ELECTRONICS-II • Exam 1 • April 8, 2004
90 Minutes • Dr. Erkaya

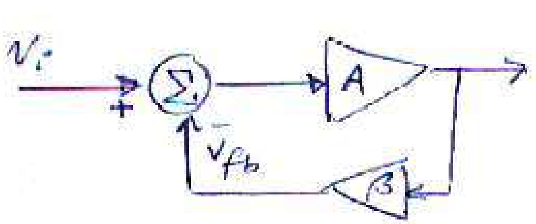
This is a closed-book, closed-notes exam. Write your answer to the space provided below each question. If you need more space, use the back of the sheet and indicate the question number. Read the questions carefully. Do not use any time on any question more than what you allocate in the beginning of the exam. Good Luck!

I have neither given nor received unauthorized help with this work; nor do I have reason to believe that anybody else has.

Student ID : ______________ *Name:* SOLUTIONS *Signature:* __________ *Grade:* ______

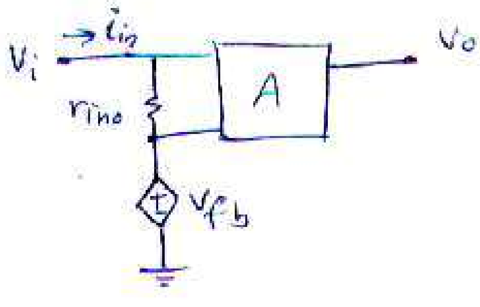
---

1) (25 pts) **Consider an amplifier with a voltage-series feedback. Assume the open loop input resistance of the amplifier is r_{ino}, the feedback factor is β, and the open-loop voltage gain is A. Show that the closed-loop amplifier input resistance is $r_{infb}=r_{ino}(1+\beta A)$**



$$\frac{V_o}{V_i} = \frac{A}{1+\beta A}$$

$$V_{fb} = \beta V_o$$



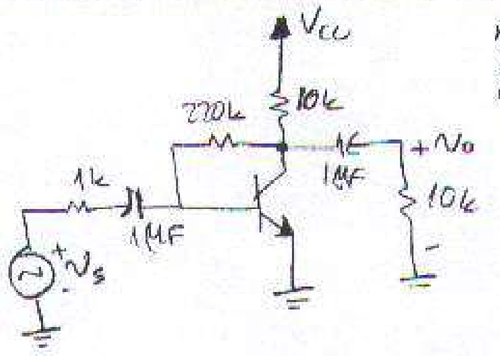
$$r_{infb} = \frac{V_i}{i_{in}} = \frac{V_i}{\frac{V_i - V_{fb}}{r_{ino}}} = r_{ino}\frac{V_i}{V_i - V_{fb}}$$

$$V_{fb} = \beta V_o = \beta\left(\frac{A}{1+\beta A}\right)V_i, \quad \frac{V_{fb}}{V_i} = \frac{\beta A}{1+\beta A}$$

$$r_{infb} = r_{ino}\frac{1}{1-\frac{V_{fb}}{V_i}} = r_{ino}\frac{1}{1-\frac{\beta A}{1+\beta A}} = r_{ino}\frac{1+\beta A}{1+\beta A - \beta A} = r_{ino}(1+\beta A)$$

Q.E.D.

2) (25 pts) Find the high 3-dB cutoff frequency for the amplifier given below.



$r_o = 100k\Omega$

$g_m = 60\,mA/V$

$f_T = 500\ MHz$

$\beta_o = 300$

$C_\mu = 1.5\,pF$

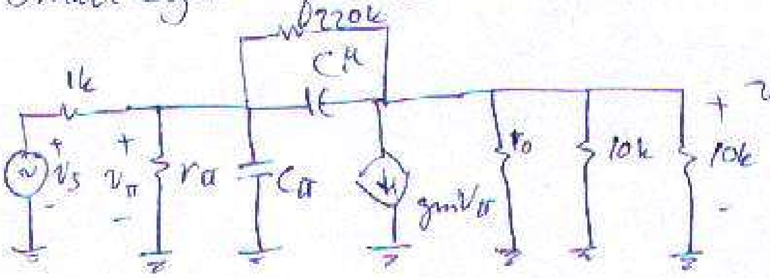
$$C_\pi = \frac{g_m}{2\pi f_T} - C_\mu$$

$$= \frac{60\times10^{-3}}{2\pi\times500\times10^{6}} - 1.5\times10^{-12}$$

$$C_\pi = 1.75\times10^{-11}\,F$$

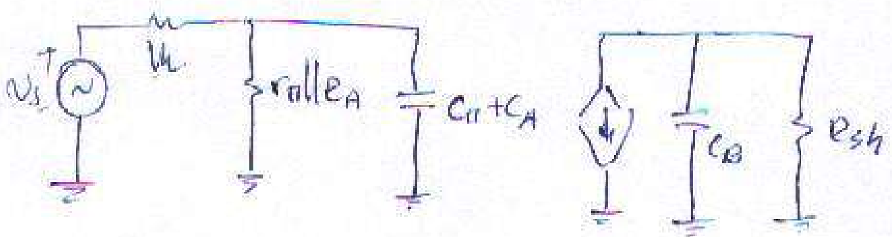
$$r_\pi = \frac{\beta_o}{g_m} = \frac{300}{60} = 5k\Omega$$

Small Signal Eq. ckt @ HF



$$\frac{v_o}{v_\pi} \simeq -g_m(R_{sh})$$

Miller's Theorem applied on C_μ and 220k resistor



$R_{sh} = R_B \| r_o \| 10k \| 10k$

$R_{sh} = 220k \| 100k \| 5k$

$= 4.66k$

$g_m R_{sh} = 60\times4.66 = 279.6$

$$R_A \simeq \frac{220k}{1+g_m R_{sh}} \qquad R_B \simeq 220k \quad , C_A = C_\mu(1+g_m R_{sh}) \ , \ C_B \simeq C_\mu$$

