ECE 342: Electronic Circuits | **Summer 2024**
Problem Set #10 | **Professor Schutt-Aine**
Due Date: 5pm, Tue, July 23, 2024

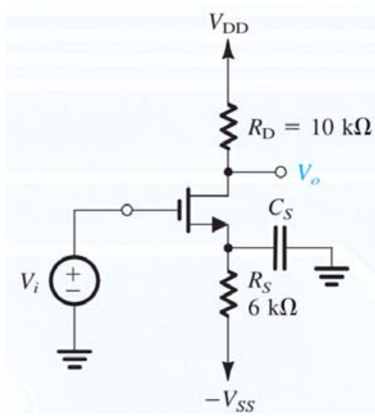
1. The amplifier in the figure below is biased to operate at $g_m = 1\ mA/V$. Neglecting r_o,

a. Find the mid-band gain.

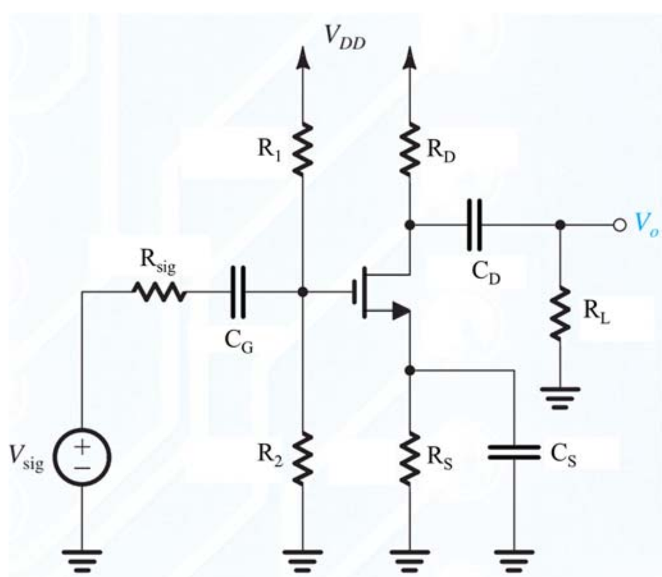
b. Find the full transfer function with C_s present. Is this circuit low-pass or high-pass?

c. Find the value of C_s that places f_L at 200 Hz.

d. With the value of C_s above, find $v_0(t)$. Given that $v_i(t) = V_0 + 10\cos(10^6\pi t)\ mV$ where V_0 is a constant.



2. The NMOS transistor in the discrete CS amplifier circuit shown below is biased to have $g_m = 5\ mA/V$. Find $A_M, f_{p1}, f_{p2}, f_{p3}, and\ f_L$. Let R_{sig} = 100kΩ, R_1 = 47MΩ, R_2 = 10MΩ, R_D = 4.7kΩ, R_S = 2kΩ, R_L = 10kΩ, C_G = 0.01µF, C_S = 10µF, C_D = 0.1µF



Ignore parasitic capacitances of the transistor and channel-length modulation effect.

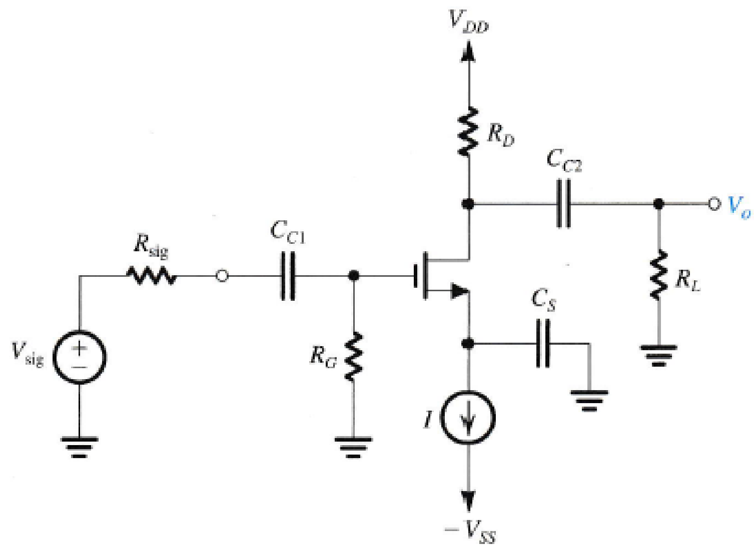
3. A discrete MOSFET common-source amplifier has $R_G = 1M\Omega$, $g_m = 5mA/V$, $r_o = 100k\Omega$, $R_D = 10k\Omega$, $C_{gs} = 2pF$, and $C_{gd} = 0.4pF$. The amplifier is fed from a voltage source with an internal resistance of 500 $k\Omega$ and is connected to a 10 $k\Omega$ load. Find:

a) The overall mid-band gain A_M

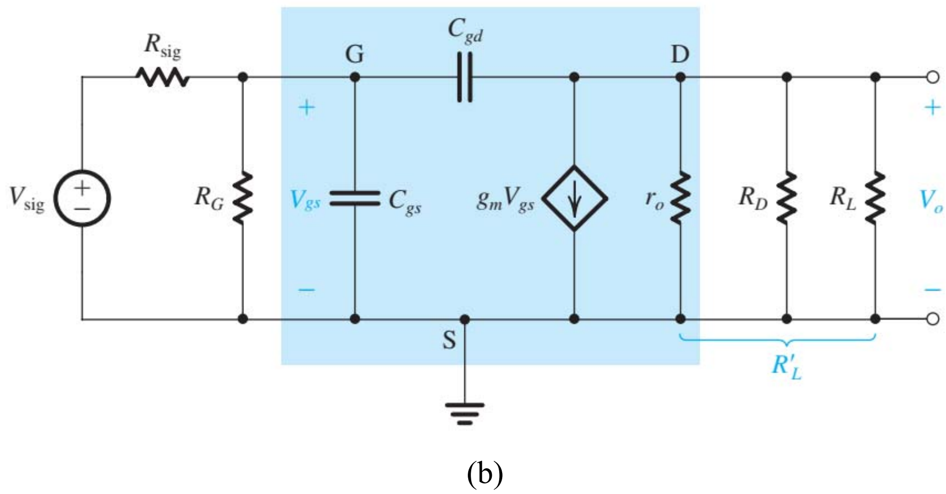
b) The upper 3-dB frequency f_H

Refer to Figs a and b for the complete setup and the small signal circuit at high frequency. Note: at high and mid-band frequency, coupling capacitor C_{C1}, C_{C2}, C_S are shorted.

Hint: In part b), find f_H using Miller's theorem then apply open-circuit time constant approach.



(a)

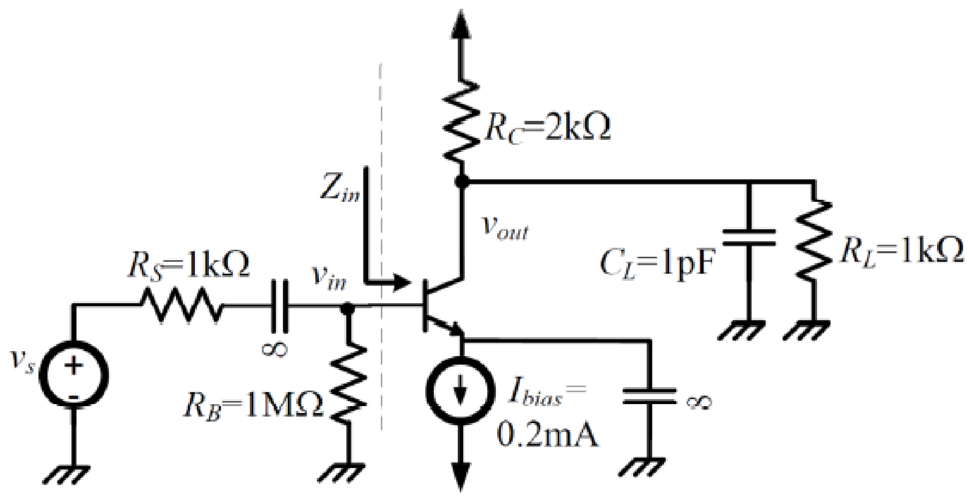


(b)

