Lec (06)

Electronic Fundamentals

Circuits, Devices, and Applications

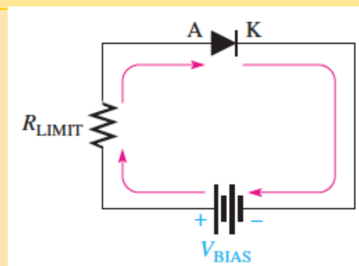
Diodes and Applications

Revision (01)

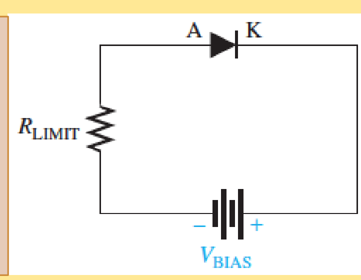
1

Summary of Diode

- The bias voltage must be greater than the barrier potential.
- Barrier potential: 0.7 V for silicon.
- Majority carriers provide the forward current.
- The depletion region narrows.



- The bias voltage must be less than the breakdown voltage.
- There is no majority carrier current after transition time.
- Minority carriers provide a negligibly small reverse current.
- The depletion region widens.



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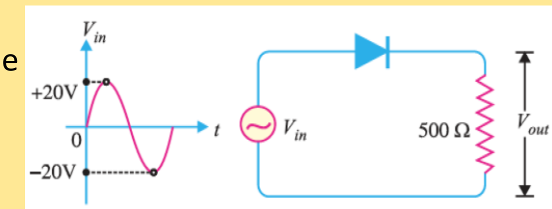
Example 1

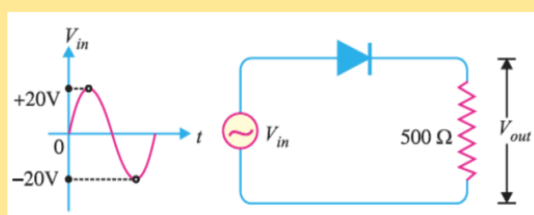
An ac voltage of peak value 20 V is connected in series with a silicon diode and load resistance of 500 Ω. If the forward resistance of the diode is 10 Ω, find:

- (a) peak current through the diode
- (b) peak output voltage.



What will be these values if the diode is considered as an ideal diode?

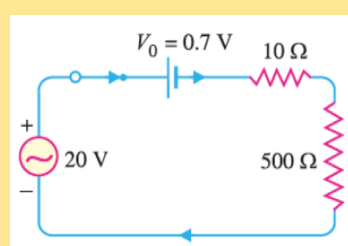
Solution. The diode will conduct during the positive half-cycles of ac input voltage. The equivalent circuit is



(a) peak current through the diode

$V_F = V_{PB} + (I_f)_{peak}\,[r_f + R_L]$

$(I_f)_{peak} = \frac{V_F - V_{PB}}{r_f + R_L} = \frac{20-0.7}{10+500} = 37.8\text{ mA}$



(b) peak output voltage

$V_{out} = (I_f)_{peak} \times R_L = 37.8\times10^{-3}\text{A} \times 500\ \Omega = 18.9\text{ V}$

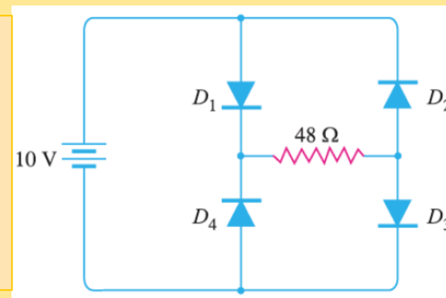
For an ideal diode $V_{PB} = 0$ and $r_f = 0$

$(I_f)_{peak} = \frac{V_F}{R_L} = \frac{20}{500} = 40\text{ mA}$ & $V_{out} = (I_f)_{peak} \times R_L = 40\times10^{-3}\text{ A} \times 500\ \Omega = 20\text{ V}$

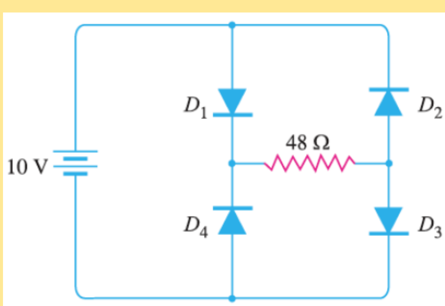
Example 2

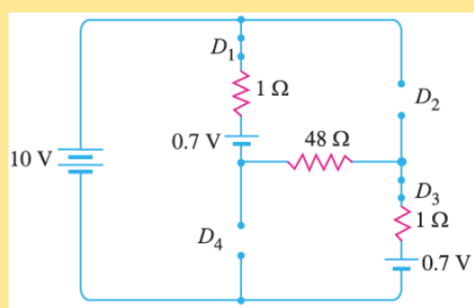
Calculate the current through 48 Ω resistor in the circuit shown in the Figure (i). Assume the diodes to be of silicon and forward resistance of each diode is 1 Ω.

