Faculty of Engineering	**Microelectronics (E301)**
Benha university	**Final-Term Exam (corrective)**
Electrical Eng.Dept.	**Data: 31/12/2014**
Dr Hossam Labib Zayed	**Time: 3 Hours**

Answer the following questions:

Q1: (a) In the circuit of Fig(1), if V_S is a 20Vp square wave of period T, $R_L = R_1 = 10\Omega$, and the diode is ideal, find the average value of V_L.

(b) Analyze the circuit of Fig. (2), to determine the voltages at all nodes and the currents through all branches. Assume that the transistor β is specified to be at least 50.

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_0 with no load and with V^+ at its nominal value.

(b) Find the change in V_0 resulting from the ± 1 V change in V^+.

(c) Find the change in V_0 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: In the circuit of Fig. (6), v_{sig} is a small sine-wave signal with zero average value. For $V_{CC}=15V$, $R_1 = R_2 = 100K\Omega$, $R_E = 200\ \Omega$, $R_C = R_L = 20\ K\Omega$, and $\beta = 100$. Find using hybrid-π model the values of R_{in}, R_o, the voltage gain (v_o / v_{sig}), and the current gain (i_o/i_i).

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 β=100.

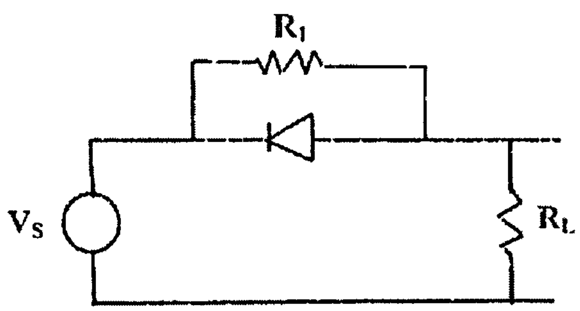


Fig.(1)

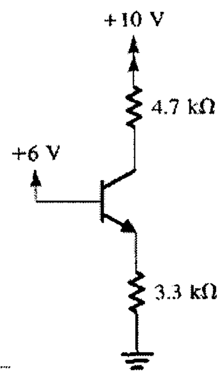


Fig.(2)

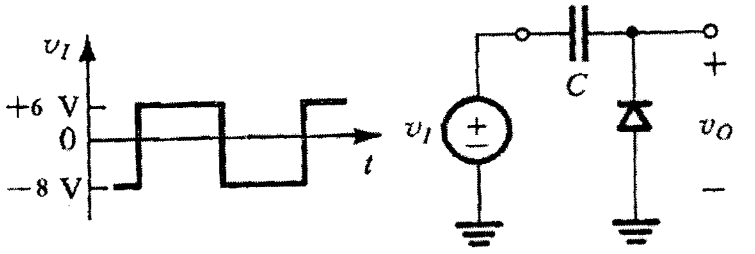


Fig.(3)

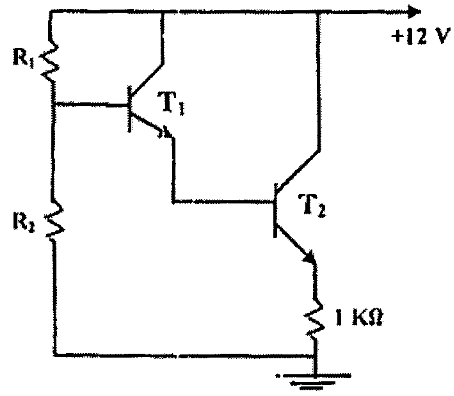


Fig.(4)

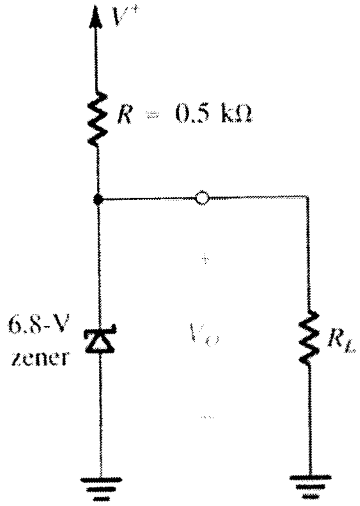


Fig.(5)

