



POSTAL BOOK PACKAGE 2024

ELECTRONICS ENGINEERING

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CONVENTIONAL Practice Sets

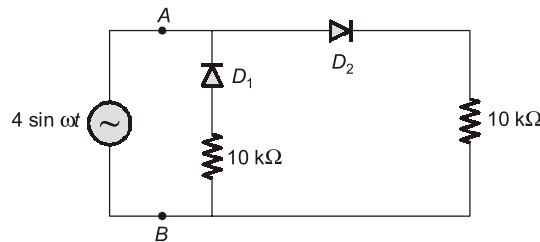
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Diode Circuits

Q1 A voltage source $V_{AB} = 4 \sin \omega t$, is applied across the terminals A and B of the circuit. The diodes are assumed to be ideal. Find the impedance offered by the circuit across the terminals A and B in kilo ohm.



Solution:

In +ve half cycle D_1 – off (R.B.)

D_2 – on (F.B.)

∴ Equivalent circuit will be

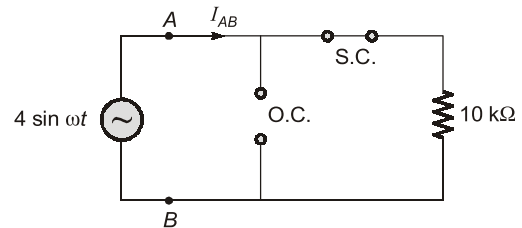
∴

$$V_{AB} = 4 \sin \omega t$$

$$I_{AB} = \frac{V_{AB}}{10 \text{ k}\Omega}$$

∴

$$R_i = \frac{V_{AB}}{I_{AB}} = 10 \text{ k}\Omega$$



For –ve half cycle,

D_1 on, D_2 off

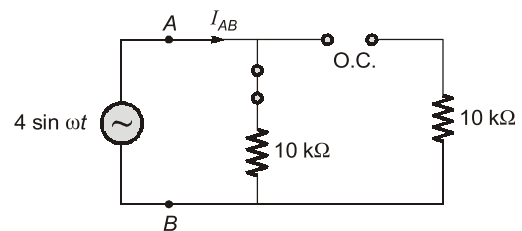
Equivalent circuit,

$$V_{AB} = 4 \sin \omega t$$

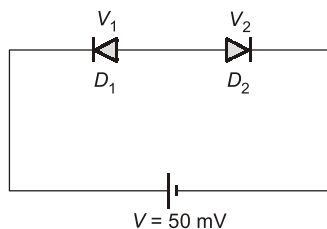
$$I_{AB} = \frac{4 \sin \omega t}{10 \text{ k}\Omega}$$

∴

$$\frac{V_{AB}}{I_{AB}} = R_i = 10 \text{ k}\Omega$$



Q2 Two ideal and identical junction diodes are connected as shown in Figure. If the current through the reverse-biased diode is I_0 and is constant, explain the circuit operation when both the diodes are connected in forward-biased condition. Assume $V_T = 25 \text{ mV}$, $V_\gamma = 0.7 \text{ V}$ and $\eta = 1$ for the diodes.



Solution:

Case 1: Diode D_1 is in reverse bias where as D_2 is forward biased.

At Node 'a'

$$I_1 + I_2 = 0$$

$$I_1 = -I_2$$

$$I_S \left(e^{-\frac{V_1}{\eta V_T}} - 1 \right) = -I_S \left(e^{\frac{+V_2}{\eta V_T}} - 1 \right)$$

$$e^{-\frac{V_1}{\eta V_T}} + e^{\frac{V_2}{\eta V_T}} = 2$$

Also,

$$V_2 = 50 - V_1$$

$$\therefore e^{-\frac{V_1}{\eta V_T}} + e^{\frac{50 - V_1}{\eta V_T}} = 2$$

$$e^{-\frac{V_1}{\eta V_T}} \left[1 + e^{\frac{50}{\eta V_T}} \right] = 2$$

$$e^{-\frac{V_1}{V_T}} = \frac{2}{1 + e^2}$$

$$e^{-\frac{V_1}{V_T}} = \frac{2}{3.39} = 0.24$$

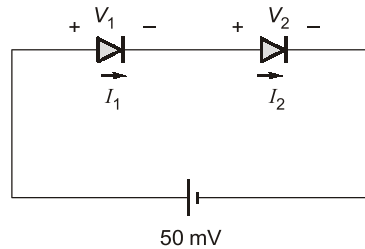
Putting in I_1 ,

$$I_1 = I_0 = I_S \left[e^{-\frac{V_1}{V_T}} - 1 \right]$$

$$I_1 = I_0 = -0.76 I_S$$

-ve sign denotes that direction of current will be opposite to the assumed direction.

Case 2: Both the diodes are forward biased.



As both diodes are ideal and identical hence voltage drop across both diodes will be same.

