EE335 Electronics

FINAL Exam, June 1, 2018

Name, Surname: Student No:
Instructor: R. Kopru

Q1. (18) For the DC analysis of a BJT amplifier seen in Fig. 1, determine the followings:

a) (4) I_{BQ}

b) (6) I_{CQ}, V_{CEQ}

c) (2) operating point Q

d) (6) V_E, V_C, V_B.

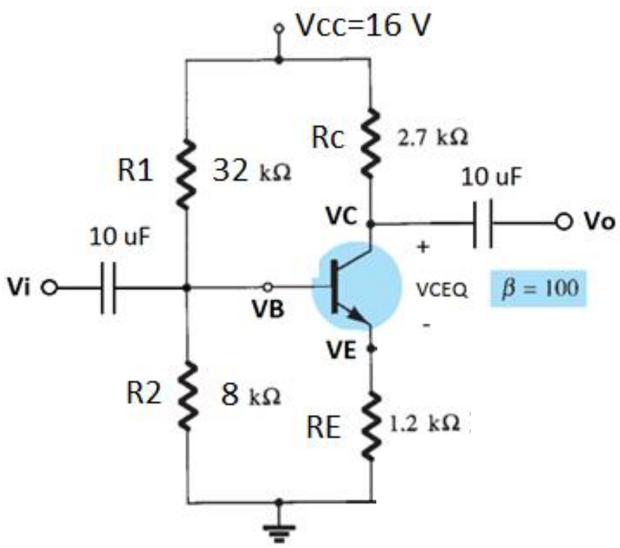


Fig. 1.

Q2. (22) Consider again the same BJT amplifier of Fig. 1.
For the AC analysis, determine the followings:

a) (03) r_e.

b) (04) calculate Z_i and Z_o.

c) (08) derive the expression of A_v

d) (03) calculate the value of A_v.

e) (04) Write the output voltage expression $v_o(t)$ if the input voltage is $v_i(t) = 10\sin(2\pi 1000t), mV$.

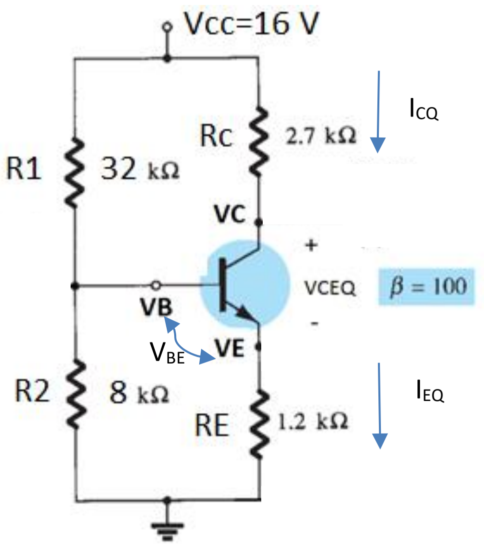
SOLUTIONS

Q1. We have VBE=0.7 V, VCC=16 V, R1=32.0 k, R2=8.0 k, RE=1.2 k, RC=2.7 k, β =100.

a) **DC ANALYSIS:**

The DC analysis of this "**UNbypassed amplifier is exactly the SAME AS the bypassed case"** worked in the document "**BJT AMP bypassed**" (see courseonline), therefore here we write everything as the same from that document.

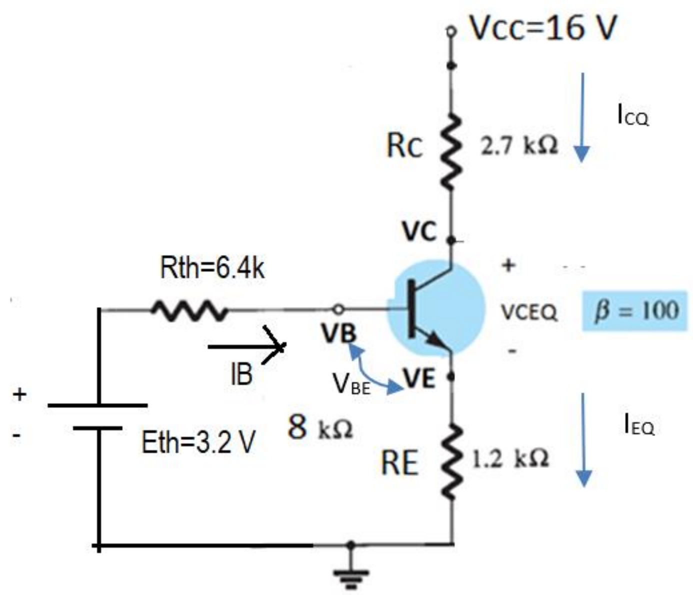
We should draw the DC eqvn. circuit. For this; we do the following:
- all caps. should be "open-circuited".



