ELECTRONICS I • FINAL EXAM

January 30, 1998 • 9:00 – 10:30 • Dr. Hasan Hüseyin Erkaya

I have neither given nor received unauthorized help with this exam.

ID: ____________ Name: SOLUTIONS ____________ Signature: ____________ Grade: ______

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6:49

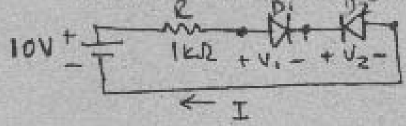
1) *(25 pts)* Two identical diodes are connected in a circuit as shown below. (I_S = 1 nA, η = 1, V_T = 25mV)

a) ***Estimate*** the current in the circuit. D2 Reverse biased $I = I_S$

$I =$ 1 nA

a) Find the ***exact*** voltages across the diodes *within tenths of mV*.

$V_1 =$ 17.3 mV $V_2 =$ 9982.7 mV



$I = I_s(e^{V_D/\eta V_T} - 1)$

$V_D = \eta V_T \ln\left(\frac{I}{I_s}+1\right)$, $V_{D_1} = 0.025 \ln\left(\frac{I_s}{I_s}+1\right) = 17.3$ mV

$10V = IR + V_1 + V_2$

$V_2 = 10 - V_1 - IR = 10000 - 17.3 - 1000 \times 10^{-9} \times 10^{3} =$

$= 10000 - 17.3 - 10^{-3} = 9982.699$ mV.

$\cong 9982.7$ mV

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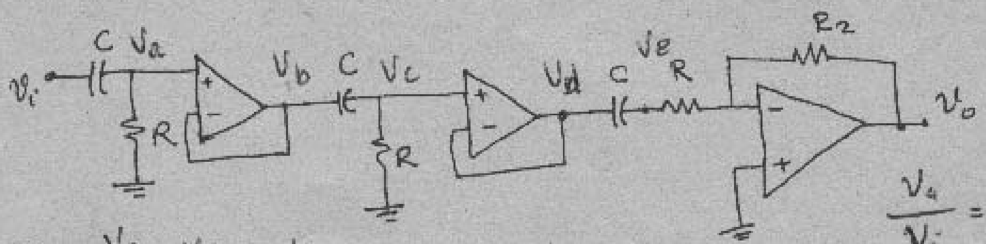
2) *(20 pts)* Find the frequency domain transfer function for the circuit given below.



$\frac{V_b}{V_a} = \frac{V_d}{V_c} = 1$

$\frac{V_a}{V_i} = \frac{R}{\frac{1}{j\omega C}+R} = \frac{j\omega RC}{1+j\omega RC}$

$\frac{V_o}{V_i} = \frac{V_o}{V_e}\cdot\frac{V_e}{V_d}\cdot\frac{V_d}{V_c}\cdot\frac{V_c}{V_b}\cdot\frac{V_b}{V_a}\cdot\frac{V_a}{V_i}$

$\frac{V_c}{V_b} = \frac{V_e}{V_d} = \frac{V_a}{V_i}$

$= \left(\frac{j\omega RC}{1+j\omega RC}\right)^3\left(-\frac{R_2}{R}\right)$

$\frac{V_o}{V_e} = -\frac{R_2}{R}$

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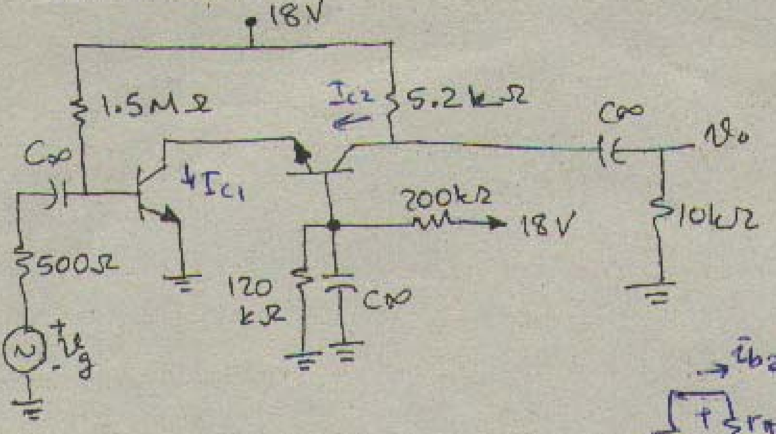
6:58

3) (25 *pts*) a) Find the small signal voltage gain in the circuit below. Assume $V_{BE} = 0.7$ V, $h_{FE} = 200$. $V_T = 25$mV

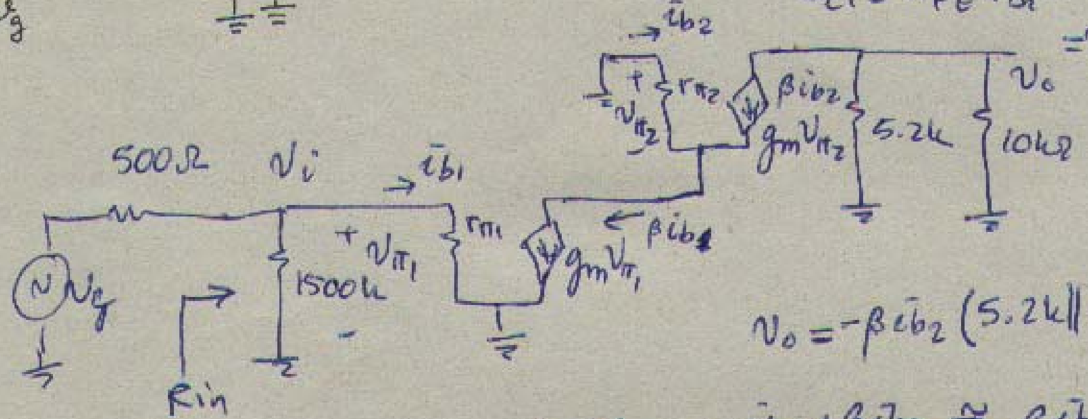
$\frac{v_o}{v_g} =$ ________



$I_{c_1} \simeq I_{c_2}$

$I_{B_1} = \frac{18-0.7}{1500} = 0{,}0115$ mA

$I_{c_1} = h_{FE} I_{B_1} = 200 \times 0{,}0115 =$
$= 2.3067$ mA.