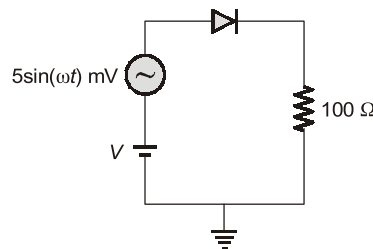
$$\therefore V_1 = V_2 = 25 \text{ mV}$$

$$\text{Now, } I_1 = I_2 = I_S \left(e^{\frac{V_1}{V_T}} - 1 \right) = I_S \left(e^{\frac{25}{25}} - 1 \right) = 1.72 I_S$$

$$\frac{I_1}{I_0} = \frac{1.72 I_S}{0.76 I_S} = 2.26$$

$$\therefore I_1 = 2.26 I_0$$

Q3 A DC current of $26 \mu\text{A}$ flows through the circuit shown. The diode in the circuit is forward biased and it has an ideality factor of one. At the quiescent point, the diode has a junction capacitance of 0.5 nF . Its neutral region resistances can be neglected. Assume that the room temperature thermal equivalent voltage is 26 mV .



For $\omega = 2 \times 10^6 \text{ rad/s}$, the amplitude of the small-signal component of diode current.

Solution:

The small-signal equivalent model of the given circuit can be drawn as shown below.

Given that,

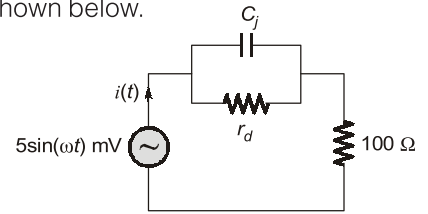
$$\omega = 2 \times 10^6 \text{ rad/sec}$$

$$C_j = 0.5 \text{ nF}$$

$$I_{DC} = 26 \mu\text{A}$$

$$V_T = 26 \text{ mV}$$

$$\eta = 1$$



Since, small signal incremental diode resistance, $r_d = \frac{\eta V_T}{I_{DC}} = \frac{26 \text{ mV}}{26 \mu\text{A}} = 1 \text{ k}\Omega$

and impedance due to junction capacitance, $\frac{1}{\omega C_j} = \frac{1}{2 \times 10^6 \times 0.5 \times 10^{-9}} \Omega = 1 \text{ k}\Omega$

So, total impedance of the circuit will be,

$$Z = \left(r_d \parallel \frac{1}{j\omega C_j} \right) + 100 \Omega$$

$$\left(r_d \parallel \frac{1}{j\omega C_j} \right) = \frac{(1000)(-j1000)}{1000 - j1000} \Omega = \frac{-j(1+j)}{2} \text{ k}\Omega = \frac{1}{2}(1-j) \text{ k}\Omega = (500 - j500) \Omega$$

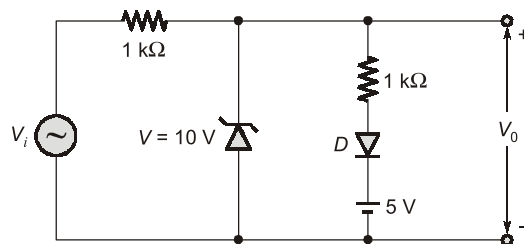
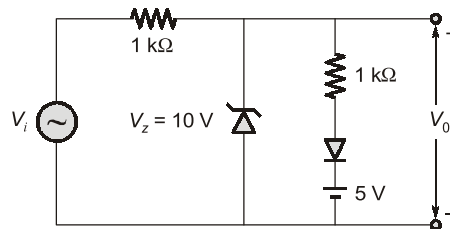
\therefore

$$Z = 600 - j500 \Omega$$

$$|Z| = 100\sqrt{36 + 25} = 100\sqrt{61} \Omega$$

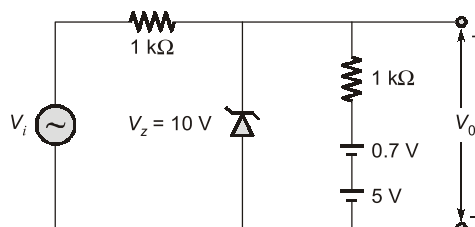
$$I_m = \frac{V_m}{|Z|} = \frac{5 \text{ mV}}{100\sqrt{61} \Omega} = \frac{50}{\sqrt{61}} \mu\text{A} = 6.40 \mu\text{A}$$

Q4 Assuming forward voltage drop across diodes to be 0.7 V, draw the transfer characteristic of the clipper circuit shown in figure.

