# Power converters
# *AC/DC Converters*

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## Single Phase Converters

- The basic rectifier principles are understood from the operation of single phase circuits.
- The emphasis will be on physical understanding not on the detailed analysis.
- First consider a simple half wave rectifier circuit with resistive load.

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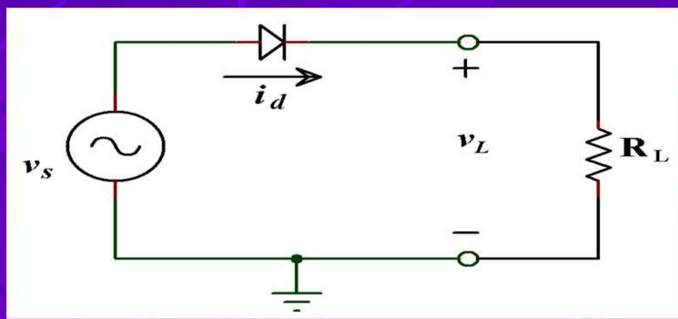
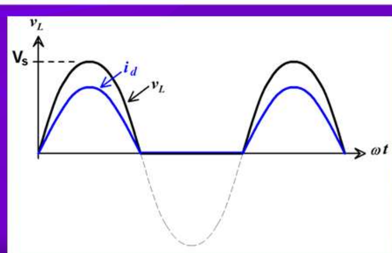
# Half-Wave Rectifier




***Resistive Load***

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# Half-Wave Rectifier

***Resistive Load***

- The load voltage is nearly same as the source voltage during positive half cycle.
- The current is also sinusoidal during positive half cycle.
- During negative half cycle, the diode is reverse biased the load current is zero, source current is zero and the load voltage is also zero.

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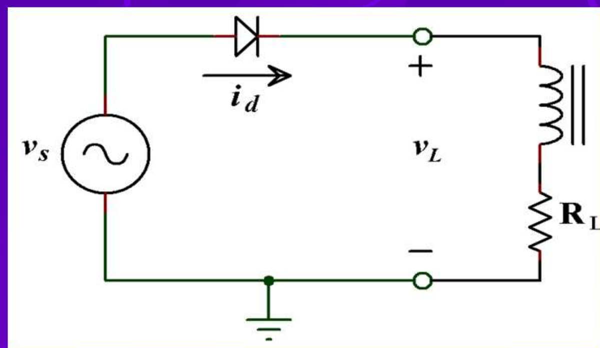
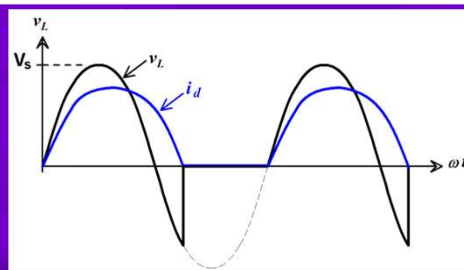
## Half wave Rectifier




***Inductive Load***

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## Half wave Rectifier

***Inductive Load***

- For inductive load, the current will keep on flowing even if the source voltage is negative.
- This is due to the stored energy in the inductor.
- When the source voltage reverses its polarity, the inductor becomes a source and the polariyty of this source is so that it will keep the current flowing in the same direction.
- When the stored energy is release the diode current will reduced to zero and the diode is reverse biased.
- During a part of the negative cycle, the load voltage will follow the source voltage.

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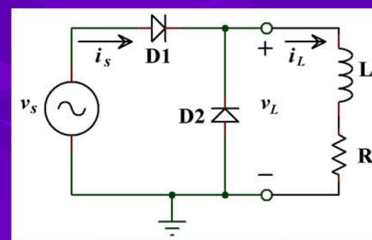
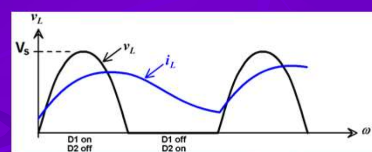
# Half wave Rectifier

***Inductive Load with Freewheeling Diode***

- The addition of diode $D_2$ permits the load current to be continuous and prevents $v_L$ from going negative.
- When $D_1$ is off, $D_2$ allows the energy in the circuit to maintain continuity by providing a path through which the inductor current can free wheel.
- Diode $D_2$ is known as free-wheel diode, by-pass, fly-back, catch diode or commutation diode.

