ERKAYA

ELECTRONICS I • MIDTERM II

December 19, 1998 • 9:00 – 10:30 • Dr. Hasan Hüseyin Erkaya

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

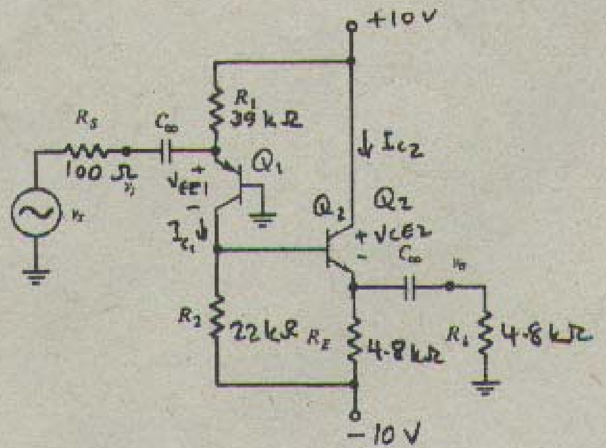
ID: ____________ Name: SOLUTIONS Signature: ____________ Grade: ______

1) (*25 pts*) A BJT amplifier circuit is given below. (h_{FE} = 499, $|V_{EB}|$ = 0.7V, V_T = 25mV)

a) Draw the DC equivalent circuit and find the operating points of the transistors.

I_{C1} = 0.238 mA I_{C2} = 0.946mA V_{EC1} = 5.46V V_{CE2} = 15.46V

6:52



$V_{E1} = 0.7V$

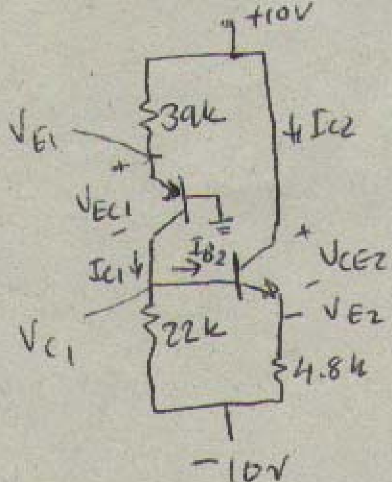
$I_{E1} = \frac{10-0.7}{39k} = 0.2385 mA$

$I_{C1} \cong I_{E1} = 0.238 mA$

ignoring I_{B2}, $V_{C1} = -10 + I_{C1} 22k$

$= -10 + 0.238 \times 22k$

$= -4.76V$



$V_{EC1} = V_{E1} - V_{C1}$

$= 0.7 - (-4.76) = 5.46V$

$V_{E2} = V_{C1} - 0.7 = -4.76 - 0.7 = -5.46V$

$I_{E2} = \frac{-5.46 - (-10)}{4.8} = 0.946 mA$

$I_{B2} = \frac{0.946}{499} = 0.0019 mA$

$I_{C2} \cong I_{E2} = 0.946mA$

$I_{B2} \ll I_{C1}$

$V_{CE2} = 10 - V_{E2} = 10 - (-5.46) = 15.46v.$

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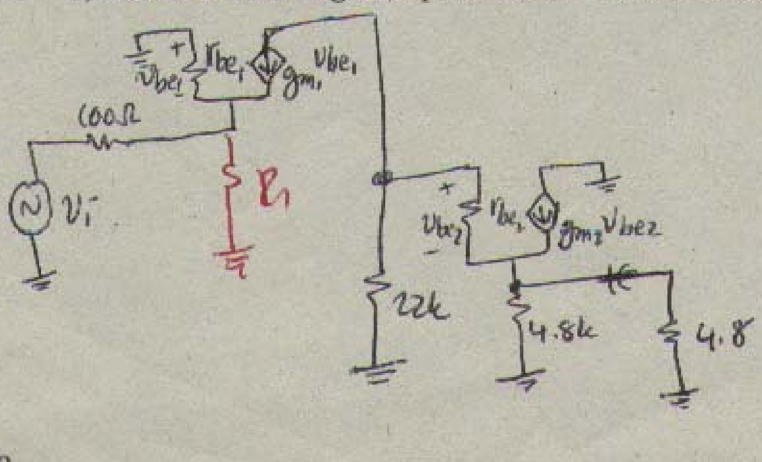
b) Obtain a small-signal equivalet of the circuit (including small signal models of the transistors).



$g_{m1} = \frac{I_{C1}}{V_T} = \frac{0.238}{0.025} = 9.52 mA/V$

$r_{be1} = \frac{\beta}{g_m} = \frac{499}{9.52} = 52.42 k\Omega$

$g_{m2} = \frac{I_{C2}}{V_T} = \frac{0.946}{0.025} = 37.84 mA/V$

$r_{be2} = \frac{499}{37.84} = 13.18 k\Omega$

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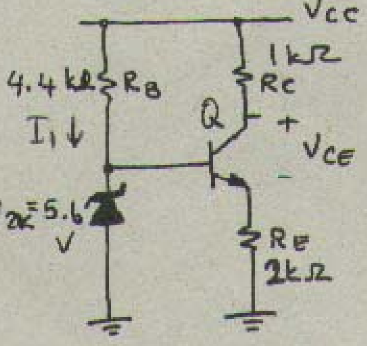
2) (25 *pts*) a) Find the operating point of the bipolar transistor in the circuit below. Assume V_{CC} = 10 V, V_{BE} = 0.7 V, h_{FE} = 100.

I_C = 2.4 mA V_{CE} = 2.7V



Expected operation

$V_B = V_{ZK} = 5.6V$

$V_E = 5.6 - 0.7 = 4.9V \rightarrow I_E = \frac{4.9}{2k} = 2.45$ mA.

$I_c \cong \frac{100}{101} 2.45 = 2.40mA$, $I_B = 0.024mA$.

$I_B \ll I_1 \Rightarrow$ zener diode is in breakdown

expected operation is valid

$I_1 = \frac{10-5.6}{4.4k} = 1mA$ $\quad V_{CE} = 10 - 1\times2.4 - 2k\times2.45 = 2.7V$

b) What will be the values of I_C and V_{CE} if the supply voltage V_{CC} is doubled?

I_C = 2.4mA V_{CE} = 12.7v

$V_B = V_{ZK} = 5.6V \rightarrow V_E = 4.9V \rightarrow I_E = 2.45mA$

the same I_c as above

$V_{CE} = 20 - 2.4 - 4.9 = 12.7V$

c) What will be the values of I_C and V_{CE} if the supply voltage V_{CC} is halved? (V_{CC} = 5 V)

I_C = 1.45mA V_{CE} = 0.2V

$V_{cc} = 5V \Rightarrow$ Zener open ckt

assume active mode: $I_B = \frac{5-0.7}{2(101)+4.4} = 0.0208mA$, $I_c = 2.08mA$.