Diodes D_1 and D_3 are forward biased while diodes D_2 and D_4 are reverse biased. We can, therefore, consider the branches containing diodes D_2 and D_4 as "open".
Replacing diodes D_1 and D_3 by their equivalent circuits and making the branches containing diodes D_2 and D_4 open,



We get the circuit shown in the Figure. Note that for a silicon diode, the barrier voltage is 0.7 V.

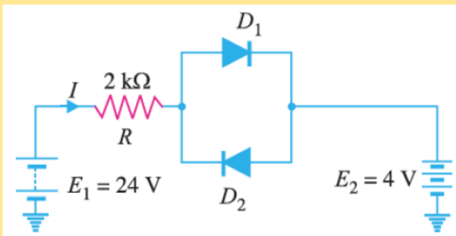


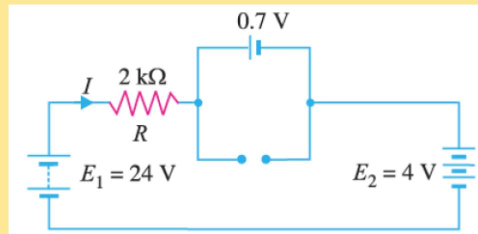


Net circuit voltage = 10 − 0.7 − 0.7 = 8.6 V
Total circuit resistance = 1 + 48 + 1 = 50 Ω
Circuit current = 8.6/50 = 0.172 A = **172 mA**

Example 3

Determine the current I in the circuit shown in the Figure. Assume the diodes to be of silicon and forward resistance of diodes to be zero.

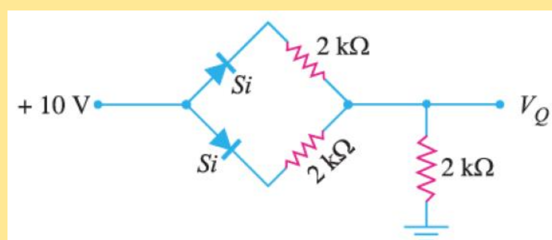




Solution. The conditions of the problem suggest that diode D_1 is forward biased and diode D_2 is reverse biased. We can, therefore, consider the branch containing diode D_2 as open. Further, diode D_1 can be replaced by its simplified equivalent circuit.

$$I = \frac{E_1 - E_2 - V_0}{R} = \frac{24 - 4 - 0.7}{2\ \text{k}\Omega} = \frac{19.3\ \text{V}}{2\ \text{k}\Omega} = \mathbf{9.65\ mA}$$

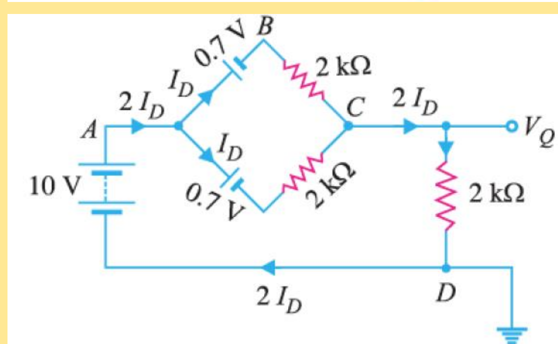
Example 4



Find V_Q and I_D in the network shown. Use practical model.

Solution. By symmetry, current in each branch is I_D so that current in branch *CD* is $2I_D$.

