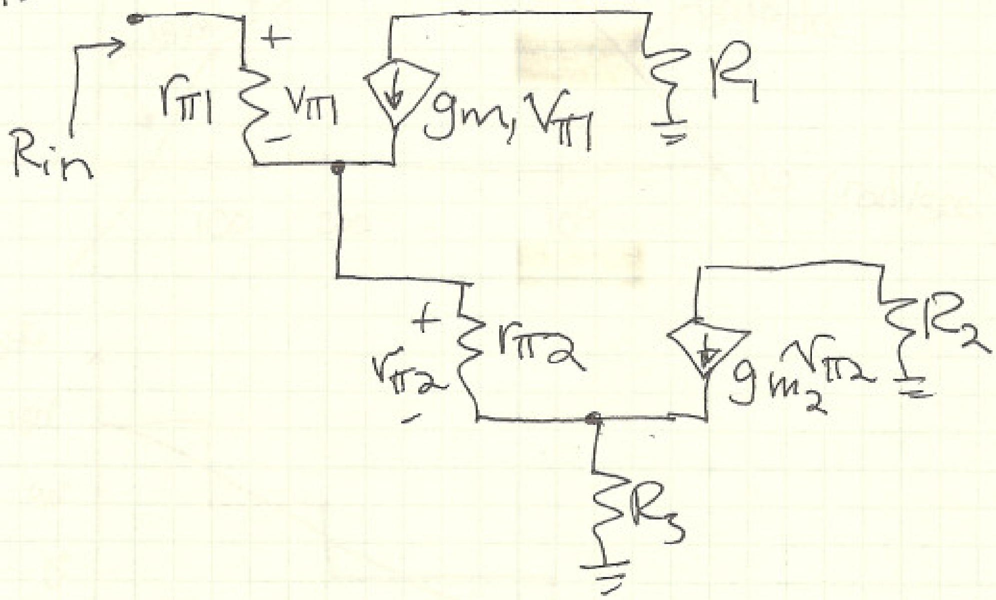
HW #4 sol'n

1.



$$\boxed{\begin{aligned} R_{in} &= r_{\pi 1} + r_{\pi 2}(\beta+1) + R_3(\beta+1)^2 \\ \text{or} \quad R_{in} &= (\beta+1)r_{e_1} + r_{e_2}(\beta+1)^2 + R_3(\beta+1)^2 \end{aligned}}$$

2. $$H(S) = \frac{10 \cdot \cancel{s} \cdot \cancel{s} \cdot 100 \cdot 200}{\cancel{\frac{s}{200}} \cdot \cancel{\frac{s}{100}}\left(1+\frac{100}{s}\right)\left(1+\frac{200}{s}\right)\left(\frac{s}{10^5}+1\right)}$$

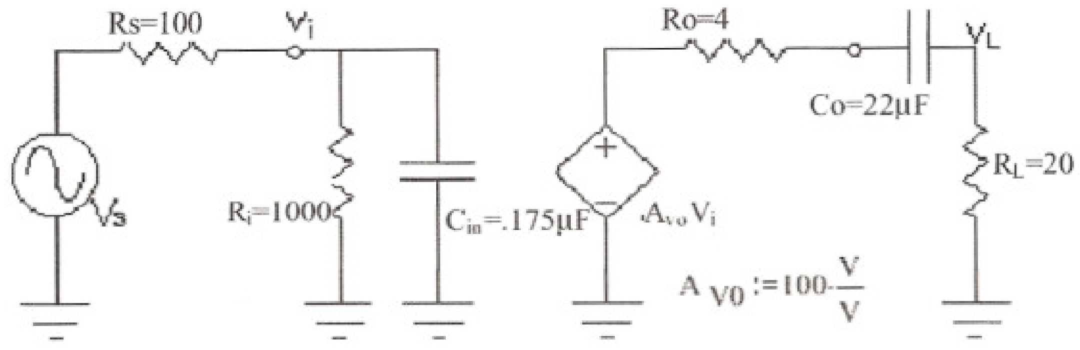
$$= \frac{200{,}000}{\left(1+\frac{100}{s}\right)\left(1+\frac{200}{s}\right)\left(\frac{s}{10^5}+1\right)}$$

pole frequencies: 100, 200 rad/sec.

zero frequencies: 2 at origin (0)

midband gain: (dB) $20 \log(200{,}000) = \boxed{106\,\text{dB}}$

3. Analyze the circuit below to find the overall gain: V_L/V_s. Sketch the Bode plots. Find
   - the midband gain A_M
   - the low-frequency 3-dB point $?_L$
   - the high-frequency 3-dB point $?_H$



