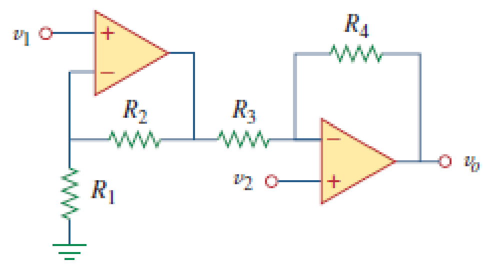
Q 1 Figure displays a two-op-amp instrumentation amplifier. Derive an expression for vo in terms of v1 and v2. How can this amplifier be used as a subtractor?



Solution

The output, v_a, of the first op amp is,

$$v_a = (1 + (R_2/R_1))v_1 \qquad (1)$$

Also, $$v_o = (-R_4/R_3)v_a + (1 + (R_4/R_3))v_2 \qquad (2)$$

Substituting (1) into (2),

$$v_o = (-R_4/R_3)\,(1 + (R_2/R_1))v_1 + (1 + (R_4/R_3))v_2$$

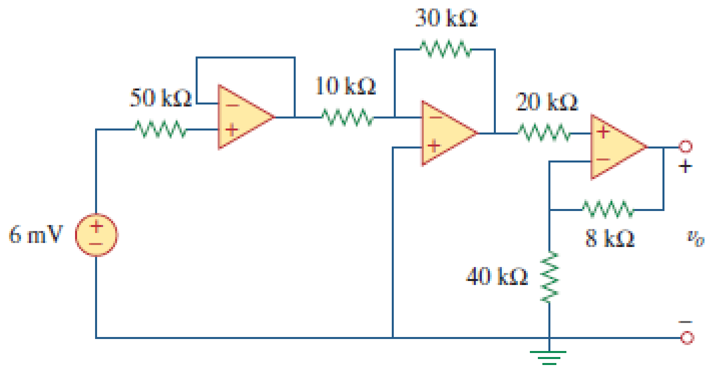
Or, $$v_o = (1 + (R_4/R_3))v_2 - (R_4/R_3 + (R_2R_4/R_1R_3))v_1$$

If $R_4 = R_1$ and $R_3 = R_2$, then,

$$v_o = (1 + (R_4/R_3))(v_2 - v_1)$$

which is a subtractor with a gain of $(1 + (R_4/R_3))$.

Q2 Find vo in the op-amp circuit shown below.



Solution

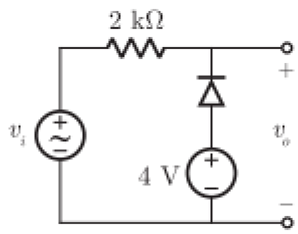
The output of the first op amp (to the left) is 6 mV. The second op amp is an inverter so that its output is

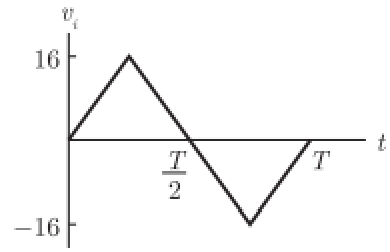
$$v_o' = -\frac{30}{10}(6\text{mV}) = \text{-}18\,\text{mV}$$

The third op amp is a noninverter so that

$$v_o' = \frac{40}{40+8}v_o \longrightarrow v_o = \frac{48}{40}v_o' = \underline{-21.6\,\text{mV}}$$

Q 3 Waveform for input signal and a circuit is shown below





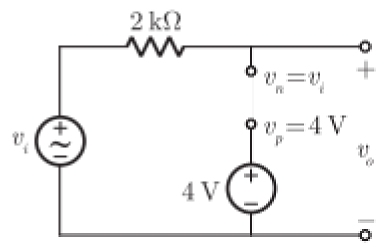
Explain the working of circuit and draw the output waveform

Solution

For the given circuit, we first determine the linear region (forward bias or reverse bias) in which the diode is operating, and then obtain the output.

Step 1: Assume that the diode is OFF, and replace it by open circuit.

So, equivalent circuit is,



Step 2: The voltage across the diode terminal is obtained as

$$v_p = 4 \text{ V} \qquad \text{at the } p\text{-terminal}$$
$$V_n = v_i \qquad \text{at the } n\text{- terminal}$$

Step 3: Now, we have the condition

$$v_p > v_n \qquad \text{diode is ON}$$
$$v_p < v_n \qquad \text{diode is OFF}$$

Applying these conditions, we determine the output voltage.