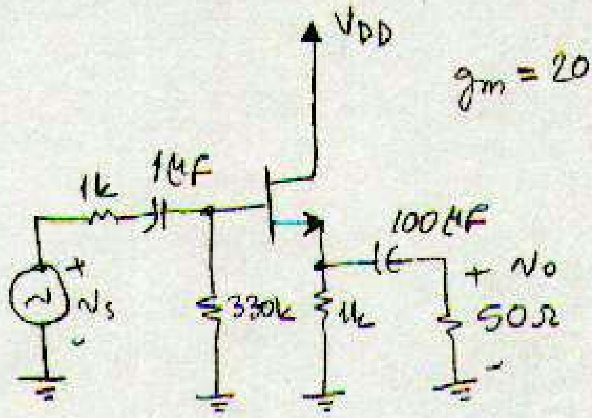
$$R_A = \frac{220k}{280.6} = 0.784\,k\Omega \ , \ C_A = 1.5(280.6) = 421\ pF$$

$$\omega_A = \frac{1}{(C_A + C_\pi)(1k\|r_\pi\|R_A)} = \frac{1}{(17.5+421)\times10^{-12}(1000\|5000\|784)} = 5.65\times10^{6}\ rad/s$$

$$\omega_B = \frac{1}{C_B R_{sh}} = \frac{1}{1.5\times10^{-12}\times4660} = 143\times10^{6}\ rad/s$$

$$\omega_H = \frac{1}{\frac{1}{\omega_A} + \frac{1}{\omega_B}} = 5.43\times10^{6}\ rad/s \rightarrow 865\ kHz$$

3) (*25 pts*) Calculate the low 3-dB cutoff frequency for the amplifier given below.



$g_m = 20\ mA/V$

$\omega_1 = \frac{1}{C_1 R_{th_1}}$, $R_{th_1} = (1+330)k\Omega$

$\omega_1 = \frac{1}{10^{-6} \times 331 \times 10^{3}} = 3.02\ rad/s$

$\omega_2 = \frac{1}{C_2 R_{th_2}}$ $\quad R_{th_2} = 0.050 + (1 \| \frac{1}{20}) = 0.0976\ k\Omega$

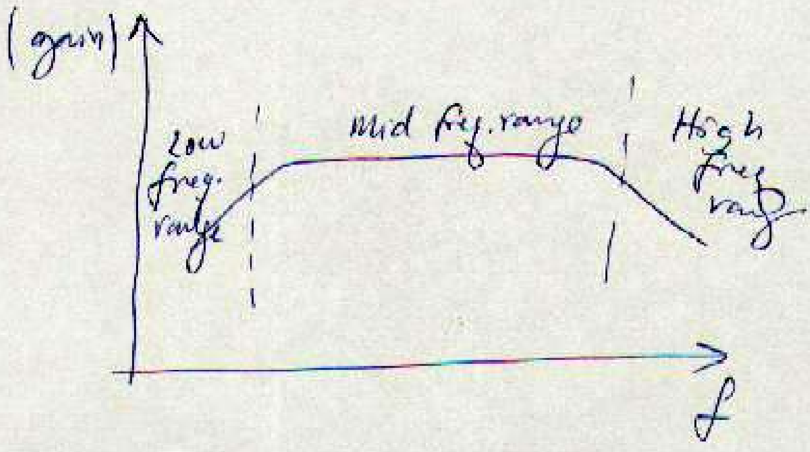
$\omega_2 = \frac{1}{100 \times 10^{-6} \times 97.6} = 102.46\ rad/s$

$\omega_L \cong \omega_1 + \omega_2 = 3.02 + 102.46 = 105.48\ rad/s$

4) (25 pts) Explain why and how the gain of a common-emitter amplifier changes with frequency. Use grammatical English sentences to answer this question.

In an amplifier, coupling and bypass capacitors are used to connect the signal source and the load to the amplifier. These capacitors block the DC currents yet allow the signals. As the signal frequency gets smaller, the impedance of these capacitors becomes significant. This causes a voltage drop across these capacitors. That is why the amplified portion of the voltage gets smaller with decreasing frequency.

At high frequencies, the parasitic and junction capacitances of the transistors do not act as open circuits. Their impedances get smaller as the frequency increases. These capacitors reduce the amount of current that is amplified. Thus the gain of the amplifier decreases with the increasing frequency. The gain vs frequency curve for a typical amplifier looks like the following:



ELECTRONICS-II • Exam 1 • April 8, 2004
90 Minutes • Dr. Erkaya

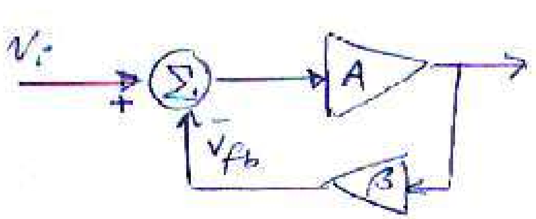
This is a closed-book, closed-notes exam. Write your answer to the space provided below each question. If you need more space, use the back of the sheet and indicate the question number. Read the questions carefully. Do not use any time on any question more than what you allocate in the beginning of the exam. Good Luck!

I have neither given nor received unauthorized help with this work; nor do I have reason to believe that anybody else has.

