# LECTURE 5

# Full-Wave Rectifier (FWR)

**Analog Electronics**

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*By*

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# Outline and Aim

**After completing this lecture, you should be able to:**

- Analyze the operation of a full-wave rectifier
- Describe how the diodes function in a rectifier
- Determine the average value of a full-wave rectified voltage
- Describe the Center-Tapped Full-Wave Rectifier
- Describe the effect of the Turns Ratio $n$ on Full-Wave Output Voltage
- Determine the peak inverse voltage (PIV)

# The Full-Wave Rectifier (FWR)

The result of full-wave rectification is a dc output voltage that pulsates every half-cycle of the input, as shown in Fig. 9.

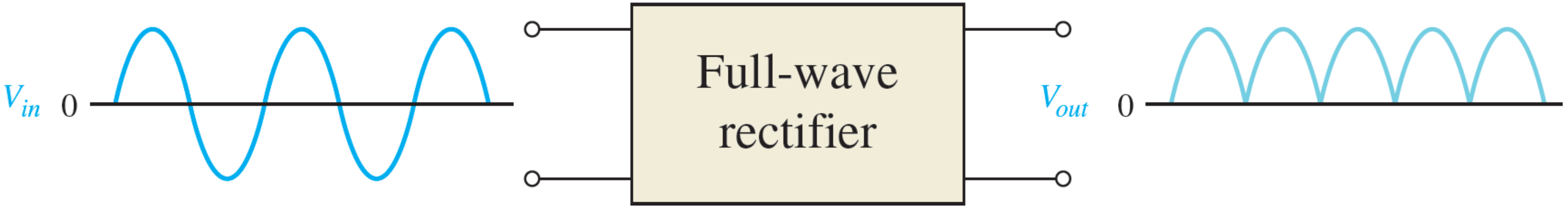



Fig. 9: Full-wave rectification

The average value for a full-wave rectified output voltage is twice that of the half-wave rectified output voltage, expressed as follows:

$$V_{AVG} = \frac{2V_{p(out)}}{\pi}$$

# The Full-Wave Rectifier (FWR)

The **difference** between half-wave and full-wave rectification is that:

## Half-wave rectifier:

Allows only one-half of the current to the load during the entire input cycle.

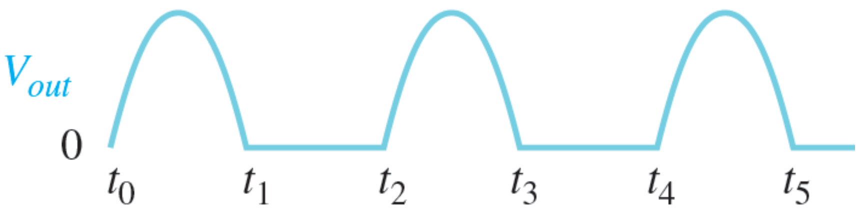



Fig. 10: Output of a half-wave rectifier

$$V_{AVG} = \frac{V_{p(out)}}{\pi}$$

## Full-wave rectifier :

Allows unidirectional current to the load during the entire input cycle.