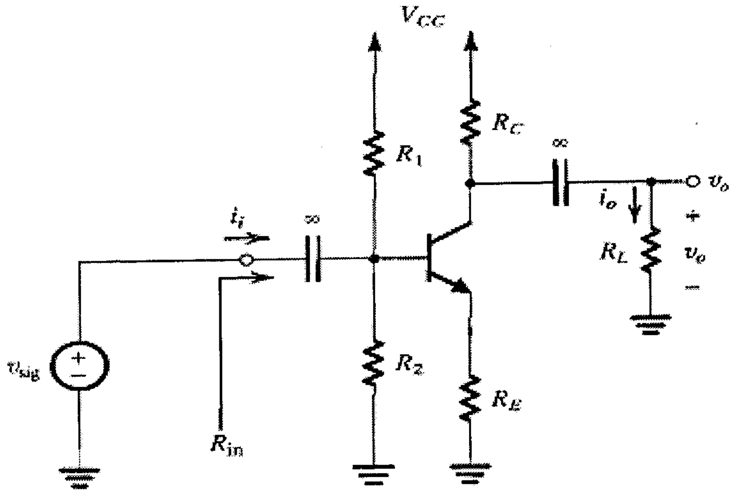


Fig.(6)

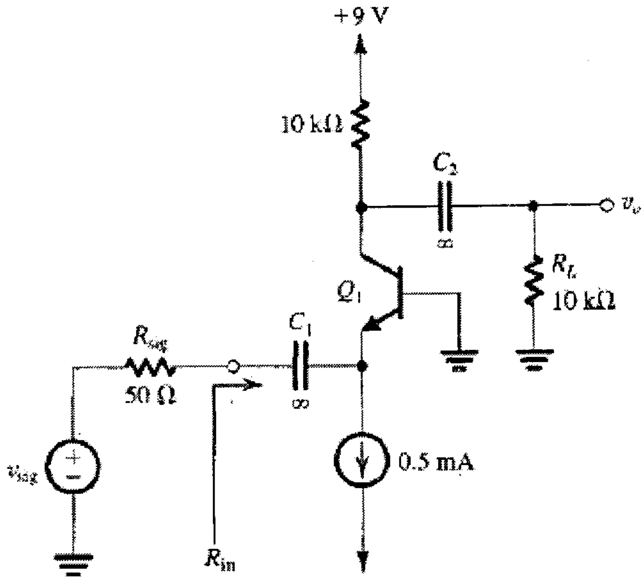


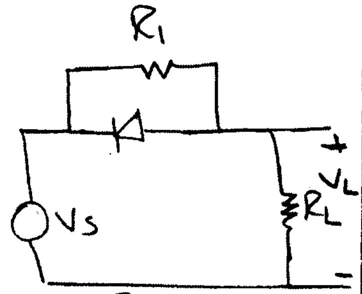
Fig.(7)

BEST WISHES

Hossam Labib

Model Answer

Q1: (a) (6 points)

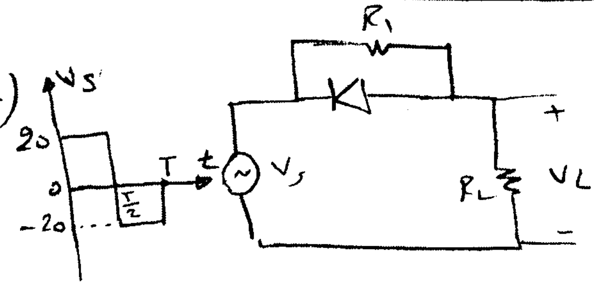


In the circuit shown, if V_s is $20V_p$ square wave of period T, $R_L = R_1 = 10\,\Omega$, and the diode is ideal, find the average value of V_L.

