Electronics II, Midterm exam I, April 17, 2012 (100pts max)
Name:

I. (25 pts): HP and LP filter?

as $\omega \to 0$, L is a short $\to \frac{V_o}{V_i}$ finite
as $\omega \to \infty$, $sL \to \infty$ (open) $\to V_o = 0$ $\Rightarrow$ LP

- For the first order filter shown below, explain qualitatively (i.e., using the fact that an inductor behaves as a short at DC and as an open circuit at high frequency) if this is a low-pass or high-pass filter.
- Depending on your previous answer, put the transfer function of the filter T(s) = $V_0(s)/V_i(s)$ in the form

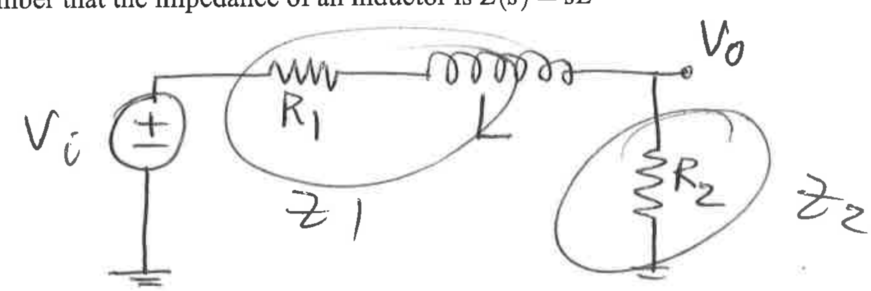
$$T(s) = \frac{K}{1+\frac{s}{\omega_0}} \tag{1}$$

or

$$T(s) = \frac{K}{1+\frac{\omega_0}{s}} \tag{2}$$

- Find the value of K by either calculating T(s=0) or T($s = \infty$) depending of your previous answer.
- Find an analytical expression for ω_0, the 3dB frequency of the filter.

Remember that the impedance of an inductor is $Z(s) = sL$



$$\frac{V_o}{V_i} = T(s) = \frac{Z_2}{Z_1+Z_2} = \frac{R_2}{R_2+R_1+sL} = \frac{R_2}{R_1+R_2} \cdot \frac{1}{\left[1+\frac{sL}{R_1+R_2}\right)}$$

$$= K \frac{1}{\left[1+\frac{s}{\omega_0}\right)}$$

$$K = \frac{R_2}{R_1+R_2} \quad \& \quad \omega_0 = \frac{R_1+R_2}{L}$$

II. (25 pts): The voltage gain of an amplifier is described by the following transfer function

$$A(s) = \frac{10^5 s}{(s+10)(s+500)}. \tag{3}$$

(a) Write A(s) in the generic form $A_M F_L(s) F_H(s)$ and give the explicit expressions for A_M, $F_L(s)$, and $F_H(s)$.

(b) Make a Bode plot of the phase A(s) using the attached diagram. Make sure to clearly indicate all the locations of the zeroes and poles and the rate of decay ($\pm 45^0$ or $\pm 90^0$/decade,...) over the various ranges of frequencies. Also indicate with vertical lines the locations where the breaks in the phase occurs (at one-tenth and ten times the frequencies of the zeroes and poles).

$$A(s) = 10^5 \frac{1}{\left(1+\frac{10}{s}\right)} \frac{1}{500} \frac{1}{\left(1+\frac{s}{500}\right)}$$

$$= \frac{10^{\cancel{5}\,3}}{\cancel{5}\,10^{\cancel{2}}} \quad F_L(s) \quad F_H(s)$$

$$A_M = 200 \qquad \frac{1}{\left(1+\frac{10}{s}\right)} \qquad \frac{1}{\left(1+\frac{s}{500}\right)}$$