$g_m = \frac{2.3}{0{,}025} = 92$ mA/V

$v_o = -\beta i_{b2} (5.2k \| 10k\Omega)$

$g_m v_{\pi_1} = i_{b_2} + \beta i_{b_2} \cong \beta i_{b_2}$ since $\beta \gg 1$

$\Rightarrow v_o \cong -g_m v_{\pi_1} (5.2k \| 10k)$

$R_{in} = 1500k \| r_{\pi_1} = 1500k \| \frac{200}{92} = 2.17$ kΩ

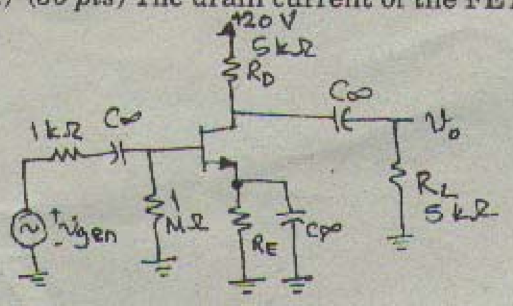
$v_\pi = v_i = v_g \frac{R_{in}}{0{,}5 + R_{in}} \cong v_g \frac{2.17}{2.67} = 0.81 v_g$

$\frac{v_o}{v_g} = \frac{v_o}{v_{\pi_1}} \cdot \frac{v_{\pi_1}}{v_i} \frac{v_i}{v_g} = -92(5.2 \| 10)(1)(0.81) = \underline{-254.9}$

7:10

7:10

4) (*30 pts*) The drain current of the FET in the circuit below is desired to be 2 mA. $V_P = -3V$, $I_{DSS} = 8mA$



$$I_D = K(V_{GS} - V_P)^2$$

$$K = \frac{I_{DSS}}{V_P^2} = \frac{8}{9} \; mA/V^2$$

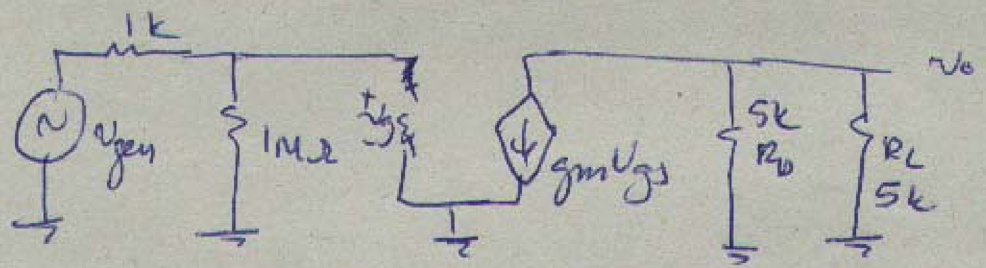
$$I_G = 0, \quad V_{GS} = -I_D R_E \Rightarrow R_E = \frac{-V_{GS}}{I_D}$$

a) Find the value of R_E $R_E = \frac{1.5}{2} = 0.75\,k\Omega$

$$2 = \frac{8}{9}(V_{GS}+3)^2 \Rightarrow (V_{GS}+3) = \sqrt{\frac{18}{8}}, \quad V_{GS} = \sqrt{\frac{18}{8}} - 3 = -1.5\,V.$$

b) Find the small signal voltage gain. $\frac{v_o}{v_{gen}} = -6.66$

$$g_m = 2\sqrt{K I_D} = 2\sqrt{\frac{8}{9} \times 2} = 2\sqrt{\frac{16}{9}} = 2\,\frac{4}{3} = \frac{8}{3} \; mA/V$$



$$\frac{v_{gs}}{v_{gen}} = \frac{1000}{1001} \simeq 1 \qquad v_o = -g_m v_{gs}(R_D \| R_L) = -v_{gs}\left(\frac{8}{3} \times 2.5\right)$$

$$\frac{v_o}{v_{gen}} = \frac{v_o}{v_{gs}} \cdot \frac{v_{gs}}{v_{gen}} \cong -\frac{8}{3} \times 2.5 = -6.66$$

