Faculty of Engineering
Benha university
Electrical Eng.Dept.
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Microelectronics (E301)
Final-Term Exam (corrective)
Date: 31/12/2016
Time: 3 Hours

Answer the following questions:

Q1: (a) Assuming that the diodes in the circuit of Fig. (1) are ideal, find the values of the labeled voltage, V, and current, I.

(b) Analyze the circuit of Fig. (2), to determine the voltages at all nodes and the currents through all branches. Assume that the transistor $\beta = 100$.

Q2: (a) Determine and sketch the output waveform for the network of Fig. (3).

(b) The Si Darlington transistor pair of Fig.(4) has $\beta_1 = \beta_2 = 50$. Let $R_2 \rightarrow \infty$ Find the values of R_1, and V_{CE1} needed to bias the circuit so that $V_{CE2} = 6V$.

Q3: The 6.8V zener diode in the circuit of Fig. (5) is specified to have $V_z = 6.8V$ at $I_z = 5mA$, $r_z = 20\Omega$, and $I_{zk} = 0.2$ mA. The supply voltage V^+ is nominally 10V but can vary by ±1 V.

(a) Find V_O with no load and with V^+ at its nominal value.

(b) Find the change in V_O resulting from the ±1 V change in V^+.

(c) Find the change in V_O when $R_L = 2$ kΩ.

(d) What is the minimum value of R_L for which the diode still operates in the breakdown region?

Q4: For the amplifier shown in Fig.(6), let $V_{CC} = 12V$, $R_1 = 22$ kΩ, $R_2 = 6.8$ kΩ, $R_E = 560$ Ω, and $R_C = 1$ kΩ. The transistor has $\beta = 100$. Calculate the dc bias current I_E. If the amplifier operates between a source for which $R_{sig} = 600$ Ω and a load of 2 kΩ, replace the transistor with its hybrid-π model, and find the values of R_{in}, R_o, and the voltage gain v_o/v_{sig}.

Q5: The transistor in the circuit shown in fig. (7) is biased to operate in the active mode. Replace the transistor with small-signal equivalent circuit T –model and then find R_{in}, the voltage gain (v_o/v_{sig}), the current gain (i_o/i_i), and the output resistance R_{out}. Assuming that $\beta = 100$.

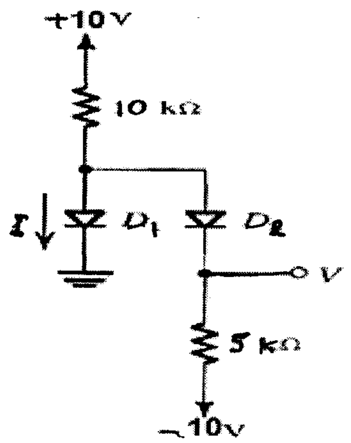


Fig.(1)

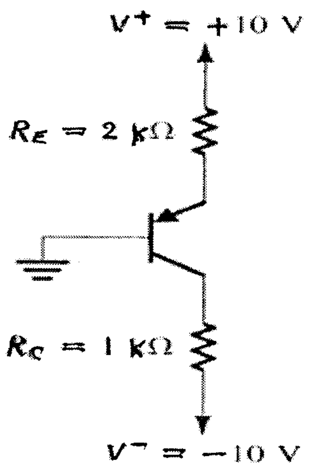


Fig.(2)

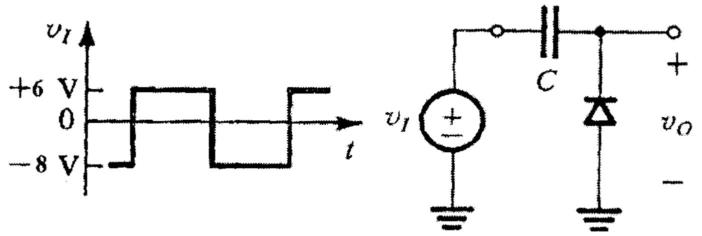


Fig.(3)

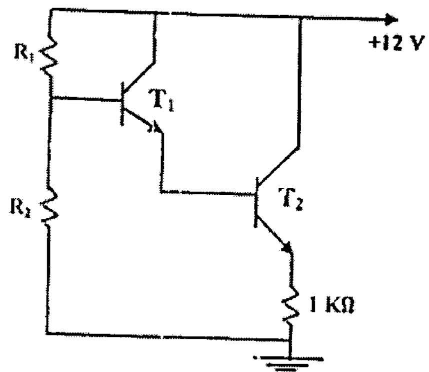


Fig.(4)