$V_{CE} \cong V_{cc} - I_cR_c - I_ER_E = 5 - 1\times2.08 - 2\times2.08 = -1.24V < 0$

saturation $\rightarrow V_{CE} = V_{CSAT} = 0.2V$, $I_c \neq 2.08mA$

$(I_c+I_B)2 + 0.7 + 4.4I_B = 5V$, $(I_c+I_B)2 + 0.2 + I_c = 5V$

d) What will be the values of I_C and V_{CE} if h_{FE} = 500? (V_{CC} = 15 V)

I_C = 2.45mA V_{CE} = 7.65V

$(6.4I_B + 2I_c = 4.3V)(3)$

$+(2I_B + 3I_c = 4.8V)(-2)$

$15.2I_B = 3.3$

$I_B = \frac{3.3}{15.2} = 0.2171mA$

$V_E = 5 - 4.4\times0.2171 - 0.7 = 3.34V$

$I_c = \frac{5-(V_E+0.2)}{1k} = \frac{5-3.54}{1} = 1.45mA$.

d) $V_B = V_{ZK} \rightarrow V_E = 4.9$

$I_E = 2.45$ mA

$I_c = 2.45mA$ Same as in (a)

$V_{CE} \cong 15 - 2.45(1+2) = 7.65V$

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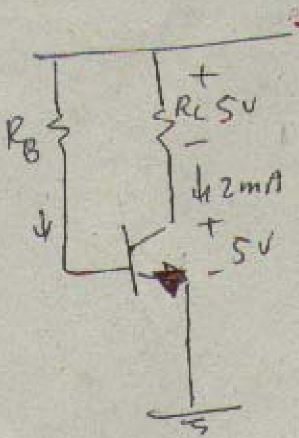
3) (*25 pts*) Design a bias circuit to have the operating point of a PNP bipolar transistor to be V_{EC} = 5 V, I_C = 2 mA. Any circuit that works is acceptable. (Assume β = 200, V_{EB} = 0.7 V)



$R_C = \frac{5}{2} = 2.5\,k\Omega$

$I_B = \frac{2}{200} = \frac{1}{100}$ mA

$R_B = \frac{10 - 0.7}{I_B} = \frac{9.3}{\frac{1}{100}} = 930\,k\Omega$

(no unique solution)

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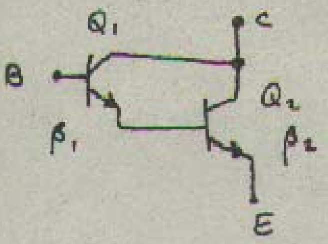
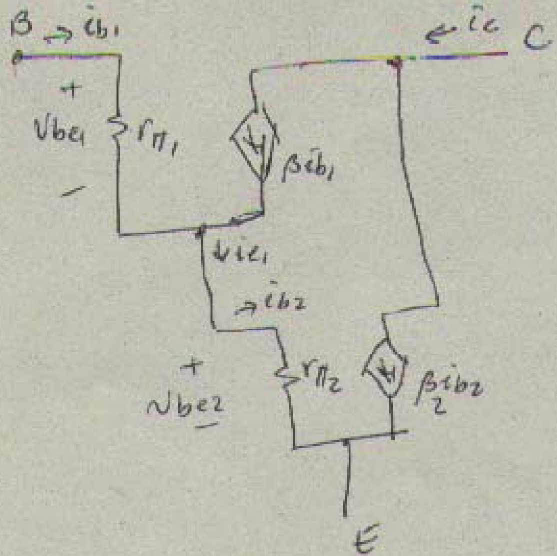
4. (*25 pts*) Sometimes, a high-β transistor is needed for applications. Two transistors are connected as shown below and used as a single transistor. This is also known as Darlington pair. Obtain a small signal model for the Darlington pair. (**Reduce it to a resistor and a current source**)





$v_{be1} = i_{b1} r_{\pi_1}$

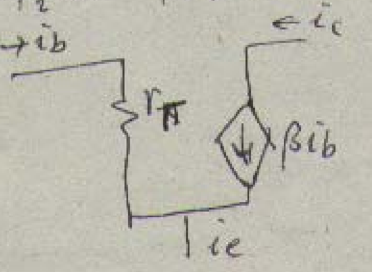
$v_{be2} = i_{b2} r_{\pi_2}$

$i_{b2} = (\beta_1 + 1) i_{b1}$

$v_{be2} = r_{\pi_2} (\beta_1 + 1) i_{b1}$

$v_{be} = v_{be1} + v_{be2} = i_{b1} \{ r_{\pi_1} + (\beta_1 + 1) r_{\pi_2} \}$

$i_c = \beta_1 i_{b1} + \beta_2 i_{b2} = \beta_1 i_{b1} + (\beta_1 + 1) i_{b1} \beta_2 = i_{b1} (\beta_1 + \beta_1 \beta_2 + \beta_2)$



$r_\pi = (\beta_1 + 1) r_{\pi_2} + r_{\pi_1}$

$\beta = (\beta_1 + \beta_1 \beta_2 + \beta_2)$

$r_{\pi_1} = \frac{V_T}{I_{B1}}$

$r_{\pi_2} = \frac{V_T}{I_{B2}} = \frac{V_T}{(\beta_1 + 1) I_{B1}}$

$r_{\pi_2} = \frac{r_{\pi_1}}{(\beta_1 + 1)}$

$r_\pi = \frac{(\beta_1 + 1) r_{\pi_1}}{(\beta_1 + 1)} + r_{\pi_1} = 2 r_{\pi_1} = 2 \frac{V_T}{I_{B1}}$

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Electronics I Exam 2 Date: 27 Dec 2001

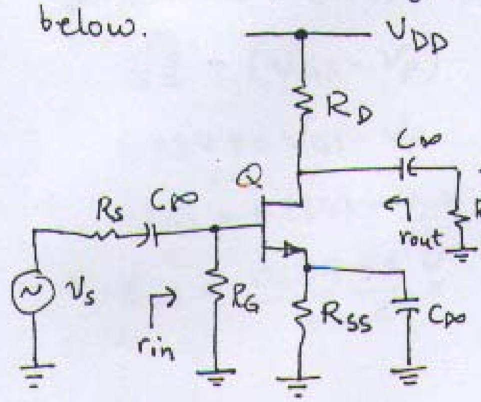
ID Number: ______ Name: SOLUTIONS Signature: ______

1) Find the operating point of the FET in the circuit below.

