POSTAL Book Package 2023

ESE

Electronics Engineering

Conventional Practice Sets

Analog Circuits

Contents

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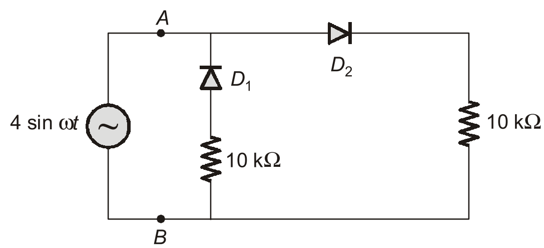
1 CHAPTER
Diode Circuits

Q.1 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.)

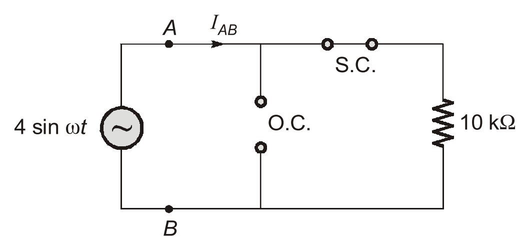
D_2 – on (F.B.)

∴ Equivalent circuit will be

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

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

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



For –ve half cycle,

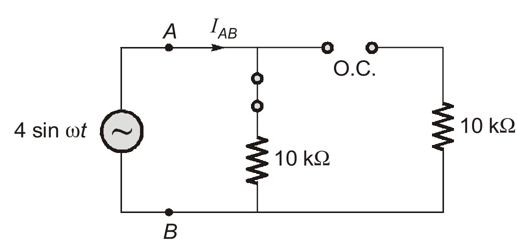
D_1 on, D_2 off

Equivalent circuit,

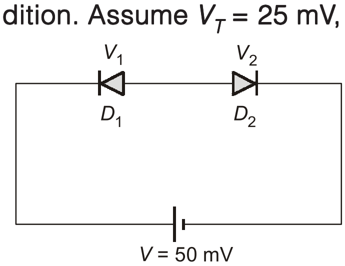
$$V_{AB} = 4 \sin\omega t$$

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

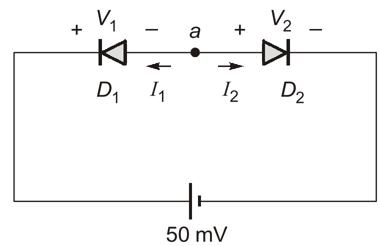
$$\therefore \quad \frac{V_{AB}}{I_{AB}} = R_i = 10\,\text{k}\Omega$$



Q.2 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 $V_T = 25$ mV, $V_\gamma = 0.7$ 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*'
$$I_1 + I_2 = 0$$
$$I_1 = -I_2$$
$$I_S\left(e^{-\frac{V_1}{\eta V_T}} - 1\right) = -I_S\left(e^{\frac{+V_2}{\eta V_T}} - 1\right)$$
$$e^{-\frac{V_1}{\eta V_T}} + e^{\frac{V_2}{\eta V_T}} = 2$$

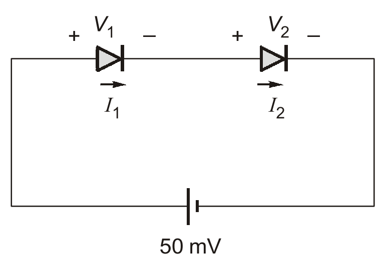
Also,
$$V_2 = 50 - V_1$$

$\therefore$
$$e^{-\frac{V_1}{\eta V_T}} + e^{\frac{50 - V_1}{\eta V_T}} = 2$$
$$e^{-\frac{V_1}{\eta V_T}}\left[1 + e^{\frac{50}{\eta V_T}}\right] = 2$$
$$e^{-\frac{V_1}{V_T}} = \frac{2}{1+e^2} \qquad (\eta = 1,\ V_T = 25\text{ mV})$$
$$e^{-\frac{V_1}{V_T}} = \frac{2}{3.39} = 0.24$$

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.



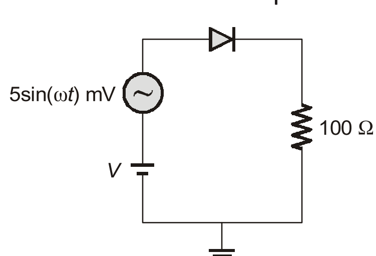
As both diodes are ideal and identical hence voltage drop across both diodes will be same.

