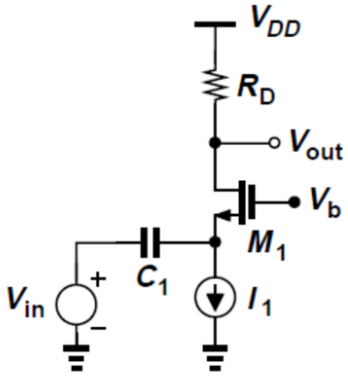
EE 332 Circuits and Devices II Autumn 2021
Midterm Exam Exam Date: Nov. 15 (5-7pm)

Full Name: ……. **Grade:** …… /100
SID : …….

Assume for all the problems: VDD=1.2V, $|Vth_{n,p}|$=0.3V, $\mu_n C_{ox} = \frac{0.5mA}{V^2}$, $\mu_n = 2\mu_p$, $\lambda_p = \lambda_n = 0.1V^{-1}$, $\gamma = 0$ for both NMOS and PMOS devices.

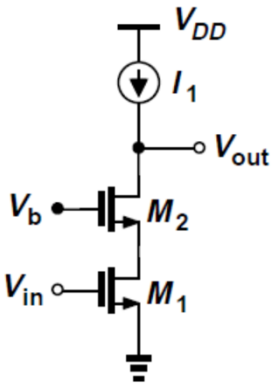
1. (35 pts) If $I_1 = 1mA$ (ideal current source), and C_1 is an AC-coupling capacitor (will be shorted in small-signal models and open for DC/bias analysis) answer following questions assuming $\lambda = 0$ for this problem.



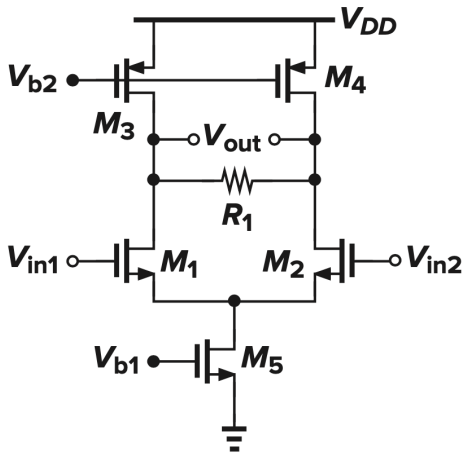
a) Find $(W/L)_1$ such that the input impedance will be 50Ω.
b) Write down the small-signal gain equation in terms of small-signal parameters and R_D.
c) Find R_D such that V_{out} bias point will be $V_{DD}/2$.
d) Find small-signal gain using R_D from part c.
e) If we realize I_1 current-source with a single NMOS device at a fixed gate bias of $V_{DD}/2$, what would be the W/L for that device?
f) What can be minimum V_b to make sure all transistors are in saturation?
g) Assuming $V_{in} = 0.5 + 0.01sin(\omega t)\ V$, what is the overall (bias and small-signal) V_{out}? (C_1 will be shorted at all frequencies)

2. (30 pts) Design a Cascode amplifier as shown in figure below to achieve a gain of 10k (10,000). Assume an ideal current source of $I_1 = 1mA \; and \; g_m r_o \gg 1$.

a) If V_{GS1}=$V_{GS2,}$ what should be the value of V_{GS1}?
b) Find R_{out} and R_{in} values for this amplifier.
c) Calculate optimal V_b to maximize the output swing.
d) To realize the current source load, we will use a PMOS active load with W/L=800. Assume the bias current will remain at 1mA, what would be the V_{OD} (=V_{GS}-V_{th}) for this device?
e) What's the output swing range?



3. (35 pts) For the differential amplifier shown below:



a) Assuming the target over-drive voltage (V_{od}) for *all the transistors* is 0.2V, find the V_{b1}, V_{b2} values.
b) Find $(W/L)_{1,2}$, $(W/L)_{3,4,}$ & $(W/L)_5$ such that current tail will be 10mA.
c) Draw the differential-mode half circuit and calculate the differential gain ($\frac{v_{out}}{v_{in1}-v_{in2}}$) in terms of small-signal parameters (g_ms, r_os, and R_1)?
d) Draw the common-mode half circuit and calculate single ended common-mode gain ($\frac{v_{out1/2}}{v_{in,cm}}$) in terms of small-signal parameters (g_ms, r_os, and R_1)?
e) For a differential gain of -10, what should be the value of R_1?
f) Find differential output peak-to-peak swing.
g) Find minimum input common-mode ($V_{in,cm}$) for this amplifier.