

EL 3003

Laboratorio de Ingeniería Eléctrica

Clase 5

Rectificadores

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Basado en las clases de la profesora
Dra. Constanza Ahumada.

Contenido



Tipos de Conversores

Rectificador Media Onda

Rectificador Onda Completa

Tipos de Conversores

	AC	DC
AC	Conversor AC/AC	Rectificador
DC	Inversor	Conversor DC/DC



Tipos de Conversores - Rectificador

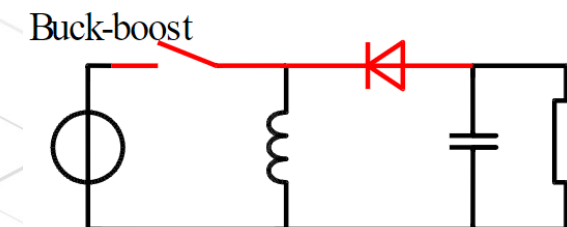
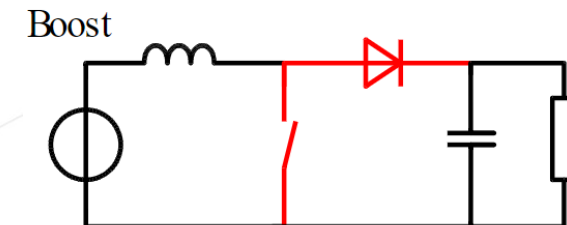
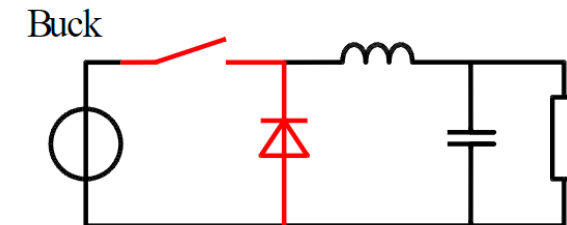
	AC	DC
AC	Conversor AC/AC	Rectificador
DC	Inversor	Conversor DC/DC

- Rectificador:
 - Puede ser controlado o no controlado.
 - Con diodos/tiristores/MOSFET/etc.

Tipos de Conversores - Conversor DC/DC

	AC	DC
AC	Conversor AC/AC	Rectificador
DC	Inversor	Conversor DC/DC

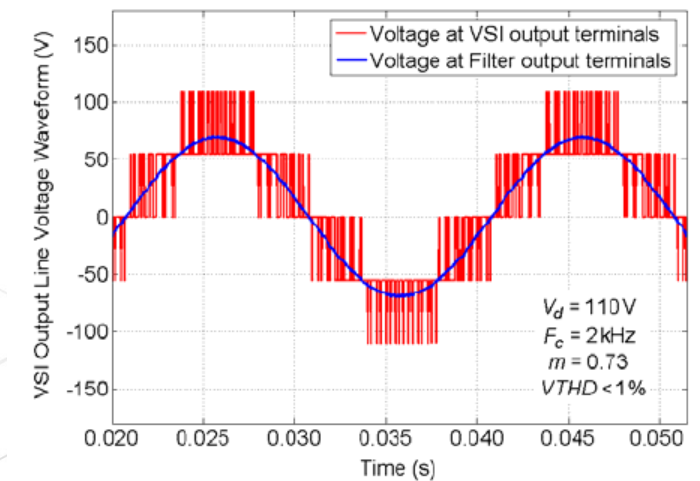
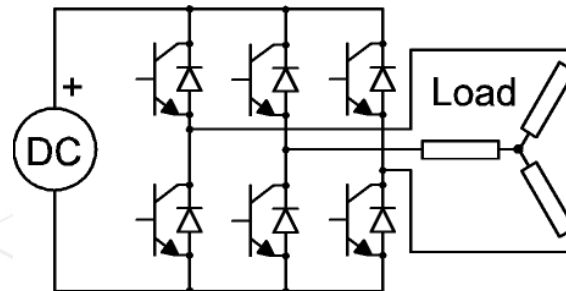
- Cambio de Voltaje:
 - Mas eficiente que regular voltaje de forma lineal.
- Aplicaciones: Computadores y Celulares
- Funcionamiento: Con pulsos
- Tipos: Buck, Boost, Buck-Boost



