Solutions to Quiz-2 Paper (Group-B) IEC103

(Q1) Analyse the phase shift oscillator shown in Fig. Q1

Obtain the values of C and R_F for oscillation frequency of 10 KHz using $R = 10\,K\Omega = R_1$.

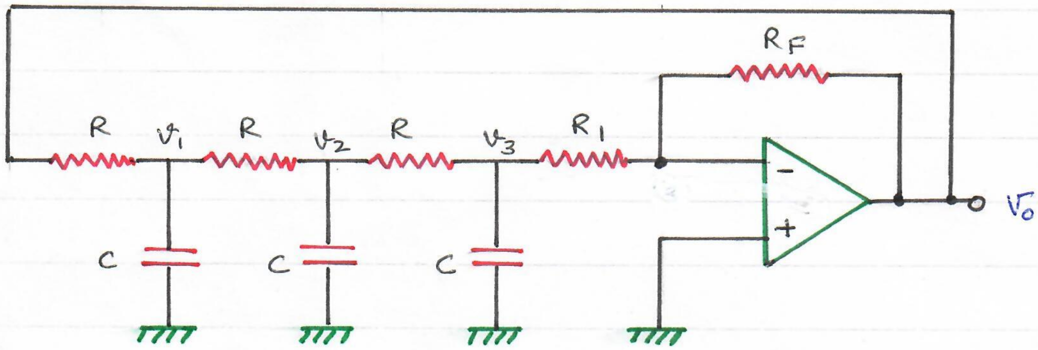
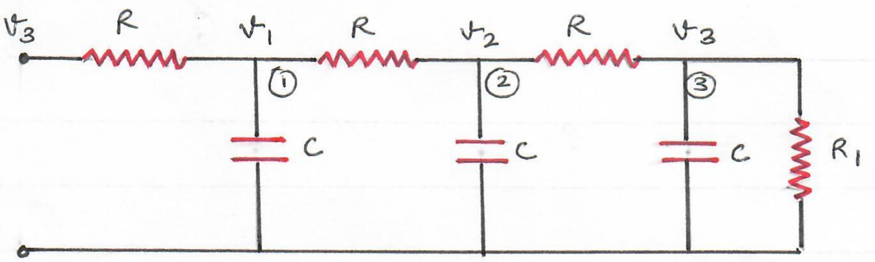


Fig. Q1

Sol.

$V_o = Av_3$



Applying KCL at node

$$\frac{v_1 - Av_3}{R} + \frac{v_1}{(1/sC)} + \frac{v_1 - v_2}{R} = 0 \quad \ldots (i)$$

$$\frac{v_2 - v_1}{R} + \frac{v_2}{(1/sC)} + \frac{v_2 - v_3}{R} = 0 \quad \ldots (ii)$$

$$\frac{v_3 - v_2}{R} + \frac{v_3}{(1/sC)} + \frac{v_3}{R_1} = 0 \quad \ldots (iii)$$

$$v_1\left(\frac{1}{R} + sC + \frac{1}{R}\right) - \frac{1}{R}v_2 - \frac{A}{R}v_3 = 0 \quad \ldots (i)$$

$$-\frac{1}{R}v_1 + \left(\frac{1}{R} + sC + \frac{1}{R}\right)v_2 - \frac{1}{R}v_3 = 0 \quad \ldots (ii)$$

$$-\frac{1}{R}v_2 + \left(\frac{1}{R} + sC + \frac{1}{R_1}\right)v_3 = 0 \quad \ldots (iii)$$

$R_1 = R$

Let $\frac{1}{R} = G$

$$v_1(2G+sC) - Gv_2 - AGv_3 = 0 \quad \cdots (i)$$
$$-Gv_1 + (2G+sC)v_2 - Gv_3 = 0 \quad \cdots (ii)$$
$$-Gv_2 + (2G+sC)v_3 = 0 \quad \cdots (iii)$$

Eq (iii) $\quad Gv_2 = (2G+sC)v_3$

$$v_2 = R(2G+sC)v_3 \quad \cdots (iv)$$

substituting the value of v_2 from the above equation in (ii)

$$-Gv_1 + (2G+sC)R(2G+sC)v_3 - Gv_3 = 0$$
$$\Rightarrow Gv_1 = [(2G+sC)R(2G+sC) - G]v_3$$
$$\Rightarrow v_1 = R[(2G+sC)^2R - G]v_3 \quad \cdots (v)$$