Applying Kirchhoff's voltage law to the closed circuit *ABCDA*, we have,



$$-0.7 - I_D \times 2 - 2\,I_D \times 2 + 10 = 0$$

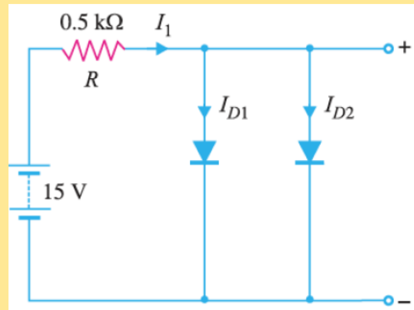
$$6\,I_D = 9.3$$

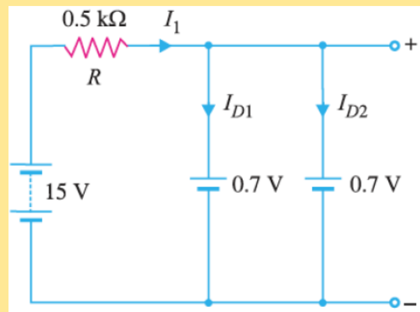
$$I_D = \frac{9.3}{6} = \mathbf{1.55\ mA}$$

$$V_Q = (2\,I_D) \times 2\ \text{k}\Omega = (2 \times 1.55\ \text{mA}) \times 2\ \text{k}\Omega = \mathbf{6.2\ V}$$

Example 5

Determine current through each diode in the circuit shown. Use practical model. Assume diodes to be similar.





Solution. The applied voltage forward biases each diode so that they conduct current in the same direction.

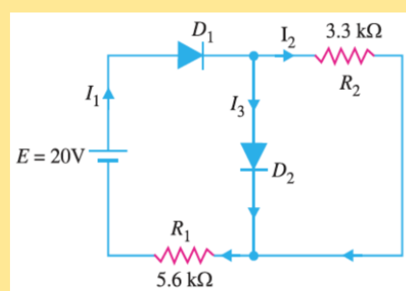
$$I_1 = \frac{\text{Voltage across } R}{R} = \frac{15 - 0.7}{0.5 \text{ k}\Omega} = 28.6 \text{ mA}$$

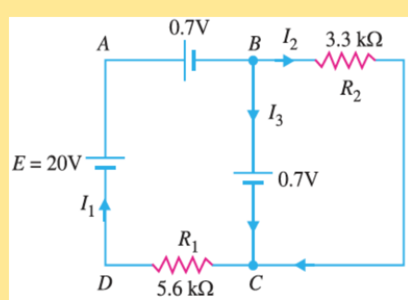
Since the diodes are similar

$$I_{D1} = I_{D2} = \frac{I_1}{2} = \frac{28.6}{2} = \mathbf{14.3\ mA}$$

Example 6

Determine the currents I_1, I_2 and I_3 for the network shown. Use practical model for the diodes.





Solution. An inspection of the circuit shown it shows that both diodes D_1 and D_2 are forward biased.

The voltage across R_2 (= 3.3 k Ω) is 0.7V.

$$\therefore \quad I_2 = \frac{0.7 \text{ V}}{3.3 \text{ k}\Omega} = \mathbf{0.212\ mA}$$

Applying Kirchhoff's voltage law to loop *ABCDA*, we have,

$$-0.7 - 0.7 - I_1 R_1 + 20 = 0$$

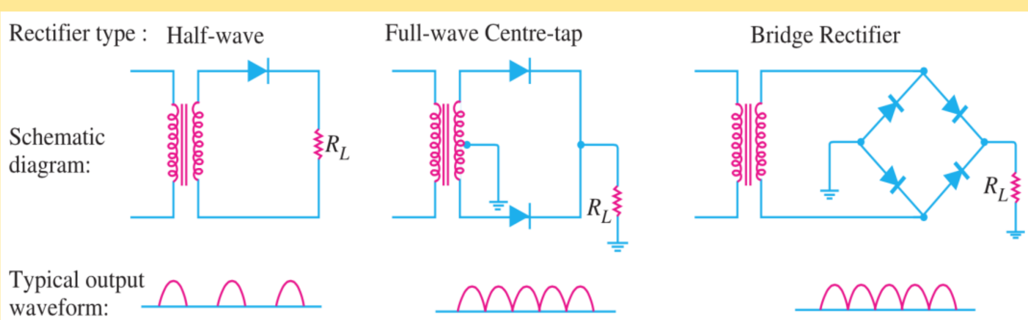
$$I_1 = \frac{20 - 0.7 - 0.7}{R_1} = \frac{18.6 \text{ V}}{5.6 \text{ k}\Omega} = \mathbf{3.32\ mA}$$

$$I_3 = I_1 - I_2 = 3.32 - 0.212 = \mathbf{3.108\ mA}$$

Diodes and Applications

Revision (02)