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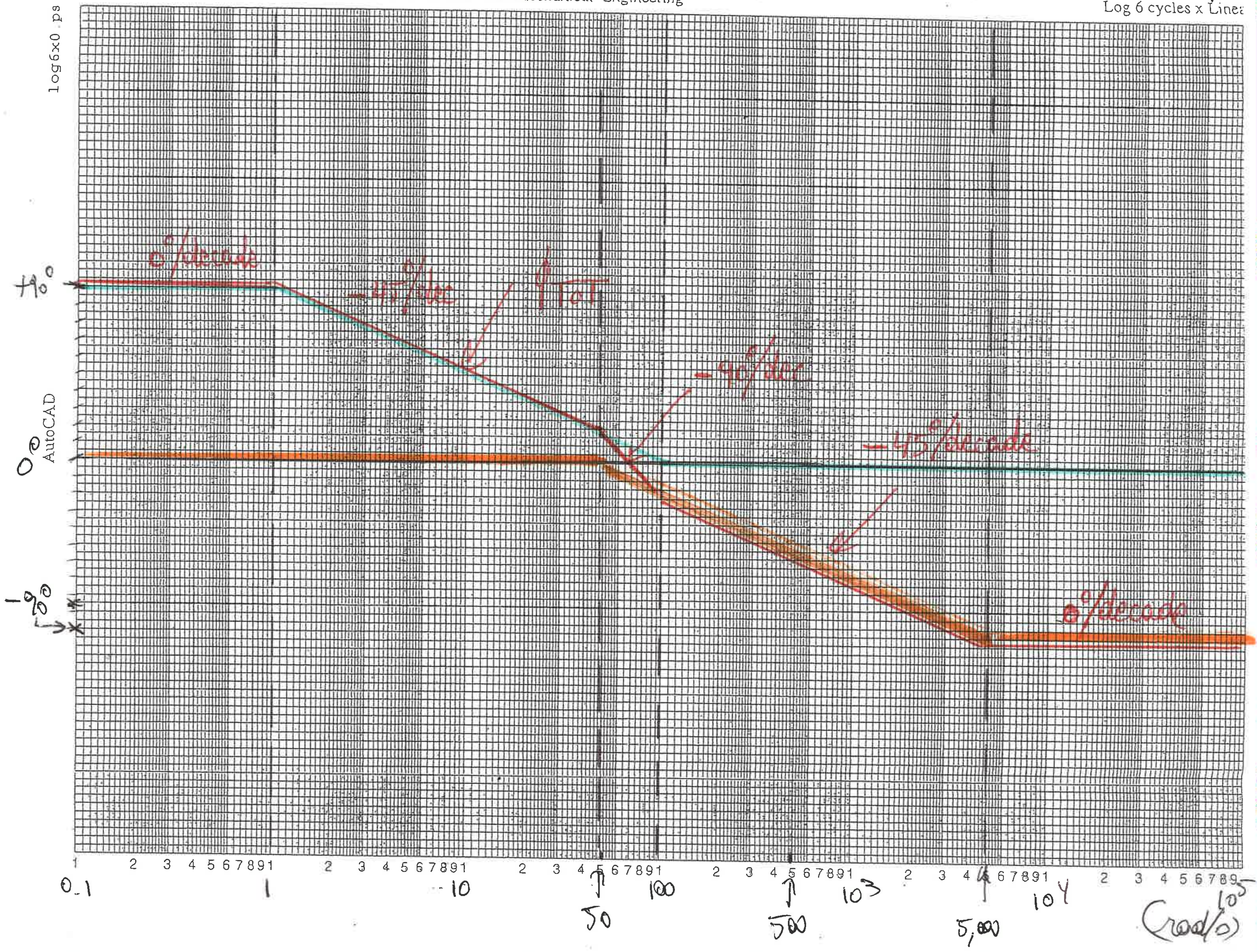
Log 6 cycles x Linear



III. (20 pts): The voltage gains of two different amplifiers are given by the following two transfer functions:

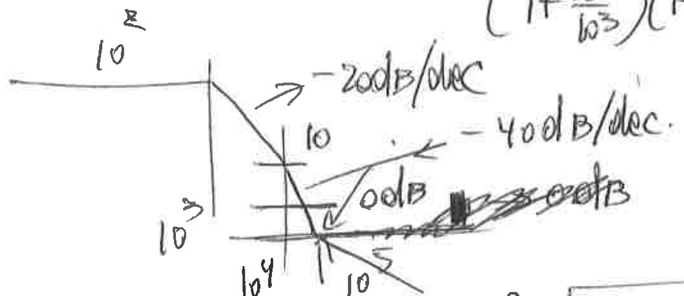
$$T_1(s) = \frac{10^4(s+10^5)}{(s+10^3)(s+10^4)}. \tag{4}$$