Substituting the expression for v_1 in eq (v) & v_2 in eq (iv) in eqn.(i)

$$(2G+sC)R[(2G+sC)^2R - G]v_3 - GR(2G+sC)v_3 - AGv_3 = 0$$

$$\Rightarrow (2G+sC)R[(2G+sC)^2R - G] - (2G+sC) - AG = 0$$

$$(2G+sC)[R^2(2G+sC)^2 - 1] - (2G+sC) - AG = 0$$

$$(2G+sC)[R^2(2G+sC)^2 - 1 - 1] - AG = 0$$
$$(2G+sC)[R^2(4G^2 + s^2C^2 + 4sGC) - 2] - AG = 0$$
$$\Rightarrow (2G+sC)[4 + s^2R^2C^2 + 4sRC - 2] - AG = 0$$
$$\Rightarrow (2G+sC)(s^2R^2C^2 + 4sRC + 2) - AG = 0$$
$$\Rightarrow (2s^2RC^2 + 8sC + 4G + s^3R^2C^3 + 4s^2RC^2 + 2sC) - AG = 0$$

put $s = j\omega$

$$-2\omega^2RC^2 + j8\omega C + 4G - j\omega^3R^2C^3 - 4\omega^2RC^2 + j2\omega C - AG = 0$$
$$\Rightarrow (4G - AG - 2\omega^2RC^2 - 4\omega^2RC^2) + j(8\omega C - \omega^3R^2C^3 + 2\omega C) = 0$$
$$\Rightarrow (4G - AG - 6\omega^2RC^2) + j(10\omega C - \omega^3R^2C^3) = 0$$

$$4G - AG - 6\omega^2 RC^2 = 0 \quad \& \quad 10\omega C - \omega^3 R^2 C^3 = 0$$

$$\Rightarrow \omega^2 R^2 C^2 = 10$$

$$\Rightarrow \boxed{\omega = \frac{\sqrt{10}}{RC}}$$

$$4G - AG - 6RC^2\omega^2 = 0$$

$$\Rightarrow 4G - AG - 6RC^2 \times \frac{10}{R^2C^2} = 0$$

$$\Rightarrow 4G - AG - 60G = 0$$

$$\Rightarrow -56G = AG$$

$$\Rightarrow A = -56 = -\frac{R_F}{R_1} = \frac{R_F}{R}$$

$$\therefore \boxed{R_F = 56R}$$

$R = 1K\Omega \Rightarrow R_F = 56K\Omega$

frequency of oscillation required $= 10\,KHz = 10 \times 10^3\,Hz$

$= 1591.5$ rad/s

$$\therefore \omega = 1591.5 = \frac{\sqrt{10}}{RC}$$

$$\Rightarrow C = \frac{\sqrt{10}}{1591.5 \times R} =$$

$$\Rightarrow C = \frac{\sqrt{10}}{1591.5 \times 1000} = 1.987\,\mu F$$

(Q2) Determine the output waveform (Vout) of the circuit shown in Fig. Q2 shown below. Use simplified model of the diode. The diodes is a silicon diode.

