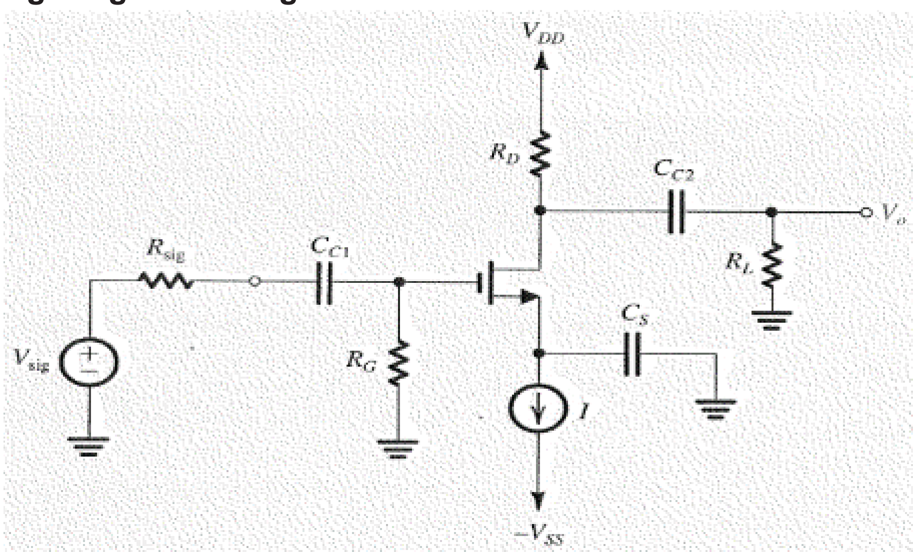
# ECE 523/421 - Analog Electronics:
# University of New Mexico

**Problem 10.6**
**Figure P10.6 shows a CS amplifier biased by a constant-current source I. Let Rsig= 0.5 MΩ, RG = 2 MΩ, gm= 3 mA/V, RD= 20 kΩ, and RL= 10 kΩ. Find AM. Also, design the coupling and bypass capacitors to locate the three low-frequency poles at 100 Hz, 10 Hz, and 1 Hz. Use a minimum total capacitance, with the capacitors specified only to a single significant digit. What value of fL results?**




Finding $A_m$

$$A_m = -\left(\frac{R_g}{R_{sig} + R_g}\right) g_m(R_D||R_L)$$

$$A_m = -\left(\frac{2M}{0.5M + 2M}\right) 3\, {}^{mA}/_{V}\, (20k||10k)$$

$$A_m = -16$$

Finding the capacitances

$$f_{lp1} = \frac{1}{2\pi(R_{sig} + R_g)C_{C1}} = \frac{1}{2\pi(2.5M)C_{C1}}$$

$$C_{C1} = \frac{1}{2\pi(2.5M)1} = 63.7\, nF$$

$$f_{lp2} = \frac{1}{2\pi(R_D + R_L)C_{C2}} = \frac{1}{2\pi(30k)C_{C2}}$$

$$C_{C2} = \frac{1}{2\pi(30k)10} = 531\ nF$$

$$f_{lp3} = \frac{1}{2\pi\left(1/g_m\right)C_s}$$

$$C_s = \frac{1}{2\pi\left(1/_{3\ mA/V}\right)100} = 4.77\ \mu F$$

$$f_L = 100 + 10 + 1 = 111\ Hz$$

**Problem 10.52**

**An amplifier with a dc gain of 60 dB has a single-pole, high-frequency response with a 3-dB frequency of 100 kHz.**

**a) Give an expression for the gain function A(s).**

**b) Sketch Bode diagrams for the gain magnitude and phase.**

**c) What is the gain–bandwidth product?**

**d) What is the unity-gain frequency?**

**e) If a change in the amplifier circuit causes its transfer function to acquire another pole at 1 MHz, sketch the resulting gain magnitude and specify the unity-gain frequency. Note that this is an example of an amplifier with a unity-gain bandwidth that is different from its gain–bandwidth product.**

a) For the gain function

$$A(s) = \frac{A_m}{1 + \frac{s}{w_H}}$$

$$60\ dB = 20 \log A_m$$

$$A_m = 1000$$

$$f_H = \frac{1}{2\pi CR}$$

$$w_H = \frac{1}{CR} = 2x10^5\pi$$

$$A(s) = \frac{1000}{1 + \frac{s}{2\pi\ x\ 100kHz}}$$

c) Gain-Bandwidth

$$GBW = f_T = 1000\ x\ 100\ kHz$$

$$GBW = 100\ MHz$$

d) Unity-gain frequency

$$f_T = 1000\ x\ 100\ kHz$$

$$Unity\ gain\ frequency\ f_T = 100\ MHz$$

**Problem 10.94**

**For the current mirror in Fig. P10.94, derive an expression for the current transfer function Io(s)/Ii(s) taking into account the BJT internal capacitances and neglecting rx and ro. Assume the BJTs to be identical. Observe that a signal ground appears at the collector of Q2. If the mirror is biased at 1 mA and the BJTs at this operating point are characterized by fT= 500 MHz, Cμ= 2 pF, and β0= 100, find the frequencies of the pole and zero of the transfer function.**