DC. eqvn. circuit.

Using Thevenin's method we have,

RTH=R1||R2=R1*R2/(R1+R2)=6.4 k
ETH=VCC*R2/(R1+R2)=3.2 V
IBQ=(ETH-VBE)/(RTH+(β +1)*RE)=0.0196 mA=19.6 uA



b)
ICQ= β *IB=1.9592 mA
IEQ=(β +1)*IB=1.9788 mA
KVL for the output: VCC=IC*RC+VCE+IE*RE, so we have VCEQ=VCC-IC*RC-IE*RE=8.3354 V

c) Q(VCEQ, ICQ)=Q(8.3354V, 1.9592mA)
d)
VE=IE*RE=2.3746 V
Since VCE=VC-VE, so we have VC=VCE+VE=10.71 V
Since VBE=VB-VE, so we have VB=VBE+VE=3.0746 V

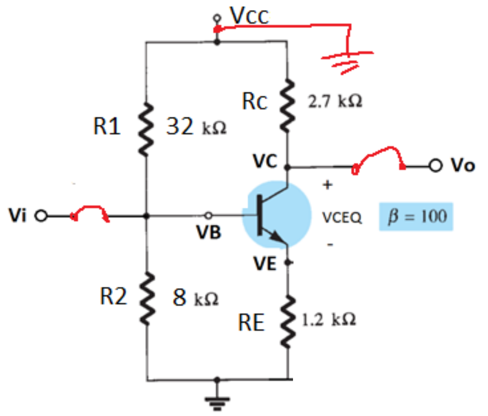
Q2.

a) re=VT/IEQ=26 mV/1.9788mA=13.1 Ω=0.0131 kΩ.
b) **AC ANALYSIS:**

The AC analysis of this "**UNbypassed amplifier is DIFFERENT FROM the bypassed case"** worked in the document "**BJT AMP bypassed**" (see courseonline), therefore we do the followings:

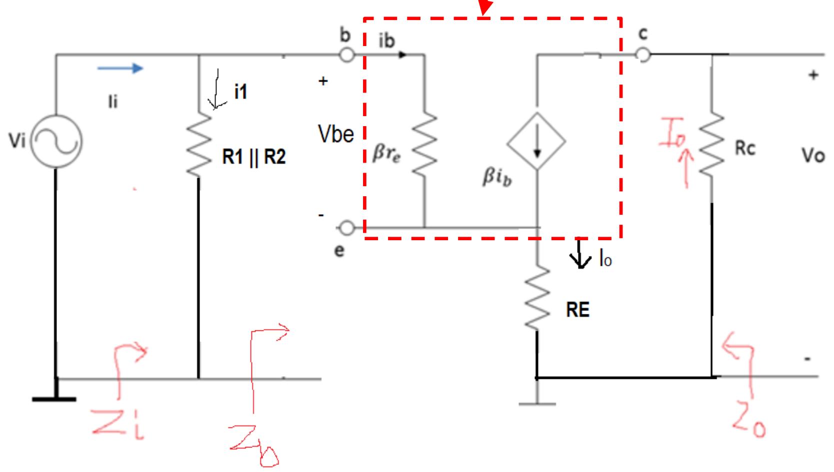
The AC equivalent circuit is to be drawn. For this, we need to make the followings:
- All caps. are to be "short-circuited".
- Supply source is to be grounded.

The resulting circuit would be as follows:
NOTICE that here, RE is NOT BYPASSED since it does not have any CE bypass cap. across it.



