EXAMINATION IN

TSEK03

RADIO FREQUENCY INTEGRATED CIRCUITS

Date: 2015-06-10

Time: 8-12

Location: TER2

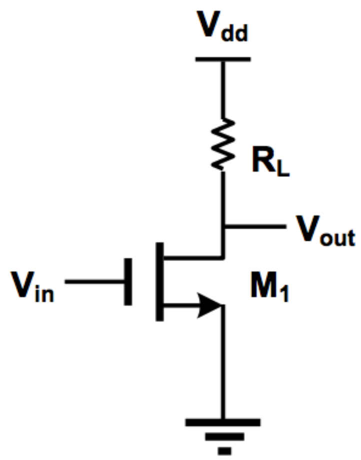
Tools: Calculator, Dictionary

Teachers: Ted Johansson (070-6270237)
alt. 1223
Ameya Bihde (8946)

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.



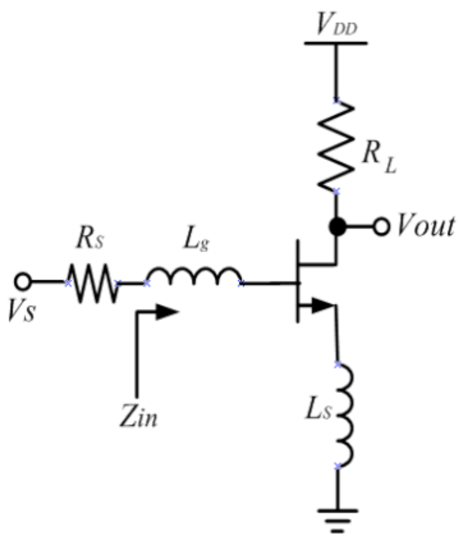
a. In the amplifier schematic shown to the right, determine the total input-referred noise voltage. Consider the thermal noise sources and the noise from the gate resistance of the transistor. Neglect flicker noise, channel-length modulation and body effect. (3 p)

b. Now also add the effect of flicker noise. (1 p)
Hint: It can be model it as another current source in the transistor channel as:

$$\overline{I_n^2} = g_m^2 \frac{K}{WLC_{ox}} \frac{1}{f}$$

c. Explain ”1/f noise corner frequency” (in equations, words, and/or a drawing). (1 p)

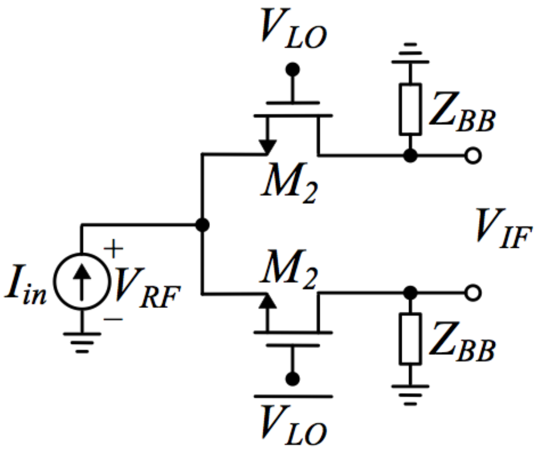
2. The inductor source degenerated amplifier shown to the right can be designed to present a noiseless resistance of 50 Ω for matching the input (Z_{in}) to a 50 Ω source.



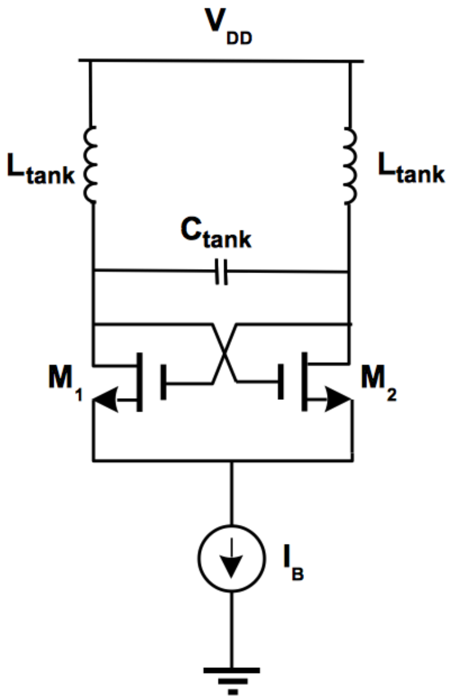
a. Calculate the input impedance. (3 p)

b. How do we select the component values (from the derived input impedance) to achieve matching to a 50 Ω source? (1 p)

