Electrical Science: 2021-22

Tutorial 10

Diode Circuits

By Dr. Sanjay Vidhyadharan

Example 1

A crystal diode having internal resistance $r_f = 20\Omega$ is used for half-wave rectification. If the applied voltage v = 50 sin ω t and load resistance $R_L = 800\ \Omega$. Find : (i) Im, Idc, Irms (ii) a.c. power input and d.c. power output (iii) d.c. output voltage (iv) efficiency of rectification.

(i) $$I_m = \frac{V_m}{r_f + R_L} = \frac{50}{20 + 800} = 0.061\text{ A} = \mathbf{61\ mA}$$

$$I_{dc} = I_m/\pi = 61/\pi = \mathbf{19.4\ mA}$$

$$I_{rms} = I_m/2 = 61/2 = \mathbf{30.5\ mA}$$

(ii) $$\text{d.c. power output} = I_{dc}^2 \times R_L = \left(\frac{19.4}{1000}\right)^2 \times 800 = \mathbf{0.301\ watt}$$

$$\text{a.c. power input} = (I_{rms})^2 \times (r_f + R_L) = \left(\frac{30.5}{1000}\right)^2 \times (20 + 800) = \mathbf{0.763\ watt}$$

(iii) $$\text{d.c. output voltage} = I_{dc} R_L = 19.4\text{ mA} \times 800\ \Omega = \mathbf{15.52\ volts}$$

(iv) $$\text{Efficiency of rectification} = \frac{0.301}{0.763} \times 100 = \mathbf{39.5\%}$$

Example 2

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

$$r_f = 20\ \Omega, \quad R_L = 980\ \Omega$$

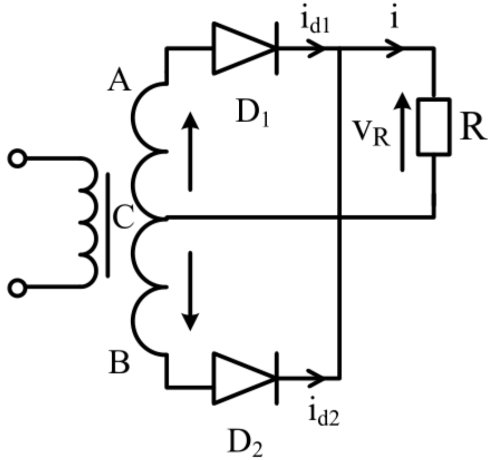
$$\text{Max. a.c. voltage, } V_m = 50 \times \sqrt{2} = 70.7\ \text{V}$$

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

$$\text{Mean load current, } I_{dc} = \frac{2 I_m}{\pi} = \frac{2 \times 70.7}{\pi} = \mathbf{45\ mA}$$

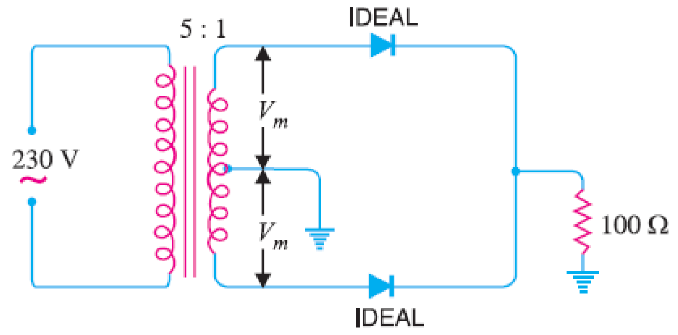
R.M.S. value of load current is

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{70.7}{\sqrt{2}} = \mathbf{50\ mA}$$



Example 3

In the centre-tap circuit shown in Fig. 2, the diodes are assumed to be ideal i.e. having zero internal resistance. Find :(i) d.c. output current (ii) peak inverse voltage (iii) rectification efficiency.



