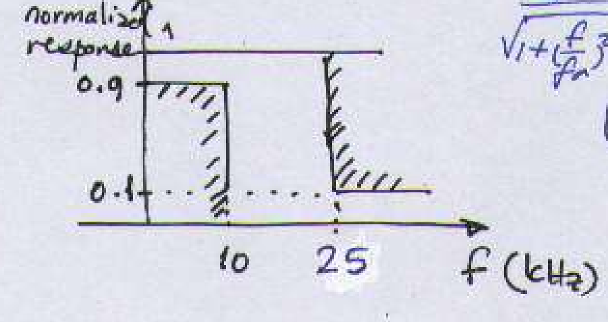
Electronics II * Final Exam * June 17, 2004 * 90 minutes

ID number: ____________ Name: SOLUTIONS Signature: ____________ Grade: ___

30 pts

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



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

$\left(\frac{1}{0.9}\right)^2 = \left(\sqrt{1+\left(\frac{10}{f_a}\right)^{2n}}\right)^2 \rightarrow \frac{1}{0.81} - 1 = \left(\frac{10}{f_a}\right)^{2n} = 0.2346$

$\left(\frac{1}{0.1}\right)^2 = 1 + \left(\frac{25}{f_a}\right)^{2n} \rightarrow \frac{1}{0.01} - 1 = \left(\frac{25}{f_a}\right)^{2n} = 99$

dividing side by side, $\left(\frac{10}{25}\right)^{2n} = \frac{0.2346}{99} = 0.0024$

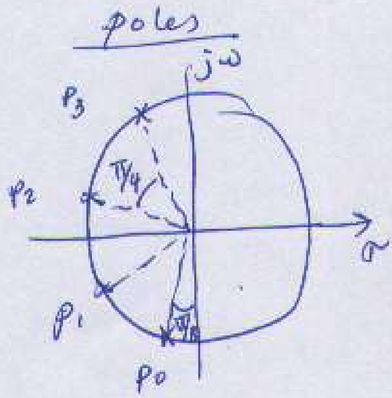
$2n \log\left(\frac{10}{25}\right) = \log(0.0024)$, $n = \dfrac{\log(0.0024)}{2\log\left(\frac{10}{25}\right)} = 3.29$

to find f_a, substitute $n = 3.29 \rightarrow \left(\frac{10}{f_a}\right)^{2n} = 0.2346$ $\boxed{n \rightarrow 4}$

$6.58 \log\left(\frac{10}{f_a}\right) = \log(0.2346)$, $\log\left(\frac{10}{f_a}\right) = \dfrac{\log(0.2346)}{6.58} = -0.0957$

$\frac{10}{f_a} = 10^{-0.0957} = 0.8022$

$f_a = \frac{10}{0.8022} = 12.465$ kHz



$P_0 = 2\pi f_a e^{-j\left(\frac{\pi}{8}+\frac{\pi}{2}\right)}$

$P_1 = 2\pi f_a e^{-j\left(\frac{\pi}{8}+\frac{\pi}{4}+\frac{\pi}{2}\right)}$

$P_2 = 2\pi f_a e^{-j\left(\frac{\pi}{8}+\frac{9\pi}{4}+\frac{\pi}{2}\right)}$

$P_3 = 2\pi f_a e^{-j\left(\frac{\pi}{8}+\frac{3\pi}{4}+\frac{\pi}{2}\right)}$

$P_0 = 2\pi f_a e^{-j\frac{5\pi}{8}} = -29973 - i\,72359$

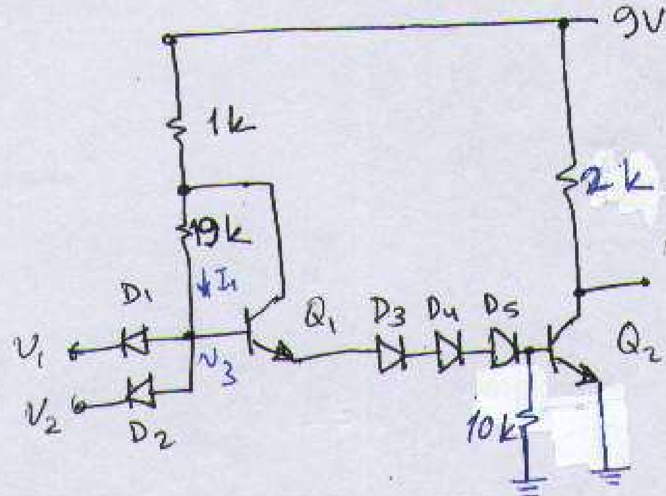
$P_1 = 2\pi f_a e^{-j\frac{7\pi}{8}} = -72359 - i\,29973$

$P_2 = 2\pi f_a e^{+j\,7\pi/8} = -72359 + i\,29973$

$P_3 = 2\pi f_a e^{+j\,5\pi/8} = -29973 + i\,72359$

30 pts

2) Find the high and low logic voltages, noise margins and fanout for the gate given below:



$\beta_F = 20$

all silicon

Q_2: sat $\rightarrow$ V(0) = 0.2V

Q_2: OFF $\rightarrow$ V(1) = 9V

NM0 = 2.2V

NM1 = −6.1V

Fanout = 125

<P_{diss}> = 34.37 mW

when $V_1 = V_2 = 0.2$ V

Q_2: OFF $\rightarrow V_o = 9V$

Q_1: OFF

D_3, D_4, D_5: OFF

$V_3 = 0.2 + 0.7 = 0.9V$

The current $I_1 = \frac{9-0.9}{19+1} = 0.405$ mA (std load)