**Solution:**

When V_i is +ve and $V_i > 5.7 \text{ V}$

Assume diode is conducting,



Assume the Zener diode is reverse biased and having voltage less than breakdown voltage

$$V_i - I(1 \text{ k}\Omega) - I(1 \text{ k}\Omega) - 0.7 - 5 = 0$$

$$V_i - I(2 \text{ k}\Omega) - 5.7 = 0$$

$$I(2 \text{ k}\Omega) = V_i - 5.7$$

$$I = \left(\frac{V_i - 5.7}{2 \text{ k}\Omega} \right)$$

$$V_0 = 5.7 + 1 \times I$$

$$= 5.7 + \left(\frac{V_i - 5.7}{2} \right) = \left(\frac{5.7 + V_i}{2} \right)$$

When,

$$V_i < 5.7 \text{ V}$$

$$V_0 = V_i$$

If,

$$5.7 < V_i < 14.3$$

(\because Diode is in off state)

$$V_0 = \left(\frac{5.7 + V_i}{2} \right)$$

Diode conducts and Zener diode is reverse biased,

When,

$$V_i > 14.3 \text{ V}$$

\Rightarrow

$$V_0 = 10 \text{ volts}$$

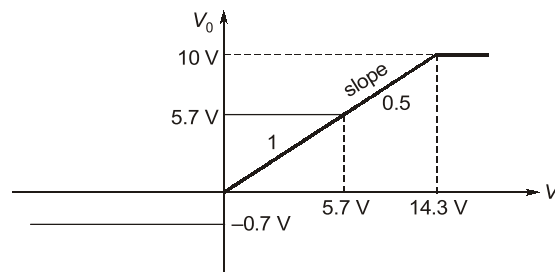
Breakdown occurs in Zener diode.

When,

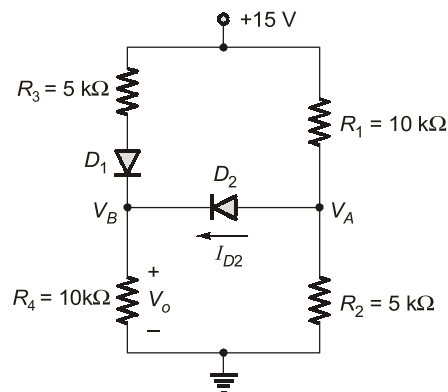
$$V_i < 0 \text{ V}$$

$$V_0 = -0.7 \text{ V}$$

Transfer characteristics:



Q5 Determine the current I_{D2} and the voltage V_0 in the multidiode circuit shown in the figure below. Assume that, cut-in voltage $V_\gamma = 0.7 \text{ V}$ for each diode.



Solution:

To begin, initially assume that, both the diodes D_1 and D_2 are in their conducting state.

By applying KCL at A and B nodes, we have

$$\frac{15 - V_A}{10} = I_{D2} + \frac{V_A}{5}$$

...(i)

$$\text{and } \frac{15 - (V_B + 0.7)}{5} + I_{D2} = \frac{V_B}{10} \quad \dots(\text{ii})$$

We note that $V_B = V_A - 0.7$. Combining the two equations and eliminating I_{D2} , we find

$$V_A = 7.62 \text{ V} \quad \text{and} \quad V_B = 6.92 \text{ V}$$

From equation (i) above, we obtain

$$\frac{15 - 7.62}{10} = I_{D2} + \frac{7.62}{5} \Rightarrow I_{D2} = -0.786 \text{ mA}$$

We assumed that D_2 was ON, so a negative current is inconsistent with that initial assumption.

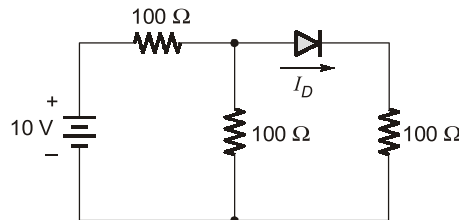
Now assume that diode D_2 is OFF and D_1 is ON. To find the node voltages, we can simply use voltage divider principle as

$$V_A = \left(\frac{5}{5 + 10} \right) (15) = 5 \text{ V}$$

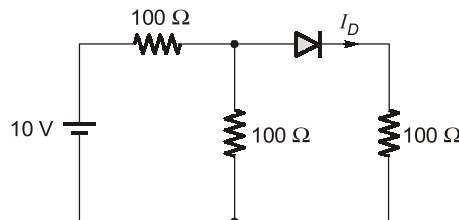
$$\text{and } V_B = V_o = \left(\frac{10}{10 + 5} \right) (15 - 0.7) = 9.53 \text{ V}$$

These voltages show that diode D_2 is indeed reverse biased so that $I_{D2} = 0$.

Q6 Find the diode current I_D in the circuit shown below when the diode has cut in voltage, $V_y = 0.7 \text{ V}$ and forward resistance, $R_f = 25 \Omega$.

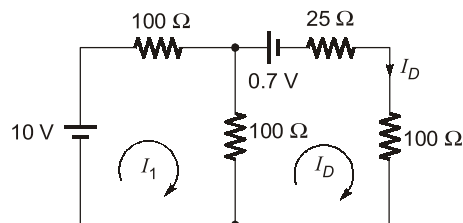
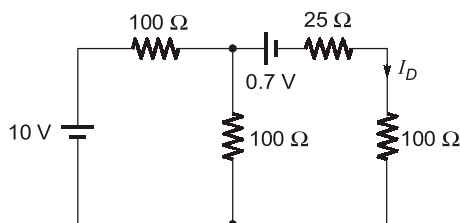


Solution:



Given : Diode cut-in voltage = 0.7 V and diode forward resistance = 25 Ω

Replacing the diode with its equivalent, we get,



$$\text{Using KVL, } 10 - 100I_1 - 100(I_1 - I_D) = 0 \quad \dots(\text{i})$$

$$-0.7 - 25I_D + 100(I_1 - I_D) = 0 \quad \dots(\text{ii})$$

Solving equation (i) and (ii)

$$10 - 200I_1 - 100I_D = 0 \quad \dots(\text{iii})$$

$$-0.7 - 225I_D + 100I_1 = 0 \quad \dots(\text{iv})$$

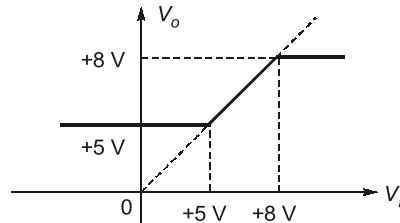
Multiplying equation (iv) by 2 and adding, we get

$$10 - 1.4 - 450I_D - 100I_D = 0$$

$$8.6 = 550I_D$$

$$\therefore I_D = \frac{8.6}{550} = 15.63 \text{ mA}$$

Q7 The ideal transfer characteristic of a particular circuit is given in figure. Design the circuit. Draw the output waveform with proper explanation, if $V_i = 10 \sin \omega t$.



Solution:

Slope of the curve between A and B is

$$m = \frac{(8-5)}{(8-5)} = 1$$

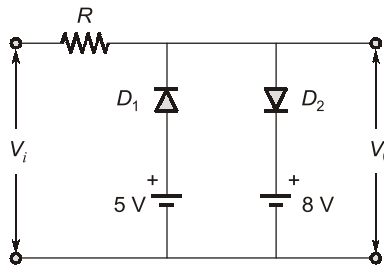
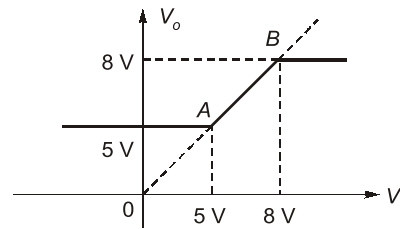
The circuit diagram for the above input-output (transfer) characteristic is a two-level clipper as shown below.

Cut in voltages of diodes are zero.

For $V_i < 5 \text{ V} \rightarrow$ diode D_1 will be on and D_2 will be off

and

$$V_o = 5 \text{ V}$$



For $V_i > 8 \text{ V} \rightarrow$ diode D_1 will be off and diode D_2 will be on

and

$$V_o = 8 \text{ V}$$

For $5 < V_i < 8 \text{ V} \rightarrow$ both the diodes will be off

and

$$V_o = V_i$$

Given that

$$V_i = 10 \sin \omega t$$

or

$$V_i = 10 \sin \theta$$

$$(\omega t = \theta)$$

For $V_i < 5$;

$$10 \sin \theta < 5 \Rightarrow 0 < \theta < 30^\circ \text{ and } 150^\circ < \theta < 360^\circ$$

$$V_o = 5 \text{ V}$$

For $V_i > 8 \text{ V}$;

$$10 \sin \theta > 8 \Rightarrow 53.13^\circ < \theta < 126.869^\circ$$

$$V_o = 8 \text{ V}$$

For $5 < V_i < 8 \text{ V}$;

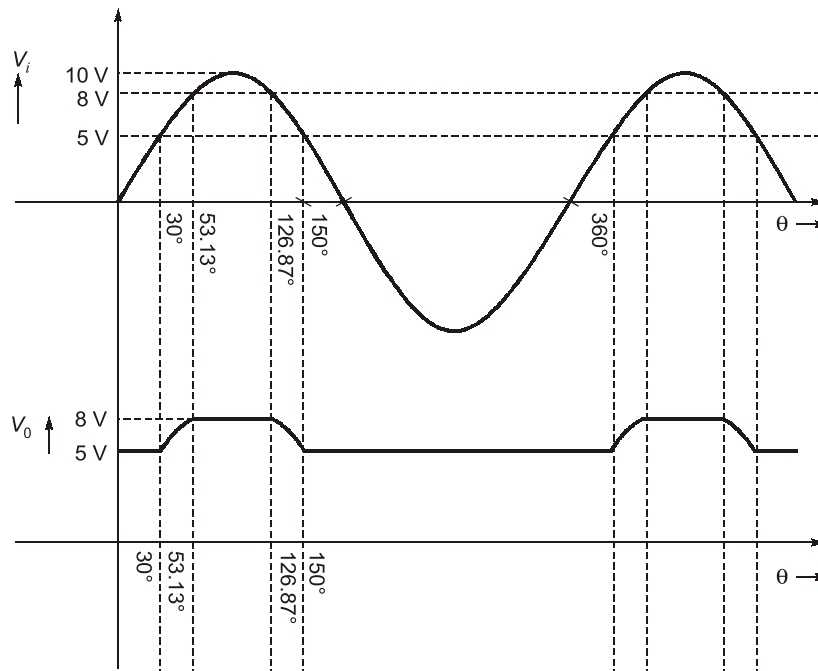
$$30^\circ < \theta < 53.13^\circ \text{ and } 126.87^\circ < \theta < 150^\circ$$