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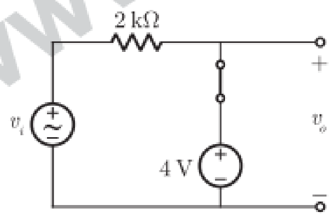
CASE I:

If $v_i < 4$ V, then diode is ON. So the equivalent circuit is

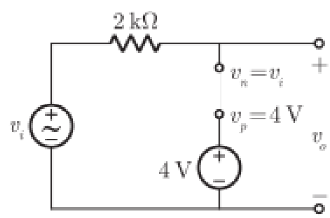


So, the output voltage is,

$$v_o = 4\text{ V}$$

CASE II:

If $v_i > 4$ V, then diode is OFF. So equivalent circuit is

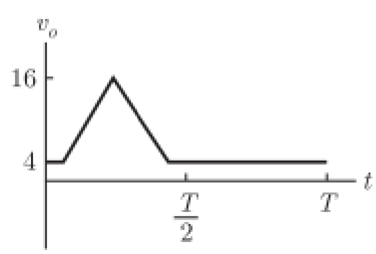


So, the output voltage is,

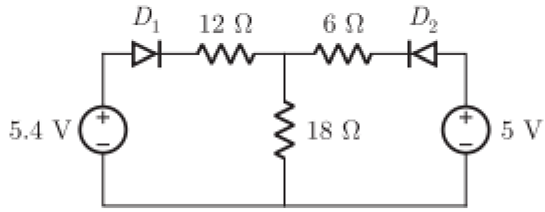
$$v_o = v_i$$

Step 4: From the two results obtained in the above steps, we sketch the

output waveform as shown below.



Q 4 In the circuit shown below diodes has cutin voltage of 0.6 V. Identify the diode/s which is in/are ON state. Explain it clearly

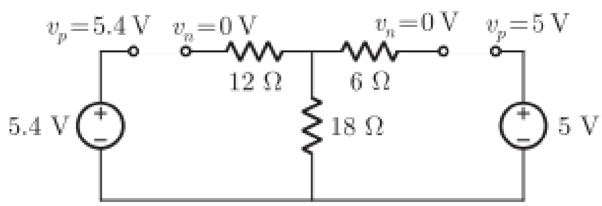


Solution

For the given circuit, we determine the linear region (forward bias or reverse bias) in which the two diodes are operating.

Step 1: Assume that the two diodes are OFF, and replace it by open circuit

So, the equivalent circuit is



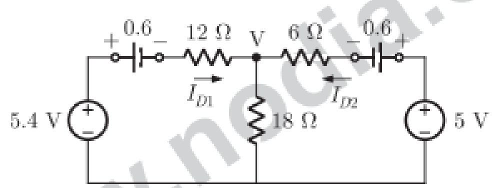
Step 2: Now, we have the condition for both the diodes

$$v_p > v_n \qquad \text{diode is ON}$$

$$v_p < v_n \qquad \text{diode is OFF}$$

Applying these conditions, we analyse the circuit.

Step 3: Both diodes are ON. So, the equivalent circuit is



Using Nodal analysis at Node 1,

$$\frac{V-4.8}{12} + \frac{V}{18} + \frac{V-4.4}{6} = 0$$

$$V = 3.71 \text{ V}$$

In this case, i_{D1} and i_{D2} are positive, so D_1 and D_2 are ON (assumption is correct).

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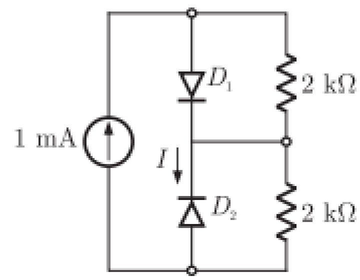
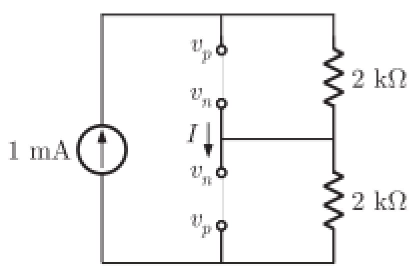
Q 5 Assuming both the diodes to be ideal determine the current I in the circuit shown below.



Solution

For the given circuit, we first determine the linear region (forward bias or reverse bias) in which the diodes are operating, and then obtain the output.

Step 1: Assume that the diodes are OFF, and replace it by open circuit. So, equivalent circuit is



Step 2: Now, we have the condition

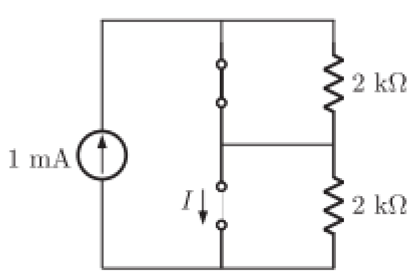
$$v_p > v_n \qquad \text{diode is ON}$$
$$v_p < v_n \qquad \text{diode is OFF}$$

Checking the given circuit for the conditions,

Diode $D_1 \rightarrow v_{pn} = 2 = +$ ve. So D_1 is ON.