Solution

- from $t = 0 : \frac{T}{2}$ (i.e +ve half cycle)

The Diode is off and the circuit become:-

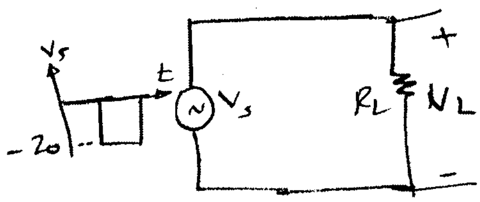


$$\therefore V_L = V_s \frac{R_L}{R_L + R_1} = 20 \frac{10}{10 + 10} = 10\,V$$

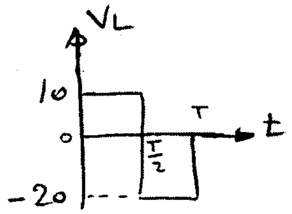
- For $t = \frac{T}{2} : T$ (i.e −ve half cycle)

The Diode is on and the circuit become:-

$$V_L = V_s = -20\,V$$



$\therefore V_L$ is



$$V_L\Big|_{ave} = \frac{1}{T}\int_0^T v_L(t)\,dt = \frac{1}{T}\left[\int_0^{\frac{T}{2}} 10\,dt + \int_{\frac{T}{2}}^{T} -20\,dt\right]$$

$$= \frac{1}{T}\left[10t\Big|_0^{\frac{T}{2}} - 20\Big|_{\frac{T}{2}}^{T}\right]$$

$$= \frac{1}{T}\left[\left(10\frac{T}{2} - 0\right) - \left(20T - \frac{20T}{2}\right)\right]$$

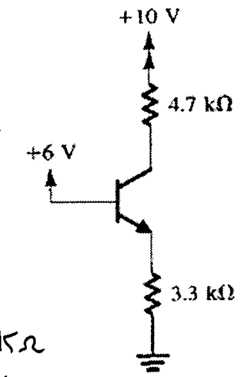
$$= \frac{1}{T}\left[5T - 20T + 10T\right]$$

$$= \frac{1}{\cancel{T}}\left[-5\cancel{T}\right] = -5\,V$$

$$\therefore V_L\Big|_{av} = -5\,V$$

Q1: (b) (6 points)

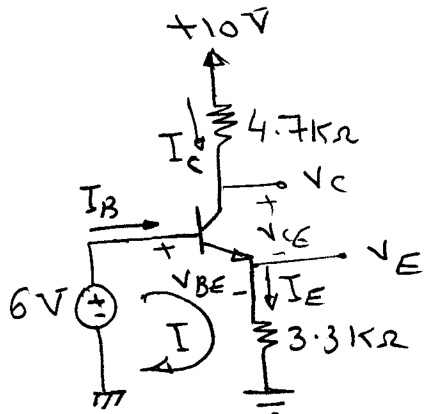
Analyze the circuit of Fig. (2), to determine the voltages at all nodes and the currents through all branches. Assume that the transistor β is specified to be at least 50.



Solution

let Transistor In Active Region

Loop (I)



$-6 + V_{BE} + 3.3K * I_E = 0$

$\therefore I_E = \frac{6 - V_{BE}}{3.3K} = \frac{6 - 0.7}{3.3k} = 1.6\ mA$

let $I_E = I_C \Rightarrow V_C = 10 - I_C * 4.7K$

$V_C = 10 - 1.6 * 4.7 = 2.48\ V$

$\because V_B = 6\ V$; $V_E = V_B - V_{BE} = 6 - 0.7 = 5.3\ V$

$\because V_B > V_E \Rightarrow$ EBJ Forward.

$\because V_B > V_C \Rightarrow$ CBJ Forward

$\therefore$ Transistor In saturation Region not active Region

$\therefore$ assumption not True

for saturation region $\Rightarrow V_{CE}|_{sat} \simeq 0.2\ V$

$\therefore V_C = V_{CE}|_{sat} + V_E = 0.2 + 5.3 = 5.5\ V$

$\therefore I_C = \frac{10 - V_C}{4.7K} = \frac{10 - 5.5}{4.7K} = 0.96\ mA$

$\because$ EBJ Forward $\Rightarrow I_E = 1.6\ mA$; $V_{BE} = 0.7$; $V_E = 5.3\ V$