$$V_o = V_i$$

The required voltage-current characteristics can be written as

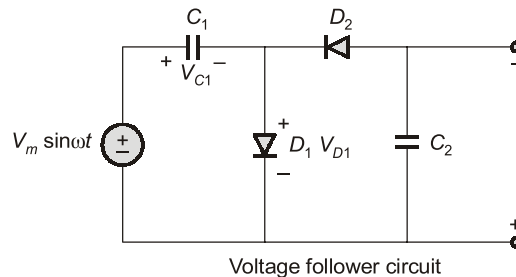
$$V_o = \begin{cases} 5 \text{ V} & ; V_i < 5 \text{ V} \\ V_i & ; 5 \text{ V} < V_i < 8 \text{ V} \\ 8 \text{ V} & ; V_i > 8 \text{ V} \end{cases}$$

Now output waveform will be



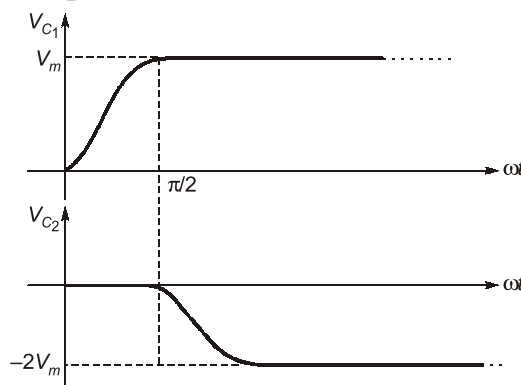
Q8 Draw the neat circuit of a voltage doubler. Explain its operation. Draw the waveforms for the voltages across the two capacitors.

Solution:



Voltage follower circuit

The figure shows a circuit-composed of two sections in cascade, a clamp circuit formed by C_1 and D_1 and peak rectifier formed by D_2 and C_2 .



When excited by a sinusoidal of amplitude V_m the clamping section provides the waveform shown. Assuming ideal diodes, while the positive peaks are damped to 0 V, the negative peak reaches $-2V_m$. In response to this wave form, the peak-detector section provides, across capacitor C_2 a negative dc voltage of magnitude $2V_m$. Because the output voltage is double the input peak, the circuit is known as a voltage doubler.

Q9 For the circuit shown in the figure (a), the input voltage waveform V_i is shown in figure (b). Assume that the RC time constant is large and the cut-in voltage of diode $V_y = 0$ V. Determine the output voltage waveform.

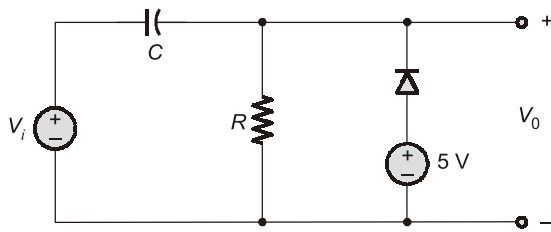


Fig. (a)

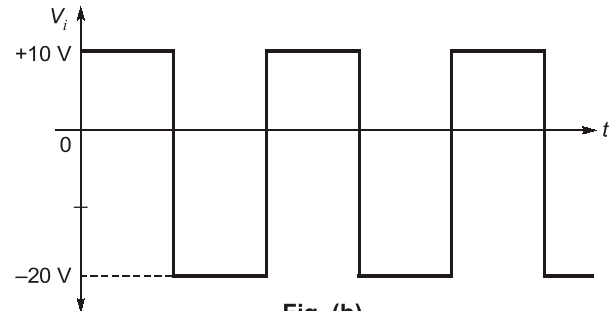
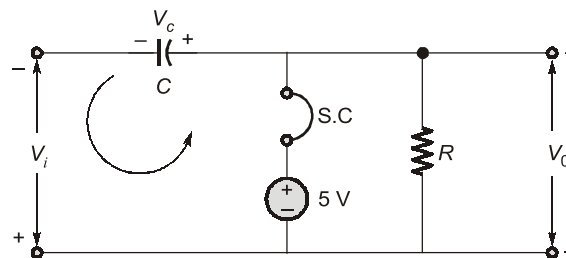


Fig. (b)

Solution:

Considering first the negative half cycle of the input signal V_i , the diode will be forward biased and acts as a short-circuit. The equivalent circuit can be drawn as:



The capacitor charges and the voltage across the capacitor can be calculated using KVL as below:

$$-V_i - 5 + V_c = 0$$

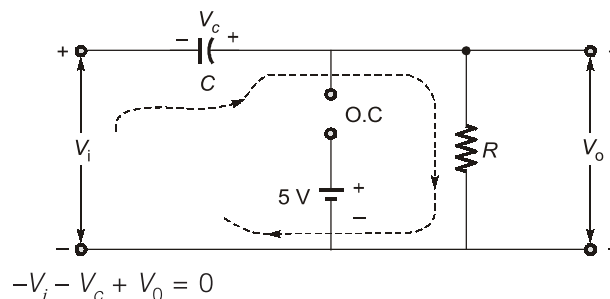
or $V_c = V_i + 5 \quad \text{or} \quad V_c = 20 + 5$

