Name: Tarik Reyhan   Section: ______

Signature: ________________   EEE 313 Fall 2013

Solutions

Bilkent University
Department of Electrical and Electronics Engineering
EEE 313 Electronic Circuit Design
Midterm 2
4 December 2013, 18:00
(4 questions, 120 minutes)

- This is a **closed book**, closed notes exam. No cheat sheet allowed.
- All cell-phones should be completely **turned off**.
- Use a calculator for numerical computations. Carry at least **4 significant digits** during calculations. Your final answer should be at least **3 significant digits**.
- Be sure to write the **units** of all numerical results.
- **Show** all work clearly.
- Please put your **final answer** for each part inside a box for easy identification. Do not give multiple answers, they will not be graded.
- Do not remove the **staple** from the exam sheets or separate pages of the exam. All extra pages must be stamped to your exam.
- You may leave the exam room when you are done. However, please do not leave during the **last five minutes** of the exam.
- At the end of the exam, please stay seated unitl **all** exam papers are collected.

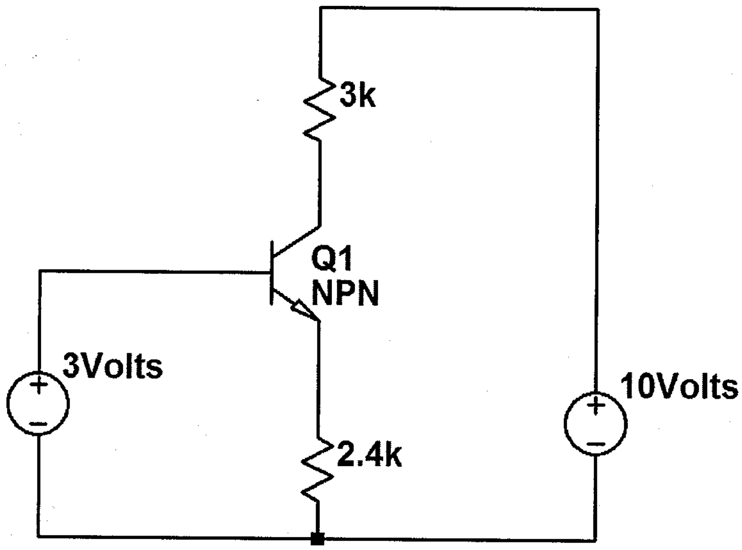
Please do not write below this line

1. 25 pts.	
2. 20 pts.	
3. 30 pts.	
4. 25 pts.	
Total 100 pts.	

1) (25 points) Find the states of the BJT transistors at the circuits given below (β=100, $V_{BE_{ON}}$ = 0.6 Volts, $V_{CE_{ONSAT}}$ = $\cancel{0.6}$ Volts) :

0.4

a) (6 points)

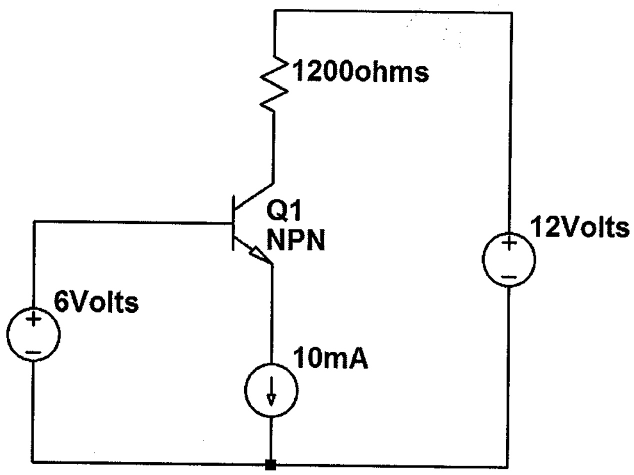


$$I_E = \frac{3-0.6}{2400\Omega} = \frac{2.4}{2400} =$$

$$V_{CE} = 10V - 0.001A[2400+3000]$$

$$= 10 - 5.4 = 4.6\ V \Rightarrow F.A.$$

b) (6 points)