$P_1 = I_1 \times 9\,V = 0.405 \times 9 = 3.645$ mW

To turn Q_2 ON (active), V_3 must be at least $0.5 + 3\times0.7 + 0.5 = 3.1$ V

V_1 can be increased to $3.1 - 0.7 = 2.4V$ w/o affecting Q_2.

acceptable $\rightarrow$ 2.4V
expected $\rightarrow$ 0.2V } $NM1 = 2.4 - 0.2 = 2.2V$

Now make $V_1 = V_2 = 9V \Rightarrow D_1, D_2$: OFF, $Q_1, Q_2, D_3 D_4 D_5 \rightarrow$ ON $V_o = 0.2V$

$V_3 = 0.8 + 3\times0.7 + 0.7 = 3.6V$. $I_{B_1} \times 19k + (\beta+1) I_{B_1} \times 1k = 9V$

$I_{B_1} = \frac{9-3.6}{19+21} = 0.135V$, $I_{E_1} = 21 \times 0.135 = 2.835$ mA

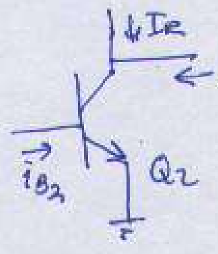
$I_{B_2} = I_{E_1} - \frac{0.8}{10k} = 2.755$ mA, $I_{C_2} = \frac{9-0.2}{2k} = 4.4$mA

$P_0 = 9(I_{E_1} + I_{C_2}) = 9 \times (2.835 + 4.4) = 65.11$ mW $\langle P_{diss} \rangle = \frac{P_0 + P_1}{2} = 34.37$ mW

V_1 and V_2 can be lowered until D1, D2 are turned on

V_1 expected $\rightarrow$ 9V
V_1 acceptable $= 3.6 - 0.7 = 2.9V$ } $NM0 = 2.9 - 9 = -6.1V$

For fanout, connect N identical stages:



saturation

$i_{C_2} < \beta i_{B_2}$

$i_{st} = 0.405$ mA (std load)

$I_R = 4.4$ mA (found earlier)

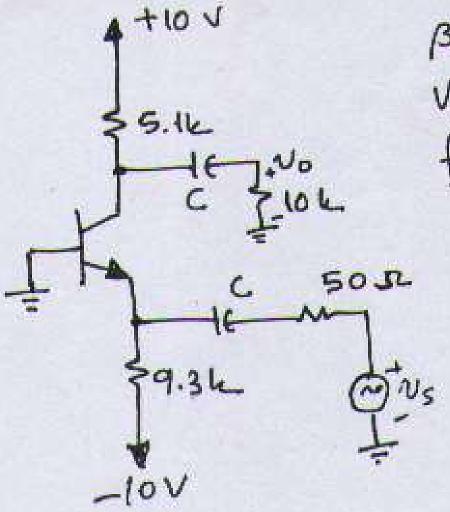
$I_R + N i_{st} < \beta i_b$

$N < \frac{\beta i_{b_2} - I_R}{i_{st}} = \frac{20 \times 2.755 - 4.4}{0.405} = 125.18$

fanout = 125

30 Pts

3) In the amplifier below, the lower cut-off frequency is desired to be less or equal to 200 Hz. If the capacitors have the same value, what should be the minimum capacitance C?



$\beta = 250$

$V_A \to \infty$

$f_T = 500\text{ MHz}$

$C_\mu = 1\text{pF}$

$I_C \cong I_E = \dfrac{-0.7-(-10)}{9.3\text{k}} = 1\text{ mA}$

$g_m = \dfrac{1}{0.025} = 40\text{ mA/V}$

$r_\pi = \dfrac{\beta}{g_m} = \dfrac{250}{40} = 6.25\text{ k}\Omega$

Thevenin resistances seen by the capacitors

$$R_{th_1} = \left(9.3\text{k} \,\|\, \frac{r_\pi}{\beta+1}\right) + 50\Omega = 24.8 + 50 = 74.8\Omega$$

$$R_{th_2} = 5.1\text{k} + 10\text{k} = 15.1\text{ k}\Omega$$

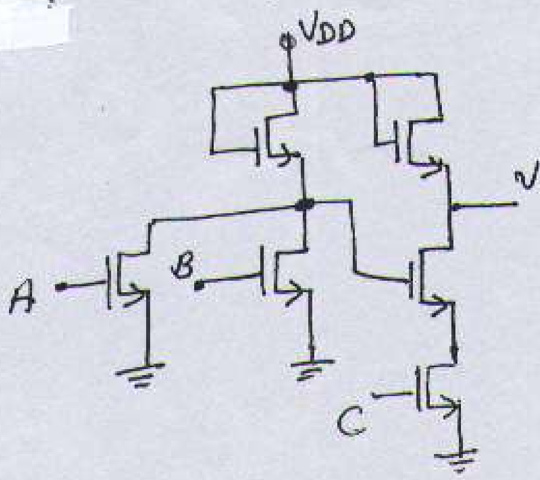
Superposition of poles $\omega_L \cong \omega_1 + \omega_2$

$$= \frac{1}{CR_{th_1}} + \frac{1}{CR_{th_2}} = \frac{1}{C}\left(\frac{1}{R_{th_1}} + \frac{1}{R_{th_2}}\right)$$

