EXAMINATION IN

TSEK03

RADIO FREQUENCY INTEGRATED CIRCUITS

Date:	2016-08-27
Time:	8-12
Location:	TER1
Tools:	Calculator, Dictionary
Teachers:	Ted Johansson (070-6270237) alt. 1223

12 points are required to pass.
(12-15: 3, 16-19: 4, 20-24: 5)

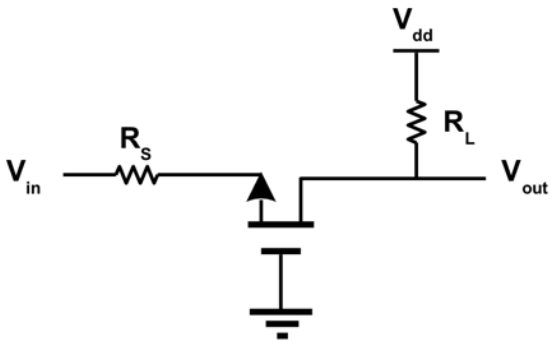
Please start each new problem at the top of a page!
Only use one side of each paper!

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)



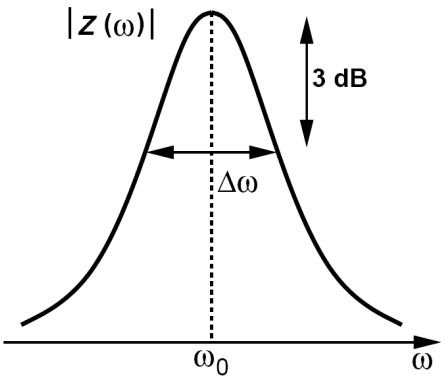
2.

A Bluetooth LNA must achieve a 3-dB bandwidth from 2350 to 2550 MHz in order to fulfill a 1-dB bandwidth in the 2400 MHz to 2485 MHz (ISM) band.

a. If the LNA incorporates a second-order LC tank as its load, what is the maximum allowable tank Q? (2 p)

b. This tank Q is given by the combination of the Q for the L:s and for the C:s. Which component of the L and C typically have the lowest Q (highest losses) when realized on-chip in a typical CMOS process, thus limiting the Q of the tank? (1 p)

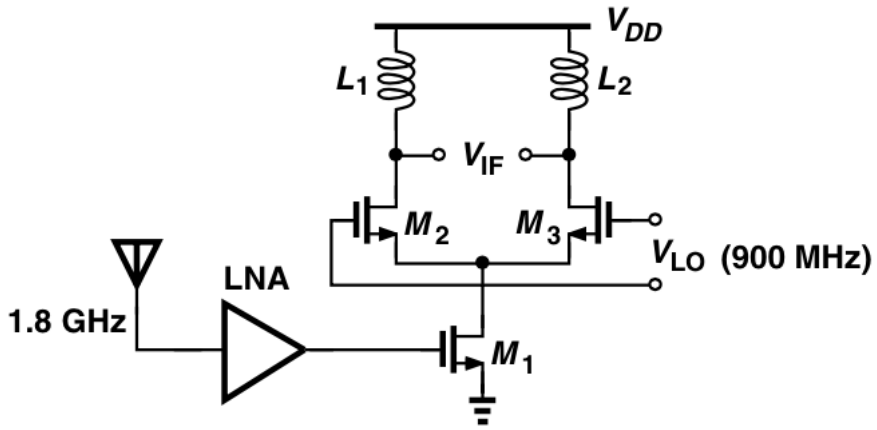
c. What are the main sources of the losses in this component (give at least one)? (1 p)



3.

a. 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)