Tipos de Conversores - Inversor

	AC	DC
AC	Conversor AC/AC	Rectificador
DC	Inversor	Conversor DC/DC

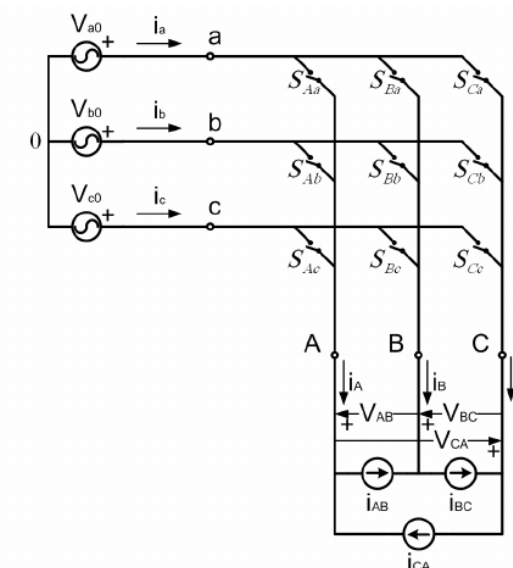
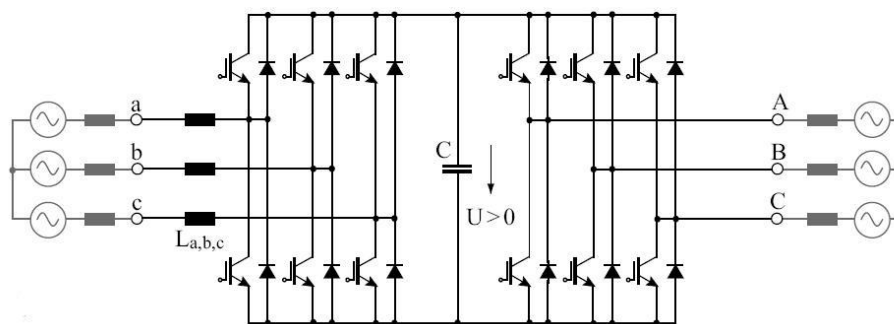
- Obtener Voltaje AC
- Aplicaciones: Paneles Solares, Baterías, Autos Eléctricos, HVDC
- Funcionamiento: Con pulsos



Tipos de Conversores - Conversor AC/AC

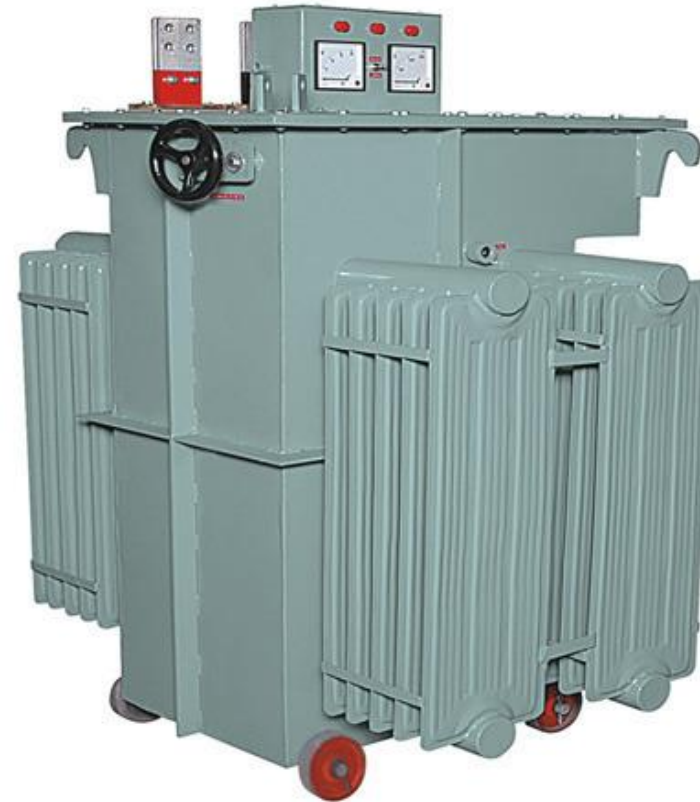
	AC	DC
AC	Conversor AC/AC	Rectificador
DC	Inversor	Conversor DC/DC

- Cambio de Voltaje: Mas controlable que con transformadores
- Aplicaciones: Generación Eólica, Motores con control de velocidad, Aviones
- Tipos
 - Cycloconverters
 - Matrix Converters
 - Back-to- Back