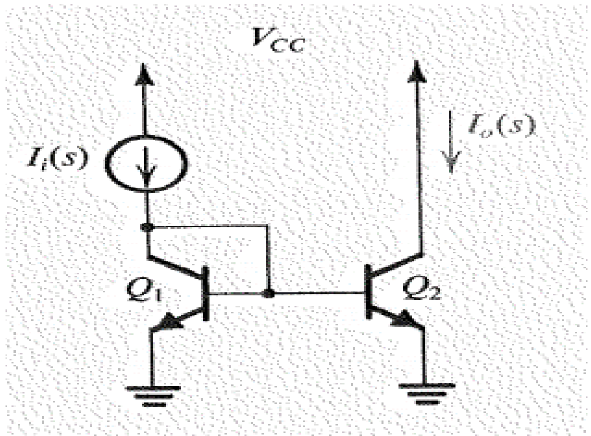



Figure P10.94

From the small signal model

$$V_\pi = \frac{I_i(s)}{\left(\frac{1}{r_{\Pi1}} + g_{m1} + \frac{1}{r_{\Pi2}}\right) + s\left(C_{\Pi1} + C_{\Pi2} + C_{\mu2}\right)}$$

$$I_o(s) = g_{m2}V_\pi - sC_{\mu2}V_\pi$$

$$\frac{I_o(s)}{I_i(s)} = \frac{g_{m2} - sC_{\mu2}}{\left(\frac{1}{r_{\Pi1}} + g_{m1} + \frac{1}{r_{\Pi2}}\right) + s\left(C_{\Pi1} + C_{\Pi2} + C_{\mu2}\right)}$$

Frequency of the zero

$$g_{m2} - sC_{\mu2} = 0$$

$$f_{pz} = \frac{g_{m2}}{2\pi C_{\mu2}}$$

$$g_{m2} = \frac{I_C}{V_t} = 40\, {}^{mA}/_{V}$$

$$r_\pi = \frac{\beta}{g_{m2}} = 2.5\ k\Omega$$

$$f_{pz} = \frac{40\, {}^{mA}/_{V}}{2\pi(2x10^{-12})} = 3.18\ GHz$$

$$f_T = \frac{g_m}{2\pi\left(C_\Pi + C_\mu\right)}$$
$$C_\Pi = 10.7\ pF$$

Pole

$$\left(\frac{1}{r_{\Pi 1}} + \frac{1}{r_{\Pi 2}}\right) + s\left(C_{\Pi 1} + C_{\Pi 2} + C_{\mu 2}\right) = 0$$
$$f_p = \frac{\frac{2}{r_\pi} + g_m}{2\pi\left(C_{\Pi 1} + C_{\Pi 2} + C_{\mu 2}\right)}$$
$$f_p = \frac{\frac{2}{2500} + 40\ {}^{mA}\!/_{V}}{2\pi(10.7 + 10.7 + 2)x10^{-12}}$$
$$f_p = 277.5\ MHz$$

**Problem 10.106**

**Figure P10.106 shows an amplifier formed by cascading two CS stages. Note that the input bias voltage is not shown. Each of *Q*1 and *Q*2 is operated at an overdrive voltage of 0.2 V, and |*VA*| =10 V. The transistor capacitances are as follows: *Cgs* = 20 fF, *Cgd*= 5 fF, and *Cdb*= 5 fF. The signal-source resistance *R*sig = 10 kΩ.**

**a) Find the dc voltage gain.**

**b) Use the method of open-circuit time constants to determine an estimate for the 3-dB frequency *fH*.**

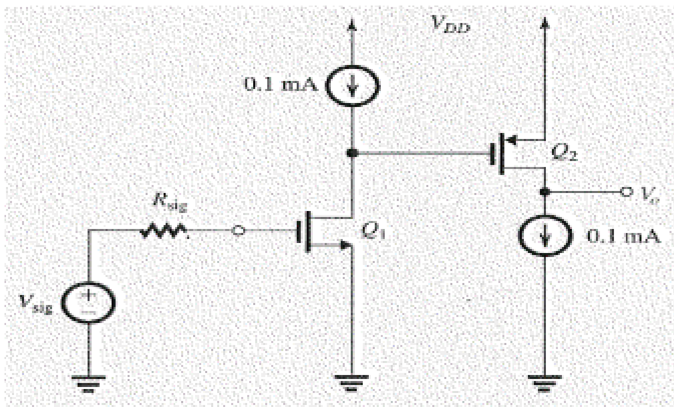


Figure P10.106

a) DC voltage gain

$$g_{m1} = g_{m2} = \frac{2\, I_D}{V_{OV}} = 1\, {}^{mA}/_{V}$$

$$r_{o1} = r_{o2} = \frac{V_A}{I_D} = 100\ k\Omega$$

$$\frac{v_o}{v_{sig}} = g_{m1} r_{o1}\ x\ g_{m2} r_{o2}$$

$$\frac{v_o}{v_{sig}} = 10000$$

b) Finding the high frequency

$$f_{p1} = \frac{1}{2\pi[C_{\text{gs1}} + C_{\text{gd1}}(1 + g_{m1} r_{o1})]R_{sig}}$$

$$f_{p1} = 30.32\ MHz$$

$$f_{p2} = \frac{1}{2\pi[C_{\text{gd1}} + C_{\text{db1}} + C_{\text{gd2}}(1 + g_{m2} r_{o2}) + C_{\text{gs2}}]r_{o1}}$$

$$f_{p2} = 2.97\ MHz$$

$$f_{p3} = \frac{1}{2\pi[C_{\text{gd2}} + C_{\text{db2}}]r_{o2}}$$

$$f_{p3} = 159\ MHz$$

$$\frac{1}{f_H} = \frac{1}{f_{p1}} + \frac{1}{f_{p2}} + \frac{1}{f_{p3}}$$

$$f_H = 2.66\, MHz$$