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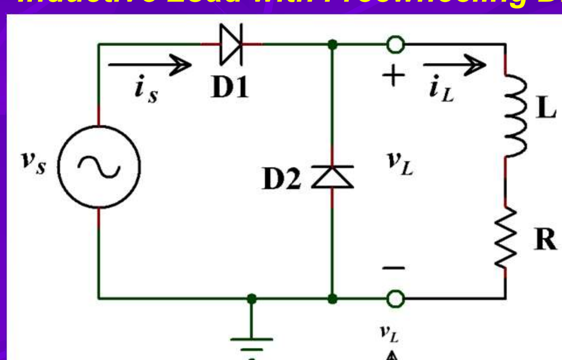
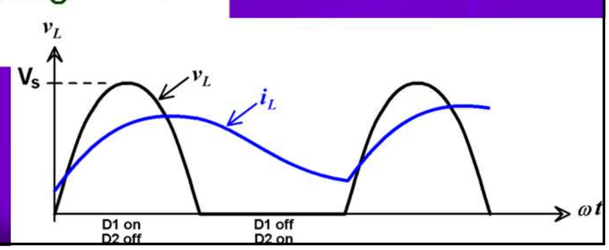
# Half wave Rectifier

***Inductive Load with Freewheeling Diode***



# Half wave Rectifier

***Inductive Load with Freewheeling Diode***

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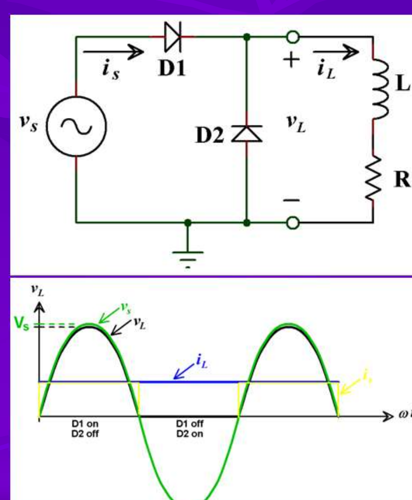
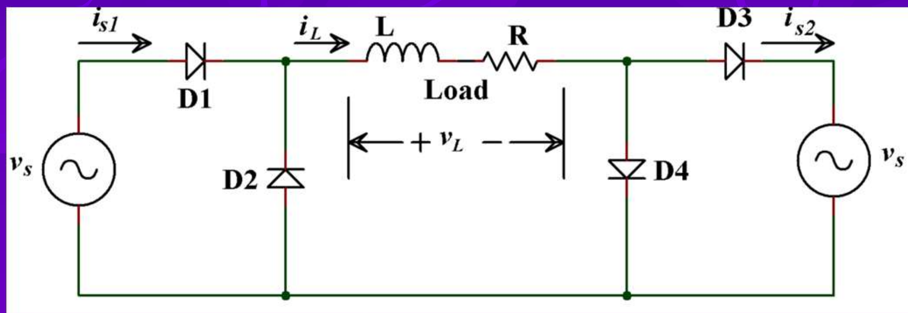
# Half wave Rectifier

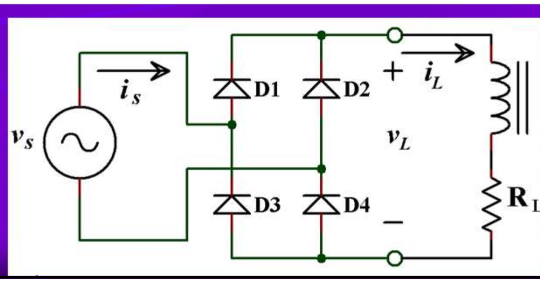
***Highly Inductive Load with Freewheeling Diode***

- If we assume that the inductor is very large approaching infinity, the load current will become constant without any fluctuations.
- The Green line shows $v_s$, Black is the load voltage, blue is the load current and yellow is the source current.
- It can be observed that the source current is unidirectional step waveform.



## 1-Φ Bridge Rectifier

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## 1-Φ Bridge Rectifier

- AC source current contain no DC component.
- For same AC source voltage, the full wave rectifier produces an average output voltage twice that of the half-wave circuit with free-wheeling diode.
- The half-wave rectifier with free wheeling diode serves as the basic building block for the bridge circuit and in this context the circuit is sometimes called a half-bridge.