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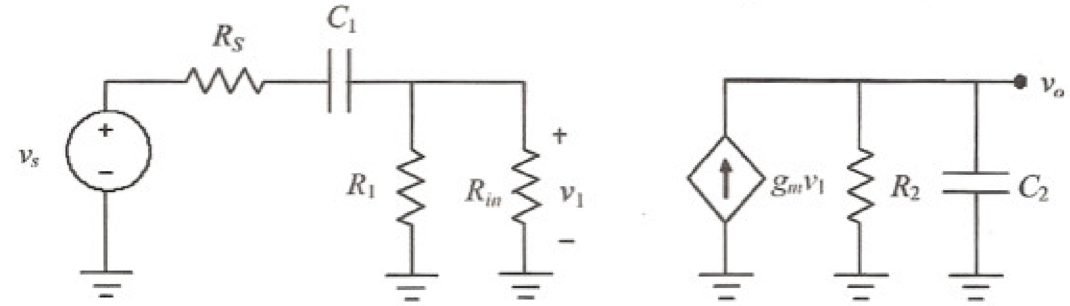
4. For the circuit shown below, derive symbolic expressions for:
   - the midband gain A_M
   - the low-frequency 3-dB point $?_L$
   - the high-frequency 3-dB point $?_H$

Next, state the actual value for all 3 expressions.

- Sketch the Bode magnitude plot
- State the phase angle at a very, very high frequency

To keep the expressions readable, express in parallel resistances as $(R_A \| R_B)$ for example, *not* $R_A R_B/(R_A + R_B)$.



Let g_m = 1mA/V, R_S=100, C_1=10μF, R_1=100kΩ, R_{in}=100kΩ, R_2=1kΩ, C_2=1μF.

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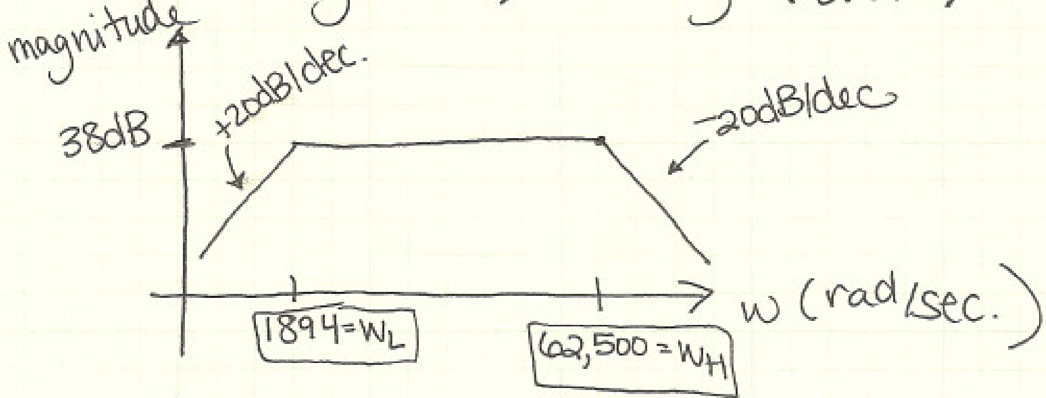
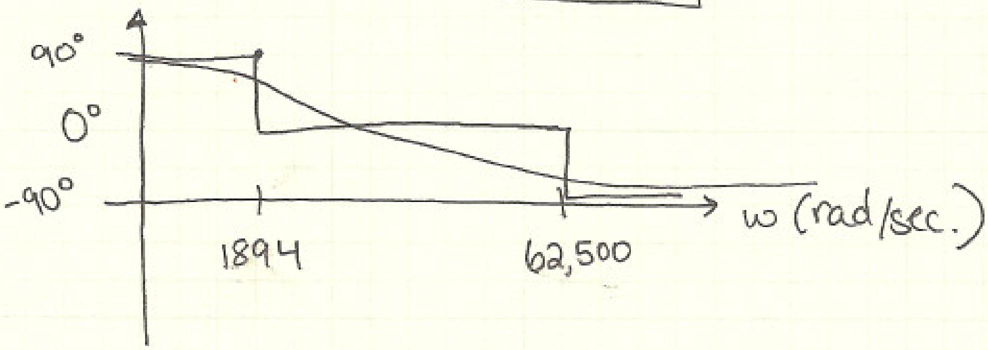
3. (cont.)

$$\frac{V_L}{V_s} = \frac{0.44 \cdot \cancel{s}}{\cancel{s} \cdot 5.81m\left(1+\frac{1}{528\mu \cdot s}\right)(1+16\mu \cdot s)}$$

poles $\Rightarrow$ 1894 , 62,500

midband gain $\Rightarrow 20 \log_{10}\left(\frac{0.44}{5.81m}\right) \approx 38dB$





- phase at midband ≈ 0°
- -90° at very high freq.