(40pts)

$I_D =$ 2 mA

$V_{DS} =$ 3.4 V



Assume the following

$V_{DD} = 12\,V$

$V_p = -2V$

$K = 2 mA/V^2$

$R_{SS} = 0.5 k\Omega$

$R_s = 1 k\Omega$

$R_G = 1 M\Omega$

$R_D = 3.8 k\Omega$

$R_L = 10 k\Omega$

from the ckt

$I_D R_{SS} + V_{GS} = 0 \Rightarrow I_D = \frac{-V_{GS}}{R_{SS}}$

also assume $I_D = K(V_{GS} - V_p)^2$

$K(V_{GS}^2 - 2V_pV_{GS} + V_p^2) = -\frac{V_{GS}}{R_{SS}}$

$K R_{SS}(V_{GS}^2 - 2V_pV_{GS} + V_p^2) + V_{GS} = 0$

Substitute the numerical values → $KR_{SS} = 1$, $V_p^2 = 4$

$V_{GS}^2 + 5V_{GS} + 4 = 0$ $\quad \frac{-b \mp \sqrt{b^2 - 4ac}}{2a} = \frac{-5 \mp \sqrt{25 - 16}}{2} = \frac{-5 \mp 3}{2}$

$V_{GS1} = -4$, $V_{GS2} = -1$ ← valid.

↑ not valid because it is less than V_p

$I_D = 2(-1+2)^2 = 2 mA$

$V_{DS} = V_{DD} - I_D(R_D + R_{SS}) = 12 - 2(3.8 + 0.5) = 3.4V$

verify assumption → $V_{DS} \overset{?}{>} V_{GS} - V_p = -1 + 2 = +1$

$3.4 > +1$ ✓

<u>cut-off</u>: $V_{GS} < V_p$, $I_D = 0$ <u>linear mode</u>: $V_{GS} > V_p$, $V_{DS} < V_{GS} - V_p$

$I_D = K[2(V_{GS} - V_p)V_{DS} - V_{DS}^2]$

<u>constant current mode</u>: $V_{GS} > V_p$, $V_{DS} > V_{GS} - V_p$

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

2) In the amplifier circuit of question 1, V_{DD} and R_{SS} are changed (40pts) to have $I_D = 3\,mA$ and $V_{DS} = 5\,V$.

a) What must be the new values of R_{SS} and V_{DD}

R_{SS} = 0.258 kΩ

V_{DD} = 17.17 V

$$I_D = 3mA = 2(V_{GS} - V_P)^2$$

$$\sqrt{\tfrac{3}{2}} = (V_{GS} - V_P)$$

$$1.2247 = V_{GS} - V_P$$

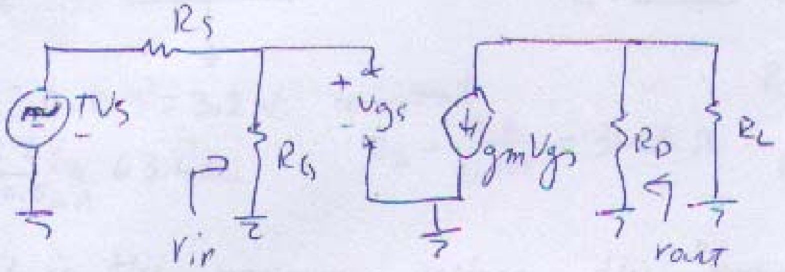
$$V_{GS} = 1.2247 - 2 = -0.7753\,V$$

$$R_{SS} = \frac{0.7753\,V}{3\,mA} = 0.258\,k\Omega$$

$$V_{DD} = 0.7753 + 5 + 3 \times 3.8 = 17.17\,V$$

b) Draw a small-signal equivalent ckt for the amplifier

g_m = 4.899 mA/V



$$g_m = 2\sqrt{K I_D} = 2\sqrt{2 \times 3} = 4.899\ mA/V$$

c) Find the input resistance, output resistance and the gain v_o/v_s of the amplifier circuit.

r_{in} = 1 MΩ

r_{out} = 3.8 kΩ

$\frac{v_o}{v_s}$ = −13.47

$$r_{in} = R_G = 1\,M\Omega$$

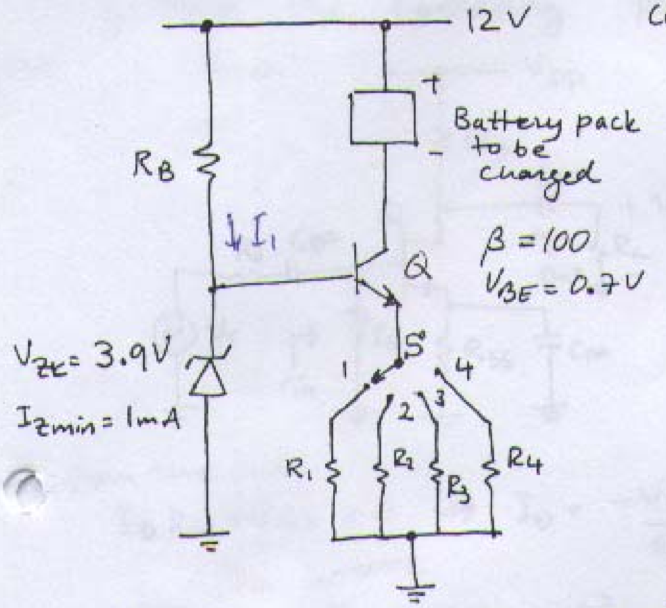
$$r_{out} = R_D = 3.8\,k\Omega$$

$$\frac{v_o}{v_s} = -g_m (R_D \| R_L) \frac{r_{in}}{R_s + r_{in}}$$

$$= -4.89\,(3.8 \| 10)\,\frac{1000}{1+1000} = -13.47$$

3) The following ckt is to be used as a constant-current battery charger. The positions of the switch S corresponds to the following current values:

Position	1	2	3	4
Current	50mA	100mA	200mA	400mA



a) Determine the max value for R_B $R_{B_{max}} =$ 1.62kΩ

$I_{Bmax} = \frac{I_{Cmax}}{\beta} = \frac{400}{100} = 4mA$

$I_1 = I_B + I_Z = 4+1 = 5mA$

$R_{Bmax} = \frac{12-3.9}{5mA} = 1.62k\Omega$

b) Determine the resistor values:

$R_1 =$ 63.4Ω $R_2 =$ 31.68Ω $R_3 =$ 15.84Ω $R_4 =$ 7.92Ω

$V_E = 3.9 - 0.7 = 3.2V$ constant

$R_1 = \frac{3.2V}{50.5mA} = 63.4\Omega$ $R_2 = \frac{3.2}{0.101} = 31.68\Omega$ $R_3 = \frac{3.2}{0.202} = 15.84\Omega$ $R_4 = \frac{3.2}{0.404} = 7.92\Omega$

c) What is the maximum voltage the "rechargeable battery pack" may have? $V_{Battery\,max} =$ 8.6

Q must be in active mode at all times → $V_{CE} \geq V_{CESAT} \cong 0.2V$

$V_{battery\,pack} < V_{DD} - V_E - V_{CESAT} = 12 - 3.2 - 0.2 = 8.6V$

d) What must be the power rating of the BJT.

