Bridge Rectifier

Semiconductor Devices and Circuits

(ECE 181302)

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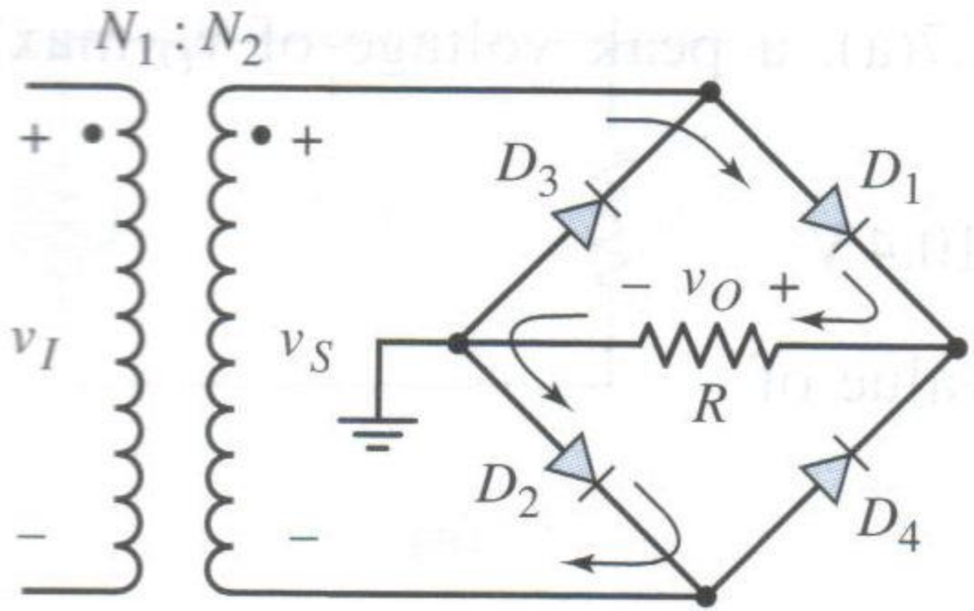
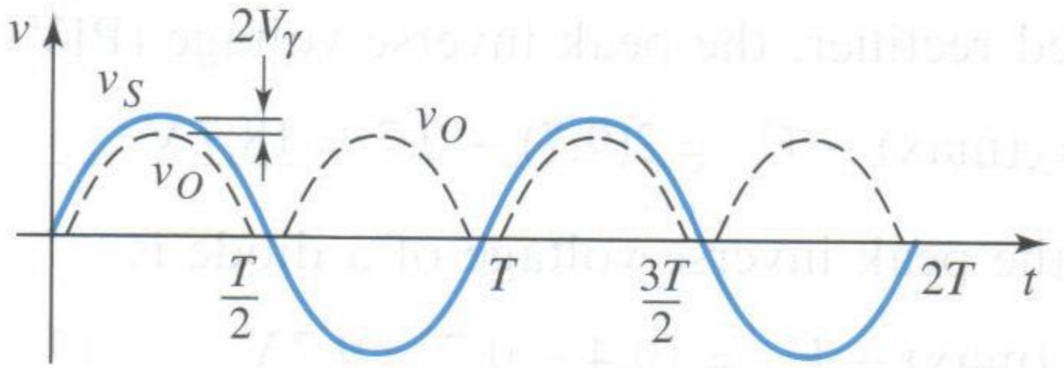
Bridge Rectifier

- **Positive cycle**, D_1 and D_2 conducts, D_3 and D_4 off;

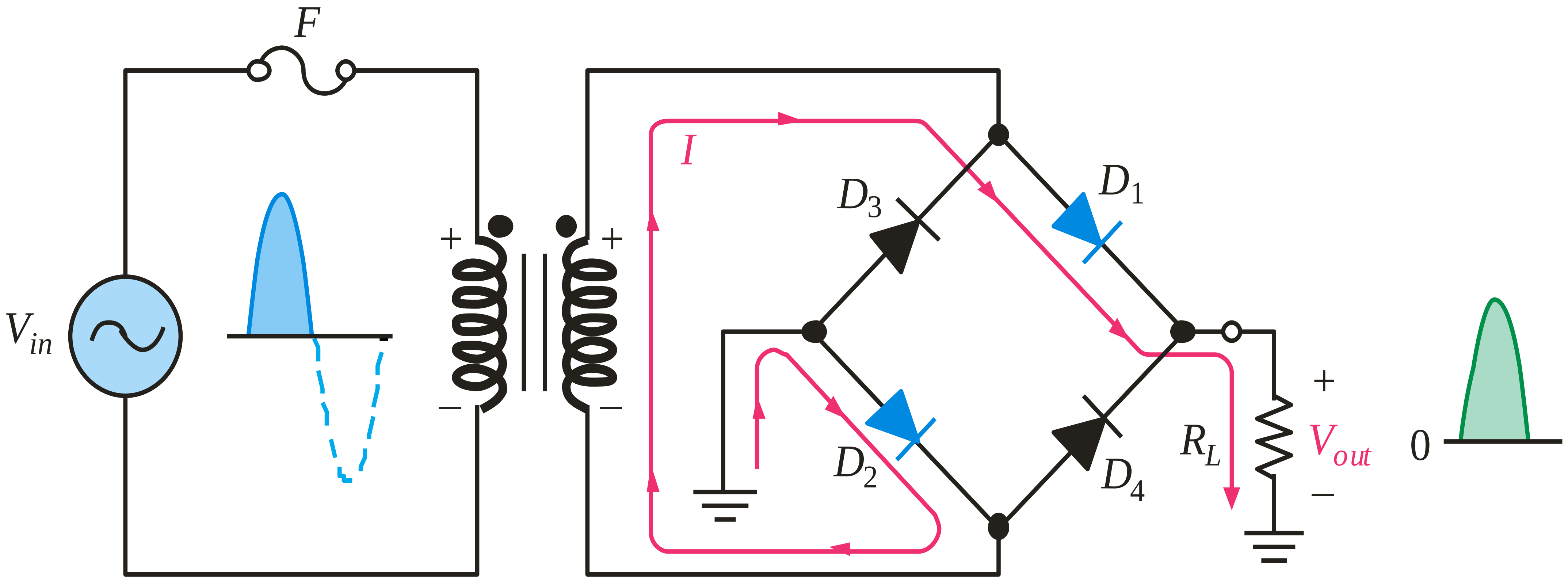
  $+ V_\gamma + V_o + V_\gamma - V_s = 0$

  <u>**$V_o = V_s - 2V_\gamma$**</u>





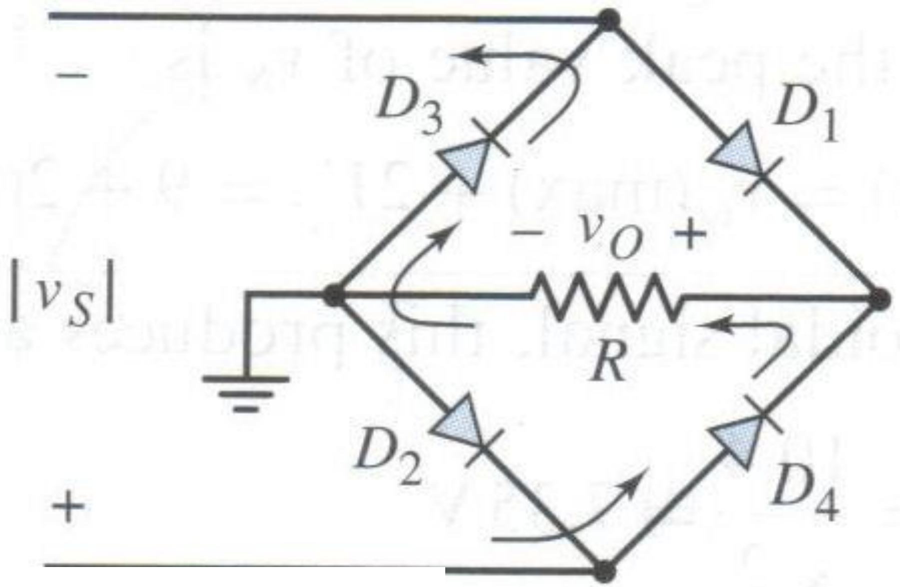
How the conduction path for the positive half-cycle looks like:

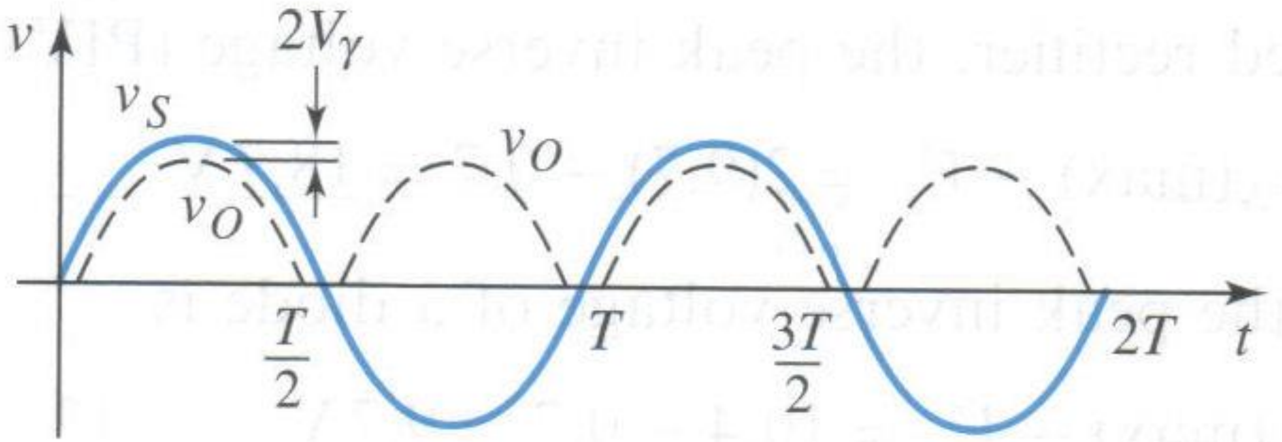


- **Negative cycle**, *D3* and *D4* conducts, *D1* and *D2* off

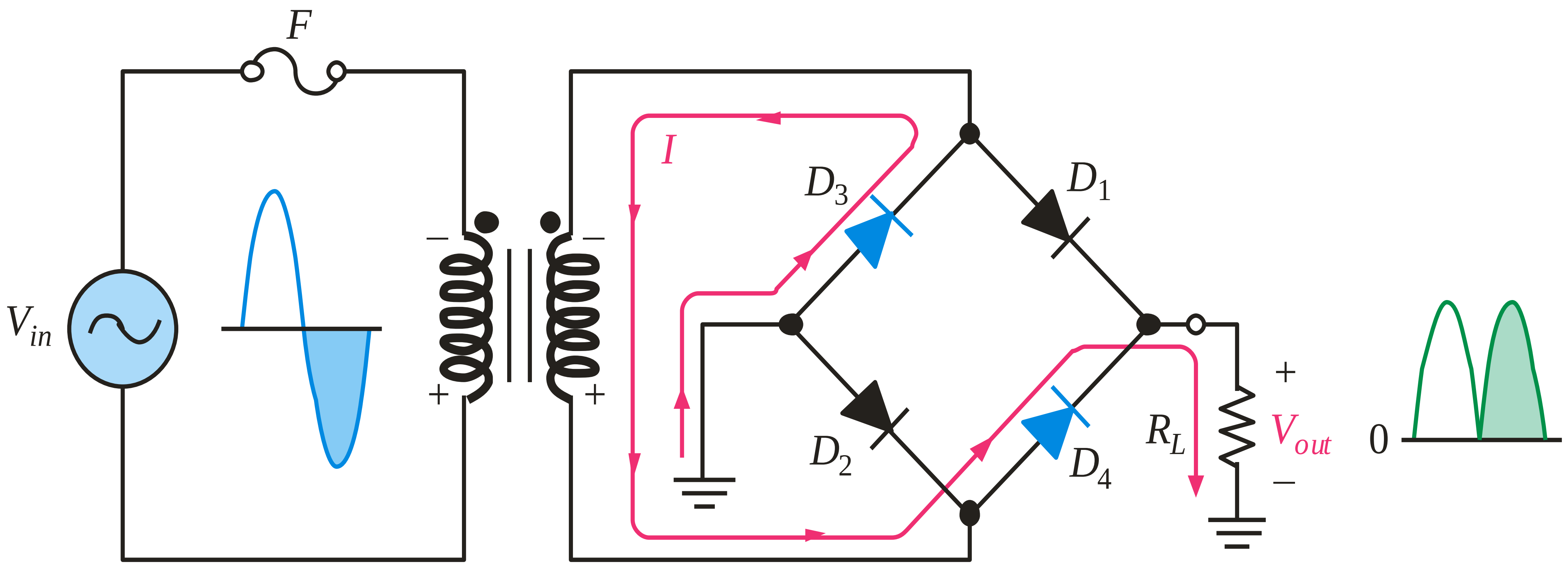
  $+ V_\gamma + V_o + V_\gamma - V_s = 0$