4. $$v_o = g_m v_1 \left(R_2 \parallel \frac{1}{C_2 \cdot s}\right) = g_m v_1 \frac{R_2 \cdot \frac{1}{C_2 \cdot s}}{R_2 + \frac{1}{C_2 s}} = \frac{g_m v_1 R_2}{R_2 \cdot C_2 \cdot s + 1}$$

$$v_1 = \left[\frac{v_s \left(R_1 \parallel R_{in}\right)}{\left(R_1 \parallel R_{in}\right) + R_s + \frac{1}{C_1 \cdot s}}\right] \cdot \frac{C_1 s}{C_1 s}$$

$$v_1 = \frac{v_s \left(R_1 \parallel R_{in}\right) \cdot C_1 \cdot s}{\left[\left(R_1 \parallel R_{in}\right) + R_s\right] \cdot C_1 \cdot s + 1}$$

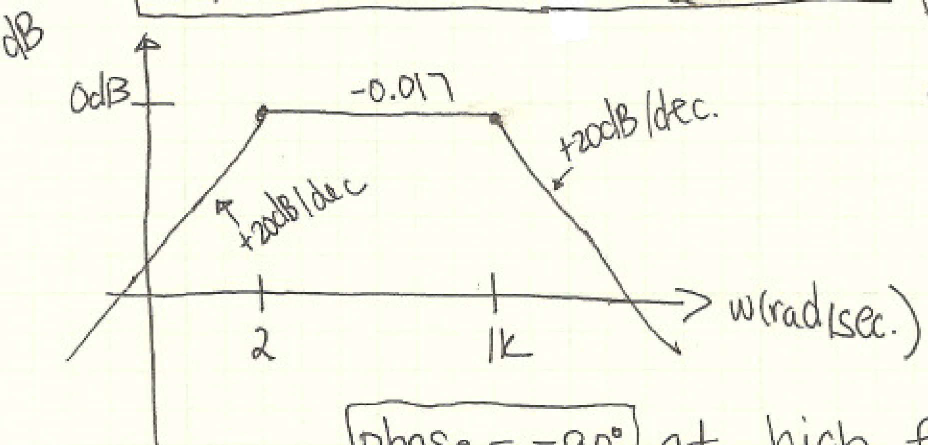
$$v_1 = \frac{v_s \left(R_1 \parallel R_{in}\right) \cancel{C_1} \cdot \cancel{s}}{\left[\left(R_1 \parallel R_{in}\right) + R_s\right] \cancel{C_1} \cancel{s} \left[1 + \frac{1}{\left[\left(R_1 \parallel R_{in}\right) + R_s\right] C_1 \cdot s}\right]}$$

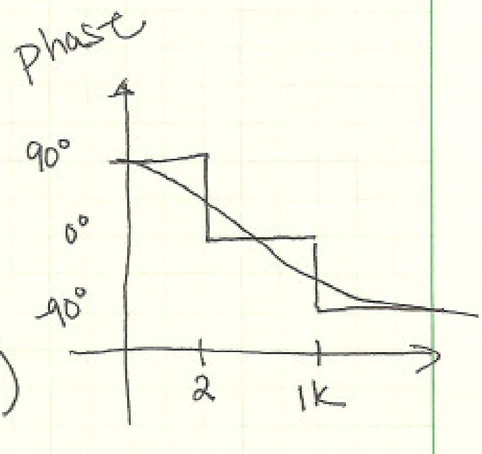
$$\frac{v_o}{v_s} = \frac{g_m R_2 \left(R_1 \parallel R_{in}\right) \cdot \cancel{v_s}}{\underbrace{\left(R_2 C_2 \cdot s + 1\right)}_{\text{High}} \underbrace{\left[1 + \frac{1}{\left[\left(R_1 \parallel R_{in}\right) + R_s\right] C_1 \cdot s}\right]}_{\text{Low}} \left[\left(R_1 \parallel R_{in}\right) + R_s\right]}$$

$$\text{midband gain} = 20 \log_{10}\left[\frac{g_m R_2 \left(R_1 \parallel R_{in}\right)}{\left(R_1 \parallel R_{in}\right) + R_s}\right]$$

$$= 20 \log_{10}\left[0.998\right] = \boxed{-0.017\,\text{dB}}$$

$$\boxed{\begin{aligned} \omega_L &\cong 2 \text{ rad/sec.} = \frac{1}{\left[\left(R_1 \parallel R_{in}\right) + R_s\right] C_1} \\ \omega_H &= 1\text{K rad/sec} = \frac{1}{R_2 C_2} \end{aligned}}$$





