EXAMINATION IN

TSEK03

RADIO FREQUENCY INTEGRATED CIRCUITS

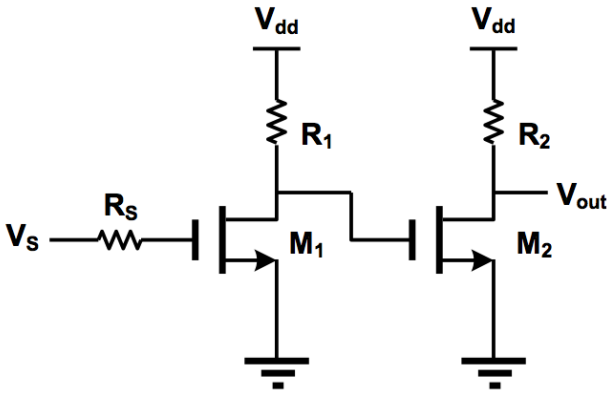
Date:	2016-06-09
Time:	8-12
Location:	TER2
Tools:	Calculator, Dictionary
Teachers:	Ted Johansson (070-6270237) alt. 1223

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.

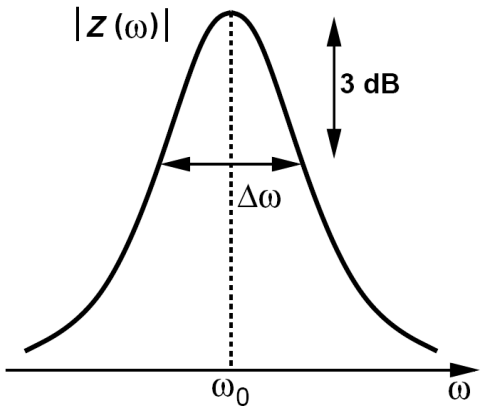
A two-stage amplifier is shown below. Determine the noise factor of this amplifier. Consider only the thermal noise sources and ignore the gate and 1/f noise of the transistors. Assume that R_1 and R_2 are noiseless and ignore all the parasitics. Also, neglect channel-length modulation. (4 p)



2.

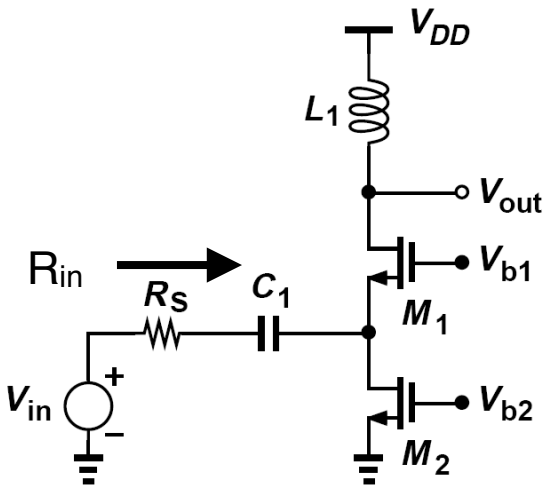
A Bluetooth LNA must achieve a -3-dB bandwidth from 2350 to 2550 MHz in order to fulfill a -1-dB bandwidth in the 2400 MHz to 2485 MHz (ISM) band.

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.

Determine the noise figure of the circuits shown below. Neglect channel-length modulation, gate, and 1/f noise. Model the losses of L_1 using a parallel resistor R_1, and assume input matching. (5 p)

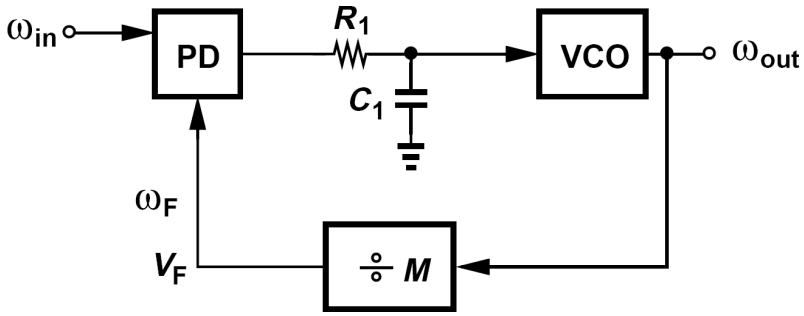


4.