7:17

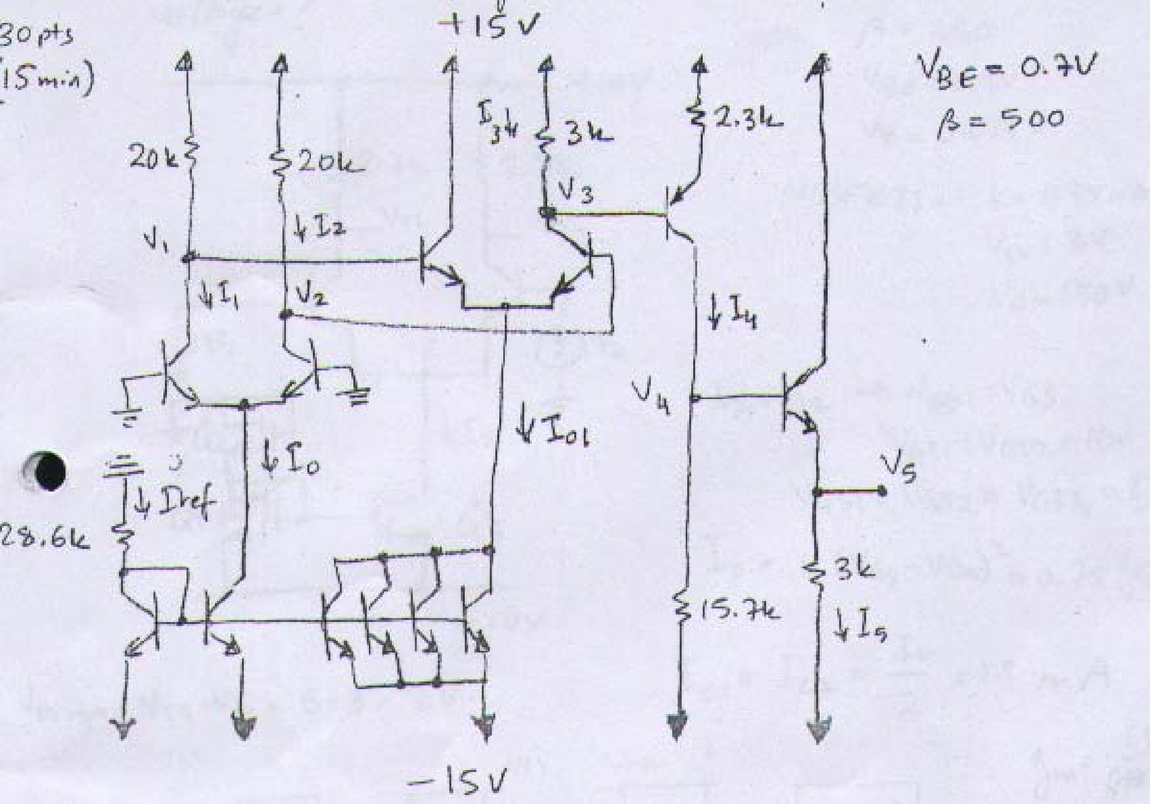
17
11
28 min. x 3 ≅ 90 min

Jan 21, 2003 ELECTRONICS-I FINAL EXAM 80 minutes

Name: ERKAYA ID No: SOLUTIONS Signature: ____________

1) Find the DC voltages and currents in the ckt given below.

30 pts (15 min)



V_1: 10V
V_2: 10V
V_3: 12V
V_4: 0.7V
V_5: 0V
I_1: 0.25mA
I_2: 0.25mA
I_3: 1mA
I_4: 1mA
I_5: 5mA

$I_{ref} = \frac{0+15-0.7}{28.6} = 0.5\,mA$, $I_o \cong I_{ref}$, $I_1 = I_2 = \frac{I_o}{2} = 0.25\,mA$

$V_1 = V_2 = 15 - 0.25 \times 20 = 10V$

$I_{01} = 4 \times I_o = 4 \times 0.5 = 2mA$, $I_3 = \frac{I_{01}}{2} = 1mA$,

$V_3 = 15 - 3 \times 1 = 12V$

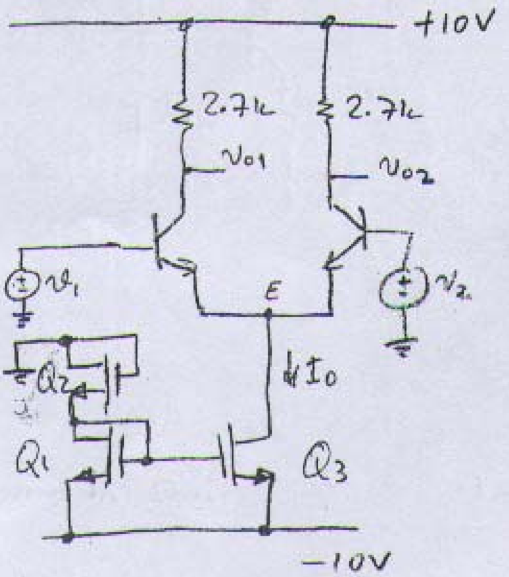
$I_4 \cong \frac{15-12-0.7}{2.3} = 1mA$, $V_4 = -15 + 15.7 = 0.7V$

$V_5 = V_4 - 0.7 = 0V$

$I_5 = \frac{0-(-15)}{3k} = 5mA.$

3) Analyze the differential amplifier given below. Find the diff. and common mode gains, input resistances and single-ended output resistance. Also, find the amplitude of v_{idm} for the max output signal w/o distortion. What are the max and min common mode input voltages?

40pts
(40 min)



$\beta = 250$
$V_{BE} = 0.7V$
$V_T = 0.025V$

MOSFETS: $K = 0.75\,mA/V^2$
$V_{TN} = 3V$
$V_A = 150V$

$A_{dm-se1} = \underline{-81}$
$A_{cm-se1} = \underline{-0.027}$
$r_{in-dm} = \underline{8.34k}$
$r_{in-cm} = \underline{25104k}$
$r_{out-se1} = \underline{2.7k}$
$|v_{idm}|_{max} = \underline{0.05V}$
$v_{icm\,min} = \underline{-12.3V}$
$v_{icm\,max} = \underline{6.45V}$

$I_{D1} = I_{D2} \rightarrow V_{GS1} = V_{GS}$
$V_{GS1} + V_{GS2} = 10V$
$V_{GS1} = V_{GS2} = V_{GS3} = 5V.$

