EE 330 Name_ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Exam 3

Spring 2018

Instructions: This is a 50 minute exam. Students may bring 3 page of notes (front and back) to this exam. There are 9 questions and 5 problems. The points allocated to each question and each problem are as indicated. Please solve problems in the space provided on this exam and attach extra sheets only if you run out of space in solving a specific problem.

If references to semiconductor processes are needed beyond what is given in a specific problem or question, assume a CMOS process is available with the following key process parameters; $\mu_n C_{OX}$=350μA/v^2 ,$\mu_p C_{OX}$ =70μA/v^2 ,V_{TNO}=0.5V, V_{TPO}= - 0.5V, C_{OX}=8 fF/μ^2, $\lambda = 0$, and $\gamma = 0$. If reference to a bipolar process is made, assume this process has key npn process parameters J_S=10^{-15}A/μ^2, β_n=100 and $V_{AF} = \infty$ and key pnp process parameters J_S=10^{-15}A/μ^2, β_p=25 and $V_{AF} = \infty$. Specify clearly what process parameters you are using in any solution requiring process parameters. Also attached to this exam is a table discussed in class that relates to the basic amplifier configurations.

1. (2pts) Which of the basic Bipolar amplifiers is characterized by a high input impedance and a voltage gain that is very near to 1?

2. (2pts) Any linear two-port network can be represented in terms of multiple small-signal parameter sets. We have focused on primarily two, the y-parameters {y_{11}, y_{12}, y_{21}, and y_{22}} (which were renamed transconductance parameters) and the amplifier parameters {R_{IN}, R_{OUT}, A_V, A_{VR}}. Express the amplifier parameter A_V in terms of y parameters.

3. (2pts) What key property of a Thyristor is critical for keeping the power dissipation in the Thyristor low when it is used to turn on loads that draw large currents?

4. (2pts) It was observed that the "common emitter with emitter resistor" had a voltage gain given by the expression $A_V = -R_C/R_E$ where R_C is the collector resistor and R_E is the emitter resistor. There were two really attractive properties associated with this expression for the voltage gain. Give one of them.

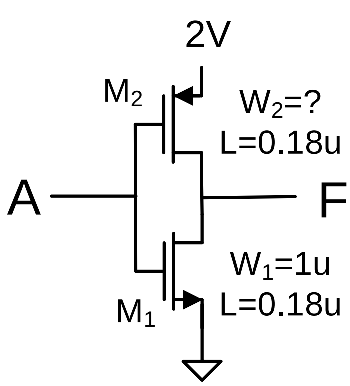
5. (2pts) The mobility ratio, μ_p/μ_n, appears in the trip-point equation where μ_p is the mobility of holes and μ_n is the mobility of electrons. In many processes this ratio is around 1/3 but in the 180 nm process described at the top of this exam it is a bit different. What is μ_p/μ_n for the process described at the top of this exam?

6. (2pts) When using the V_{TEST}-I_{TEST} method to derive the two-port amplifier models, what termination is placed on the input port when calculating the reverse voltage gain A_{VR}?

7. (2pts) What is the major reason current sources are preferred over resistors, capacitors, and dc voltage sources when biasing integrated amplifiers?

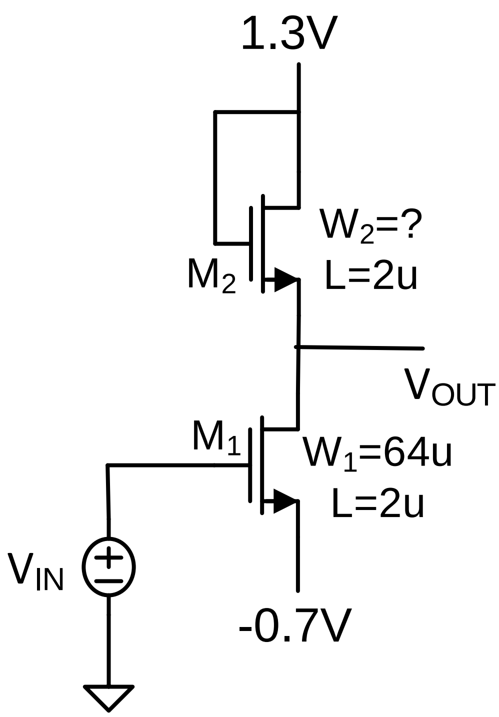
8. (2pts) What devices are typically used as the input devices for a commercial operational amplifier that is fabricated in a bipolar process if there is a requirement that the input bias current must be very small?

