Low-power radio design for the IoT
Exercise 5 (25.03.2021)

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Problem 1 Common Source Analysis

The circuit in the Figure below is a single MOSFET Common Source (CS) Amplifier.

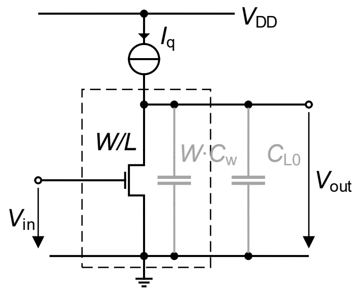

Figure 1: Common Source Amplifier.

- Draw the small-signal equivalent circuit of the CS. Consider the bias current source to be ideal. (*Hint*: split the gate capacitance, C_G, into the intrinsic and the extrinsic parts, C_{Gi} and C_{Ge}, and the load capacitance, C_L, into a constant capacitance and a self-loading capacitance per unit width, C_{L0} and C_w, respectively).
- Derive the expression of the transit frequency, ω_t, by using the small signal equivalent circuit.
- Express ω_t in terms of the inversion coefficient, IC. (*Hint*: introduce the specific frequency, $\omega_{spec} \triangleq \frac{2\mu U_T}{L^2}$, and neglect the velocity saturation ($\lambda_c = 0$)).
- Derive ω_{tspec}, the transit frequency for $IC = 1$ and WI.
- Derive the expression for the unity-gain frequency, ω_u. (*Hint*: neglect the output conductance of the transistor ($g_{ds} = 0$)).
- Express ω_u in terms of the normalized gain-bandwidth (GBW) for a squared transistor biased in WI, $\omega_L \triangleq \frac{I_{spec\square}}{nU_T C_L}$, and the normalized source transconductance, g_{ms}.

Problem 2 Common Source Design

Once the self loading capacitance per unit width is taken into account, the formulas for the I_D and W/L normalized to $\Omega \triangleq \frac{\omega_u}{\omega_L}$ are

$$\begin{aligned} i_b &\triangleq \frac{I_D}{I_{spec\square}} \cdot \frac{1}{\Omega} = \frac{IC}{g_{ms} - \Theta}; \\ AR &\triangleq \frac{W}{L} \cdot \frac{1}{\Omega} = \frac{1}{g_{ms} - \Theta}, \end{aligned} \tag{1}$$

where Θ is equal to $\frac{C_w L}{C_{L0}} \cdot \frac{\omega_u}{\omega_L} = \frac{\omega_u}{\omega_{tspec}}$. Design the CS amplifier, shown in Fig. 1, for the following specifications at room temperature:

$$f_u = 18\,\text{MHz} \quad C_{L0} = 60\,\text{fF} \quad V_{DD} = 1.8\,\text{V} \quad L = 40\,\text{nm} \quad C_w = 0.450\,\text{fF/nm}, \tag{2}$$

and by assuming the following values for the technology parameters

$$I_{spec\square} = 950\,\text{nA} \quad n = 1.5 \quad V_{T0} = 455\,\text{mV} \quad \lambda_c = 0.4875 \quad L_{sat} = 19.5\,\text{nm}. \tag{3}$$

- Find the IC_{opt}, the value of the inversion coefficient for which the bias current is minimum. Assume no velocity saturation.
- Based on the IC_{opt}, find the values of the bias current, I_q, and the transistor aspect ratio, W/L, to achieve the specified gian-bandwidth, w_u.