$I_o = K(V_{GS} - V_{tn})^2 = 0.75(5-3)^2 = \underline{3mA}.$

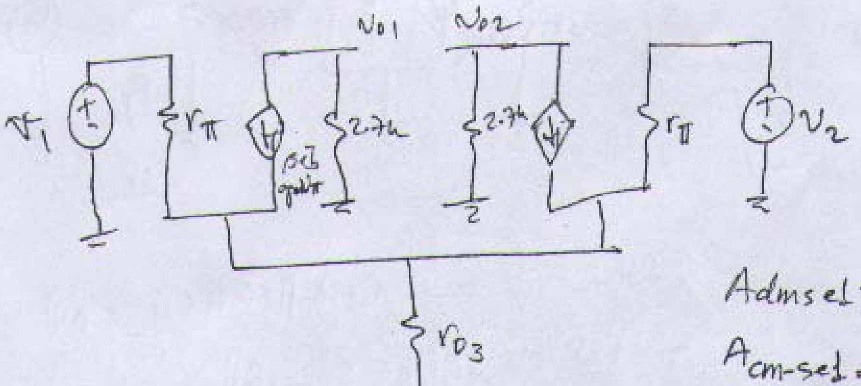
$V_{DS\,min} = V_{GS} - V_{tn} = 5 - 3 = 2V.$

$I_{C1} = I_{C2} = \frac{I_o}{2} = 1.5\,mA$

$r_{o3} = \frac{150}{3} = 50k\Omega$

$g_m = \frac{1.5}{0.025} = 60mA/V$

$r_\pi = \frac{250}{60} = 4.17k$



$A_{dmse1} = \frac{-g_m R_C}{2} = -\frac{60 \times 2.7}{2} = -81$

$A_{cm-se1} = \frac{-\beta R_C}{r_\pi + 2(\beta+1) r_{o3}} = \frac{-250 \times 2.7}{4.17 + 502 \times 50} = -0.027$

$r_{indm} = 2r_\pi = 8.34k\Omega$, $r_{in-cm} = r_\pi + 2(\beta+1) r_{o3} = 4.17 + 502 \times 50 = 25104\,k\Omega$

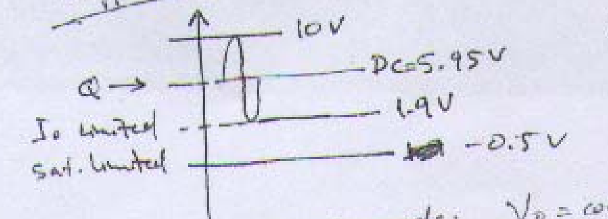
$r_{out-se} = 2.7k$

Each collector current : 0 — 3 mA , DC output voltage: $10 - 2.7 \times 1.5 = 5.95V.$

Saturation limit → $V_{o\,min\,SAT} = -0.7 + 0.2 = -0.5V.$

Current source limit $V_{o\,min} = 10 - 3 \times 2.7 = \underline{1.9V}.$

diff mode



w/o distortion max output signal ampl. $\underline{2.7 \times 1.5V.} = \underline{4.05V}$

$|v_{idm}|_{max} = \frac{4.05}{81} = \underline{0.05\,V.}$

common mode: V_o = constant

$V_o - V_{CESAT} + V_{BE} = 5.95 - 0.2 + 0.7 = 6.45V$

$V_{icm\,max} =$ ... $-15 + 2 + 0.7 = -12.3V.$

45

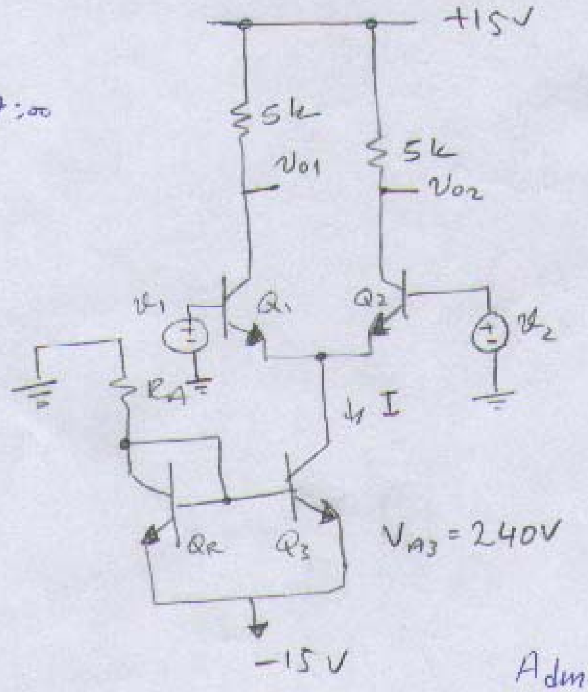
ELECTRONICS II – Exam I – July 29, 2002 – Dr. Erkaya – minutes – Closed book, closed notes.

I have neither given nor received unauthorized help with this exam, neither do I have a reason to believe that anybody else has.
(Kimseye kopya vermedim, kimseden kopya almadım. Kopya çekmedim. Başkalarının kopya çektiklerini düşünmüyorum.)

ID Number: ____________ *Name:* Solutions *Signature:* __________ *Grade:* __________

For the amplifier below, I = 3 mA, and the BJTs have a beta of 200. Find the differential and common mode single-ended voltage gain and input resistance.