$P_{Q_{max}} \cong V_{CEmax} I_{Cmax} = 8.8 \times 0.4 = 3.52W.$

possible $V_{CEmax} = 12 - 3.2 = 8.8V$

$I_{Cmax} = 400mA$

The power rating must be greater than 3.52 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. V_p = -2.44 V

b) Find the input resistance of the amplifier. r_{in} = 0.1 kΩ

c) Find the output resistance of the amplifier. r_{out} = 5kΩ

d) Find $\frac{v_o}{v_s}$ voltage gain $\frac{v_o}{v_s}$ = 14.90

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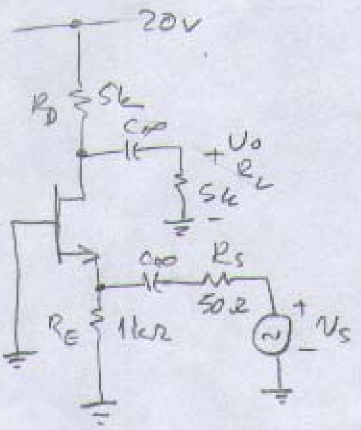
5:47



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

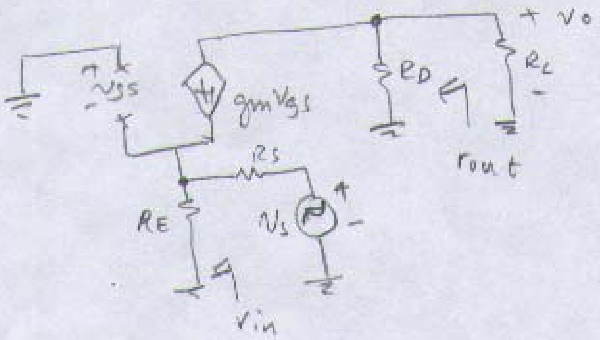
$V_G = 0$, $V_S = R_E I_D = 2V \rightarrow V_{GS} = -2V$

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) $r_{in} = R_E \| \frac{1}{g_m} = 1 \| \frac{1}{8.94} = 0.1$ kΩ

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

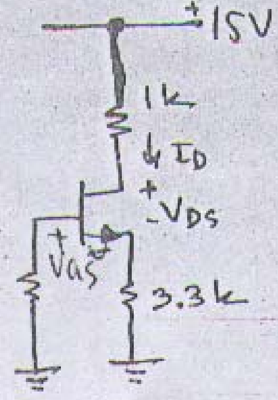
d) $\frac{v_o}{v_i} = +g_m R_D \| R_L = 8.94 \times 5 \| 5 = 22.35$

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

3. Find the operating point for the JFET in the circuit below.

$I_D =$ <u>0.726 mA</u>

$V_{DS} =$ <u>11.88 V</u>



$V_p = -3V$

$I_{DSS} = 18\ mA$ $K = \frac{I_{DSS}}{V_p^2} = \frac{18}{9} = 2 mA/V^2$

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

$3.3 I_D + V_{GS} = 0$

$3.3 \times K(V_{GS} - V_p)^2 + V_{GS} = 0$

$3.3 \times 2 (V_{GS} + 3)^2 + V_{GS} = 0$

$6.6 (V_{GS}^2 + 6 V_{GS} + 9) + V_{GS} = 0$

$6.6 V_{GS}^2 + 40.6 V_{GS} + 59.4 = 0$

$V_{GS} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$V_{GS1} = \frac{-40.6 - \sqrt{(40.6)^2 - 4 \times 6.6 \times 59}}{2 \times 6.6}$

$= \frac{-40.6 - 8.955}{2 \times 6.6} = -3.75 V$

$V_{GS2} = \frac{-40.6 + 8.955}{2 \times 6.6} = -2.39 V$

Since V_{GS} must be greater than V_p,

Valid solution → $V_{GS} = -2.397\ V.$

$I_D = 2(-2.397 + 3)^2 = 0.726\ mA.$

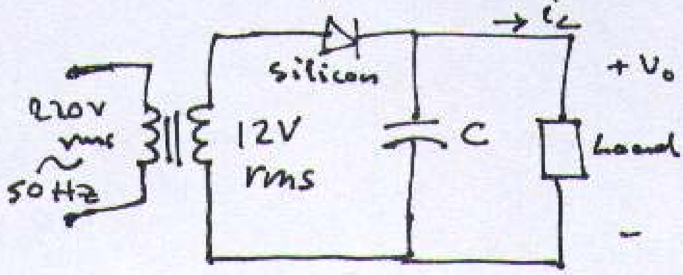
$V_S = 0.726 \times 3.3 = 2.39 V$
$V_D = 15 - 1 \times 0.726 = 14.27 V$
} $V_{DS} = \underline{11.88 V}.$

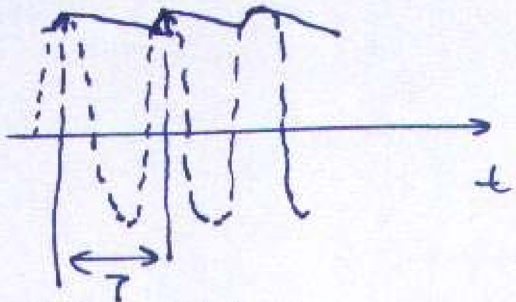
Electronics I - Exam 2 - 30 minutes

ID No: ERIGAYA Name: SOLUTIONS Signature: ______

1) For the rectifier circuit below, the peak-to-peak ripple is required to be less than 5% of the peak voltage. Determine the minimum C value for a load current of 500 mA.

C = 12300 μF





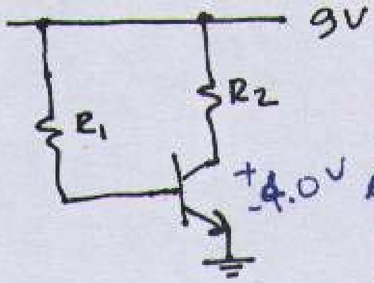
The peak voltage $= 12\sqrt{2} - 0.7 = 16.27\,V$

5% ripple $\rightarrow$ $0.81\,V = \Delta V$

$$\Delta Q = I_L T = 0.5 \times \frac{1}{50} = 0.01\,C$$

$$C = \frac{\Delta Q}{\Delta V} = \frac{0.01}{0.81} = 0.0123\,F = 12300\,\mu F$$

2) The transistor in the ckts below has the operating point of $I_c = 1\,mA$, $V_{CE} = 4\,V$; it is made of silicon and has a β of 300. Find R_1 and R_2 in each bias circuit. ($V_{BE} = 0.7\,V$)



