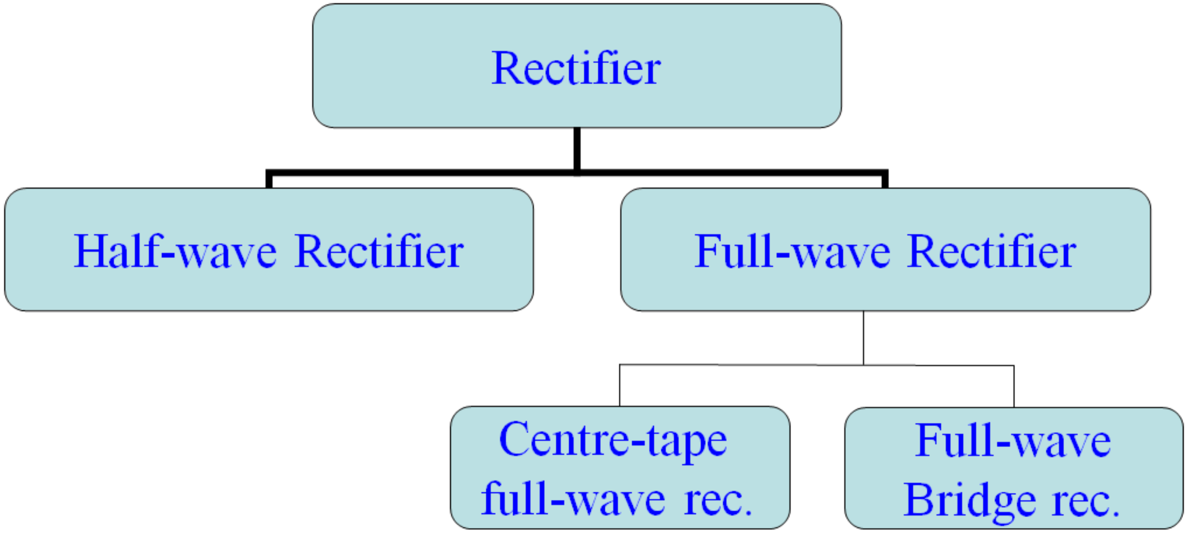
# ELG4139: Rectifiers and Controlled Rectifiers

## AC to DC Converters

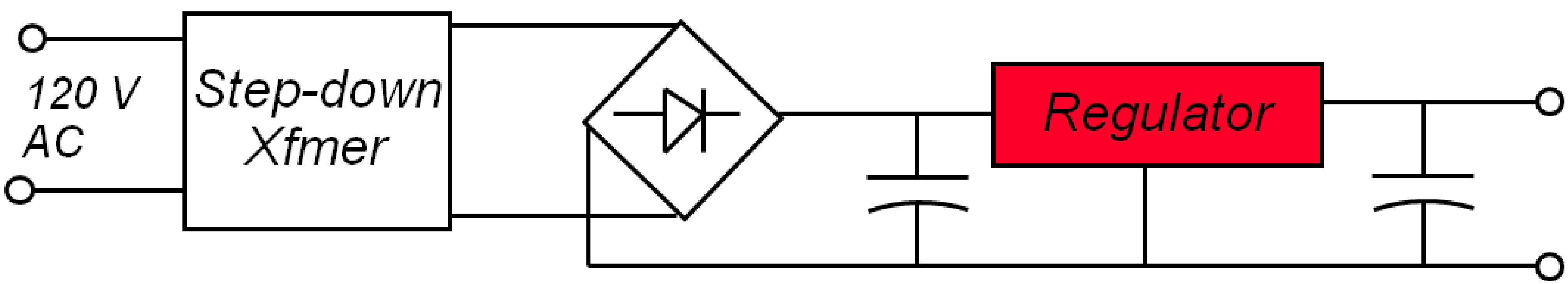



| | Half-wave | Centre-tap | Bridge type |
|---|---|---|---|
| No. of diode | 1 | 2 | 4 |
| Transformer necessary | No | Yes | No |
| Maximum efficiency | 40.6% | 81.2% | 81.2% |

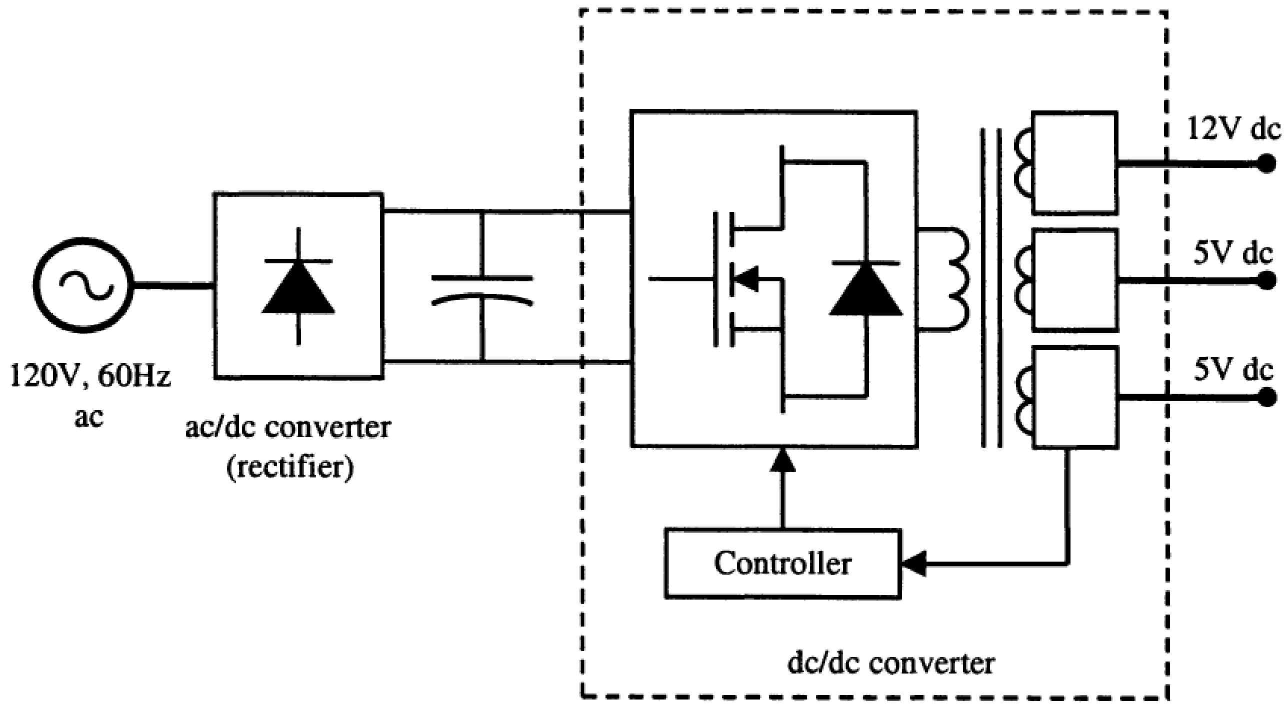
# Linear Rectifier

Consist of:

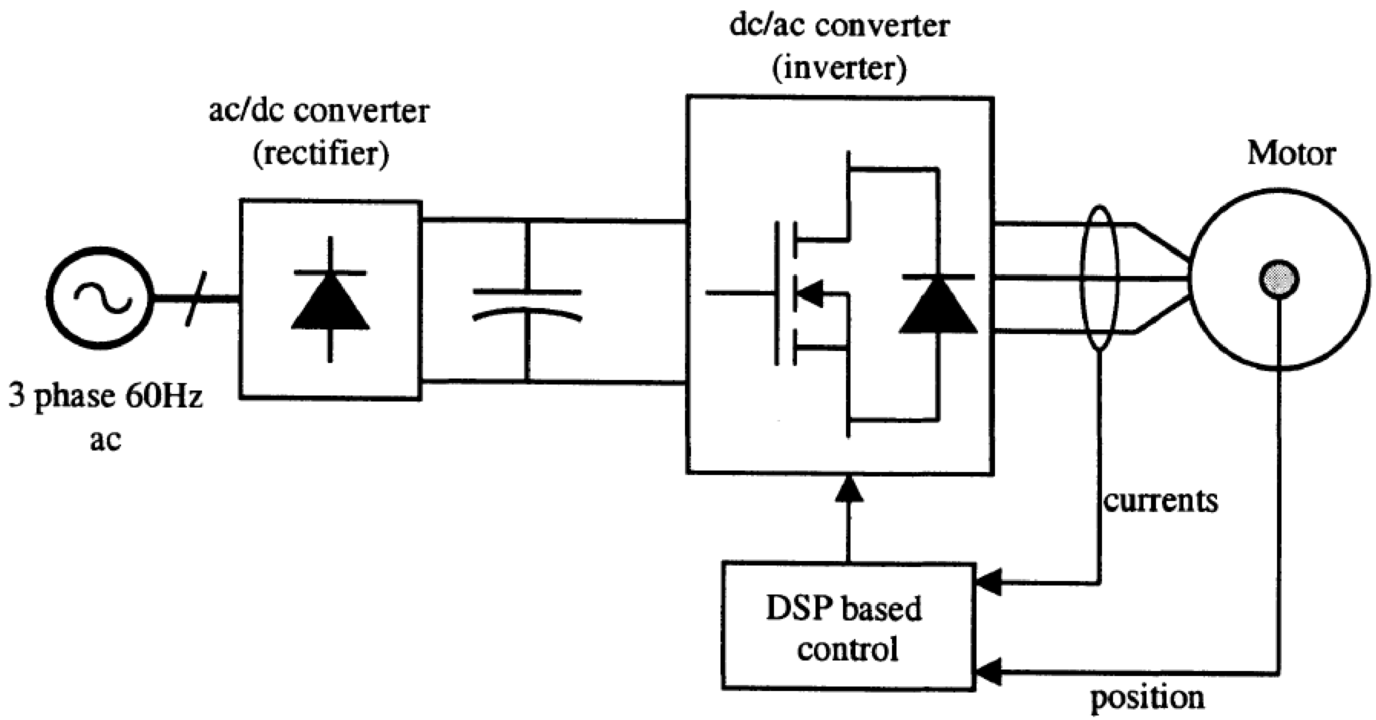
- Transformer: steps ac voltage up or down.
- Rectifier Diodes: change ac to “bumpy” dc.
- Filter Network: includes capacitors and inductors, smooths out the bumps.
- Voltage Regulator: keeps the voltage constant.
- Protection: usually a zener diode circuit.



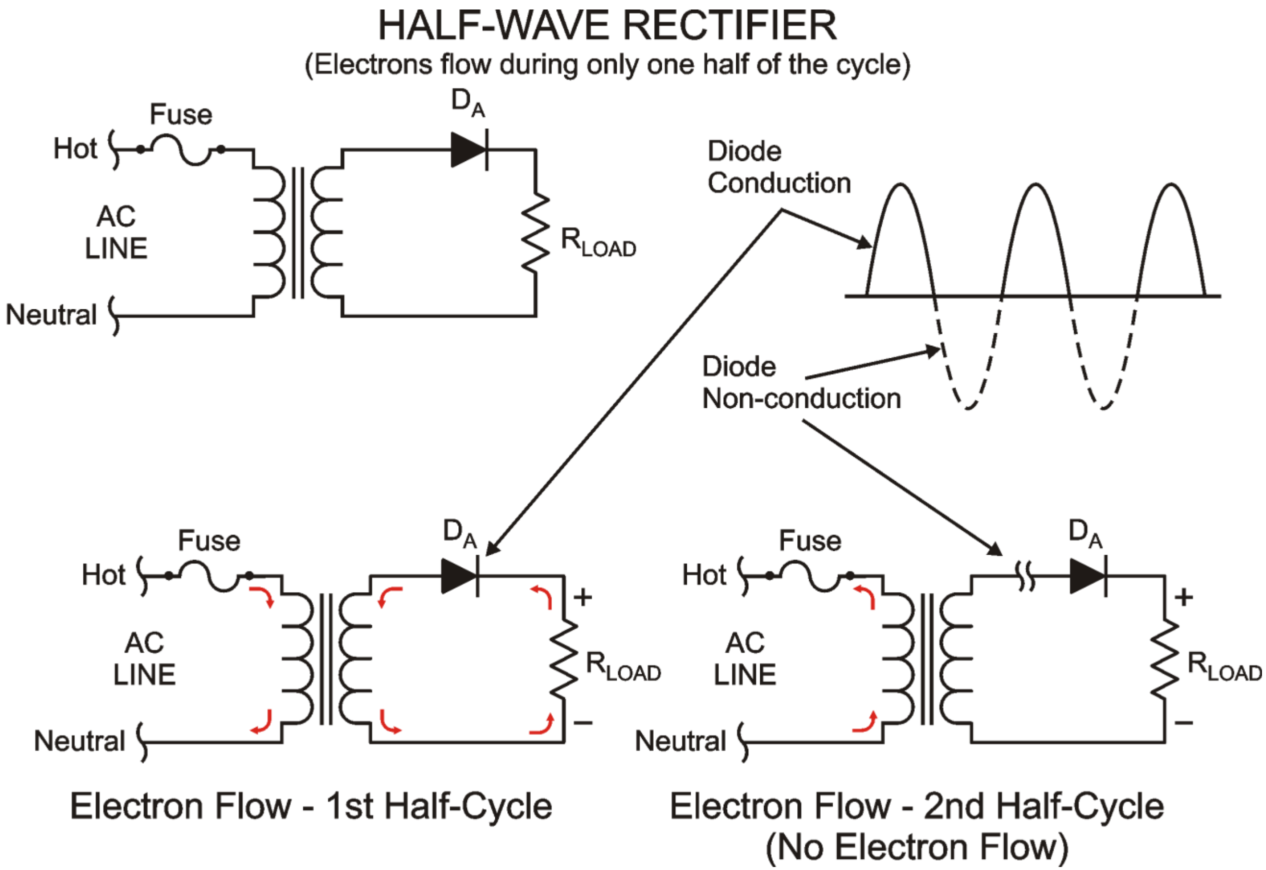
# Example: Computer Power Supply



# Example: Adjustable Motor Speed Drive



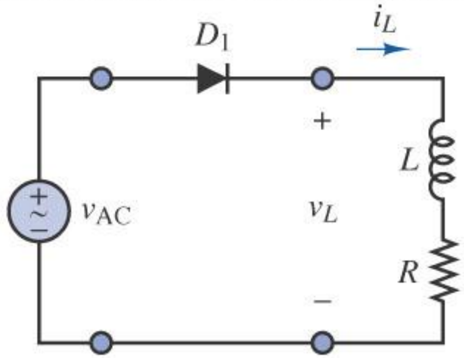
# Power Supply Specifics: Half Wave Rectifier