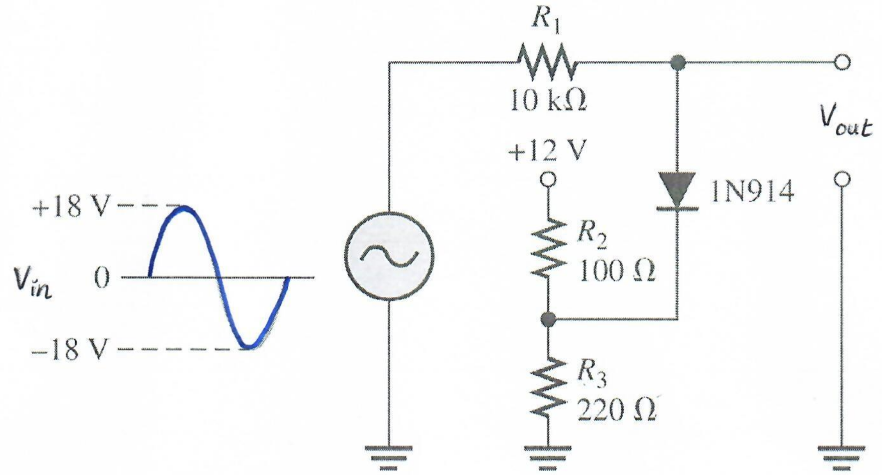


Fig. Q

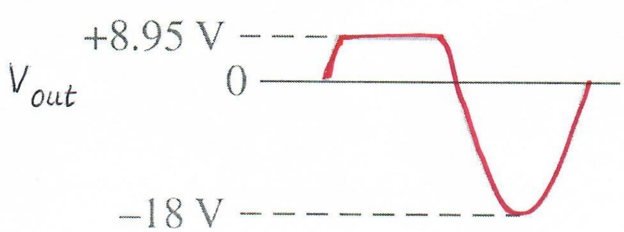
Sol. The circuit is a +ve limiter. Use voltage divider formula to determine the bias voltage.

V_{BIAS} = Voltage at cathode terminal of diode =

$$= \frac{R_3}{R_2 + R_3} \times 12 = \frac{220}{100 + 220} \times 12 = 8.25\,V$$

The output voltage waveform is shown in Fig. below. The +ve part of the voltage waveform is limited to $V_{BIAS} + 0.7$

$= 8.95V$.



Q3. Derive expression for ripple factor of the unregulated power supply using capacitor filter shown in Fig. Q3 below.

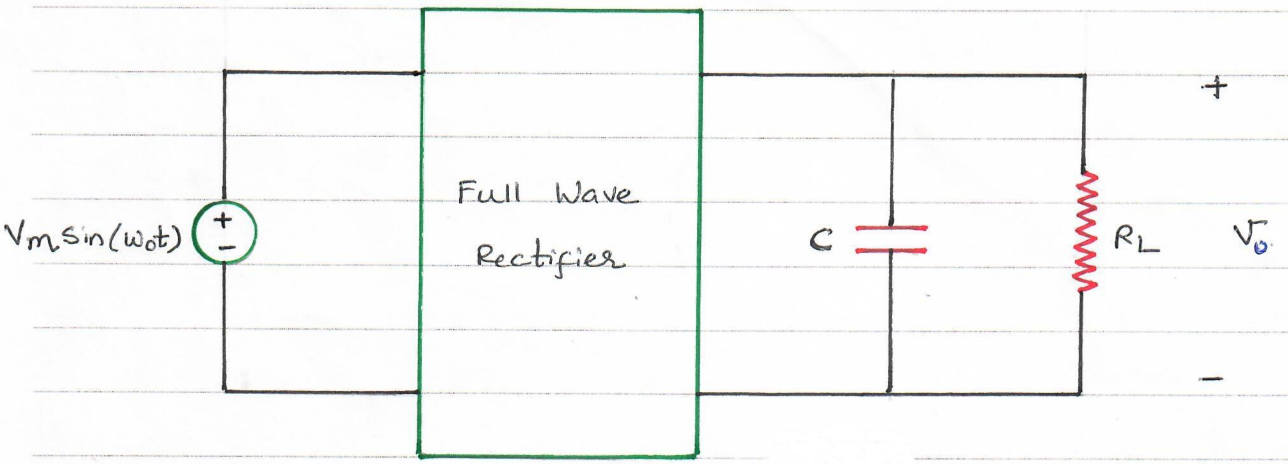


Fig. Q3

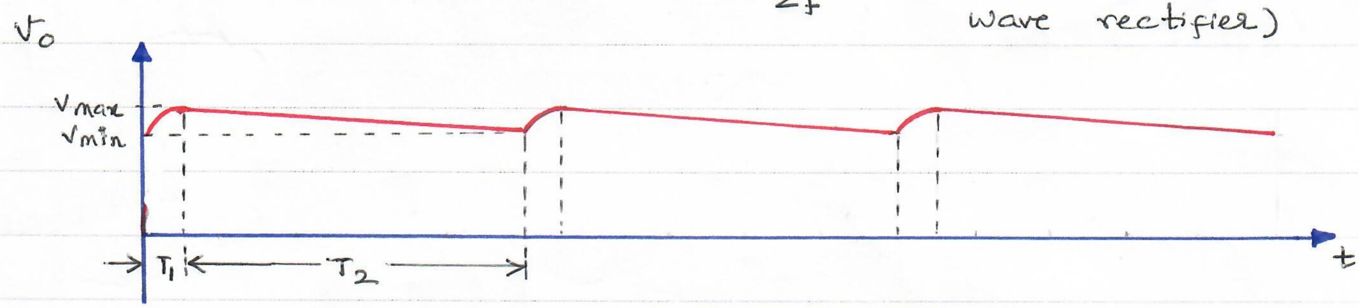
Assume the time constant $R_L C$ is much greater than the time period of the source voltage.

