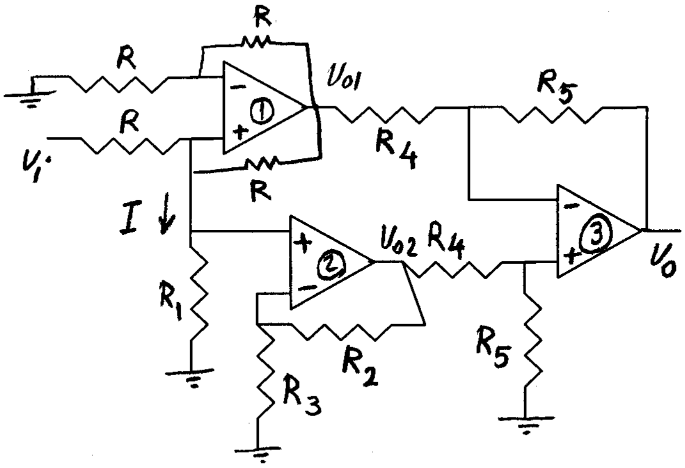
(25 Points)(1) (a)Find Vo/Vi in term of R, R1, R2, R3, R4 and R5.
b) If R=10 K, R1=3.3 K, R2=4.7 K, R3=5.6 K, R4=18 K and R5=33 K, Calculate Vo/Vi using relation obtained From part (a).



solution :

The Current I shown is equal to V_i/R . (refer to Positive Integrator)

The voltage of V_+ at op-Amp #2 is

$$V_+(2) = I \cdot R_1 = \frac{V_i}{R} \cdot R_1 \qquad \text{also } V_{01} = 2 V_i \frac{R_1}{R}$$

op-Amp #2 is a non-inverting Amp.

$$V_{o2} = V_+ \left(1 + \frac{R_2}{R_3}\right) = V_i \frac{R_1}{R}\left(1 + \frac{R_2}{R_3}\right)$$

The third op-amp is a differential amplifier

$$V_o = \frac{R_5}{R_4}\left(V_{o2} - V_{o1}\right)$$

substituting for V_{o1} and V_{o2} from Previous results

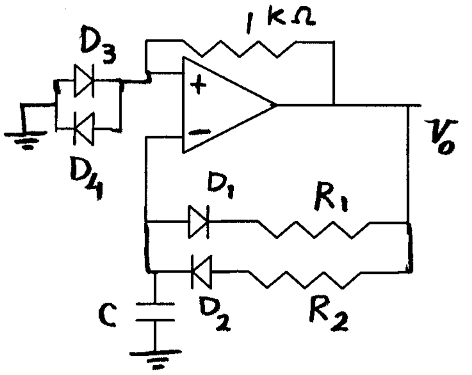
$$V_o = \frac{R_5}{R_4}\left(V_i \frac{R_1}{R}\left(1 + \frac{R_2}{R_3}\right) - 2 V_i \frac{R_1}{R}\right)$$

or

$$\frac{V_o}{V_i} = \frac{R_1}{R} \cdot \frac{R_5}{R_4}\left(\frac{R_2}{R_3} - 1\right)$$

b) $$\frac{V_o}{V_i} = \frac{3.3}{10} \cdot \frac{33}{18}\left(\frac{4.7}{5.6} - 1\right) = -0.097$$

(20 Points) (2) In the square wave generator shown, assume diodes D1 and D2are ideal but assume constant voltage drop model of 0.7 [V] for D3 and D4. L+=-L-=10[V]. Find the frequency of the waveform if R1=10 K, R2=1.2 K and C=1 microF.   K = KΩ



Solution :

The voltage of V_+ is ± 0.7 volts.

The β is $\beta = \frac{0.7}{10} = 0.07$

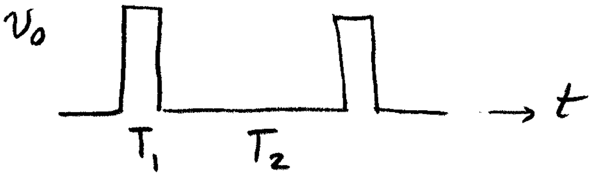
$$T_1 = 2\beta R_1 C$$
$$T_2 = 2\beta R_2 C$$