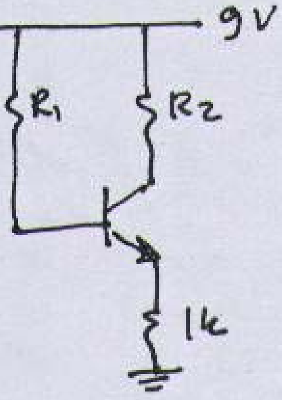
$I_E \cong I_C = 1\,mA$

$R_2 = \frac{9-4}{1} = 5k$

$R_1 = \frac{9-0.7}{\frac{1}{300}} = 2.49\,M\Omega$

$R_1 = \underline{2.49\,M\Omega}$

$R_2 = \underline{5k}$

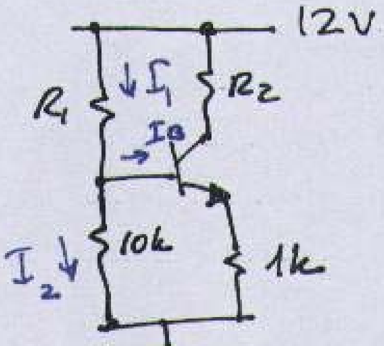


$R_2 = \frac{9-4-1\times1}{1} = 4k\Omega$

$R_1 = \frac{9-(1+0.7)}{\frac{1}{300}} = 2.19\,M\Omega$

$R_1 = \underline{2.19\,M\Omega}$

$R_2 = \underline{4k\Omega}$



$V_B = 1\times1 + 0.7 = 1.7\,V$

$I_2 = \frac{1.7}{10k} = 0.17\,mA$

$I_1 = I_2 + I_B = 0.17 + \frac{1}{300} = 0.1733\,mA$

$R_1 = \frac{12 - V_B}{I_1} = \frac{12-1.7}{0.1733} = 59.43\,k\Omega$

$R_2 = \frac{12-4-1\times1}{1} = 7k\Omega$

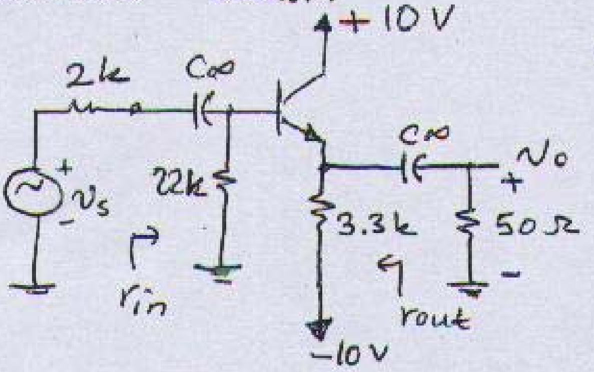
$R_1 = \underline{59.43\,k\Omega}$

$R_2 = \underline{7\,k\Omega}$

Electronics I – Exam 3 – 9.8.2004 30 minutes

ID number ERKAYA Name: SOLUTIONS Signature: ______

Find the DC operating point for the transistor in the amplifier circuit below. Also find the voltage gain, input resistance and output resistance of the amplifier using a small-signal equivalent circuit.



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

V_{CE} : 10.97V
I_c : 2.73 mA
$\frac{v_o}{v_s}$ = 0.6874
r_{in} = 8.795k
r_{out} : 16.4Ω

DC analysis: KVL

$$-10 + 3.3I_E + 0.7 + 22I_B = 0$$

$$(3.3 \times 251 + 22)\, I_B = 9.3$$

$$I_B = \frac{9.3}{3.3 \times 251 + 22} = 0.0109\,mA$$

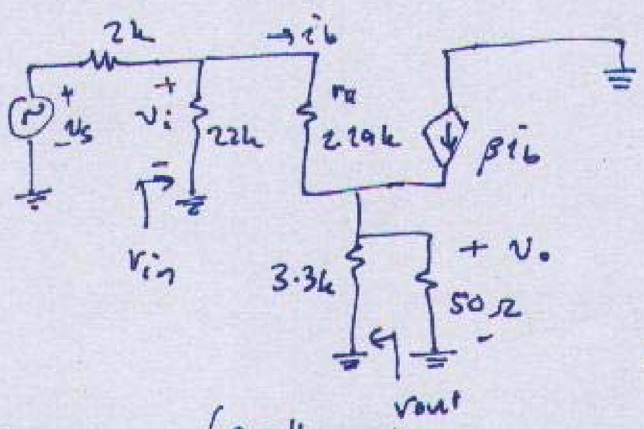
$I_E \simeq I_C$ since $\beta \gg 1$

$$I_c = 250\, I_B = 2.73\, mA$$

KVL

$$-10 + 3.3 \times 2.73 + V_{CE} = 10V, \quad V_{CE} = 20 - 3.3 \times 2.73 = 10.97V$$

SS. eq. ckt



$$g_m = \frac{I_c}{V_T} = \frac{2.73}{0.025} = 109.2\ mA/V$$

$$r_\pi = \frac{250}{109.2} = 2.29\,k\Omega$$

$$r_{in} = 22k \,||\, [2.29 + 251 \times (3.3||0.05)] = 8.795\,k\Omega$$

$$r_{out} = 3.3k \,||\, \frac{2.29k + 22||2k}{251} = 16.4\,\Omega$$

$$\frac{v_o}{v_i} = \frac{251\,(3.3||0.05)}{2.29 + 251\,(3.3||0.05)} = \frac{12.36}{14.65} = 0.8437$$

$$\frac{v_i}{v_s} = \frac{r_{in}}{R_s + r_{in}} = \frac{8.795}{10.795} = 0.8147$$

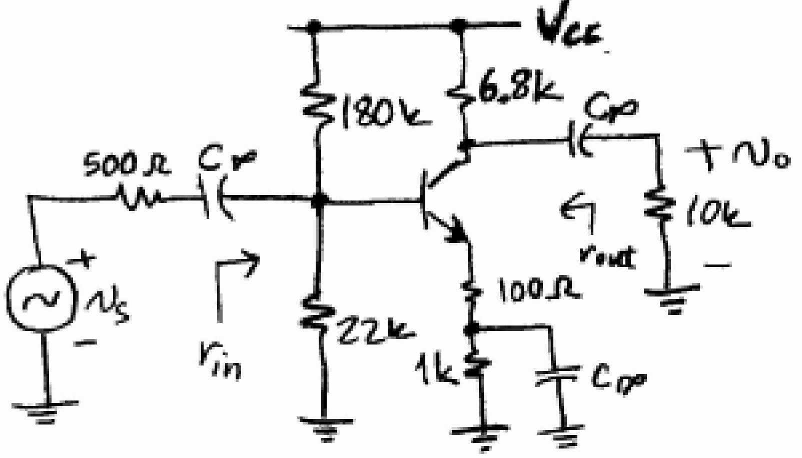
$$\frac{v_o}{v_s} = 0.8437 \times 0.8147 = 0.6874$$

Electronics I * Midterm II * December 05, 2006 * 60 minutes

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

ID number: SOLUTIONS *Name:* ERKAYA *Signature:* ______________

1) Obtain a small-signal equivalent circuit for the amplifier given below. Then find the input resistance, output resistance and voltage gain of the amplifier.