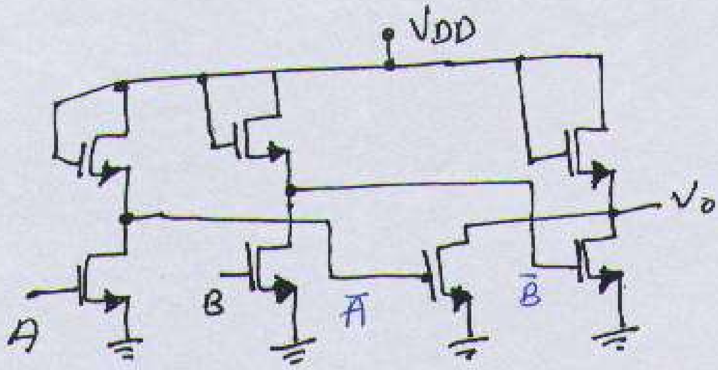
$$C = \frac{1}{\omega_L}\left(\frac{1}{R_{th_1}} + \frac{1}{R_{th_2}}\right) = \frac{1}{200 \times 2\pi}\left(\frac{1}{15100} + \frac{1}{74.8}\right) = 1.069 \times 10^{-5}\text{ F}$$

$$= 10.69\ \mu\text{F}$$

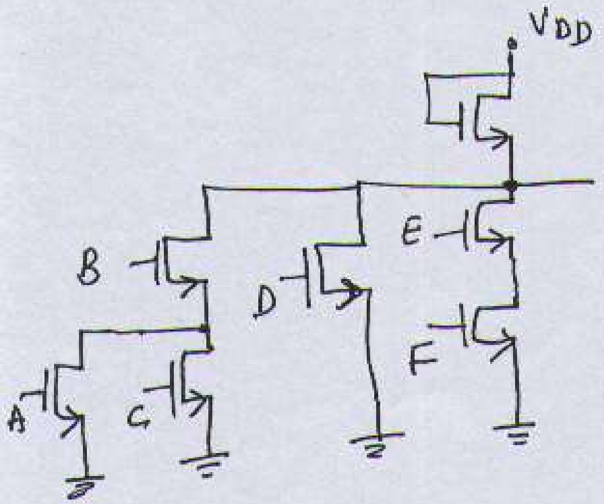
10 pts 4. Find the logic functions for the NMOS gates given below. $V_{DD} \gg V_{tn}$



$V_o = \overline{\overline{A+B}\cdot C}$



$V_o = \overline{\overline{A}+\overline{B}}$



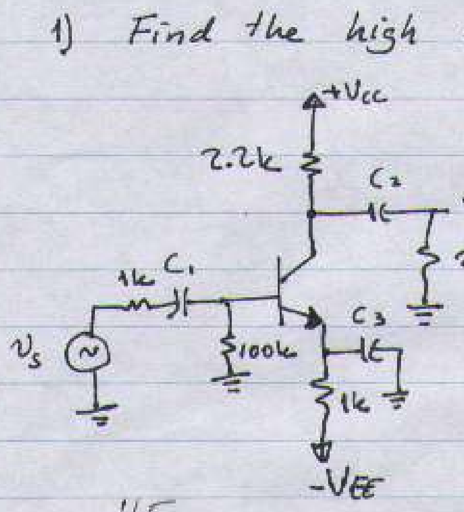
$V_o = \overline{(A+C)\cdot B + D + E\cdot F}$

Electronics II - Exam 1 - Summer 2004

Name: SOLUTIONS ID number: ERKAYA Signature: 28-7-2004

1) Find the high cut-off frequency for the amp circuit given below:

$f_H =$ ______



$I_c = 2\,mA$

$\beta_o = 300$

$C_\mu = 2\,pF$

$f_T = 400\,MHz$

$C_1 = C_2 = C_3 = 100\,\mu F$

$V_A = 200\,V$

$r_x = 90\,\Omega$

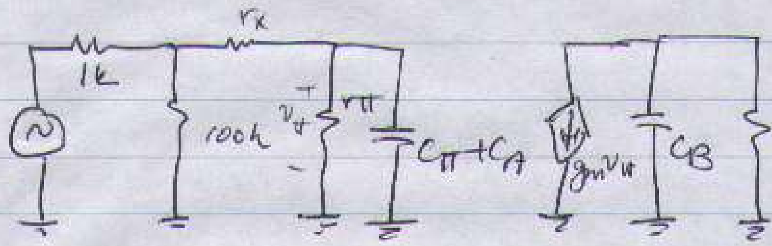
$g_m = \frac{I_C}{V_T} = \frac{2}{0.025} = 80\,mA/V$

$C_\pi = \frac{g_m}{2\pi f_T} - C_\mu = \frac{80\times10^{-3}}{2\pi\times4\times10^{8}} - 2\times10^{-12} \cong 30\times10^{-12}\,F$

$r_o = \frac{200V}{2mA} = 100k\Omega$

$r_\pi = \frac{\beta_o}{g_m} = \frac{300}{80} = 3.75\,k\Omega$

HF Small signal eq. ck – Miller's Theorem is applied on C_μ



$R_{sh} = r_o \| R_L \| R_C \simeq 1.1k\Omega$

$g_m R_{sh} = 88$

$C_A = 2(1+88) = 178\,pF$, $C_B \simeq C_\mu = 2\,pF$

Thevenin resistance seen by $C_\pi + C_A$

$R_{th_A} = r_\pi \| [r_x + (1k\|100k)] \cong 3.75 \| [0.09 + 1] = 844\,\Omega$

Thevenin resistance seen by C_B $R_{th_B} = R_{sh} = 1.1k\Omega$

$\omega_A = \frac{1}{(C_A + C_\pi) R_{th_A}} = \frac{1}{(30+178)\times10^{-12}\times844} = 5.69\times10^{6}\,rad/s$