  $V_o = V_s - 2V_\gamma$

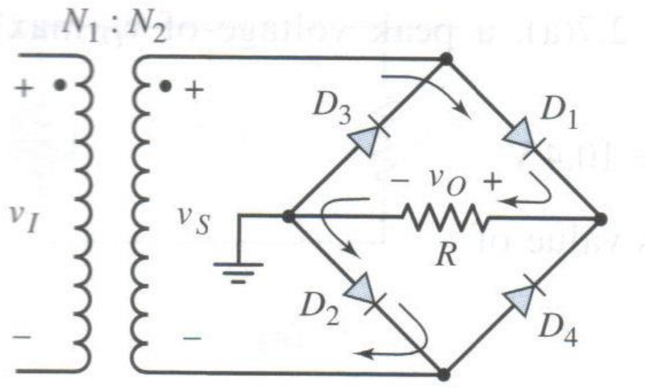


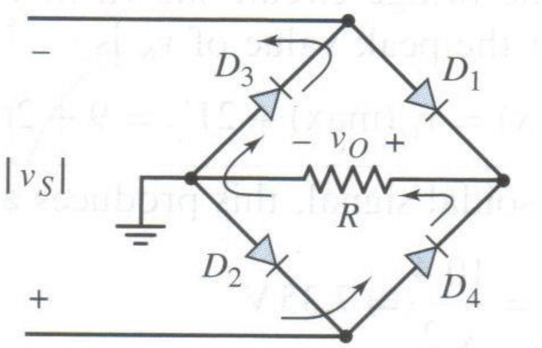


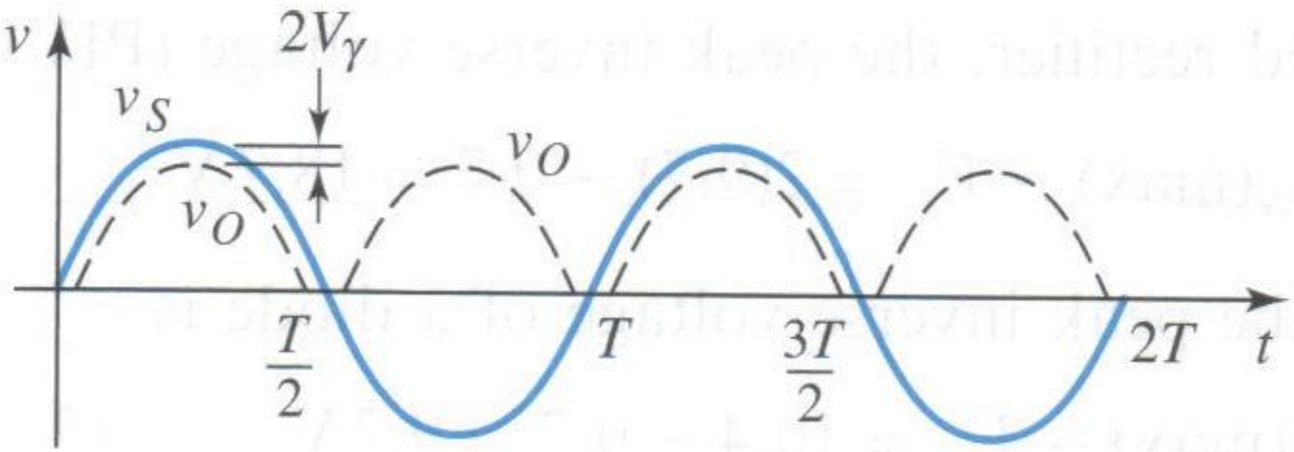
How the conduction path for the negative half-cycle looks like:



Full-Wave Rectification:





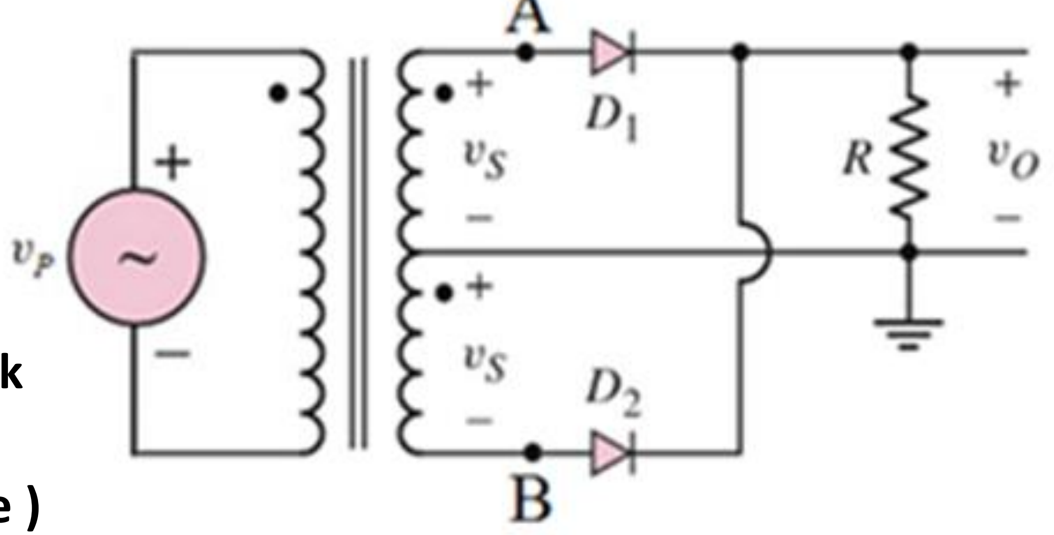


➢Also notice that the **polarity of the output voltage for both cycles is the same**

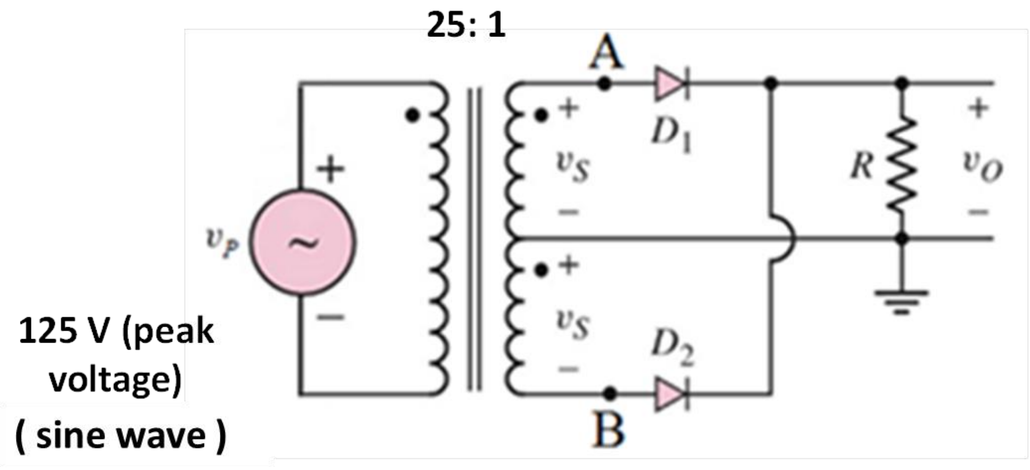
Example:

- Assume that for each diode, the cut-in voltage, V_γ = 0.6V and the diode forward resistance, r_f is 15Ω. The load resistor, R = 95 Ω. Determine:
  - The peak output voltage, V_o across the load, R
  - Sketch the output voltage, V_o and label its peak value.

25: 1



125 V (peak voltage)
(sine wave)



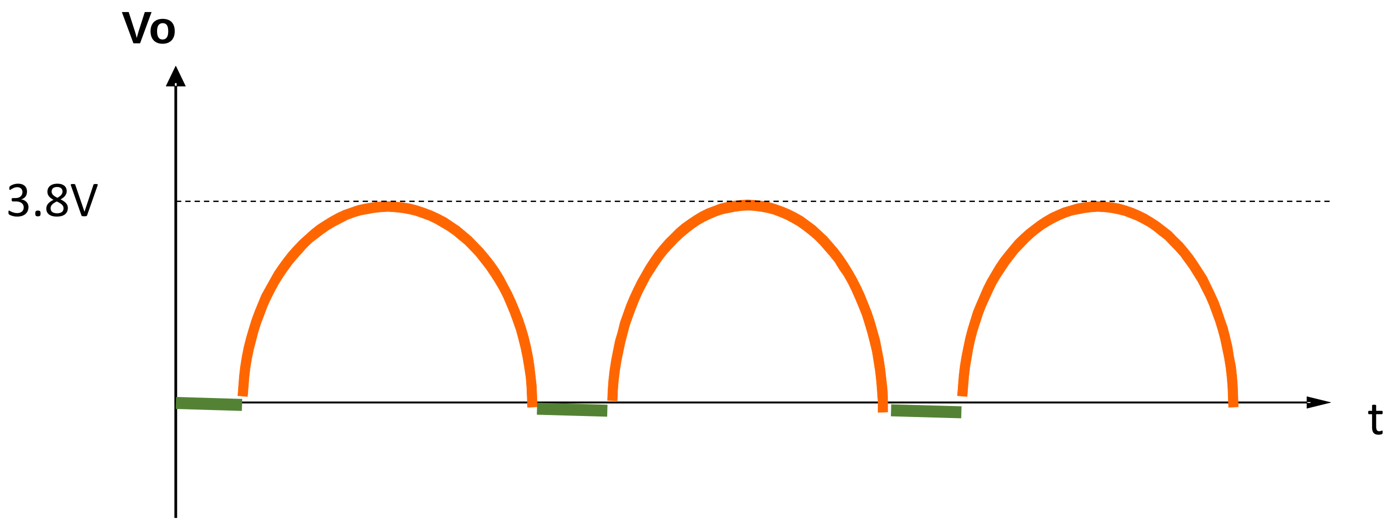
- **<u>SOLUTION</u>**
- peak output voltage, V_o

