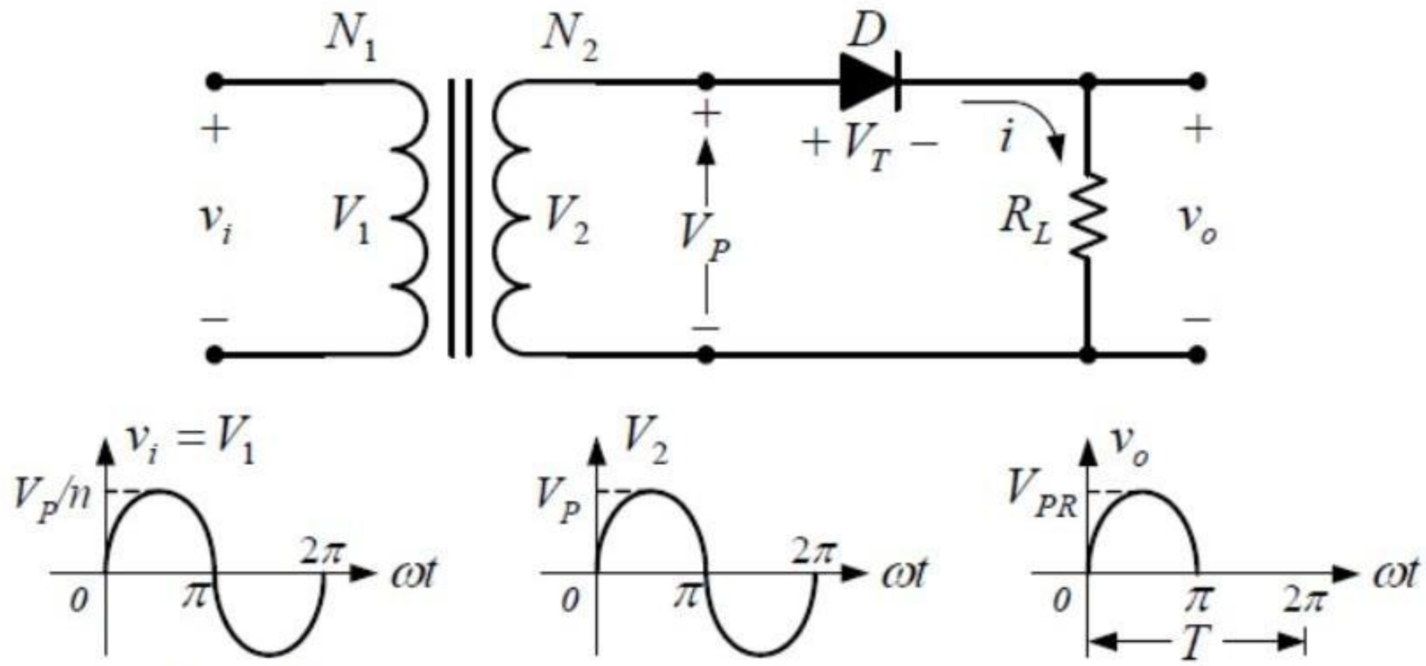
Diode Rectifier Circuits

Basic Definition:

A diode circuit that converts an ac voltage to a pulsating dc voltage and permits current to flow in one direction only is called "***rectifier***" and the ac-to-dc conversion process is termed "***rectification***".

Half-Wave Rectifier (HWR):



$$n = \frac{N_2}{N_1} = \frac{V_2}{V_1}$$

$$f_o = f_i = 1/T$$

Fig. 5-1

For the half-wave rectifier circuit of Fig. 5-1:

◀ The average (dc) value of a half-wave rectified sine-wave voltage (V_{dc}) is

$$V_{dc} = \frac{1}{T}\int_0^T v_o(\omega t)\cdot d\omega t = \frac{1}{2\pi}\int_0^\pi V_{PR} Sin\,\omega t \cdot d\omega t = \frac{V_{PR}}{\pi}$$

For V_P close to V_T,

$$\boxed{V_{dc} = 0.318(V_P - V_T)} \qquad [5.1a]$$

For $V_P >> V_T$,

$$\boxed{V_{dc} = 0.318 V_P} \qquad [5.1b]$$

◀ The root mean square (rms) value of the load voltage (V_{rms}) is

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v_o^2(\omega t)\cdot d\omega t} = \sqrt{\frac{1}{2\pi}\int_0^\pi V_{PR}^2 Sin^2\,\omega t \cdot d\omega t} = \frac{V_{PR}}{2}$$