Student ID : _______________ *Name:* SOLUTIONS *Signature:* ____________ *Grade:* _______

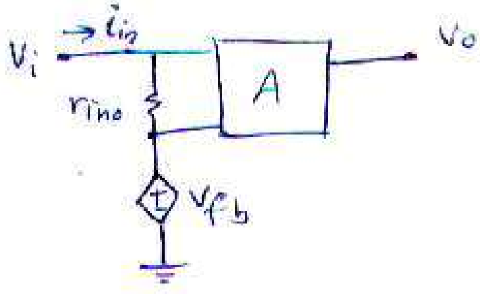
---

1) (25 pts) **Consider an amplifier with a voltage-series feedback. Assume the open loop input resistance of the amplifier is r_{ino}, the feedback factor is β, and the open-loop voltage gain is A. Show that the closed-loop amplifier input resistance is $r_{infb}=r_{ino}(1+\beta A)$**



$$\frac{V_o}{V_i} = \frac{A}{1+\beta A}$$

$$V_{fb} = \beta V_o$$



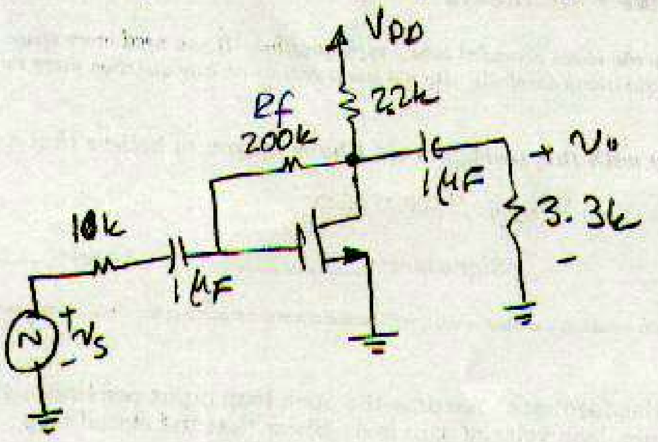
$$r_{infb} = \frac{V_i}{i_{in}} = \frac{V_i}{\frac{V_i - V_{fb}}{r_{ino}}} = r_{ino}\frac{V_i}{V_i - V_{fb}}$$

$$V_{fb} = \beta V_o = \beta\left(\frac{A}{1+\beta A}\right)V_i \;, \quad \frac{V_{fb}}{V_i} = \frac{\beta A}{1+\beta A}$$

$$r_{infb} = r_{ino}\frac{1}{1-\frac{V_{fb}}{V_i}} = r_{ino}\frac{1}{1-\frac{\beta A}{1+\beta A}} = r_{ino}\frac{1+\beta A}{1+\beta A-\beta A} = r_{ino}(1+\beta A)$$

Q.E.D.

2) (25 pts) Find the high 3-dB cutoff frequency for the amplifier given below.



$C_{gs} = 2\ pF$

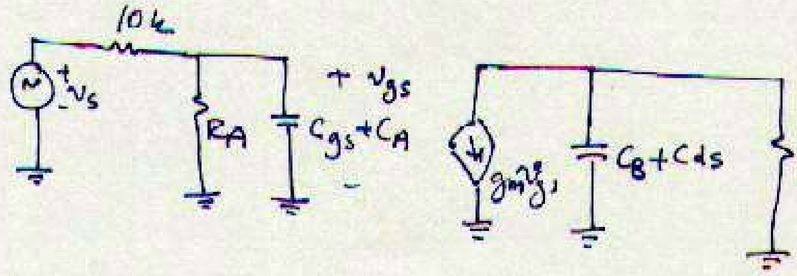
$C_{gd} = 1.5\ pF$

$C_{ds} = 1\ pF$

$r_o = 250\ k\Omega$

$g_m = 18\ mA/V$

HF small signal eq. ckt: (Miller's theorem applied on C_{gd} and R_f)



$R_{sh} = 2.2k \| 3.3k \| r_o \| R_B$

$R_B \simeq R_f = 200k$

$r_o = 250k\Omega$

$R_{sh} \simeq 1.304\ k\Omega$

$g_m R_{sh} = 18 \times 1.304 \cong 23.5$

$$R_A \cong \frac{R_f}{1+g_m R_{sh}} = \frac{200k}{24.5} = 8.163 k\Omega$$

$C_B \simeq C_{gd} = 1.5 \times 10^{-12} F$, $C_A = C_{gd}(1+g_m R_{sh}) = 1.5 \times 24.5 \times 10^{-12} = 3.675 \times 10^{-11} F.$

There are two high freq poles:

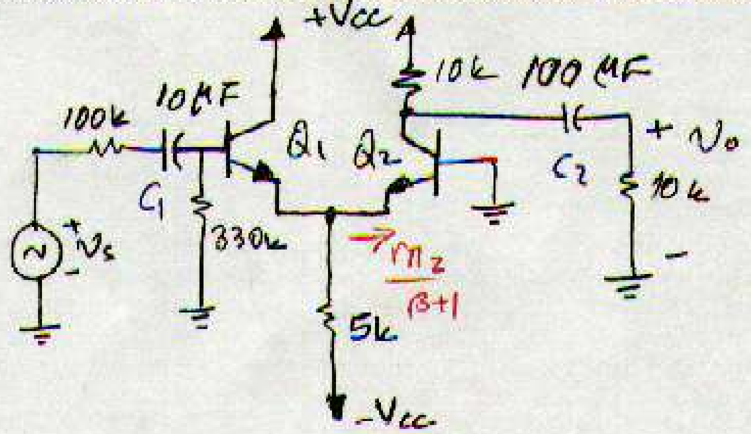
$$\omega_A = \frac{1}{(C_{gs}+C_A) R_{thA}} \quad , \quad R_{thA} = R_A \| 10k = 4.494\ k\Omega. \quad , \quad \omega_A = \frac{1}{(36.75+2)\times 10^{-12} \times 4494} = 5.74 \times 10^{6}\ rad/s$$

$$\omega_B = \frac{1}{(C_{ds}+C_B) R_{sh}} = \frac{1}{(1+1.5)\times 10^{-12} \times 1304} = 306.7 \times 10^{6}\ rad/s$$

$$\omega_H = \frac{1}{\frac{1}{\omega_A} + \frac{1}{\omega_B}} = \frac{1}{\frac{1}{5.74} + \frac{1}{306.7}} = 5.63 \times 10^{6}\ rad/s$$

<u>896.8 kHz</u>

3) (*25 pts*) Calculate the low 3-dB cutoff frequency for the amplifier given below.



