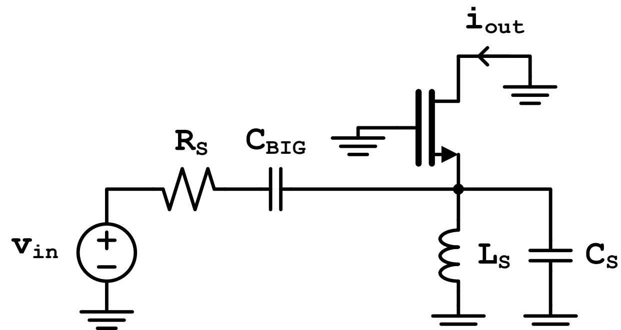
University of Michigan
EECS 522: Analog Integrated Circuits
Winter 2008

Problem Set 6

Issued 3/25/2008 – 4/1/Due 2008

Problem 6.1: Use the common-gate amplifier below for this problem. Use the combined model for drain and gate noise, $\overline{i_{ndg}^2}$, derived in lecture, making the same assumptions on the small-signal model (no r_o, include C_{gs}, etc.). Assume C_{BIG} is a short at AC, and the circuit is operated at the self-resonant frequency $\omega_0 = 1/\sqrt{L_S(C_S + C_{gs})}$.



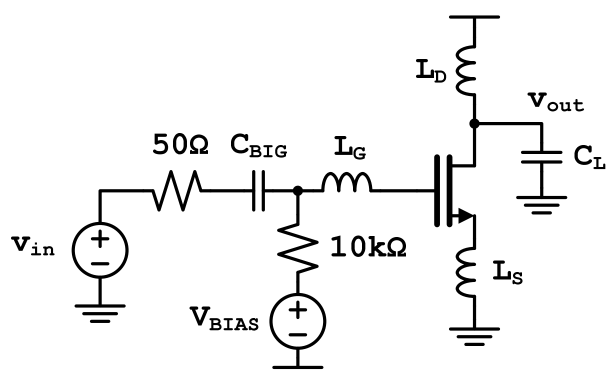
a) What is the small-signal transconductance $G_m = i_{out}/v_{in}$ of the circuit at $\omega = \omega_0$ assuming the transistor is biased so that $1/g_m = R_S$.

b) Derive expressions for η and $\overline{Z_{gsw}}$ for the combined drain and gate noise, $\overline{i_{ndg}^2}$.

c) Derive an expression for the noise factor of the amplifier using your results from b).

d) Assuming c is negative and imaginary, $\omega = \omega_0 = 1/\sqrt{L_S(C_S + C_{gs})}$, $Q_{in} = \frac{1}{2}R_S(C_S + C_{gs})\omega_0$, and $\omega_t = g_m/C_{gs}$, simplify your expression from c) into a form containing these quantities and device constants.

Problem 6.2: Use the amplifier below for this problem. Consider only C_{gs} and g_m for the FET, neglect all other small signal parameters. Assume the input and output resonances are tuned to 1GHz, and that C_{BIG} is a short circuit at 10GHz.



a) Assume that Q=10 for all inductors at 1GHz, and the inductors are modeled as a series R and L. Given that $\omega_t = 2\pi 10GHz$ and $g_m = 5mMho$, calculate the values of L_G and L_S to provide a 50Ω match to the source.

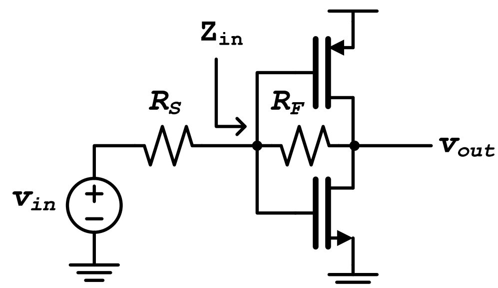
b) Assuming $V_{GS} - V_{th} = 150mV$, calculate the bias current in the FET and the voltage drop across L_S.

c) Assume this amplifier is loaded by an identical FET, therefore $C_L = C_{gs}$. Calculate the value of L_D required to resonate out this capacitance at 1GHz. Is this a reasonable value?

d) What is the overall voltage gain of your amplifier at 1GHz? Provide a numerical value (still neglecting r_o of the FET) with Q=10 for all inductors at 1GHz.

e) What is the noise factor of your amplifier. Assume $\gamma = 3$, $\delta = 6$, $\alpha = 0.75$, and $c = -0.55j$.

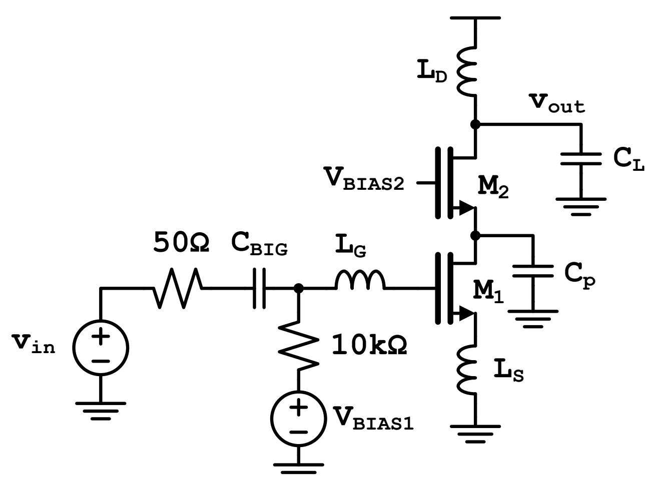
Problem 6.3: Derive expressions for the input impedance Z_{in}, voltage gain v_{out}/v_{in}, and noise factor of the following circuit seen in lecture. Consider only drain thermal noise and thermal noise in the resistors.



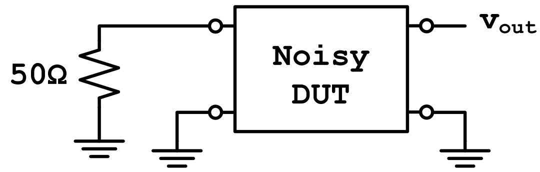
Problem 6.4: Use the cascode LNA shown below.

a) Derive an expression for the output-referred short-circuit noise current contributed from the drain thermal noise of transistor M2 neglecting r_o for both devices.

b) Now including r_{o1}, what is the impedance seen looking into the drain of M1 at the resonant frequency of the input matching circuit? Assume infinite Q in the inductors, and C_{BIG} is a short.



Problem 6.5: This question concerns the measurement of noise figure of an arbitrary device under test (DUT).



a) Assume that the temperature of the 50Ω source resistor can be precisely controlled. The noisy DUT has voltage gain A(s) and contributes a mean-square output referred noise voltage N_{DUT} in a given bandwidth Δf. Sketch a graph of the total mean square noise voltage measured at the output as a function of source resistor temperature. What is the slope of the line in V^2/T?

b) What is the significance of the intercept of this graph at T=0 K?

c) Propose a technique to measure the noise figure of the DUT by only varying the temperature of the source. How many temperatures do you need?

d) What if temperature control of R_S isn't available, but its temperature is known. How could you measure noise figure in this case?