$\therefore V_c = 25 \text{ volt}$

During this period, diode is short circuited, hence battery voltage (+5 V) appears across the output,

$$V_o = 5 \text{ V}$$

Now, we have to consider the positive half cycle of the input voltage where the diode 'D' is reversed biased and so it acts as open circuit. The capacitor voltage ' V_c ' (due to charging in the previous negative half cycle duration) comes in the series as shown in the circuit given below:



$$-V_i - V_c + V_o = 0$$

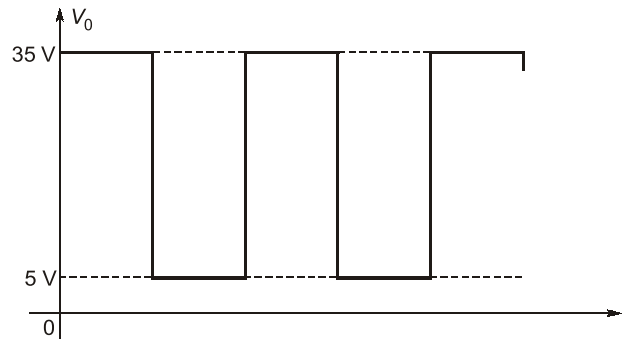
or $V_o = V_i + V_c \quad \text{or} \quad V_o = 10 + 25$

$\therefore V_o = 35 \text{ V}$

Since the time constant RC is very large, the capacitor voltage negligibly discharges through R and the capacitor voltage can be treated as constant at $V_c = 25$ V. The diode, therefore, remains reverse-biased during both positive and negative input cycle.

Hence, $V_o = V_i + V_c = V_i + 25$

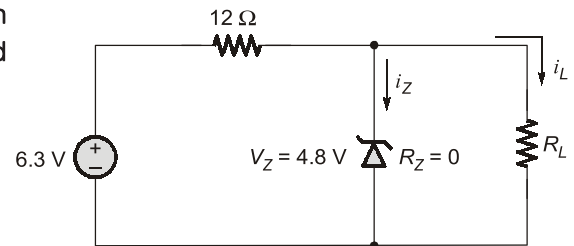
So, the output waveform (V_o) is shown below:



Q.10 In the Zener diode voltage regulator circuit as shown in the figure below, the Zener diode current is to be limited to the range, $5 \leq i_Z \leq 100$ mA.

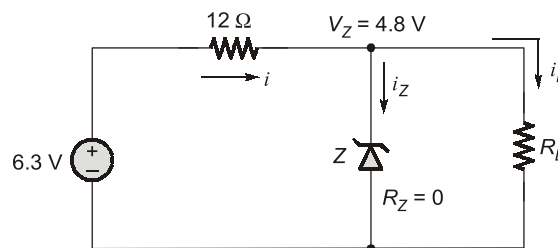
Determine:

- the range of the possible load currents.
- the range of the possible load resistances.
- power rating required for the load resistor.



Solution:

(a)



The total current (i) = $i_Z + i_L$

$$\text{or} \quad \frac{6.3 - 4.8}{12} = i_Z + i_L$$

$$\text{or} \quad i_Z + i_L = 0.125 \text{ A} \approx 125 \text{ mA} \quad \dots(i)$$

$$\text{Also,} \quad i_L = (125 - i_Z) \text{ mA} \quad \dots(ii)$$

As we are given that, the Zener diode current varies as,

$$5 \leq i_Z \leq 100 \text{ mA}$$

$$\Rightarrow 5 \leq (125 - i_L) \leq 100 \text{ mA}$$

$$\Rightarrow 5 - 125 \leq -i_L \leq (100 - 125) \text{ mA}$$

$$\Rightarrow -120 \leq -i_L \leq -25 \text{ mA}$$

$$120 \geq i_L \geq 25 \text{ mA}$$

So, the possible range of the load current ' i_L ' is as, $25 \leq i_L \leq 120$ mA

(b) Load current (i_L) = V_Z / R_L

$$\Rightarrow R_L = \frac{V_Z}{i_L} = \frac{4.8 \text{ V}}{i_L}$$

when, $i_L = 25$ mA then,

$$R_L = \frac{4.8}{25} = 192 \Omega$$

and when $i_L = 120 \text{ mA}$ then,

$$R_L = \frac{4.8}{120} = 40 \Omega$$

So, the range of the possible load resistance (R_L) is given as,

$$40 \leq R_L \leq 192 \Omega$$

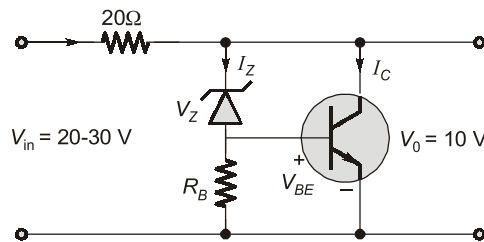
(c) Power rating required for the load resistor is given as,