$g_{m_1} = 40\,mA/V$

$g_{m_2} = 30\,mA/V$

$\beta_0 = 200$

$r_{\pi_1} = \dfrac{200}{40} = 5\,k\Omega$

$r_{\pi_2} = \dfrac{200}{30} = 6.66\,k\Omega$

$$\omega_1 = \frac{1}{C_1 R_{th_1}} \qquad R_{th_1} = 100k + \left[330k \parallel r_{\pi_1} + (\beta_0+1)\left(5k \parallel \frac{r_{\pi 2}}{\beta_0+1}\right)\right]$$

$$= 100k + \left[330k \parallel 5k + (201)\left(5k \parallel \frac{6.66}{30}\right)\right] = 141.69\,k\Omega$$

$$\omega_1 = \frac{1}{10\times10^{-6} \times 141690} = 0.7 \text{ rad/s}$$

$$R_{th_2} = 10k + 10k = 20k$$

$$\omega_2 = \frac{1}{C_2 R_{th_2}},$$

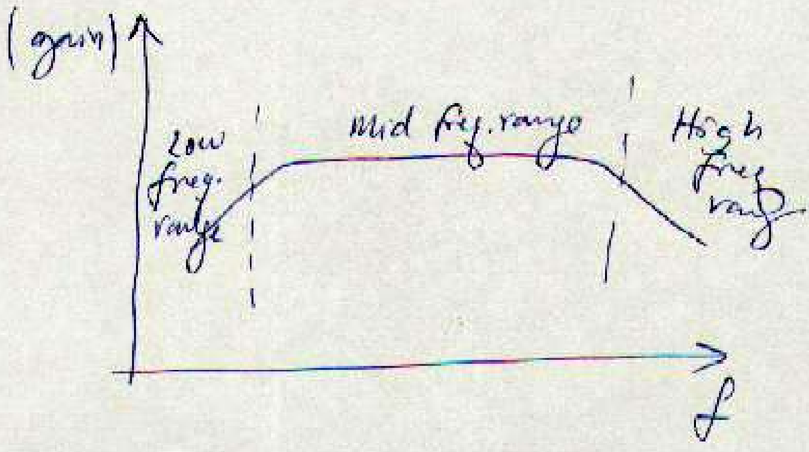
$$\omega_2 = \frac{1}{100\times10^{-6} \times 20000} = 0.5 \text{ rad/s}$$

$$\omega_L = \omega_1 + \omega_2 = 0.7 + 0.5 = 1.2 \text{ rad/s}$$

4) (25 pts) **Explain why and how the gain of a common-emitter amplifier changes with frequency. Use grammatical English sentences to answer this question.**

In an amplifier, coupling and bypass capacitors are used to connect the signal source and the load to the amplifier. These capacitors block the DC currents yet allow the signals. As the signal frequency gets smaller, the impedance of these capacitors becomes significant. This causes a voltage drop across these capacitors. That is why the amplified portion of the voltage gets smaller with decreasing frequency.

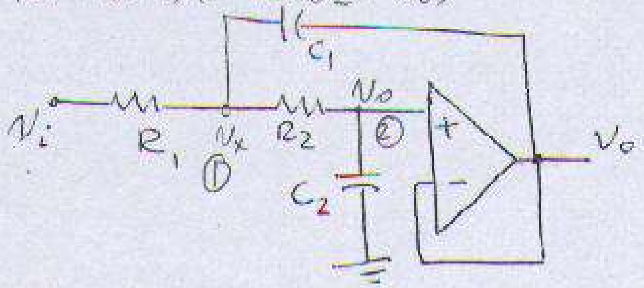
At high frequencies, the parasitic and junction capacitances of the transistors do not act as open circuits. Their impedances get smaller as the frequency increases. These capacitors reduce the amount of current that is amplified. Thus the gain of the amplifier decreases with the increasing frequency. The gain vs frequency curve for a typical amplifier looks like the following:



Electronics II * Exam II * May 13, 2004 * 90 minutes

ID number: ______________ Name: SOLUTIONS Signature: ______________

1) Find the transfer function of the circuit given below. Indicate what kind of a filter it is (i.e., high-pass, low-pass, band-pass). Put the transfer function in the form as follows: $(as^2 + bs + c)/(s^2 + s\omega_o/Q + \omega_o^2)$



$a =$ 0

$b =$ 0

$c =$ $\frac{1}{C_1C_2R_1R_2}$

$\omega_o =$ $\frac{1}{\sqrt{C_1C_2R_1R_2}}$

$\omega_o/Q =$ $(R_1+R_2)/C_1R_1R_2$

$type =$ LP

KCL ①

$$\frac{V_i - V_x}{R_1} = \frac{V_x - V_o}{R_2} + \frac{V_x - V_o}{\frac{1}{sC_1}} \qquad (1)$$

KCL ②

$$\frac{V_x - V_o}{R_2} = \frac{V_o}{\frac{1}{sC_2}} = sC_2 V_o \qquad (2)$$

$$V_x - V_o = sR_2C_2V_o$$

$$V_x = (1 + sC_2R_2)V_o \quad \text{substitute in (1)}$$

$$\frac{V_i - (1+sC_2R_2)V_o}{R_1} = \left(\frac{1}{R_2} + sC_1\right)\left[(1+sC_2R_2)V_o - V_o\right]$$

$$V_i - (1+sC_2R_2)V_o = \left(\frac{R_1}{R_2} + sC_1R_1\right) sC_2R_2V_o$$

$$V_i = \left[\left(\frac{R_1}{R_2} + sC_1R_1\right)sC_2R_2 + 1 + sC_2R_2\right]V_o$$