For V_P close to V_T,

$$\boxed{V_{rms} = 0.5(V_P - V_T)} \qquad [5.2a]$$

For $V_P >> V_T$,

$$\boxed{V_{rms} = 0.5 V_P} \qquad [5.2b]$$

- The rms value of the ac component (or ***the ripple voltage***) of the rectified signal [$V_r(rms)$] is

$$V_r(rms) = \sqrt{V_{rms}^2 - V_{dc}^2} = \sqrt{(0.5V_{PR})^2 - (0.318V_{PR})^2} = 0.385V_{PR}$$

For V_P close to V_T,

$$\boxed{V_r(rms) = 0.385(V_P - V_T)} \qquad [5.3a]$$

For $V_P >> V_T$,

$$\boxed{V_r(rms) = 0.385V_P} \qquad [5.3b]$$

- The percent ripple (r) in the rectified waveform (also called ***the ripple factor***) is

$$r = \frac{V_r(rms)}{V_{dc}} \times 100\% = \frac{0.385V_{PR}}{0.318V_{PR}} \times 100\% = 121\%$$

◀ Efficiency (η) = [$P_{dc}(load)$ / $P_{total}(circuit)$] × 100%

$$\eta = \frac{I_{dc}^2 R_L}{I_{rms}^2 (r_d + R_L)} \times 100\% = \frac{(0.318 I_P)^2 R_L}{(0.5 I_P)^2 (r_d + R_L)} \times 100\% = \frac{40.5}{1 + r_d / R_L} \%$$

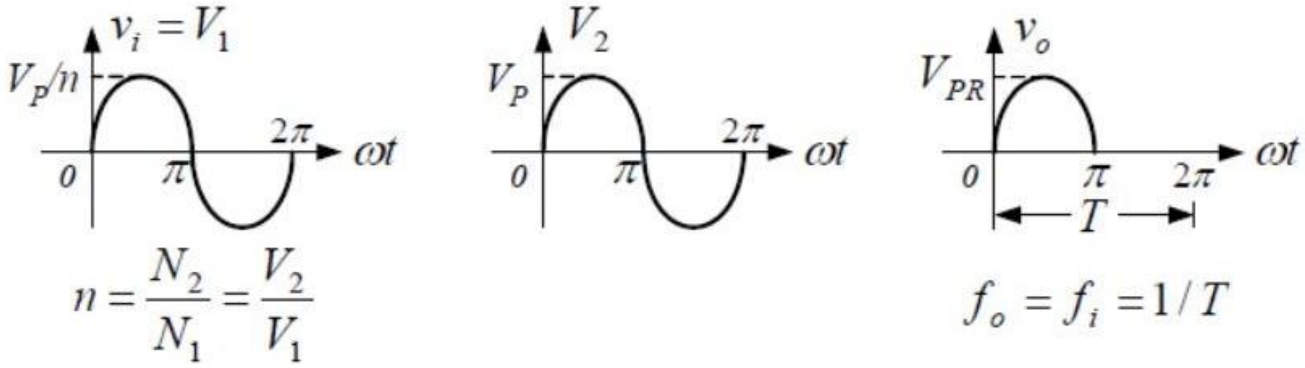
For ideal diode ($r_d = 0\ \Omega$), $\eta = \eta_{max} = 40.5\ \%$

◀ The peak inverse voltage (PIV) of the diode is

$$\boxed{PIV = V_P} \qquad [5.4]$$

◀ The frequency of the output rectified signal (f_o) is

$$\boxed{f_o = f_i} \qquad [5.5]$$



Full-Wave Rectifiers (FWRs):