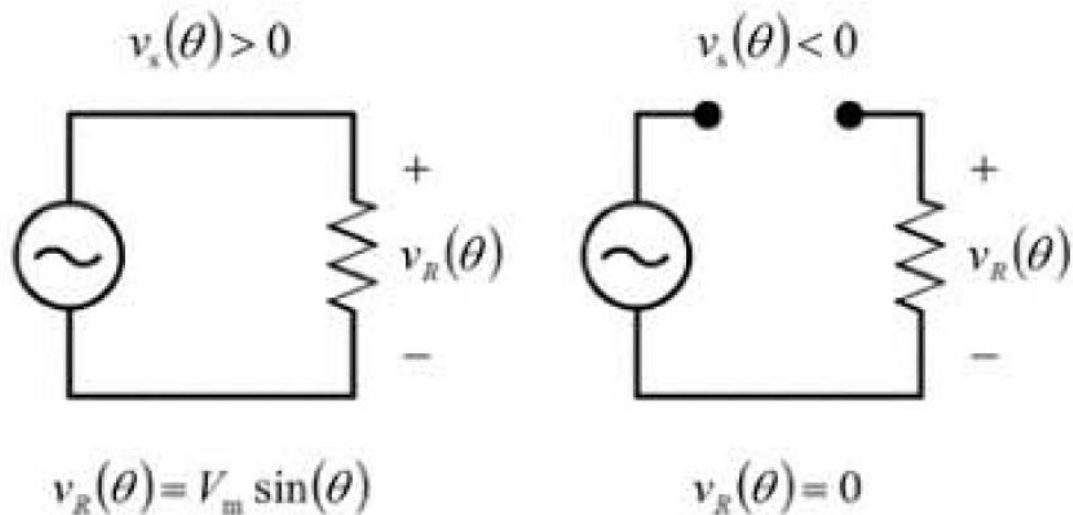
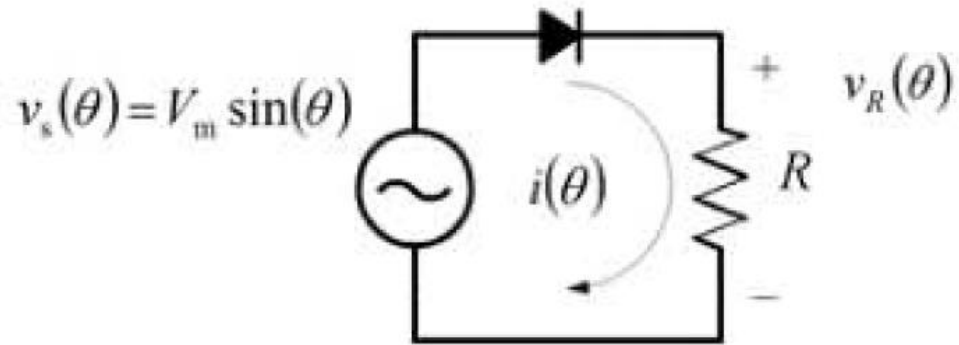


Rectificadores

- Objetivo producir onda continuas a partir de ondas sinusoidales.
- Pueden ser monofásicos, trifásicos, multifases.

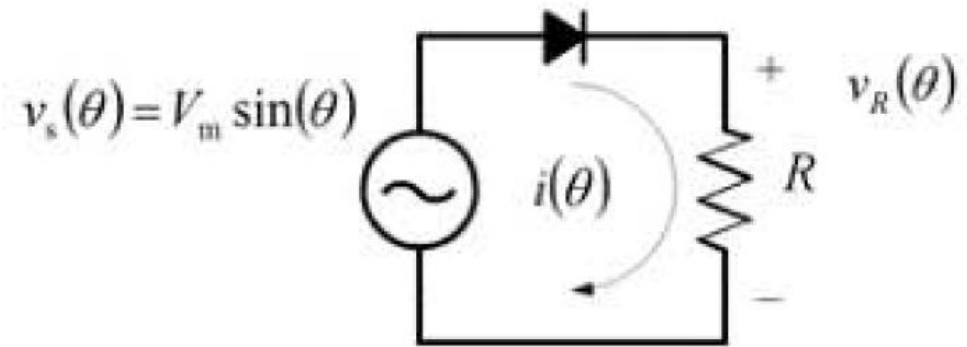


Rectificadores Monofásicos – Media Onda



- Voltaje de entrada:
$$v_s(\omega t) = V_m \sin(\omega t)$$
- Voltaje de salida:
$$v_o(\omega t) = v_R(\omega t) = \begin{cases} V_m \sin(\omega t), & 0 \leq \omega t \leq \pi \\ 0, & \pi \leq \omega t \leq 2\pi \end{cases}$$
- Corriente:
$$i = \begin{cases} \frac{V_m}{R} \sin(\theta), & 0 \leq \theta \leq \pi \\ 0, & \pi \leq \theta \leq 2\pi \end{cases}$$

Rectificadores Monofásicos – Media Onda



- Valores medios (DC)
 - El valor medio de voltaje de salida viene dado por:

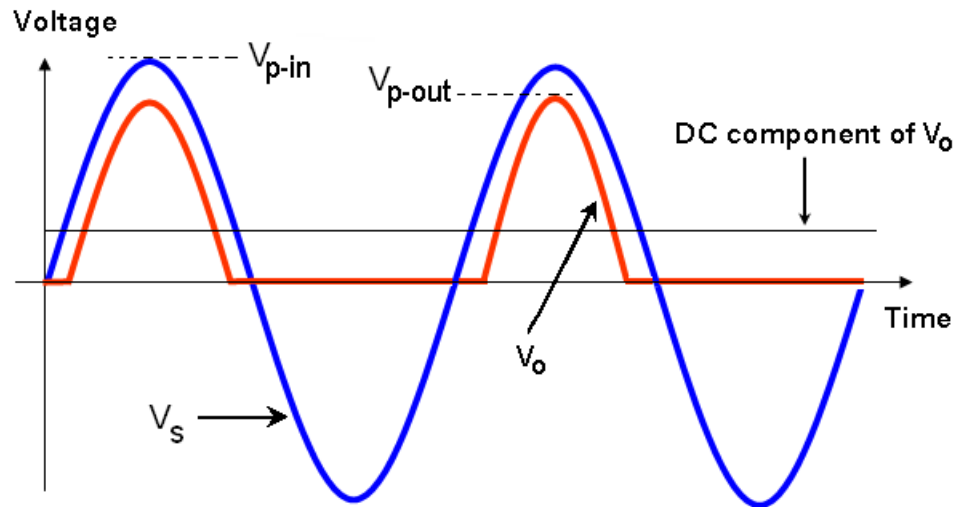
$$V_{DC} = \frac{1}{T} \int_0^T V_s dt = \frac{1}{2\pi} \int_0^\pi V_m \sin(\omega t) d(\omega t)$$

$$V_{DC} = -\frac{V_m}{2\pi} \cos(\omega t) \Big|_0^\pi$$

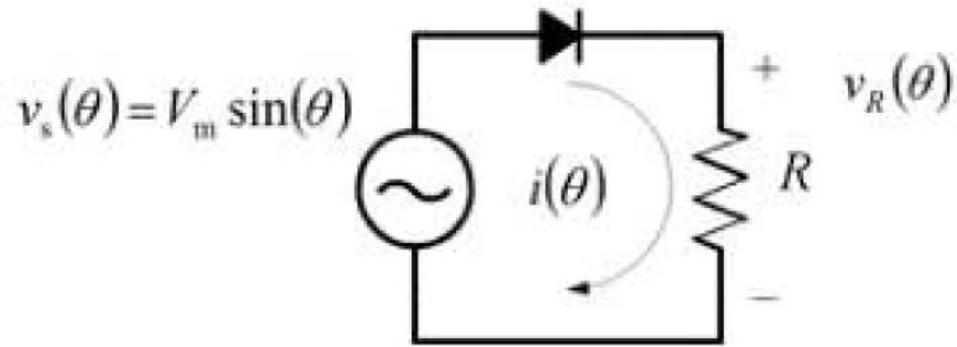
$$V_{DC} = \frac{V_m}{\pi}$$

- La corriente media viene dada por:

$$I_{DC} = \frac{V_m}{\pi R}$$



Rectificadores Monofásicos – Media Onda

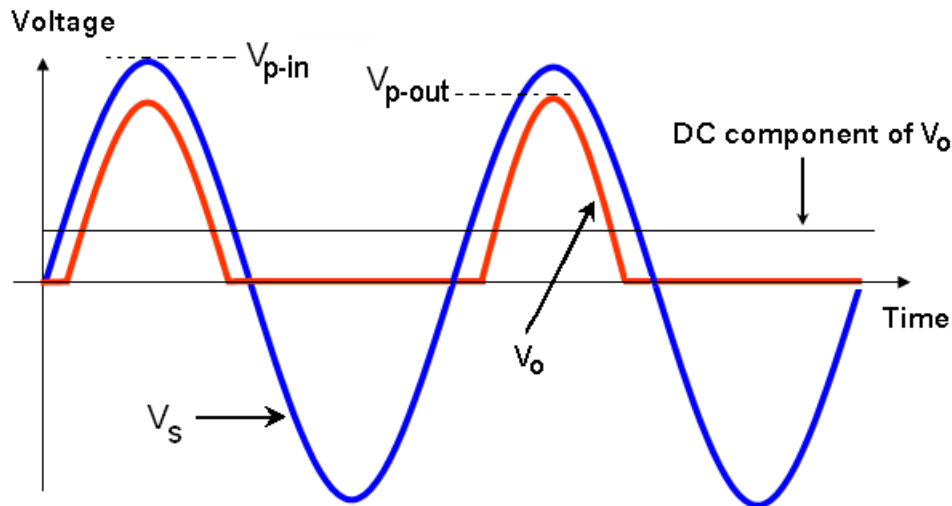


- Valores RMS

$$V_{iRMS} = \frac{V_m}{\sqrt{2}}$$

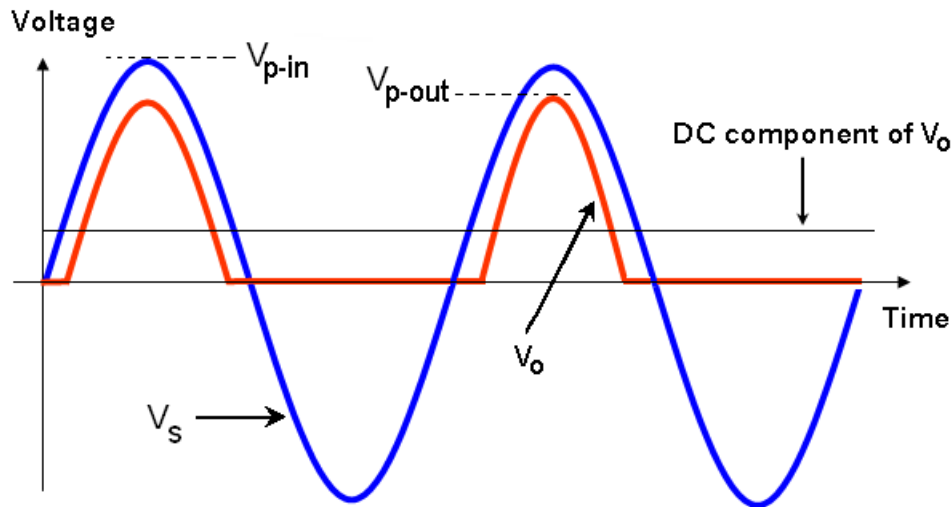
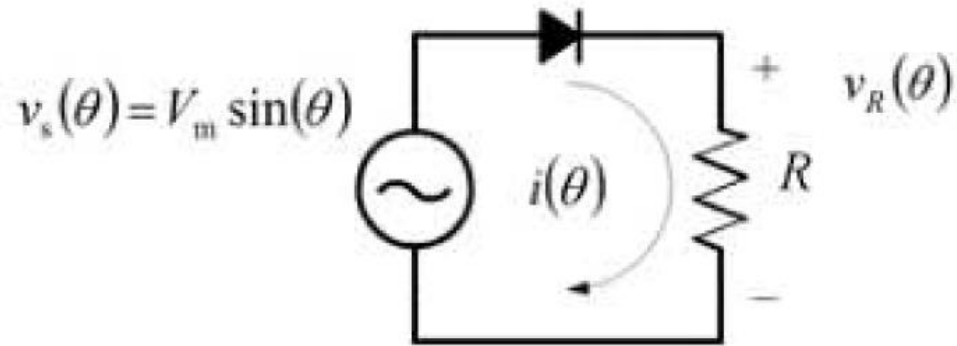
$$V_{oRMS} = \sqrt{\frac{1}{T} \int_0^T V_s^2 dt} = \sqrt{\frac{1}{2\pi} \int_0^\pi (V_m \sin(\omega t))^2 d\omega t}$$

$$V_{oRMS} = \frac{V_m}{2}$$



$$I_{RMS} = \frac{V_{oRMS}}{R} = \frac{V_m}{2R}$$

Rectificadores Monofásicos – Media Onda



- Potencia de entrada:

$$P_i = V_{iRMS} I_{RMS} = \frac{V_m^2}{2\sqrt{2}R}$$

- Potencia de salida:

$$P_o = V_{oRMS} I_{RMS} = \frac{V_m^2}{4R}$$

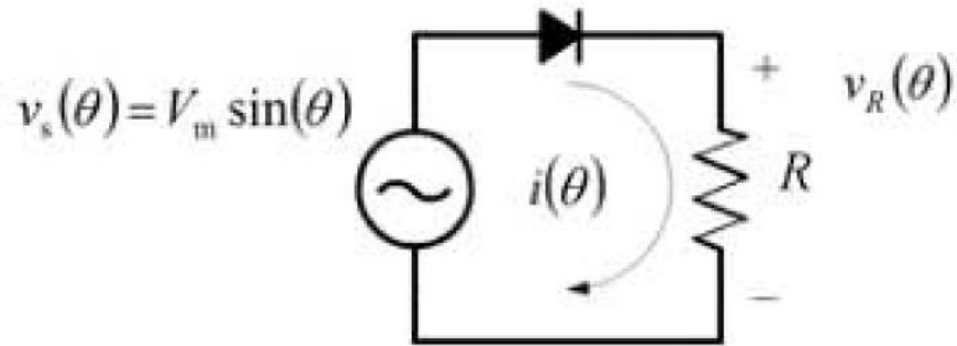
- Eficiencia:

$$\eta = \frac{P_o}{P_o + P_{diodo}} = \frac{P_o}{P_i}$$

- Peak factor:

$$pf = \frac{Peak}{RMS} = \frac{V_m}{\frac{V_m}{2}} = 2$$

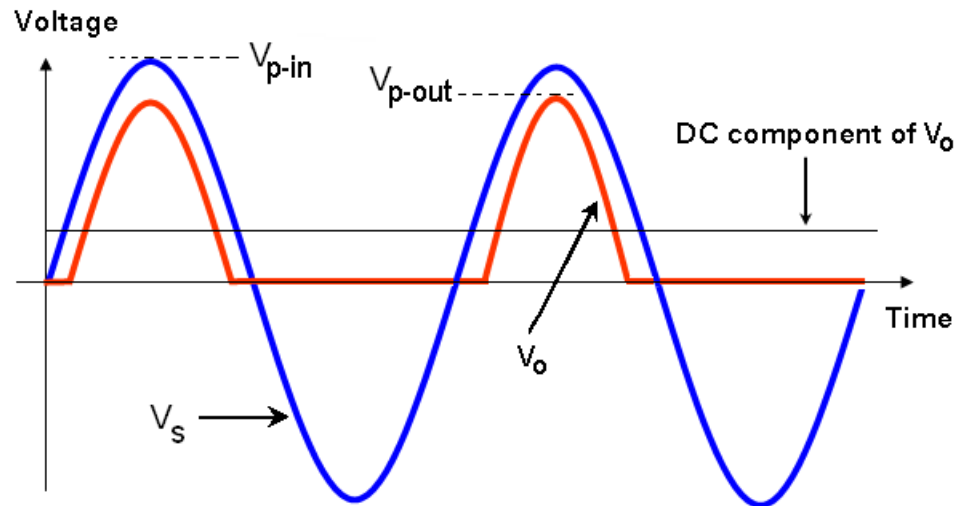
Rectificadores Monofásicos – Media Onda



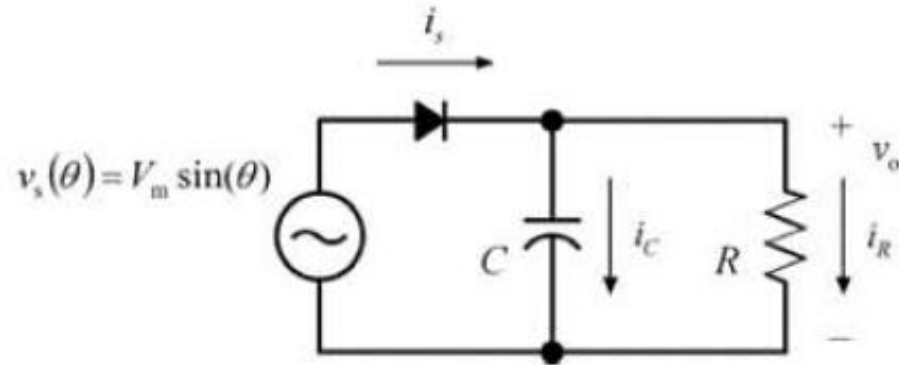
- Voltaje peak to peak (Ripple):
$$V_{pp} = V_{\max} - V_{\min}$$

- Factor de ripple:

$$r = \frac{\sqrt{V_{RMS}^2 - V_{DC}^2}}{V_{DC}} = \frac{\sqrt{\pi^2 - 4}}{2} \approx 1.21$$



Rectificadores Monofásicos – Media Onda

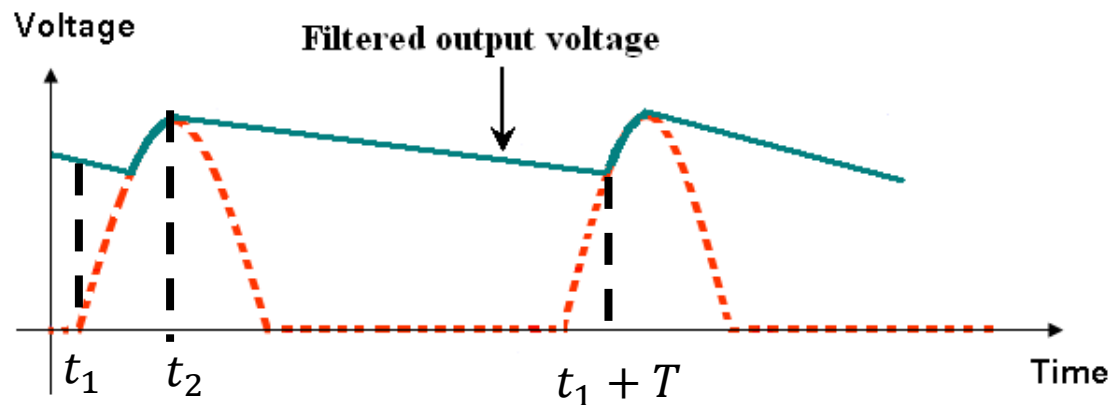


- **Rectificador Media Onda con filtro RC**

- Permite reducir el ripple.

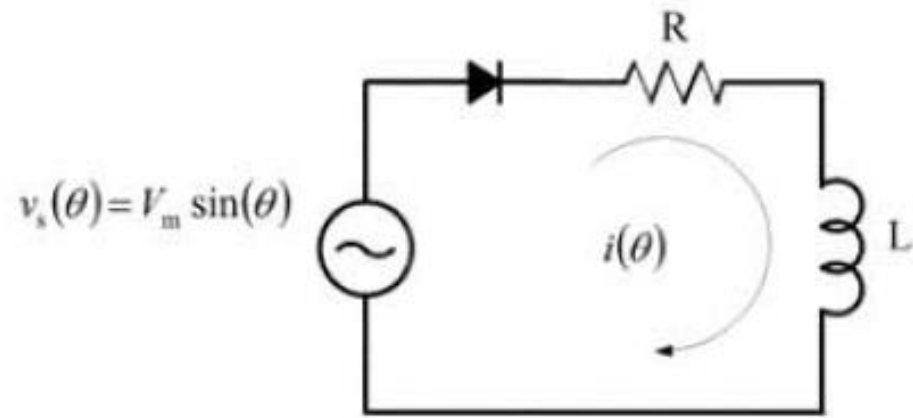
- Voltaje de salida:

$$v_o = \begin{cases} V_m \sin \omega t, & t_1 \leq t \leq t_2 \\ V_m \sin(\omega t_2) e^{-\frac{\omega(t-t_2)}{q}}, & t_2 \leq t \leq t_1 + T \end{cases}$$