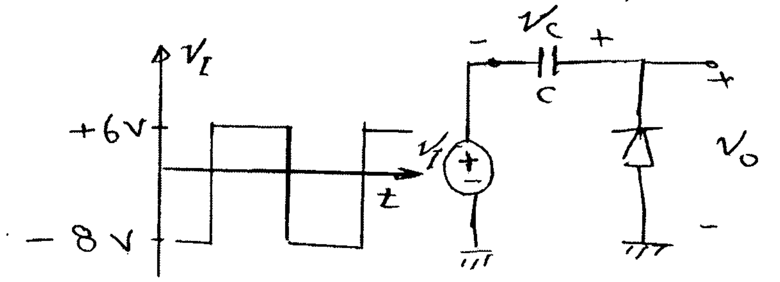
$\therefore I_B = I_E - I_C = 1.6m - 0.96m = 0.64\ mA$

$\beta|_{forced} = \frac{I_C|_{sat}}{I_B|_{sat}} = \frac{0.96m}{0.64m} = 1.5$

- since $\beta|_{forced}$ is less Than min. value of β, Then The Transistor is in fact saturated

Q2: (12 points)

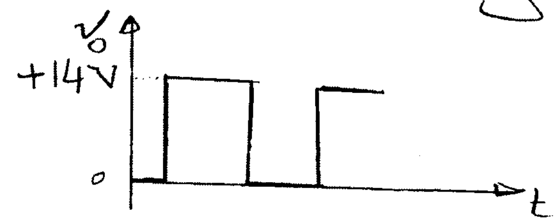
Q2: (a) Determine and sketch the output waveform for the network shown



$v_C = 8$ V

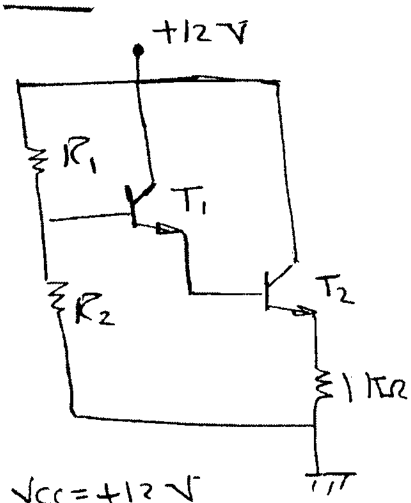
$v_o = v_i + v_C$ i.e $v_o = v_i$ + shifted by −ve half cycle

$= v_i + 8$



Q2: (b)

The Si Darlington Transistor pair shown has $B_1 = B_2 = 50$. 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 $R_2 \to \infty \Rightarrow I_2 = 0$

$\therefore I_1 = I_{B_1}$

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

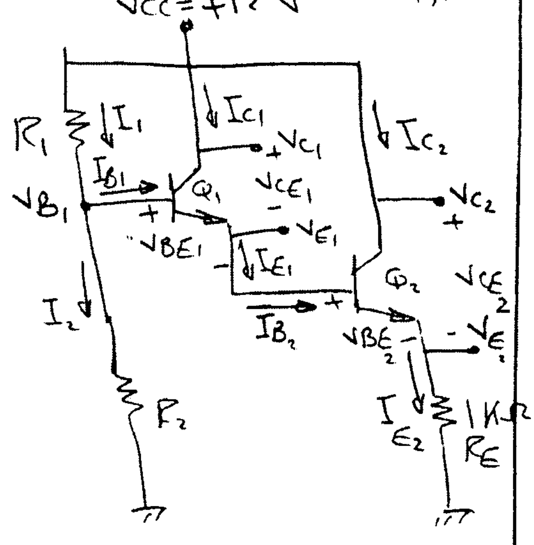
$\because V_{CE_2} = 6 = V_{C_2} - V_{E_2}$

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

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

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

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

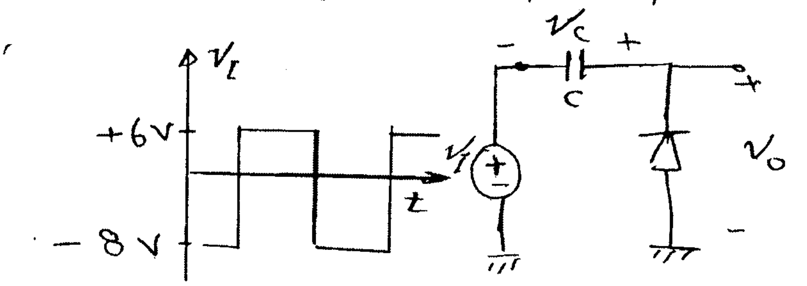


$\therefore I_{B_2} = I_{E_1} = \frac{I_{E_2}}{1+B_2} = \frac{6 mA}{1+50} = 0.118$ mA