$$T_2(s) = \frac{10^5 s(s+10^4)}{(s+10)(s+10^3)}. \tag{5}$$

- Write $T_1(s)$ and $T_2(s)$ in the generic from $A_M F_L(s) F_H(s)$ and give the expression for A_M, $F_L(s)$, and $F_H(s)$.
- At what value(s) of the angular frequency does the magnitude of the transfer functions $T_1(s)$ and $T_2(s)$ reach unity (or 0 dB)?

$$T_1(s) = \frac{10^4\, 10^5\left(1+\frac{s}{10^5}\right)}{10^3\left(1+\frac{s}{10^3}\right) 10^4\left(1+\frac{s}{10^4}\right)} = \underbrace{10^2}_{A_M} F_H(s)$$

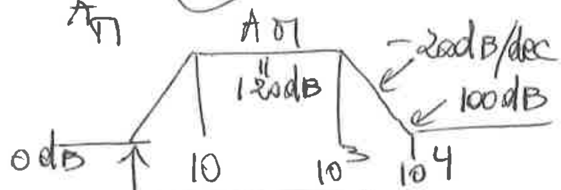
$$F_L(s) = 1 \qquad F_H(s) = \frac{1+\frac{s}{10^5}}{\left(1+\frac{s}{10^3}\right)\left(1+\frac{s}{10^4}\right)}$$



$$20\log_{10}|T_1(s)| = 0\,\text{dB for } \boxed{10^4 < \omega < 10^5}$$

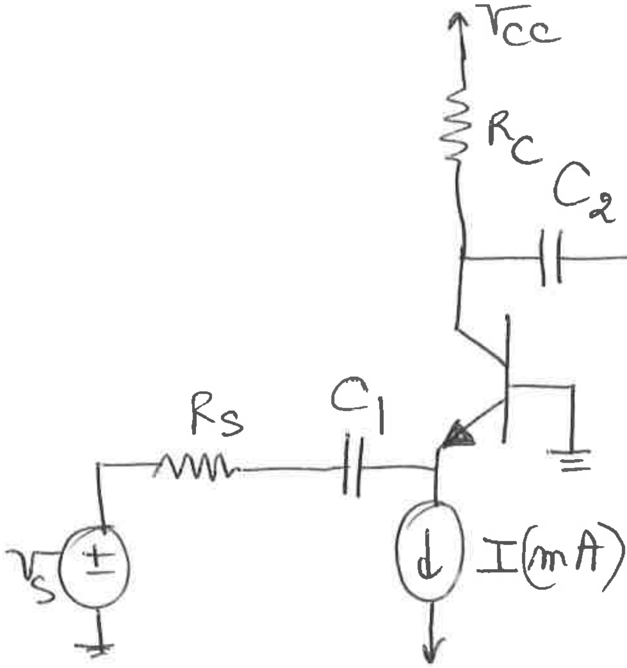
$$T_2(s) = 10^5 \underbrace{\frac{1}{1+\frac{10}{s}}}_{F_L(s)} \underbrace{\frac{10^4\left(1+\frac{s}{10^4}\right)}{10^3\left(1+\frac{s}{10^3}\right)}}_{F_H(s)}$$

$$= \underbrace{10^6}_{A_M} F_L(s)\, F_H(s) \qquad F_H(s) \rightarrow \frac{\left(1+\frac{s}{10^4}\right)}{\left(1+\frac{s}{10^3}\right)}$$