$I_c = 1.5\,mA$

$\beta = 240$

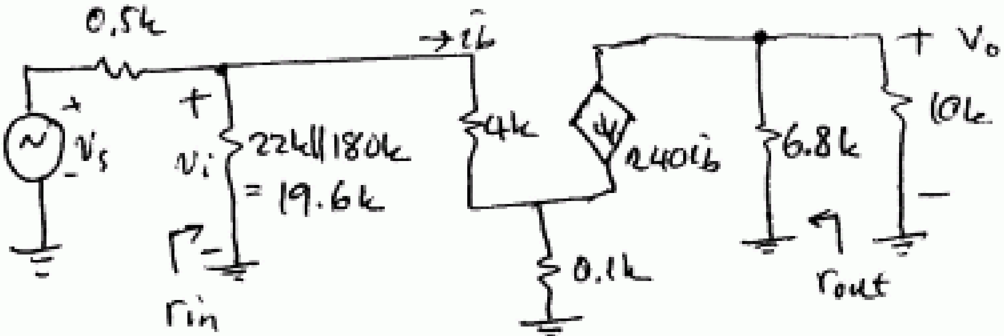
$g_m = \frac{I_c}{V_T} = \frac{1.5}{0.025} = 60\ mA/V$

$r_\pi = \frac{\beta}{g_m} = \frac{240}{60} = 4k\Omega$

$r_{in} =$ 11.54 kΩ

$r_{out} =$ 6.8 kΩ

$v_o/v_s =$ −33.13



$r_{in} = 19.6k \| [4k + 0.1(240+1)] = 19.6k \| 28.1k = 11.54k$

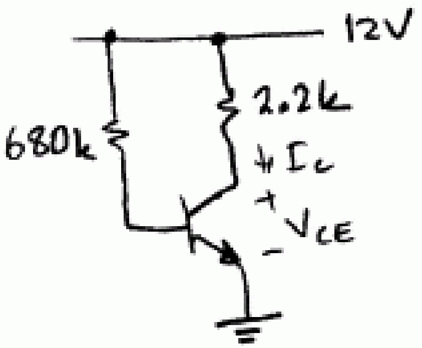
$r_{out} = 6.8k$

$$\left.\begin{aligned} v_o &= -240\, i_b\,(6.8 \| 10) \\ v_i &= [4k + 0.1(240+1)]\, i_b \end{aligned}\right\} \quad \frac{v_o}{v_i} = \frac{-240\,(6.8\|10)}{28.1} = -34.57$$

$$\frac{v_o}{v_s} = -34.57\,\frac{11.54}{0.5 + 11.54} = -33.13$$

2) Find the operating points of the bipolar junction transistors in the circuits given below:

$\beta = 250$, $V_{BE} = 0.7\,V$



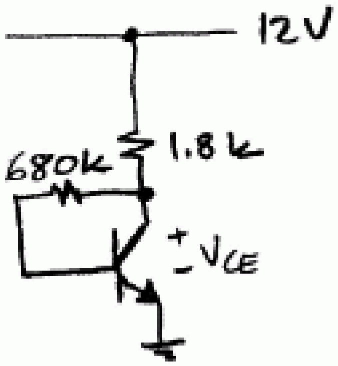
I_c = 4.154 mA

V_{CE} : 2.86

$$I_B = \frac{12-0.7}{680k} = 0.0166\,mA$$

$$I_c = \beta I_B = 4.154\,mA$$

$$V_{CE} = 12 - 2.2 \times 4.154 = 2.86\,V$$



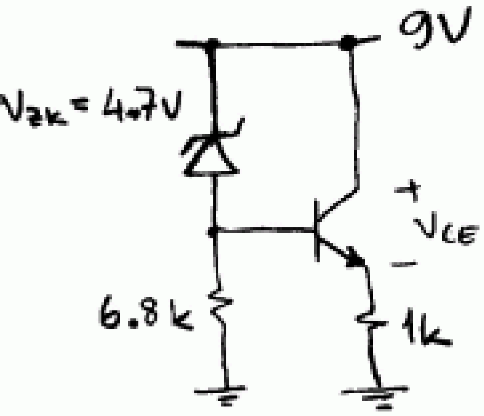
I_c = 2.5 mA

V_{CE} = 7.5 V

$$I_B = \frac{12-0.7}{680 + 251 \times 1.8} = 0.01\,mA$$

$$I_c = 250 \times I_B = 2.5\,mA$$

$$V_{CE} = 12 - 1.8 \times 2.5 = 75\,V$$



I_c = 3.6 mA

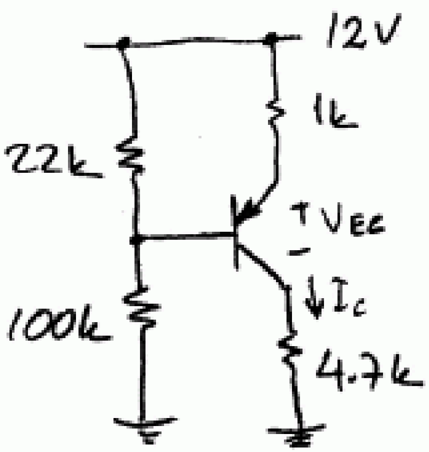
V_{CE} = 5.4 V

$$V_B = 9 - 4.7 = 4.3\,V$$

$$V_E = V_B - V_{BE} = 4.3 - 0.7 = 3.6\,V$$

$$I_E = \frac{3.6V}{1k} = 3.6\,mA. \quad I_c \simeq I_E$$

$$V_{CE} = 9 - 3.6 = 5.4\,V$$



I_c = 1.47V

V_{EC} : 3.65V

$$V_B = 12\,\frac{100}{100+22} = 9.83\,V$$

$$V_E = V_B + 0.7 = 10.53\,V$$

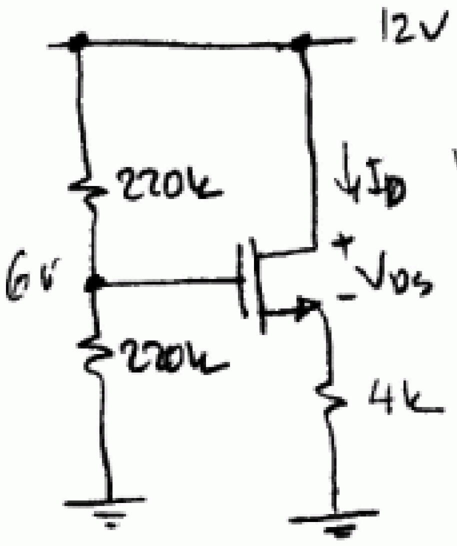
$$I_E = \frac{12 - 10.53}{1k} = 1.47\,mA$$

$$I_c \simeq I_E$$

$$V_{EC} = 12 - 1 \times 1.47 - 4.7 \times 1.47$$

$$V_{EC} = 3.65\,V.$$

3) Find the operating points of the field effect transistors in the circuits given below:



$K = 1 mA/V^2$

$V_t = 1V$

$I_D =$ <u>1mA</u>

$V_{DS} =$ <u>8V</u>

$V_G = 12 \frac{220}{220+220} = 6V$

$4 I_D + V_{GS} = 6$

$4 \times 1 (V_{GS} - V_t)^2 + V_{GS} - 6 = 0$

$4 (V_{GS}^2 - 2 V_{GS} V_t + V_t^2) + V_{GS} - 6 = 0$

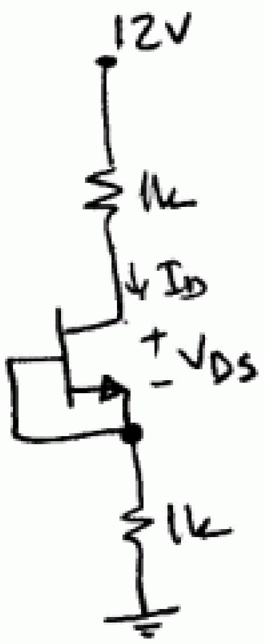
$4 V_{GS}^2 - 7 V_{GS} + 4 - 6 = 0$

$V_{GS1} = \frac{7 + \sqrt{49 + 32}}{8} = 2$ valid

$V_{GS2} = \frac{7 - \sqrt{49+32}}{8} = -\frac{2}{8} < V_t$ not valid

$I_D = 1(2-1)^2 = 1mA.$

$V_{DS} = 12 - 4 = 8V$



$I_{DSS} = 2mA$

$V_p = -2V$

$I_D =$ <u>2mA</u>

$V_{DS} =$ <u>8V</u>

$V_{GS} = 0$

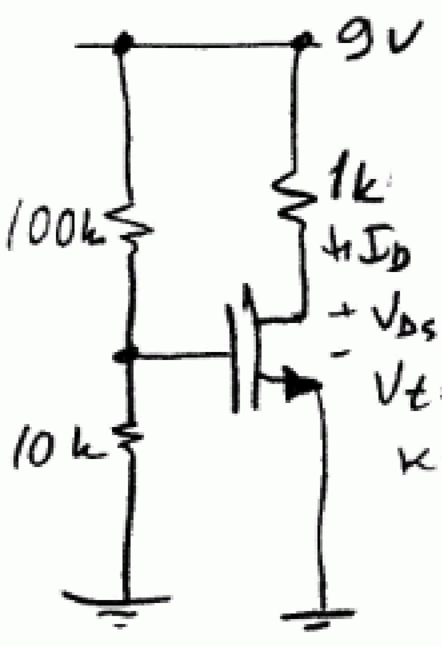
By definition of I_{DSS}, $I_D = I_{DSS} = 2mA$

$V_{DS} = 12 - 2(1+1) = 8V$

$V_{GS} = 9 \frac{10}{10+100} = 0,82 V < V_t = 2V$

CUTOFF $\rightarrow$ $I_D = 0$

$V_{DS} = 9 - I_D \times 1 = 9V.$



$I_D =$ <u>0</u>

$V_{DS} =$ <u>9V</u>

$V_t = 2V$

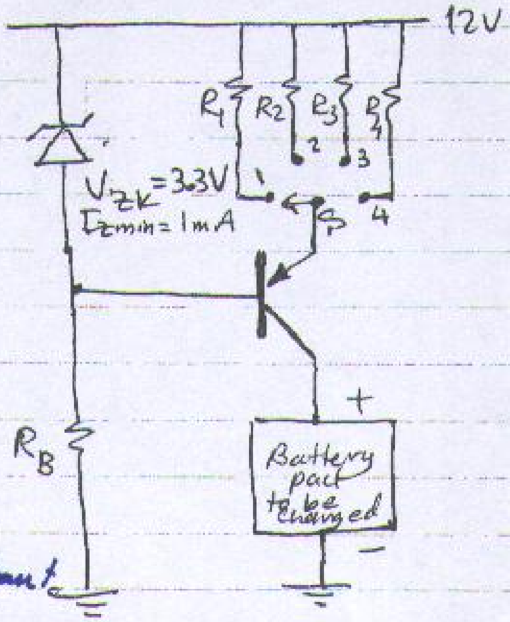
$K = 5mA/V^2$

Dec 13, 2005 — Electronics I – Midterm 2 — 60 minutes

Name: ERKAYA ID number: SOLUTIONS Signature: ________

1) The circuit below is to be used as a constant current battery charger. The positions of the switch S corresponds to the following current values:

Position	Current
1	100 mA
2	200 mA
3	300 mA
4	400 mA



Silicon BJT
$\beta = 70$

R_{Bmax}: 1.29 kΩ
R_1 = 26 Ω
R_2 = 13 Ω
R_3 = 8.66 Ω
R_4 = 6.5 Ω

a) What could be the max value for R_B?

The current in R_B is constant. It must be at least

$$I_{Zmin} + I_{Bmax} = 1 + \frac{400}{70} = 6.71 mA, \quad R_{Bmax} = \frac{12-3.3}{6.71} = 1.29\,k\Omega$$

b) What should be the resistor values R_1, R_2, R_3, R_4?

The voltage across R_1, R_2, R_3, R_4 is $3.3 - 0.7 = 2.6V$

$$R_1 = \frac{2.6}{0.1} = 26\,\Omega, \quad R_2 = \frac{2.6}{0.2} = 13\,\Omega \quad R_3 = \frac{2.6}{0.3} = 8.66\,\Omega \quad R_4 = \frac{2.6}{0.4} = 6.5\,\Omega$$

c) What is the maximum voltage that the rechargeable battery pack may have?

$$V_{Cmax} = V_E - V_{CEsat} = 12 - 2.6 - 0.2 = 9.2V. \quad V_{battery\,max} = 9.2V$$

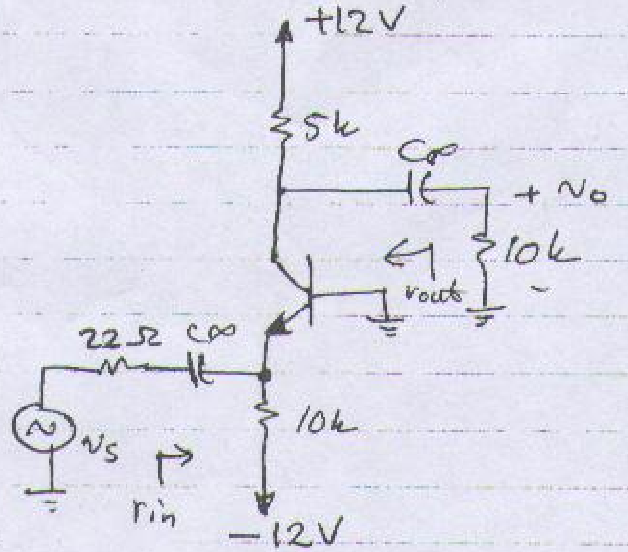
d) What must be the power rating of the BJT?

$$P_{max} = \left| I_{Cmax} V_{CEmax} \right| = 0.4 \times (12 - 2.6) = 3.76\,W$$

2) Find the operating point of the transistor given in the circuit below. Also find a small signal equivalent circuit, input resistance, output resistance and voltage gain for the amplifier.