$I_{B_1} = \frac{I_{E_1}}{1+B_1} = \frac{0.118m}{1+50} = 2.314$ μA

Q2: (12 points)

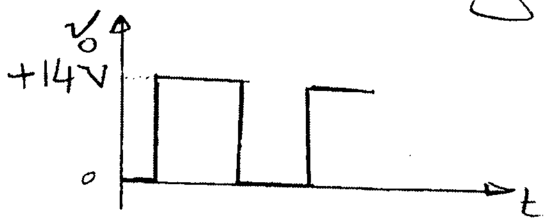
Q2: (a) Determine and sketch the output waveform for the network shown



$v_C = 8$ V

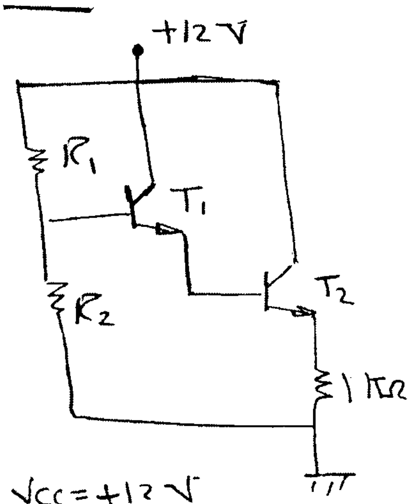
$v_o = v_i + v_C$ i.e $v_o = v_i$ + shifted by −ve half cycle

$= v_i + 8$



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

$\therefore I_1 = I_{B_1}$

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

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

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

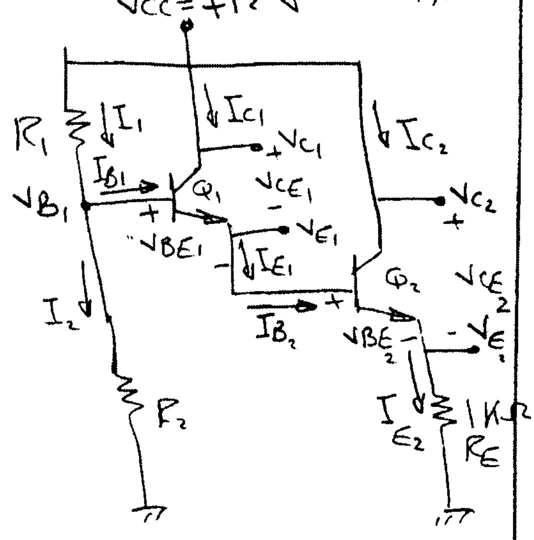
$V_{C_2} = V_{C_1} = V_{CC} = 12$ V

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

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

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

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



Q2: (b) (cont.)

$$R_1 = \frac{V_{CC} - V_{B1}}{I_1}$$

$$V_{B1} = V_{BE1} + V_{BE2} + V_{E2}$$

$$= 0.7 + 0.7 + 6 = 7.4 V$$

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

$$\because V_{E1} = V_{BE2} + V_{E2}$$

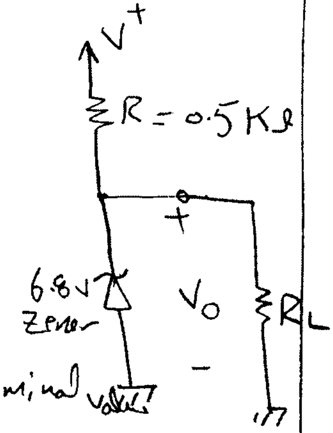
$$= 0.7 + 6 = 6.7 V$$

$$\therefore V_{CE1} = V_{C1} - V_{E1}$$

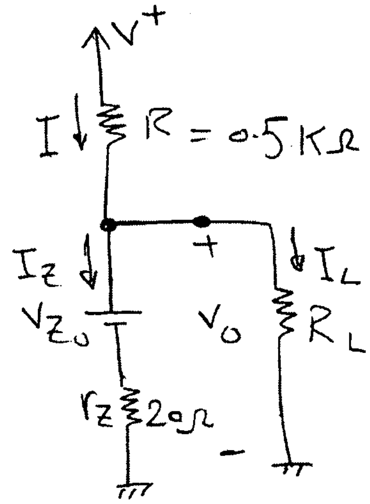
$$= 12 - 6.7 = 5.3 V$$

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.