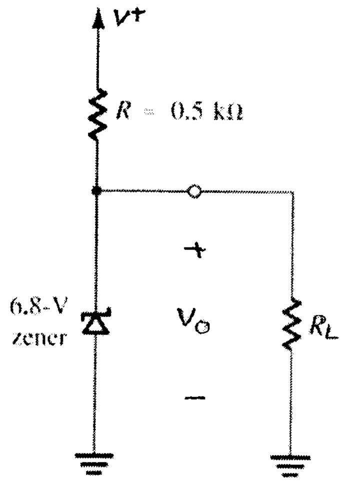


Fig.(5)

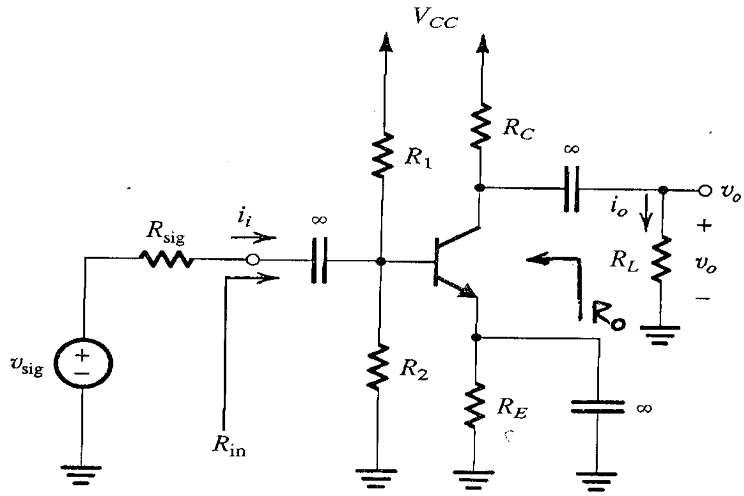


Fig.(6)

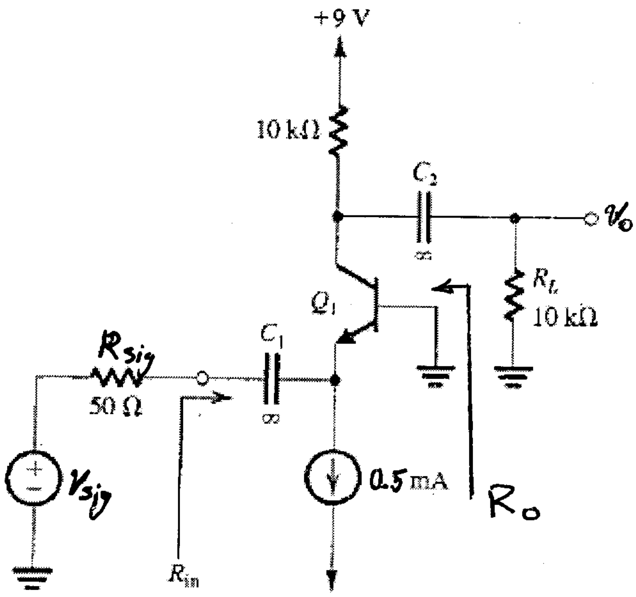


Fig.(7)

BEST WISHES

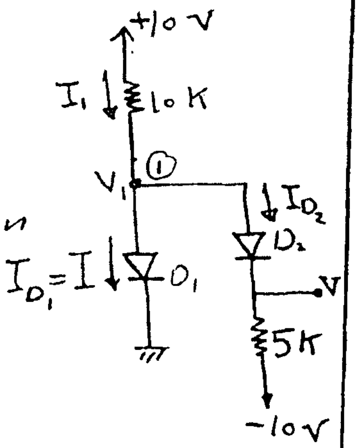
Hossam Labib

Q1 (12 points)

Q1 (a) (6 points)

Assuming that the diodes in the circuit of Fig.(2) are ideal, find the values of the labeled voltage, V, and current, I.

Solution



let $I = I_{D_1}$

let D_1 and D_2 are on

For D_1 on $\Rightarrow V_1 = 0 \Rightarrow V = 0$ for D_2 on

$\therefore I_1 = \frac{10 - V_1}{10K} = \frac{10-0}{10K} = 1mA$

$I_{D_2} = \frac{V_1 - (-10)}{5K} = \frac{0+10}{5K} = 2mA$

From node ① $\Rightarrow I_1 = I_{D_1} + I_{D_2}$

$I_{D_1} = I_1 - I_{D_2} = 1mA - 2mA = -1mA$

$\because I_{D_1}$ -ve $\therefore$ not true

i.e the assumption not correct

Let D_1 off and D_2 on

- For D_1 off $\Rightarrow I_{D_1} = 0$; $I_1 = I_{D_2}$

- For D_2 on $\Rightarrow I_1 = \frac{10-(-10)}{10K + 5K} = \frac{20}{15K} = 1.333\ mA$