$$V_i = \left[sC_2R_1 + s^2C_1C_2R_1R_2 + 1 + sC_2R_2\right]V_o$$

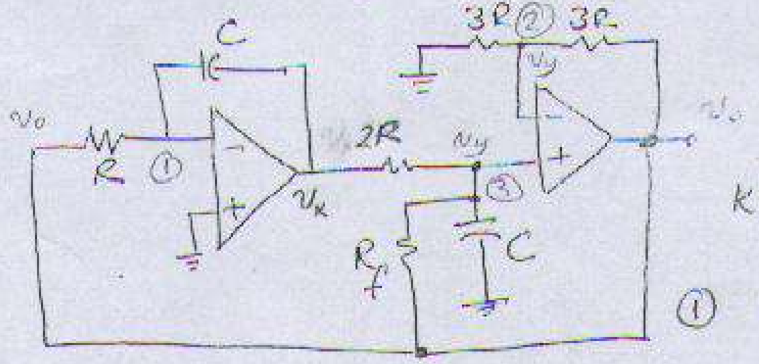
$$\frac{V_o}{V_i} = \frac{1}{s^2C_1C_2R_1R_2 + sC_2(R_1+R_2) + 1} = \frac{\frac{1}{C_1C_2R_1R_2}}{s^2 + s\frac{C_2(R_1+R_2)}{C_1C_2R_1R_2} + \frac{1}{C_1C_2R_1R_2}}$$

$a = 0$
$b = 0$
$c = \frac{1}{C_1C_2R_1R_2}$
$\omega_o = \frac{1}{\sqrt{C_1C_2R_1R_2}}$

$$\frac{\omega_o}{Q} = \frac{R_1+R_2}{C_1R_1R_2}$$

$$= \frac{as^2 + bs + c}{s^2 + s\frac{\omega_o}{Q} + \omega_o^2}$$

2) Find the oscillation frequency and oscillation condition for the circuit given below:



$\omega_o = \frac{1}{CR}$

condition : $R_f = 2R$

KCL equations at nodes 1, 2 and 3

1 $\quad \frac{V_o}{R} = -\frac{V_x}{\frac{1}{j\omega C}} \rightarrow V_x = -\frac{V_o}{j\omega CR}$

2 $\quad \frac{V_y}{3R} = \frac{V_o - V_y}{3R} \rightarrow 2V_y = V_o$

$V_y = \frac{V_o}{2}$

3 $\quad \frac{V_x - V_y}{2R} = \frac{V_y - V_o}{R_f} + \frac{V_y}{\frac{1}{j\omega C}}$ $\qquad$ Substitute V_x and V_y

$$\frac{-\frac{V_o}{j\omega CR} - \frac{V_o}{2}}{2R} = \frac{\frac{V_o}{2} - V_o}{R_f} + j\omega C \frac{V_o}{2}$$

$$-\frac{V_o}{j\omega 2CR^2} - \frac{V_o}{4R} = -\frac{V_o}{2R_f} + \frac{j\omega C V_o}{2}$$

Real parts are equal $\rightarrow -\frac{V_o}{4R} = -\frac{V_o}{2R_f} \longrightarrow 4R = 2R_f$

$$\boxed{R_f = 2R}$$

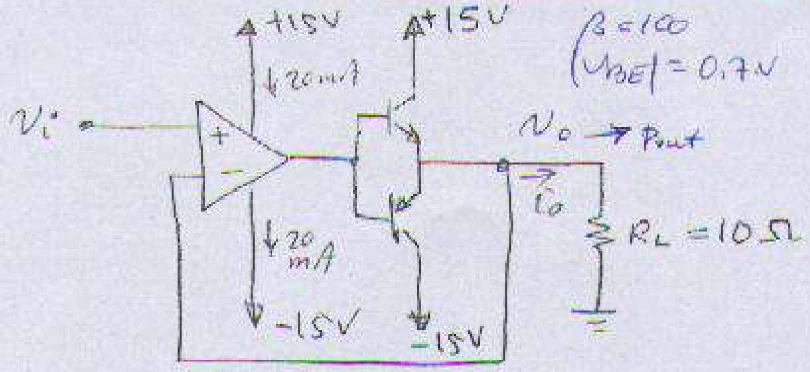
Imaginary parts are equal $\rightarrow -\frac{V_o}{j\omega 2CR^2} = j\omega \frac{C V_o}{2}$

$$-\frac{1}{j\omega CR^2} = j\omega C$$

$$-1 = -\omega^2 C^2 R^2$$

$$\boxed{\frac{1}{CR} = \omega}$$

3) Calculate the **maximum efficiency** in the circuit given below. Assume that the Opamp draws 20 mA from both supplies on the average and that the opamp output voltage is limited by ± 13.7 V.:



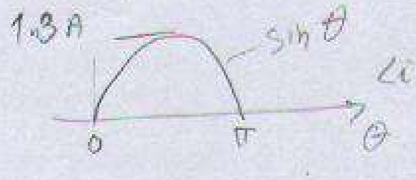
$\eta_{max} =$ ____________

$V_{omax} = 13.7 - 0.7 = 13.V$

$I_{omax} = \frac{V_{omax}}{R_L} = \frac{13}{10} = 1.3\ A$

$P_{o\,max} = V_{orms} \cdot I_{orms} = \frac{V_{omax}\, I_{omax}}{\sqrt{2} \cdot \sqrt{2}} = \frac{13.0 \times 1.3}{2} = 8.45\ W$

$P_{DC} = 15 \times 0.02 + 15 \times 0.02 +$ average load current over half interval $\times 15V$



$\langle i \rangle = 1.3\ \frac{1}{\pi}\int_0^{\pi} \sin\theta\, d\theta\ 1.3 = \frac{1.3}{\pi}\left[-\cos\theta\right]_{\theta=0}^{\pi} = \frac{1.3}{\pi}(+1+1) = \frac{2.6}{\pi} = 0.827\ A.$