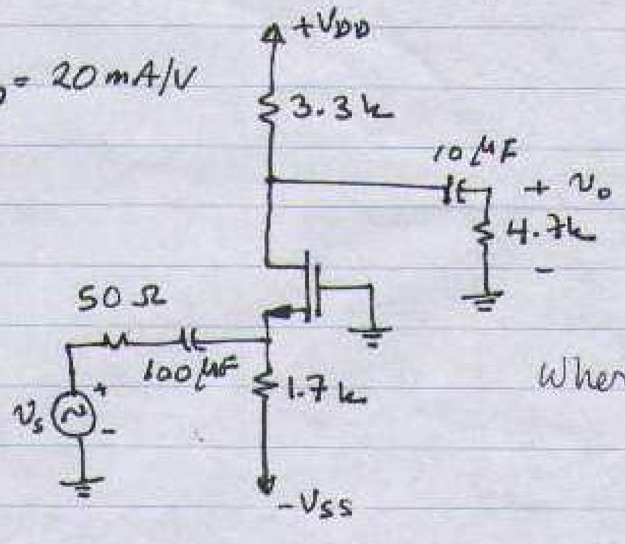
$\omega_B = \frac{1}{C_B R_{th_B}} = \frac{1}{2\times10^{-12}\times1100} = 454.\times10^{6}\,rad/s$

$f_H = \frac{1}{2\pi}\omega_H = \frac{1}{2\pi}\frac{1}{\frac{1}{\omega_A}+\frac{1}{\omega_B}} = \frac{5.69\times10^{6}\,rad/s}{2\pi} = 0.906\,MHz$

2) Find the low cut-off frequency for the amplifier given below:

$f_L = \underline{18.13}$

$g_m = 20\ mA/V$



Common gate amplifier

$$f_L \cong \frac{1}{2\pi C_1 R_{th_1}} + \frac{1}{2\pi C_2 R_{th_2}}$$

Where $C_1 = 100\ \mu F$

$R_{th_1} = 50 + \left(\frac{1}{g_m} \| 1.7k\right) = 98.6\ \Omega$

$C_2 = 10\ \mu F$

$R_{th_2} = 3.3k + 4.7k = 8k$

$$f_L \cong \frac{1}{2\pi \times 100 \times 10^{-6} \times 98.6} + \frac{1}{2\pi \times 10 \times 10^{-6} \times 8000} = 16.14 + 1.99 = 18.13\ Hz$$

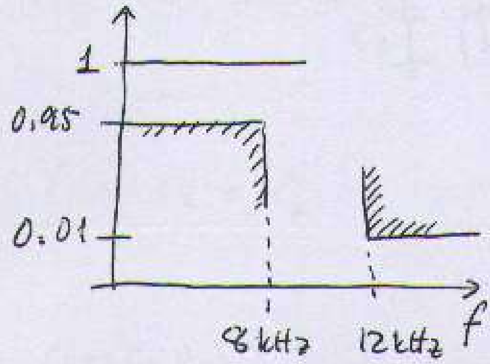
Electronics 2 * Exam 4 * Summer 2004

ID Number: ERKAYA Name: SOLUTIONS Signature: 18.8.2004

1) Find the poles of the minimum order Butterworth filter to meet the specification given below.

normalized gain

9:15



$$\frac{1}{\sqrt{1+\left(\frac{8}{f_a}\right)^{2n}}} = 0.95$$

$$\frac{1}{\sqrt{1+\left(\frac{12}{f_a}\right)^{2n}}} = 0.01$$

$$\left(\frac{1}{0.95}\right)^2 - 1 = \left(\frac{8}{f_a}\right)^{2n} = 0.108$$

$$\left(\frac{1}{0.01}\right)^2 - 1 = \left(\frac{12}{f_a}\right)^{2n} = 9999$$

$$\left(\frac{8}{12}\right)^{2n} = 1.08 \times 10^{-5}$$

$$2n \log\left(\frac{8}{12}\right) = \log\left(1.08 \times 10^{-5}\right)$$

$$n = \frac{\log(1.08 \times 10^{-5})}{2\log\left(\frac{8}{12}\right)} = \frac{-4.966}{-0.35} = +14.08$$

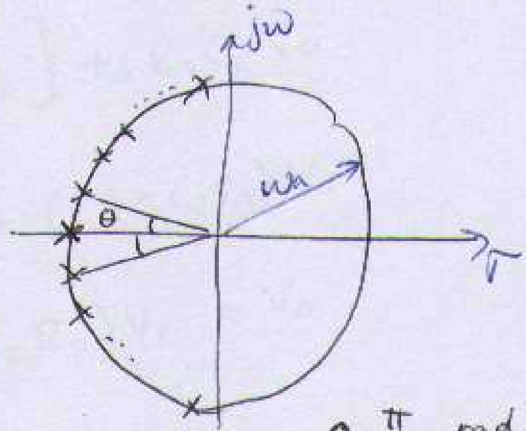
n must be raised to 15.

$$\left(\frac{12}{f_a}\right)^{28.06} = 9999$$

$$28.06 \log\left(\frac{12}{f_a}\right) = \log(9999) = 4$$

$$\log\left(\frac{12}{f_a}\right) = \frac{4}{28.06} = 0.142$$

$$10^{\log\left(\frac{12}{f_a}\right)} = \frac{12}{f_a} = 10^{0.142} = 1.3869$$



$\theta = \frac{\pi}{15}$ rad.