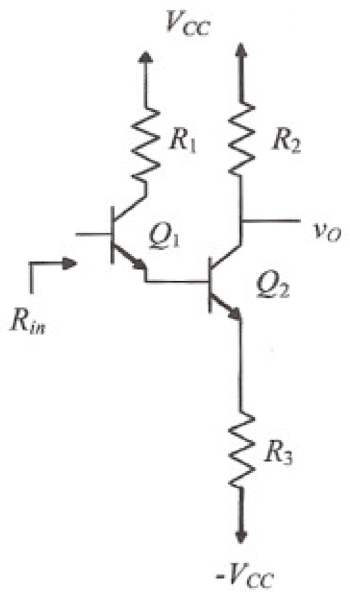
$\boxed{\text{phase} = -90°}$ at high freq.

ECE3110 **Homework #4** **Fall 2005**

(Due Sept. 21 by 6pm in homework locker)

1. Assume the transistors below have a finite β and an infinite Early voltage.

Write an expression for the input resistance R_{in} in the circuit shown below. Your expression should include *only* real resistances (R_1, R_2, R_3, or a subset of these) and possibly β, r_{e1}, and r_{e2}. (Assume both transistors have the same β.) Circle your answer. *Hint: Use Resistance-Reflection rule*



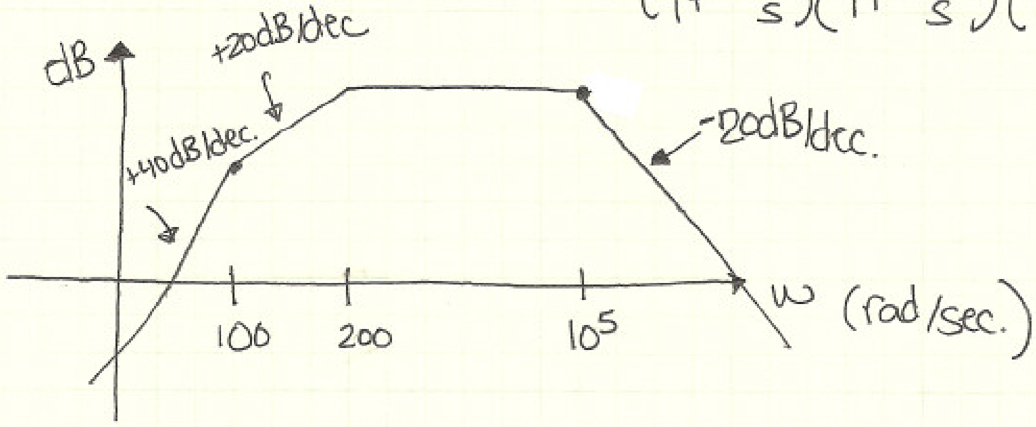
2. An amplifier has the following transfer function:

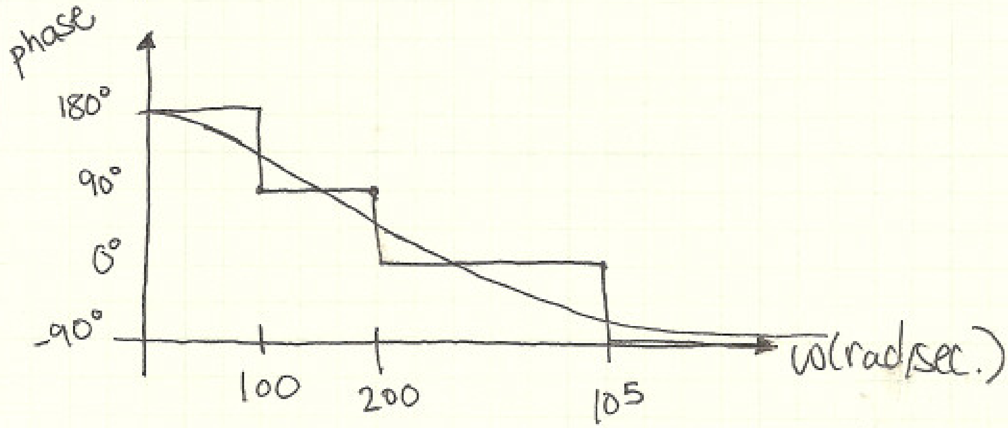
$$H(s) = \frac{10s^2}{(s/100+1)(s/200+1)(s/10^5+1)}$$

- List the pole frequencies
- List the zero frequencies
- State the midband gain <u>in dB</u>
- Sketch the Bode plots for this system, labeling frequencies, gains, and slopes of interest.