1. A Bridge Full-Wave Rectifier:

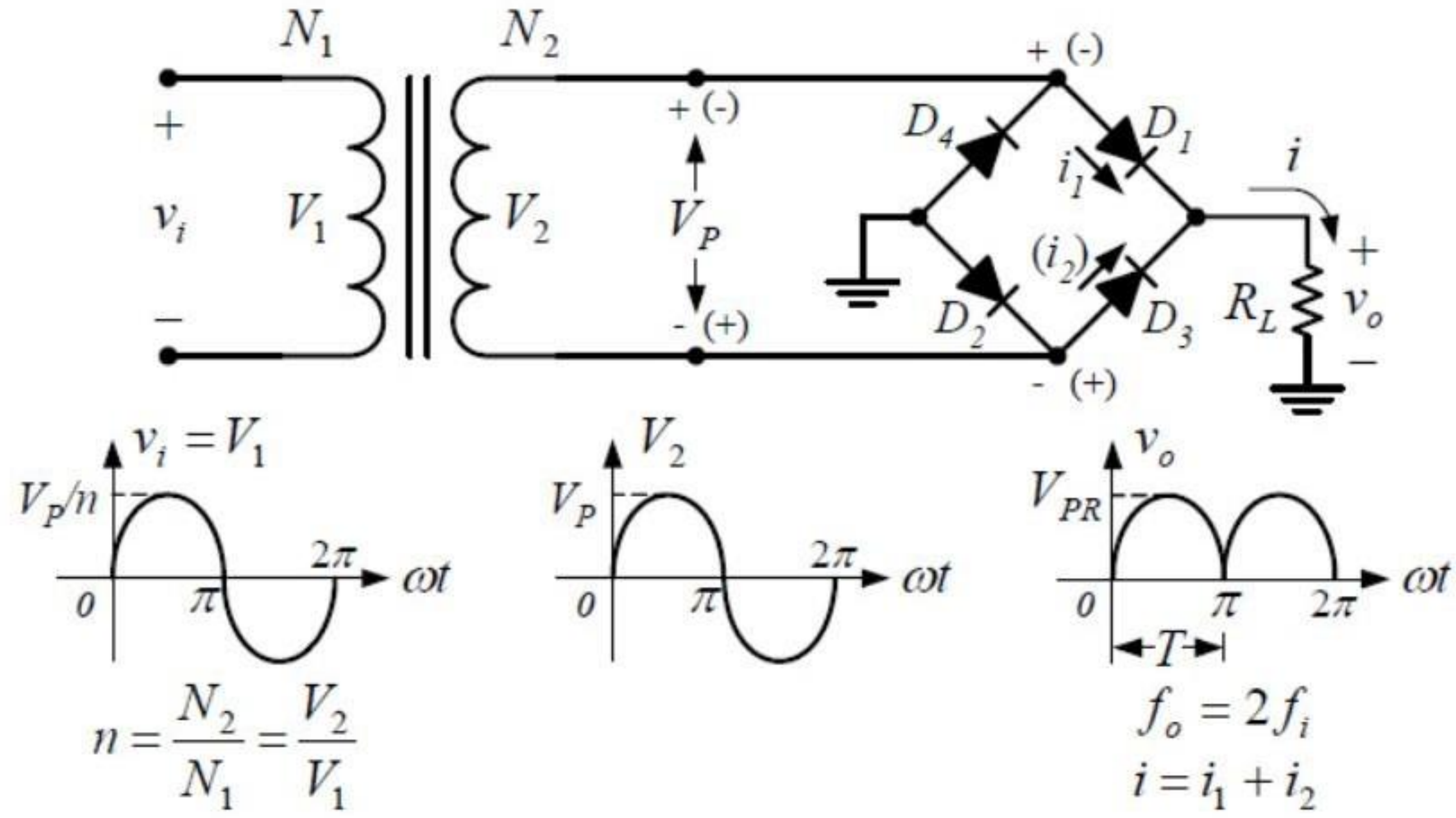


Fig. 5-2

For the bridge full-wave rectifier circuit of Fig. 5-2:

◀ $$V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_{PR} Sin\,\omega t \cdot d\omega t = \frac{2V_{PR}}{\pi}$$

For V_P close to $2V_T$,

$$\boxed{V_{dc} = 0.636(V_P - 2V_T)} \qquad [5.6a]$$

For $V_P >> 2V_T$,

$$\boxed{V_{dc} = 0.636V_P} \qquad [5.6b]$$

◀ $$V_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} V_{PR}^2 Sin^2\,\omega t \cdot d\omega t} = \frac{V_{PR}}{\sqrt{2}}$$

For V_P close to $2V_T$,

$$\boxed{V_{rms} = 0.707(V_P - 2V_T)} \qquad [5.7a]$$

For $V_P >> 2V_T$,

$$\boxed{V_{rms} = 0.707V_P} \qquad [5.7b]$$

◀ $V_r(rms) = \sqrt{V_{rms}^2 - V_{dc}^2} = \sqrt{(0.707V_{PR})^2 - (0.636V_{PR})^2} = 0.308V_{PR}$