$P_{DC} = 30 \times 0.02 + 15 \times 0.827 = 13.0\ W.$

$\eta = \frac{P_{out}}{P_{DC}} = \frac{8.45}{13} = 0.6498$

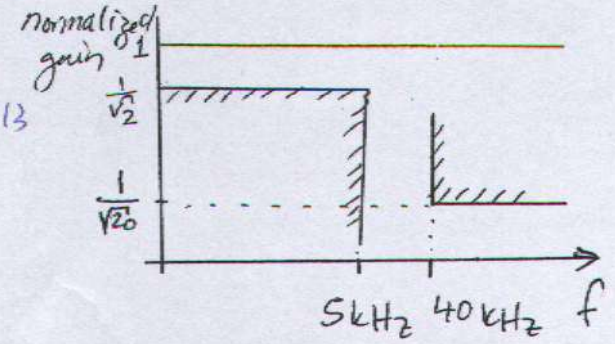
Electronics II * Exam II * May 15, 2004 * 90 minutes

ID number: ____________ Name: SOLUTIONS Signature: ____________

30 pts

1) Determine the poles of the minimum order Butterworth filter for the filter specification given below:

11:13



$$\frac{1}{\sqrt{1+\left(\frac{f}{f_0}\right)^{2n}}} = \text{normalized response}$$

$$\frac{1}{\sqrt{2}} \rightarrow -3dB \rightarrow f_a = 5kHz$$

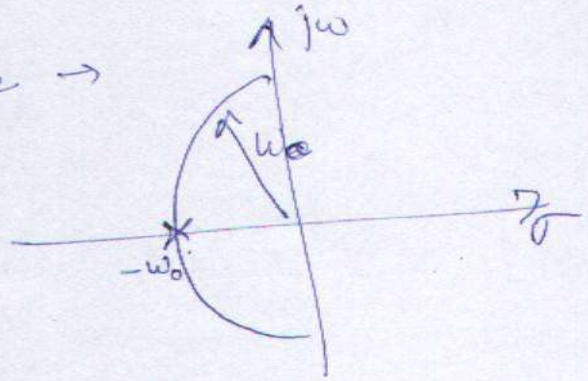
$$\frac{1}{\sqrt{20}} = \frac{1}{\sqrt{1+\left(\frac{40}{5}\right)^{2n}}} \rightarrow 20 = 1+(8)^{2n}$$

$$19 = 8^{2n}$$

$$\log 19 = 2n \log 8 \Rightarrow \quad n = \frac{\log 19}{2 \log 8} = 0.708$$

$$\boxed{n = 1}$$

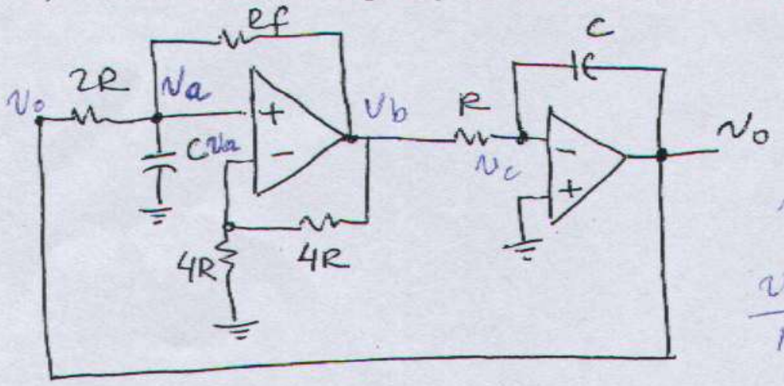
one pole $\rightarrow$



$\omega_0 = 2\pi \times 5 \times 10^3$ rad/s

35 pts

2) Find the oscillation frequency and oscillation condition for the circuit given below:



$\omega_o = \underline{\frac{1}{CR}}$

condition: $\underline{2R = R_f}$

$$v_c = 0$$

$$\frac{v_b}{R} = -j\omega C v_o$$

$$v_b = -j\omega CR v_o$$

$$v_a = \frac{v_b}{8R} 4R = \frac{v_b}{2} \longrightarrow v_a = -\frac{j\omega CR v_o}{2}$$

$$\frac{v_o - v_a}{2R} = \frac{v_a}{\frac{1}{j\omega C}} + \frac{(v_a - v_b)}{R_f}$$

$$\frac{v_o + j\omega CR\frac{v_o}{2}}{2R} = j\omega C\left(-j\omega CR\frac{v_o}{2}\right) + \frac{\left(-j\omega CR\frac{v_o}{2} + j\omega CR v_o\right)}{R_f}$$

$$\frac{1}{2R} + j\omega\frac{CR}{4R} = \frac{\omega^2 C^2 R}{2} - j\omega\frac{CR}{2R_f} + j\omega\frac{CR}{R_f}$$

Real parts $\rightarrow$ $\frac{1}{2R} = \frac{\omega^2 C^2 R}{2}$

$$\frac{1}{R^2C^2} = \omega^2 \rightarrow \omega = \frac{1}{RC}$$

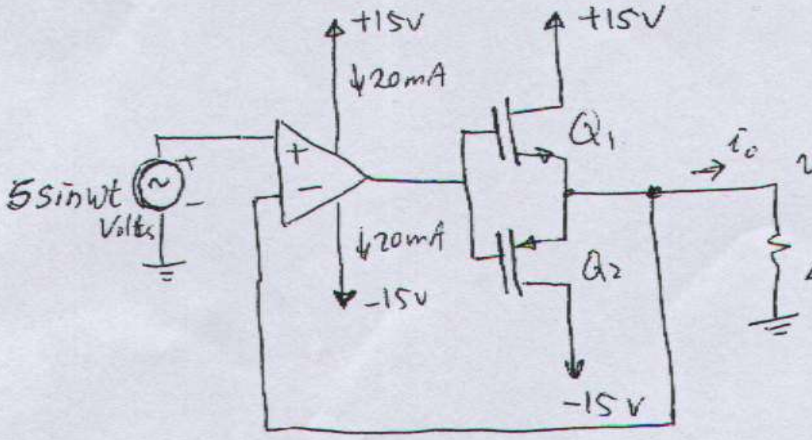
imaginary parts: $\frac{j\omega CR}{4R} = j\omega CR\left(-\frac{1}{2R_f} + \frac{1}{R_f}\right)$

$$\frac{1}{4R} = \frac{1}{R_f}\left(1 - \frac{1}{2}\right) = \frac{1}{2R_f}$$

$$\boxed{2R = R_f}$$

35 Pts

3) Calculate the **efficiency** in the circuit given below. Assume that the Opamp draws 20 mA from both supplies on the average and that the opamp output voltage is limited by ± 13.7 V. The enhancement type MOSFETS have the same threshold voltage ± 1 V, and K = 100 mA/V²