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

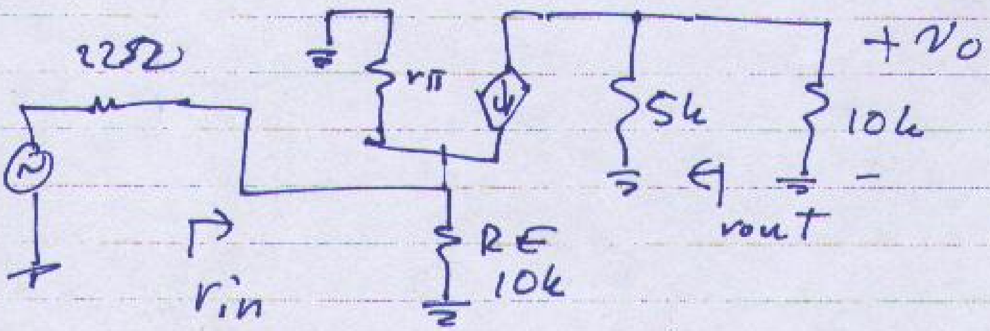
I_c = 1.13 mA
r_{in} = 22 Ω
r_{out} = 5k
$\frac{v_o}{v_s}$ = 75



$$I_c \cong I_E = \frac{-0.7-(-12)}{10} = 1.13\ mA$$

$$g_m = \frac{I_c}{V_T} = \frac{1.13}{0.025} = 45.2\ mA/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{250}{45.2} = 5.53k\Omega$$



$$r_{in} = 10k \| \frac{r_\pi}{\beta+1} = 10k \| \frac{5.53k}{251} = 0.022k\Omega$$

$r_{out} = 5k$

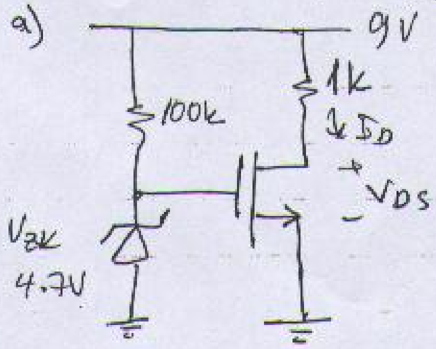
$$\frac{v_o}{v_i} = g_m (R_c \| R_L) = 45.2 \times 5\|10 = 150$$

$$\frac{v_i}{v_s} = \frac{r_{in}}{R_s + r_{in}} = \frac{22}{22+22} = \frac{1}{2}$$

$$\frac{v_o}{v_s} = 150 \times \frac{1}{2} = \underline{\underline{75}}$$

3) Find the operating points for the FETs given below:

a)



$V_t = 2.5$ V

$K = 0.5$ mA/V^2

$I_D =$ 2.42 mA

$V_{DS} =$ 6.58V

$V_{GS} = 4.7V$

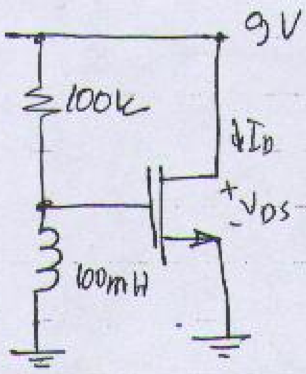
$I_D = 0.5\,(4.7-2.5)^2 = 2.42$ mA

$V_{DS} = 9 - 1\times 2.42 = 6.58V$

verification $\quad V_{DS} \overset{?}{\geq} V_{GS} - V_t = 2.2V$

$6.58 > 2.2$ assumption is valid

b)



$V_t = 2.5V$

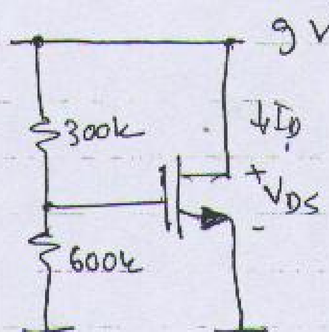
$K = 0.5$ mA/V^2

$I_D =$ 0

$V_{DS} =$ 9V

$V_{GS} = 0$, $< V_t \rightarrow I_D = 0$

c)



$V_t = 2.5$ V

$K = 0.5$ mA/V^2

$I_D =$ 6.12 mA

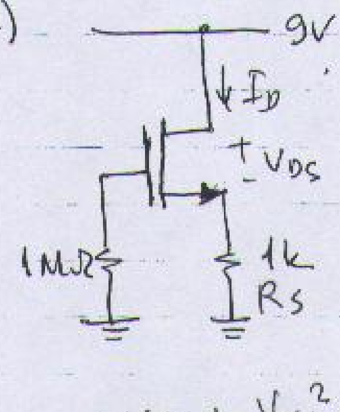
$V_{DS} =$ 9V

$V_{GS} = 9\,\frac{600}{300+600} = 6V$

$I_D = 0.5\,(6-2.5)^2 = 6.12$ mA

$V_{DS} = 9V > 6-2.5 = 3.5$ ✓

d)



$V_t = -1V$

$K = 0.5$ mA/V^2

$I_D =$ 0.27 mA

$V_{DS} =$ 9-0.27 = 8.73V

$V_G = 0$, $V_S = I_D R_S$

$V_{GS} = V_G - V_S = -I_D R_S$

$V_{GS} = -K\,(V_{GS} - V_t)^2 R_S$

$V_{GS} + KR_S\,(V_{GS}^2 - 2V_{GS}V_t + V_t^2) = 0$

$2V_{GS} + V_{GS}^2 + 2V_{GS} + 1 = 0$

$V_{GS}^2 + 4V_{GS} + 1 = 0$

$V_{GS1,2} = \frac{-4 \mp \sqrt{16-4}}{2} = -2 \mp \sqrt{3}$

$-2-\sqrt{3} < V_t = -1$ not valid

$-2+\sqrt{3} = 0.27$ V

$I_D = \frac{+0.27}{1k} = 0.27$ mA