$$V_{s\,(peak)} = 125 / 25 = 5V$$

$$V_\gamma + I_D(15) + I_D(95) - V_{s(peak)} = 0$$

$$I_D = (5 - 0.6) / 110 = 0.04\ A$$

$$V_{o\,(peak)} = 95 \times 0.04 = \underline{\mathbf{3.8V}}$$



DC Voltage and RMS Voltage: Centre Tapped

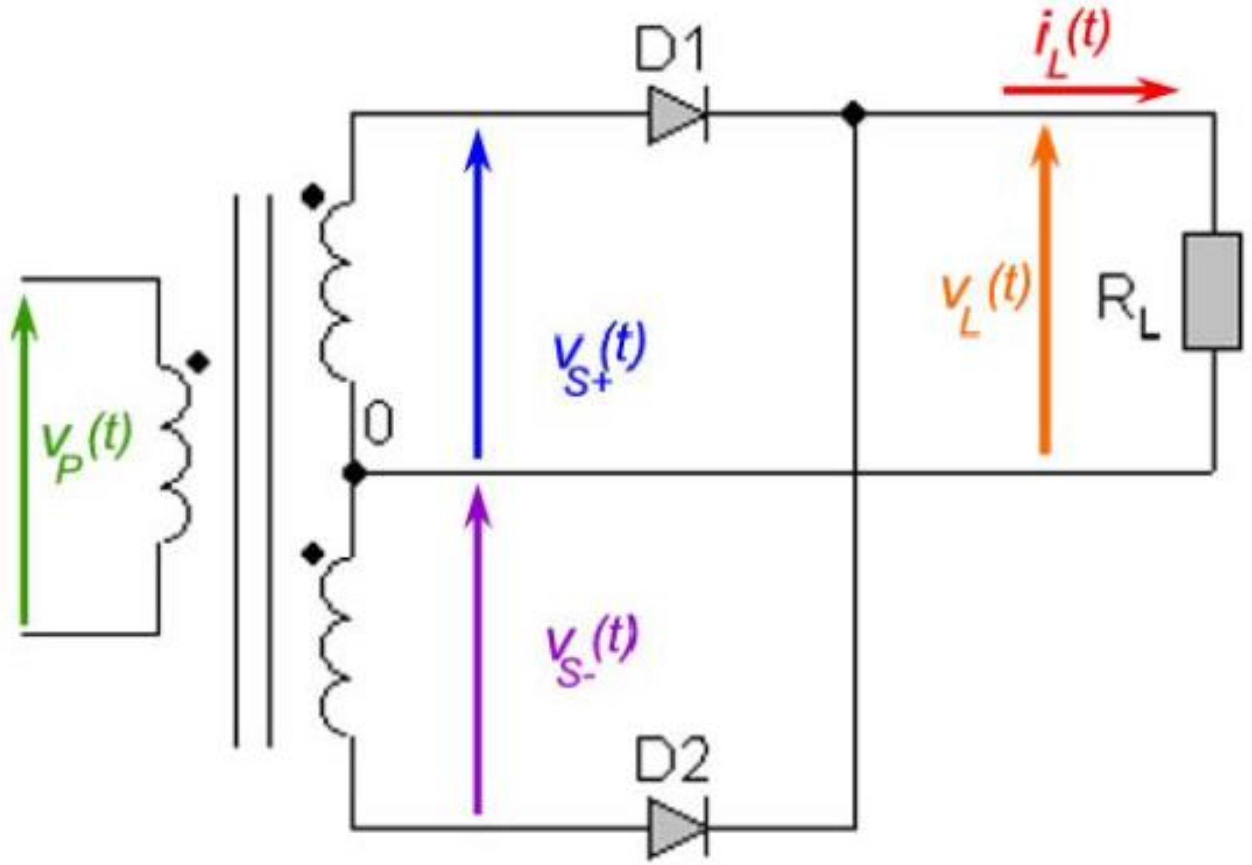
- Average value/DC value/mean value = $\frac{Area\ over\ one\ period}{Total\ time\ period}$

$$V_{DC} = \frac{1}{T}\int_0^T v_L(t)\mathrm{d}t = \frac{2}{2\pi}\int_0^\pi V_S \sin(\varpi t)\mathrm{d}t = \frac{2\cdot V_S}{\pi}$$

V_{DC}= 0.636 V_s = 2 x 0.318 V_s

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v_L^2(t)\mathrm{d}t} = \sqrt{\frac{1}{\pi}\int_0^\pi V_S^2 \sin^2(\varpi t)\mathrm{d}t} = \frac{V_S}{\sqrt{2}}$$

Structure of Full Wave Rectifier: Centre Tapped



$$I_{\mathrm{DC}} = \frac{V_{\mathrm{DC}}}{R_{\mathrm{L}}} = \frac{2 \cdot V_{\mathrm{S}}}{\pi \cdot R_{\mathrm{L}}}$$

$$I_{rms} = \frac{V_{rms}}{R_{\mathrm{L}}} = \frac{V_{\mathrm{S}}}{\sqrt{2} \cdot R_{\mathrm{L}}}$$

$$FF = \frac{V_{rms}}{V_{\mathrm{DC}}} = \frac{\pi}{2 \cdot \sqrt{2}} = 1.11$$

$$\eta = \left(\frac{1}{FF}\right)^2 = 0.81$$

$$RF = \sqrt{FF^2 - 1} = 0.483 .$$

PIV

The **peak inverse voltage (PIV)** of the diode is the peak value of the voltage that a diode can withstand when it is reversed biased

Type of Rectifier	PIV
Half Wave	Peak value of the input secondary voltage, $V_{s\ (peak)}$
Full Wave : Center-Tapped	$2V_{s(peak)} - V_{\gamma}$
Full Wave: Bridge	$V_{s(peak)} - V_{\gamma}$