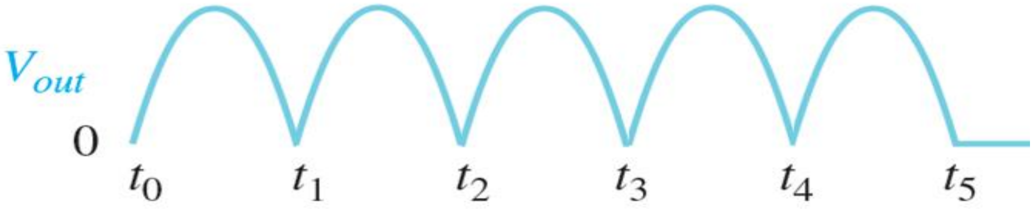



Fig. 11: Output of a full-wave rectifier

$$V_{AVG} = \frac{2V_{p(out)}}{\pi}$$

# The Full-Wave Rectifier (FWR)

## EXAMPLE 5:

Find the average value of the full-wave rectified output voltage in Fig. 12

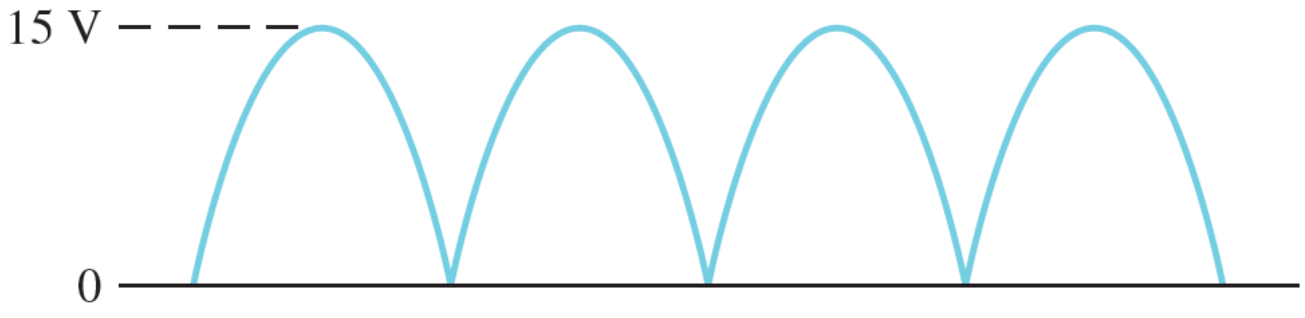



Fig. 12: Output of a half-wave rectifier

## Solution:

$$V_{AVG} = \frac{2V_{p(out)}}{\pi} = \frac{2*15}{3.14} = 9.55\ V$$

# The Full-Wave Rectifier (FWR)

## 1. Center-Tapped Full-Wave Rectifier

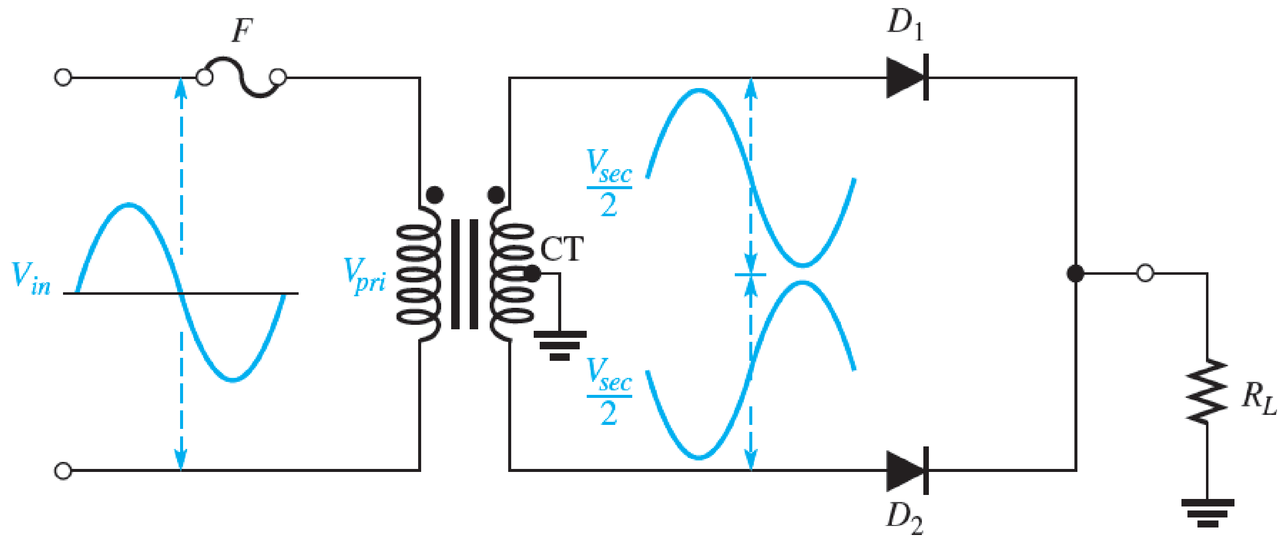



Fig. 13: Center-Tapped Full-Wave Rectifier

## 2. Full-Wave Bridge Rectifier

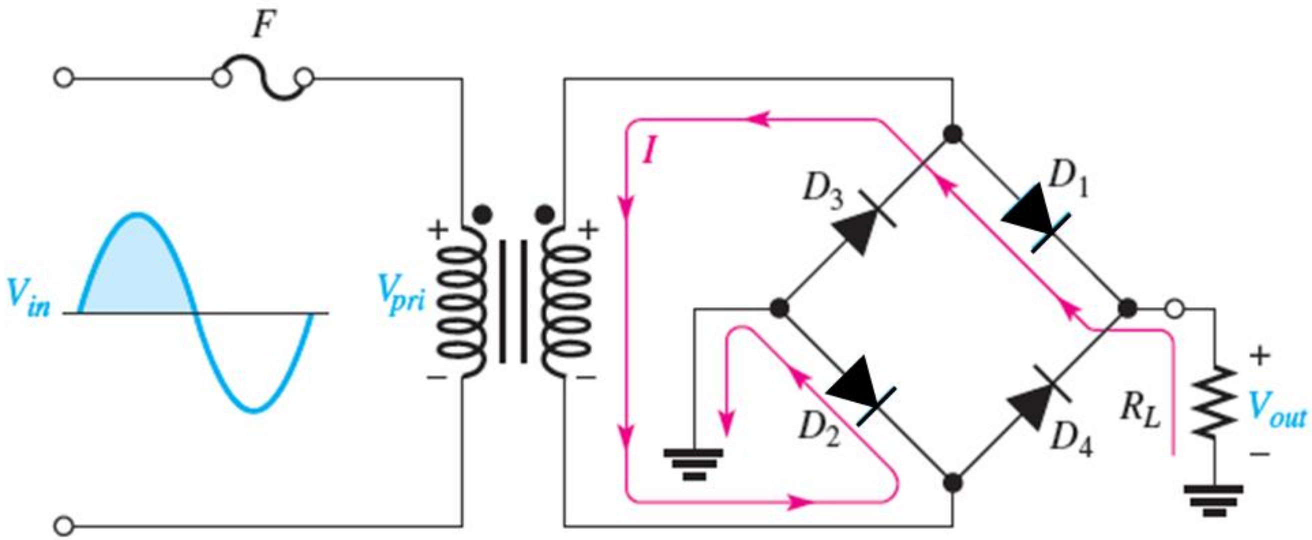



Fig. 14: Full-Wave Bridge Rectifier

# The Full-Wave Rectifier (FWR)

## 1. Center-Tapped Full-Wave Rectifier

- The center-tapped (CT) full-wave rectifier uses two diodes connected to the secondary of a center-tapped transformer.

- The input signal is coupled through the transformer to the secondary.

- Half of the secondary voltage appears between the center tap and each end of the secondary winding, as shown in Fig. 13.