9. (4 pts) Size the transistor M_2 so that the trip point of the inverter is at 1V.



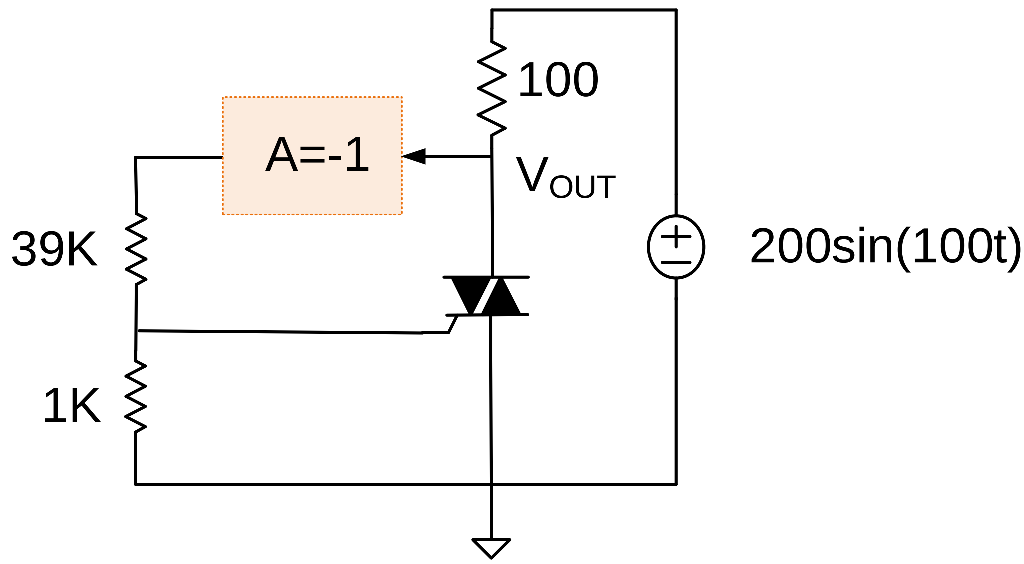
Problem 1 (16 Pts.) Consider the following amplifier.

a) Assuming the transistors are all operating in the saturation region, derive the small signal gain in terms of the small signal model parameters
b) Size M_2 so that V_{OUTQ}=0V
c) Numerically determine the voltage gain for the circuit.

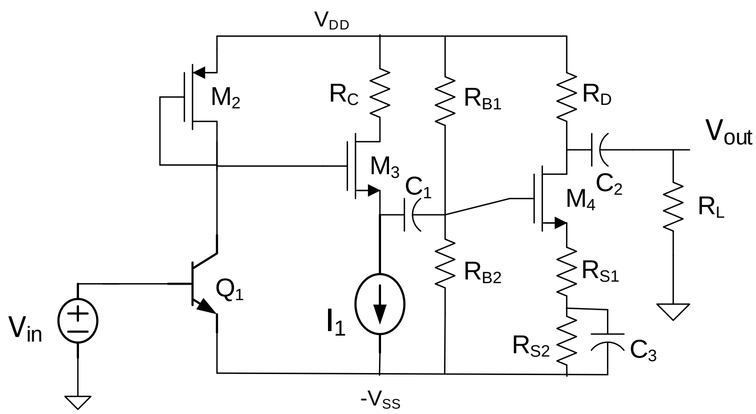


Problem 2 (16 Pts.) Consider the following circuit. Assume the Triac has a gate trigger voltage of +2V and -2V in the positive and negative directions respectively and that the magnitude of the ON voltage across the Triac is 1V. The block marked with A=-1 is a voltage amplifier with a gain of -1.

a) Obtain an expression for and plot the output voltage for one period of the 200V source.
b) Determine the operating regions of the Triac



Problem 3 (16 Pts.) Consider the following circuit which appeared on Exam 2. Assume the MOS transistors are operating in the saturation region, the BJTs are operating in the forward active region, and the capacitors are large. Determine the small-signal voltage gain in terms of the small-signal model parameters.