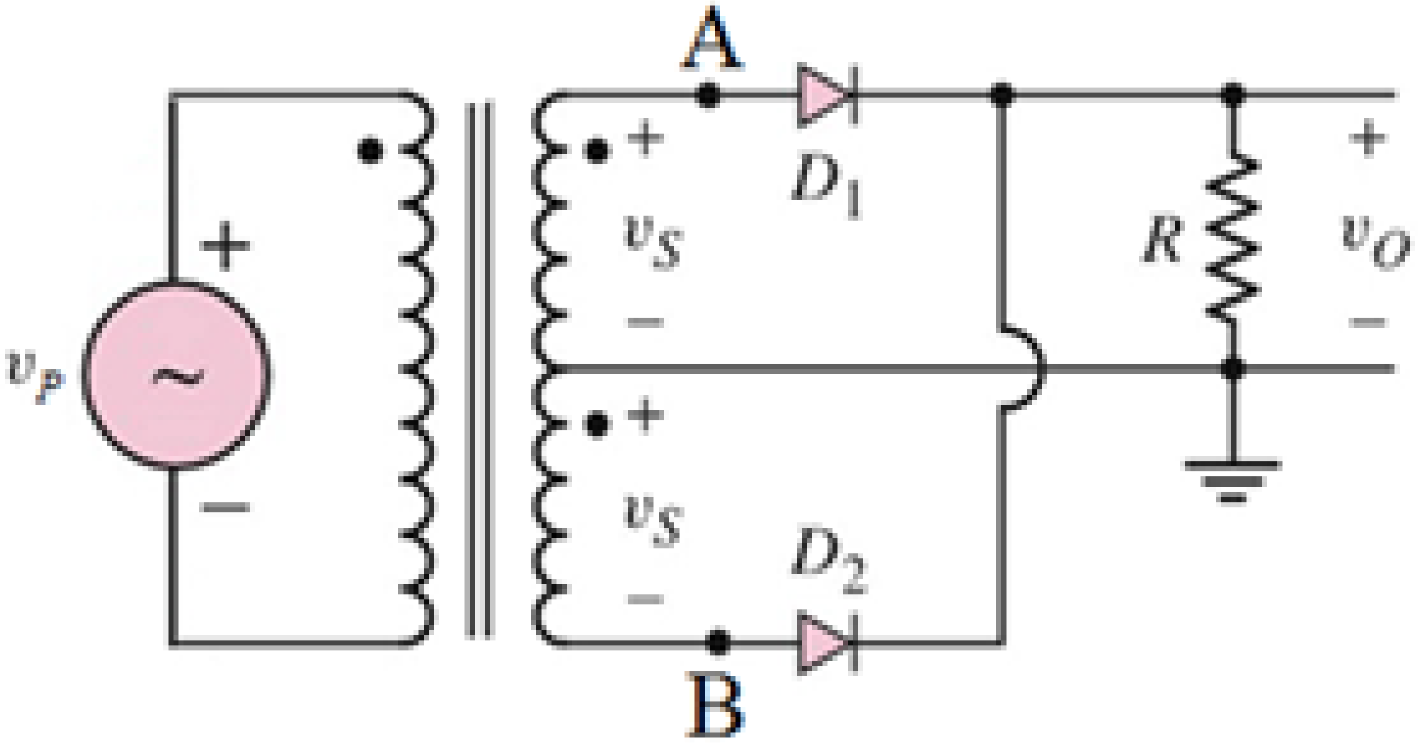
Example:

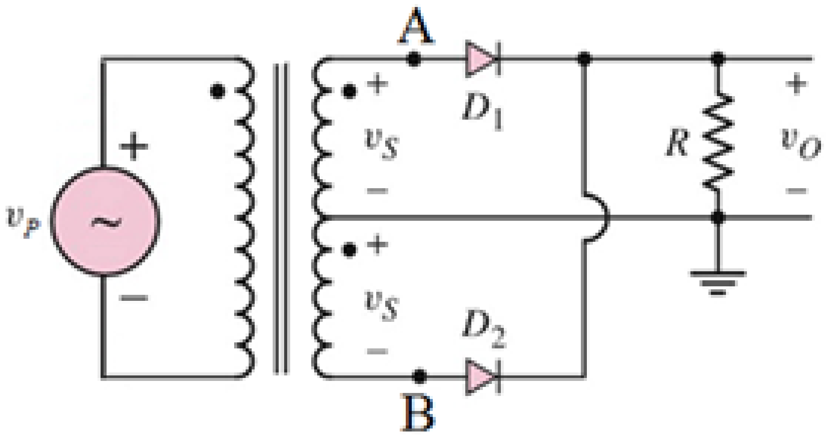
- Calculate the transformer turns ratio and the PIV voltages for each type of the full wave rectifier

  a) center-tapped

  b) bridge

- Assume the input voltage of the transformer is 220 V (rms), 50 Hz from ac main line source. The desired peak output voltage is 9 volt; also assume diodes cut-in voltage = 0.6 V.


A
B
D_1
D_2
v_S
v_S
v_p
R
v_O



$$\frac{v_P}{v_S} = \frac{N_1}{N_2}$$

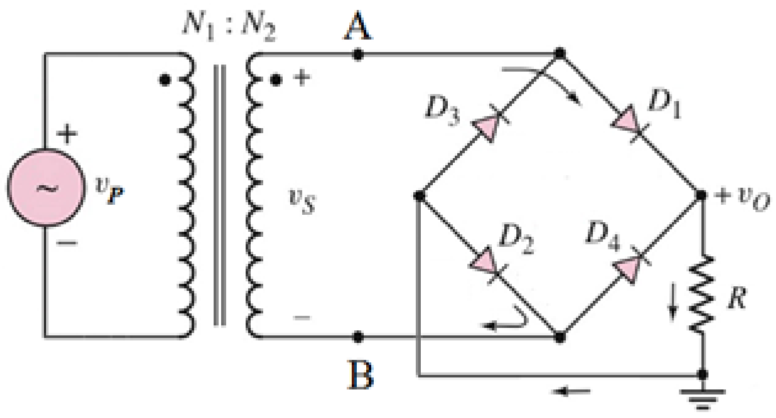
Solution: For the centre-tapped transformer circuit the **peak voltage of the transformer secondary is required**

The peak output voltage = 9V
Output voltage, Vo = Vs - Vγ
Hence, Vs = 9 + 0.6 = 9.6V
Peak value = Vrms x √2
So, Vs (rms) = 9.6 / √2 = 6.79 V

The turns ratio of the primary to each secondary winding is

$$\frac{N_1}{N_2} = \frac{220}{6.79} = 32.40$$

The PIV of each diode: $2V_{s(peak)} - V_{\gamma}$ = 2(9.6) - 0.6 = 19.6 - 0.6 = **18.6 V**



Solution: For the bridge transformer circuit the **peak voltage of the transformer secondary is required**