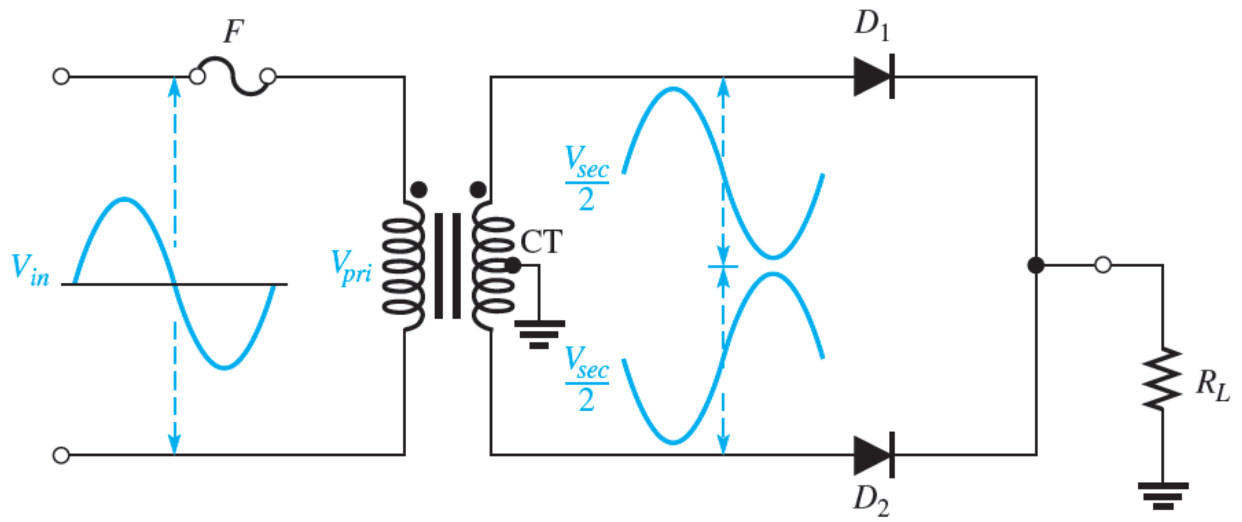



Fig. 13: Center-Tapped Full-Wave Rectifier

# The Full-Wave Rectifier (FWR)

## 1. Center-Tapped Full-Wave Rectifier

For a **positive half-cycle** of the input voltage, the polarities of the secondary voltages are shown in Fig 15.

**a)** Forward-biases the upper diode $D_1$

**b)** Reverse-biases the lower diode $D_2$.

The current path is through $D_1$ and the load resistor $R_L$, as indicated.

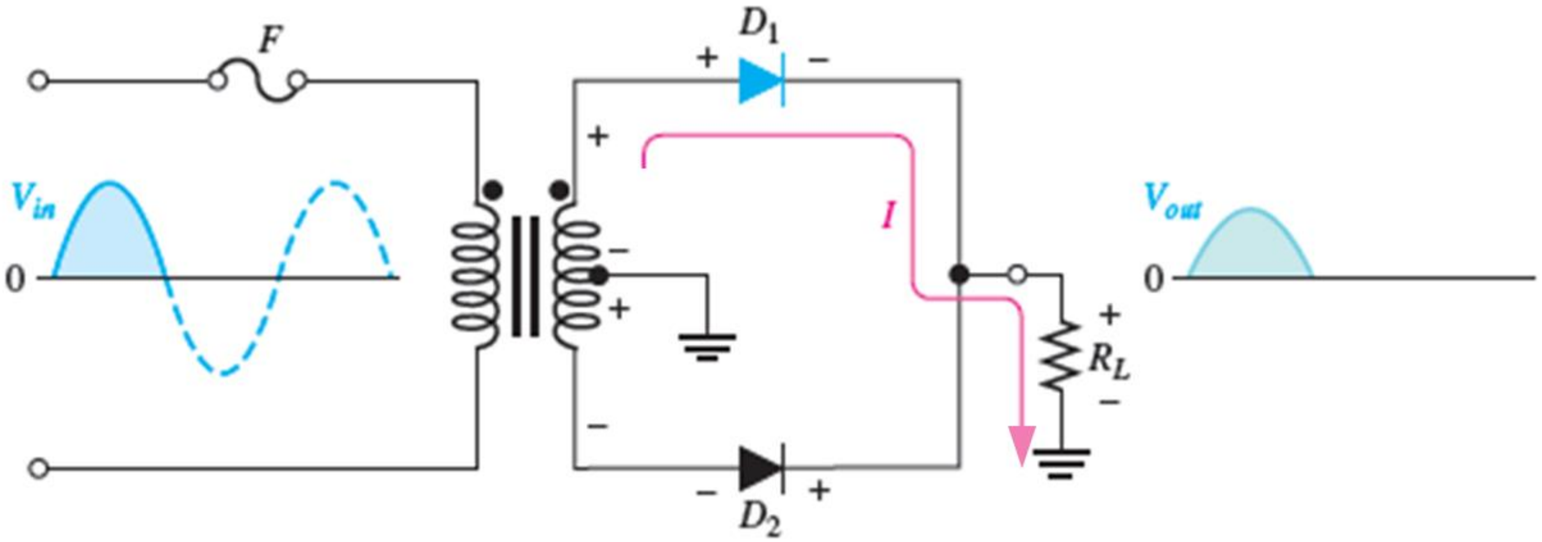



Fig. 15: During positive half-cycles, $D_1$ is forward-biased and $D_2$ is reverse-biased.

# The Full-Wave Rectifier (FWR)

## 1. Center-Tapped Full-Wave Rectifier

For a **negative half-cycle** of the input voltage, the polarities of the secondary voltages are shown in Fig 15.

**a)** Forward-biases the lower diode $D_2$ **b)** Reverse-biases the upper diode $D_1$.

The current path is through $D_2$ and the load resistor $R_L$, as indicated.