Summary of power supply rectifiers



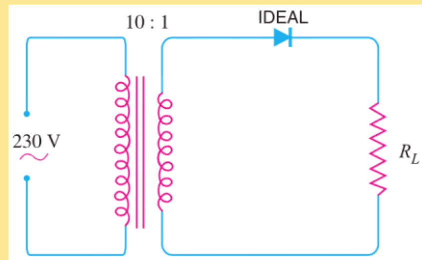
S. No.	Particulars	Half-wave	Centre-tap	Bridge type
1	No. of diodes	1	2	4
2	Transformer necessary	no	yes	no
3	Max. efficiency	40.6%	81.2%	81.2%
4	Ripple factor	1.21	0.48	0.48
5	Output frequency	f_{in}	$2 f_{in}$	$2 f_{in}$
6	Peak inverse voltage	V_m	$2 V_m$	V_m

Example 1

An ac supply of 230 V is applied to a half-wave rectifier circuit through a transformer of turn ratio 10:1. Assume the diode to be ideal. Find

(i) **the output dc voltage**

(ii) **the peak inverse voltage.**



Solution

Primary to secondary turns is $N_1/N_2 = 10$

rms of the primary voltage = 230 V

∴ Max primary voltage $V_{pm} = \sqrt{2} \times 230 = 325.3$ V

∴ Max secondary voltage $V_{sm} = V_{pm} \times (N_2/N_1) = 325.3 \times (1/10) = 32.53$ V

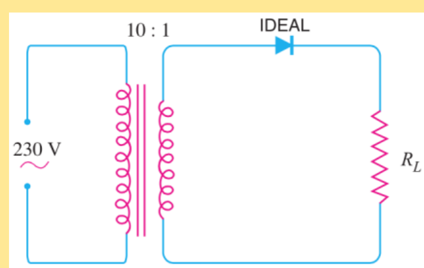
(i) the output dc voltage

$$I_{d.c.} = \frac{I_m}{\pi}$$

$$V_{dc} = \frac{I_m}{\pi} \times R_L$$

$$= \frac{V_{sm}}{\pi}$$

$$= \frac{32.53}{\pi} = 10.36 \text{ V}$$



(ii) the peak inverse voltage.

- The maximum secondary voltage appears across the diode.
- ∴ Peak inverse voltage V_{sm} = **32.53 V**

Example 2

A half-wave rectifier is used to supply 50V dc to a resistive load of 800 Ω. The diode has a resistance of 25 Ω. **Calculate ac voltage required.**

Solution

Output dc voltage, V_{dc} = 50 V

Diode resistance, r_f = 25 Ω

Load resistance, R_L = 800 Ω

Let V_m be the maximum value of ac voltage required.

$$\therefore V_{dc} = I_{dc} \times R_L$$

$$V_{dc} = \frac{I_m}{\pi} \times R_L$$

$$\left[\because I_m = \frac{V_m}{r_f + R_L}\right]$$

$$V_{dc} = \frac{V_m}{\pi (r_f + R_L)} \times R_L$$

$$50 = \frac{V_m}{\pi (25 + 800)} \times 800$$

$$V_m = \frac{\pi \times 825 \times 50}{800} = \mathbf{162\ V}$$

Hence, ac voltage of maximum value 162 V is required.

Example 3

A full-wave rectifier uses two diodes, the internal resistance of each diode may be assumed constant at 20 Ω. The transformer rms secondary voltage from center tap to each end of secondary is 50 V and load resistance is 980 Ω. Find: (i) *the average load current,* (*ii*) *the rms value of load current*

Solution

Max. ac voltage $V_m = 50 \times \sqrt{2} = 70.7\ V$

Max. load current $I_m = \frac{V_m}{r_f + R_L} = \frac{70.7\ V}{(20 + 980)\ \Omega} = 70.7\ mA$

(*i*) *average* load current $I_{dc} = \frac{2 I_m}{\pi} = \frac{2 \times 70.7}{\pi} = \mathbf{45\ mA}$

(ii) RMS value of load current is $I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{70.7}{\sqrt{2}}\overline{AB} = \mathbf{50\ mA}$

Example 4

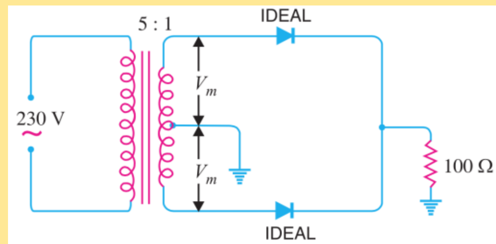
In the center-tap circuit shown, the diodes are assumed to be ideal i.e. having zero internal resistance. Find: (i) dc output voltage (ii) peak inverse voltage.