$V = I_{D_2} * 5K - 10 = 1.333 * 5 - 10 = -3.335\ v$

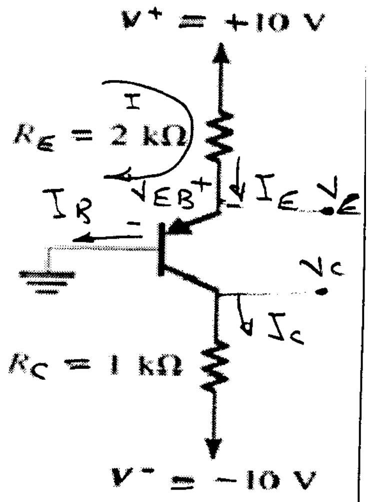
For $V = -3.335\ v$; $\because V_1 = V = V_{p1} = -3.335$; $V_{n_1} = 0$

i.e $V_{p_1} < V_{n_1} \Rightarrow D_1$ off

$\therefore$ The assumption is true (D_1 off & D_2 on)

$\therefore V = -3.335\ v$ and $I = I_{D1} = 0\ A$

Analyze the circuit of Fig. (2), to determine the voltages at all nodes and the currents through all branches. Assume that the transistor $\beta = 100$.



Solution:

let Transistor operate in Active Region

Loop (I)

$$-V^+ + I_E R_E + V_{EB} = 0$$

$$I_E = \frac{V^+ - V_{EB}}{R_E} = \frac{10 - 0.7}{2K} = 4.65\,mA$$

$$I_C = \alpha I_E = \frac{\beta I_E}{1+\beta} = \frac{100}{1+100} * 4.65\,m = 4.604\,mA$$

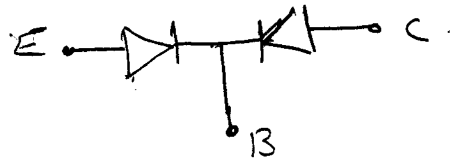
$$\therefore I_B = I_E - I_C = 4.65 - 4.604 = 46\,\mu A$$

$$V_B = 0$$

$$\therefore V_{EB} = V_E - V_B \Rightarrow V_E = V_{EB} + V_B = 0.7\,V$$

$$V_C = I_C R_C + V^-$$

$$= 4.604\,m * 1K - 10 = -5.396\,V$$



$V_E > V_B \Rightarrow$ EBJ Forward

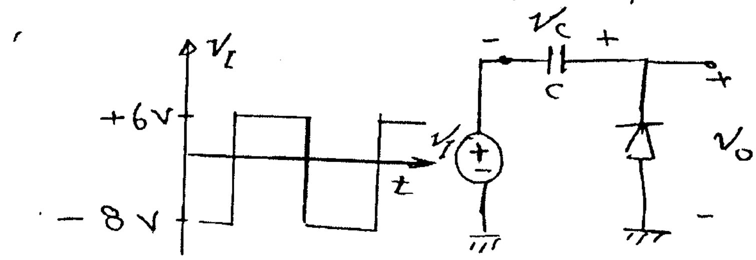
$V_C < V_B \Rightarrow$ CBJ Reverse

$\therefore$ Transistor in Active region

$\therefore$ assumption is True

Q2: (12 points)

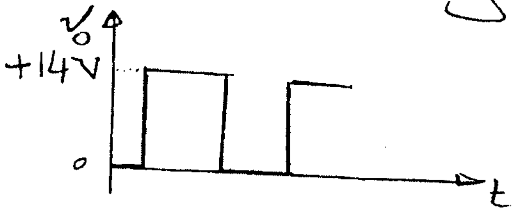
Q2: (a) Determine and sketch the output waveform for the network shown



$V_c = 8\,V$

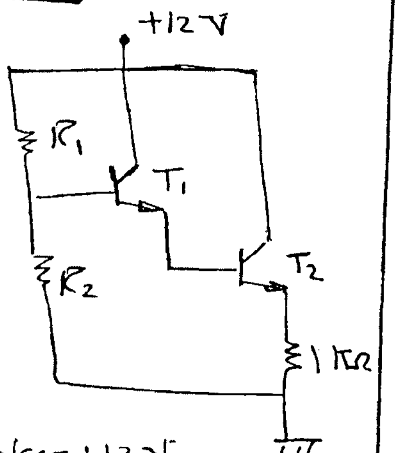
$V_o = V_i + V_c$ i.e $V_o = V_i$ + shifted by -ve half cycle