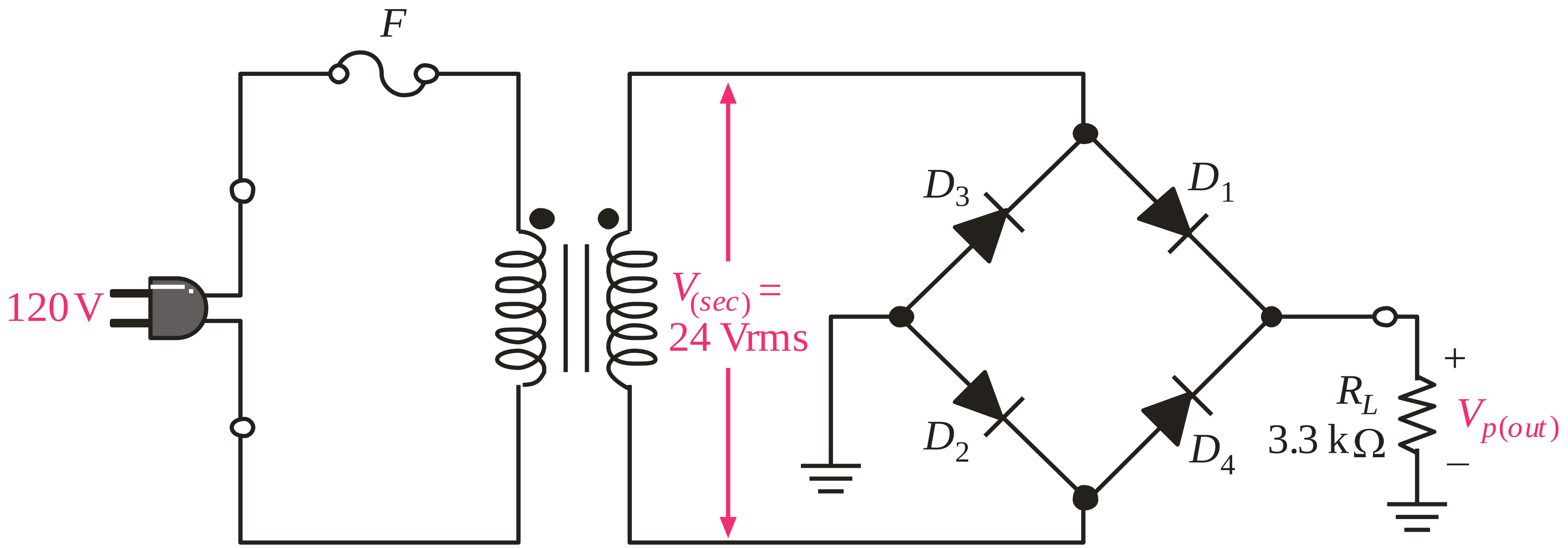
The peak output voltage = 9V
Output voltage, Vo = Vs - 2Vγ
Hence, Vs = 9 + 1.2 = 10.2 V
Peak value = Vrms x √2
So, Vs (rms) = 10.2 / √2 = 7.21 V

The turns ratio of the primary to each secondary winding is

$$\frac{N_1}{N_2} = \frac{220}{7.21} = 30.51$$

The PIV of each diode: $V_{s(peak)} - V_\gamma$ = 10.2 - 0.6 = **9.6 V**

Determine the peak output voltage and current in the 3.3 kΩ load resistor if V_{sec} = 24 V_{rms}. Use the practical diode model.



The peak output voltage is:

$$V_{p(sec)} = 1.41V_{rms} = 33.9\ \text{V}$$

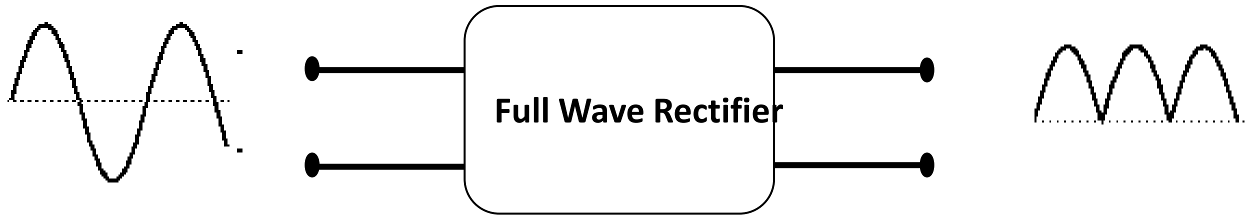
$$V_{p(out)} = V_{p(sec)} - 1.4\ \text{V} = 32.5\ \text{V}$$

Applying Ohm's law,

$I_{p(out)}$ = 9.8 mA

Review: Full Wave Rectifiers

- A full wave rectifier allows unidirectional current through the load during the entire 360 degree of input cycle.



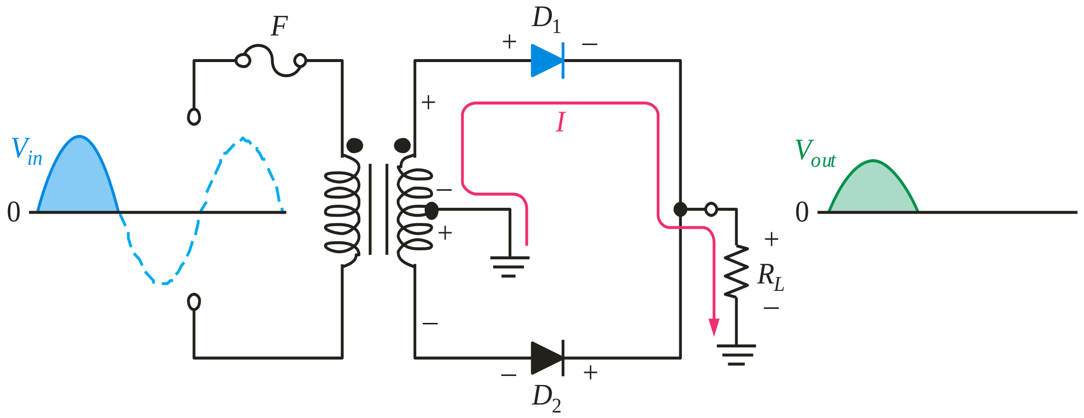
- The output voltage have twice the input frequency.

$V_{AVG} = 2V_{peak} / pi$

- V_{AVG} is 63.7% of Vpeak

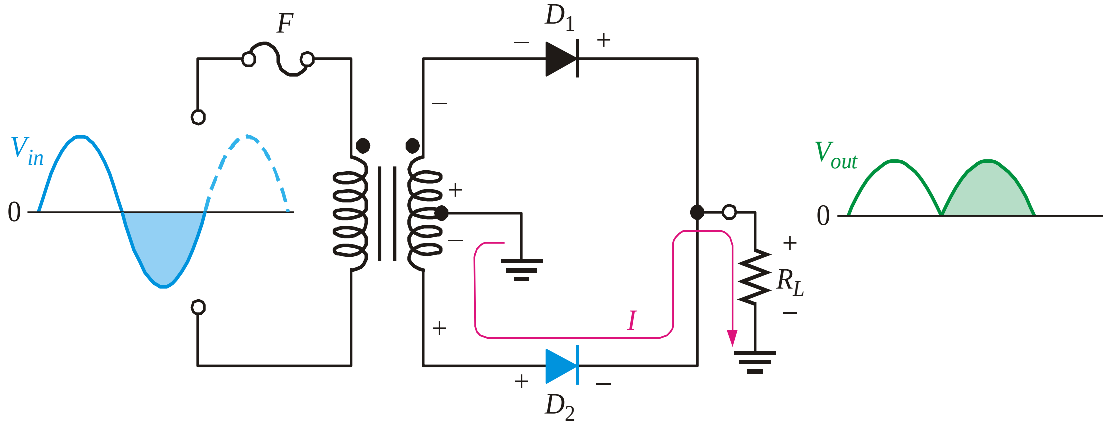
Recap: Center-Tapped Full Wave Rectifier

- A center-tapped transformer is used with two diodes that conduct on alternating half-cycles.



