EE140/240A Problem Set 5

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For all the problems in this homework, assume $\mu_n C_{ox} = 0.5\text{mA/V}^2$, $V_{Tn} = 0.3\text{V}$, for the NMOS transistors. Also, assume that the channel length modulation parameter $\lambda = 0$, unless otherwise mentioned. Numbers adjacent to the MOS transistors indicate the (W/L) ratio of the transistors.

Problem 1. In lecture, we saw how to come up with a current mirror with higher accuracy and output resistance (Fig. 1). Here, we see another way of generating the bias voltage V_{b2} required for this current mirror.

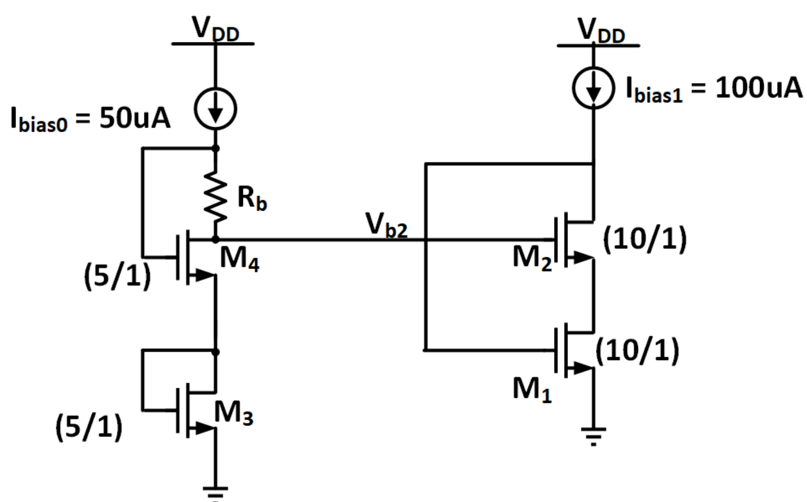

Figure 1: Problem 1

(a) What is the range of resistor values R_b for which all transistors remain in saturation?

(b) Which transistor is at the edge of triode region at the lower end of the range? Which transistor is at the edge of triode region at the upper end of the range?

Problem 2. For the circuit in Fig. 2, assume $C_{gs} = 25\text{fF}$, $C_{gd} = 10\text{fF}$, $C_{db} = 10\text{fF}$. In lecture, we saw that a common source amplifier had a response of the form

$$\frac{v_{out}}{v_{in}}(s) = A\frac{1 - \frac{s}{\omega_z}}{1 + as + bs^2} \tag{1}$$

Under certain conditions and at low enough frequencies, we saw that we

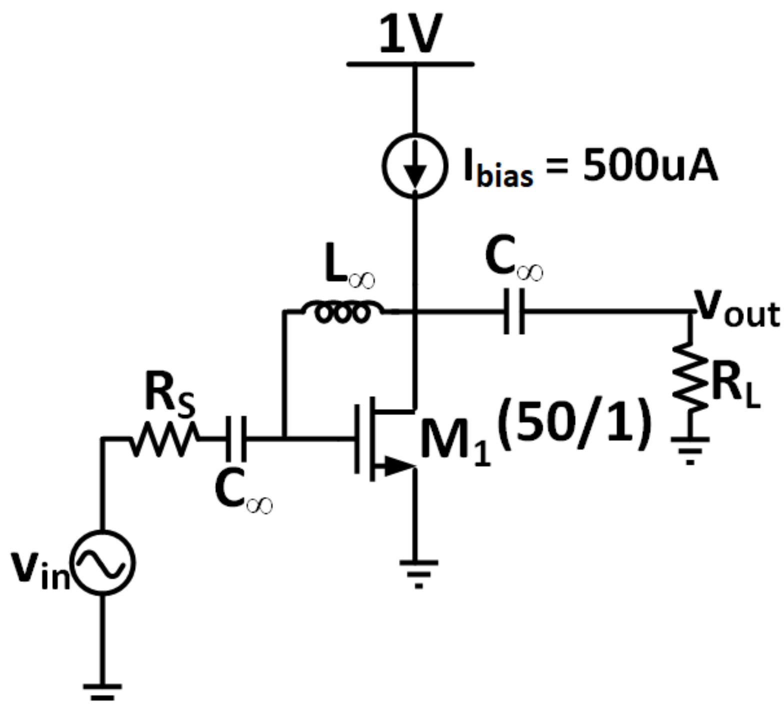

Figure 2: Problem 2

could approximate the response as,

$$\frac{v_{out}}{v_{in}}(s) \approx A\frac{1 - \frac{s}{\omega_z}}{1 + as} \tag{2}$$

(a) In this part, assume $R_S = 2\text{k}\Omega$, $R_L = 400\Omega$, and $\lambda = 0$. Compute the full frequency response of the form equation (1), and the approximate frequency response of the form equation (2). You may use any method taught in lecture to compute the approximate frequency response.