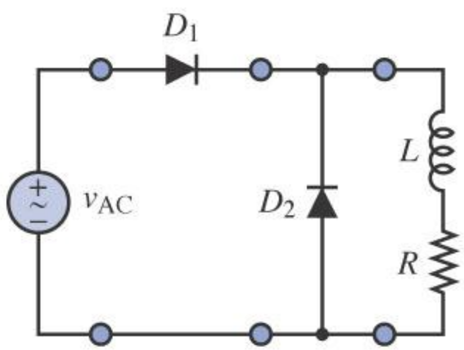

Source: ARRL

# Half-Wave Rectifier






Simple half-wave rectifier




Same arrangement with freewheeling diode

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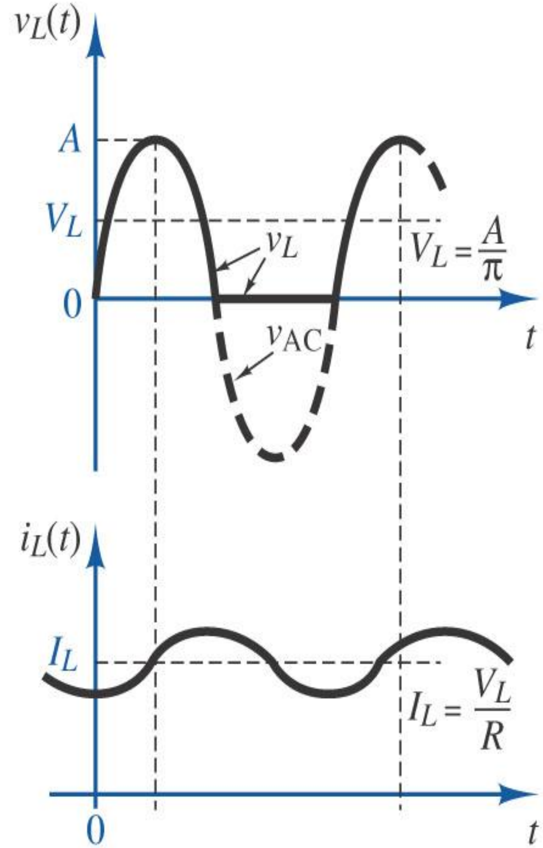
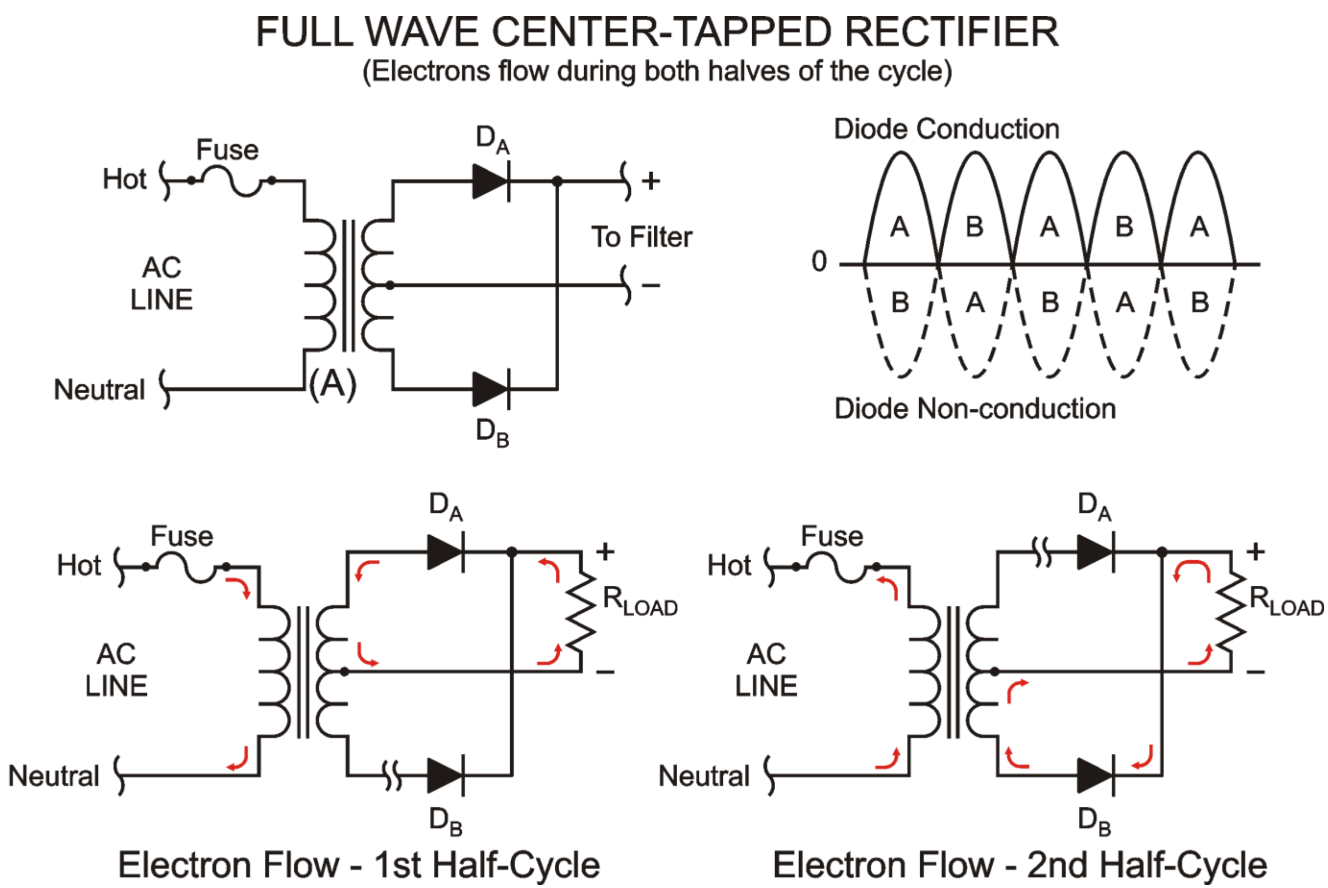



High ripple factor.

Low rectification efficiency.