$$f_a = \frac{12}{1.3869} = \underline{8.65\ \text{kHz}}.$$

$$w_a = 2\pi\, 8.65 = 54.36 \times 10^3\ \text{rad/s}$$

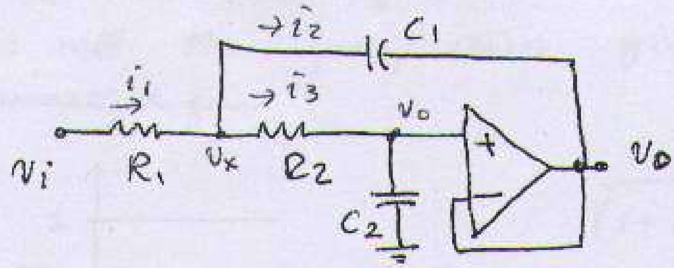
Poles $w_a e^{j(\pi \mp k\frac{\pi}{15})}$

where $\underline{k = 0, \mp 1, \mp 2, \cdots \mp 7}$

$w_a = 54.36 \times 10^3$ rad/s

9:25

2) Find the transfer function for the filter given below. Indicate what kind of a filter it is (Lowpass, bandpass, ...etc.)



type:

$\frac{V_o}{V_i} =$ ______

$i_2 = \frac{V_x - V_o}{\frac{1}{sC_1}} = sC_1(V_x - V_o)$

$i_1 = i_2 + i_3$

$i_3 = \frac{V_x}{R_2 + \frac{1}{sC_2}} = \frac{V_x - V_o}{R_2} = \frac{V_o}{\frac{1}{sC_2}}$ — solve for V_x

$\frac{V_i - (1+sC_2R_2)V_o}{R_1} = sC_1\left[(1+sC_2R_2)V_o - V_o\right] + sC_2V_o$

$i_1 = \frac{V_i - V_x}{R_1}$

$V_x - V_o = sC_2R_2V_o$

$V_x = (1+sC_2R_2)V_o$

$V_i - (1+sC_2R_2)V_o = sC_1R_1\left[sC_2R_2V_o\right] + sR_1C_2V_o$

$V_i = s^2C_1C_2R_1R_2V_o + sR_1C_2V_o + (1+sC_2R_2)V_o$

$= s^2C_1C_2R_1R_2V_o + s(R_1C_2 + C_2R_2)V_o + V_o$

$\frac{V_o}{V_i} = \frac{1}{s^2C_1C_2R_1R_2 + s(R_1C_2 + C_2R_2) + 1}$

$$\boxed{\frac{V_o}{V_i} = \frac{1/C_1C_2R_1R_2}{s^2 + s\frac{(R_1+R_2)}{C_1R_1R_2} + \frac{1}{C_1C_2R_1R_2}}}$$

Second order Low Pass filter

9:35

Electronics II * Exam 5 * Aug 25, 2004

IDnumber: ERKAYA Name: SOLUTIONS Signature: ________

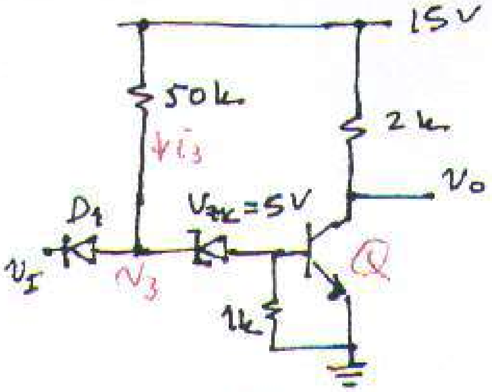
For the inverter given below, a) Find logic high and low voltages

b) Obtain the transfer characteristics (v_O vs. v_I)

c) Indicate V_{OH}, V_{IH}, V_{OL}, V_{IL} on (b)

d) Calculate noise margins using the results of (c)

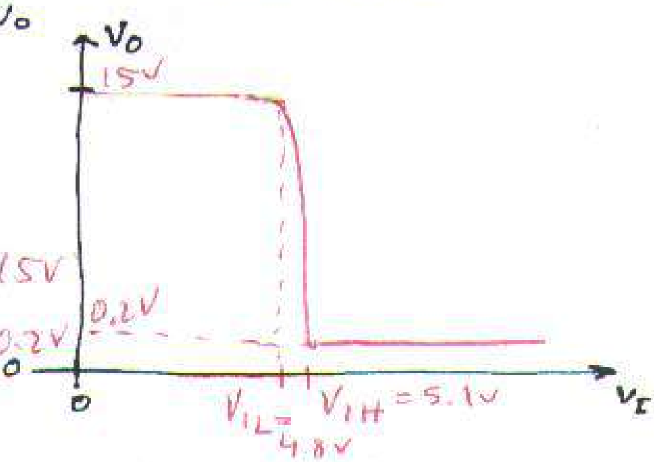
e) Calculate the power dissipation in the gate (average)



Silicon BJT

$\beta = 70$

D1: silicon diode



$V(1) = 15V$

$V(0) = 0.2V$

V_{OH} : 15V

V_{OL} = 0.2V

V_{IH} : 5.1V

V_{IL} : 4.8V

NM_H : -9.9

NM_L : 4.6V

P_{diss} : 58.99 mW

Q: OFF, $V_O = V(1) = V_{OH} = 15V$

Q: ON, $V_O = V(0) = V_{OL} = 0.2V$

$V_I = 0.2V \rightarrow$

To bring Q from OFF to active mode V_3 must be raised to $0.5 + 5.0 = 5.5V$. This makes $V_I = 5.5 - 0.7 = 4.8V$.

