph



Efficiency comparision:



Gildenbalt method is far more superior than numerical one i.e more than 3 orders of magnitude faster for discretization of 1000 or greater.