3. Prove that the voltage conversion gain of a sampling mixer approaches 6 dB as the width of the LO pulses tends to zero (i.e., as the hold time approaches the LO period). (4 p)



4. A negative resistance cross-coupled LC oscillator, used for carrier generation in a GSM downlink transmitter for the 925-960 MHz band, is shown in the figure to the right. The RFIC-designer has already designed an on-chip spiral inductor with L_{tank}=1.25 nH.



a. Calculate C_{tank} so that the oscillation frequency will appear in the middle of the desired frequency band. No losses in L or C are included in the calculations (1 p).

b. To cover the full frequency band, the RFIC-designer would like to use a varactor, replacing the C_{tank} in the schematic with a Cvar, a varactor with a tuning range from C_{min} to C_{max}.

Calculate the tuning range using the (slightly modified) Equation 8.53 from the book:

$$\Delta\omega_{osc} \approx \frac{1}{\sqrt{LC}} \frac{C_{max} - C_{min}}{2C}$$

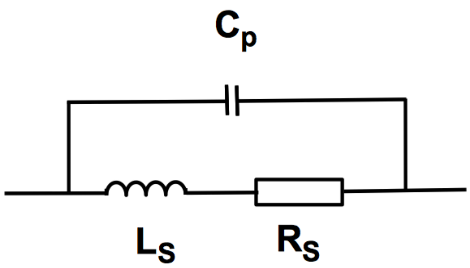
Is the required tuning range (express it in %!) possible to achieve with a conventional CMOS varactor? What do you think? (1 p)

c. Now we need to add losses! The capacitor C_{tank} is practically lossless but for the inductor, the RFIC designer uses the loss model in the figure below with an estimated R_s=1 Ohm, C_p=0.5 pF (metal-to-metal cap of the spiral layout), and using the previous value of L_{tank} as L_s.

   What is the oscillation frequency with added inductor losses? (1p)

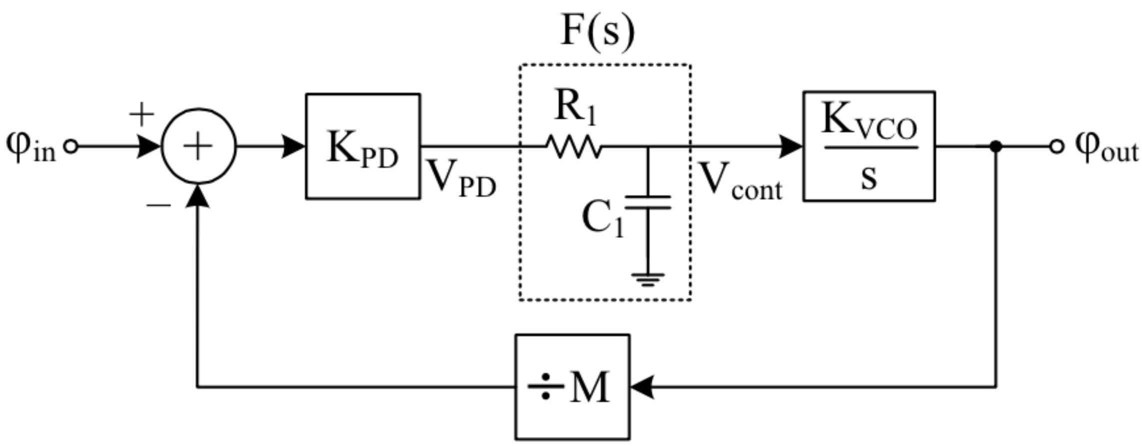
   What is the required negative resistance M1 and M2 have to provide, to have the circuit to oscillate? (0.5 p)

   Hints: $Q = \omega_0 L_s / R_s$, $L_p = (1 + 1/Q^2) * L_s$, $R_p = (Q^2 + 1) * R_s$



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. The following table lists two 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. (0.5 p for each correctly identified class => 2.5 p)

Maximum drain efficiency [%]	100	100	78.5	50	100
Peak drain voltage [*Vdd]	1	2	2	2	3.6
Power Amplifier Class					