R.M.S. primary voltage = 230 V

∴ R.M.S. secondary voltage

$= 230 \times (1/5) = 46\ V$

Maximum voltage across secondary

$= 46 \times \sqrt{2} = 65V$

Maximum voltage across half secondary winding is

$V_m = 65/2 = 32.5\ V$

Average current, $I_{dc} = \dfrac{2V_m}{\pi R_L} = \dfrac{2 \times 32.5}{\pi \times 100} = 0.207\ A$

$PIV = 65\ V$

$$\eta = \frac{Pdc}{Pac} = \frac{4}{\pi * \pi} I^2 max\, R_L / \frac{1}{2} I^2 max\, (R_L + R_F)$$

$$= \frac{8}{\pi * \pi} \frac{1}{(1+2RF/RL)} = \frac{0.812}{(1+2RF/RL)}$$

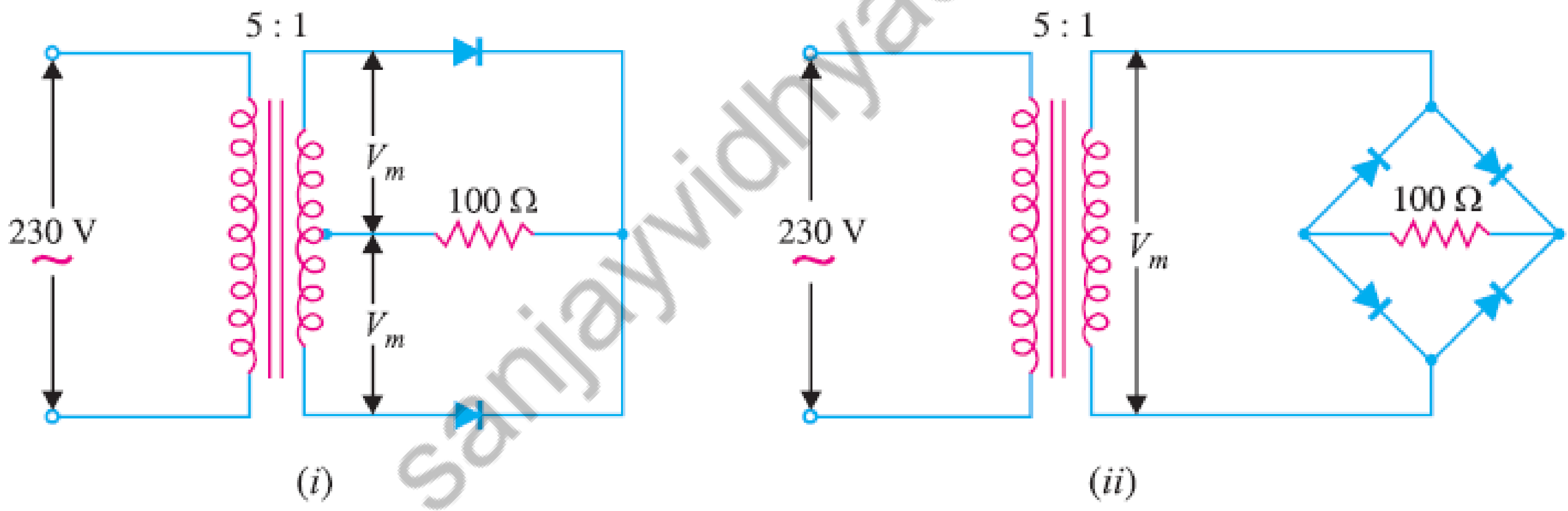
$$\text{Rectification efficiency} = \frac{0.812}{1 + \dfrac{r_f}{R_L}}$$