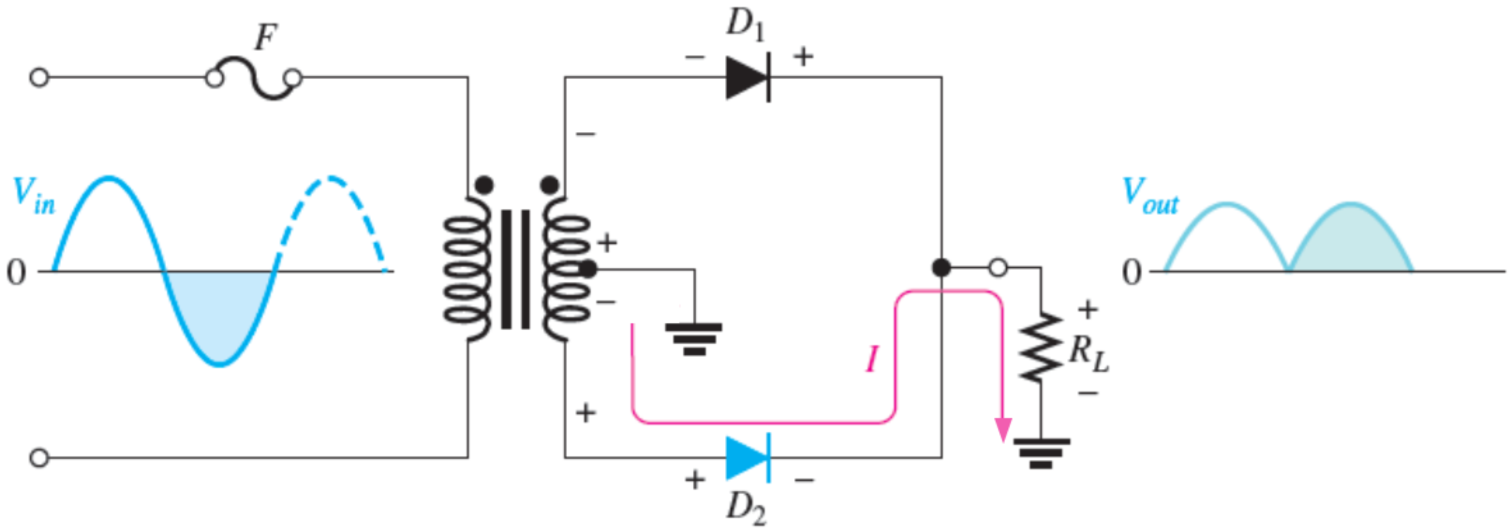



Fig. 15: During negative half-cycles, $D_2$ is forward-biased and $D_1$ is reverse-biased.

# Center-Tapped Full-Wave Rectifier

## Effect of the Turns Ratio *n* on Full-Wave Output Voltage:

- The output voltage is determined by the **turns ratio, *n***, of the transformer.
- The peak output voltage is one-half the peak secondary voltage.

$$n = \frac{N_{sec}}{N_{pri}}$$

$$V_{p(out)} = \frac{nV_{p(in)}}{2}$$

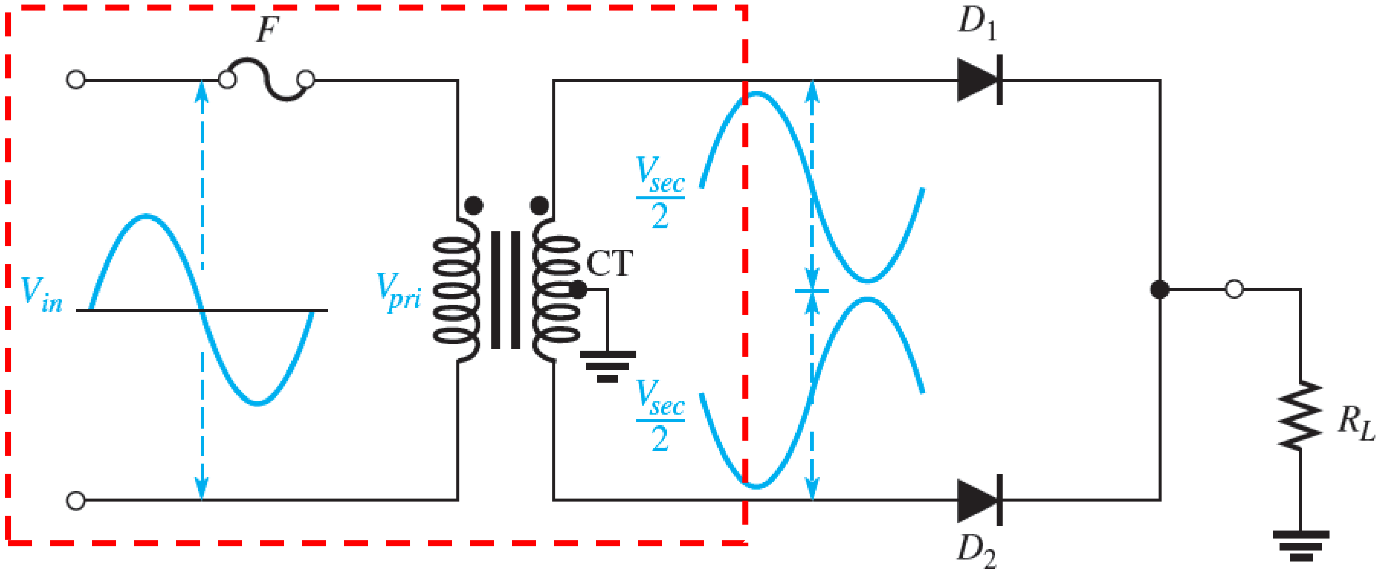



Fig. 16: Center-Tapped Full-Wave Rectifier

The primary voltage $V_{pri}$ is the same as the input voltage $V_{in}$.

# Center-Tapped Full-Wave Rectifier

**Example1:** To obtain an output voltage $\mathbf{V}_{\boldsymbol{p(out)}}$ with a peak value approximately equal to the input peak $\boldsymbol{V}_{\boldsymbol{p(in)}}$, what would be the turn ratio $\boldsymbol{n}$ of a transformer?

**Solution:**

$$\mathbf{V}_{\boldsymbol{p(out)}} = \frac{\boldsymbol{n}\boldsymbol{V}_{\boldsymbol{p(in)}}}{\mathbf{2}}$$

$$\boldsymbol{n} = \frac{\mathbf{2}\mathbf{V}_{\boldsymbol{p(out)}}}{\boldsymbol{V}_{\boldsymbol{p(in)}}}$$

Since, $\mathbf{V}_{\boldsymbol{p(out)}}$ equal $\boldsymbol{V}_{\boldsymbol{p(in)}}$