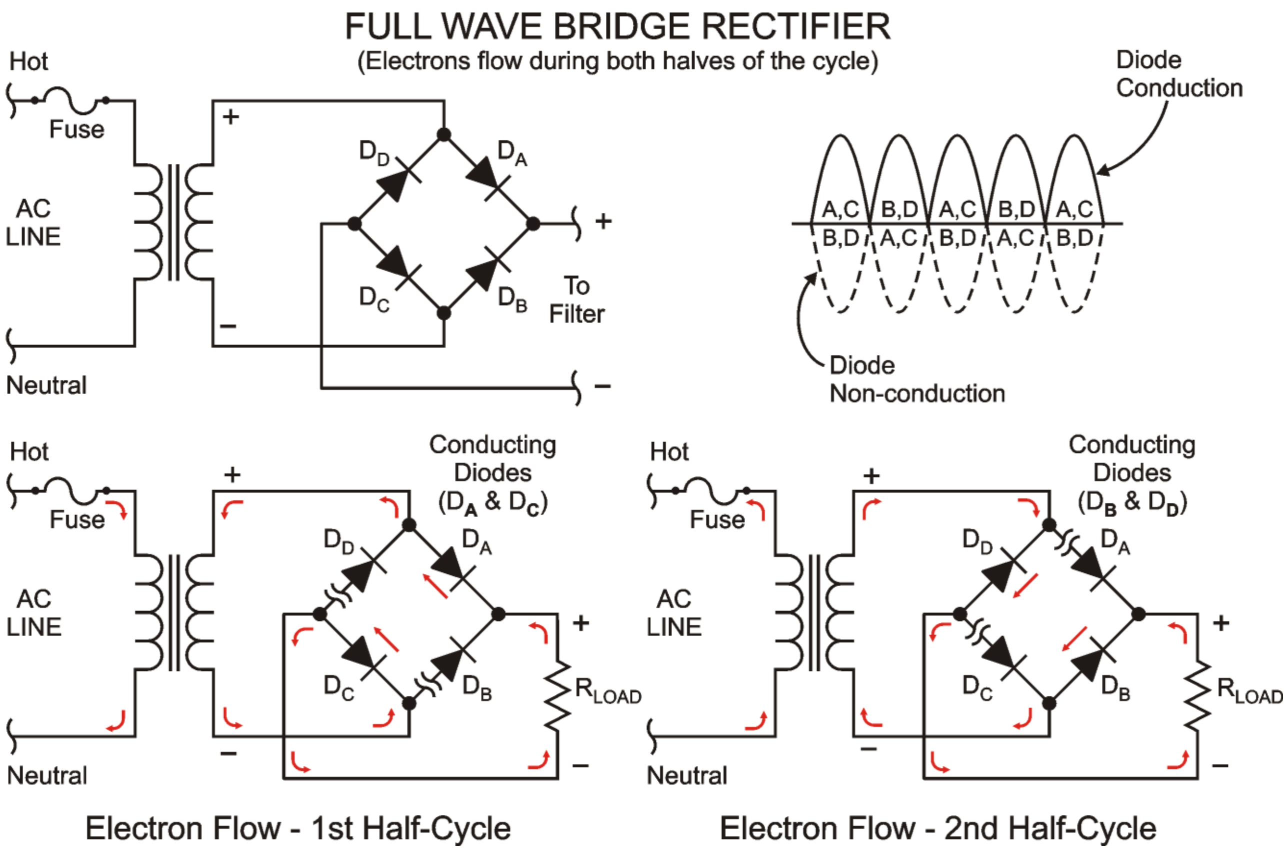
Low transformer utilization factor.

# Power Supply Specifics
# Full Wave Center-Tapped Rectifier




Source: ARRL

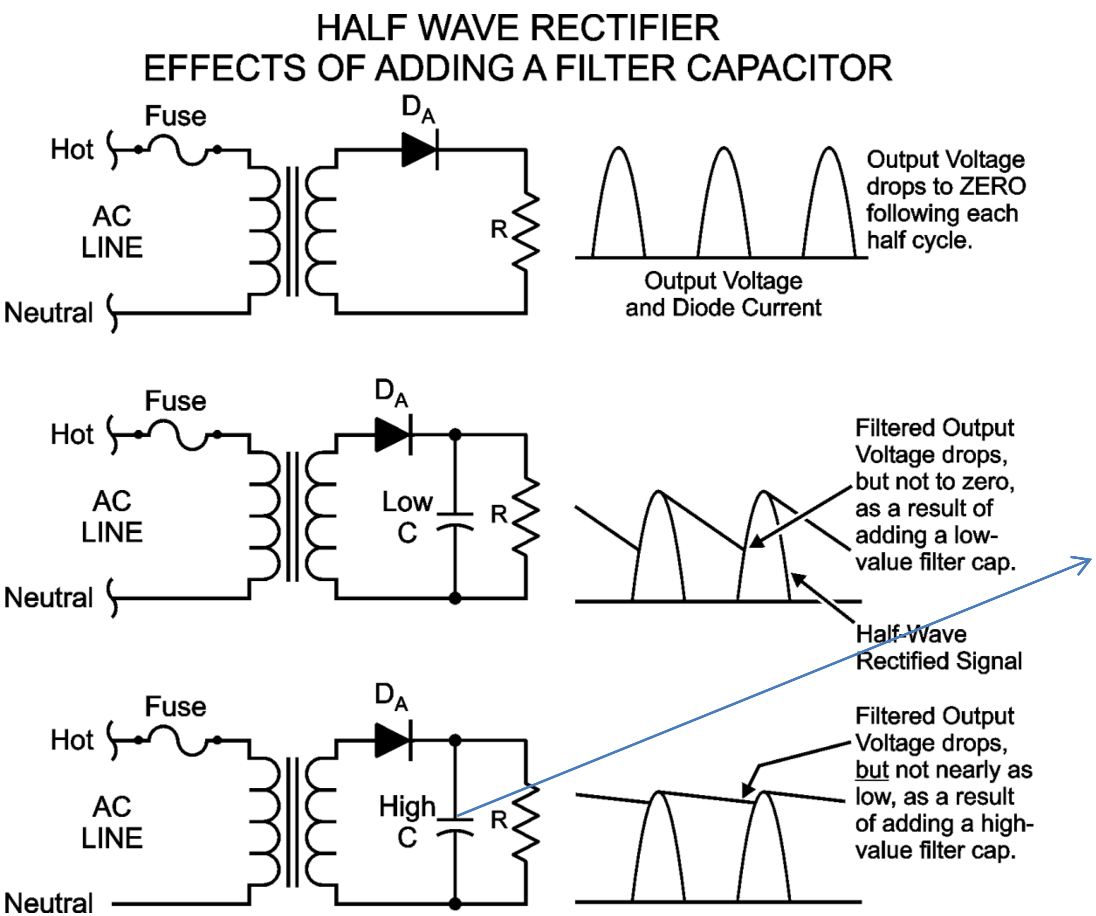
# Power Supply: Full Wave Bridge Rectifier

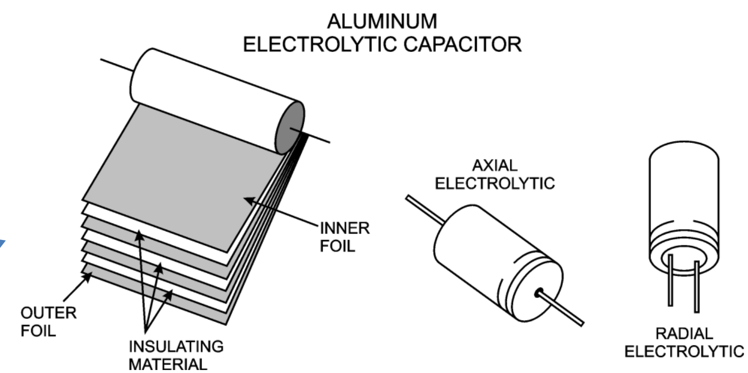



Source: ARRL

# Filtering

Capacitors are used in power supply filter networks. The capacitors smooth out the rippled AC to DC.