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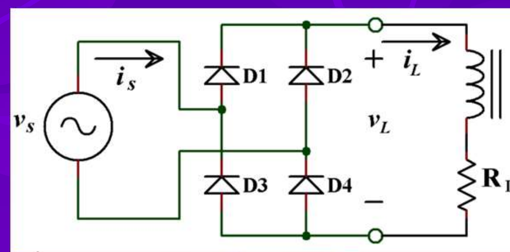
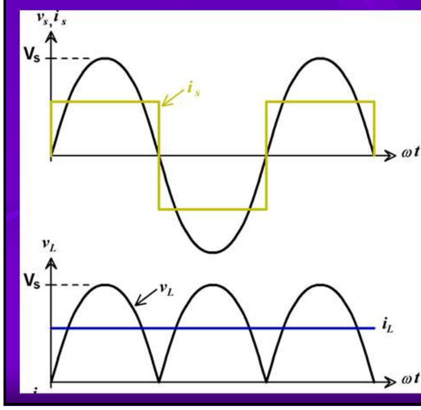
# 1-Φ Bridge Rectifier

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# 1-Φ Bridge Rectifier

- The source currents $i_{s1}$ and $i_{s2}$ contain DC components, however, the total source current for the full-bridge circuit does not contain any DC components.
- The reason is that the source current in the bridge is sum of the two source currents, which have DC components of equal magnitude but of opposite polarity.
- As the load is highly inductive, the load current $i_L$ is constant.

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# 1-Φ Bridge Rectifier

- During positive half cycle, $i_L$ is supplied by D1 and D4, therefore, $i_s = i_L$.
- During negative half cycle, $i_L$ is supplied by D2 and D3, therefore, $i_s = - i_L$.
- Therefore the source current will have a square wave shape with zero DC component.

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# Analysis of 1-Φ Converter

***Power Transfer From Mains***

Consider that a Single Phase Bridge rectifier is connected to the mains supply an it draws a non-sinusoidal current from the mains.

The average or mean output Voltage is

$$V_{mean} = \frac{1}{\pi}\int_0^{\pi} V_s \sin \omega t d\omega t \quad (1)$$

$$V_{mean} = \frac{2V_s}{\pi} \quad (2)$$

The average load current is

$$I_L = \frac{V_{mean}}{R} = \frac{2V_s}{\pi R} \quad (3)$$

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# Analysis of 1-Φ Converter

***Power Transfer From Mains***

The average load Power is

$$P_{av} = V_{mean} I_L \quad \textbf{(4)}$$

$$= \frac{2V_s}{\pi}\frac{2V_s}{\pi R} = \frac{4V_s^{\,2}}{\pi^2 R} \quad \textbf{(5)}$$

Since $V_s = \sqrt{2}V_{rms}$

$$P_{av} = \frac{8V_{rms}^2}{\pi^2 R} \quad \textbf{(6)}$$

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# Analysis of 1-Φ Converter

***Power Transfer From Mains***

Since the AC current is a simple square wave, it has the well known spectrum of odd harmonics with amplitude inversely proportional to the order.

$$I_n = \frac{4I_L}{n\pi} \quad \textbf{(7)}$$

For n=1,3,5…

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# Analysis of 1-Φ Converter

We also know that in case of non-sinusoidal mains current, only the fundamental component of current contributes towards average power.

$$P_{av} = V_{mean} I_{1rms} \qquad \textbf{(8)}$$

Peak value of fundamental current is

$$I_1 = \frac{4 I_L}{\pi} = \frac{4 \times 2 \times V_s}{\pi \times \pi \times R} = \frac{8V}{\pi^2 R} = \frac{8 V_{rms} \times \sqrt{2}}{\pi^2 R}$$

$$I_{1rms} = \frac{I_1}{\sqrt{2}} = \frac{8 V_{rms}}{\pi^2 R} \qquad \textbf{(9)}$$

Therefore

$$P_{av} = \frac{8 V_{rms}^2}{\pi^2 R} \qquad \textbf{(10)}$$

Note that the results obtained in equations (6) and (10) is same