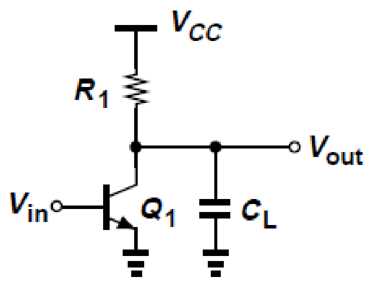
Problem Set 4: Frequency Response (Chapter 11)

Transfer function and frequency response:

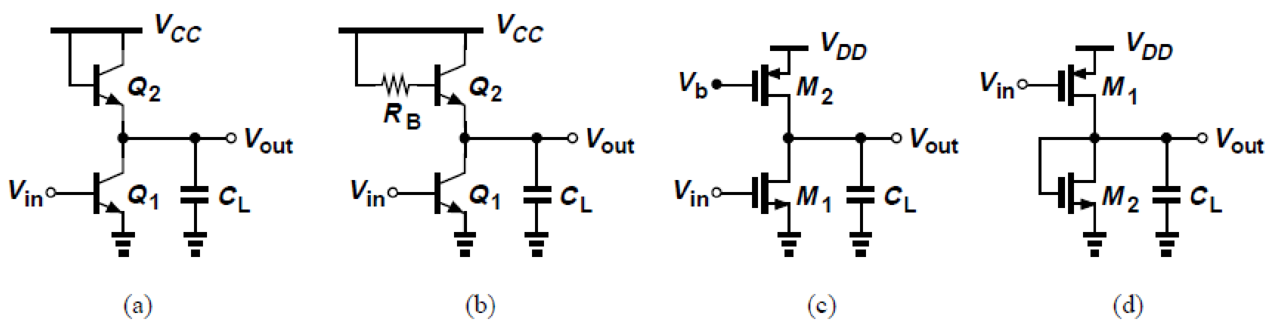
Problem 11.2

In the circuit of Fig. 11.61, we wish to achieve a −3-dB bandwidth of 1 GHz with a load capacitance of 2 pF. What is the maximum (low-frequency) gain that can be achieved with a power dissipation of 2 mW? Assume $V_{CC} = 2.5$ V and neglect the Early effect and other capacitances.



Problem 11.3 (a, c)

Determine the −3-dB bandwidth of the circuits shown in Fig. 11.62. Assume $V_A = \infty$ but $\lambda > 0$. Neglect other capacitances.



Bode Plot:

Problem 11.6

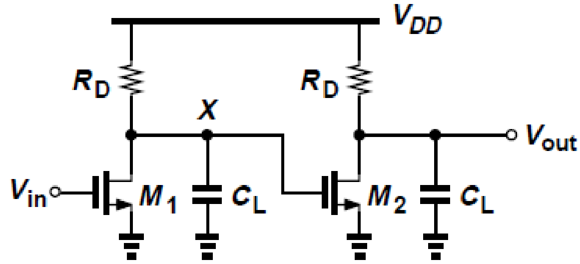
An amplifier exhibits two poles at 100 MHz and 10 GHz and a zero at 1 GHz. Construct the Bode plot of $|V_{out}/V_{in}|$.

Problem 11.7

An ideal integrator contains a pole at the origin, i.e., $\omega_p = 0$. Construct the Bode plot of $|V_{out}/V_{in}|$. What is the gain of the circuit at arbitrarily *low* frequencies?

Problem 11.9

Figure 11.63 illustrates a cascade of two identical CS stages. Neglecting channel-length modulation and other capacitances, construct the Bode plot of $|V_{out}/V_{in}|$. Note that $V_{out}/V_{in} = (V_X/V_{in})(V_{out}/V_X)$.

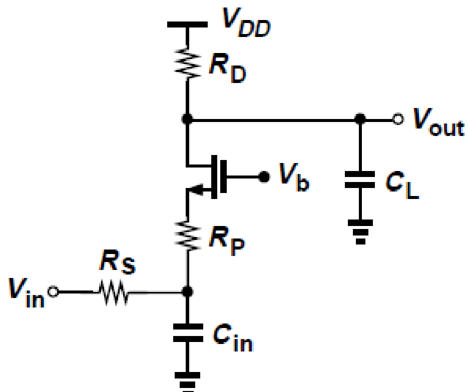


Problem 11.10

In Problem 9, derive the transfer function of the circuit, substitute $s = j\omega$, and obtain an expression for $|V_{out}/V_{in}|$. Determine the −3-dB bandwidth of the circuit.