$$P_{Zm} = i_{L \max} \times V_Z = 120 \text{ mA} \times 4.8 \text{ V}$$

\therefore

$$P_{Zm} = 576 \text{ mWatt}$$

Q.11 The transistor shunt regulator shown in the figure has a regulated output voltage of 10 V, when the input varies from 20 V to 30 V. The relevant parameters for the Zener diode and the transistor are: $V_Z = 9.5$, $V_{BE} = 0.5 \text{ V}$, $\beta = 99$. Neglect the current through R_B . Find the maximum power dissipated in the Zener diode (P_Z) and the transistor (P_T).



Solution:

$$I_{1 \max} = \frac{V_{in \max} - V_0}{20}$$

$$I_{1 \max} = \frac{30 - 10}{20} = 1 \text{ A}$$

$$I_E = I_B + I_C$$

$$I_E = I_C + I_Z$$

$$[\because I_B = I_Z \text{ (as no current flows in } R_B)]$$

...(i)

$$\beta = \frac{I_C}{I_B} = \frac{I_C}{I_Z}$$

\Rightarrow

$$I_C = \beta I_Z$$

From (i), $I_E = \beta I_Z + I_Z = (99 + 1) I_Z$

$$I_E = 100 I_Z$$

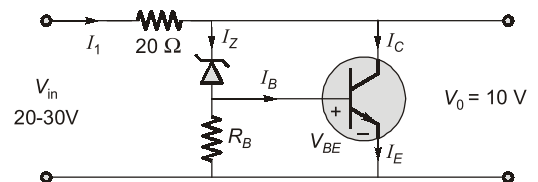
$$I_1 = I_E = 100 I_Z$$

$$I_Z = \frac{I_1}{100} = \frac{1}{100} = 0.01 \text{ A}$$

$$P_Z = V_Z I_Z = 9.5 \times 0.01 = 95 \text{ mW}$$

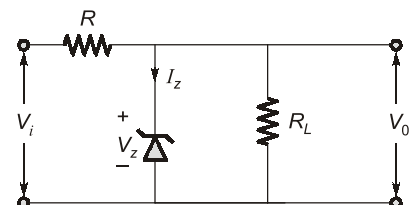
$$I_C = 99 I_Z = 99 \times 0.01 = 0.99 \text{ A}$$

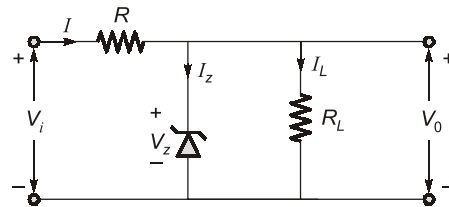
$$P_C = V_{CE} I_C = 10 \times 0.99 = 9.9 \text{ W}$$



Q.12 Answer the following with respect to the circuit shown:

- Why is it called a 'shunt regulator'?
- Which is the regulating element?
- Draw the v - i characteristic of the regulating element.
- Mark the portion of the curve used for regulation.
- Show the range of current over which regulator will operate satisfactorily.



Solution:

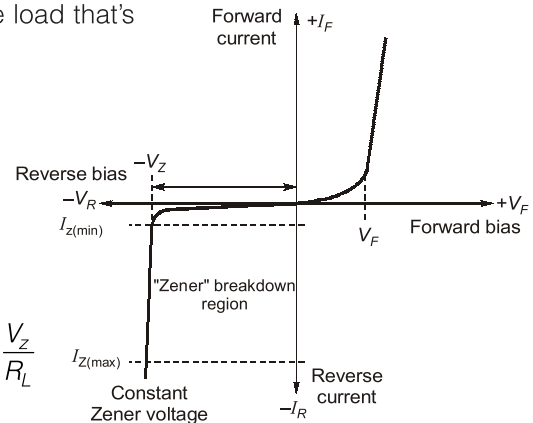
- The control element (Zener diode) is in parallel with the load that's why it is called a shunt regulator.
- The regulating element is Zener diode.
- For fixed values of R_L , the voltage V_i must be sufficiently large to turn the Zener diode on. The minimum turn-on voltage,

$$V_{i, \min} = \frac{(R + R_L)V_z}{R_L}$$

$$\therefore I_{\max} = I_z + I_L; \quad \text{where, } I_L = \frac{V_z}{R_L}$$

The maximum value of V_i

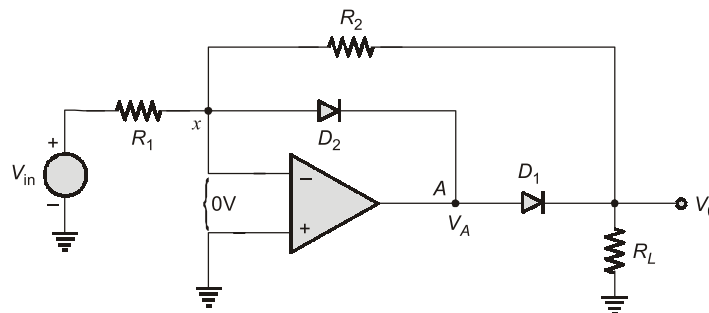
$$V_{i \max} = I_{\max} R + V_z$$



Q.13 Why do we use precision rectifiers? Draw the circuit diagram and explain the operation of an inverting half-wave precision rectifier.