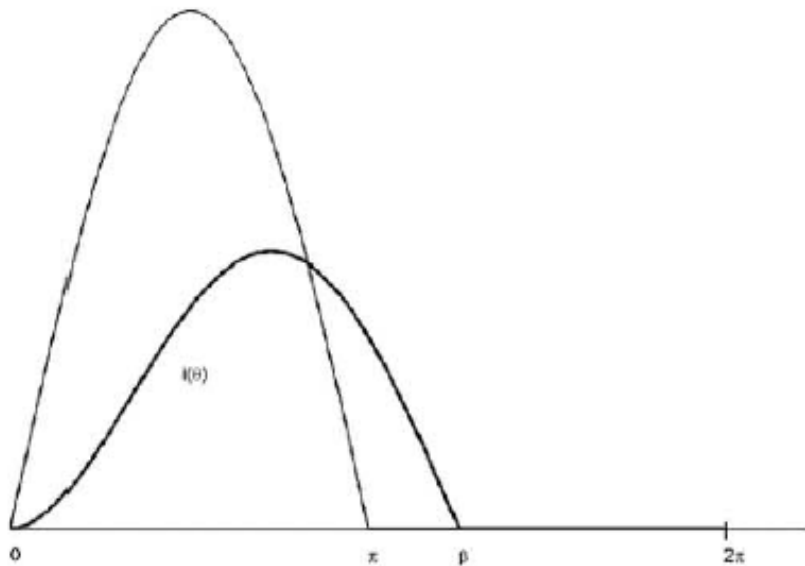


- Factor de calidad: $q = \omega RC$

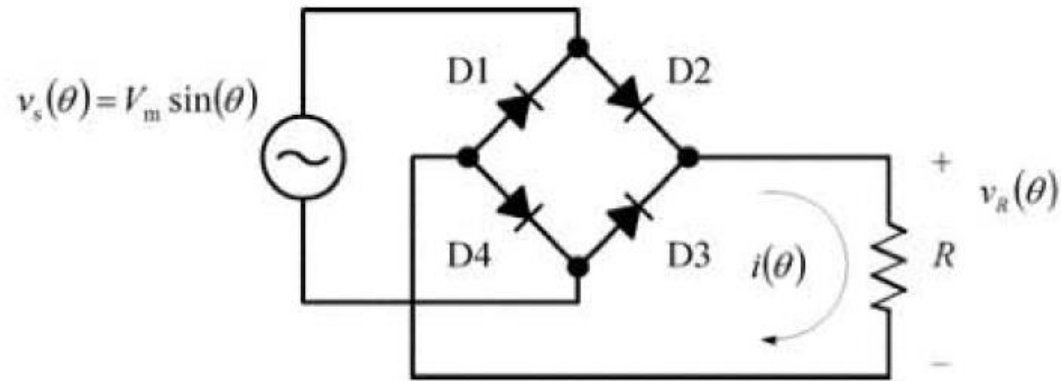
Rectificadores Monofásicos – Media Onda



- **Rectificador Media Onda con filtro RL**
 - Se agrega para mejorar los peak de corriente. Si se utiliza una inductancia grande se obtiene un corriente casi constante.
 - Factor de calidad: $q = \frac{\omega L}{R}$



Rectificadores Monofásicos – Onda Completa



- Voltaje de entrada:

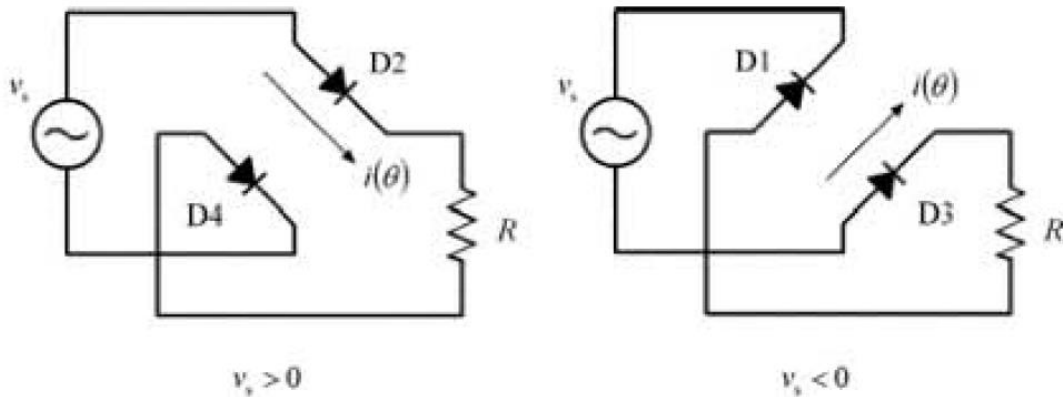
$$v_s(\omega t) = V_m \sin(\omega t)$$

- Voltaje de salida (DC):