$= V_i + 8$



Q2: (b)

The Si Darlington Transistor pair shown has $\beta_1 = \beta_2 = 50$. Let $R_2 \to \infty$. Find the values of R_1, and V_{CE_1} needed to biase the circuit so that $V_{CE_2} = 6\,V$



Solution

For $R_2 \to \infty \Rightarrow I_2 = 0$

$\therefore I_1 = I_{B_1}$

$, I_{E_1} = I_{B_2}$

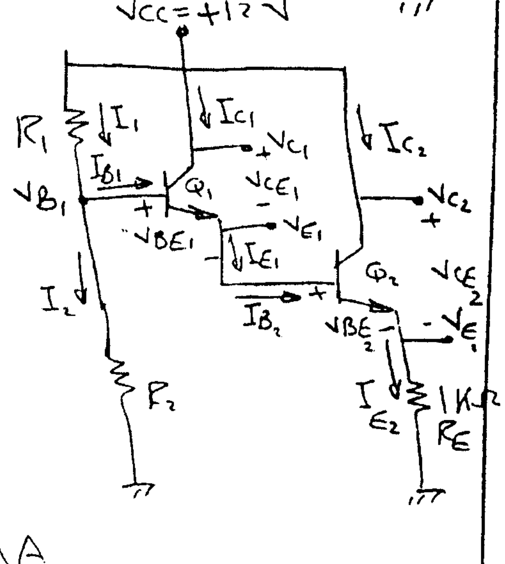
$\because V_{CE_2} = 6 = V_{C_2} - V_{E_2}$

$\therefore V_{E_2} = V_{C_2} - 6$

$V_{C_2} = V_{C_1} = V_{CC} = 12\,V$

$\therefore V_{E_2} = 12 - 6 = 6\,V$

$\therefore I_{E_2} = \frac{V_{E_2}}{R_E} = \frac{6}{1K} = 6\,mA$

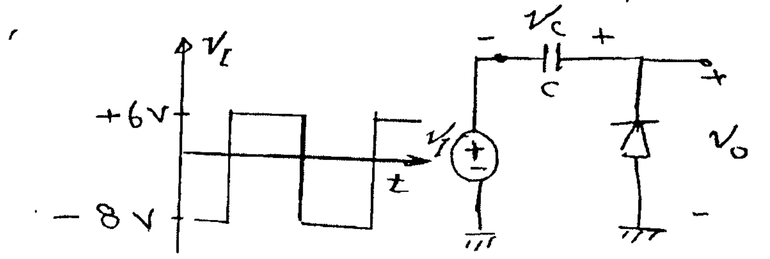


$\because I_{B_2} = I_{E_1} = \frac{I_{E_2}}{1+\beta_2} = \frac{6\,mA}{1+50} = 0.118\,mA$

$I_{B_1} = \frac{I_{E_1}}{1+\beta_1} = \frac{0.118m}{1+50} = 2.314\,MA$

Q2: (12 points)

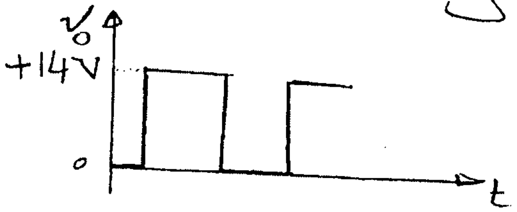
Q2: (a) Determine and sketch the output waveform for the network shown



$V_C = 8\ V$

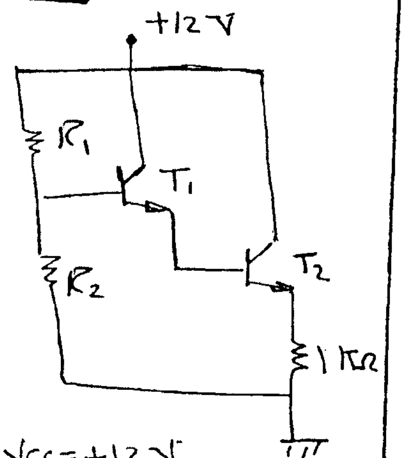
$v_o = v_i + v_C$ i.e $v_o = v_i$ + shifted by −ve half cycle

$= v_i + 8$



Q2: (b)

The Si Darlington Transistor pair shown has $\beta_1 = \beta_2 = 50$. Let $R_2 \to \infty$. Find the values of R_1, and V_{CE_1} needed to biase the circuit so that $V_{CE_2} = 6\ V$



