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EXAMINATION IN
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TSEK03/TEN1
RADIO FREQUENCY INTEGRATED CIRCUITS

Date:	2012-05-24
Time:	14-18
Location:	Kåra
Aids:	Calculator, Dictionary
Teachers:	Behzad Mesgarzadeh (5719)
	Amin Ojani (2815)

5 problems give totally 24 points. 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) Fig. 1 shows a two-stage amplifier schematic. Determine the noise factor of this amplifier. Consider only the thermal noise sources and ignore the gate noise of the transistors. Ignore all the parasitics and assume that the transistors are long-channel devices and $\lambda_n = 0$.

(5 p)

Hint: $\overline{i^2_{n,M}} = 4kT\gamma g_m \Delta f$

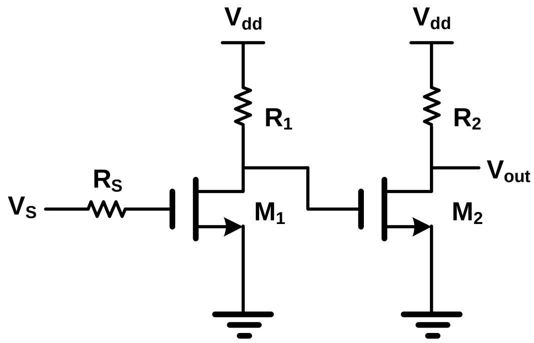


Fig. 1. A two-stage amplifier schematic.

2) A low noise amplifier (LNA) is shown in Fig. 2. R_S is the input source resistance. Assume that the transistor is a long-channel device and $\lambda = 0$. Furthermore, assume that the transconductance of M_1 is g_{m1}.

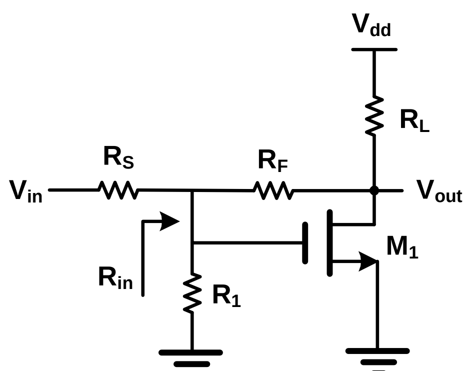


Fig. 2. A low-nose amplifier (LNA).

(a) Derive an expression for the input impedance (R_{in}) of the LNA. (2 p)

(b) Derive an expression for the output noise contributed by the drain noise of the transistor M_1. Consider only the thermal noise and ignore all of the prasictics. (3 p)

Hint: For a long-channel transistor: $\overline{i^2_{n,M}} = 4kT\gamma g_m \Delta f$

3) Prove that in a square-law mixer the conversion gain is $c_2 v_{LO}$, where c_2 is the coefficient of the second-order term in input/output nonlinear characteristic and v_{LO} is the amplitude of the LO signal. (4 p)

4) A parallel LC tank is shown in Fig. 3. Assume that all components are ideal.

(a) Determine the transfer function of the tank in the frequency domain (i.e., $\frac{V_{out}}{I_{in}}(\omega)$) and the oscillation frequency. (2 p)

(b) Determine the quality factor of the tank with respect to R, C, and L. As hint, you can consider that the quality factor is defined as $Q = \frac{\omega_0}{2} \frac{d\Phi}{d\omega}\Big|_{\omega = \omega_0}$, where ω_0 is the oscillation frequency of the tank, and Φ is the phase of the open-loop transfer function. (3 p)

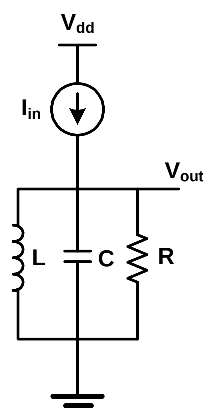


Fig. 3. A parallel LC tank.

5) The block diagram of a first-order PLL system is shown in Fig. 4, where $H(s) = K_D$ which is a constant value.

(a) Determine the transfer function of the PLL (ϕ_{out}/ϕ_{in}) and its closed-loop bandwidth. (2 p)

(b) If we apply a unit step function in the input phase of the PLL, determine the required time for the output phase to settle within 5% of its final value. Laplace transform of a unit step function is $1/s$. (3 p)

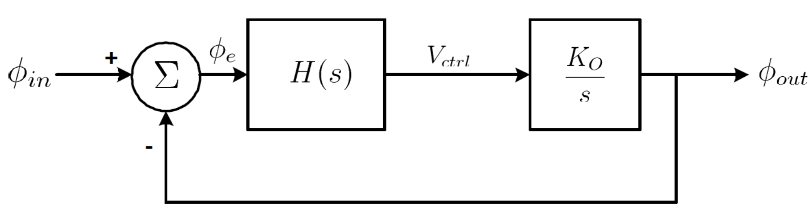
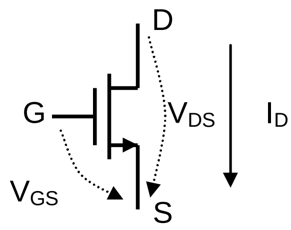


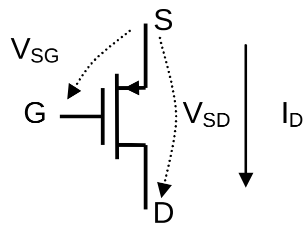
Fig. 4. Block diagram of a first-order PLL.

TRANSISTOR EQUATIONS

NMOS



PMOS



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 $(V_{SD} > V_{SG} - |V_{TP}|)$