Problem 11.12

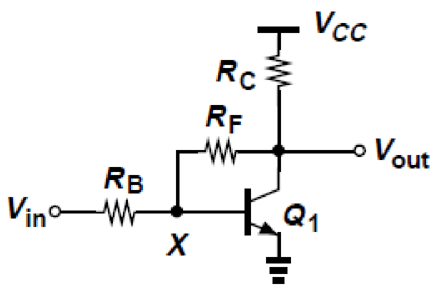
Due to a manufacturing error, a parasitic resistance R_p has appeared in series with the source of M_1 in Fig. 11.65. Assuming $\lambda = 0$ and neglecting other capacitances, determine the input and output poles of the circuit.



Miller theorem:

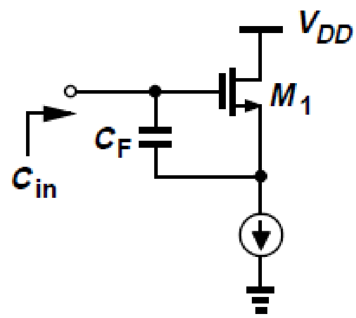
Problem 11.16

Apply Miller's theorem to resistor R_F in Fig. 11.68 and estimate the voltage gain of the circuit. Assume $V_A = \infty$ and R_F is large enough to allow the approximation $v_{out}/v_X = -g_m R_C$.



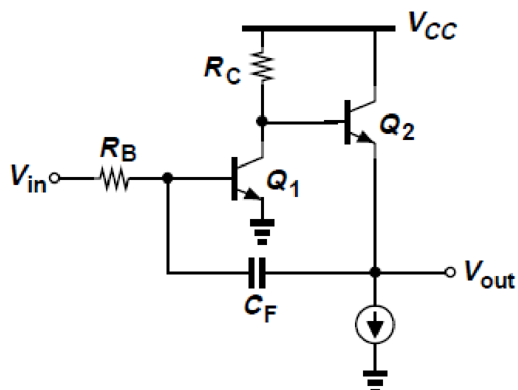
Problem 11.20

Using Miller's theorem, estimate the input capacitance of the circuit depicted in Fig. Assume $\lambda > 0$ but neglect other capacitances. What happens if $\lambda \to 0$?



Problem 11.23

Use Miller's theorem to estimate the input and output poles of the circuit shown in Fig. Assume $V_A = \infty$ and neglect other capacitances.

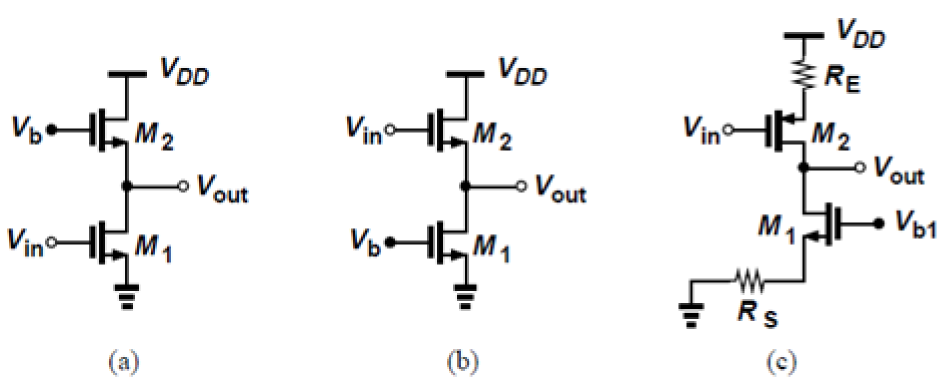


High frequency model of MOS transistor:

Problem 11.25 (a)

For the MOS circuits shown in Fig. 11.77, identify all of the transistor capacitances and determine which ones are in parallel and which ones are grounded on both ends.

Find the value of C_{gs} and C_{gd} if C_{ox}=10fF/µm^2 C_{ov}=1fF/µm, $(W/L)_1=(W/L)_2$=100µm/1µm?



Problem 11.26

The transit frequency f_T of a transistor is defined as the frequency where the current gain is equal to unity (i_{out} is measured when V_{out}=0).

Show that: $f_T = \frac{g_m}{2\pi C_{gs}}$; consider C_{gs} only in the small-signal model.

Problem 11.28

It can be shown that $C_{GS} \approx (2/3)WLC_{ox}$ for a MOSFET operating in saturation. Using Eq. (11.49), prove that $2\pi f_T = \frac{3}{2}\frac{\mu_n}{L^2}(V_{GS} - V_{TH})$.