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

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

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

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

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

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

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

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

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

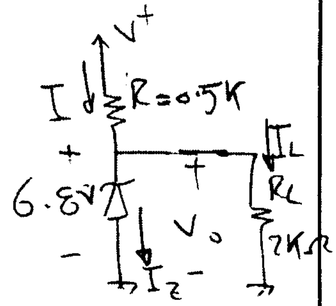
The change in V_o can be found from

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

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

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

If $R_L = 2K\Omega$ is connected



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

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

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

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

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 breakdown region?

For the Zener at edge of the breakdown region then

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

$\therefore$ At this point the lowest current supplied through R

is $I = \dfrac{V^+ - V_{ZK}}{R}$

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

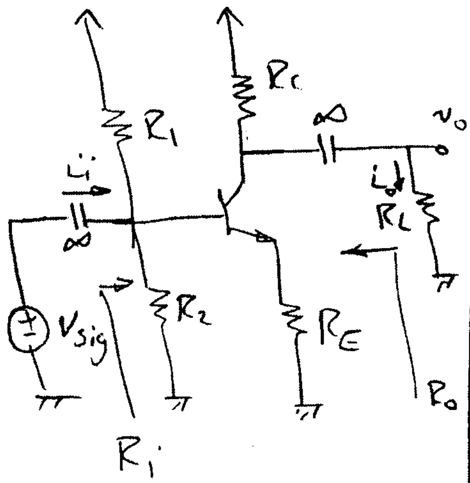
$\because I_L = I - I_Z = 4.6 - 0.2 = 4.4\,m$

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

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

Q4: (12 points)

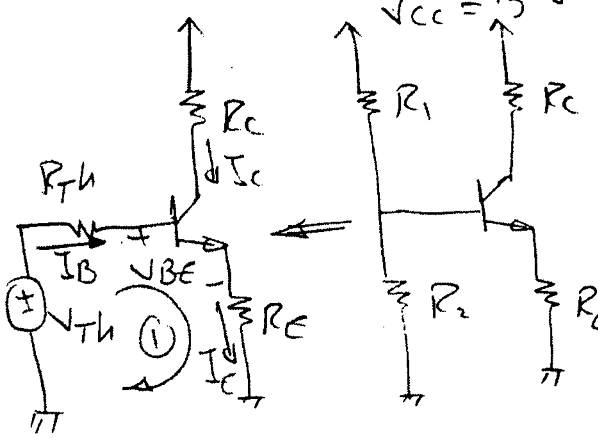
In the circuit of fig. (4), v_{sig} is a small sine-wave signal with zero average value. For $V_{CC} = 15$ V, $R_1 = R_2 = 100$ KΩ, $R_E = 200$ Ω, $R_C = R_L = 20$ KΩ, and $\beta = 100$. Find using hybrid-π model the values of R_{in}, R_o, the voltage gain $\left(\frac{v_o}{v_{sig}}\right)$, and the current gain $\left(\frac{i_o}{i_i}\right)$.



Solution

DC Analysis

- All cap. o.c
- reduce AC sources



$R_{Th} = R_1 \parallel R_2$

$= 100K \parallel 100K = 50$ KΩ.

$$V_{Th} = \frac{V_{CC}\, R_2}{R_1 + R_2} = \frac{15 * 100K}{100K + 100K} = 7.5 \text{ V}$$

Loop (1)

$-V_{Th} + I_B R_{Th} + V_{BE} + I_E R_E = 0$

$\because I_E = (1+\beta) I_B$

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

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

$$I_B = \frac{V_{Th} - V_{BE}}{R_{Th} + (1+\beta) R_C} = \frac{7.5 - 0.7}{50K + 101 * 200} = 96.87 \text{ μA}$$