$$T = T_1 + T_2 = 2\beta C(R_1 + R_2)$$

$$T = 2 \times 0.07 \times 1 \times 10^{-6} (10 + 1.2) \times 10^{3}$$

$$T = 1.57 \text{ ms}$$

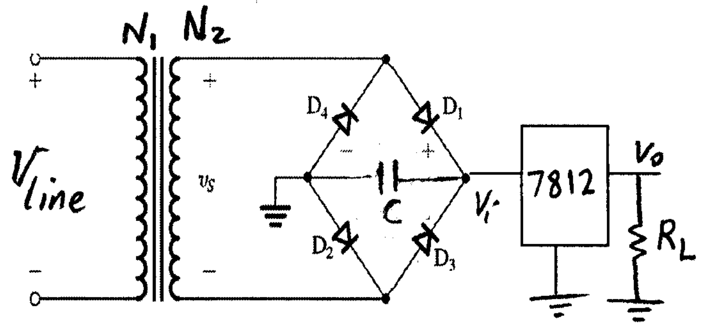
$$f = \frac{1}{T} = 638 \text{ Hz}$$



$$T_1 = 2\beta C R_2$$
$$T_2 = 2\beta C R_1$$

$$T_1 = 2 \times 0.07 \times 1 \times 10^{-6} \times 1.2 \times 10^{3} = 0.168 \text{ ms}$$
$$T_2 = 2 \times 0.07 \times 1 \times 10^{-6} \times 10 \times 10^{3} = 1.4 \text{ ms}$$

(20Points) (3) In the regulated power supply shown, V(line)=170Cos(377t) and Vo is 9 volt(DC). If RL=60 ohms, find appropriate value for C and transformer turn ratio N2/N1.



solution :

$V_o(DC) = 9 [V]$

$V_i(DC) = 4 + 9 = 13 [V]$

$V_r = 1.3 [V]$ $\qquad V_p = 13 + \frac{1}{2} \times 1.3 = 13.65 [V]$

$$R'_L = \frac{13}{I_L} = \frac{13}{9/60} = 86.6 \ \Omega$$

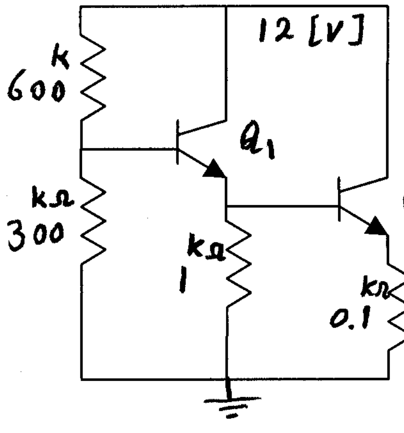
$$C = \frac{V_p}{2 \times f \times R'_L \times V_r}$$

$$C = \frac{13.65}{2 \times 60 \times 86.6 \times 1.3} = 1010 \ \mu F$$

$$V_s = V_p + 1.4 = 13.65 + 1.4 = 15.05 [V]$$

$$\frac{N_2}{N_1} = \frac{V_s}{170} = \frac{15.05}{170} = 0.088$$

(25 Points) (4) In the circuit shown, find the DC current of collector of Q1 and Q2. V(BE)=0.7 V and beta=100.



Solution:

By Putting the thevenin eq. of R_{B1} and R_{B2}, as in Fig 2

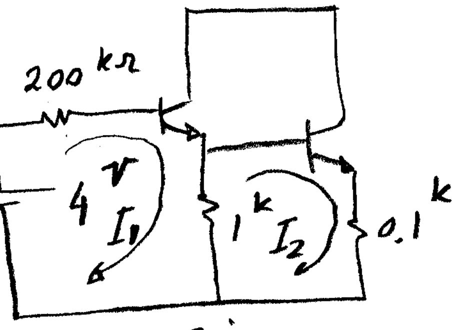
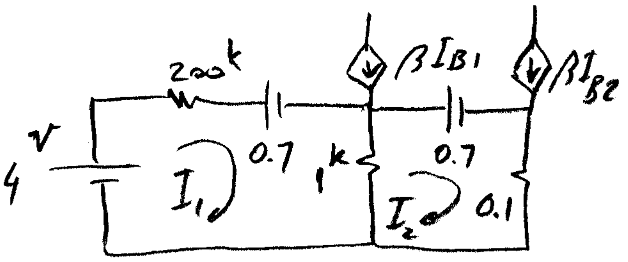


Fig 2

Now we Can write

2 Mesh Current equations,

$$\begin{cases} 4 = 200\, I_1 + 0.7 + (101\, I_1 - I_2)\times 1 \\ (101\, I_1 - I_2)\times 1 = 0.7 + (101\, I_2)\times 0.1 \end{cases}$$



$$\begin{cases} 301\, I_1 - I_2 = 3.3 \\ 101\, I_1 - 11.1\, I_2 = 0.7 \end{cases}$$