Source: ARRL

# Rectifier Performance Parameters

$\eta = P_{dc} / P_{ac}$ Rectification Efficiency

$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$ $\qquad P_{ac} = V_{rms} I_{rms}$

$FF = V_{rms} / V_{dc}$ Form Factor

Ripple factor $RF = \dfrac{V_{ac}}{V_{dc}} = \dfrac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\dfrac{V_{rms}^2}{V_{dc}^2} - 1} = \sqrt{FF^2 - 1}$

**Example 1:** A half-wave rectifier has a pure resistive load of *R* Determine (a) The efficiency, (b) Form factor (c) Ripple factor.

$$V_{dc} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{V_m}{2\pi}(-\cos\pi - \cos(0)) = \frac{V_m}{\pi} \qquad I_{dc} = \frac{V_{dc}}{R} = \frac{V_m}{\pi R}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} (V_m \sin \omega t)^2} = \frac{V_m}{2} \qquad I_{rms} = \frac{V_m}{2\ R}$$

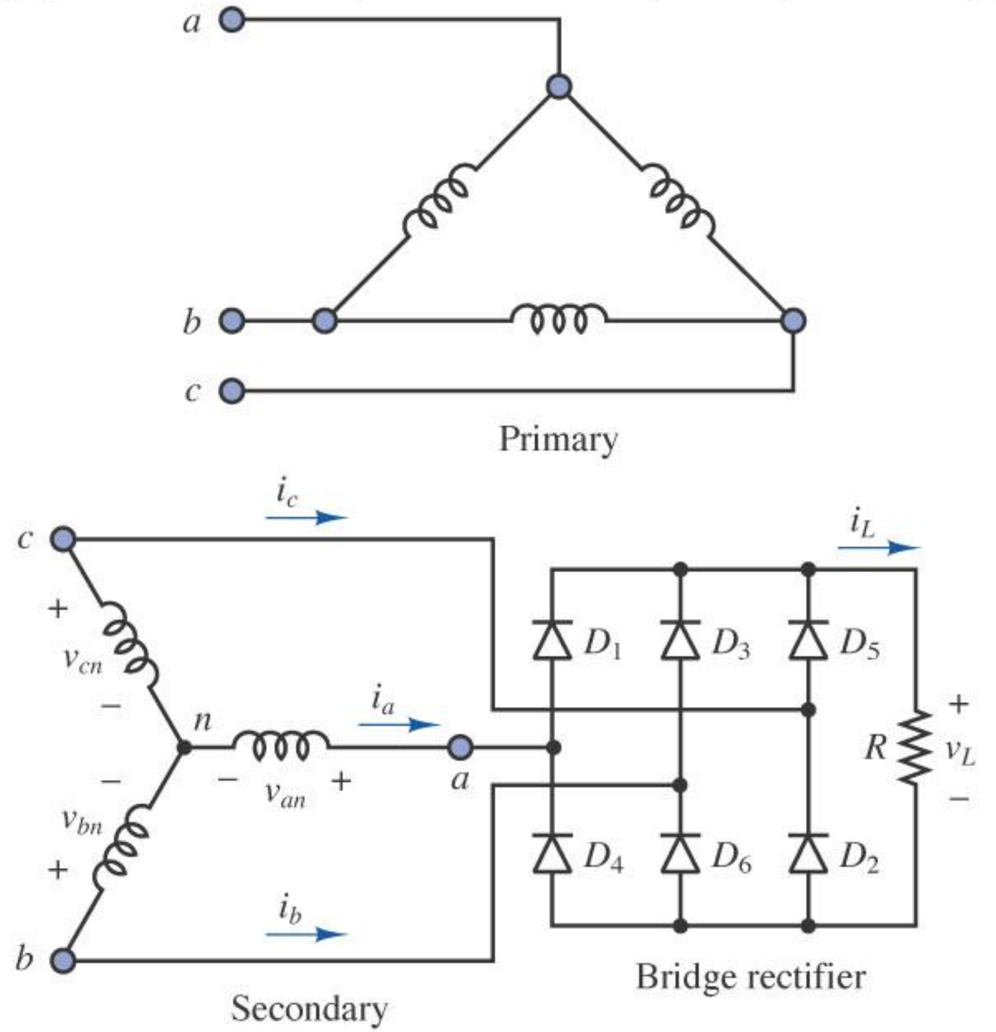
$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{V_{dc} * I_{dc}}{V_{rms} * I_{rms}} = \frac{\frac{V_m}{\pi} * \frac{V_m}{\pi R}}{\frac{V_m}{2} * \frac{V_m}{2R}} = 40.53\%$$

$$FF = \frac{V_{rms}}{V_{dc}} = \frac{\frac{V_m}{2}}{\frac{V_m}{\pi}} = \frac{\pi}{2} = 1.57$$

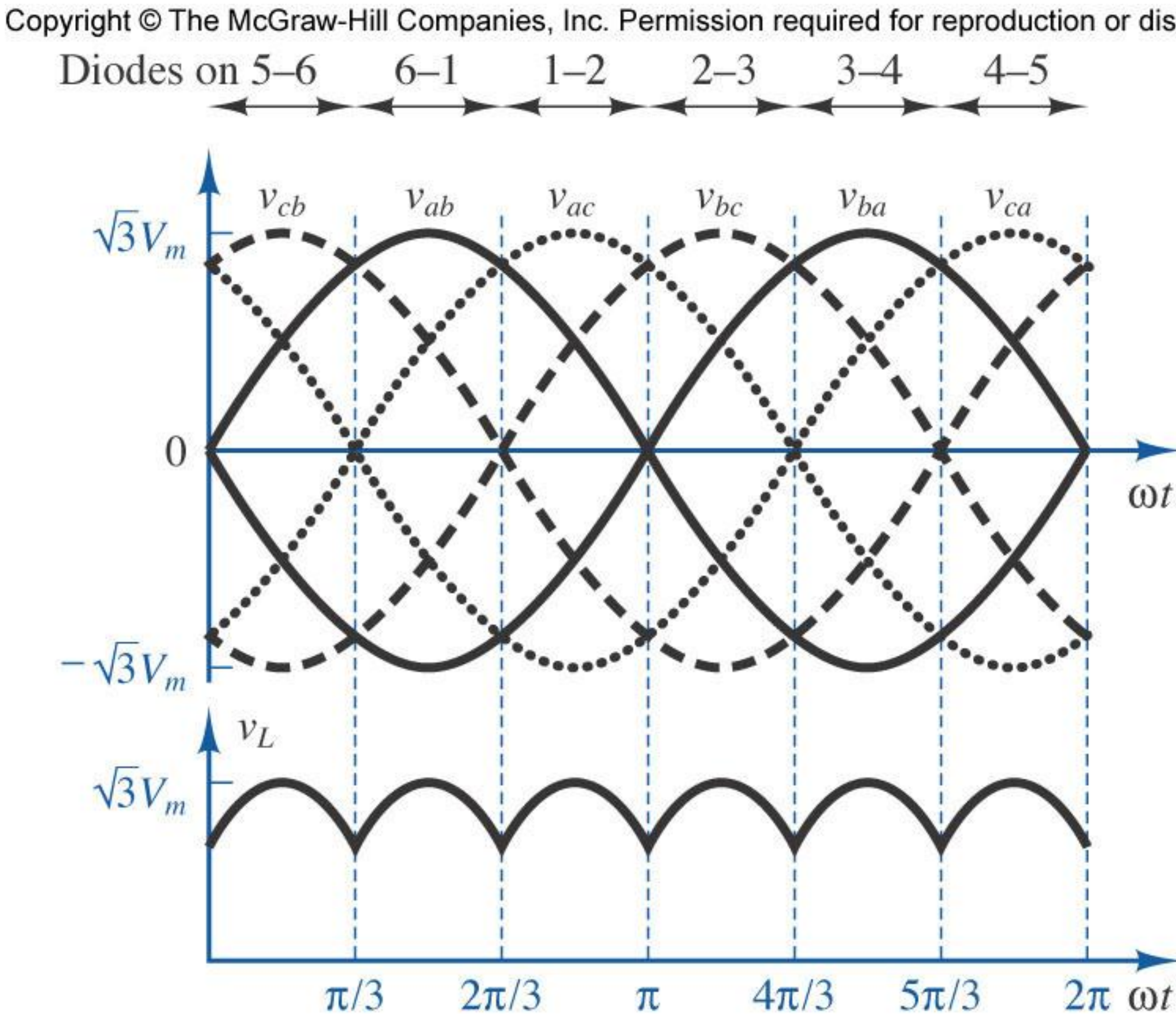
$$RF = \frac{V_{ac}}{V_{dc}} = \sqrt{FF^2 - 1} = \sqrt{1.57^2 - 1} = 1.211$$