$1200 \times 0.01 = \frac{1200}{100} = 12V$

$\Rightarrow V_c = 12 - 12 = 0V$ but

$V_B = 6V \Rightarrow V_{CB}$ is forward biased

$\Rightarrow$ SAT

to verify

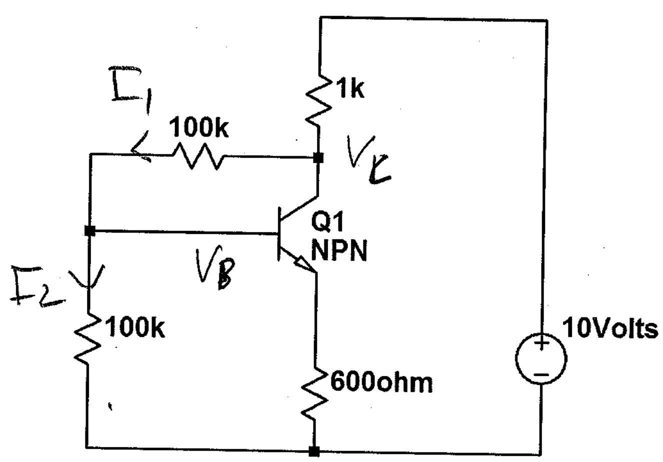
$V_{CE_{SAT}} = 0.4V \Rightarrow I_C = \frac{12V - 0.4V}{1200} = 9.6\overline{6}$ mA

$\Rightarrow I_B = 10 - 9.6666 = 3.3\overline{3} \times 10^{-4} = 333 \mu A$

$\beta I_B = 3.33 \times 10^{-4} \times 100 = 3.33 \times 10^{-2} = 33.3 mA > I_C = 9.66mA$

$\Rightarrow$ SAT

c) (7 points)



Assume F.A.

$V_B = \frac{V_C}{2}$ neglect I_1 & I_2

$$\underbrace{1000}_{R_C} \times \underbrace{\frac{\frac{V_C}{2} - 0.6}{600}}_{I_E \cong I_C} + V_C = 10V$$

$$1.667 \times \frac{V_C}{2} - 1.667 \times 0.6 + V_C = 10V$$

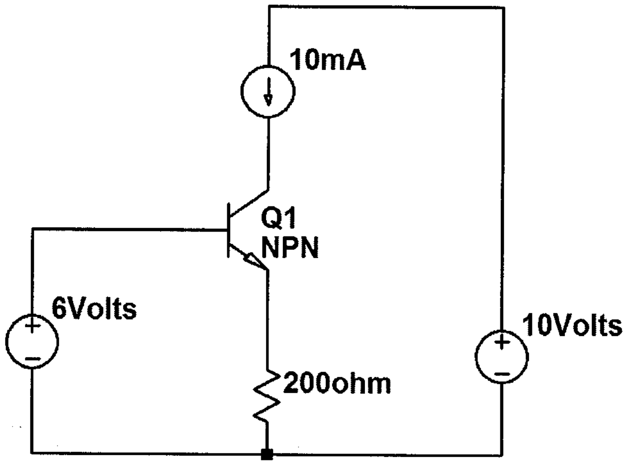
$$0.83\bar{3}\, V_C - 1 + V_C = 10$$

$$1.835 V_C = 11 \Rightarrow V_C = 5.99V$$

$$\frac{V_C}{2} = 2.997 \simeq 3V \Rightarrow V_{CB} = 5.99 - 3 = 2.99V$$

$\Rightarrow$ F.A.

d) (6 points)



$$I_E = \frac{6-0.6}{200} = \frac{5.4}{200} = 27mA \Rightarrow$$

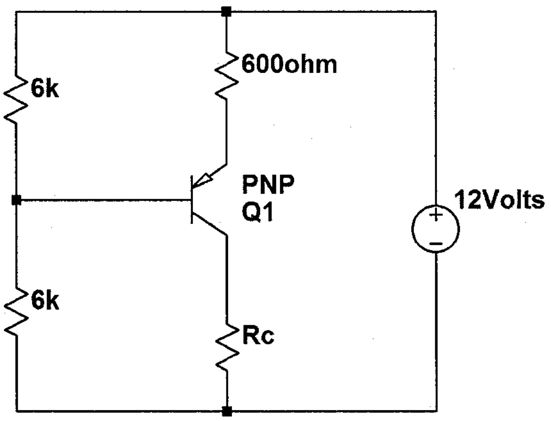
$$I_B = I_E - I_C = 27 - 10 = 17mA$$

$$\beta I_B = 17 \times 100 = 1700 > I_C = 10mA$$

$$\Rightarrow SAT$$

2. (20 points) The transistor in the common-emitter circuit shown below has the following parameters:
β=100, $V_{BE_{ON}}$ = 0.7 Volts, $V_{CE_{ONSAT}}$ = 0.4 Volts
Please find the state and the bias (voltages and currents) of the transistor for:

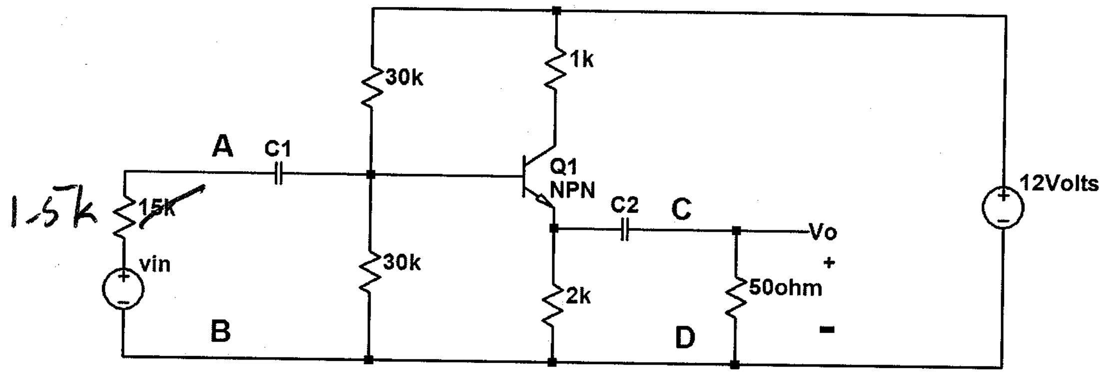
a) (10 points) Rc=300 Ω,
b) (10 points) Rc=1200 Ω



a-) $\dfrac{6V - 0.7}{\frac{3000}{101} + 600} = I_E = \dfrac{5.3}{629.7} = 8.416mA$

$V_{CE} = 12V - 8.416\times10^{-3}(600+300) = 12 - 7.575$
$= 4.425 \Rightarrow$ FA.

b-) $V_{CE} = 12 - 8.416\times10^{-3}(600+1200)$
$= 12 - 15.15 = -3.15V$
$\Rightarrow$ not F.A. $\Rightarrow$ SAT



3. (30 points) At the circuit given above:
β=74, $V_{BE_{ON}} = 0.7$ Volts, $V_{CE_{ONSAT}} = 0.3$ Volts, C_1 and C_2 are very large

Please answer the following:

a) (6 points) Find the DC bias of the transistor,
b) (6 points) Draw the AC equivalent circuit,
c) (6 points) Find the gain of the circuit defined as Vo/Vin
d) (6 points) Find the input impedance (between points A and B),
e) (6 points) Find the output impedance (between points Cand D) by taking the source as only Vin .

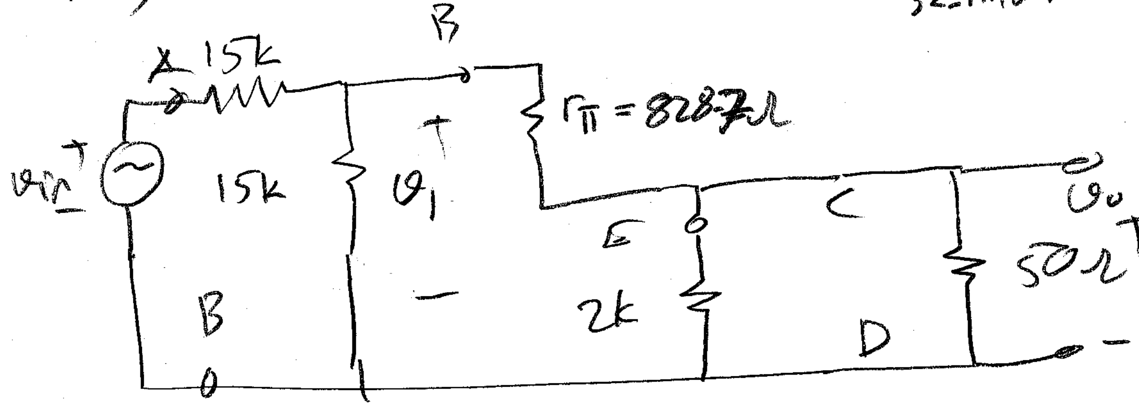
a-) $\frac{12}{2} - 0.7 = 15000\, I_B + 75 \times 2000\, I_B = (15000 + 150000) I_B$