$$\boldsymbol{n} = \mathbf{2}$$

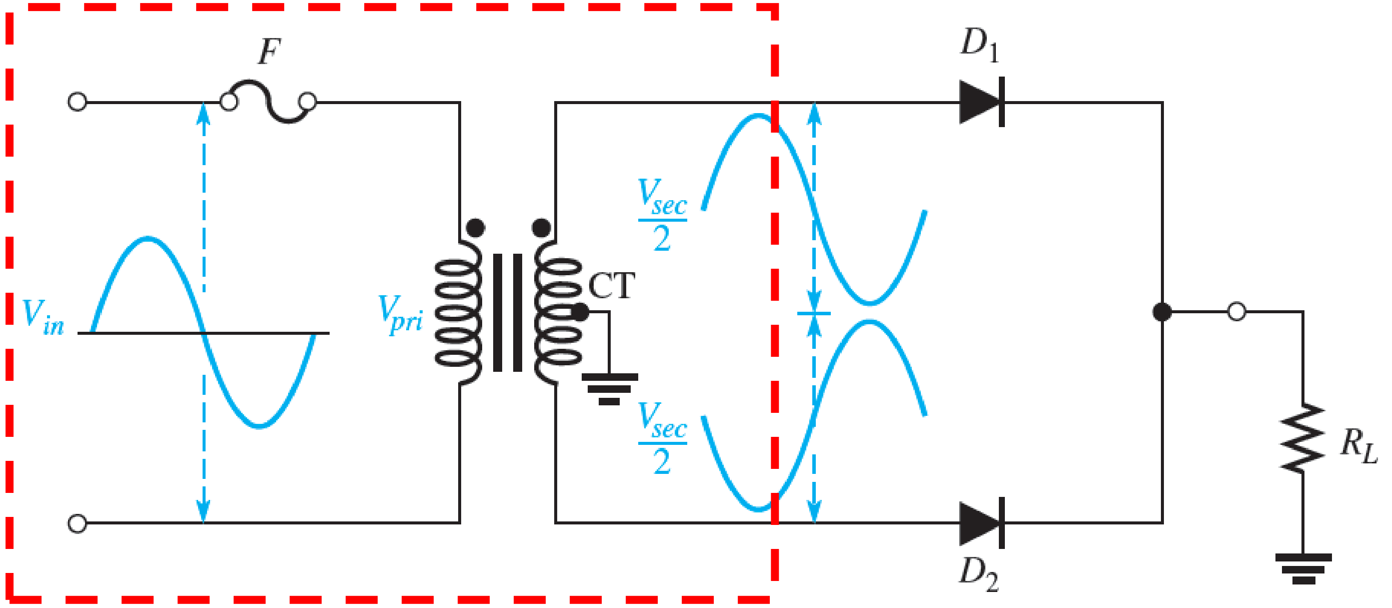



Fig. 16: Center-Tapped Full-Wave Rectifier

# Center-Tapped Full-Wave Rectifier

**Example2:** Specify the turns ratio of a transformer required for a center-tapped full-wave rectifier if the input voltage is 220 $V_{rms}$ and the required output is 12 V peak?

**Solution:**

$$V_{p(in)} = \frac{V_{rms(in)}}{0.707}$$

$$V_{p(in)} = \frac{220\ V}{0.707} = 311\ V$$

$$n = \frac{2V_{p(out)}}{V_{p(in)}}$$

$$n = \frac{2 \times 12}{311} = 0.0771$$

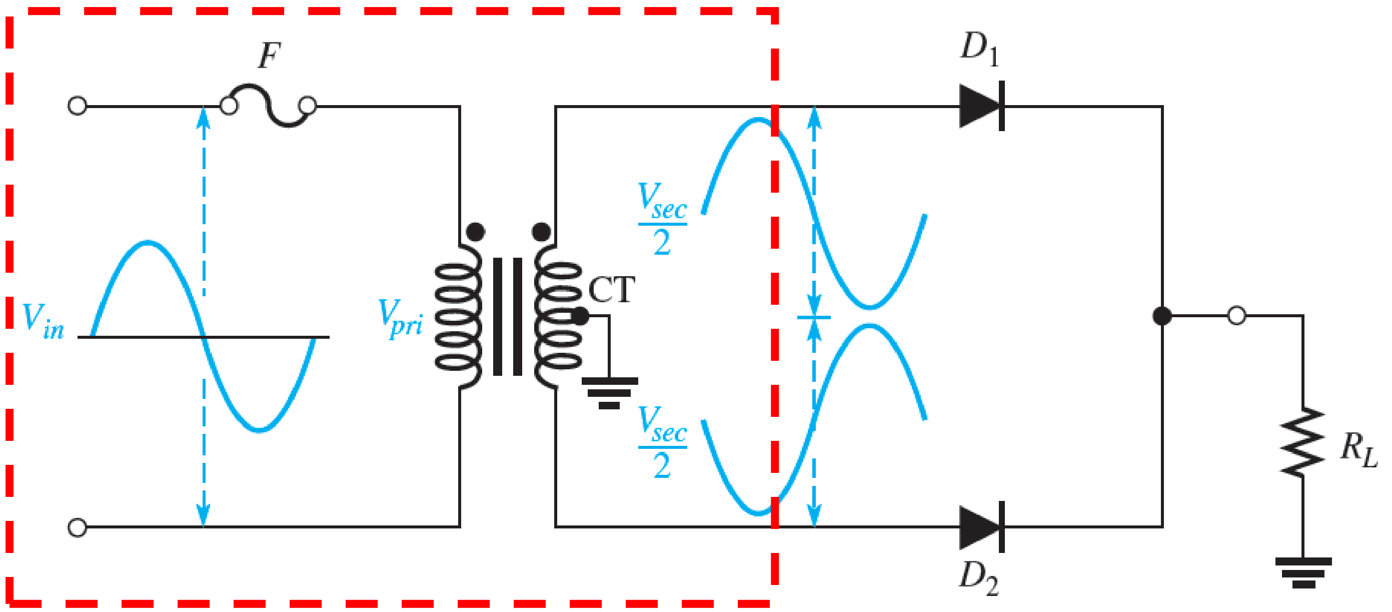



Fig. 16: Center-Tapped Full-Wave Rectifier

# Center-Tapped Full-Wave Rectifier

**Example3:** For a center-tapped full-wave rectifier if the input voltage is 220 $V_{rms}$, What is the peak output if the turns ratio is 0.15?