$\eta =$ 17.42 %

$v_o = 5\sin\omega t$

$i_o = \frac{5}{40}\sin\omega t$

$V_{orms} = \frac{5}{\sqrt{2}}$ V $\quad P_o = \frac{25}{80}$ W

$\hat{i}_{orms} = \frac{5}{\sqrt{2}\,40}$ A

average drain current $= \frac{1}{\pi}\int_0^{\pi} \frac{5}{40}\sin\omega t\,(d\omega t)$

$= \frac{1}{\pi}\frac{5}{40}\Big|-\cos\omega t\Big|_{\omega t=0}^{\pi} = \frac{2\times 5}{\pi\,40} = \frac{1}{4\pi}$ A.

DC power: $\quad 15\times 0.02 + 15\times 0.02 + 15\times\frac{1}{4\pi} = 1.7937$ W

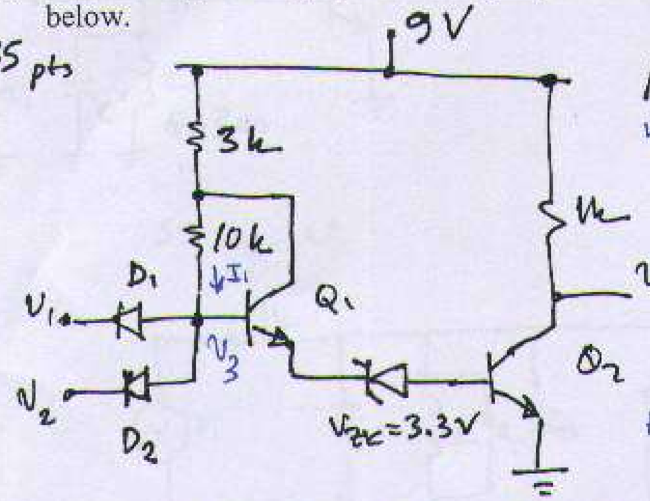
$\eta = \frac{P_o}{P_{DC}} = \frac{25/80}{1.7937} = 0.1742 \rightarrow \underline{\underline{17.42\%}}$

Electronics II * Final Exam * June 9, 2004 * 90 minutes

ID number: ____________ Name: SOLUTIONS ____________ Signature: ____________

1) Find the logic voltages, noise margins, fanout and average power dissipation for the gate given below.

35 pts



$\beta_F = 150$ Q_2: saturation, cut-off

$V(0) = $ 0.2 V

$V(1) = $ 9V

NM0 : -4.9 V

NM1 : 3.4 V

fanout: 315

$\langle P_{diss.} \rangle$: 48.56 mW

when $v_1 = v_2 = 0.2V$, $v_3 = 0.9V$

Q_1, Q_2, zener $\to$ OFF $\quad V_o = 9V$

$I_1 = \frac{9-0.9}{10+3} = 0.6231$ mA (std. load)

$P_1 = 9 \times 0.6231 = 5.6$ mW

when $v_1 = v_2 = 9V$, D_1, D_2 : OFF, Q_1, zener, Q_2 : ON $\quad v_3 = 0.8 + 3.3 + 0.7 = 4.8V$

$v_3 + I_{B_1} \times 10 + 3(150+1) I_{B_1} = 9V \qquad I_{B_1} = \frac{9-4.8}{10+151\times 3} = 0.0091$

$I_{E_1} = 151\, I_{B_1} = 1.37\,mA = I_{B2}$

$I_{C_1} = \frac{9-0.2}{1k} = 8.8\,mA. \qquad P_0 = 9 \times (I_{E_1} + I_{C2}) = 9 \times (1.37 + 8.8) = 91.52\,mW$

$\langle P_{diss} \rangle = \frac{91.52 + 5.6}{2} = 48.56\,mW$

NM1: $v_1 = v_2 = 0.2$ can be increased until v_3 becomes $0.5 + 3.3 + 0.5 = 4.3V$

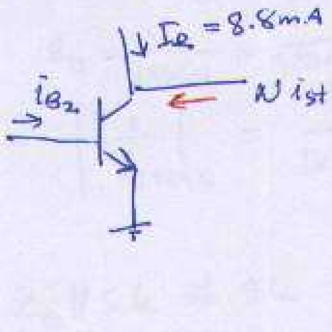
that is $v_1 = v_2 = 4.3 - 0.7 = 3.6V$ acceptable low input

$NM1 = 3.6 - 0.2 = 3.4V.$

NM0: $v_1 = v_2 = 9V$, can be lowered until D1, D2 turned on $\quad 4.8 - 0.7 = 4.1V$ acceptable

$NM0 = 4.1 - 9 = -4.9V$

For fanout, load the gate with N identical gates



$i_{C_2} < \beta i_{B2}$

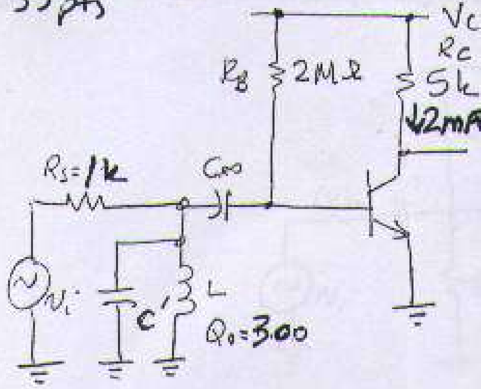
$I_R + N i_{st} < 150 \times 1.37$

$N < \frac{150 \times 1.37 - 8.8}{0.6231} = 315.68$

fanout $\to$ $\underline{315}$

35 pts

2) Find the center frequency, Q, the 3-dB bandwidth and the center frequency gain of the amplifier given below. Assume that $\beta = 200$, $C_\pi = 10pF$, $C_\mu = 1pF$, $L = 4\mu H$, $C' = 200pF$