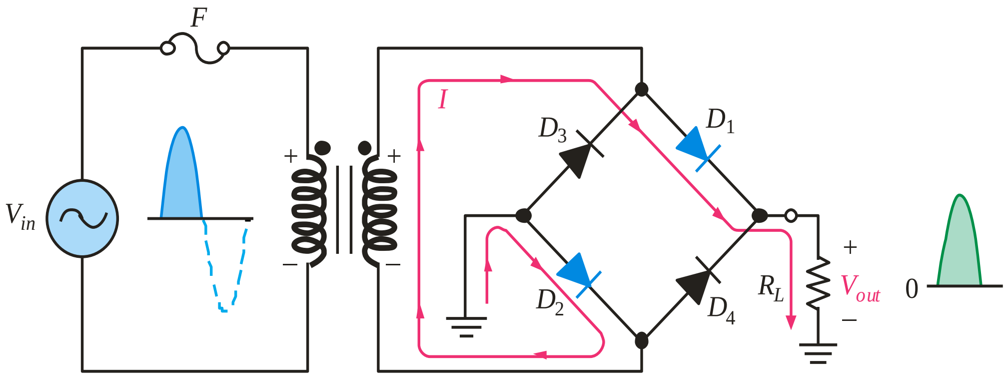
During the positive half-cycle, the upper diode is forward-biased and the lower diode is reverse-biased.

During the negative half-cycle, the lower diode is forward-biased and the upper diode is reverse-biased.



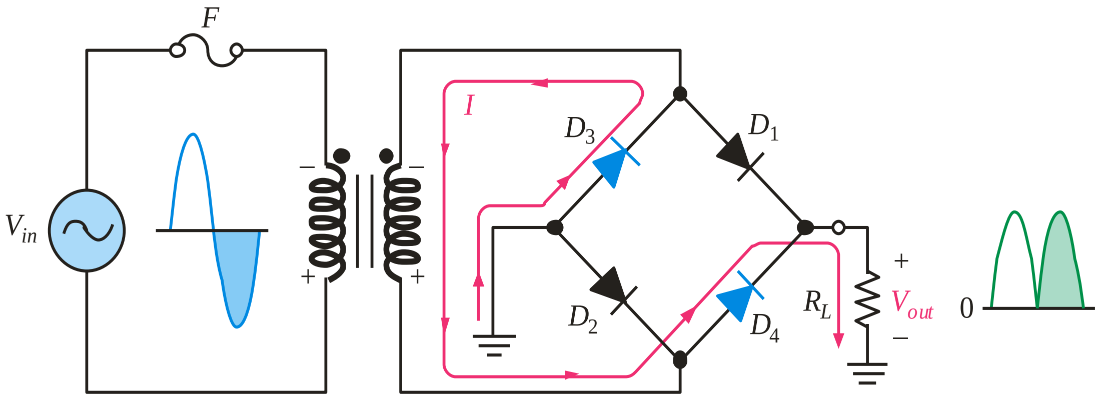
Recap: Bridge Full-Wave Rectifier

❖The Bridge Full-Wave rectifier uses four diodes connected across the entire secondary as shown.



Conduction path for the positive half-cycle.

Conduction path for the negative half-cycle.



Advantages of Full-Wave Rectifier Over Half-Wave Rectifier

1. The DC output voltage and load current values of full wave rectifier are twice than those of half wave rectifier.

2. The ripple factor is much less (0.482) than that of half wave rectifier (1.21).

3. The efficiency of full wave rectifier is twice (81.2%) than that of half wave rectifier (40.6%).

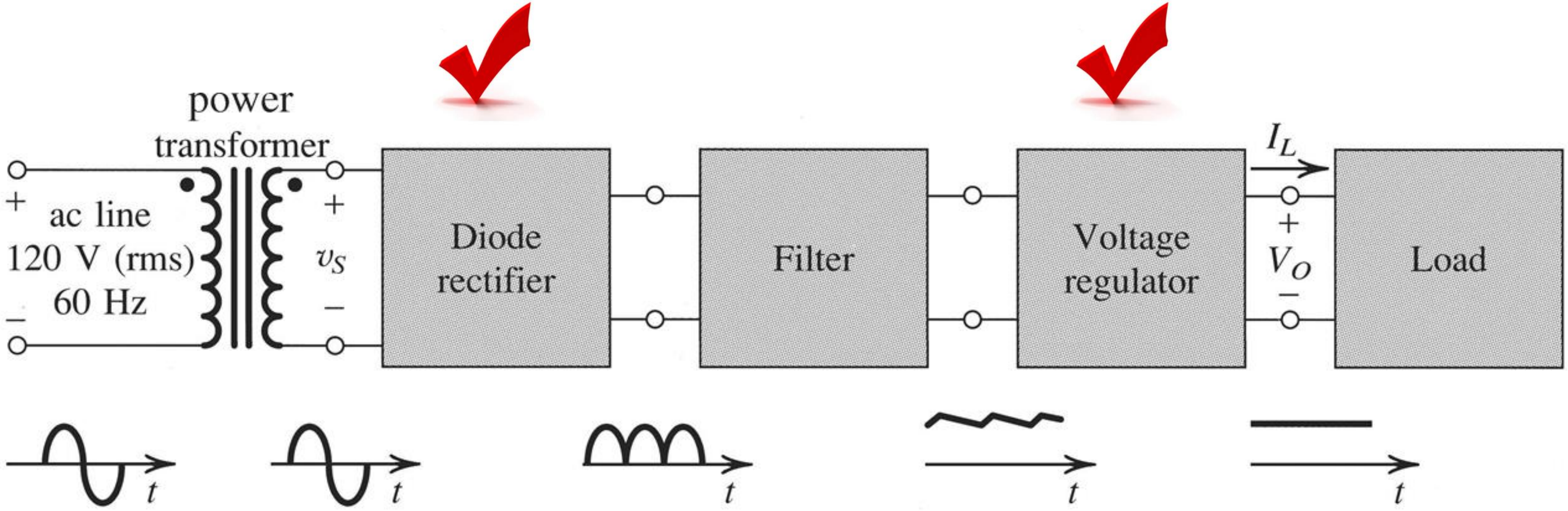
4. The TUF (Transformer Utilization Factor) of full wave rectifier is more than that of half wave rectifier.

Difference Between Half-Wave and Bridge Full-Wave Rectifier

	Parameters	Half Wave	Bridge Full Wave
1	Number of diodes	1	4
2	Peak secondary voltage, Vs	Vm	Vm
3	Peak Inverse voltage	Vm	Vm
4	D.C. current ID.C	Im/ π =0.318 Im	2Im/ π =0.636 Im
5	Maximum rectification efficiency,		
6	ηmax	40.6%	81.2%
6	Transformer utilization factor(TUF)	0.287	0.812
7	Ripple frequency, fr	fi	2fi

Points to Note…

- The most important consideration in designing a power supply is the DC voltage at the output
- It should be able to furnish the maximum current needed, maintaining the voltage at a constant level
- The AC ripple should be low
- The power supply should be protect in the event of short circuit on the load side
- The response of the power supply to temperature changes should be minimum