**Solution:**

$$V_{p(in)} = \frac{V_{rms(in)}}{0.707}$$

$$V_{p(in)} = \frac{220\,V}{0.707} = 311\ V$$

$$V_{p(out)} = \frac{nV_{p(in)}}{2}$$

$$V_{p(out)} = \frac{0.15 \times 311}{2} = 23.3\ V$$

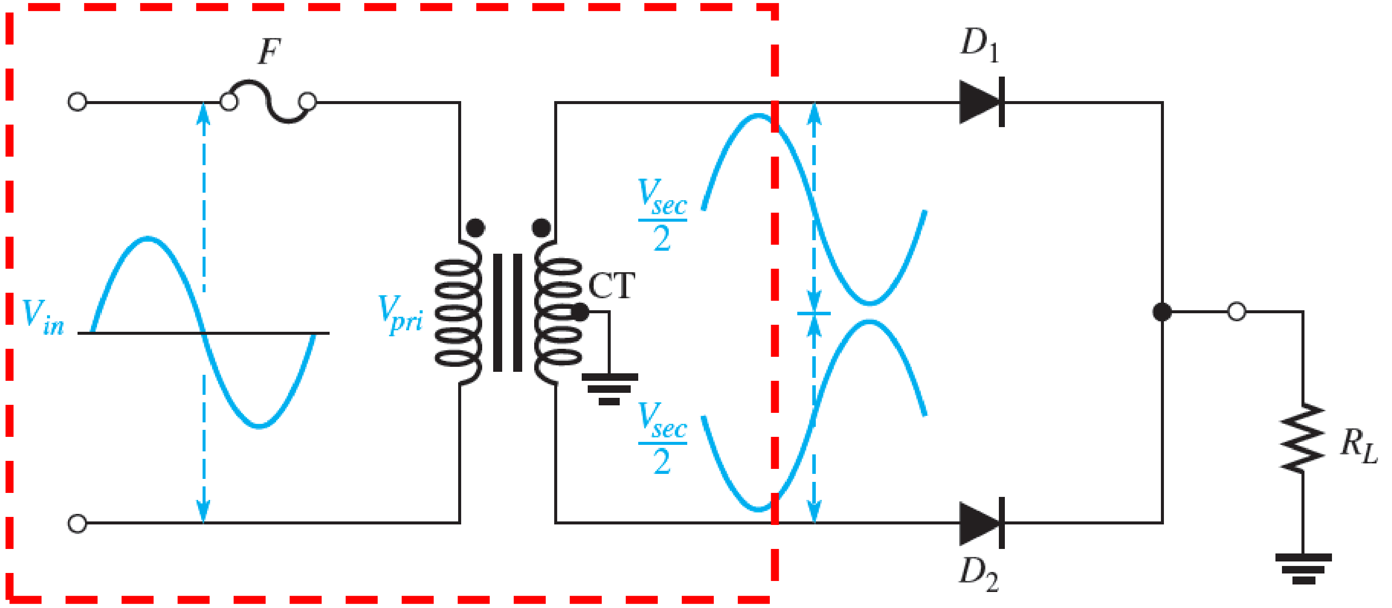



Fig. 16: Center-Tapped Full-Wave Rectifier

# Center-Tapped Full-Wave Rectifier

## Peak Inverse Voltage (PIV)

Each diode in the FWR is alternately forward-biased and then reverse-biased.

**The maximum** **reverse voltage $V_R$** **that each diode must withstand** is the peak value of the total secondary voltage $V_{p(sec)}$.

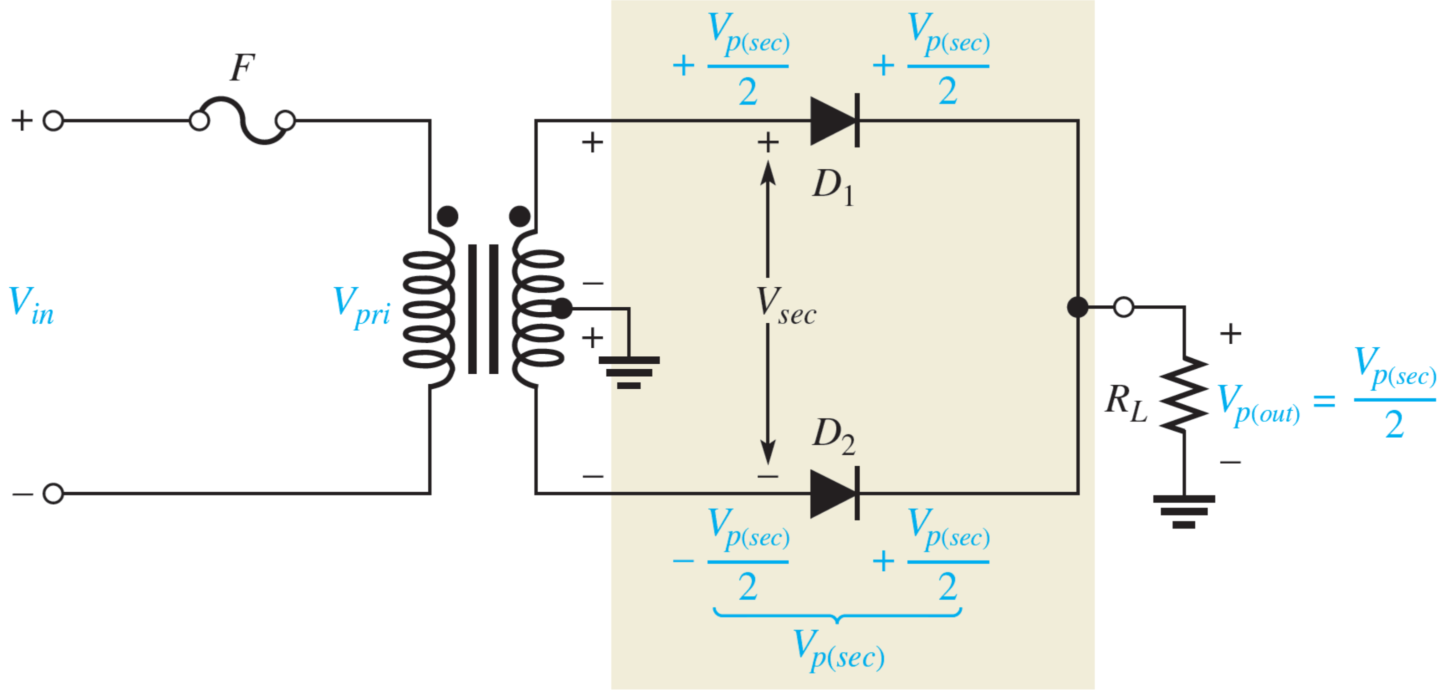



Fig. 17: Center-Tapped Full-Wave Rectifier showing the Peak Inverse Voltage PIV

# Center-Tapped Full-Wave Rectifier

## Peak Inverse Voltage (PIV)

When the total secondary voltage has the polarity shown in Fig. 17,

The anode of $D_1$ is $+\frac{V_{p(sec)}}{2}$ Which is equal to the cathode voltage