Diode $D_2 \rightarrow v_{pn} = -2 = -$ ve. So D_2 is OFF.

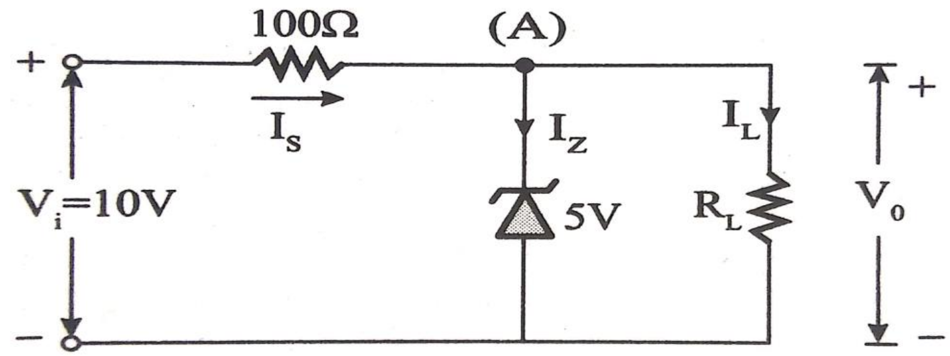
Step 3: Thus, for the obtained result, we draw the equivalent circuit as



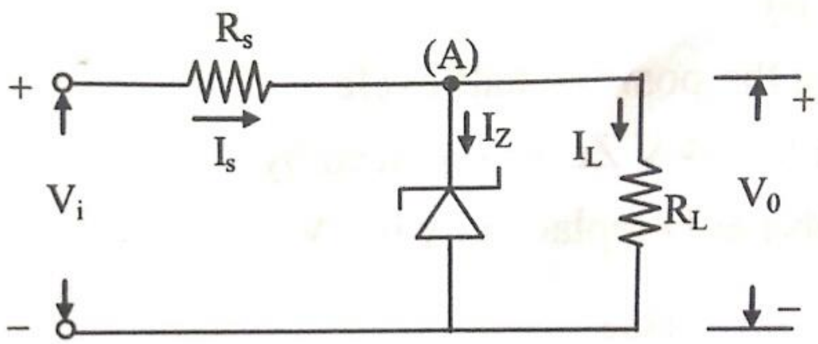
Step 4: From the equivalent circuit, we get

$$I = 0$$

Q-6 In the circuit given below the 5V zener diode requires a minimum current of 10 mA. For obtaining a regulated output of 5V,find the maximum permissible load current (I_L) and the minimum power rating of Zener diode.



Sol:



Step 1:

$$I_S = \frac{V_i - V_z}{R_s} = \frac{10-5}{100} = 50mA \qquad \text{.................... (1)}$$

Step 2:

KCL at (A)

$$I_s = I_{zk} + I_{L\,max} \qquad \text{.................. (2)}$$

$$\therefore I_{L\,max} = I_S - I_{ZK} = 50 - 10 = 40 \text{ mA} \qquad \text{................ (3)}$$

Step 3:

When R_L is open $\Rightarrow$ $I_L = 0$

$$\Rightarrow \qquad I_{Z\,max} = I_s \qquad \text{....................(4)}$$

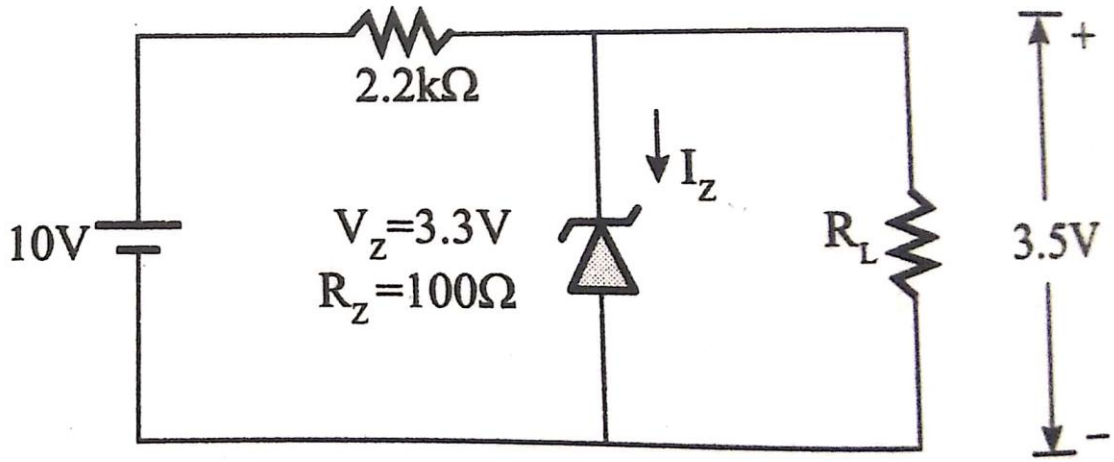
$$\therefore \qquad P_{Z\,min} = V_Z I_{Z\,max} = 5\text{ V} \times I_{Z\,max}$$

