EXAMINATION IN

TSEK03

RADIO FREQUENCY INTEGRATED CIRCUITS

Date:	2015-03-19
Time:	8-12
Location:	TER2
Tools:	Calculator, Dictionary
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12 points are required to pass.
(12-16: 3, 16-20: 4, 20-24: 5)

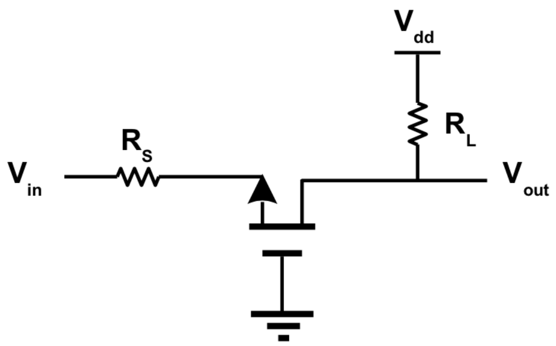
Please start each new problem at the top of a page!
Only use one side of each paper!

1.

Consider the common-gate broadband amplifier below.

a. Derive an expression for the noise figure in the absence of gate noise. Select the transistor's g_m for use as an LNA. Neglect transistor capacitances, body effect, and channel-length modulation. (3 p)

b. Re-derive the noise figure, now taking gate noise into account. Hint: Model the gate noise using a voltage source of $4kTR_G/3$. (1 p)

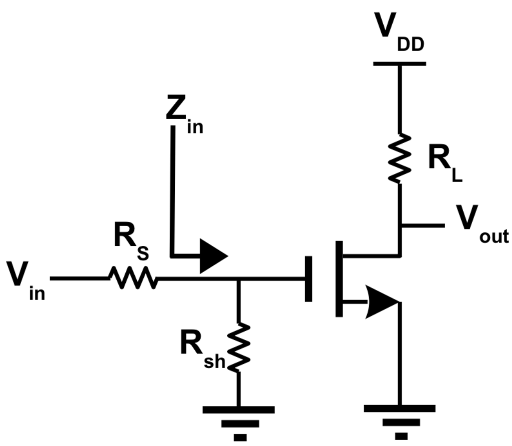


ˆ2.

Consider the resistively shunted common-source amplifier shown in the figure below.

a. Derive expressions for gain, input impedance and noise figure for the amplifier. Neglect gate noise and noise from the load resistor as well as transistor capacitances, body effect, and channel-length modulation. (3 p)

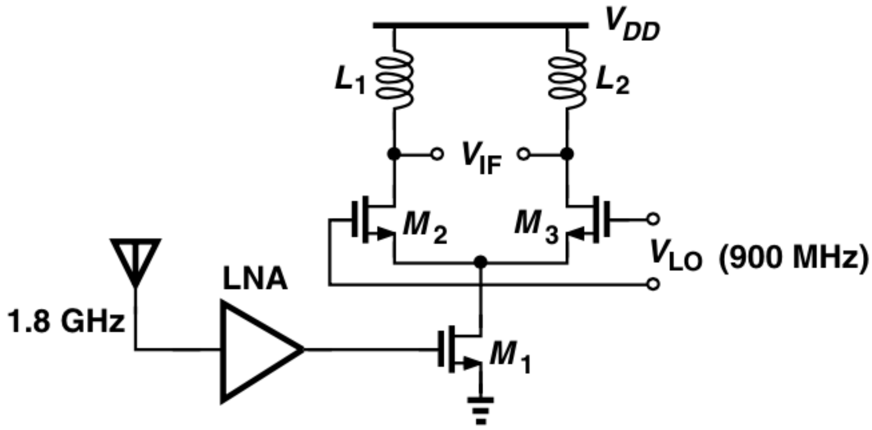
b. When used in a 50 Ω system (R_S = 50 Ω), how should R_{sh} be selected so that the amplifier is best suited as an Rx-LNA? Simplify the NF expression using this value! (1 p)



3.

Shown in the figure below is the frontend of a 1.8-GHz receiver. The LO frequency is chosen to be 900 MHz and the load inductors and capacitances resonate with a quality factor of Q at IF. Assume M_1 is biased at a current of I_1, the mixer and the LO are perfectly symmetric, and M_2 and M_3 switch abruptly and completely.

Compute the LO-IF feedthrough, i.e., the measured level of the 900-MHz output component in the absence of an RF signal. Model the inductor losses with parallel resistors, $Q = R_p / (\omega_0 L_p)$. (3 p)



4.

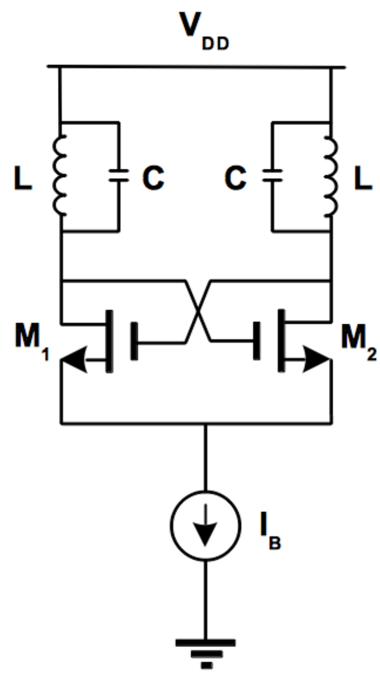
A negative resistance LC oscillator used for carrier generation in a 3G uplink transmitter is shown here.