The anode of $D_2$ is $-\frac{V_{p(sec)}}{2}$

$$V_{D2} = \frac{V_{p(sec)}}{2} - \frac{-V_{p(sec)}}{2}$$

$$V_{D2} = V_{p(sec)}$$

$$\text{PIV} = V_{p(sec)}$$

$$\text{PIV} = 2V_{p(out)}$$

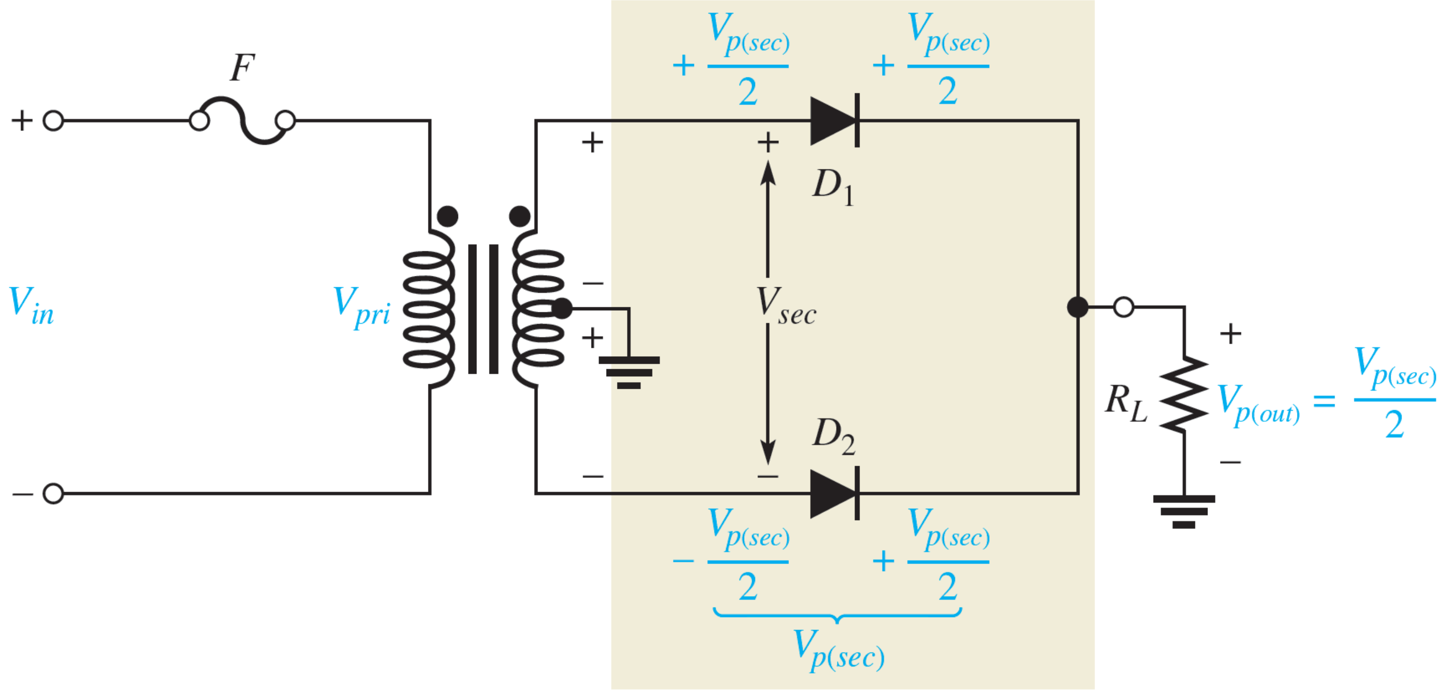



Fig. 17: Center-Tapped Full-Wave Rectifier showing the Peak Inverse Voltage PIV

# Center-Tapped Full-Wave Rectifier

**Example 4:**

a) For ideal diodes, show the voltage waveforms across the secondary winding and $R_L$ when a 120 $V_{rms}$ sine wave is applied to the primary winding in Fig. 18.

b) What minimum PIV rating must the diodes have?