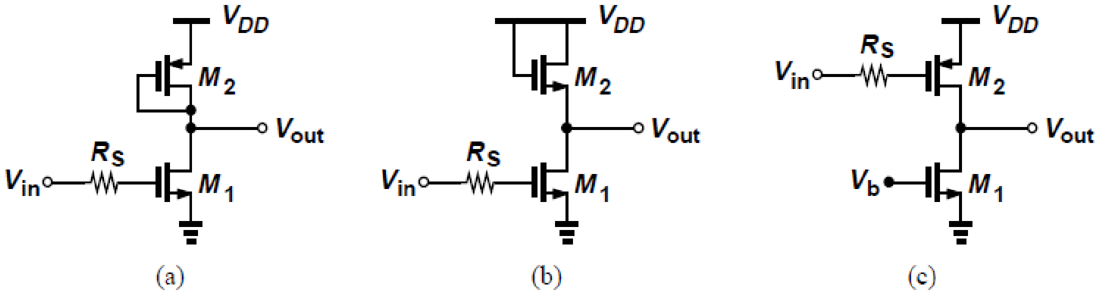
Problem 11.34

We wish to halve the overdrive voltage of a transistor so as to provide a greater voltage headroom in a circuit. Determine the change in the f_T if (a) I_D is constant and W is increased, or (b) W is constant and I_D is decreased. Assume L is constant.

Frequency response of CS stage:

Problem 11.38 (a)

Assuming $\lambda > 0$ and using Miller's theorem, determine the input and output poles of the stages depicted in Fig. 11.80.

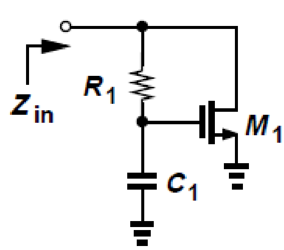


Problem 11.39 (neglect C_{DB})

In the CS stage of Fig. 11.29(a), $R_S = 200\ \Omega$, $R_D = 1\ \text{k}\Omega$, $I_{D1} = 1$ mA, $C_{GS} = 50$ fF, $C_{GD} = 10$ fF, $C_{DB} = 15$ fF, and $V_{GS} - V_{TH} = 200$ mV. Determine the poles of the circuit using (a) Miller's approximation, and (b) the transfer function given by Eq. (11.70). Compare the results.

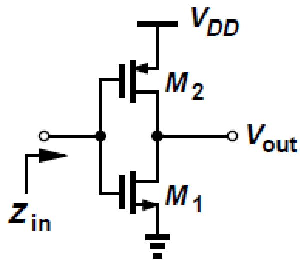
Problem 11.42

The circuit depicted in Fig. 11.82 is called an "active inductor." Neglecting other capacitances and assuming $\lambda = 0$, compute Z_{in}. Use Bode's rule to plot $|Z_{in}|$ as a function of frequency and explain why it exhibits inductive behavior.



Problem 11.45

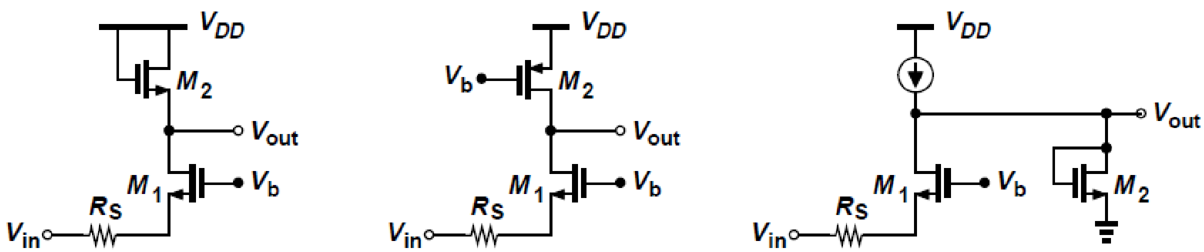
Calculate the input impedance of the stage illustrated in Fig. 11.85 without using Miller's theorem. Assume $\lambda = 0$.



Frequency response of CG stage & CD stage:

Problem 11.46 (b) with added AC coupling cap in series with Rs

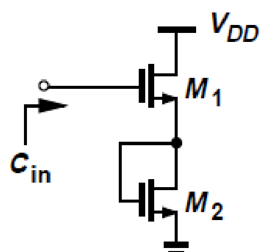
Determine the transfer function of the circuits shown in Fig. 11.86. Assume $\lambda = 0$ for M_1.



(a) (b) (c)

Problem 11.47

Consider the source follower shown in Fig. 11.87, where the current source is mistakenly replaced with a diode-connected device. Taking into account only C_{GS1}, compute the input capacitance of the circuit. Assume $\lambda \neq 0$.



Problem 11.57

An NMOS source follower must drive a load resistance of 100 Ω with a voltage gain of 0.8. If $I_D = 1$ mA, $\mu_n C_{ox} = 100\ \mu\text{A/V}^2$, $C_{ox} = 12\ \text{fF}/\mu\text{m}^2$, and $L = 0.18\ \mu$m, what is the minimum input capacitance that can be achieved? Assume $\lambda = 0$, $C_{GD} \approx 0$, $C_{SB} \approx 0$, and $C_{GS} = (2/3)WLC_{ox}$.