17:00



$V_{A3} = 240V$

A_{dmse1}= ______

A_{cmse1}= ______

R_{in-dm}= ______

R_{in-cm}= ______

$I_{C1} = I_{C2} = \frac{3}{2} = 1.5\text{ mA}$

$g_{m1} = g_{m2} = \frac{1.5}{0.025} = 60\text{ mA/V}$

$r_{\pi 1} = r_{\pi 2} = \frac{200}{60} = 3.33k\Omega$

$r_{o3} \approx \frac{V_{A3}}{I} = \frac{240V}{3mA} = 80k\Omega$

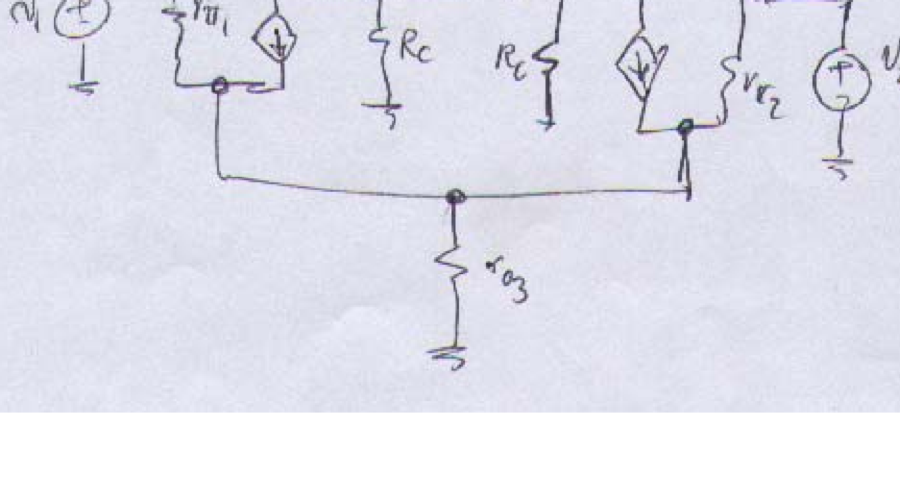
$A_{dm-se1} = -\frac{g_m R_C}{2} = -\frac{60 \times 5}{2} = -150$

$A_{cm-se1} = \frac{-\beta R_C}{2r_o(\beta+1) + r_\pi} = \frac{-200 \times 5}{402 \times 80 + 3.33} = \frac{-1000}{32163.33} = -0.0311$

$R_{in-dm} = 2r_\pi = 6.66k\Omega$

$R_{in-cm} = r_\pi + 2(\beta+1)r_o = 32163.33k\Omega$

Small signal eq. ckt:



3) The circuit below is to be used as a battery charger. Assume $\beta = 400$, $V_{BE} = 0.7$ V.

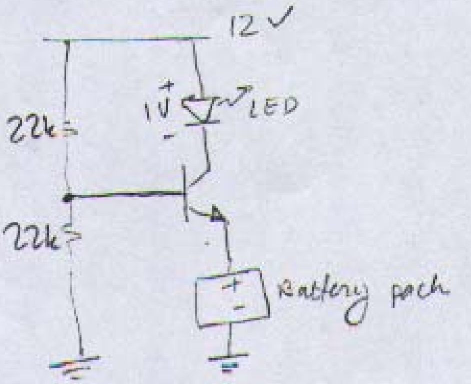
a) What would be the battery voltage when it is completely charged? $V_{battery\ max}$ = 5.3V

b) What would be the maximum charging current when the battery is completely drained to 0 V? $I_{battery\ max}$ = 193 mA

c) What must be the minimum *power rating* of the transistor? P_{min} = 2.12 W

5:50

5:57

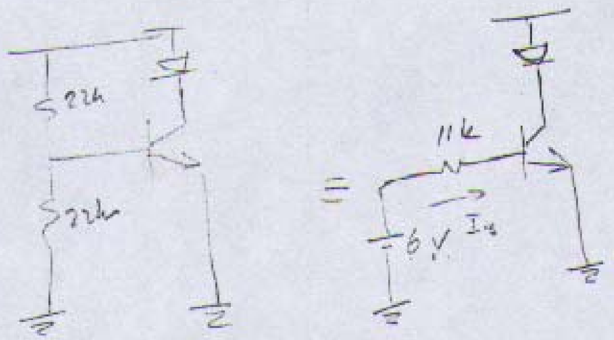


$V_{battery\,max} \doteq V_B - V_{BE}$

$V_B = 12 \frac{22}{22+22} = 6.0$ V

$V_{battery\,max} = 6 - 0.7 = 5.3$ V

b)



$I_B = \frac{6-0.7}{11k} = \frac{5.3V}{11k} = 0.4818$ mA

$I_E = (\beta+1) I_B = 401 \times 0.482 \doteq 193$ mA

c) max possible power dissipation in the transistor

$V_{CEmax} I_{cmax} = (12-1)\, 0.193 = 2.12$ W

min power rating 2.12 W

$I_D = 2mA$

2) For the FET in the circuit below, assume , $K = 10$ mA/V².

a) Find V_p *and* a small signal equivalent of the amplifier circuit.

b) Find the input resistance of the amplifier.

c) Find the output resistance of the amplifier.

d) Find $\frac{v_o}{v_s}$ voltage gain

$V_p = -2.44V$

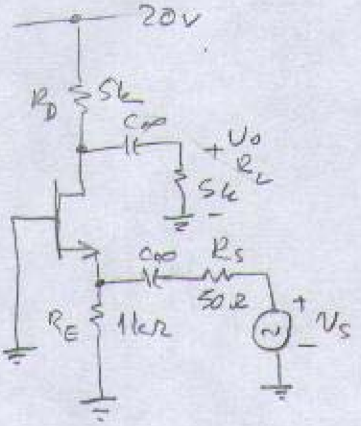
$r_{in} = 0.1\,k\Omega$

$r_{out} = 5k\Omega$

$\frac{v_o}{v_s} = 14.90$

5:39

5:47



a) $I_D = 2mA$, $R_E I_D = 2V$

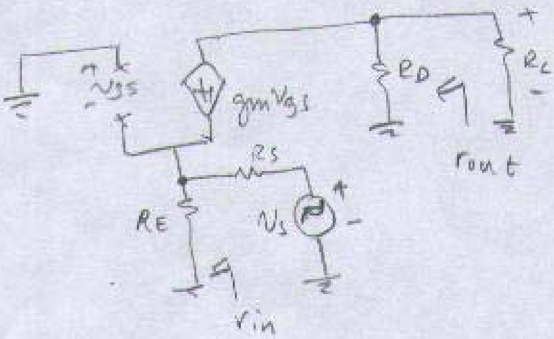
$V_G = 0$, $V_S = R_E I_D = 2V \rightarrow V_{GS} = -2V$

