EXAMINATION IN

TSEK03

RADIO FREQUENCY INTEGRATED CIRCUITS

Date:	2017-08-26
Time:	8-12
Location:	TER3
Tools:	Calculator, Dictionary
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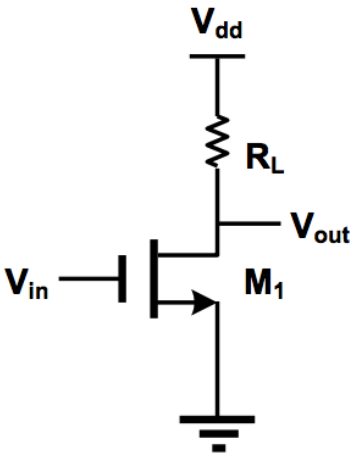
12 points are required to pass.
(12-15: 3, 16-19: 4, 20-24: 5)

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)



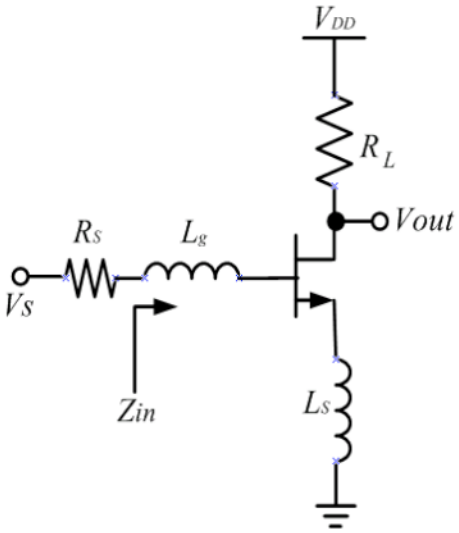
b. Now also add the effect of flicker noise. (1 p)
Hint: It can be model it as another current source in the transistor channel as:

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

c. Explain ”Friis’ equation” in words! What is the practical implication for the noise in a receiver chain ? (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.

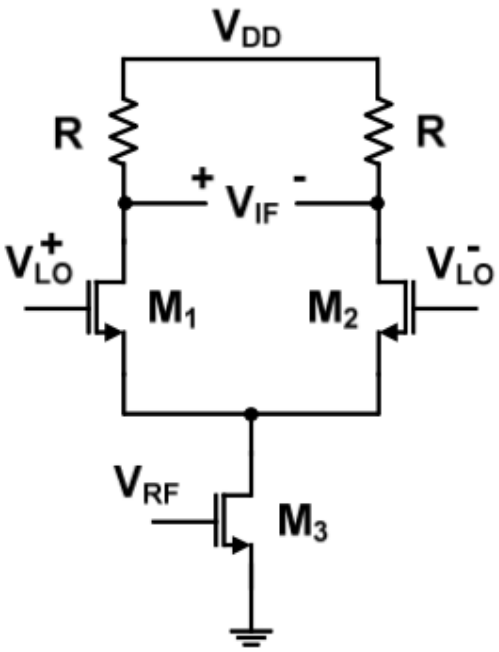


a. Calculate the input impedance. (3 p)

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

3.

A single-balanced mixer is shown below. Assume that the switching transistors M_1 and M_2 are ideal switches with zero on-resistance and there is no CLM.



a. Derive an expression for the conversion gain of this mixer. (2 p)

b. Derive an expression for the noise factor of this mixer. (3 p)

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 (not shown in the figure). Consider only the thermal noise sources and ignore the gate noise of the transistor.