$$= 5 \times 50 \text{ mA}$$

$$= 250 \text{ mW}$$

$$P_{Z\,min} = 0.25 \text{ W}$$

Q-7 Find the current through the zener diode in the circuit given below.



Sol: Given that $V_0 = 3.5$ V

$V_Z = 3.3$ V

Then zener offers $R_z = 0.1$ kΩ of dynamic resistance.

So $V_z = I_z R_z = 3.5$

$$I_z = \left(\frac{3.5 - 3.3}{R_z}\right) = 2 \text{ mA}$$

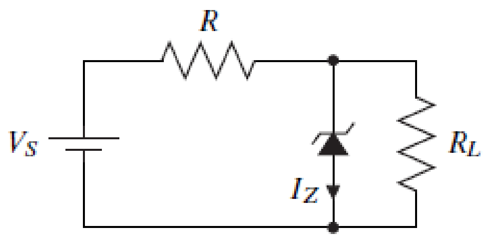
Q-8

The Zener diode in the circuit shown has a working range of current for proper regulation:

$$5\,\text{mA} \leq I_z \leq 50\,\text{mA}$$

and a Zener voltage

$$V_z = 50\,\text{V}.$$



(a) If the input voltage, V_s, varies from 150 and 250 V and $R_L = 2.2\,\text{k}\Omega$, determine the range of values for the resistor, R, to maintain regulation.

(b) If R is chosen as the midpoint of the range determined in part (a), how much variation in the load resistance, R_L, is now possible without losing regulation?

Solution:

(a) The current through the load is given by:

$$I_L = \frac{50\ V}{2.2\ \mathrm{k\Omega}} = 22.74\ \mathrm{mA}.$$

The current through the resistor R must lie in the range of the load current plus the diode current:

$$5\ \mathrm{mA} + 22.74\ \mathrm{mA} \leq I \leq 50\ \mathrm{mA} + 22.74\ \mathrm{mA}$$
$$27.74\ \mathrm{mA} \leq I \leq 72.74\ \mathrm{mA}$$

but this current is also dependent on the source voltage, the Zener voltage, and the resistance R:

$$I = \frac{V_s - V_z}{R} = \frac{V_s - 50}{R}$$

or

$$R = \frac{V_s - 50}{I}.$$

Since regulation must occur for both extremes of the source voltage, R must be the intersection of the limits determined by the above equation:

$$\frac{V_{s(\min)} - 50}{I_{(\max)}} \leq R \leq \frac{V_{s(\min)} - 50}{I_{(\min)}} \quad \& \quad \frac{V_{s(\max)} - 50}{I_{(\max)}} \leq R \leq \frac{V_{s(\max)} - 50}{I_{(\min)}}$$

or, after applying the intersection of the ranges:

$$\frac{V_{s(\max)} - 50}{I_{(\max)}} \leq R \leq \frac{V_{s(\min)} - 50}{I_{(\min)}}$$
$$\frac{250 - 50}{72.74} \leq R \leq \frac{150 - 50}{27.74} \quad \Rightarrow \quad 2.75\ \mathrm{k\Omega} \leq R \leq 3.60\ \mathrm{k\Omega}.$$

(b) The midpoint of the above range is $R = 3.175\ \mathrm{k\Omega}$.

The resistor current is given by:

$$I = \frac{V_s - 50}{R} \quad \Rightarrow \quad 31.5\ \mathrm{mA} \leq I \leq 63\ \mathrm{mA}.$$

Since regulation must hold for all values of R, the load current must lie in the intersection of the possible ranges of the resistor current minus the diode current:

$$31.5 - 50\ \mathrm{mA} \leq I_L \leq 31.5 - 5\ \mathrm{mA} \quad \& \quad 63 - 50\ \mathrm{mA} \leq I_L \leq 63 - 5\ \mathrm{mA}$$

thus,

$$13\ \mathrm{mA} \leq I_L \leq 26.5\ \mathrm{mA}.$$

Since

$$R_L = \frac{V_Z}{I_L},$$

the range of R_L is found to be

$$3.85\ \mathrm{k\Omega} \geq R_L \geq 1.93\ \mathrm{k\Omega}.$$