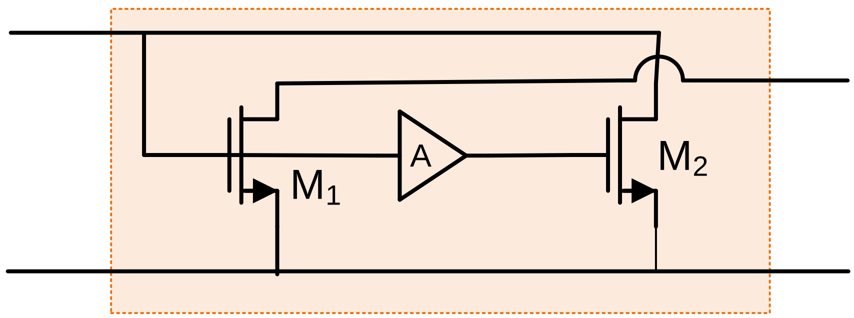


Problem 4 (16 Pts.) Design a voltage amplifier that drives a 1K load, that has an input impedance greater than 10K ,and that has a voltage gain of +16. Clearly specify where the load is connected in your circuit. You may use any number of resistors, capacitors, BJTs and dc voltage or current sources. Be sure to include the biasing circuit.

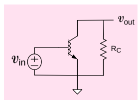
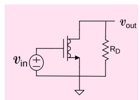
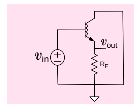
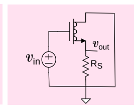
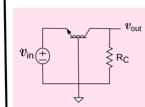
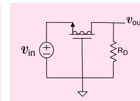
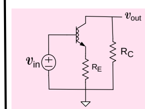
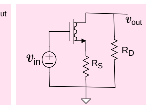
Problem 5 (16 Pts) Consider the following two-port network where the transistors M_1 and M_2 are operating in the saturation region and where the amplifier block designated with A is a small signal voltage amplifier with a gain of -1. Assume the small-signal model parameters of M_1 and M_2, g_{01} and g_{02} , are not negligible.

a) Determine the input impedance for the two-port model of the circuit inside the shaded section (the input port is the port on the left) in terms of the small-signal model parameters of the transistors

b) Determine the forward voltage gain, A_V, in terms of the small-signal model parameters of the transistors.



Basic Amplifier Gain Table

	CE/CS		CC/CD		CB/CG		CEwRE/CSwRS	
	BJT	MOS	BJT	MOS	BJT	MOS	BJT	MOS
								
A_V	$-g_m R_C$		$\frac{g_m}{g_m + g_E}$ □1		$g_m R_C$		$-\frac{R_C}{R_E}$	
	$-\frac{I_{CQ}R_C}{V_t}$	$-\frac{2I_{DQ}R_D}{V_{EB}}$	$\frac{I_{CQ}R_E}{I_{CQ}R_E + V_t}$	$\frac{2I_{DQ}R_E}{2I_{DQ}R_E + V_{EB}}$	$\frac{I_{CQ}R_C}{V_t}$	$\frac{2I_{DQ}R_C}{V_{EB}}$		
R_{in}	r_π		$r_\pi + \beta R_E$		g_m^{-1}		$r_\pi + \beta R_E$	
	$\frac{\beta V_t}{I_{CQ}}$	∞	$\beta\left(\frac{V_t}{I_{CQ}} + R_E\right)$	∞	$\frac{V_t}{I_{CQ}}$	$\frac{V_{EB}}{2I_{DQ}}$	$\beta\left(\frac{V_t}{I_{CQ}} + R_E\right)$	∞
R_{out}	R_C		g_m^{-1}		R_C		R_C	
			$\frac{V_t}{I_{CQ}}$	$\frac{V_{EB}}{2I_{DQ}}$				