Since $r_f = 0$

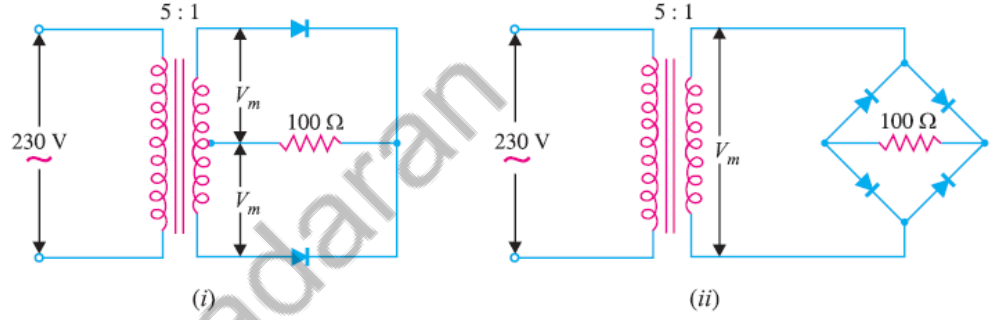
Rectification efficiency $= 81.2\ \%$

Example 4

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



Example 4



DC output voltage :

Centre-tap circuit :

$$\text{R.M.S. secondary voltage} = 230 \times 1/5 = 46 \text{ V}$$

$$\text{Max. voltage across secondary} = 46 \times \sqrt{2} = 65 \text{ V}$$

Max. voltage appearing across half secondary winding is

$$V_m = 65/2 = 32.5 \text{ V}$$

$$\text{Average current, } I_{dc} = \frac{2V_m}{\pi R_L}$$

$$\text{D.C. output voltage, } V_{dc} = I_{dc} \times R_L = \frac{2V_m}{\pi R_L} \times R_L$$

$$= \frac{2V_m}{\pi} = \frac{2 \times 32.5}{\pi} = \mathbf{20.7 \text{ V}}$$

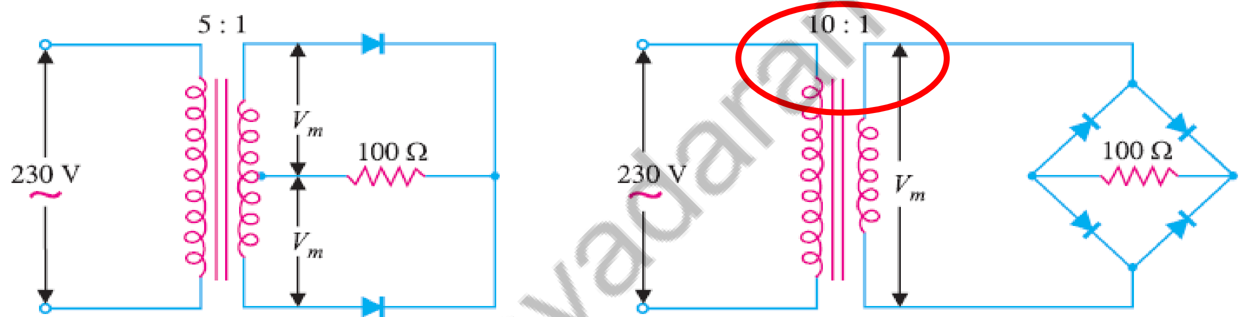
Bridge circuit :

$$\text{Max. voltage across secondary, } V_m = 65 \text{ V}$$

$$\text{D.C. output voltage, } V_{dc} = I_{dc} R_L = \frac{2V_m}{\pi R_L} \times R_L = \frac{2V_m}{\pi} = \frac{2 \times 65}{\pi} = \mathbf{41.4 \text{ V}}$$

Example 5

(ii) PIV for each case for the same d.c. output. Assume the diodes to be ideal.



