E151 Lecture 13 – MOSFET Introduction

Matthew Spencer
Harvey Mudd College
ENGR151

Disclaimer

These are notes for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I’m putting them up as a courtesy. Remember that they are not intended as a substitute for attending lecture.
Midterm is Coming Up

• Lab on Friday, but stays in 3 hour lab time, gentle grading
• Practice problems and maybe solutions on Sakai
• In class, 1 hr 15 min, no calculator, book, notes
• Get 1 page cheat sheet, must make your own
• Note that tour through MOS physics & amplifiers is kind of a review

Current Mirror Reminder and Error

• Error example here, not commonly calculated b/c MOSFETs different
• Similarly, lots of cool types of mirrors ~ Widlar has feedback for low ε
• But cascade mirror commonly used in MOS b/c big rout
• Reminder: FOM are V_IN, V_MIN, ε, rout
Introduction to MOS Physics

- 4 terminals, 2 types NMOS and PMOS
- METAL OXIDE SEMICONDUCTOR FIELD EFFECT TRANSISTOR
- Unlike BJT: no $I_G$ AND symmetric, D&S switch if voltage does
- NMOS S and B $\rightarrow$ GND whereas PMOS S and B $\rightarrow$ VDD (Latchup!)

Channel, Inversion, Regions of Operation

- Ground D&S for now and apply +ve voltage on gate
- +ve charge on gate drives away holes (field lines terminate on -ve P-)
- Depletion and then inversion and formation of a channel
- Happens at threshold voltage $V_T$, Note that $V_{SB}$ makes $V_T$ bigger
How Much Drain Current?

- Apply Vds to make current move
- Do current continuity at every spot y in the channel
- Conduction product of charge density (Cox helps) & speed (mu helps)

\[ dQ(y) = WC_{ox}(V_{GS} - V_T - V(y))dy \]

\[ I_D = \frac{dQ(y)}{dt} = \frac{dQ(y)}{dy}v(y) \]

\[ v(y) = \mu_n E(y) = \mu_n \frac{dV}{dy} \]

\[ I_D = \mu_n WC_{ox}(V_{GS} - V_T - V(y))dV/dy \]

\[ \int_0^L I_D dy = \mu_n WC_{ox} \int_0^{V_{DS}} (V_{GS} - V_T - V(y))dV \]

Assume linear region

\[ I_D = \mu_n \frac{W}{L} C_{ox} \left( (V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2} \right) \]