This would be acceptable low input voltage: $V_{IL} = 4.8V$

$V_I = 15V \rightarrow$ To bring Q from saturation to active mode, D1 must be turned on. $V_3 = 0.8 + 5.0 = 5.8V$

$V_{IH} = 5.8 - 0.7 = 5.1V$.

$NMH = 5.1 - 15 = -9.9V$

$NML = 4.8 - 0.2 = 4.6V$

Q: ON $\rightarrow$ $i_{supply} = i_C + i_3 = \frac{15-0.2}{2k} + \frac{15-5.8}{50k} = 7.58mA$ $P_0 = 15 \times 7.58 = 113.7$ mW

Q: OFF $\rightarrow$ $i_{supply} = i_3 = \frac{15-0.9}{50k} = 0.282mA$ $P_1 = 15 \times 0.282 = 4.23mW$

$P_{ave} = \frac{P_0 + P_1}{2} = 58.99 mW$

Electronics II * Exam I * March 29, 2006 * 70 minutes

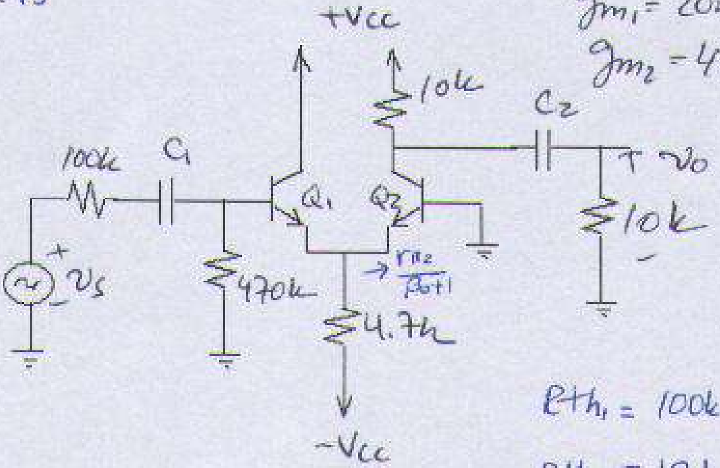
ID number: ____________ Name: SOLUTIONS ____________ Signature: ____________

30 pts

1) The lower 3 dB cutoff frequency of the amplifier below is desired to be below 300 Hz. If equal capacitor values are to be used, what should minimum value of the capacitors be?

$C_1 = C_2 = C = \underline{3\times10^{-8}\,F}$

8:43



$g_{m1} = 20mA/V$

$g_{m2} = 40mA/V$

$\beta_o = 300$

$r_{\pi_1} = \frac{\beta_o}{g_{m1}} = \frac{300}{20} = 15k\Omega$

$r_{\pi_2} = \frac{\beta_o}{g_{m2}} = \frac{300}{40} = 7.5k\Omega$

$Rth_1 = 100k + \left[470k \,\|\, \left[15k + 301\left(4.7k \,\|\, \frac{7.5k}{301}\right)\right]\right]$

$Rth_1 = 121.43k$

$Rth_2 = 10k + 10k = 20k$

$$300 = \frac{1}{2\pi}\left(\frac{1}{C_1 Rth_1} + \frac{1}{C_2 Rth_2}\right) = \frac{1}{2\pi C}\left(\frac{1}{Rth_1} + \frac{1}{Rth_2}\right)$$

$$C = \frac{1}{2\pi 300}\left(\frac{1}{121430} + \frac{1}{20000}\right) = 3\times10^{-8} F = 30\,nF$$

8:49

35 pts

2) Find the high 3dB cutoff frequency of the amplifier given below.

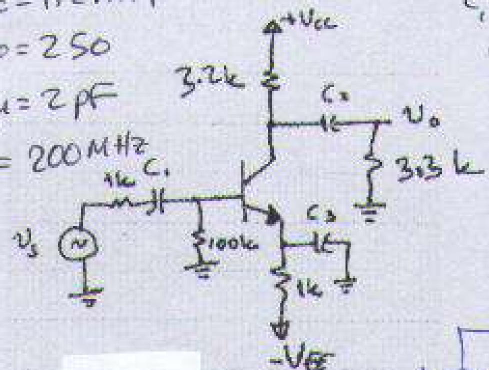
8:49

$I_c = 1.2 mA$

$\beta_0 = 250$

$C_\mu = 2 pF$

$f_T = 200 MHz$



$C_1 = C_2 = C_3 = 100 \mu F$

$V_A = 240V$

$r_x = 80 \Omega$

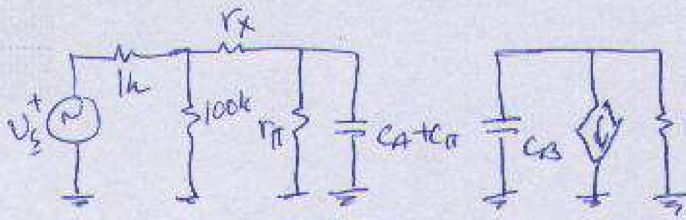
$g_m = \frac{1.2}{0.025} = 48 mA/V$

$r_\pi = \frac{250}{48} = 5.2 k\Omega$

$f_H =$ 923 kHz

Small signal eq. ck w/ miller's theorem applied on C_μ

$r_o = \frac{240}{1.2} = 200k$



$R_{sh} = 200k \| 3.2k \| 3.3k = 1.61k$

$C_\pi = \frac{g_m}{2\pi f_T} - C_\mu = \frac{48 \times 10^{-3}}{2\pi \times 200 \times 10^{6}} - 2 \times 10^{-12} = 36.2 \times 10^{-12} F$