Below is shown a frequency-multiplying PLL. The transfer function of the VCO is K_{VCO}/s and the transfer function of the PFD/CP is K_{PD}.

Derive an expression for:

a. the closed-loop phase transfer function, $H(s) = \Phi_{out}(s)/\Phi_{in}(s)$ (2 p)
b. the damping factor, ζ (1 p)
c. the natural frequency ω_n (1 p)



5.

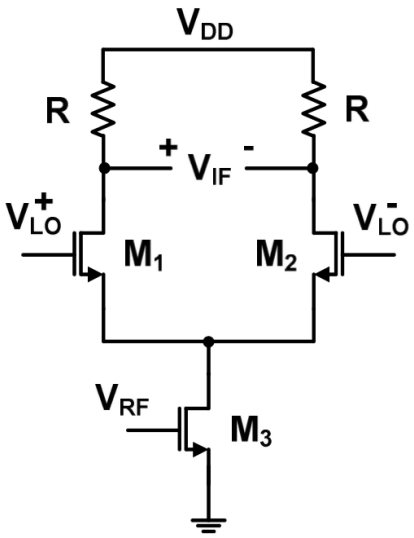
A single-balanced mixer is shown in the figure below. Assume that the switching transistors M_1 and M_2 are ideal switches with zero on-resistance and neglect channel-length modulation.

a. Derive an expression for the conversion gain of this mixer. (2 p)
b. Derive an expression for the noise figure of this mixer. Assume the switching transistors do not generate noise. The total noise is contributed by transistor M_3, load resistors R and source resistor R_S connected to the RF input (is not shown in the figure). Consider only the thermal noise sources and ignore the gate noise of the transistor. (3 p)

Hints:

i) $\overline{i_{n,M}^2} = 4kT\gamma g_m$

ii) $V_{LO}(t) = \frac{4}{\pi}\cos\omega_{LO}(t) - \frac{4}{3\pi}\cos 3\omega_{LO}(t) + \frac{4}{5\pi}\cos 5\omega_{LO}(t) - ...$



6.

Suppose a given balun design has a loss of 1.5 dB. In which one of the transmitters shown below does this loss affect the efficiency more unfavorable, 6a or 6b? Estimate the power losses in the transmitter assuming 0 dBm output power from the upconverter in Figure 6a and 30 dBm output power from the PA in Figure 6b. (2 p)

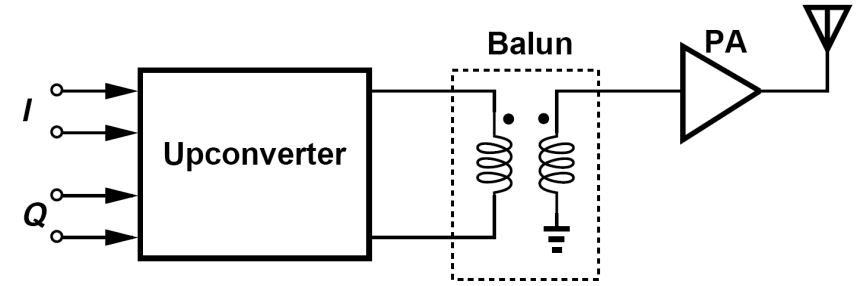


Figure 6a

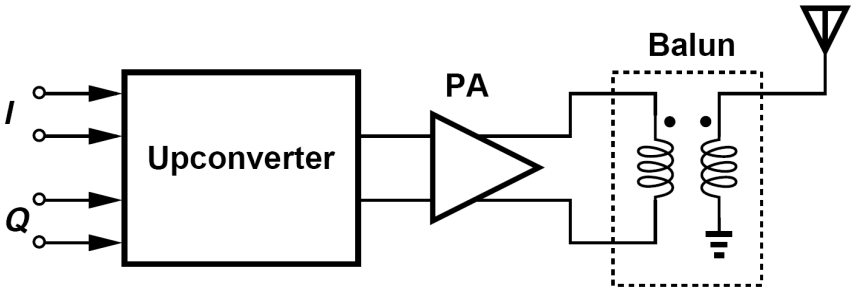


Figure 6b