$I_c = 2mA$, $g_m = \frac{2}{0.025} = 80mA/V$

$r_\pi = \frac{\beta}{g_m} = \frac{200}{80} = 2.5k\Omega$

$\omega_0 =$ 20.22×10^6 rad/s

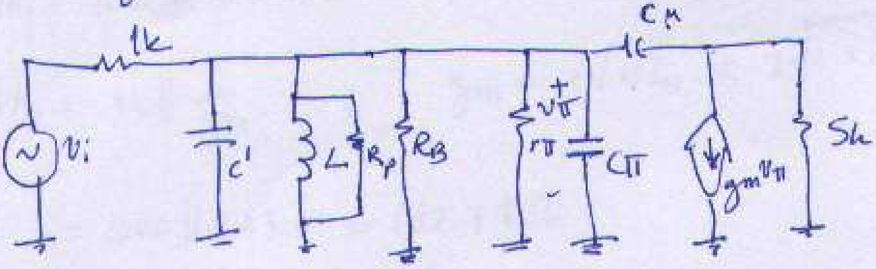
$Q =$ 8.58

$B =$ 2.35 rad/s

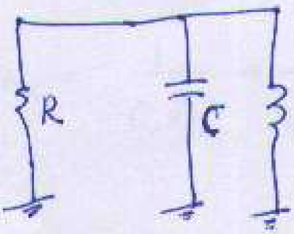
$\left|\frac{v_o}{v_i}\right|_{max} =$ 277.59

SS eq-cht

$\frac{\omega_0 L}{R_p} = \frac{1}{Q_0}$



after miller's theorem applied on C_μ, the resonant cht becomes



where $R = 1k \| R_p \| r_\pi \| R_B$

$C = C' + C_\pi + C_A$

$C_A = C_\mu(1 + 80\times5) = 401\ pF$, $C_B = 1pF$

$C = 200 + 10 + 401 = 611\ pF$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4\times10^{-6}\times611\times10^{-12}}} = 20.22\times10^6\ rad/s$$

$$Q = \frac{R}{\omega_0 L} = \frac{694}{20.22\times10^6\times4\times10^{-6}} = 8.58$$

$$R_p = Q_0\omega_0 L = 300\times20.22\times10^6\times4\times10^{-6} = 24273\ \Omega$$

$$B = \frac{\omega_0}{Q} = 2.35\ rad/s$$

$$R = 1k \| 24.27k \| 2.5k \| 2M = \underline{\underline{694\ \Omega}}$$

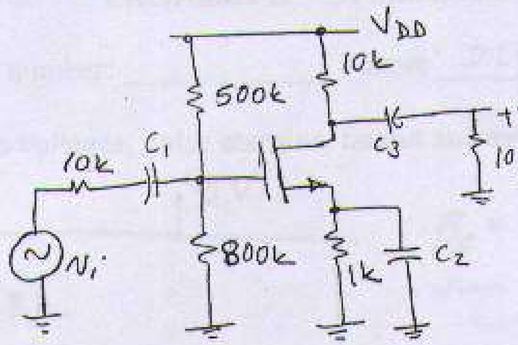
$$Z_B = \frac{1}{j\omega_0 C_B} = \frac{1}{j20.22\times10^6\times1\times10^{-12}} = \frac{10^6}{j20.22}$$

$$\left|\frac{v_o}{v_i}\right|_{max} = \frac{R_p \| r_\pi \| R_B}{1k + (R_p \| r_\pi \| R_B)}(80\times5) = \frac{2.266}{3.266}\times400 = 277.59$$

$Z_B \| 5k \cong 5k$

30 pts

3) The MOSFETs in the amplifier circuit below have $K = 2.5\ \mathrm{mA/V^2}$, $I_D = 2\ \mathrm{mA}$, and $r_o = 50\ \mathrm{k\Omega}$. If the capacitors are of equal value, what should be the min capacitor value to have the lower cutoff frequency less than or equal to 100 Hz?



$C_1 = C_2 = C_3 = \underline{8.8\ \mu F}$ min.

Superposition of poles

$\omega_L \cong \omega_1 + \omega_2 + \omega_3$

where $\omega_1 = \dfrac{1}{C_1 R_{th_1}}$, $\omega_2 = \dfrac{1}{C_2 R_{th_2}}$, $\omega_3 = \dfrac{1}{C_3 R_{th_3}}$

$R_{th_1} = 10k + 800k \| 500k = 317.7k$

$R_{th_2} = 1k \| \dfrac{1}{g_m}$, $\quad g_m = 2\sqrt{K I_D} = 2\sqrt{2.5 \times 2} = 4.47\ \mathrm{mA/V}$

$= 1000 \| 223.6 = 182.7\ \Omega$

$\omega_L = 2\pi \times 100$ rad/s

$R_{th_3} = 10k \| 50k + 10k = 18.33\ k\Omega$

$$\omega_L = \frac{1}{C_1 R_{th_1}} + \frac{1}{C_2 R_{th_2}} + \frac{1}{C_3 R_{th_3}} = \frac{1}{C}\left(\frac{1}{R_{th_1}} + \frac{1}{R_{th_2}} + \frac{1}{R_{th_3}}\right)$$

$$C = \frac{1}{\omega_L}\left(\frac{1}{R_{th_1}} + \frac{1}{R_{th_2}} + \frac{1}{R_{th_3}}\right) = \frac{1}{200\pi}\left(\frac{1}{317700} + \frac{1}{182.7} + \frac{1}{18333}\right) = 8.8 \times 10^{-6}\ \mathrm{F.}$$