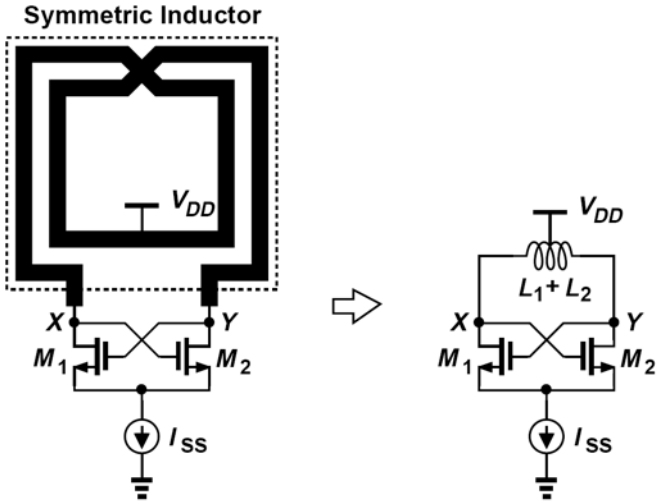


b. Assuming that all components of this heterodyne mixer are noiseless — except for the equivalent thermal noise from the antenna — what is the noise figure of the mixer (also called SSB noise figure)? (1 p)

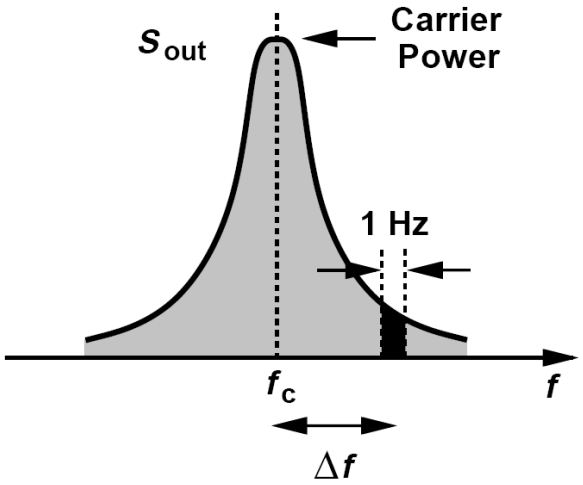
4.

The symmetric inductor in the figure below has a value of 2 nH (from port X to port Y) and a Q of 5 at 2.45 GHz. $M_1 = M_2$.

a. What is the minimum required transconductance (g_m) of M_1 and M_2 to guarantee startup? (2 p)



b. Phase noise: At high carrier frequencies, it is difficult to measure the noise power in a 1-Hz bandwidth. Suppose a spectrum analyzer measures a noise power of -70 dBm in a 1-kHz bandwidth at 1-MHz offset. How much is the phase noise at this offset if the average oscillator output power is -2 dBm? (2 p)



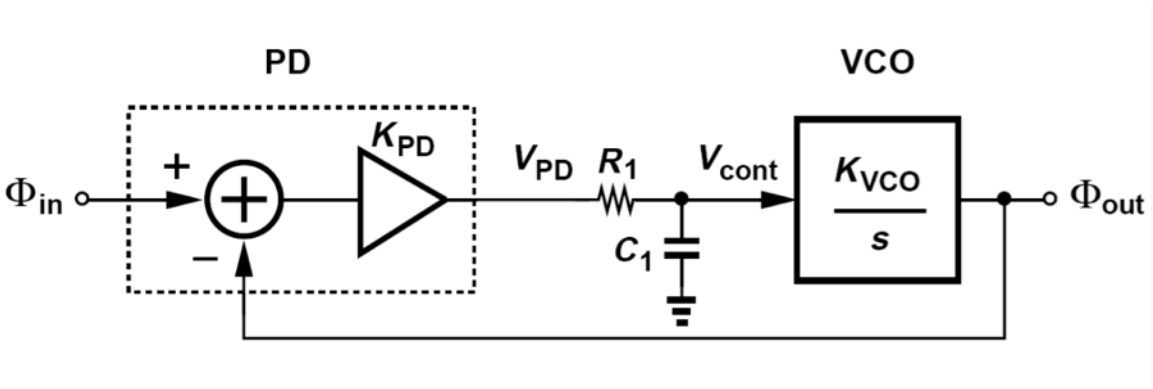
5.

A block level description of a PLL is shown below.

a. Derive an expression for the closed-loop transfer function, $H(s) = \Phi_{out}(s)/\Phi_{in}(s)$. (2 p)

b. What type of PLL is it? (1 p)

c. Prove that for slow input phase variations, the output tracks the input. (2 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 [%]	50	78.5	100	100	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 do you design a Doherty amplifier with only one amplifier (transistor)? (0.5 p)