(i) (ii)

Centre-tap circuit :

$$\text{R.M.S. secondary voltage} = 230 \times 1/5 = 46 \text{ V}$$

$$\text{Max. voltage across secondary} = 46 \times \sqrt{2} = 65 \text{ V}$$

Max. voltage across half secondary winding is

$$V_m = 65/2 = 32.5 \text{ V}$$

$$PIV = 2\,V_m = 2 \times 32.5 = \mathbf{65\ V}$$

Bridge circuit :

$$\text{R.M.S. secondary voltage} = 230 \times 1/10 = 23 \text{ V}$$

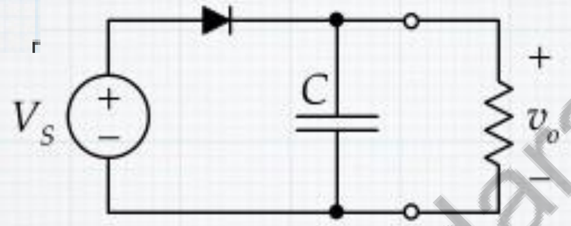
$$\text{Max. voltage across secondary, } V_m = 23 \times \sqrt{2} = 32.5 \text{ V}$$

$$\therefore \quad PIV = V_m = \mathbf{32.5\ V}$$

Example 6

$$V_S = (15\text{V})\sin\left(\frac{2\pi}{T}t\right)$$

$T = 16.67$ ms



$C = 100\ \mu\text{F}$

$R = 5000\ \Omega$

Find the average value of v_o and the ripple voltage. Repeat for $R = 1000\ \Omega$ and $200\ \Omega$.

$$V_{ripple} = [V_P - 0.7\text{V}]\left[1 - \exp\left(-\frac{T}{RC}\right)\right]$$

$$= [15\text{V} - 0.7\text{V}]\left[1 - \exp\left(-\frac{16.67\text{ms}}{(5000\Omega)(100\mu\text{F})}\right)\right]$$

$$= 0.47\text{ V}$$

$$V_o(avg) = V_o(max) - \frac{V_{ripple}}{2} = 14.3\text{V} - \frac{0.47\text{V}}{2} = 14.1\text{V}$$

$R = 1\text{ k}\Omega$

$V_{ripple} = 2.19$ V

V_o (avg) = 13.2 V

$R = 200\ \Omega$

$V_{ripple} = 8.09$ V

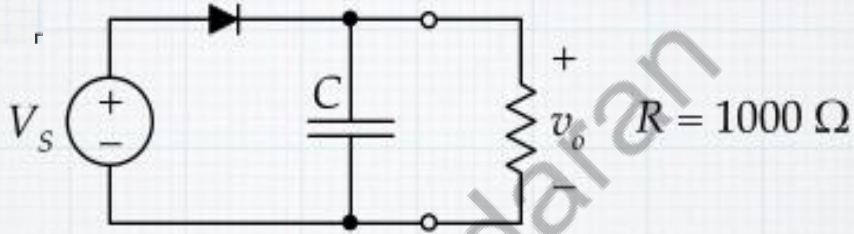
V_o (avg) = 10.2 V

Drawing more current causes the ripple to increase and V_{DC} to droop. Can fight this with more capacitance.

Example 7

$$V_S = (25\text{V})\sin\left(\frac{2\pi}{T}t\right)$$

$T = 16.67$ ms



Find the capacitance so that the ripple will be no bigger than 1 V.

What is the DC voltage?

$$V_{ripple} = [V_P - 0.7\text{V}]\left[1 - \exp\left(-\frac{T}{RC}\right)\right]$$

$$C = -\frac{T}{R}\left[\ln\left(1 - \frac{V_{ripple}}{V_P - 0.7\text{V}}\right)\right]^{-1} = -\frac{16.67\text{ms}}{1000\Omega}\left[\ln\left(1 - \frac{1\text{V}}{24.3\text{V}}\right)\right]^{-1} = 397\ \mu\text{F}$$

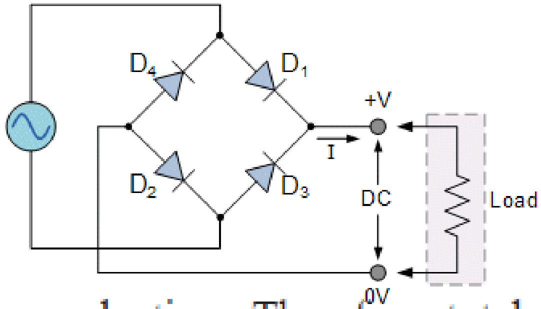
$$V_o\,(avg) = V_o\,(max) - \frac{V_{ripple}}{2} = 24.3\text{V} - \frac{1\text{V}}{2} = 23.8\text{V}$$

What capacitance is needed to limit the ripple to 0.1 V?