For V_P close to $2V_T$,

$$\boxed{V_r(rms) = 0.308(V_P - 2V_T)} \qquad [5.8a]$$

For $V_P >> 2V_T$,

$$\boxed{V_r(rms) = 0.308V_P} \qquad [5.8b]$$

◀ $r = \frac{V_r(rms)}{V_{dc}} \times 100\% = \frac{0.308V_{PR}}{0.636V_{PR}} \times 100\% = 48.4\%$

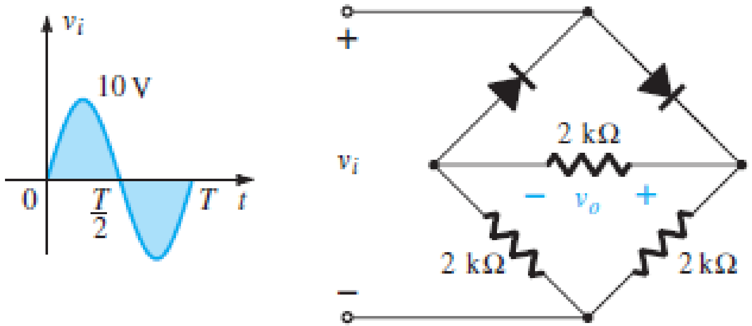
◀ $\eta = \frac{I_{dc}^2 R_L}{I_{rms}^2 (2r_d + R_L)} \times 100\% = \frac{(0.636I_P)^2 R_L}{(0.707I_P)^2 (2r_d + R_L)} \times 100\% = \frac{81}{1 + 2r_d / R_L}\%$

For ideal diode ($r_d = 0\ \Omega$), $\eta = \eta_{max} = 81\ \%$

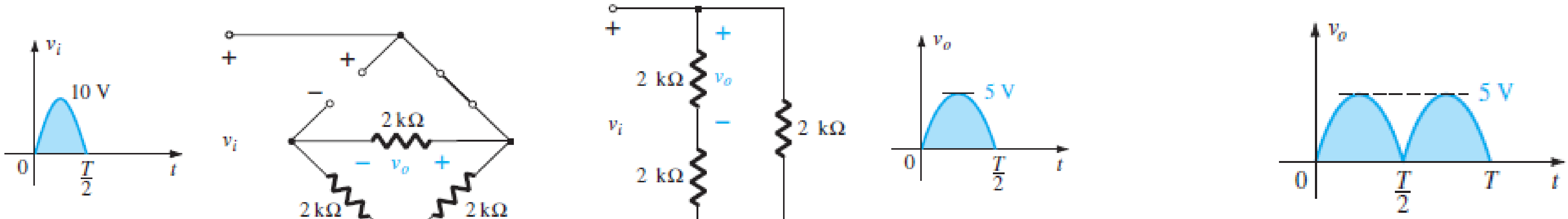
◀ $\boxed{PIV = V_P - 2V_T}$ [5.9]

◀ $\boxed{f_o = 2f_i}$ [5.10]

EXAMPLE : Determine the output waveform for the network of Figure below. Calculate the output dc level and the required PIV of each diode