2. (cont.)

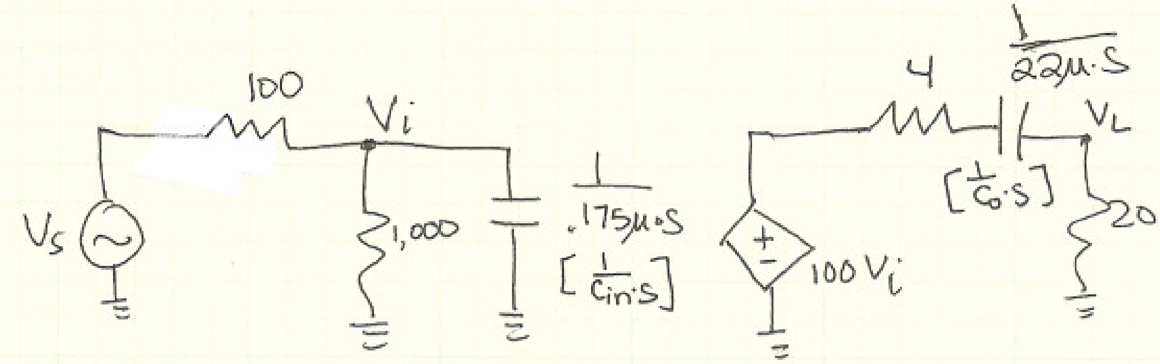
$$H(s) = \frac{200{,}000}{\left(1+\frac{100}{s}\right)\left(1+\frac{200}{s}\right)\left(\frac{s}{10^5}+1\right)}$$





· There is no phase shift during the midband gain. There is a −90° shift at high frequencies.

3.



$$V_L = \frac{20 \cdot 100 \cdot V_i}{20 + 4 + \frac{1}{C_o \cdot s}} = \frac{2000 \cdot 22\mu \cdot s \cdot V_i}{(24 \cdot 22\mu \cdot s + 1)}$$

$$V_L = \frac{44m \cdot s \cdot V_i}{528\mu \cdot s + 1}$$

$$V_i = \frac{[1{,}000 \,||\, \frac{1}{C_{in} \cdot s}] \cdot V_s}{[1{,}000 \,||\, \frac{1}{C_{in} \cdot s}] + 100}$$

$$[1{,}000 \,||\, C_{in} \cdot s] = \frac{[1{,}000 \cdot \frac{1}{C_{in} \cdot s}]}{(1{,}000 + \frac{1}{C_{in} \cdot s})} = \frac{C_{in} \cdot s \; 1{,}000 \frac{1}{C_{in} \cdot s}}{(1{,}000 \cdot C_{in} \cdot s + 1)}$$

$$V_i = \frac{\frac{1{,}000 \cdot V_s}{\cancel{(1{,}000 C_{in} \cdot s + 1)}}}{\frac{1{,}000 + 100(1{,}000 C_{in} \cdot s + 1)}{\cancel{(1{,}000 C_{in} \cdot s + 1)}}} = \frac{1{,}000 \cdot V_s}{1{,}000 + 100{,}000 C_{in} \cdot s + 100}$$

$$V_i = \frac{\cancel{100} \cdot 10 \cdot V_s}{\cancel{100}\,(11 + 1{,}000 C_{in} \cdot s)} = \frac{10 \cdot V_s}{(11 + 175\mu \cdot s)}$$

$$\frac{V_L}{V_s} = \frac{44m \cdot \cancel{V_s} \cdot 10 \cdot s}{(528\mu s + 1)(11 + 175\mu s)} = \frac{0.44 \cdot s}{528\mu \cdot s\,(1 + \frac{1}{528\mu \cdot s}) \cdot 11 \cdot (1 + \frac{175\mu \cdot s}{11})}$$

pole = 1894 pole ≅ 63K

∴ Low High