$g_m R_{sh} = 48 \times 1.61 = 77.28$

$C_A = C_\mu (1 + g_m R_{sh}) = 2 \times 78.28 = 156.6 pF$

$C_B = C_\mu \left(1 + \frac{1}{g_m R_{sh}}\right) \simeq 2 pF$

$R_{thA} = r_\pi \| (r_x + 1k \| 100k)$

$\cong 5.2k \| 1.080 = 0.894 k$

$\omega_A = \frac{1}{(C_A + C_\pi) R_{thA}}$, $\omega_B = \frac{1}{C_B R_{sh}}$

$\omega_A = \frac{1}{(156.6 + 36.2) \times 10^{-12} \times 894} = 5.8 \times 10^{6} rad/s$

$\omega_B = \frac{1}{2 \times 10^{-12} \times 1610} = 310 \times 10^{6} rad/s$

$\omega_H = \frac{1}{\frac{1}{\omega_A} + \frac{1}{\omega_B}} \cong \omega_A = 5.8 \times 10^{6} rad/s$

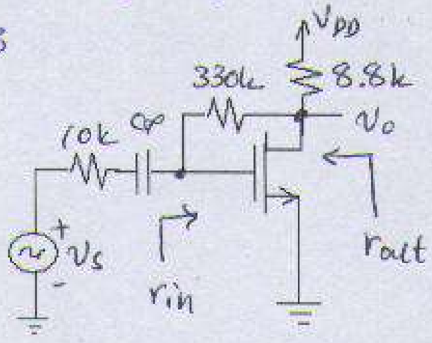
$f_H = \frac{5.8 \times 10^{6}}{2\pi} = 923 kHz$

8:58

35 Pts

3) Find the gain, input resistance and output resistance of the amplifier given below.

8:58



$r_o = 500k\Omega$

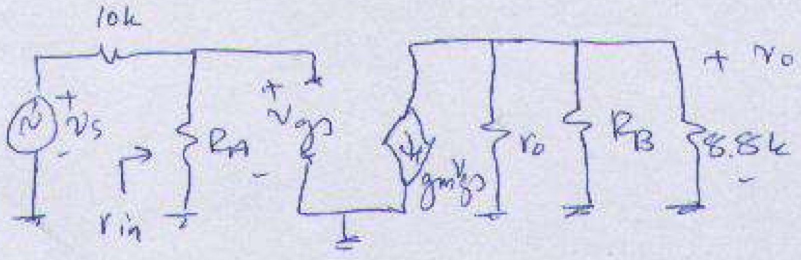
$g_m = 20mA/V$

Apply Miller's Theorem on 330k resistor

$\frac{v_o}{v_s} \cong -27.5$

$r_{in} = \underline{1.94\ k\Omega}$

$r_{out} = \underline{1.41\ k\Omega}$



$R_{sh} = r_o \| R_B \| 8.8k$

$R_B \cong 330k$

$R_{sh} \cong 8.42\ k\Omega$

$g_m R_{sh} = 168.5$

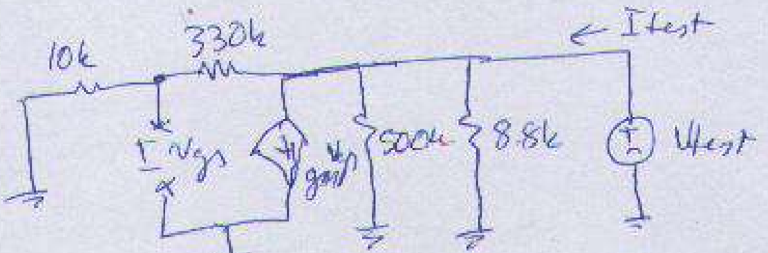
$$R_A = \frac{330k}{1+168.5} = 1.94\ k\Omega$$

$$\frac{v_o}{v_s} = -g_m R_{sh} \frac{1.94}{1.94+10k} = -27.5$$

$$r_{in} = R_A = 1.94k$$

rout must be found from the following ckt:

$$r_{out} = \frac{V_{test}}{I_{test}}$$



$$g_m v_{gs} = g_m \frac{10}{340} V_{test} = \frac{V_{test}}{\frac{34}{g_m}} = \frac{V_{test}}{1.7k}$$

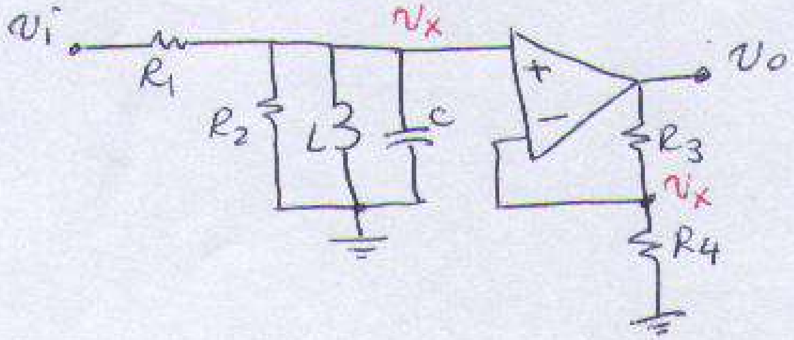
$$r_{out} = \frac{V_{test}}{\frac{V_{test}}{500k} + \frac{V_{test}}{8.8k} + \frac{V_{test}}{340k} + \frac{V_{test}}{1.7k}} = 500k \| 8.8k \| 340k \| 1.7k = 1.41\ k\Omega$$

9:06

Electronics II * Exam II * May 3, 2006 * 90 minutes

ID number: ____________ *Name:* SOLUTIONS *Signature:* ____________ *Grade:* ____