constant current mode $\rightarrow$ $I_D = K(V_{GS} - V_P)^2$

$2 = 10(V_{GS} - V_P)^2$

$\sqrt{\frac{2}{10}} = V_{GS} - V_P$

$V_P = V_{GS} - \sqrt{\frac{2}{10}} = -2 - \sqrt{\frac{2}{10}} = -2.44V$



$g_m = 2\sqrt{K I_D} = 2\sqrt{2 \times 10} = 8.94\,mA/V$

b) $r_{in} = R_E \| \frac{1}{g_m} = 1 \| \frac{1}{8.94} = 0.1\,k\Omega$

c) $r_{out} = R_D = 5k\Omega$

d) $\frac{v_o}{v_i} = +g_m R_D \| R_L = 8.94 \times 5 \| 5 = 22.35$

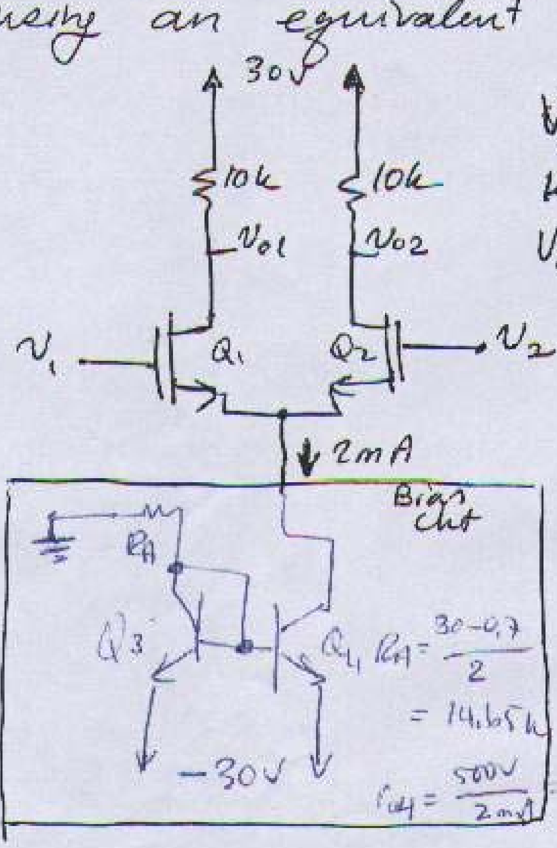
$\frac{v_o}{v_s} = \frac{v_o}{v_i} \frac{r_{in}}{R_s + r_{in}} = 22.35 \frac{100}{50 + 100} = 14.90$

Electronics I - Exam 5

ID number SOLUTIONS Name: ERKAYA Signature: ______

1) Design a bias circuit for the differential amplifier given below.
2) Calculate the diff. and common mode single ended gain using an equivalent circuit. Also find the input resistance

A_{dm-sel} = -31.6
A_{cm-sel} = -0.02
r_{in-dm} = ∞
r_{in-cm} = ∞



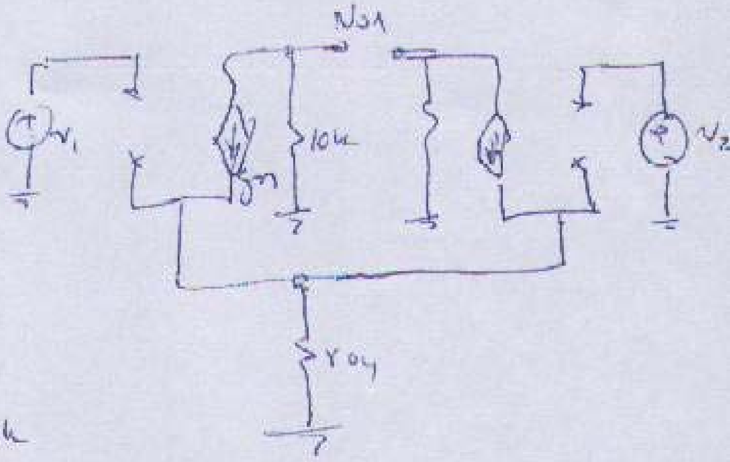
$V_{tn} = 2$ V
$K = 10$ mA/V
$V_A = 500$ V

$I_D = 1$ mA
$g_m = 2\sqrt{1 \times 10} = 6.32$ mA/V

$R_A = \frac{30-0.7}{2} = 14.65$ k

$r_{o4} = \frac{500V}{2mA} = 250$ kΩ

Small signal eq. cht



diff. mode gain $A_{dm-sel} = \frac{-g_m 10k}{2}$

$= -\frac{63.2}{2} = -31.6$

Common mode gain $\frac{-g_m 10k}{(2 r_{o4} g_m + 1)} = \frac{-63.2}{250 \times 6.32 + 1} = -0.02$

Since the input current = 0, the input resistance → ∞

Electronics I * Final Exam * February 1, 2005 * 90 minutes

I have never received or given any unauthorized help with this exam, nor do I have reason to believe that anybody else has.