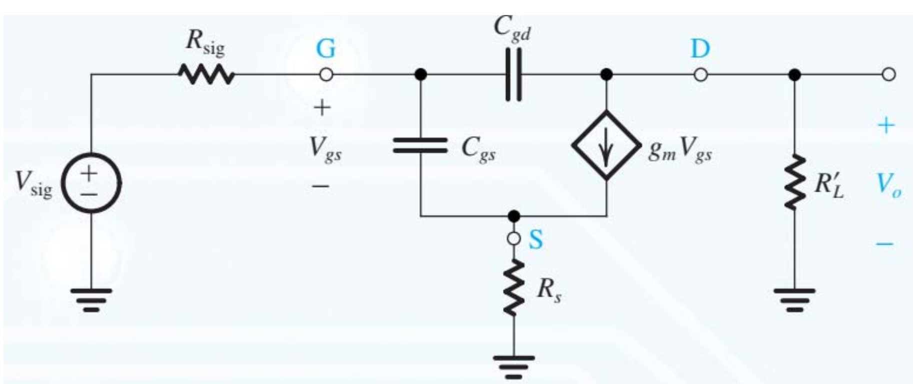
4. Consider the common-emitter amplifier in the following figure, with $\beta = 100$, $V_A = 100V$, $C_\pi = 25fF$, $C_\mu = 10fF$.

a) Draw the small-signal model of this circuit. Apply Miller's theorem to split C_μ to input and output nodes. Calculate the time constants at the input and output nodes, τ_{in} *and* τ_{out}.

b) Based on the time constants from part a), calculate the input and output pole frequencies, f_{in} *and* f_{out}. What is the dominant pole of this amplifier?



5. The figure below shows the high-frequency equivalent circuit of a CS amplifier with a resistance R_s, connected to S. The purpose of this problem is to show that the value of R_s, can be used to control the gain and bandwidth of the amplifier, specifically to allow the designer to trade gain for increased bandwidth.



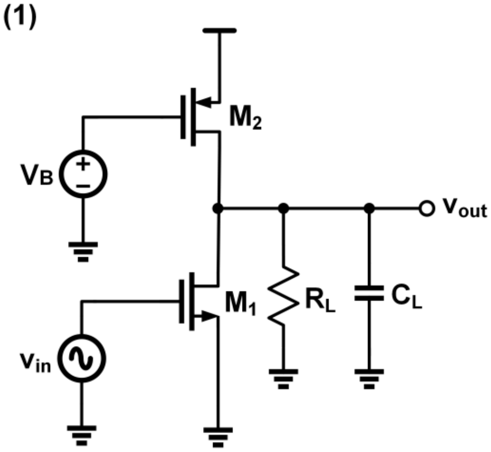
a) Derive an expression for the low-frequency voltage gain (i.e. set C_{gs} *and* C_{gd} to zero).

b) To be able to determine ω_H using the open-circuit time-constants method, derive expressions for R_{gs} and R_{gd} (equivalent resistance seen by C_{gs} and C_{gd}, respectively.

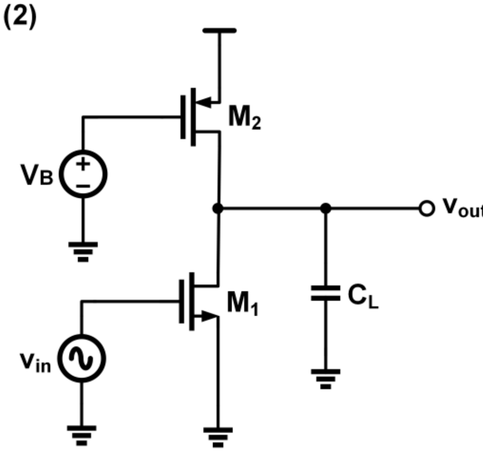
c) Let $R_{sig} = 100k\Omega$, $g_m = 4mA/V$, $R_L' = 5k\Omega$, and $C_{gs} = C_{gd} = 1pF$. Use the expressions found in a) and b) to determine the low-frequency gain and the 3-dB frequency f_H for three cases: $R_s = 0\Omega,\ 100\Omega, and\ 250\Omega$. In each case, also evaluate the gain-bandwidth product.

