*Department of Electrical and Computer Engineering, Cornell University*

# ECE 3150: Microelectronics

## Spring 2016

**Homework 9** **Due on April 14, 2016 at 7:00 PM**

### Suggested Readings:

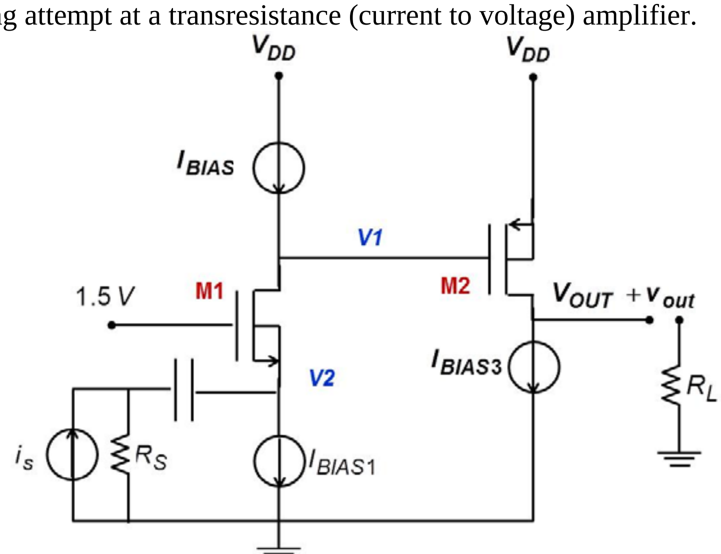
a) Lecture notes

### Important Notes:

**1) MAKE SURE THAT YOU INDICATE THE UNITS ASSOCIATED WITH YOUR NUMERICAL ANSWERS. OTHERWISE NO POINTS WILL BE AWARDED.**
**2) Unless noted otherwise, always assume room temperature.**

### Problem 9.1: (Designing a cascade transresistance amplifier)

Consider the following attempt at a transresistance (current to voltage) amplifier.




A current to voltage amplifier requires a small input resistance and a small output resistance. Assume the following parameter values:

$L = 4\ \mu m$

$\mu_n C_{ox} = 50\ \mu A/V^2$

$\mu_p C_{ox} = 25\ \mu A/V^2$

$\lambda_n = 0.02\ 1/V$

$\lambda_p = 0.05\ 1/V$

$V_{DD} = 5.0\ V$

$V_{TN} = 0.7\ V$

$V_{TP} = -1.0\ V$

$I_{BIAS1} = 200\ \mu A$

$I_{BIAS3} = 500\ \mu A$

$r_{oc1} = r_{oc3} = \infty$

$R_S = 10\ k\Omega$

Assume that $V_{OUT} = 2.5\ V$

a) Identify the two stages in the cascade (e.g. CE, CC, CS, etc).

b) Suppose that the voltage $V2$ is needed to be at least 0.5 V so that the FET making up the current bias $I_{BIAS1}$ in the source of M1 does not go into the linear region. Calculate the width $W_1$ of the FET M1 needed to ensure that $V2$ is 0.5 V.

c) Suppose we need $V1$ to be 3.0 V. Find the width $W_2$ of the FET M2 needed to achieve this.

d) Find an expression for and calculate the value of $R_{in}$ for this cascade amplifier.

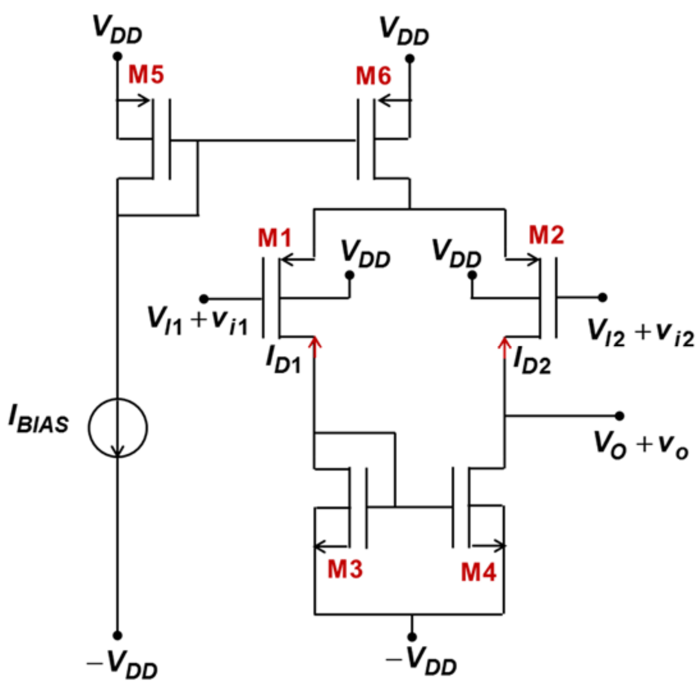
e) Find an expression for and calculate the value of $R_{out}$ for this cascade amplifier.

f) Find an expression for and calculate the value of the transresistance $R_m = v_{out}/i_S$ of this amplifier assuming that the output is open (i.e $R_L = \infty$) and the resistance $R_S$ is also infinite.

g) The value of $R_{out}$ for this cascade amplifier found in part (e) is fairly large. Transresistance amplifiers need to have a small output resistance. Suppose you can use one more FET (PFET or NFET) and one more infinite output resistance bias current source to modify the design shown above. Suppose you need, as a design spec, $R_{out}$ less than 5 kΩ and $V_{OUT}$ greater than 1.5 V. Choose the FET type, together with its width in microns, and the value of the bias current source, and redesign the amplifier such that it pretty much keeps the previous values of the $R_{in}$ and the open circuit $R_m = v_{out}/i_S$ but meets the specs on $R_{out}$ and $V_{OUT}$. Show (numerically) that your design works.

## Problem 9.2: (A Differential Amplifier)

Consider the following differential amplifier:



The amplifier is DC biased such that $V_{I1} = V_{I2}$. M3 and M4 are matched. M1 and M2 are matched. And M5 and M6 are matched.

a) What is the purpose of M6 and M5?

b) What is the purpose of M3 and M4?

c) Find an expression for the open circuit difference-mode voltage gain $A_{vd} = v_o / v_{id}$ .

d) Find an expression for the open circuit common-mode voltage gain $A_{vc} = v_o / v_{ic}$ .

e) Find an expression for the output resistance.

f) Suppose $I_{BIAS}$ = 500 μA and $V_{DD}$ = 2.5 V. What is the DC power dissipation (in Watts) in the entire amplifier when it is DC biased as shown?