If the transistor in the above circuit is replaced by its AC eqvn. circuit and the circuit is rearranged, the **"complete AC eqvn. circuit of the BJT amplifier"** would be as follows

1) **IMPORTANT: ro is IGNORED, i.e. $r_o \rightarrow \infty$**
2) **NOTE: YOU ARE RESPONSIBLE TO DRAW THIS AC EQVN. CIRCUIT WITH ONLY $r_o \rightarrow \infty$ IN THE FINAL EXAM.**



FINDING INPUT IMPEDANCE (Zi): from the AC eqvn. circuit above, we write;

Zi= V_i/I_i=R1||R2||Zb

where Zb=Vb/ib with $V_b = V_{be} + V_{RE} = (\beta r_e)i_b + i_o R_E$. Notice that here $V_{be} = (\beta r_e)i_b$ and $V_{RE} = i_o R_E$. Also it is easy to see that $i_o = i_b + \beta i_b = (\beta + 1)i_b$, therefore we have

$$V_b = (\beta r_e)i_b + (\beta + 1)i_b R_E$$

İf we assume that $\beta + 1 \cong \beta$ then we can rewrite the equation above as follows

$$V_b \cong (\beta r_e)i_b + \beta i_b R_E$$

$$\boxed{\boldsymbol{V_b = \beta i_b(r_e + R_E)}}$$

Inserting this into the above expression of Zb=Vb/ib, we would have

$$Z_b = \frac{V_b}{i_b} = \frac{\beta \cancel{i_b}(r_e + R_E)}{\cancel{i_b}} = \beta(r_e + R_E)$$

which yields the input impedance as

Zi= V_i/I_i=R1||R2||Zb

$$\boxed{\begin{array}{c} Z_i = \text{R1}||\text{R2}||\ \beta(r_e + R_E) \\ \text{or} \\ Z_i = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{\beta(r_e + R_E)} \right)^{-1} \end{array}}$$

Putting the numerical value into Zi expression we write

$$Z_i = \left(\frac{1}{32} + \frac{1}{8} + \frac{1}{100(0.0131 + 1.2)} \right)^{-1}$$

(Note: since we know the result will be in $k\Omega$, we do not put

"k" near 32, 8, 0.0131 and 1.2).

$$= \left(0.0313 + 0.125 + \frac{1}{100(1.2131)} \right)^{-1}$$

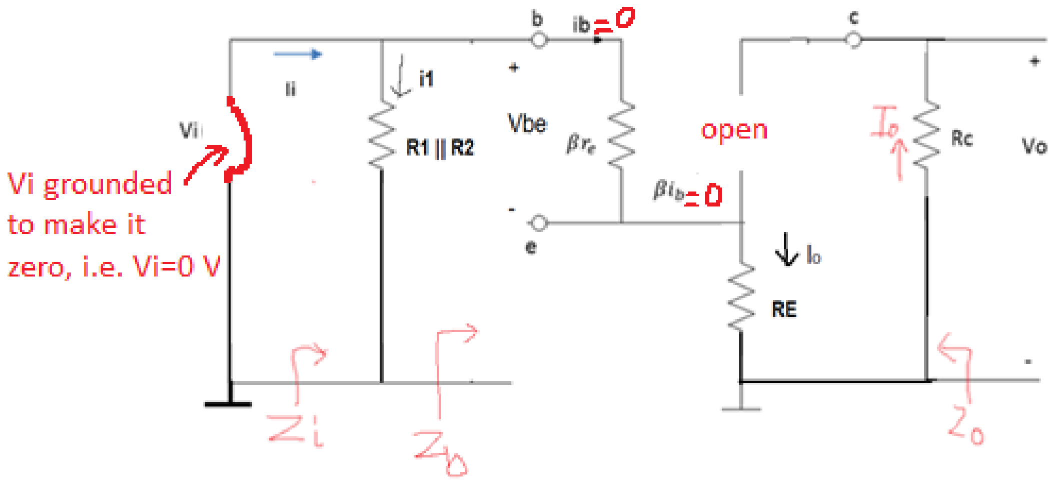
$$= \left(0.0313 + 0.125 + \frac{1}{121.31} \right)^{-1}$$