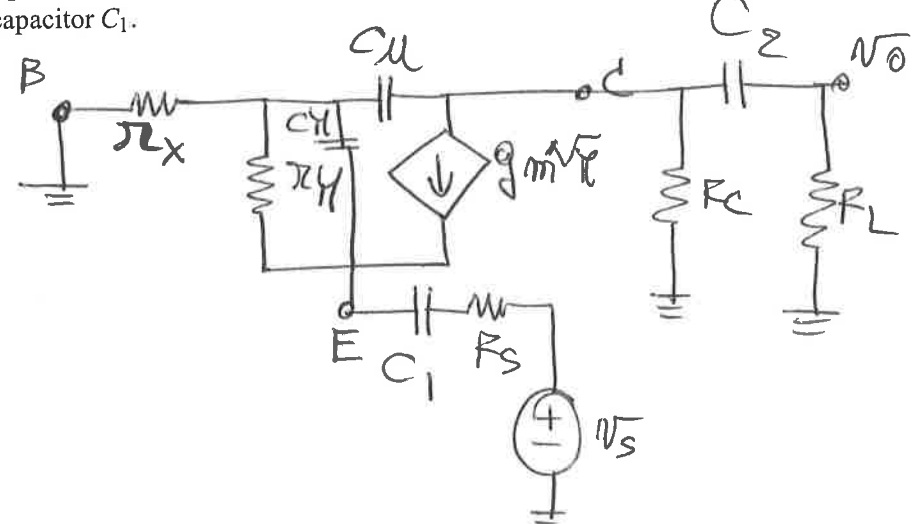
$$\boxed{\omega = 10^{-5}\ \text{rad/s}}$$

IV. (25 pts): For the amplifier shown below

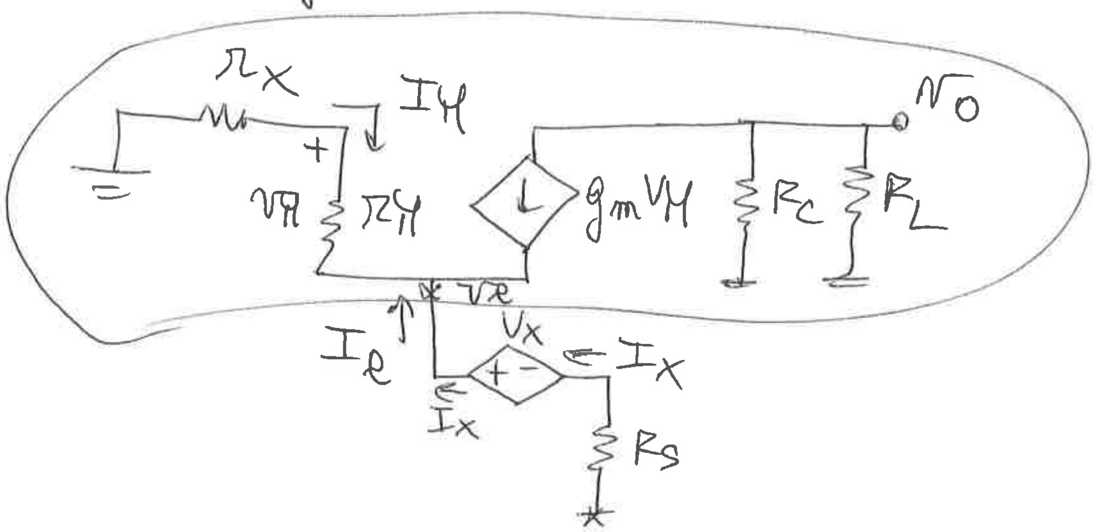


- What type of configuration is the amplifier (circle correct answer): (a) common emitter, (b) common base, (c) or common collector.
- Draw the small ac equivalent circuit of the network including the coupling, bypass, and internal capacitances C_π and C_μ of the BJT. Neglect the effects of r_0 when drawing the small AC equivalent circuit, but include r_x.
- Use the Gray-Searles procedure to determine the low frequency pole associated to the coupling capacitor C_1.

Hybrid-π



low frequency



$$\frac{v_x}{I_x} = R_S + r_e \qquad r_e = \frac{v_e}{I_e}$$

$$v_e = -I_\pi (r_x + r_\pi)$$

$$I_e = -I_\pi - g_m v_\pi = -I_\pi (1 + \underbrace{g_m r_\pi}_{\beta})$$

$$\frac{v_e}{I_e} = \frac{r_x + r_\pi}{\beta + 1}$$

$$\rightarrow \boxed{\frac{v_x}{I_x} = R_S + \frac{r_x + r_\pi}{\beta + 1}}$$