Solution:

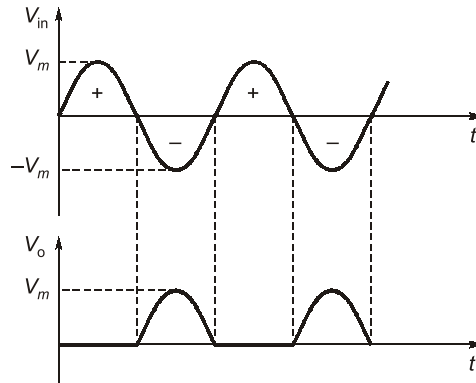
- The major limitation with the silicon rectifiers is that, it cannot rectify an AC signal (V_{in}), whose magnitude is less than the forward voltage drop of a diode (V_D), which is typically 0.7 V.
- To remove this defect, precision rectifiers are used. An inverting half wave precision rectifier utilizes two diodes D_1 and D_2 and one op-amp as shown in the figure below. Using the precision rectifier, voltages in mV range can be rectified.

**Case-1**

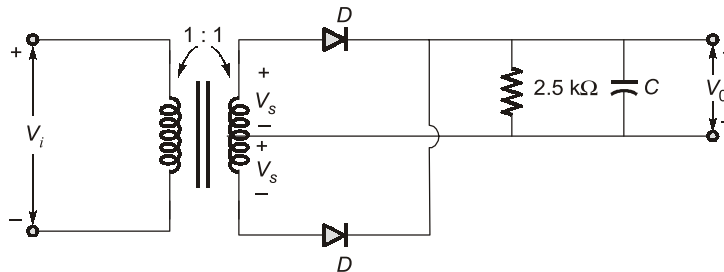
When V_{in} goes positive ($V_{in} > 0$) or during positive half cycle, the op-amp's output (V_A) becomes negative, which turns ON diode and as a result the negative feedback is established. As the non-inverting terminal of op-amp is at ground, the node (x) is virtual ground, therefore V_A is clamped at $-V_{D_2}$. As a result diode D_1 does not conduct and no current flows in the feedback resistor R_2 , and so causes the rectifier output zero ($V_{out} = 0$). Thus when $V_{in} > 0$, $V_{out} = 0$.

Case-2

When $V_{in} < 0$ or during negative half cycle, the op-amp's output (V_A) becomes positive causing diode D_2 to turn OFF and diode D_1 is turned ON. The circuit behaves as an inverting amplifier. If $R_2 = R_1$ then $V_{out} = -V_{in}$ or V_{out} is out of phase with input. For a pure sinusoidal input the resulting output is shown below:



Q.14 Consider a Full Wave Rectifier (FWR) circuit shown below:



If $V_i = 120 \sin(2\pi 60)t$, the diode cut-in voltage is 0.7 V and the output voltage cannot be dropped below 100 volt. Then calculate the required value of the capacitor 'C'?

Solution:

For a Full Wave Rectifier, it has been given that,

$$V_i = V_s = 120 \sin(2\pi 60)t \quad \dots(i)$$

Here,

$$V_{i, \max} = 120 \text{ volt}$$

and

$$\text{frequency } (f) = 60 \text{ Hz}$$

We also know that in a FWR,

Frequency of output voltage, $f_{\text{out}} = 2f$; So time period of rectified V_o

$$T_1 = T_2 = \frac{T}{2} = \frac{1}{2f}$$

where, 'T' is the time period and the ripple voltage (V_{rip}) is related with peak voltage (V_p) as,

$$V_{\text{rip}} \approx V_p \cdot \frac{T_1}{CR}$$

\Rightarrow

$$V_{\text{rip}} \approx \frac{V_p}{2fRC} \quad \dots(ii)$$

we know that,

$$\text{Peak voltage across capacitor } (V_p) = (V_{\text{imax}} - V_f)$$

$$\therefore V_p = (120 - 0.7) = 119.3 \text{ V}$$

and the ripple voltage (V_{rip}) may be defined as,

$$V_{\text{rip}} = (V_p - 100) = (119.3 - 100) \text{ V}$$

$$\therefore V_{\text{rip}} = 19.3 \text{ volt}$$

Now from equation (ii) we obtained the value of 'C' by putting the values of V_p , V_{rip} , R and f as,

$$19.3 = \frac{119.3}{2 \times 60 \times 2.5 \times 10^3 \times C}$$

$$C = \frac{119.3}{5 \times 60 \times 10^3 \times 19.3} = 20.6 \mu\text{F}$$