From the first eq. $\Rightarrow$ $I_2 = 301\, I_1 - 3.3$

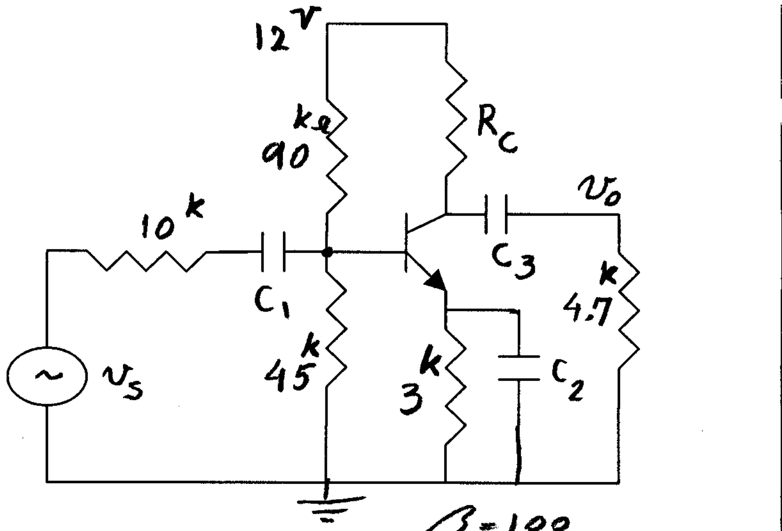
$$101\, I_1 - 11.1\,(301\, I_1 - 3.3) = 0.7$$

$$-3240.1\, I_1 + 36.63 = 0.7$$

$$I_1 = I_{B1} = 0.011 \qquad \boxed{I_{C1} = 1.1 \text{ mA}}$$

$$I_2 = 301\, I_1 - 3.3 \qquad I_2 = 0.037 \qquad \boxed{I_{C2} = 3.78 \text{ mA}}$$

(25 Points) (5)Find Rc, C1, C2 and C3 so that the amplifier has a passband gain of –20 and lower cut-off frequency of 100 Hz. Assume that all 3 capacitors has equal time constants.



$\beta = 100$

$V_T = 25\ mV$

$V_{BE} = 0.7\ V$

$v_o / v_s = -20$

solution :

First we do DC analysis to Find I_C . From Fig. 2

$$4 = 30\ I_B + 0.7 + 3(101\ I_B)$$

$$I_B = 0.01\ mA \qquad \boxed{I_C = 1\ mA}$$

$$r_\pi = \frac{\beta V_T}{I_C} = \frac{100 \times 25}{1} = 2.5\ k\Omega$$

$$g_m = I_C / V_T = \frac{1}{25} = 40\ m℧$$

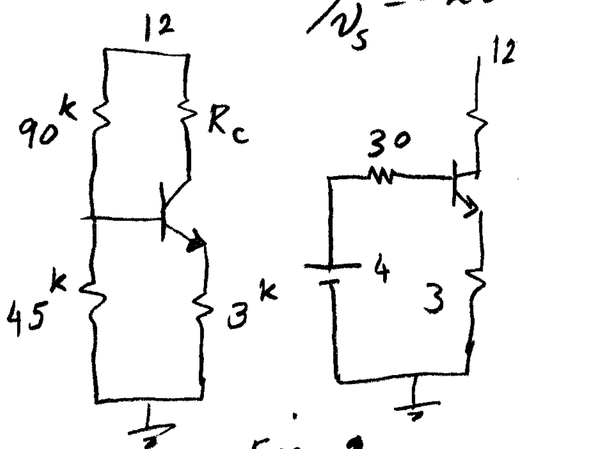


Fig. 2

From Fig. 3 , we can find the Passband gain as a function of R_c

$$v_i / v_s = \frac{2.5 \| 30}{2.5 \| 30 + 10} = \frac{2.3}{2.3 + 10} = 0.187$$

$$v_o / v_i = -g_m (R_c \| 4.7)$$

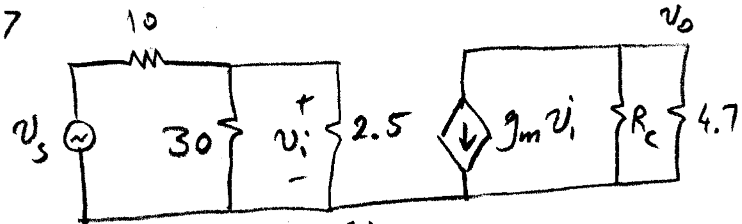


Fig. 3

$$v_o / v_s = -40(R_c \| 4.7) \times 0.187 = -20$$

$$R_c \| 4.7 = 2.67 \qquad \frac{1}{R_c} + \frac{1}{4.7} = \frac{1}{2.67}$$

$$\boxed{R_c = 6.18\ k\Omega}$$

$$\tau_1 = \tau_2 = \tau_3 = \tau \qquad \omega_L = \frac{1}{\tau_1} + \frac{1}{\tau_2} + \frac{1}{\tau_3} = \frac{3}{\tau} \qquad \tau = \frac{3}{\omega_L} = \frac{3}{2\pi \times 100}$$

$$\tau = 4.77\ ms$$

$$C_1 [10 + 30 \| 2.5] = 4.77\ ms$$

$$C_2 \left[3 \| \frac{2.5 + 30 \| 10}{101}\right] = 4.77$$

$$C_3 [6.18 + 4.7] = 4.77$$

$C_1 = 0.38\ \mu F$
$C_2 = 64.2\ \mu F$
$C_3 = 0.43\ \mu F$