$C = 4000\ \mu$F !!!

Example 8

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 r.m.s. and load resistance is 480 Ω. Calculate (i) mean load current and (ii) power dissipated in each diode.



Max. a.c. voltage, $V_m = 240 \times \sqrt{2}$ V

(*i*) At any instant in the bridge rectifier, two diodes in series are conducting. Therefore, total circuit resistance = $2\,r_f + R_L$.

$$\text{Max. load current, } I_m = \frac{V_m}{2\,r_f + R_L} = \frac{240 \times \sqrt{2}}{2 \times 1 + 480} = 0.7 \text{ A}$$

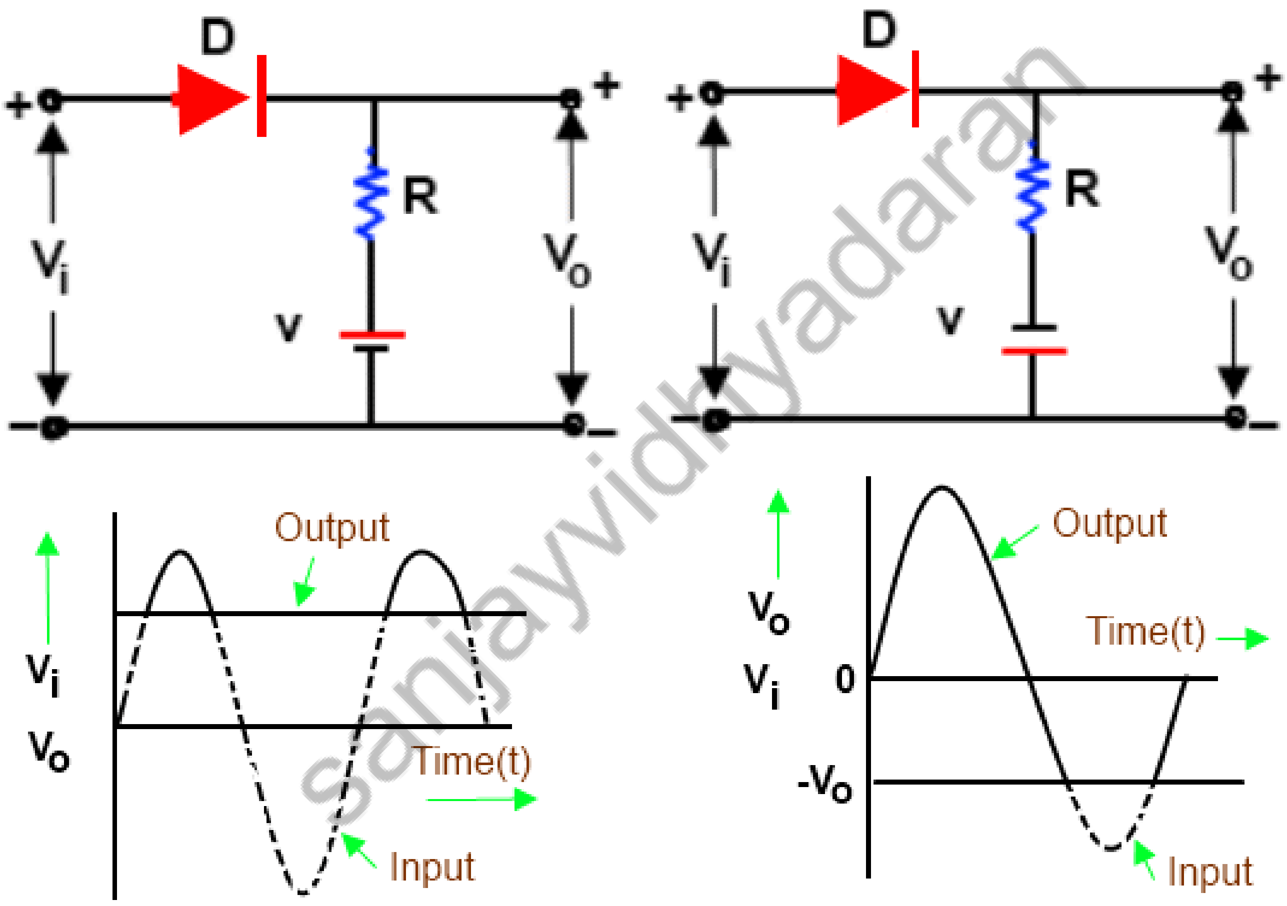
$$\therefore \quad \text{Mean load current, } I_{dc} = \frac{2\,I_m}{\pi} = \frac{2 \times 0.7}{\pi} = \mathbf{0.45\ A}$$