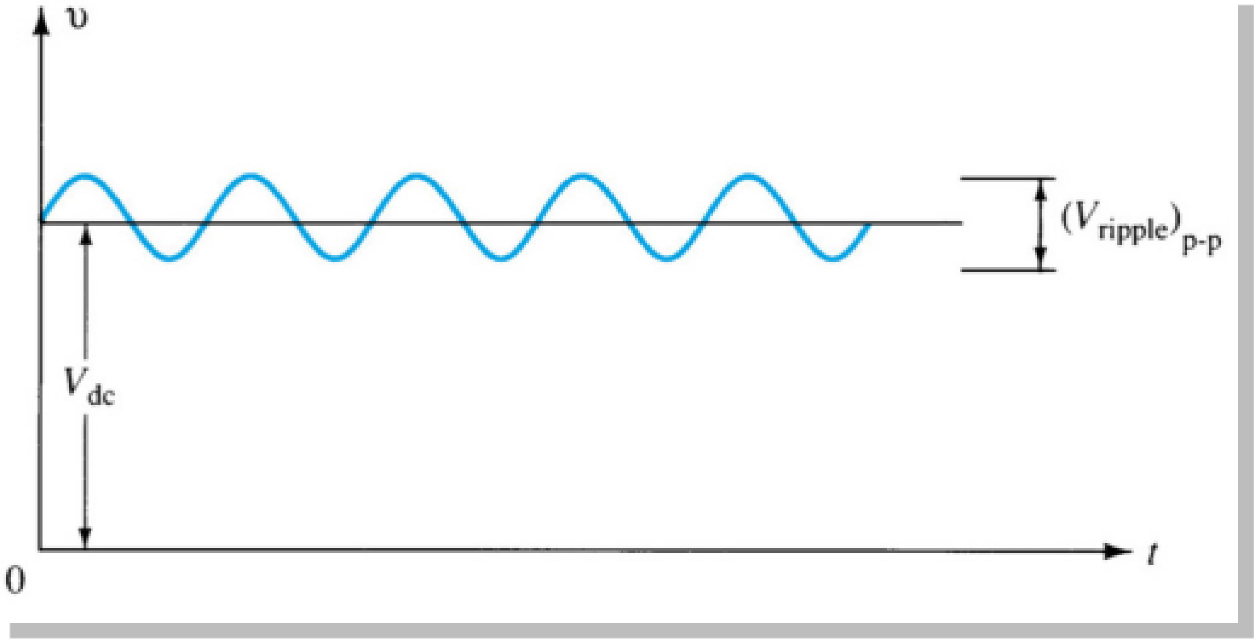


- Ripples: The output from the rectifier section is a pulsating DC.

- Need the filter circuit to reduce the peak-to-peak pulses to a small ripple voltage.

Ripple Factor

After the filter circuit a small amount of AC is still remaining. The amount of ripple voltage can be rated in terms of ripple factor (r).



$$\%r = \frac{\text{ripple voltage (rms)}}{\text{dc voltage}} = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

Ripple Factor: Comparison

Half-Wave

DC output:

$$V_{dc} = 0.318V_m$$

AC ripple output:

$$V_{r(rms)} = 0.385V_m$$

Ripple factor:

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

Full-Wave

DC output:

$$V_{dc} = 0.636V_m$$

AC ripple output:

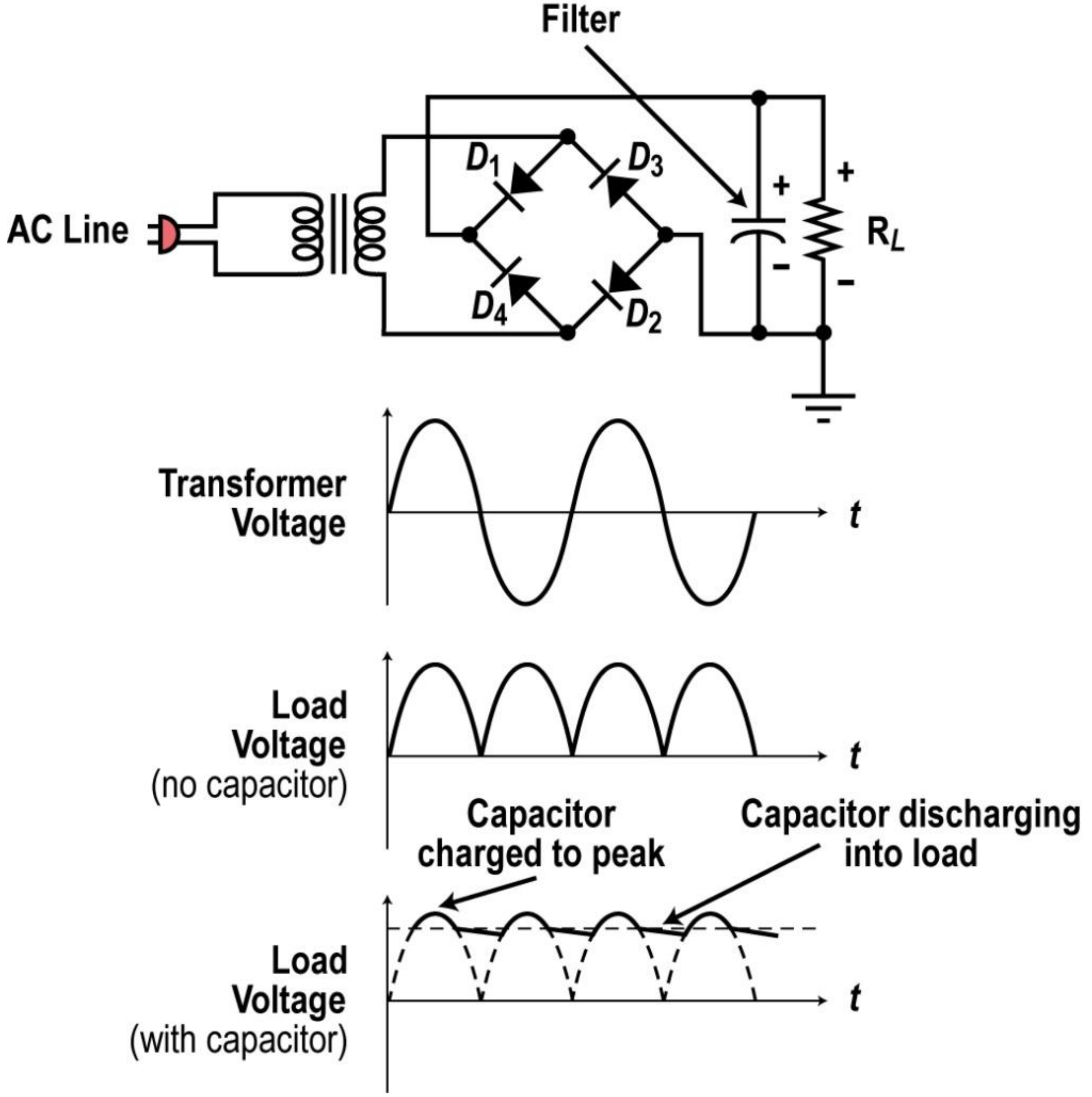
$$V_{r(rms)} = 0.308V_m$$

Ripple factor:

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100$$
$$= \frac{0.308_{Vm}}{0.636_{Vm}} \times 100 = 48\%$$

How the Filter Works

- A large capacitor is connected across the load resistor. This capacitor filters the pulses into a more constant DC.
- When the diode conducts, the capacitor charges up to the peak of the sine wave.
- Then when the sine voltage drops, the charge on the capacitor remains. Since the capacitor is large it forms a long time constant with the load resistor. The capacitor slowly discharges into the load maintaining a more constant output.
- The next positive pulse comes along recharging the capacitor and the process continues.



- The capacitor does a good job of smoothing the pulses from the rectifier into a more constant DC.
- A small variation occurs in the DC because the capacitor discharges a small amount between the positive and negative pulses. Then it recharges. This variation is called ripple.
- The ripple can be reduced further by making the capacitor larger.
- The ripple appears to be a sawtooth shaped AC variation riding on the DC output.
- A small amount of ripple can be tolerated in some circuits but the lower the better overall.

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