E151 Lecture 13 – MOSFET Introduction

Matthew Spencer
Harvey Mudd College
ENGR151

Disclaimer

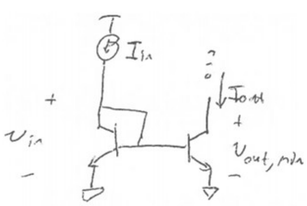
These are notes for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for attending lecture.

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

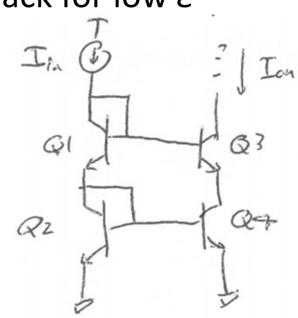


"Simple Mirror"

$I_{in} = I_{b1} + I_{c1} + I_{b2} = (\beta+1) I_{b1}$

$I_{out} = \beta I_{b1}$

$\epsilon = \frac{\beta}{\beta+2}$

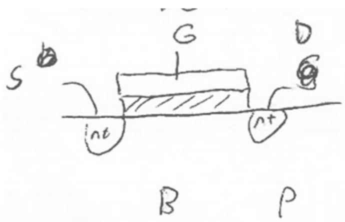


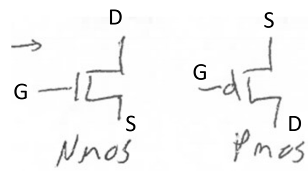
$v_{in} = 2 \cdot v_{be,on}$

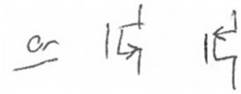
$v_{out,min} = 2 \cdot v_{CE,sat}$

Introduction to MOS Physics

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

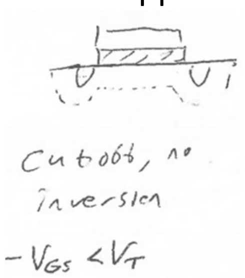


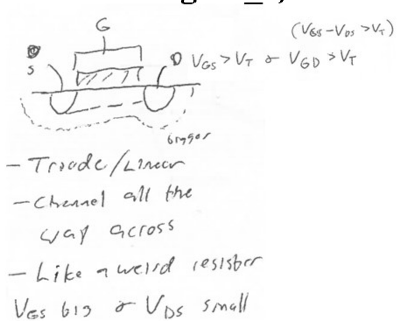


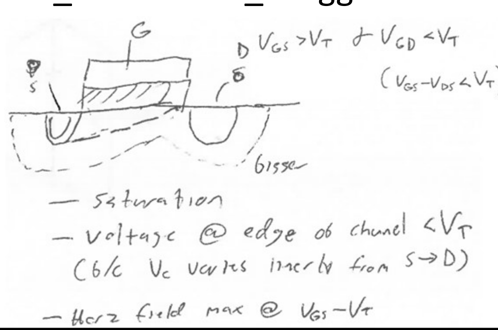


Channel, Inversion, Regions of Operation

- 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)

$$dQ(y) = WC_{ox}(V_{GS} - V_T - V(y))dy$$

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

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

$$I_D = \mu_n W C_{ox}(V_{GS} - V_T - V(y))dV/dy$$

$$\int_0^L I_D dy = \mu_n W C_{ox} \int_0^{V_{DS}} (V_{GS} - V_T - V(y))dV$$

Assume linear region

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