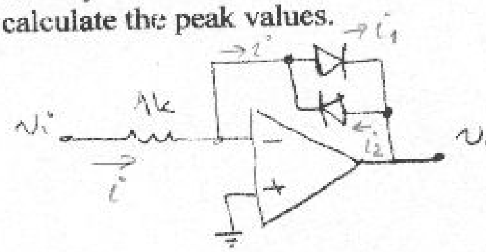
ID Number: ERKAYA Name: SOLUTIONS Signature:__________

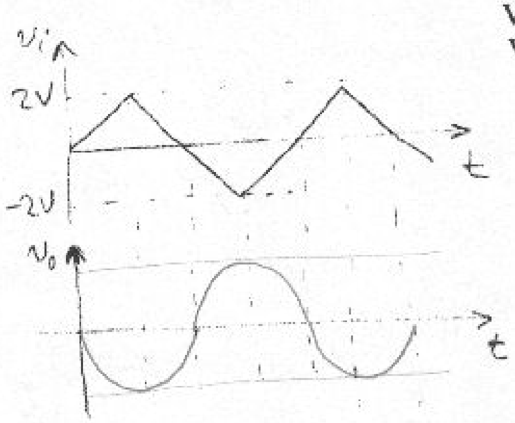
15 pts

1) The diodes in the circuit below are identical with a reverse saturation current of 10 nA and an ideality factor of 1.4. The input voltage is as shown below. Sketch the output voltage and calculate the peak values.

Vmax = ________

Vmin = ________





$v_i > 0 \rightarrow i = i_1 = I_s(e^{-v_o/\eta V_T} - 1) = \frac{v_i}{1k}$, $i_2 = 0$

$v_o = -\eta V_T \ln\left(\frac{i}{I_s} + 1\right)$

$v_i < 0$ $\quad i = -i_2 = -I_s(e^{v_o/\eta V_T} - 1)$, $i_1 = 0$

$v_o = \eta V_T \ln\left(\frac{-i}{I_s} + 1\right)$

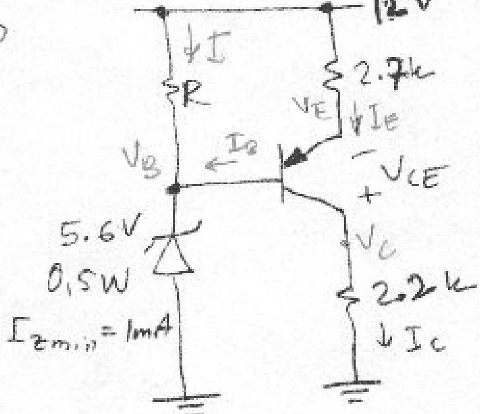
$\eta = 1.4$

$I_s = 10 \times 10^{-9}$ A

v_i	i	v_o
0	0	0 V
1V	1mA	0.42 V
2V	2mA	0.427 V

15 pts

2) In the circuit below assume R is selected to bias the BJT in active mode. Find the operating point for the transistor. Also find the minimum and maximum values for R to keep the transistor at the same operating point without any damage to any components in the circuit.



Silicon

$\beta = 300$

$V_B = 5.6V$

$V_E = 5.6 + 0.7 = 6.3V$

$I_E = \frac{12 - 6.3}{2.7} = 2.11\,mA$

$I_C \simeq I_E = 2.11\,mA$

$I_C \cong$ 2.11 mA

V_{CE} = -1.66 V

R_{min} = 71.7 Ω

R_{max} = 6.445 kΩ

$V_{CE} = 2.2 \times 2.11 = 4.64V$

$V_{CE} = V_C - V_E = 4.64 - 6.30 = -1.66\,V$

$I = I_Z - I_B$

$I_{Zmin} = 1mA$

$I_{Zmax} = \frac{500\,mW}{5.6\,A} = 89.285\,mA$

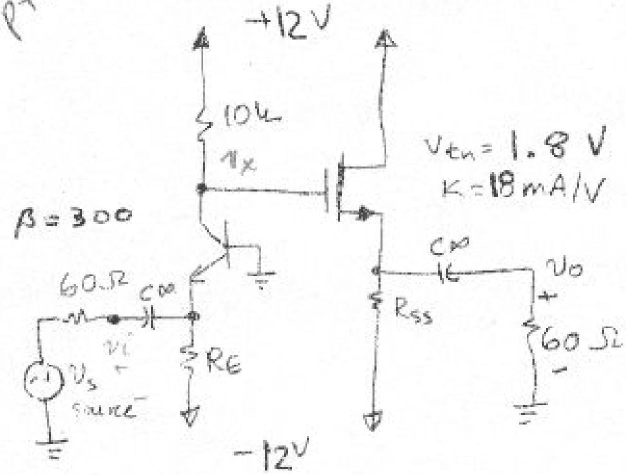
$I_B = \frac{2.11}{300} = 0.007\,mA$

$I_{min} = I_{Zmin} - I_B = 1 - 0.007 = 0.993\,mA \rightarrow R_{max} = \frac{12 - 5.6}{0.993} = 6.445\,k\Omega$

$I_{max} = I_{Zmax} - I_B = 89.285 - 0.007 = 89.278\,mA$ $\quad R_{min} = \frac{12 - 5.6}{89.278} = 0.0717\,k\Omega = 71.7\,\Omega$

35 pts

3) The circuit below is to be used as an impedance matching amplifier. Determine R_E and R_{SS} so that the input resistance as well as the output resistance of the amplifier is 60 ohms. With your design values, what is the voltage gain when this amplifier is placed between a 60-ohm output signal source and a 60 ohm load?



R_E = 27kΩ

R_{SS} = 4.56kΩ

v_o/v_s = 41.65

$r_{in} \cong R_E \| \frac{r_\pi}{\beta+1} \cong \frac{1}{g_{m1}}$

$r_{out} = R_{SS} \| \frac{1}{g_{m2}} \cong \frac{1}{g_{m2}}$

$g_{m1} = g_{m2} = \frac{1}{60\,\Omega} = \frac{1}{0.06\,k\Omega} = 16.66$ mA/V

BJT: $g_{m1} = \frac{I_C}{V_T} \rightarrow I_C = g_m V_T = 16.66 \times 0.025 = 0.417$ mA

$g_{m2} = 2\sqrt{K I_D} \rightarrow g_m^2 = 4 K I_D$

$I_D = \frac{g_m^2}{4K} = \frac{(16.66)^2}{4 \times 18} = 3.85$ mA

$I_C \cong I_E = \frac{12 - 0.7}{R_E} \Rightarrow \frac{11.3}{R_E} = 0.417$

$R_E = \frac{11.3}{0.417} \cong 27k\Omega$

$I_D = K(V_{GS} - V_{tn})^2$

$V_{GS} = V_{tn} + \sqrt{\frac{I_D}{K}}$

$= 1.8 + \sqrt{\frac{3.85}{18}} = 2.26$ V.

