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CARLETON UNIVERSITY

FINAL EXAMINATION December 1999

DURATION: 3 **HOURS** **ANSWER ALL QUESTIONS** **No. of Students:** 44

Department Name & Course Number: Electronics 97.469A

Course Instructor(s): N.G. Tarr

AUTHORIZED MEMORANDA: calculators **NO BOOKS OR NOTES**

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has six (6) pages.

This examination question paper **may** be taken from the examination room.

Physical constants:

$q = 1.6\times10^{-19}$ C $\quad k = 1.38\times10^{-23}$ JK^{-1} $\quad \epsilon_0 = 8.85\times10^{-12}$ Fm^{-1} $\quad$ (= 8.85×10^{-14} Fcm^{-1})
1eV = 1.6×10^{-19} J $\quad$ kT/q = 0.0259 V

Data for silicon at 300K:

$n_i = 10^{10}$ cm^{-3} $\quad E_G = 1.12$ eV $\quad N_C = 2.8\times10^{19}$ cm^{-3} $\quad N_V = 1\times10^{19}$ cm^{-3} $\quad \epsilon_s = 11.9\epsilon_0$
$\mu_n = 1350$ cm^{2}V^{-1}s^{-1} $\quad \mu_p = 480$ cm^{2}V^{-1}s^{-1}

Data for SiO$_2$: $\quad \epsilon_{ox} = 3.9\epsilon_0$

Resistivity: $\rho = 1/(q\,\mu\,N)$ $\qquad$ Doping profile produced by drive-in diffusion: $C(x) = \frac{Q}{\sqrt{\pi D t}}\exp(-\frac{x^2}{4Dt})$

Doping profile produced by ion implant:

$$C(x) = \frac{Q}{\sqrt{2\pi}\Delta R_P}\exp-[\frac{(x-R_P)^2}{2\Delta R_P^2}]$$

Equations for MOSFET threshold voltage:

$$V_{Tn} = V_{FB} + 2\phi_b + \frac{\sqrt{2\epsilon_s q N_A(2\phi_b + V_{SB})}}{C_{ox}} - \frac{qD_{impl}}{C_{ox}} \qquad \phi_b = \frac{kT}{q}\ln(\frac{N_A}{n_i}) \qquad C_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$$

$$V_{Tp} = V_{FB} - 2\phi_b - \frac{\sqrt{2\epsilon_s q N_D(2\phi_b - V_{SB})}}{C_{ox}} - \frac{qD_{impl}}{C_{ox}} \qquad \phi_b = \frac{kT}{q}\ln(\frac{N_D}{n_i})$$

Square law model for the n-channel MOSFET:

Triode regime ($V_{GS}-V_T > V_{DS}$): $\quad I_D = \frac{W}{L}\mu_n C_{ox}(V_{GS} - V_T - \frac{V_{DS}}{2})V_{DS}$

Saturation regime ($V_{DS} > V_{GS}-V_T$): $\quad I_D = \frac{W}{L}\mu_n C_{ox}\frac{(V_{GS} - V_T)^2}{2}$