Solution

Primary to secondary turns, $N_1/N_2 = 5$

RMS primary voltage = 230 V

∴ RMS secondary voltage = 230×(1/5) = 46V



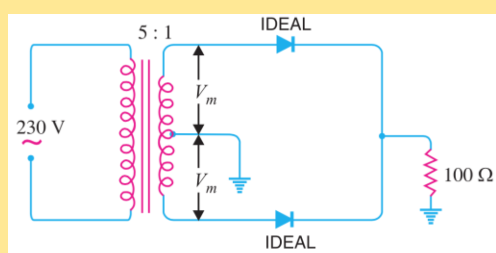
Maximum voltage across secondary = 46 x $\sqrt{2}$ = 65V

Maximum voltage across half secondary winding is V_m =65/2 = 32.5V

(i) dc output voltage

$$V_{AVG} = \frac{2V_m}{\pi}$$

$V_{dc} = V_{AVG}$= 2 x 32.5 / 3.14 = **20.7V**



(ii) peak inverse voltage.

The peak inverse voltage is equal to maximum secondary voltage, *i.e.*

PIV = **65 V**

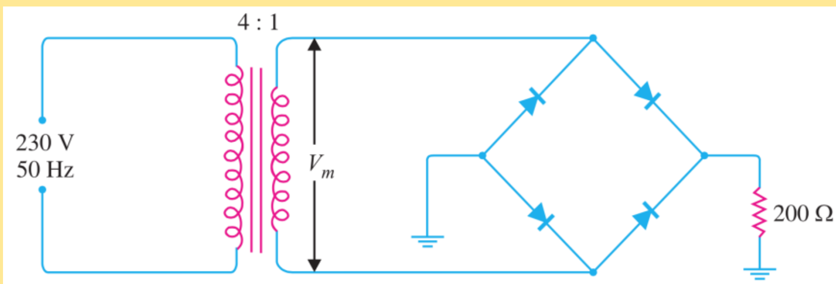
Example 5

In the bridge type circuit shown, the diodes are assumed to be ideal. Assume primary to secondary turns to be 4. Find:

(i) dc output voltage

(ii) peak inverse voltage

(iii) output frequency.



Solution

Primary/secondary turns, $N_1/N_2 = 4$

RMS primary voltage = 230 V

∴ RMS secondary voltage = 230 (N_2/N_1) = 230 × (1/4) = 57.5 V

Maximum voltage across secondary is

$V_m = 57.5 \times \sqrt{2} = 81.3V$

Average output voltage, $V_{AVG} = \frac{2V_m}{\pi}$

(i) ∴ dc output voltage, $V_{dc} = V_{AVG} = 2 \times 81.3 / 3.14 =$ **52V**

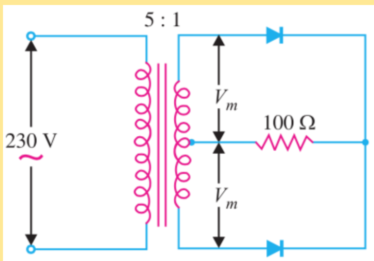
(ii) peak inverse voltage (*PIV* = **81.3V**)

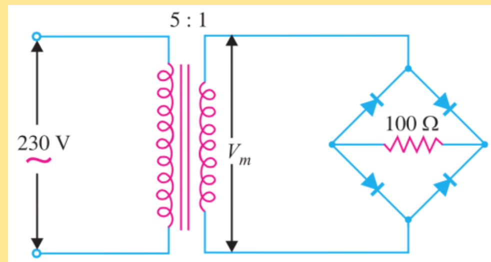
(iii) In full wave rectification, there are two output pulses for each complete cycle of the input ac voltage. Therefore, the output frequency is twice that of the ac supply frequency *i.e.*

$$f_{out} = 2 \times f_{in} = 2 \times 50 = \textbf{100Hz}$$

More problem to be solved by your self

(1) Figures show the center-tap and bridge type circuits having the same load resistance and transformer turn ratio. The primary of each is connected to 230 V, 50 Hz supply. Assume the diodes to be ideal. (i) Find the dc voltage in each case. (ii) PIV for each case for the same dc output.





(2) The four diodes used in a bridge rectifier circuit have forward resistances which may be considered constant at 1Ω and infinite reverse resistance. The alternating supply voltage is 240 V rms and load resistance is 480 Ω. Calculate (i) average load current and (ii) power dissipated in each diode.