# Three-Phase Diode Bridge Rectifier

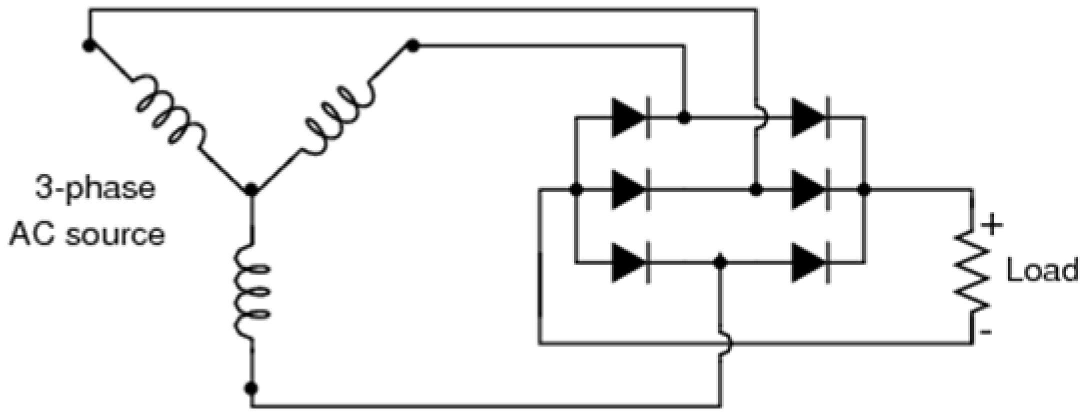


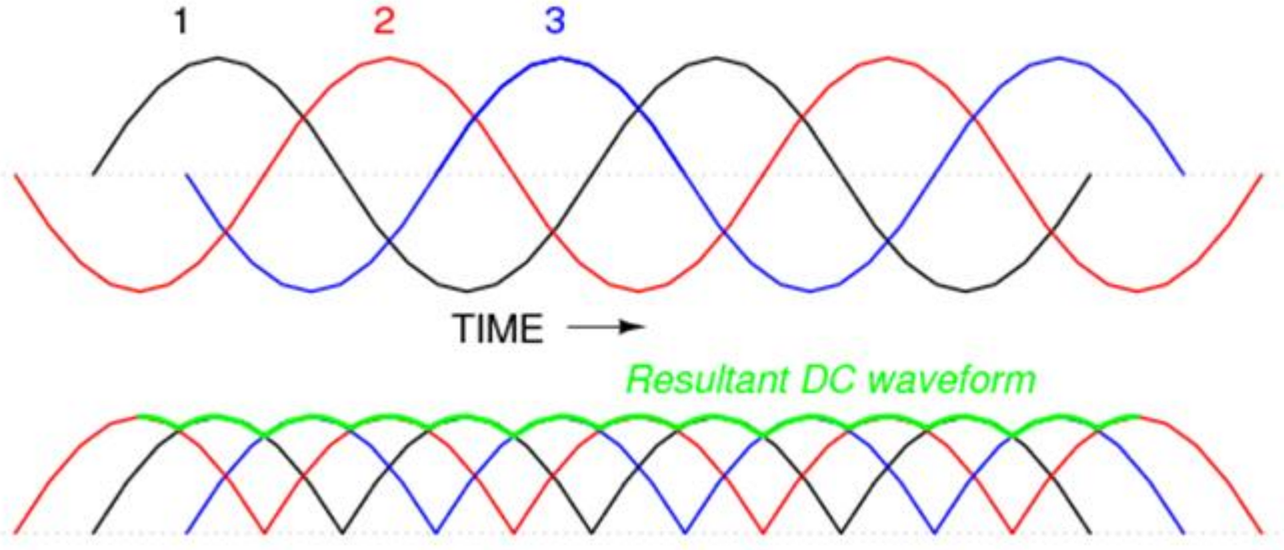


# Waveforms and Conduction Times of Three-Phase Bridge Rectifier



# Three-Phase Full-Wave Rectifier



**Example 2:** A single-phase diode bridge rectifier has a purely resistive load of *R*=15 ohms and, *VS*=300 sin 314 *t* and unity transformer ratio. Determine (a) The efficiency, (b) Form factor, (c) Ripple factor, (d) and, (d) Input power factor.

$$V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \; d\omega t = \frac{2V_m}{\pi} = 190.956 \; V \qquad I_{dc} = \frac{2V_m}{\pi \; R} = 12.7324 \quad A$$

$$V_{rms} = \left[ \frac{1}{\pi}\int_0^{\pi} (V_m \sin\omega t)^2 \; d\omega t \right]^{1/2} = \frac{V_m}{\sqrt{2}} = 212.132 \;\; V$$

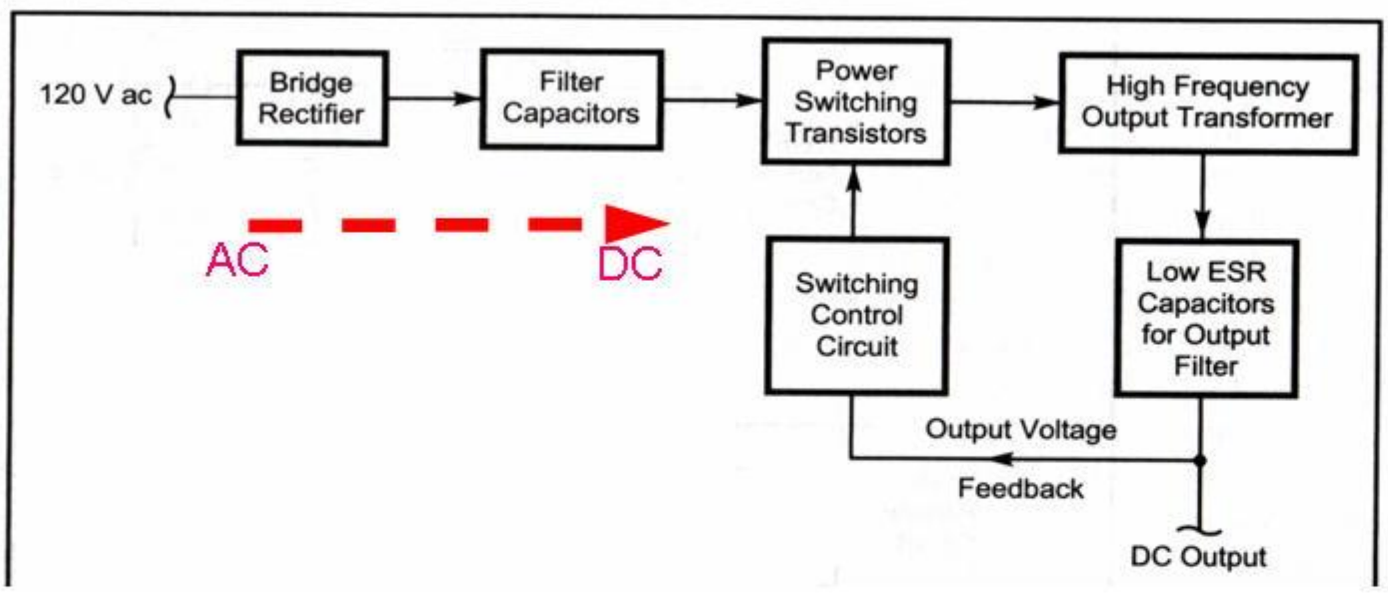
$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{V_{dc}\, I_{dc}}{V_{rms}\, I_{rms}} = 81.06 \;\; \% \qquad FF = \frac{V_{rms}}{V_{dc}} = 1.11$$