Hints:

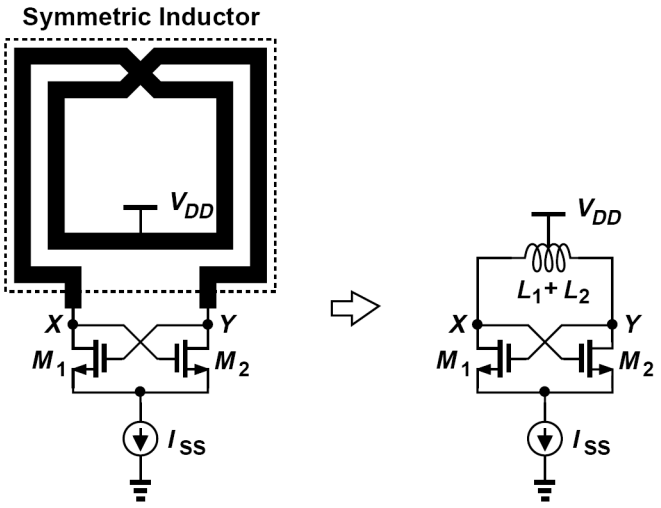
i) $\overline{i_{n,M}^2} = 4kT\gamma g_m$

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

4.

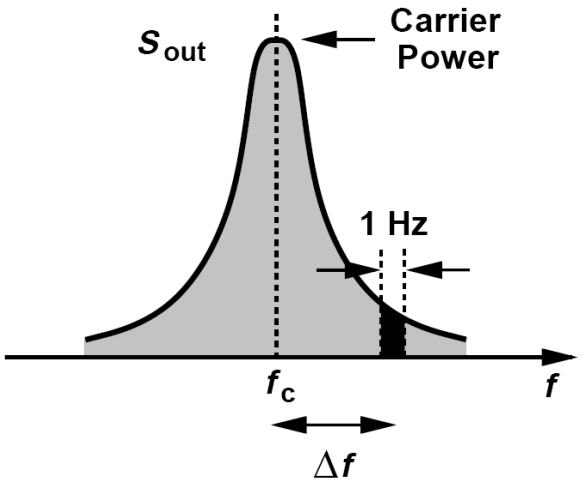
The symmetric inductor in the figure below has a value of 2 nH (from port X to port Y) and a Q of 5 at 2.45 GHz. $M_1 = M_2$.

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



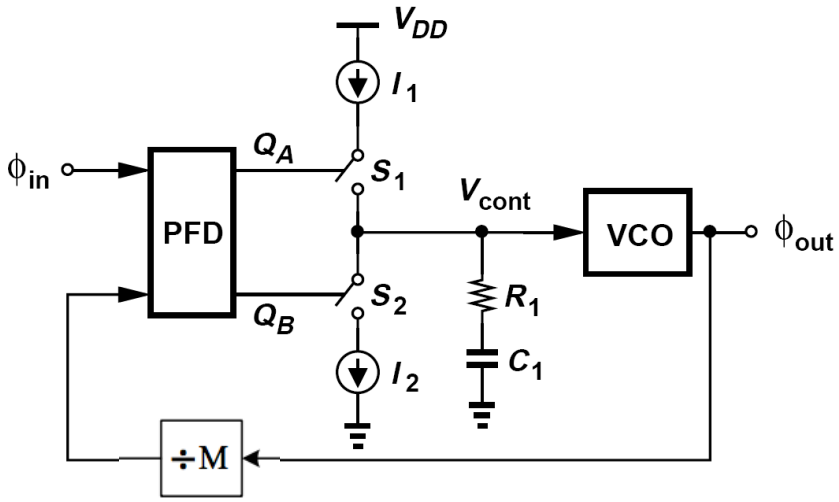
startup? (2 p)

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.

Derive an expression for the closed-loop phase transfer function, $H(s) = \Phi_{out}(s)/\Phi_{in}(s)$, of the CP-PLL shown below. The transfer function of the VCO is K_{VCO}/s and the transfer function of the PFD/CP is $I_0/(2\pi)$ (I_o is the charge pump current). (4 p)



6.

Please answer the following power amplifier questions and with (short) motivations for your answers.

a. Best class for linearity? AB or B? (0.5 p)
b. Best class for linearity? AB or D (inverter-based class-D)? (0.5 p)
c. Best class for efficiency? AB or C? (0.5 p)
d. Best class for lowest voltage peaks? AB or E? (0.5 p)

Please give short motivations for your answers.