$I_C = \beta I_B = 100 * 96.87 \mu A = 9.687$ mA

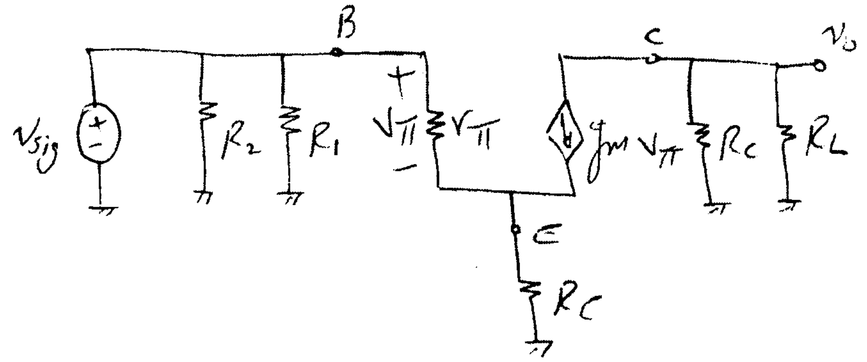
$$g_m = \frac{I_C}{V_T} = \frac{9.687m}{25m} = 0.388 \text{ A/V}$$

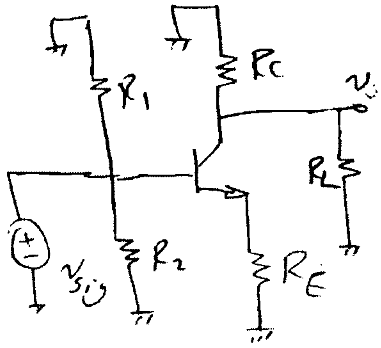
$$r_\pi = \frac{\beta}{g_m} = \frac{100}{0.388} = 258 \text{ Ω}$$

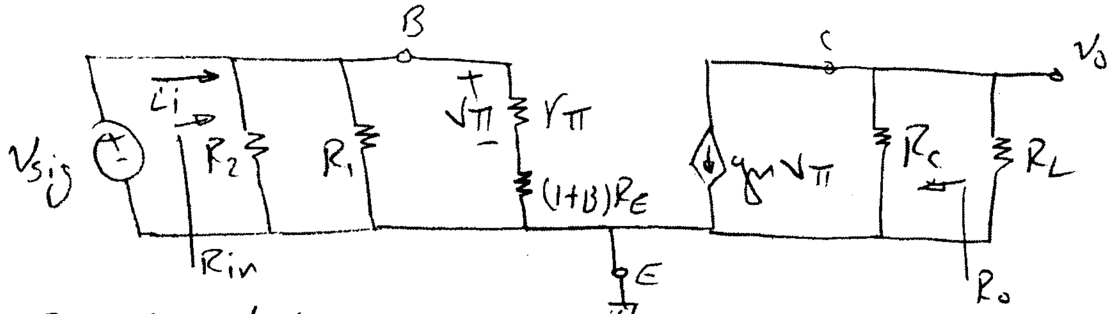
AC Analysis

- All cap. s.c & reduce DC sources

Q4: (Cont.)







$$R_{in} = R_1 \| R_2 \| (r_\pi + (1+\beta) R_E)$$

$$= 100K \| 100K \| (258 + 101 * 200)$$

$$= 50K \| 20.458K = 14.5 K\Omega$$

$$R_o \big|_{v_{sig}=0} = R_C = 20 K\Omega .$$

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

$$v_\pi = v_{sig} \frac{r_\pi}{r_\pi + (1+\beta) R_E}$$

$$v_o = -g_m v_{sig} \frac{r_\pi (R_C \| R_L)}{r_\pi + (1+\beta) R_E}$$

$$A_v = \frac{v_o}{v_{sig}} = -g_m r_\pi \frac{R_C \| R_L}{r_\pi + (1+\beta) R_E} = -g_m \frac{\beta}{g_m} \frac{R_C \| R_L}{r_\pi + (1+\beta) R_E}$$

$$= -100 \frac{(20K \| 20K)}{258 + 101 * 200} = -48.88 \ V/V$$

$$i_o = -g_m v_\pi \frac{R_C}{R_C + R_L}$$

$$\because v_{sig} = i_i R_{in} \quad ; \quad v_\pi = v_{sig} \frac{r_\pi}{r_\pi + (1+\beta) R_E}$$

$$\therefore v_\pi = i_i R_{in} \frac{r_\pi}{r_\pi + (1+\beta) R_C}$$

$$i_o = -g_m \left(i_i R_{in} \frac{r_\pi}{r_\pi + (1+\beta) R_C} \right) \frac{R_C}{R_C + R_L}$$