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

$b = \frac{1}{C}\left(\frac{R_3+R_4}{R_1 R_4}\right)$

$c =$ 0

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

$\omega_o/Q = \frac{1}{C}\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$

type = bandpass

$$\frac{V_i - V_x}{R_1} = \frac{V_x}{R_2} + \frac{V_x}{sL} + \frac{V_x}{\frac{1}{sC}}$$

$$V_x = V_o \frac{R_4}{R_3+R_4}$$

$$\frac{V_i}{R_1} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{sL} + sC\right) V_x$$

$$V_i = \frac{R_1 R_4}{R_3+R_4}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{sL} + sC\right) V_o$$

$$\frac{V_o}{V_i} = \frac{1}{\frac{R_1 R_4}{R_3+R_4}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{sL} + sC\right)} \qquad \frac{sL}{sL}$$

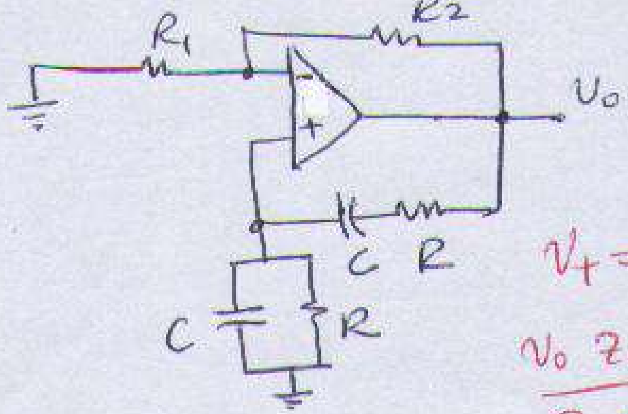
multiply by 1

$$= \frac{sL}{\frac{R_1 R_4}{R_3+R_4}\left(\frac{sL}{R_1} + \frac{sL}{R_2} + 1 + s^2 LC\right)}$$

dividing by LC

$$\frac{V_o}{V_i} = \frac{R_3+R_4}{R_1 R_4} \frac{s\frac{1}{C}}{s^2 + s\left(\frac{1}{R_1 C} + \frac{1}{R_2 C}\right) + \frac{1}{LC}}$$

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



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

condition : $\frac{R_2}{R_1} = 2$

$V_+ = V_-$

$\frac{V_o Z_1}{Z_1 + Z_2} = \frac{V_o R_1}{R_1 + R_2}$

$Z_1 = R \| \frac{1}{j\omega C} = \frac{R}{1 + j\omega CR}$

$Z_2 = R + \frac{1}{j\omega C}$

$$\frac{\frac{R}{1+j\omega CR}}{\frac{R}{1+j\omega CR} + R + \frac{1}{j\omega C}} = \frac{R_1}{R_1+R_2}$$

$$\frac{R}{R + \left(R + \frac{1}{j\omega C}\right)(1 + j\omega CR)} = \frac{R_1}{R_1 + R_2}$$

$$\frac{R}{R + R + R + j\omega CR^2 + \frac{1}{j\omega C}} = \frac{R_1}{R_1+R_2}$$

Real parts $\rightarrow$ $\frac{R}{3R} = \frac{R_1}{R_1+R_2}$ $\rightarrow$ $\boxed{\frac{R_2}{R_1} = 2}$

$\frac{1}{3} = \frac{1}{1 + \frac{R_2}{R_1}}$

Imaginary part

$j\omega CR^2 + \frac{1}{j\omega C} = 0$

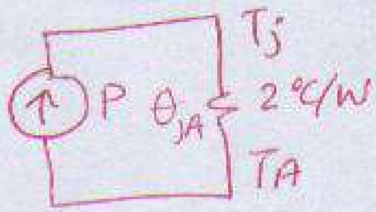
$j\omega CR^2 = -\frac{1}{j\omega C}$ $\rightarrow$ $\boxed{\omega = \frac{1}{CR}}$

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

3) A particular transistor having a thermal resistance $\theta_{JA} = 2°C/W$ is operating at an ambient temperature of 30°C with a collector-emitter voltage of 20 V. If long life requires a maximum junction temperature of 130°C, what is the corresponding device power rating? What is the greatest average collector current that should be considered?

$P =$ 50W

$I_{C\text{-}ave\text{-}max} =$ 2.5A

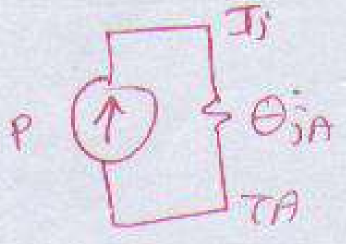


$T_j = T_A + \theta_{JA} P$

$\frac{T_j - T_A}{\theta_{JA}} = P \rightarrow P = \frac{130 - 30}{2} = 50\ W$

$50W = 20V\ I_C \rightarrow I_c = \frac{50}{20} = 2.5\ A$

4) A particular transistor has a power rating at 25°C of 200 mW, and a maximum junction temperature of 150°C. What is its thermal resistance? What is its power rating when operated at an ambient temperature of 70°C? What is its junction temperature when dissipating 100 mW at an ambient temperature of 50°C?



$\theta_{JA} = \frac{T_j - T_A}{P} = \frac{150 - 25}{0.2} = \frac{125}{0.2} = 625\ °C/W$

$\theta_{JA} =$ 625 °C/W

$P =$ 0.13 W

$T_J =$ 112.5°C

$P = \frac{150 - 70}{625} = \frac{80°C}{625°C/W} =$

$T_j = 50 + 0.100 \times 625 = 112.5\ °C$