$\Rightarrow I_B = \frac{5.3}{165000} = 3.21 \times 10^{-5} A = 32.1\ \mu A$

$I_E = 75 \times I_B = 2.41\ mA$, $I_C = 74 \times I_B = 2.38\ mA$

$V_{CE} = 12V - 2.41 \times 10^{-3} \times 2000 - 2.38 \times 10^{-3} \times 1000$
$= 12 - 7.2 = 4.8V \Rightarrow$ F.A.

b-) $r_\pi = \frac{26.6\ mV}{32.1 \times 10^{-3}\ mA} = 828.7\Omega$



c-) $2000 // 50 = \frac{2000 \times 50}{2050} = 48.78\Omega$

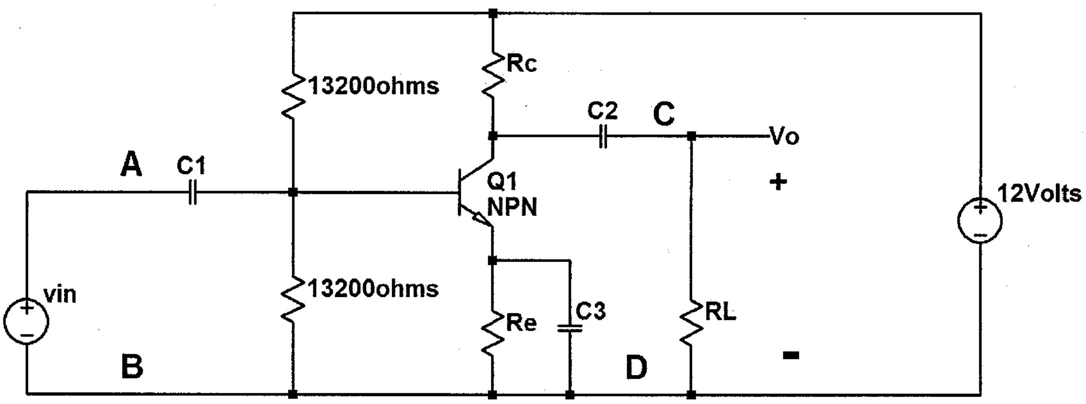
$r_\pi + (\beta+1)\, 48.78\Omega = 828.7 + 75 \times 48.78 = 4487.2$

$1800 // 4487.2 = 3454\,\Omega$

$v_1 = v_{in} \times \frac{3454\Omega}{3454 + 1500} = 0.697$

$v_0 = v_1 \cdot \frac{48.78 \times 75}{48.78 \times 75 + 828.7\Omega} = v_1\, 0.8153$

$\frac{v_0}{v_{in}} = 0.5684$



4. (20 points) At the BJT circuit given above:
$\beta=100$, $V_{BE_{ON}} = 0.8$ Volts, $V_{CE_{ONSAT}} = 0.2$ Volts, C_1, C_2 and C_3 are very large :

The desired characteristics of the amplifier are:
$R_{in}=550\ \Omega$, $R_o=1000\ \Omega$, Voltage gain $A_v=100$ defined as Vo/Vin
Please note that R_{in} is between A and B, R_o is between C and D.