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\frac{V_{rms}^2}{V_{dc}^2} - 1} = \sqrt{FF^2 - 1} = 0.482$$

Input power factor = $\dfrac{\text{Real Power}}{Apperant \;\; Power} = \dfrac{V_S \;\; I_S \cos\phi}{V_S \;\; I_S} = 1$

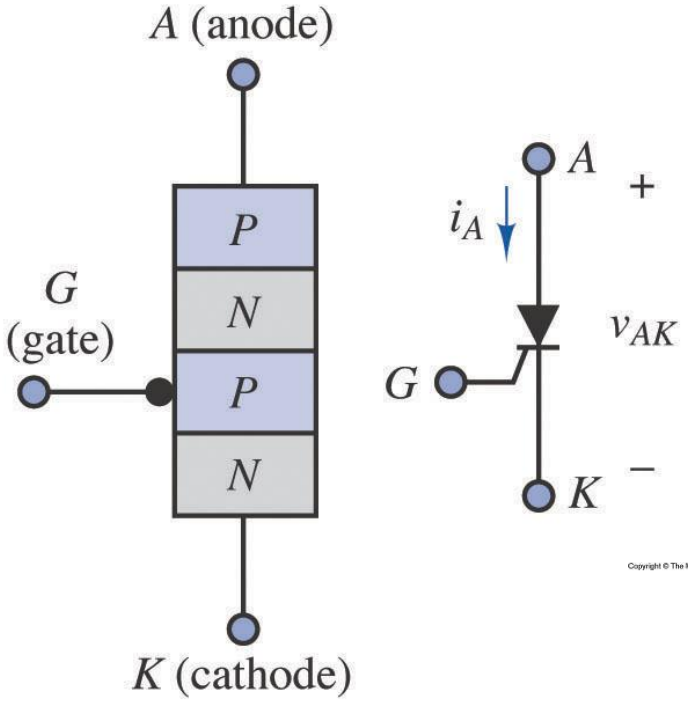
# Alternative! Controlled Switching Mode

- By using linear regulator, the AC to DC converter is not efficient and of large size and weight!
- Using Switching-Mode
- High efficiency
- Small size and light weight
- For high power (density) applications.
- **Use Power Electronics!**

