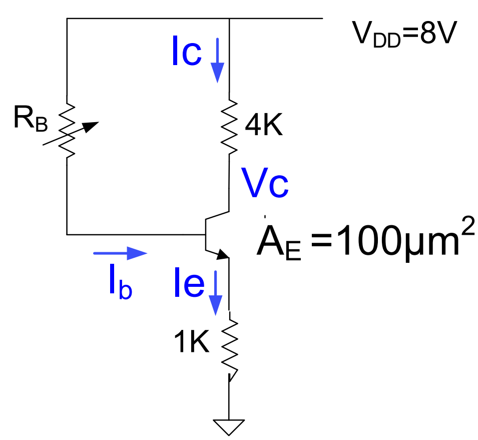
EE 330
Homework 8
Spring 2019 (Due Friday March 8th)

Unless stated to the contrary, assume all MOS transistors have model parameters $\mu_n C_{OX}$=300µA/V^2 , V_{Tn}=0.5V, μ_n/μ_p=4, V_{Tp}=-0.5V, C_{OX}=4fF/µ^2 , $\lambda = 0$, $\gamma = 0$, and all BJT transistors have model parameters $J_S A$= 10^{-12}A, βn=100 , and , βp=30.

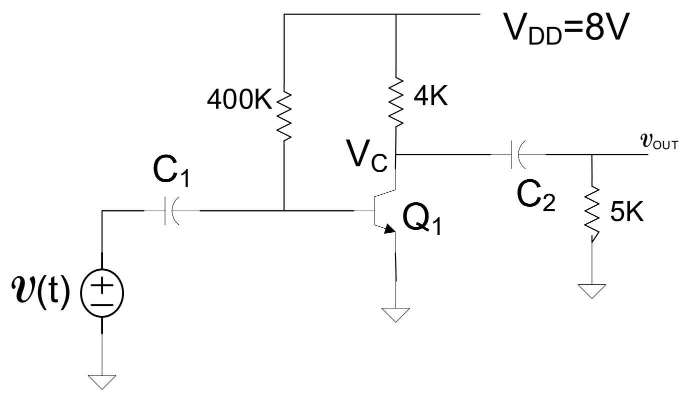
Problem 1 The following circuit was constructed for measuring the β of the bipolar transistor. To obtain the β, the resistor R_B was adjusted so that the current I_c was precisely 1.000mA. The current I_e was then measured to be 1.050mA. From these measurements the parameter α of the transistor was obtained and then β was calculated using the well-known relationship between α and β.

a) What is the value of β for the transistor?
b) What would be the worst-case error (in percent) in measuring the β of the transistor using this approach if the current measurements were only accurate to ±1%?

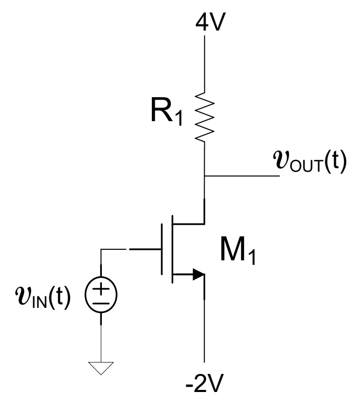


Problem 2 As an alternative to measuring β in the circuit for the previous problem (assuming β is the value determine in part a) of the previous problem), the currents I_b and I_c were measured. What would be the worst-case error (in percent) in measuring the β of the transistor using this alternative approach if the current measurements of I_b and I_c were only accurate to ±0.25%?