Please design the circuit to have the desired characteristics (i.e., find the values of R_c, R_e, and R_L)

Solutions:

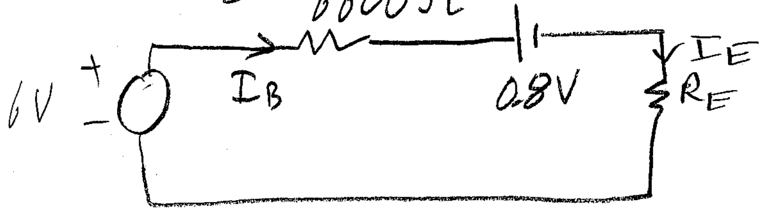
$$R_o = R_c = 1000\Omega$$

$$R_{in} = 550\Omega = (13200/2) /\!/ r_\pi = 6600\Omega /\!/ r_\pi \Rightarrow$$

$$r_\pi = \frac{6600 \times 550}{6600 - 550} = 600\Omega = \frac{\beta}{g_m} = \frac{\beta V_T}{I_{CQ}} \Rightarrow$$

$$I_{CQ} = \frac{\beta V_T}{600} = \frac{100 \times 26.6}{600} \text{ mA} = 4.4\bar{3} \text{ mA}$$

$$V_{TH} = \frac{12}{2} = 6V \qquad R_{TH} = 13200/2 = 6600\Omega$$



$$6V - 0.8V = \frac{6600}{\beta+1} I_E + R_E I_E$$

$$\Rightarrow$$

$$I_E = 4.43 \times \frac{\beta+1}{\beta} = 4.477\text{mA}$$

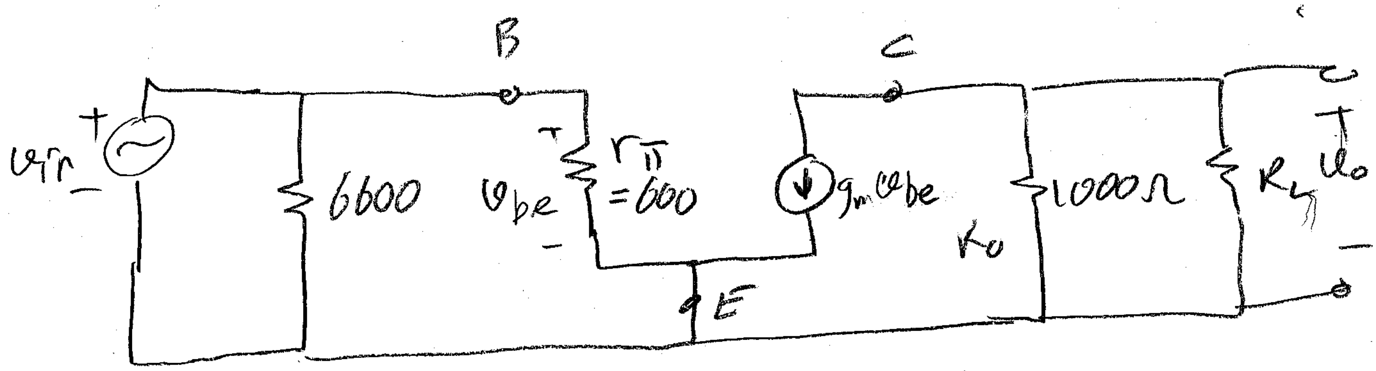
$$5.2 = \frac{6600}{101} 4.477\times 10^{-3} + 4.477\times 10^{-3} R_E = 0.2926 + 4.477\times 10^{-3} R_E$$

$$R_E = \frac{5.2 - 0.2926}{4.477 \times 10^{-3}} = 1095.97 \cong 1096\,\Omega$$

Checking the FA state

$$V_{CE} = 12V - 4.477 \times 10^{-3} \times 1096 - 4.43 \times 10^{-3} \times 1000$$
$$= 2.6626 \checkmark \text{ F.A.}$$

Drawing the A.C. equivalent circuit



$$A_V = \frac{v_o}{v_{in}} = g_m (1000 \| R_L) = 100$$

$$g_m = \frac{\beta}{r_\pi} = \frac{100}{600} = \frac{1}{6} = 0.1666\,S$$

$$\frac{1}{6}(1000 \| R_L) = 100 \Rightarrow 1000 \| R_L = 6 \times 100 = 600$$

$$\Rightarrow R_L = \frac{1000 \times 600}{1000 - 600} = \frac{600.000}{400} = 1500\,\Omega$$

to check

$$1000 \| 1500 = \frac{1000 \times 1500}{1000 + 1500} = 600\,\Omega$$

$$A_L = 100 = \frac{1}{6} \times 600 = 100$$