Solution

For $R_2 \to \infty \Rightarrow I_2 = 0$

$\therefore I_1 = I_{B_1}$

, $I_{E_1} = I_{B_2}$

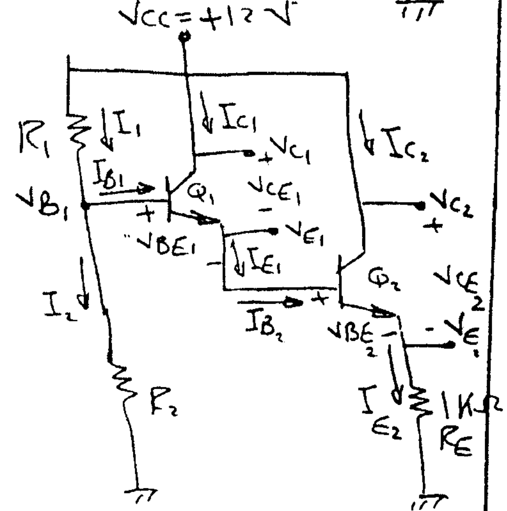
$\because V_{CE_2} = 6 = V_{C_2} - V_{E_2}$

$\therefore V_{E_2} = V_{C_2} - 6$

$V_{C_2} = V_{C_1} = V_{CC} = 12\ V$

$\therefore V_{E_2} = 12 - 6 = 6\ V$

$\therefore I_{E_2} = \dfrac{V_{E_2}}{R_E} = \dfrac{6}{1K} = 6\ mA$



$\therefore I_{B_2} = I_{E_1} = \dfrac{I_{E_2}}{1+\beta_2} = \dfrac{6\ mA}{1+50} = 0.118\ mA$

$I_{B_1} = \dfrac{I_{E_1}}{1+\beta_1} = \dfrac{0.118m}{1+50} = 2.314\ \mu A$

Q2: (b) (cont.)

$$R_1 = \frac{V_{CC} - V_{B_1}}{I_1}$$

$$V_{B_1} = V_{BE_1} + V_{BE_2} + V_{E_2}$$
$$= 0.7 + 0.7 + 6 = 7.4\,V$$

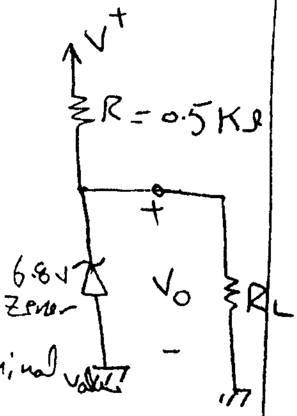
$$\therefore R_1 = \frac{12 - 7.4}{2.314\,\mu A} = 1.99\,M\Omega$$

$$\because V_{E_1} = V_{BE_2} + V_{E_2}$$
$$= 0.7 + 6 = 6.7\,V$$

$$\therefore V_{CE_1} = V_{C_1} - V_{E_1}$$
$$= 12 - 6.7 = 5.3\,V$$

Q3:- (12 Points)

The 6.8 V Zener diode in the circuit shown is specified to have $V_Z = 6.8\,V$ at $I_Z = 5\,mA$, $r_Z = 20\,\Omega$, and $I_{ZK} = 0.2\,mA$. The supply voltage V^+ is nominally 10 V but can vary by $\pm 1\,V$.



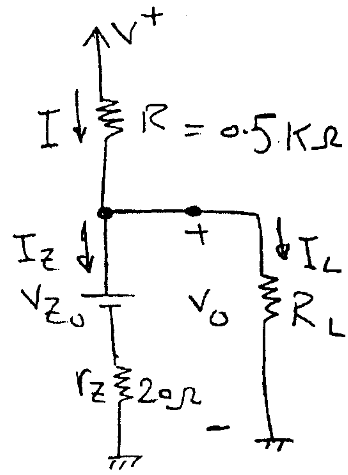
(a) Find V_o with no load and with V^+ at its nominal value.

$\because V_Z = V_{Z_0} + r_Z I_Z$

$6.8 = V_{Z_0} + 20 * 5*10^{-3}$

$\therefore V_{Z_0} = 6.8 - 0.1 = 6.7\,V$

with no load i.e $R_L = \infty$



$$I = I_Z = \frac{V^+ - V_{Z_0}}{R + r_Z}$$

$$= \frac{10 - 6.7}{0.5K + 20} = 6.35\,mA$$

$\therefore V_o = V_{Z_0} + I_Z r_Z$

$$= 6.7 + 6.35 * 20 = 6.83\,V$$

(b) Find the change in V_o resulting from the $\pm 1\,V$ change in V^+.