$$= (\ 0.0313 + 0.125 + 0.0082\ )^{-1}$$

$$= (\ 0.1645\ )^{-1}$$

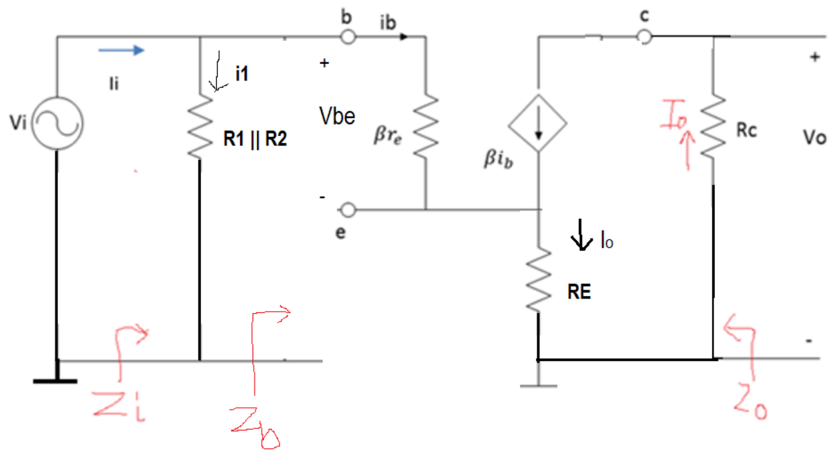
$$Z_i = 6.079\ k\Omega$$

FINDING OUTPUT IMPEDANCE (Zo): $Z_o = \frac{v_o}{i_o}|_{Vi\to 0}$. This expression tell us, first Vi input voltage must be set to zero volt (i.e. it should be connected to ground.) therefore, the circuit can further be drawn as follows to find Zo. Notice that since Vi is grounded (i.e. Vi->0 V), Vb also becomes 0 V. Then, since Vb=0V, i_b will be zero. Therefore the current source of βi_b has become zero amper source which means that it can be assumed as "**open**" (see the figüre below).



And now, seeing Zo=Rc=2.7 $k\Omega$ is really very easy !

FINDING AC VOLTAGE GAIN (Av): Let us redraw the **"complete AC eqvn. circuit of the BJT amplifier"** drawn in part b as seen in the following:



The AC voltage gain is given by

$$A_v = \frac{v_o}{v_i}$$

where from the examining the circuit above we see that the output AC voltage can be written as

$$v_o = -i_o R_c$$

İf we remember again we know that $i_o = i_b + \beta i_b = (\beta + 1) i_b$

$$v_o = -(\beta + 1) i_b R_c$$

Again if we assume that $\beta + 1 \cong \beta$, we write

$$\boxed{v_o \cong -\beta i_b R_c}$$

If we look at the circuit, we can see that the input voltage v_i is equal to the voltage V_b at the base (b) terminal of the transistor; and we can write it as

$$v_i = v_b$$

where we see from the circuit that $v_b = v_{be} + v_{RE}$. We can also see from the circuit that $v_{be} = (\beta r_e)i_b$ and $v_{RE} = R_E(\beta + 1)i_b$. Thus,

$$v_i = v_b$$

$$v_i = (\beta r_e)i_b + R_E(\beta + 1)i_b$$

Again since we assume that $\beta + 1 \cong \beta$, we write

$$\boxed{v_i \cong \beta i_b(r_e + R_E)}$$

As a conclusion we write

$$A_v = \frac{v_o}{v_i} = \frac{\cancel{-\beta} i_b R_c}{\cancel{\beta i_b}(r_e + R_E)}$$

$$\boxed{A_v = \frac{v_o}{v_i} = \frac{-R_c}{(r_e + R_E)}}$$

d)

Putting the numerical value into Av expression we write

$$A_v = \frac{v_o}{v_i} = -\frac{(2.7\ k\Omega)}{(0.0131\ k\Omega + 1.2\ k\Omega)}$$

$$= -\frac{2.7\ k\Omega}{1.2131\ k\Omega}$$

$$= -\frac{2700\ \ \Omega}{1213.1\ \Omega}$$

$$A_v = \frac{v_o}{v_i} = -2.1932$$

e)

$$v_o = A_v v_i = (-2.1932)(10\sin(2\pi 1000t)\,, mV) = -21.932\sin(2\pi 1000t)\,, mV$$