6. Determine -3dB bandwidth of the circuits shown below. Assume MOS transistors in saturation and BJTs in forward active region with $\mathrm{r_{ds}} = \infty, r_{\mathrm{o}} = \infty$. Ignore intrinsic capacitances.

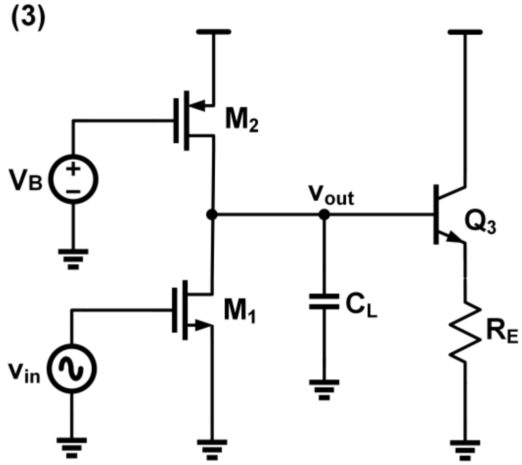
(1)



(2)

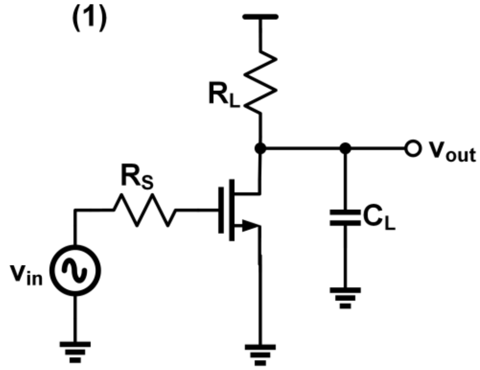


(3)



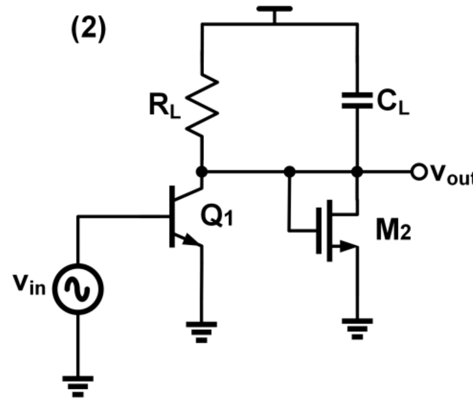
7. Approximate transfer function for the circuits below. Assume MOS transistors operate in saturation with $r_{ds} = \infty$, and BJTs in forward active region with $r_o = \infty$

(1)



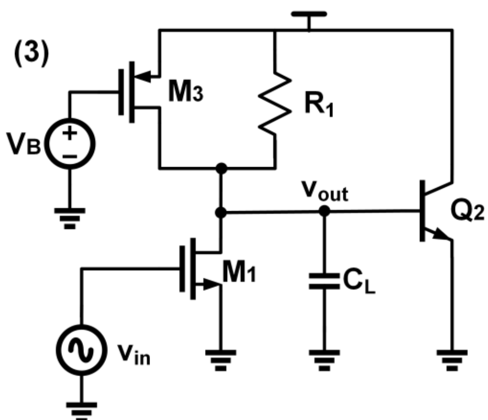
R_L
R_S
v_out
C_L
v_in

(2)



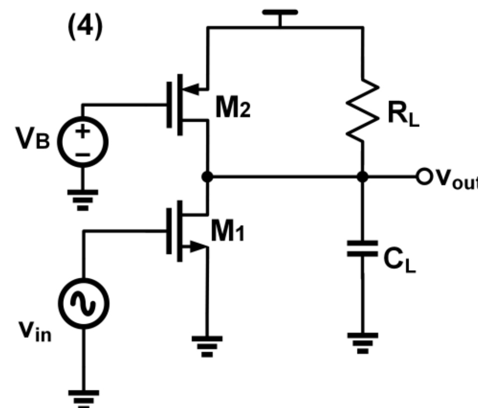
R_L
C_L
v_out
Q1
M2
v_in

(3)



M3
R1
V_B
v_out
Q2
M1
C_L
v_in

(4)



M2
R_L
V_B
v_out
M1
C_L
v_in