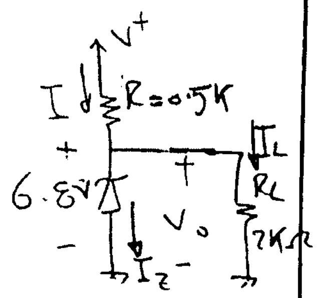
The change in V_o can be found from

$$\Delta V_o = \Delta V^+ \frac{r_Z}{R + r_Z}$$

$$= \pm 1 * \frac{20}{0.5K + 20} = \pm 38.5\,mV$$

(c) Find the change in V_o when $R_L = 2K\Omega$

If $R_L = 2K\Omega$ is connected



$$\therefore I_L \simeq \frac{V_Z}{R_L} \simeq \frac{6.8}{2K} = 3.4\,mA$$

$$I = \frac{10 - 6.8}{0.5K} = 6.4\,mA$$

$\because I = I_Z + I_L \Rightarrow I_Z\big|_{Loaded} = I - I_L =$

$I_Z\big|_{Loaded} = 6.4m - 3.4m = 3\,mA$

Q3: (Cont.)

change in Zener current $\Delta I_Z = I_Z\Big|_{Load} - I_Z\Big|_{No-Load}$

$\Delta I_Z = 3 - 6.35 = -3.4\,mA$

$\therefore$ change in $V_o \Rightarrow \Delta V_o = \Delta I_Z\, r_Z$

$\Delta V_o = -3.4m \times 20 = -68\,mV$

(d) what is the min. value of R_L for which the diode still operates in the break down region?

For the Zener at edge of the break down region then

$I_Z = I_{ZK} = 0.2\,mA$ and $V_{Z_0} \simeq V_{ZK} \simeq 6.7\,V$

$\therefore$ At this point the lowest current supplied through R is $I = \dfrac{V^+ - V_{ZK}}{R}$

$= \dfrac{9 - 6.7}{0.5K} = 4.6\,mA$

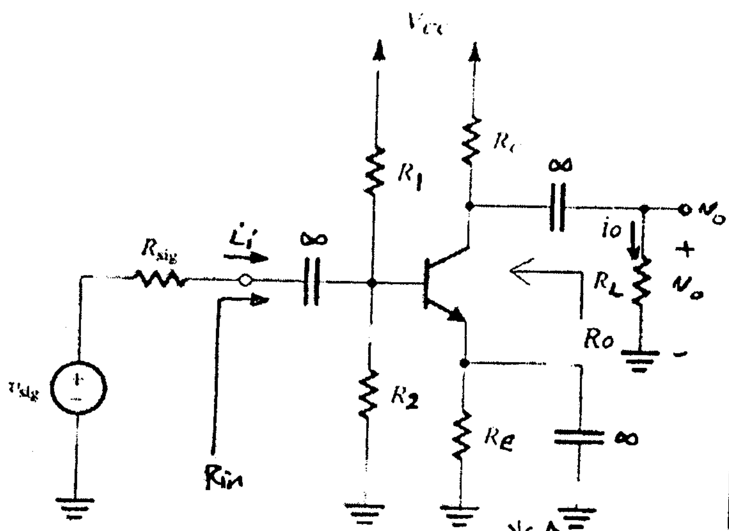
$\therefore I_L = I - I_Z = 4.6 - 0.2 = 4.4\,m$

$R_L\Big|_{min} = \dfrac{V_o}{I_L} \simeq \dfrac{V_Z}{I_L}$

$= \dfrac{6.7}{4.4m} = 1.5\,K\Omega$

(Q4) (12 points)

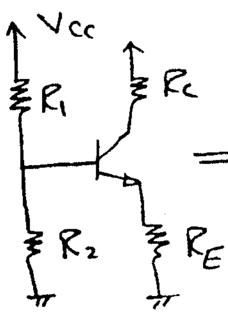
For the amplifier shown in Fig.(3), let V_{CC} = 12V, R_1= 22 kΩ, R_2= 6.8 kΩ, R_E = 560 Ω, and R_C = 1 kΩ. The transistor has β = 100. Calculate the dc bias current I_E. If the amplifier operates between a source for which R_{sig} = 600 Ω and a load of 2 kΩ, replace the transistor with its hybrid-π model, and find the values of R_{in}, R_o, and the voltage gain v_o/v_{sig}.