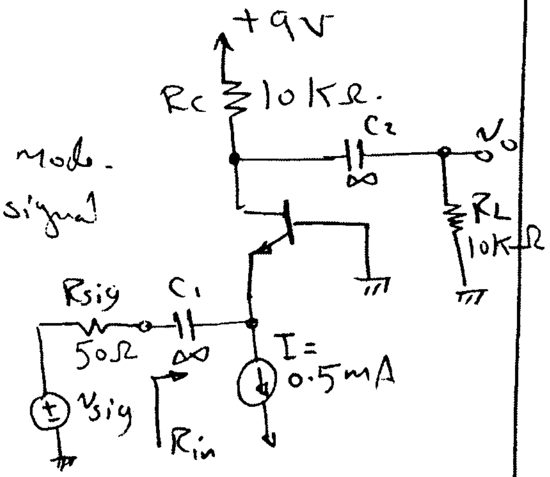
(8)

$$A_i = \frac{i_o}{i_i} = -g_m R_i \left(\frac{r_\pi}{r_\pi + (1+\beta) R_E} \right) \frac{R_C}{R_C + R_L} = -0.388 * 14.5K \frac{258}{258 + 101 * 200} * \frac{20K}{40K}$$

$$= -35.5 \ A/A$$

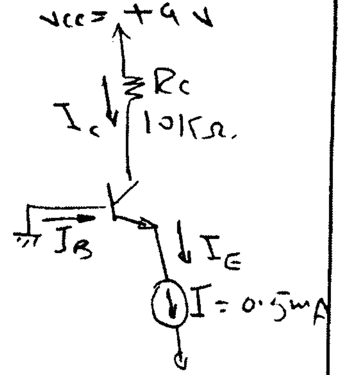
Q5: (12 points)

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



Solution

DC Analysis
- reduce AC sources
- All capacitors are o.c



$$I_E = I = 0.5\ mA$$

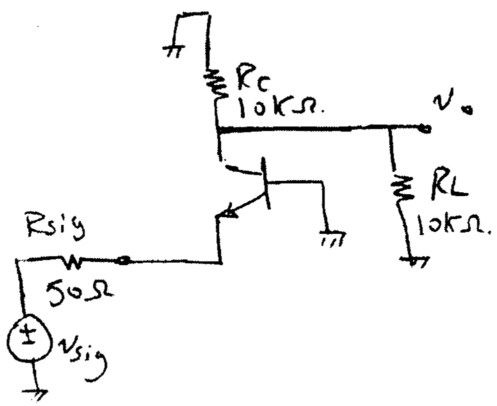
$$I_C = \alpha I_E = \frac{\beta}{1+\beta} I_E = \frac{100}{101} * 0.5m$$

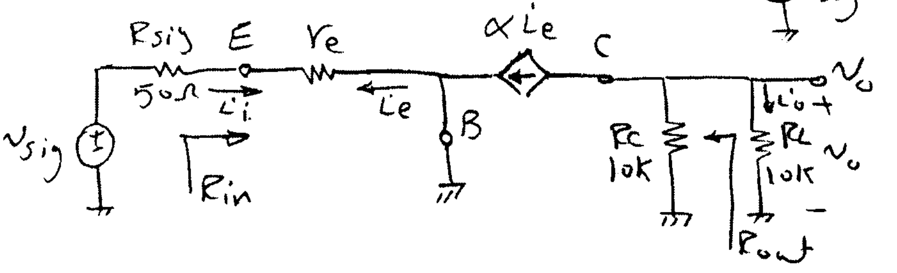
$$= 0.99 * 0.5m = 0.495\ mA$$

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

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

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

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

$$i_e = -i_i$$

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

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

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