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

Now,
$$I_1 = I_2 = I_s\left(e^{\frac{V_1}{V_T}} - 1\right) = I_s\left(e^{\frac{25}{25}} - 1\right) = 1.72\, I_s$$
$$\frac{I_1}{I_0} = \frac{1.72\, I_s}{0.76\, I_s} = 2.26$$

$\therefore$
$$I_1 = 2.26 I_0$$

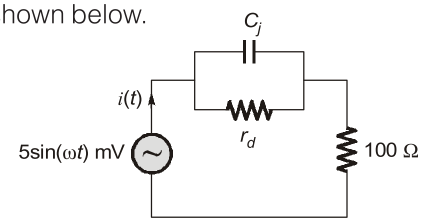
Q3 A DC current of 26 μA flows through the circuit shown. The diode in the circuit is forward biased and it has an ideality factor of one. At the quiescent point, the diode has a junction capacitance of 0.5 nF. Its neutral region resistances can be neglected. Assume that the room temperature thermal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



For ω = 2 × 10^6 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, $r_d = \dfrac{\eta V_T}{I_{DC}} = \dfrac{26 \text{ mV}}{26\ \mu\text{A}} = 1\text{k}\Omega$

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

So, total impedance of the circuit will be,

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

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

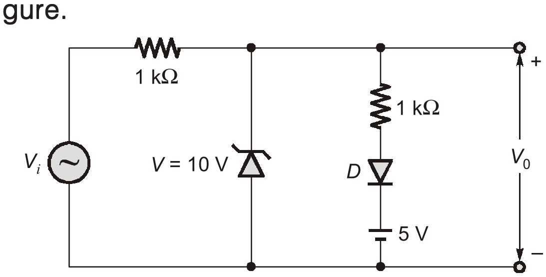
$\therefore$

$$Z = 600 - j500\ \Omega$$

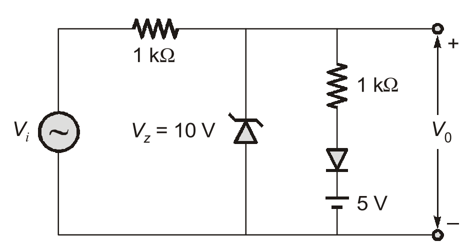
$$|Z| = 100\sqrt{36+25} = 100\sqrt{61}\ \Omega$$

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

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

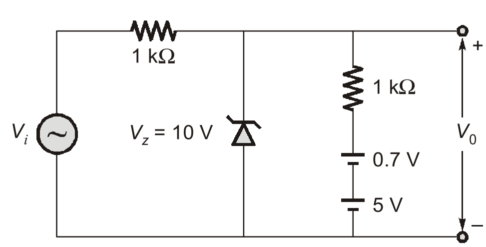


Solution:



When V_i is +ve and $V_i > 5.7$ 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, $V_i < 5.7$ 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, $V_i > 14.3$ V

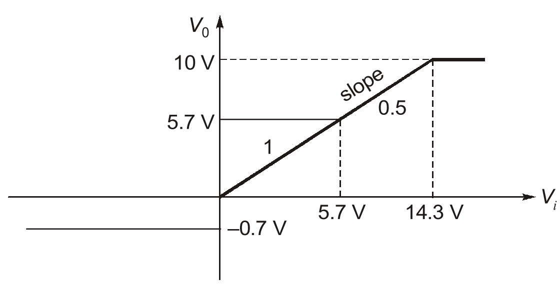
$\Rightarrow$ $V_0 = 10$ volts

Breakdown occurs in Zener diode.

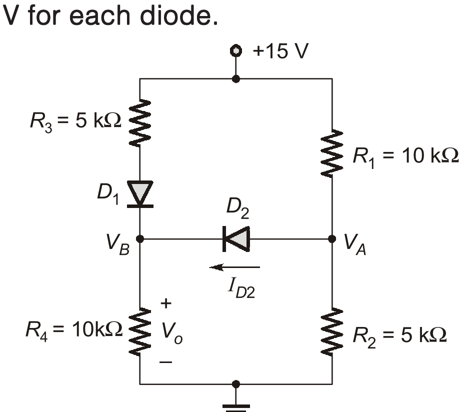
When, $V_i < 0$ V

$V_0 = -0.7$ V

Transfer characteristics:



Q.5 Determine the current I_{D2} and the voltage V_o in the multidiode circuit shown in the figure below. Assume that, cut-in voltage $V_\gamma = 0.7$ 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

$$\frac{15 - V_A}{10} = I_{D2} + \frac{V_A}{5} \quad \text{...(i)}$$

and $$\frac{15-(V_B+0.7)}{5}+I_{D2} = \frac{V_B}{10}$$ ...(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