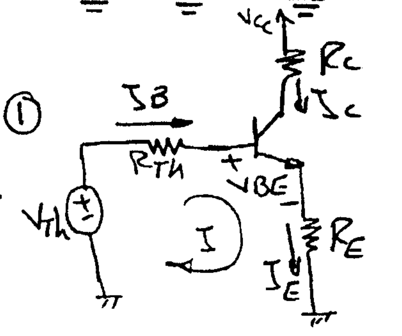


Solution

DC Analysis

- All capacitor are o.c
- Reduce AC sources





$R_{Th} = R_1 \parallel R_2 = 22K \parallel 6.8K$

$R_{Th} = 5.19\ K\Omega$

$V_{Th} = V_{CC} \dfrac{R_2}{R_1 + R_2}$

$V_{Th} = 12 \dfrac{6.8K}{22K + 6.8K} = 2.833\ V$

Loop (I)

$-V_{Th} + I_B R_{Th} + V_{BE} + I_E R_E = 0$; $\because I_E = (1+\beta) I_B$

$\dfrac{I_E}{1+\beta} R_{Th} + I_E R_E = V_{Th} - V_{BE}$

$I_E = \dfrac{V_{Th} - V_{BE}}{R_E + \dfrac{R_{Th}}{1+\beta}} = \dfrac{2.833 - 0.7}{560 + \dfrac{5.19K}{101}} = 3.489\ mA$ → ①

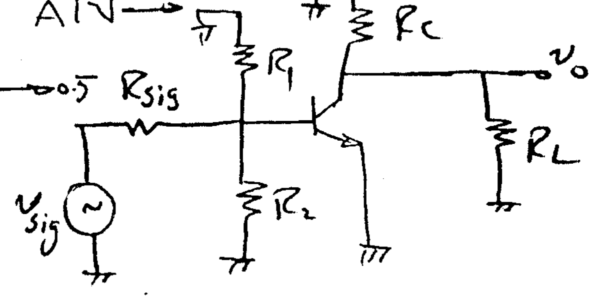
$I_C = \alpha I_E = \dfrac{\beta}{1+\beta} I_E = \dfrac{100}{101} * 3.489\ mA = 3.454\ mA$

$g_m = \dfrac{I_C}{V_T} = \dfrac{3.454\ mA}{25\ mV} = 0.138\ A/V$ → 0.5

$r_\pi = \dfrac{\beta}{g_m} = \dfrac{100}{0.138} = 724.64\ \Omega$ → 0.5

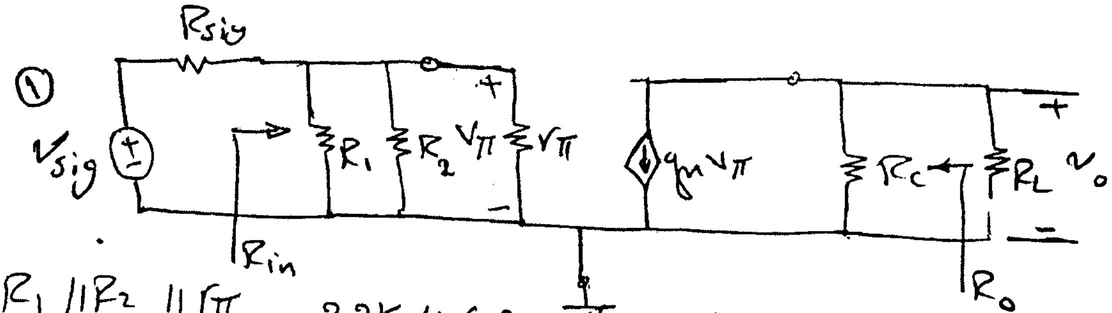
- AC Analysis

- All capacitor are s.c
- reduce DC sources



Q4 (cont.)

Using π-model



$R_{in} = R_1 \| R_2 \| r_\pi = 22K \| 6.8K \| 724.61$

$= 635.93 \simeq 636\ \Omega$ ⟶ ①

$R_o|_{v_{sig}=0} = R_C = 1\ K\Omega.$ ⟶ ①

To find $\frac{v_o}{v_{sig}}$:-

$v_o = -g_m v_\pi (R_C \| R_L)$

$v_\pi = v_{sig} \frac{R_{in}}{R_{in}+R_{sig}}$

$v_o = -g_m v_{sig} \frac{R_{in}}{R_{in}+R_{sig}} (R_C \| R_L)$ ⟶ ②

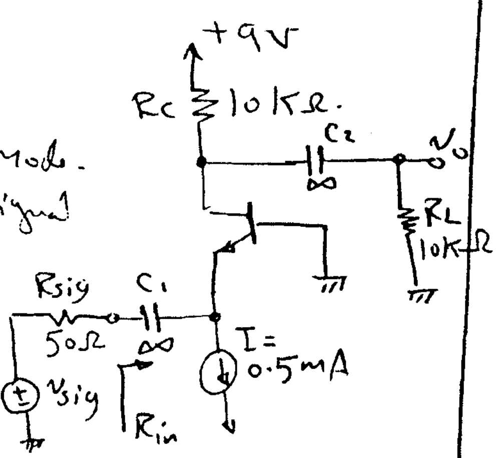
$\frac{v_o}{v_{sig}} = -g_m \frac{R_{in}}{R_{in}+R_{sig}} (R_C \| R_L)$