**Solution:**

$$a)\ V_{p(pri)} = \frac{V_{rms}}{0.707} = 169.7\ V$$

$$V_{p(sec)} = nV_{p(pri)}$$

$$V_{p(sec)} = 2V_{p(pri)} = 2 \times 169.7$$

$$= 339.4\ V$$

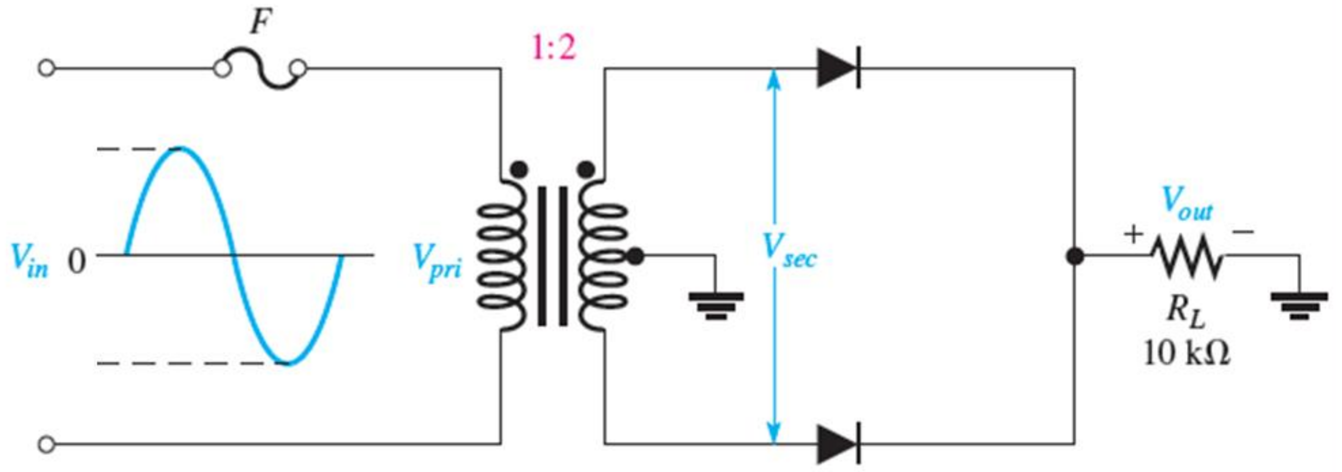
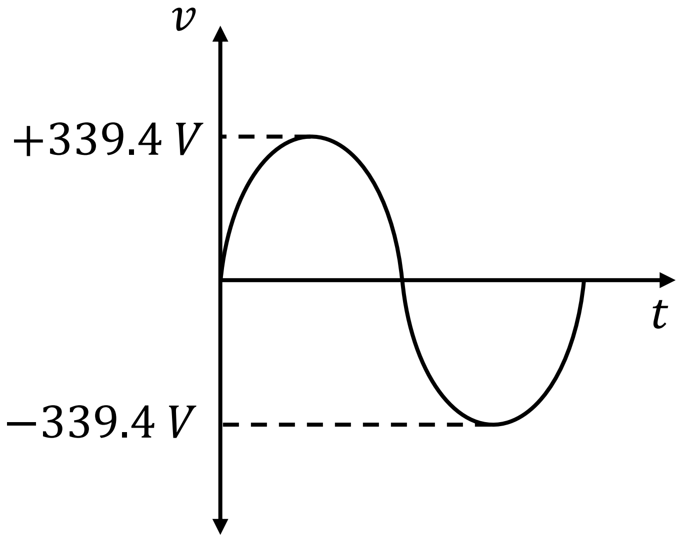



Fig. 18: Center-Tapped Full-Wave Rectifier

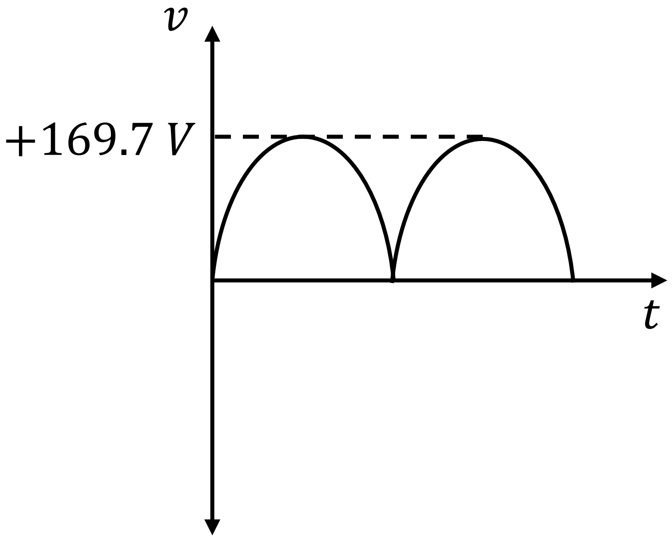
$$V_{p(RL)} = \frac{V_{p(sec)}}{2} = \frac{339.4}{2} = 169.7\ V$$

# Center-Tapped Full-Wave Rectifier

## Complement example 4:




Waveforms across the secondary winding




Waveforms across the $R_L$

$$b)\ PIV = V_{p(sec)} = 339.4\,V$$

# Center-Tapped Full-Wave Rectifier

**Example 5:**

a) For the diodes, show the voltage waveforms across the secondary winding and $R_L$ when a 120 $V_{rms}$ sine wave is applied to the primary winding in Fig. 18.

b) What minimum PIV rating must the diodes have?

Exercises

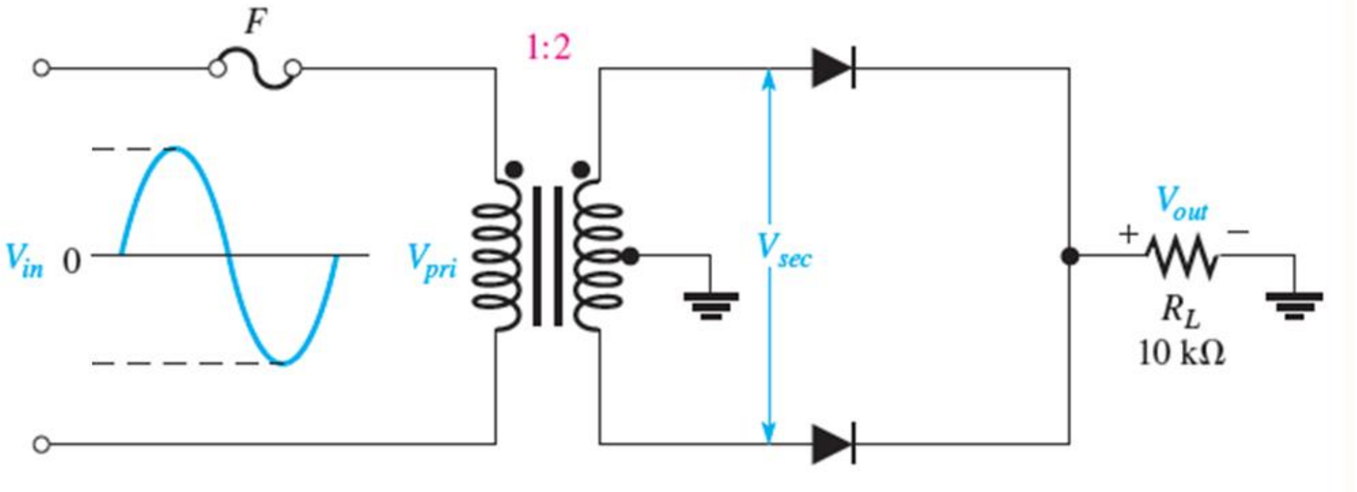



Fig. 18: Center-Tapped Full-Wave Rectifier