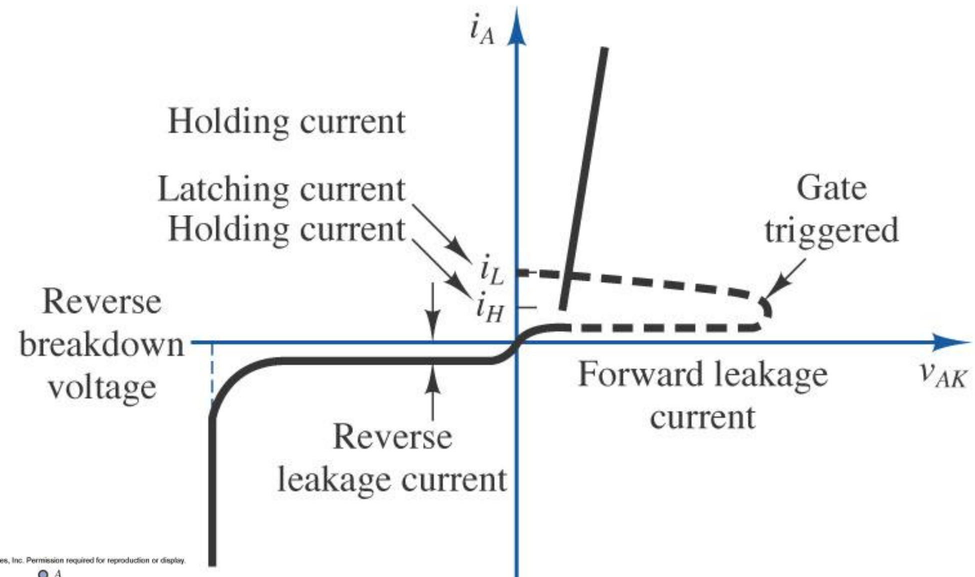


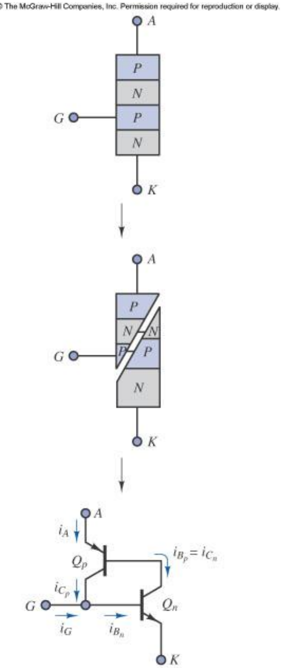
# Thyristors and Controlled Rectifiers





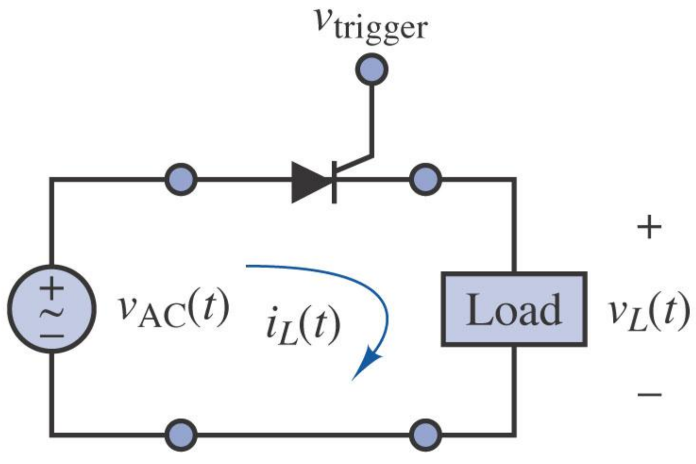


# Controlled Rectifier Circuit



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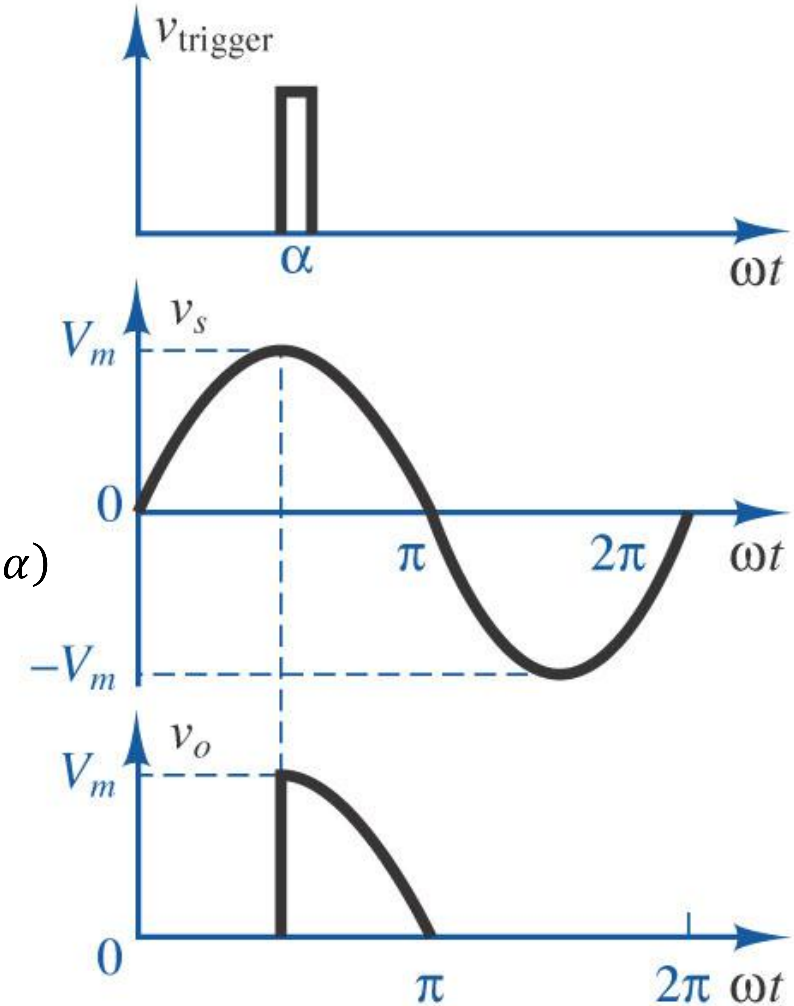


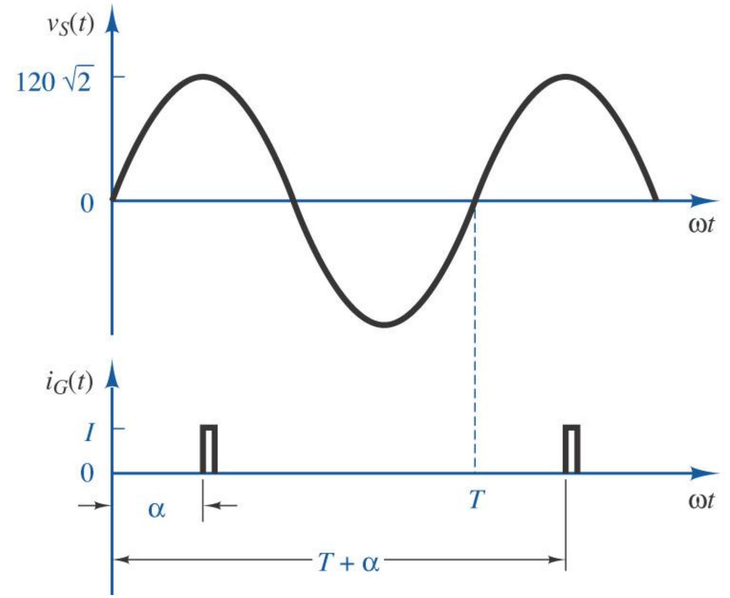

$$V_{dc} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_p sin\omega t d\omega t = \frac{V_p}{2\pi}(1 + cos\alpha)$$

$$V_{rms} = \left[\frac{1}{2\pi}\int_{\alpha}^{\pi} \quad {V_p}^2 sin^2\omega t d\omega t\right]^{1/2}$$

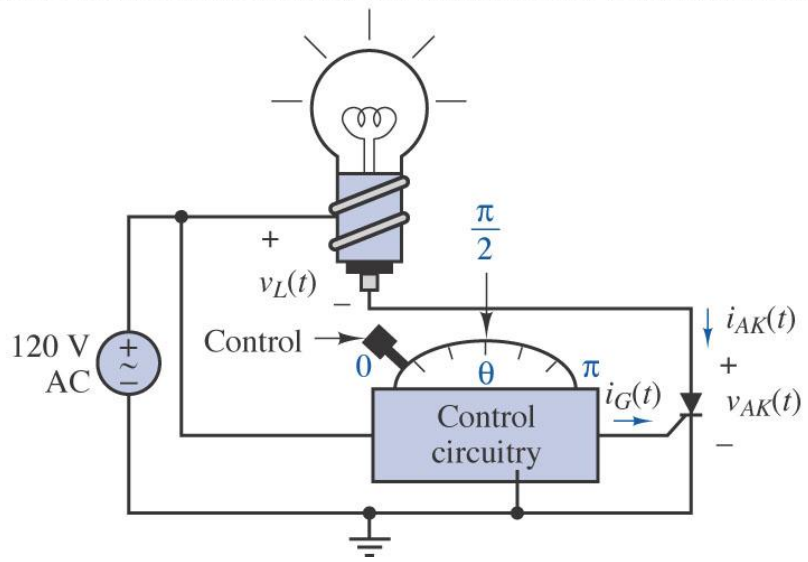
$$=\frac{V_p}{2}\left[\frac{1}{\pi}\left(\pi - \alpha + \frac{sin2\alpha}{2}\right)\right]^{1/2}$$

**Example:** Consider the following SCR-based variable voltage supply. For RL=240 Ohm, derive the RMS value of the load voltage as a function of the firing angle, and then calculate the load power when the firing angle $\alpha$ is 0, $\pi/2$, and $\pi$.

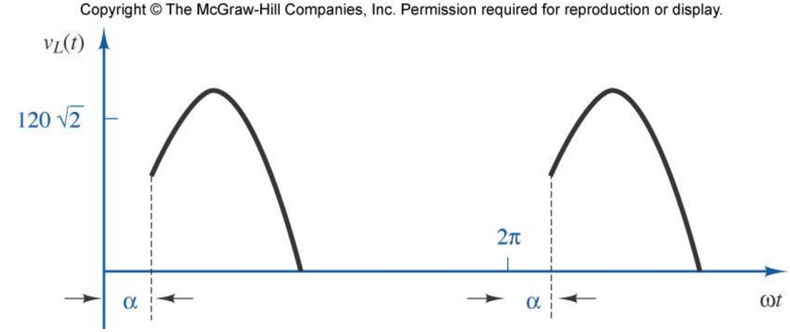




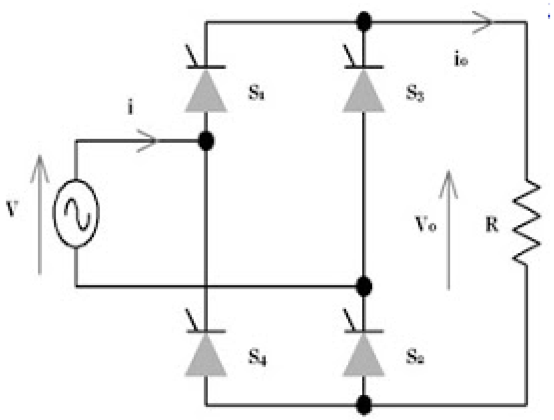




# Full-Wave Rectifiers Using SCR




$$V_{dc} = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_p sin\omega t d\omega t = \frac{2V_p}{\pi}(cos\alpha)$$

$$V_{rms} = \left[\frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} {V_p}^2 sin^2\omega t d\omega t\right]^{1/2}$$

$$= \frac{V_p}{\sqrt{2}} = V_s$$

With a purely resistive load, SCRs $S_1$ and $S_2$ can conduct from $\alpha$ to $\pi$, and SCRs $S_3$ and $S_4$ can conduct from $\alpha+\pi$ to $2\pi$.