$= -0.138 \frac{636}{636+600} (1K \| 2K)$

$= -0.138 * 0.515 * 666.667 = -47.34\ V/V$ ⟶ ①

Q5: (12 points)

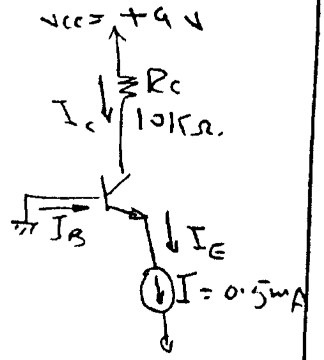
The transistor in the circuit shown is biased to operate in the Active mode. Replace the transistor with small-signal equivalent circuit T-mode and then find R_{in}, the voltage gain (v_o/v_{sig}), the current gain (i_o/i_i) and the o/p resistance R_{out}. Assuming that $\beta = 100$.



Solution

DC Analysis

- reduce AC sources
- ALL capacitors are o.c



$I_E = I = 0.5\ mA$

$I_C = \alpha I_E = \frac{\beta}{1+\beta} I_E = \frac{100}{101} * 0.5m$

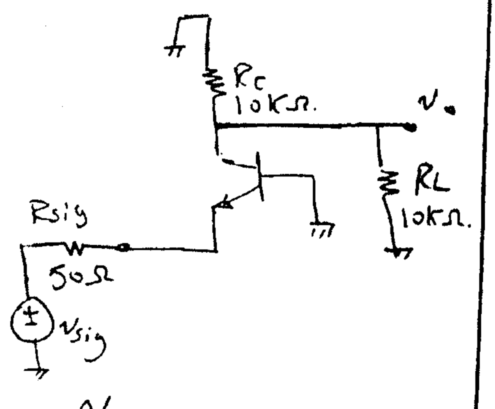
$= 0.99 * 0.5m = 0.495\ mA$

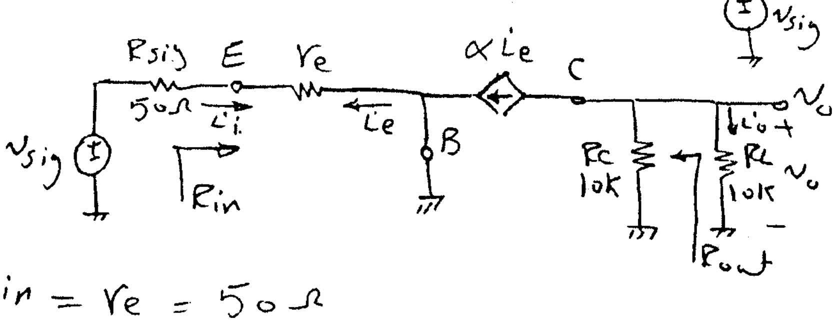
$g_m = \frac{I_C}{V_T} = \frac{0.495m}{25m} = 19.8\ mA/V$

$r_e = \frac{V_T}{I_E} = \frac{25m}{0.5m} = 50\ \Omega$

AC Analysis

- reduce DC sources
- ALL capacitors are s.c





$R_{in} = r_e = 50\ \Omega$

$R_{out}\big|_{v_{sig}=0} = R_C = 10\ K\Omega$

Q5 : (Cont.)

To find $A_v = \frac{v_o}{v_{sig}}$

$$v_o = -\alpha i_e (R_C \parallel R_L)$$

$$i_e = -\frac{v_{sig}}{R_{sig} + r_e}$$

$$v_o = +\alpha \frac{v_{sig}}{R_{sig} + r_e} (R_C \parallel R_L)$$

$$\frac{v_o}{v_{sig}} = \alpha \frac{(R_C \parallel R_L)}{R_{sig} + r_e}$$

$$= (0.99) \frac{(10K \parallel 10K)}{50 + 50}$$

$$= (0.99) \frac{5K}{100} = 49.5 \text{ V/V}$$

To find $A_i = \frac{i_o}{i_i}$

$$i_o = -\alpha i_e \frac{R_C}{R_C + R_L}$$

$$i_e = -i_i$$

$$i_o = +\alpha i_i \frac{R_C}{R_C + R_L}$$

$$A_i = \frac{i_o}{i_i} = \alpha \frac{R_C}{R_C + R_L}$$

$$= (0.99) \frac{10K}{10K + 10K} = 0.495 \text{ A/A}$$