(*ii*) Since each diode conducts only half a cycle, diode r.m.s. current is :

$$I_{r.m.s.} = I_m/2 = 0.7/2 = 0.35 \text{ A}$$

$$\text{Power dissipated in each diode} = I^2_{r.m.s.} \times r_f = (0.35)^2 \times 1 = \mathbf{0.123\ W}$$

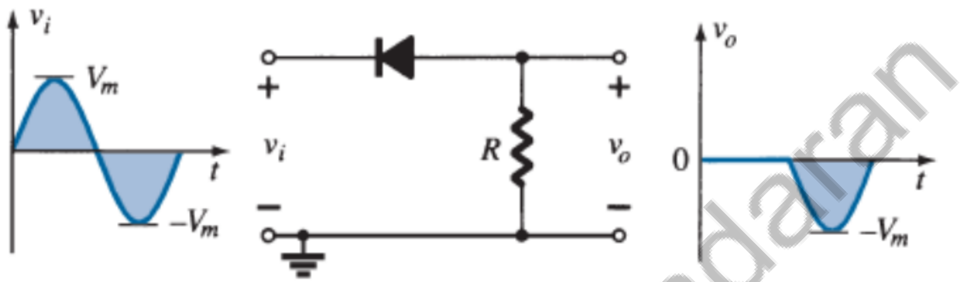
Example 9



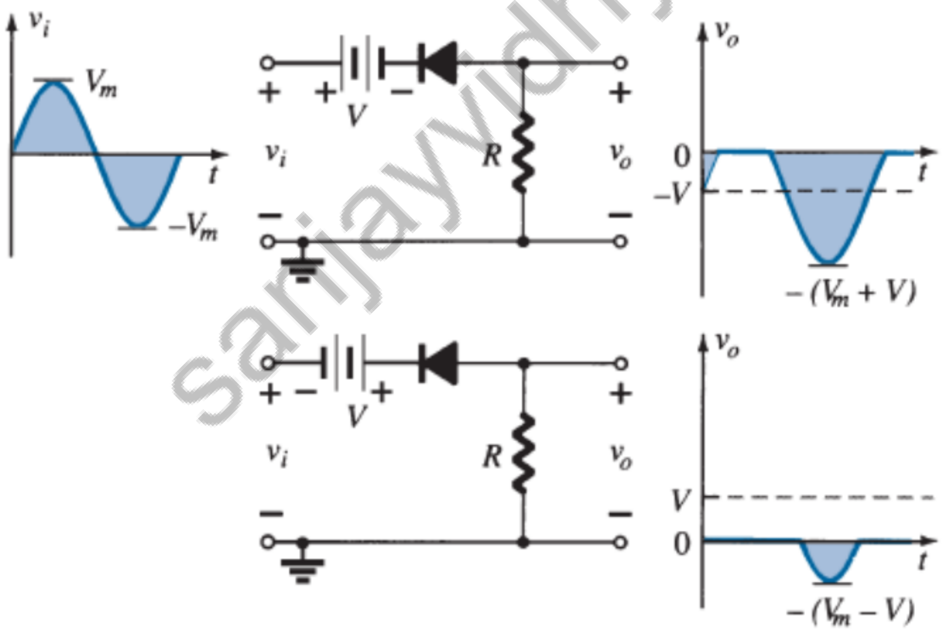
(a) Positive biased

(b) Negative biased

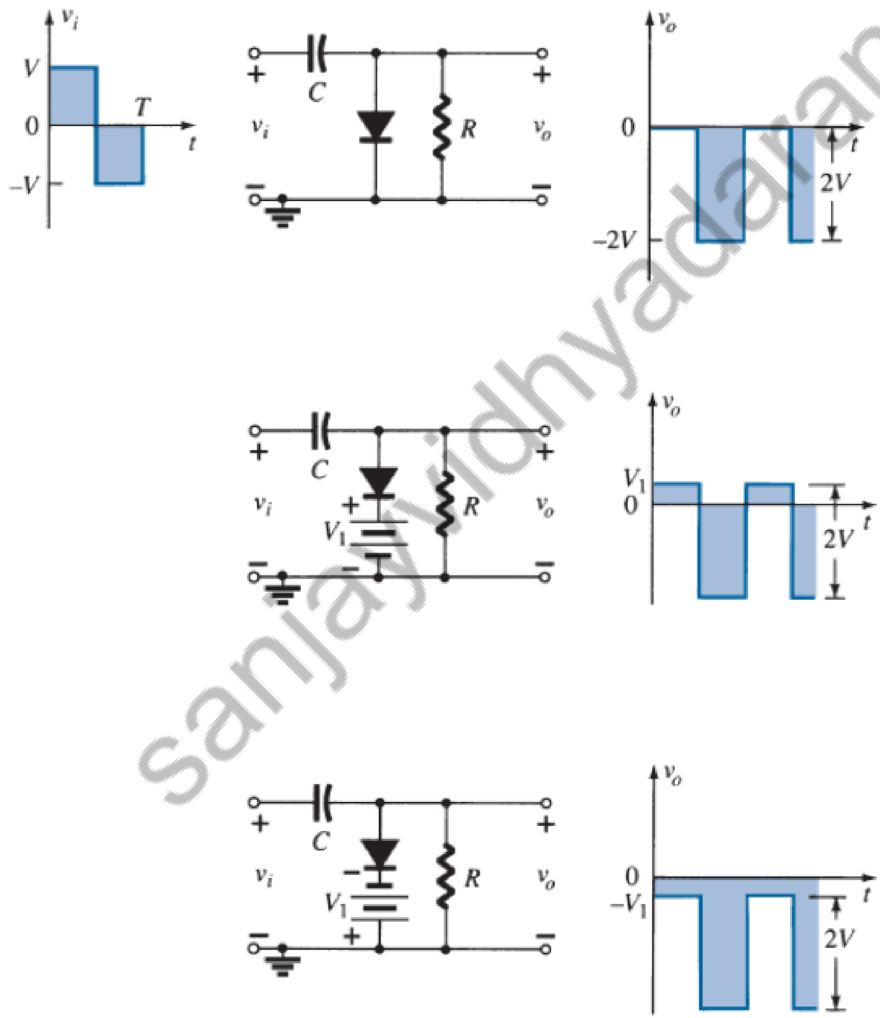
Example 10



Biased Series Clippers (Ideal Diodes)



Example 11



Thank you