Sol.

$\omega_0 = 2\pi f$

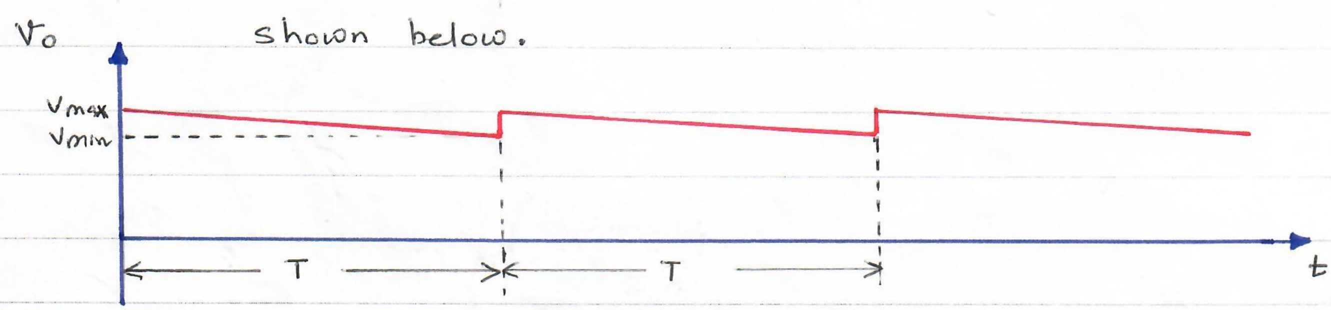
The output waveform will be as shown below.

$T = T_1 + T_2 = \frac{1}{2f}$ (since rectifier is a full wave rectifier)



$T = T_1 + T_2$

The above waveform can be approximated to waveform shown below.



$R_L C >> T$

$R_L C >> T$

$$V_{min} = V_{max}\, e^{-T/R_L C}$$

$$= V_{max}\left(1 - \frac{T}{R_L C} + \frac{T^2}{2R_L^2 C^2} - \cdots\right)$$

$$\simeq V_{max}\left(1 - \frac{T}{R_L C}\right) \qquad \because R_L C >> T$$

$$\text{Ripple factor} = \frac{\text{RMS value of ripple voltage}}{\text{DC value of the voltage}}$$

$$V_{dc} = \frac{(V_{max} + V_{min})}{2} = \frac{1}{2}\left[V_{max} + V_{max}\left(1 - \frac{T}{R_L C}\right)\right]$$

$$= \frac{1}{2}\left[V_{max} + V_{max} - V_{max}\frac{T}{R_L C}\right]$$

$$= \frac{1}{2}\left[2V_{max} - V_{max}\frac{T}{R_L C}\right]$$

$$= V_{max}\left(1 - \frac{T}{2R_L C}\right)$$

$$\text{Peak - peak to ripple voltage} = V_{max} - V_{min} \quad = V_{p\text{-}pr}$$

$$= V_{max} - V_{max}\left(1 - \frac{T}{R_L C}\right)$$

$$= V_{max}\frac{T}{R_L C} = V_{p\text{-}pr}$$

$$\text{RMS value of ripple voltage} = \frac{V_{p\text{-}pr}}{2\sqrt{3}} = \frac{V_{max}T}{2\sqrt{3}R_L C}$$

$$\therefore \gamma = \frac{V_{max}T}{2\sqrt{3}R_L C}$$

$$\therefore \gamma = \frac{\dfrac{V_{max}T}{2\sqrt{3}R_L C}}{V_{max}\left(1 - \dfrac{T}{R_L C}\right)} = \frac{T}{2\sqrt{3}R_L C\left(1 - \dfrac{T}{R_L C}\right)} = \frac{T}{2\sqrt{3}(R_L C - T)}$$

$$\simeq \frac{T}{2\sqrt{3}R_L C} = \frac{1}{4\sqrt{3} f R_L C}$$

$$\because T = \frac{1}{2f}$$

$$\because T = \frac{1}{2f}$$