$V_G = 12 - 10 I_C = 12 - 10 \times 0.417 = 7.83$ V

$\frac{v_o}{v_s} = \frac{v_o}{v_x} \cdot \frac{v_x}{v_i} \cdot \frac{v_i}{v_s}$

$V_S = V_G - V_{GS} = 7.83 - 2.26 = 5.57$ V

$-12 + R_{SS} I_D = 5.57$

$R_{SS} = \frac{5.57 + 12}{I_D} = \frac{17.57}{3.85}$

$R_{SS} = 4.56k\Omega$

$\frac{v_o}{v_x} = \frac{(R_{SS} \| R_L) g_m v_{gs}}{v_{gs} + (R_{SS} \| R_L) g_m v_{gs}} \cong \frac{0.06 \times 16.66}{1 + 0.06 \times 16.66} = 0.5$

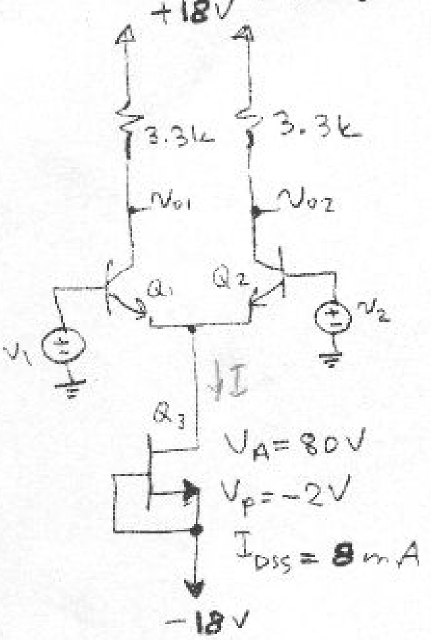
$\frac{v_x}{v_i} = g_m R_C = 16.66 \times 10 = 166.6$

$\frac{v_i}{v_s} = \frac{r_{in}}{R_s + r_{in}} = \frac{60}{60 + 60} = \frac{1}{2}$

$\frac{v_o}{v_s} = 0.5 \times 166.6 \times 0.5 = 41.65$ V/V

35 pts

4) Draw a small-signal equivalent circuit for the differential amplifier given below. Find the gain, input resistance and output resistance for differential and common modes. Also, find the maximum differential mode input signal amplitude, maximum and minimum commom mode input voltages for the proper operation of the circuit.



$\beta = 250$ for Q_1, Q_2

Silicon BJT:

$I = 8mA = I_{DSS}$

$r_{o3} = \frac{80V}{8mA} = 10k\Omega$

$I_{C1} = I_{C2} = \frac{I}{2} = 4mA$

$g_{m1} = g_{m2} = \frac{4}{0.025} = 160$ mA/V

$V_{o1} = 18 - 4 \times 3.3 = 4.80V$

$V_{o2} = 4.8V$. (no signal)

$r_\pi = \frac{250}{160} = 1.56k$

$r_{in\text{-}dm} =$ 3.12kΩ

$r_{in\text{-}cm} =$ 5021 kΩ

$r_{out\text{-}se} =$ 3.3k

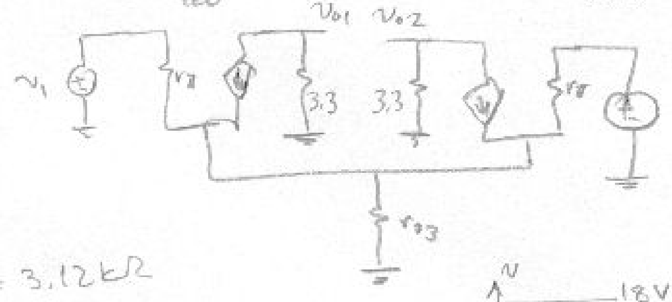
$A_{dm\text{-}se} =$ -264

$A_{cm\text{-}se} =$ 0.164

$max|v_{idm}| =$ 0.0163 V

$max(v_{icm}) =$ 5.3 V

$min(v_{icm}) =$ -15.3 V



$r_{out\,se} = 3.3k$

differential mode

$r_{indm} = 2r_\pi = 2 \times 1.56 = 3.12k\Omega$

$A_{dm\text{-}sel} = -\frac{g_m R_C}{2} = \frac{-160 \times 3.3}{2} = -264$

max signal amplitude w/o distortion

$4.8 - 0.5 = 4.3V$

saturation Limit

$V_E + 0.2 = -0.5V$

$max|V_{icm}| = \frac{4.3}{264} = 0.0163V$

Common mode

$r_{incm} = r_\pi + 2(\beta+1)r_{o3} = 1.56 + 2 \times 251 \times 10 = 5021.56k\Omega$

$A_{cm\text{-}sel} = \frac{-\beta R_C}{r_\pi + 2(\beta+1)r_{o3}} = \frac{-250 \times 3.3}{5021.56} = 0.164$

$Max(V_{icm}) = V_{o1} - V_{CESAT} + V_{BE} = 4.8 - 0.2 + 0.7 = 5.3V$

$V_{DSmin} = V_{GS} - V_{tn} = 0 - (-2) = 2V.$

$min(V_{icm}) = -18V + V_{DSmin} + V_{BE}$

$= -18 + 2 + 0.7 = -15.3V$