(b) Compute the 3-dB bandwidth from both the accurate response (you may use any computational tool for this) and the approximate response. Which time constant dominates the frequency response?

(c) In this part and the subsequent part, assume $R_S = 2\text{k}\Omega$, $R_L = \infty$, and $\lambda = 0.1$. Compute the full frequency response of the form equation (1), and the approximate frequency response of the form equation (2). You may use any method taught in lecture to compute the approximate frequency response.

(d) Compute the 3-dB bandwidth from both the accurate response (you may use any computational tool for this) and the approximate response. Which time constant dominates the frequency response?

(e) Comment on the Miller effect and the location of the zero frequency in both the cases.

Problem 3. In this problem, you will be introduced to the concept of transit frequency (f_T) of a transistor. Transit frequency is a figure of merit quantifying the intrinsic speed of a transistor. Transit frequency f_T is defined as the frequency at which the magnitude of the current gain of the transistor becomes unity. The current gain $H_i(s)$ is defined as the ratio of the small-signal output short circuit current to the small-signal input current of the transistor.

$$H_i(s) = \frac{i_{out}(s)}{i_{in}(s)} \tag{3}$$

Assume that the transistor is biased in the saturation region of operation.

(a) Compute the f_T symbolically in terms of g_m, C_{gs}, C_{gd}, C_{db} and r_o.

(b) What is the expression for f_T when $C_{gd} \ll C_{gs}$.

(c) Under this assumption, write out the expression for f_T in terms of the channel length L, gate voltage V_G and threshold voltage V_T. What do you infer about the relationship between f_T and channel length L.

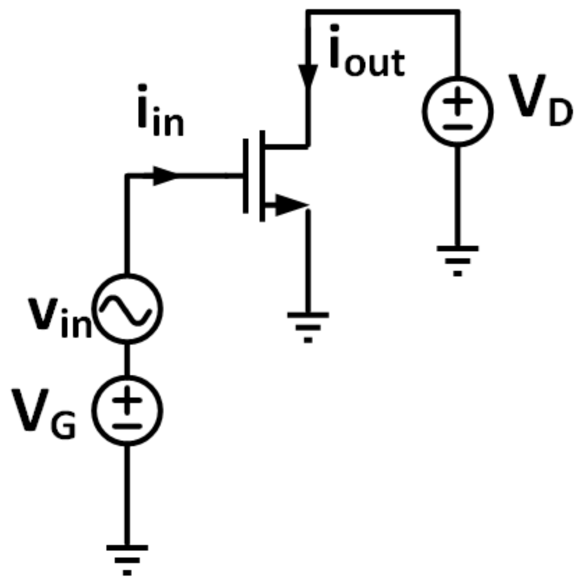

Figure 3: Problem 3

Problem 4. In this problem, you will analyze a circuit known as the continuous time linear equalizer (CTLE). Assume $R_A = 300k\Omega$, $R_B = 700k\Omega$, $R_S = 200\Omega$, $R_L = 400\Omega$, $C_2 = 25\text{fF}$, $C_3 = 1\text{pF}$. Ignore all other parasitic capacitances.

(a) Compute the full frequency response of the circuit shown in Fig. 4. How many poles and zeros are there in the transfer function?

(b) Plot the magnitude Bode response and mark the poles and zeros.

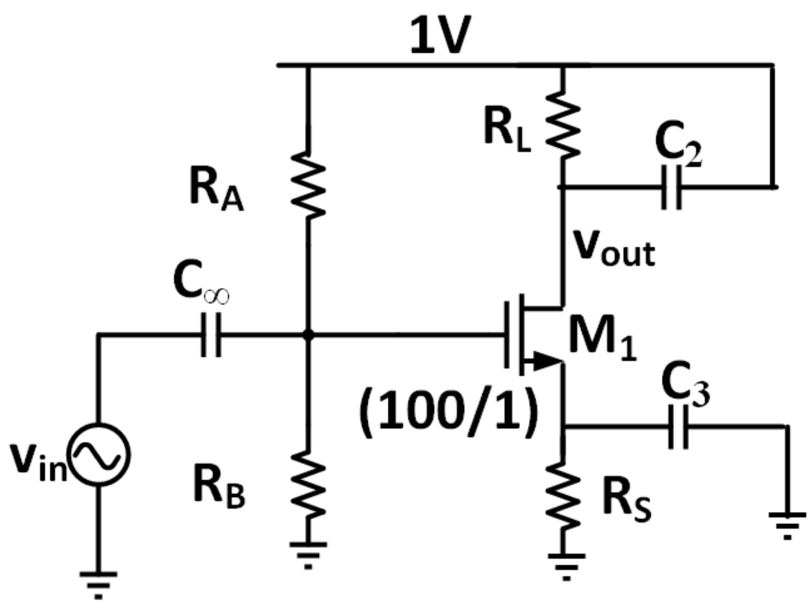

Figure 4: Problem 4