ELEN E6312
Spring 2004
Prof. P. Kinget

Midterm

Instructions:

- ***You are allowed to use a calculator; please CLEAR the calculator memory before the exam!***
- ***You are allowed to use one side of a letter size sheet with formulas.***
- Clearly write your name on every page and every examination booklet you hand in.
- You are graded for your derivations. *Results without a clear derivation do not receive a grade.*
- Do your derivations and calculations in the examination booklets. Clearly indicate which question the derivation is for.
- Give all answers their appropriate S.I. Unit or indicate that the number is unitless.
- Hand in clean and clear derivations.

- If you think information is missing to solve the question, make a reasonable assumption and document your assumptions.
- Always make reasonable approximations but document and justify which approximations you are making.

You can assume the following transistor characteristics:

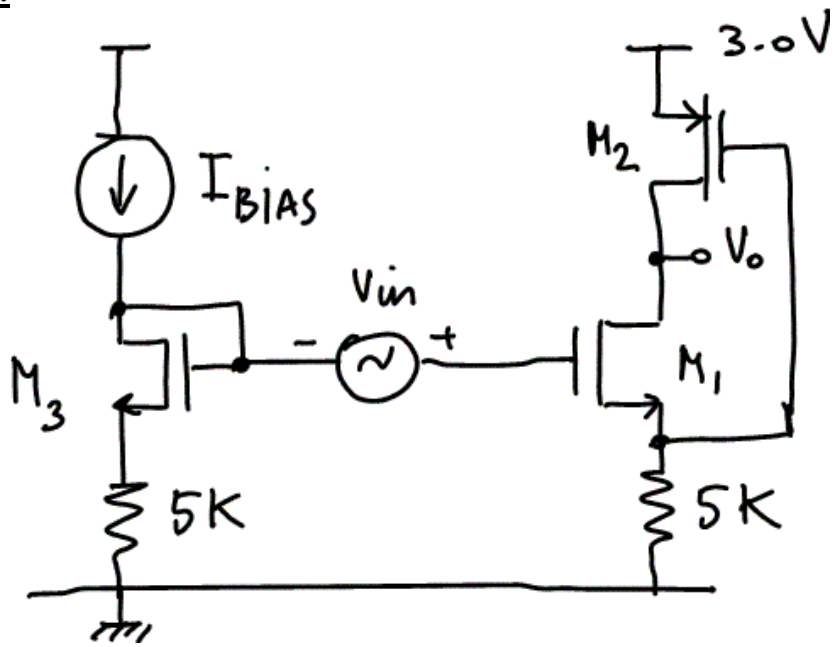
- $(uC_{ox})_{nMOS} = 100\ uA/V^2$ and $(uC_{ox})_{pMOS} = 50\ uA/V^2$
- $V_{Tn} = |V_{Tp}| = 0.5\ V$
- $V_{AL} = 10\ V/um$
- n=1 (sub-threshold slope)

For devices in *strong inversion*, you can use the following simplified I/V relationships:

- Saturation: $I_{DS} = u\ C_{ox} / 2\ (W/L)\ (V_{GS}-V_T)^2\ (1 + V_{DS}/V_A)$
- Non-Saturation: $I_{DS} = u\ C_{ox}\ (W/L)\ (V_{GS}-V_T)\ V_{DS}$

Good luck !

Question 1:



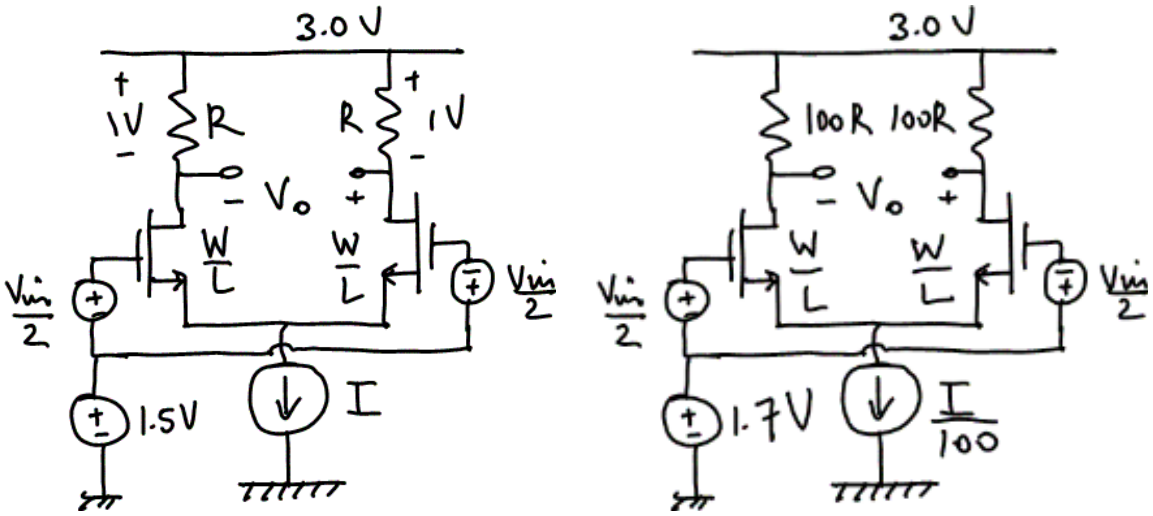
I_{BIAS}=100e-6A; M1=M3; $(W/L)_1$=50um/1um ; $(W/L)_2$=1um/1um ;

1) Find the DC bias point for the circuit
   a) Put the node voltage of all nodes on the schematic.
   b) Give the region of operation of all devices:
      i) Saturation/non-Saturation,
      ii) Strong/Moderate/Weak inversion.
   c) Calculate the small signal equivalent circuit for all devices.

If you cannot find the solution to part 1, make reasonable assumptions and solve for the symbolic expressions below.

2) Find a symbolic expression for the small signal output impedance of the circuit. Calculate the value of the output impedance.
3) Find a symbolic expression for the small signal gain of the circuit. Calculate the value of the small signal gain.

Question 2:

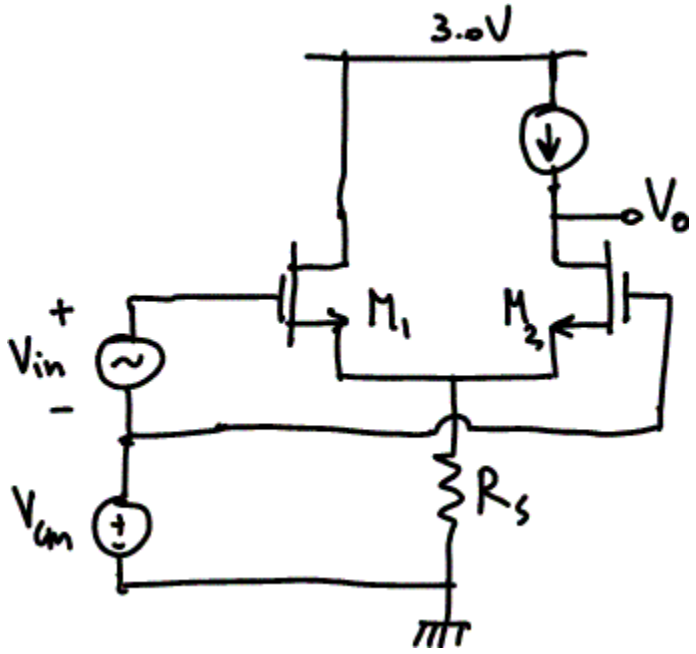


(a) (b)

- For circuit (a) the bias information is indicated on the schematic and the (V_{GS}-V_T) of the nMOS devices is 200mV; you can assume the early voltage of the transistors is infinitely large.
  - Find an expression for the small signal gain (V_o/V_{in}),
  - and calculate its value.

- Circuit (b) uses the same devices but with a 100 times smaller bias current and 100 times larger load resistors; you can again assume the early voltage of the transistors is infinitely large.
  - Find an expression for the small signal gain (V_o/V_{in}),
  - and calculate its value.

Question 3:



You can assume the circuit is properly biased and that all devices are operating in strong inversion and saturation with the following parameters: M1=M2, g_{m1}=2mS, r_{o1}=10K; R_s=5K

1) Find a symbolic expression for small signal gain (V_o/V_{cm}) and calculate its value.

2) Find a symbolic expression for small signal gain (V_o/V_{in}) and calculate its value.