The component values are L=2 nH and C=3 pF.
Q of the inductors around the relevant frequency is 5.
$L_p = (1 + 1/Q^2) * L_s$, $R_p = (Q^2 + 1) * R_s$
$I_B = 1$ mA, $\mu_n * C_{ox} = 200\ \mu A/V^2$.

a. Calculate the oscillation frequency, neglecting losses in the inductors. (1 p)

b. Calculate the oscillation frequency, including losses in the inductors. How much does the oscillation frequency change, and in what direction, when inductor losses are included? (1 p)

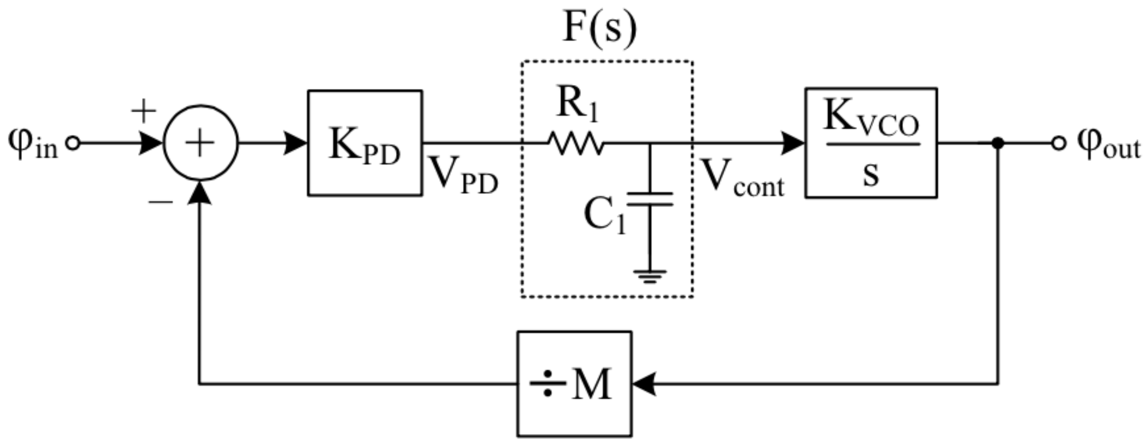
c. What is the required width in μm of M1 and M2 to ensure oscillation? We will use the minimum transistors in a 65 nm CMOS technology (Ldrawn = 0.060 um) which are operated at V_{DD} = 1.2 V. Assume that the electrical channel length is the same as Ldrawn and neglect all parasitics associated with the transistors. (2 p)



5.

For the frequency-multiplying PLL shown below, determine the:

a. closed-loop transfer function (2 p)
b. damping factor ζ (1 p)
c. natural frequency ω_n (1 p)
d. loop bandwidth (1 p)



6.

a. The following table lists three different properties for the A, B, C, D, and E power amplifier classes and their typical values. Identify the power amplifier class for each column. (2.5 p)

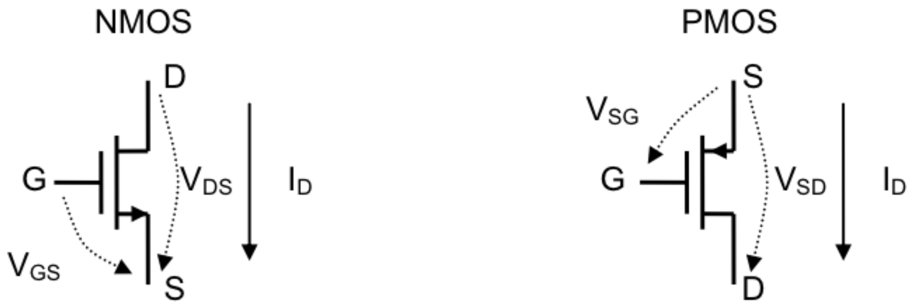
Maximum drain efficiency [%]	100	78.5	100	50	100
Peak drain voltage [* V_{DD}]	2	2	1	2	3.6
Normalized power output capability [Pout/(max V and I)]	0.125	0.125	0.32	0.125	0.098
Power Amplifer Class					

b. How would you select the gate-bias $V_{g,bias}$ for a class-AB power amplifier? (0.5 p)

c. What are the performance trade-offs when choosing this $V_{g,bias}$-value? (0.5 p)

d. What is the purpose of a ”load-pull characterization” of a power amplifier? (0.5 p)

TRANSISTOR EQUATIONS



NMOS

- **Cutoff:** $I_D = 0$ $(V_{GS} < V_{TN})$
- **Linear mode:**

$$I_D = \mu_n C_{ox} \frac{W}{L}\left((V_{GS} - V_{TN})V_{DS} - \frac{V_{DS}^2}{2} \right)$$ $(V_{GS} > V_{TN})$ and $(V_{DS} < V_{GS} - V_{TN})$

- **Saturation mode:**

$$I_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TN})^2(1 + \lambda V_{DS})$$ $(V_{GS} > V_{TN})$ and $(V_{DS} > V_{GS} - V_{TN})$

PMOS

- **Cutoff:** $I_D = 0$ $(V_{GS} < |V_{TP}|)$
- **Linear mode:**

$$I_D = \mu_p C_{ox} \frac{W}{L}\left((V_{SG} - |V_{TP}|)V_{SD} - \frac{V_{SD}^2}{2} \right)$$ $(V_{GS} > |V_{TP}|)$ and $(V_{SD} < V_{SG} - |V_{TP}|)$

- **Saturation mode:**

$$I_D = \frac{1}{2}\mu_p C_{ox} \frac{W}{L}(V_{SG} - |V_{TP}|)^2(1 + \lambda V_{SD})$$ $(V_{GS} > |V_{TP}|)$ and $(V_{SD} > V_{SG} - |V_{TP}|)$