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

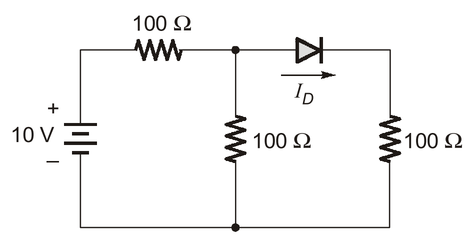
We assumed that D_2 was ON, so a negative current is inconsistent with that initial assumption.
Now assume that diode D_2 is OFF and D_1 is ON. To find the node voltages, we can simply use voltage divider principle as

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

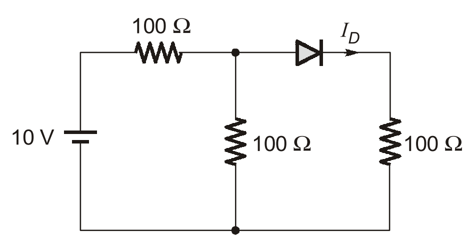
and $$V_B = V_o = \left(\frac{10}{10+5}\right)(15-0.7) = 9.53 \text{ V}$$

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

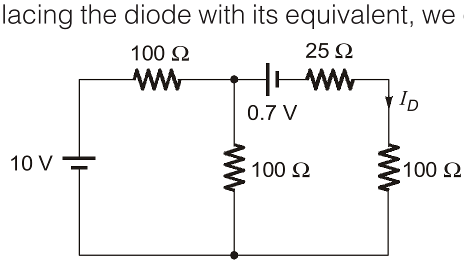
Q.6 Find the diode current I_D in the circuit shown below when the diode has cut in voltage, V_γ = 0.7 V and forward resistance, R_f = 25 Ω.

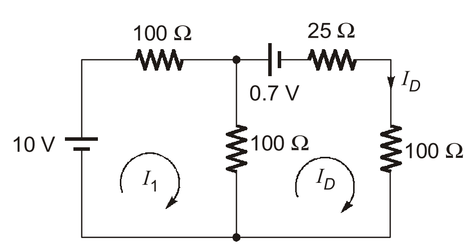


Solution:



Given : Diode cut-in voltage = 0.7 V and diode forward resistance = 25 Ω
Replacing the diode with its equivalent, we get,





Using KVL, $$10-100I_1-100(I_1-I_D) = 0$$ ...(i)

$$-0.7-125I_D+100(I_1-I_D) = 0$$ ...(ii)

Solving equation (i) and (ii)

$$10-200I_1-100I_D = 0$$ ...(iii)

$$-0.7-225I_D+100I_1 = 0$$ ...(iv)

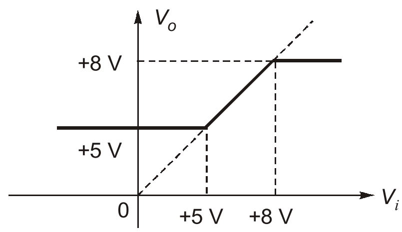
Multiplying equation (iv) by 2 and adding, we get

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

$$8.6 = 550I_D$$

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

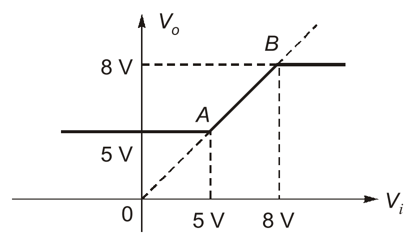
Q.7 The ideal transfer characteristic of a particular circuit is given in figure. Design the circuit. Draw the output waveform with proper explanation, if $V_i = 10 \sin \omega t$.



Solution:

Slope of the curve between A and B is

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

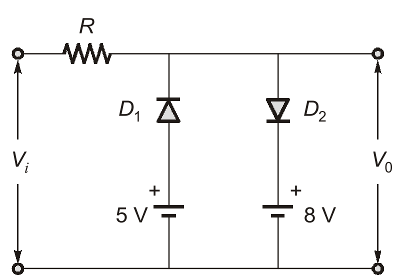


The circuit diagram for the above input-output (transfer) characteristic is a two-level clipper as shown below.

Cut in voltages of diodes are zero.

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

and $\boxed{V_0 = 5 \text{ V}}$



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

and $\boxed{V_0 = 8 \text{ V}}$

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

and $\boxed{V_0 = V_i}$

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

or $V_i = 10 \sin\theta$ $\quad (\omega t = \theta)$

For $V_i < 5$; $\quad 10\sin\theta < 5 \Rightarrow 0 < \theta < 30°$ and $150° < \theta < 360°$

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

For $V_i > 8$ V; $\quad 10\sin\theta > 8 \Rightarrow 53.13° < \theta < 126.869°$

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

For $5 < V_i < 8$ V; $\quad 30° < \theta < 53.13°$ and $126.87° < \theta < 150°$

$$V_o = V_i$$

The required voltage-current characteristics can be written as

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