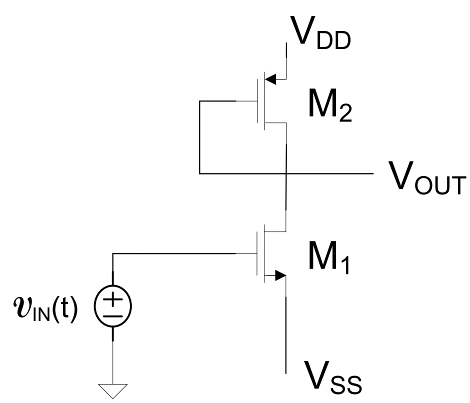
Problem 3 Assume the capacitors are very large. Determine the quiescent value of V_C and V_{OUT}



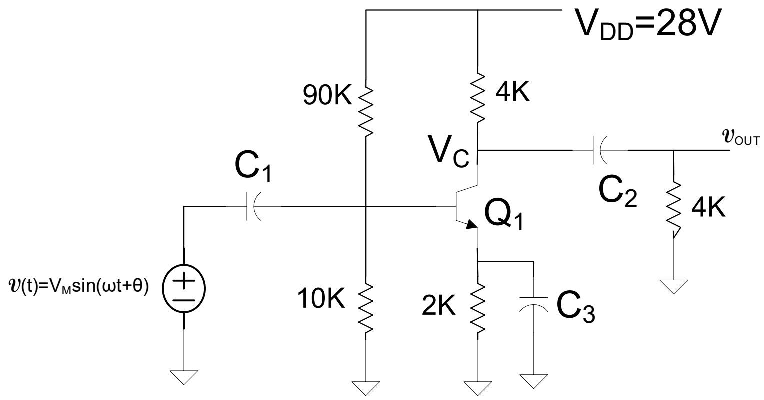
Problem 4 Determine the maximum value of R_1 that will keep M_1 in saturation. M_1 has dimensions W=8u and L=2u. Assume the magnitude of the input is arbitrarily small.



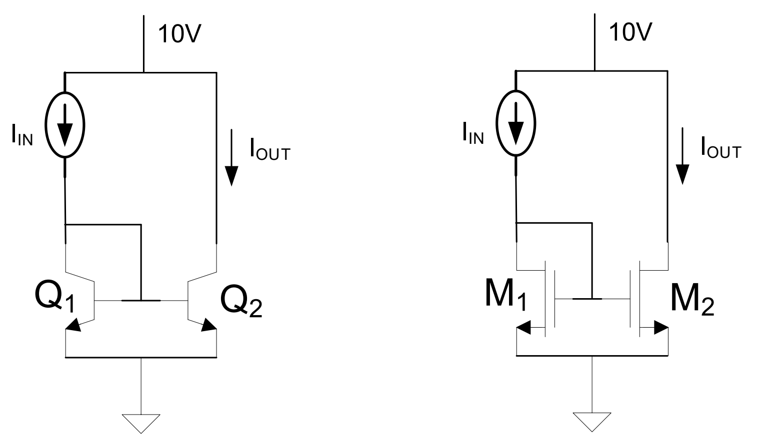
Problem 5 Consider the following circuit. Determine the quiescent output voltage if V_{DD}=2V, V_{SS}=-2V, W_1=10u, L_1=2u, W_2=50u and L_2=1u. Assume the magnitude of the input is arbitrarily small.



Problem 6 Assume the capacitors are all very large. Determine the quiescent value of V_C and V_{OUT}



Problem 7 Consider the two circuits shown.
a) Determine the output current for the bipolar circuit if A_{E1}=200u^2 and A_{E2}=1000u^2 and I_{IN}=1.5mA.. Assume β is very large.
b) Determine the output current for the MOS circuit if W_1/L_1=5 and W_2/L_2=20 and I_{IN}=1.5mA.



Problem 8 Express the output current for the bipolar circuit in terms of the input current and the emitter areas for the circuit of Problem 9. Assume β is very large. Also express the output current for the MOS circuit in terms of the input current and the "W/L" ratios for the circuit of Problem 9. What conclusion can be drawn about the usefulness of these structures?

Problem 9 Use the D-flip flop you created in the previous homework to create a 4-bit register with an enable input that turns it on or off depending on its level. Show your Verilog code, testbench, and waveform output.
Note: Enable can be implement on the individual flip flop level or on the register level.