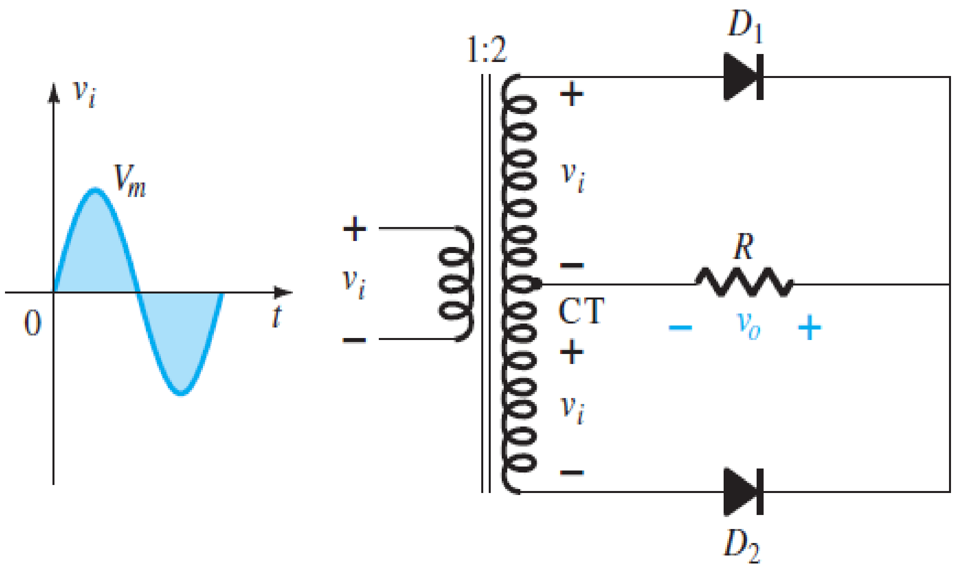


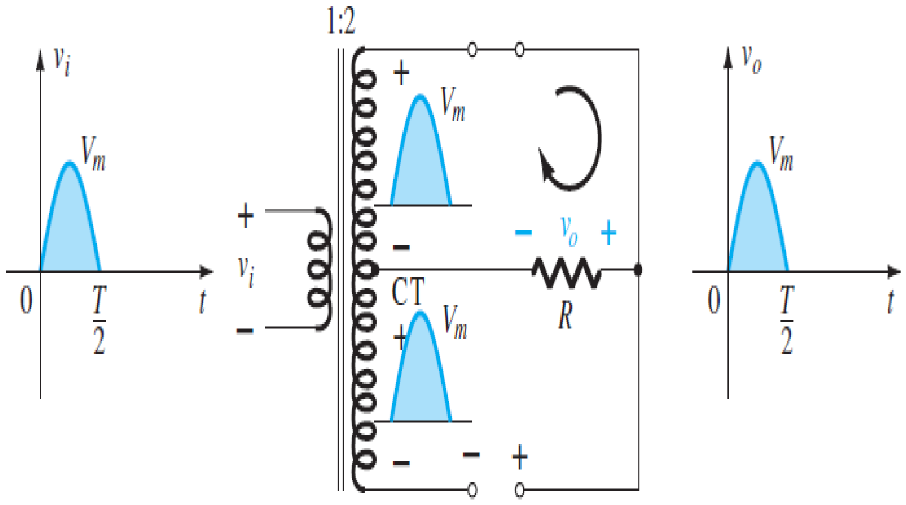
Solution: The network appears as shown in Fig.

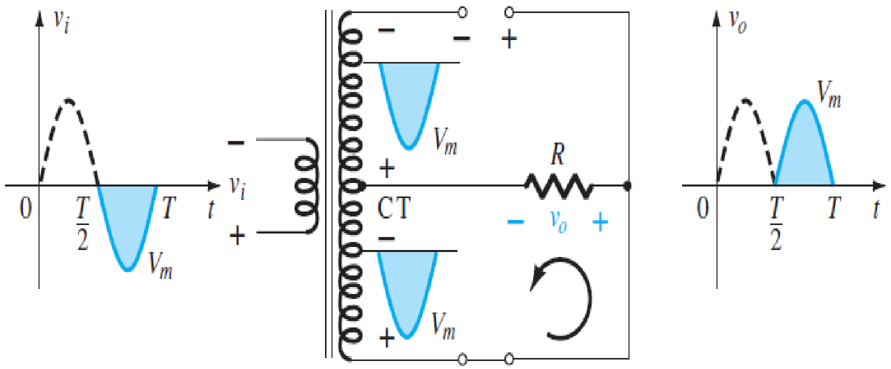


for the positive and negative region of the input voltage. Redrawing the network results in the configuration of Fig, where $v_o = 1/2(v_i)$, then $v_o = 1/2$ (10 V) = 5 V and $V_{dc} = 0.636(5\text{ V}) = 3.18$ V.

2. A Center-Tapped (CT) Full-Wave Rectifier:







Center-tapped transformer
full-wave rectifier.

For the center-tapped full-wave rectifier circuit

$$V_{dc} = 0.636(V_p - V_T)$$

$$V_{dc} = 0.636 V_p$$

The average (dc) value

$$V_{rms} = 0.707(V_p - V_T)$$

$$V_{rms} = 0.707 V_p$$

The root mean square (rms)

$$V_r(rms) = 0.308(V_p - V_T)$$

$$V_r(rms) = 0.308 V_p$$

The (rms) value of the ripple voltage

$$\text{PIV} = V_{\text{secondary}} + V_R = V_m + V_m$$

$$PIV = 2V_p - V_T$$

$$f_o = 2 f_i$$