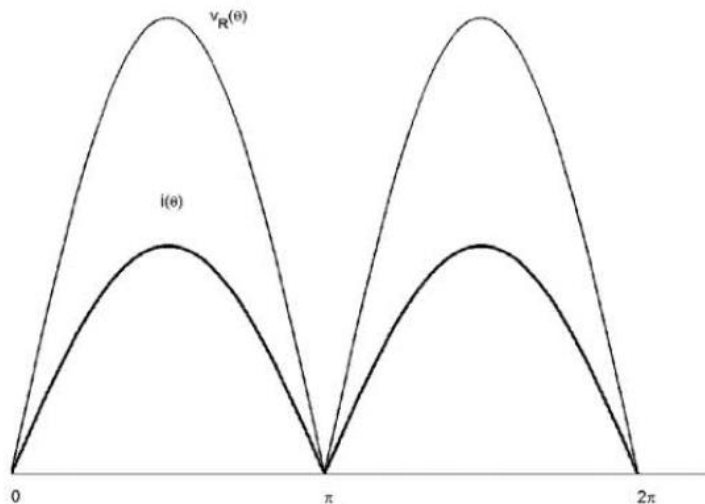
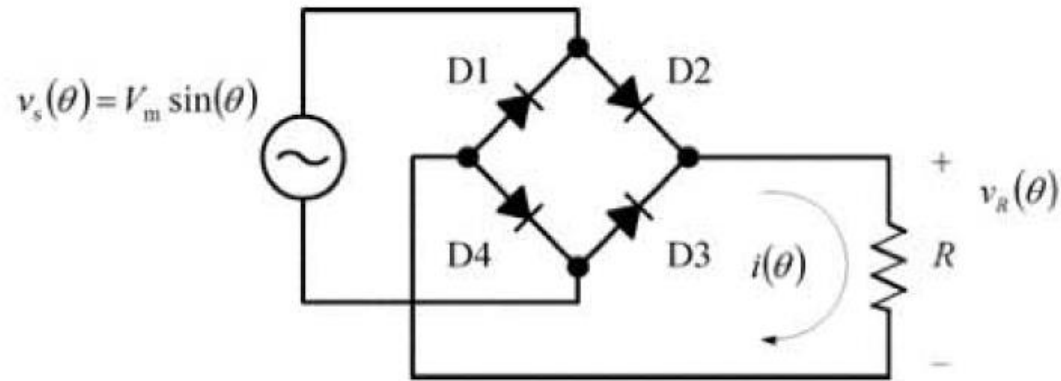
$$v_o(\omega t) = v_R(\omega t) = V_m \sin(\omega t), \quad 0 \leq \omega t \leq \pi$$

- Corriente:

$$i = \frac{V_m}{R} \sin(\theta), \quad 0 \leq \theta \leq \pi$$



Rectificadores Monofásicos – Onda Completa



- Valores medios (DC)
 - El valor medio de voltaje de salida viene dado por:

$$V_{DC} = \frac{2V_m}{\pi}$$

- La corriente media viene dada por:

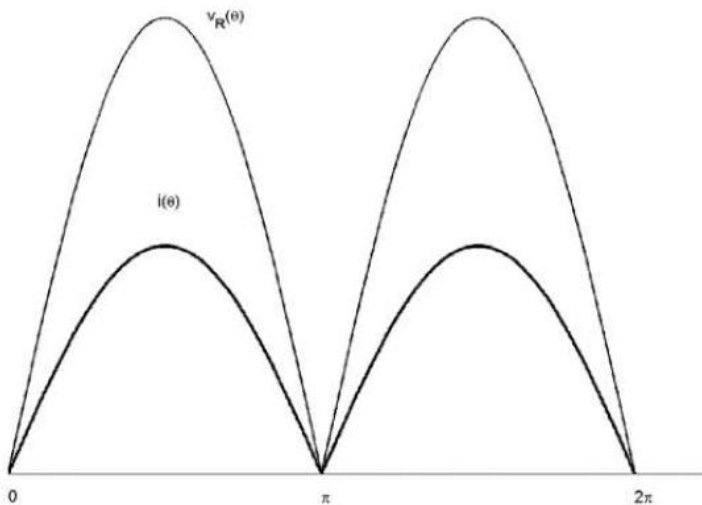
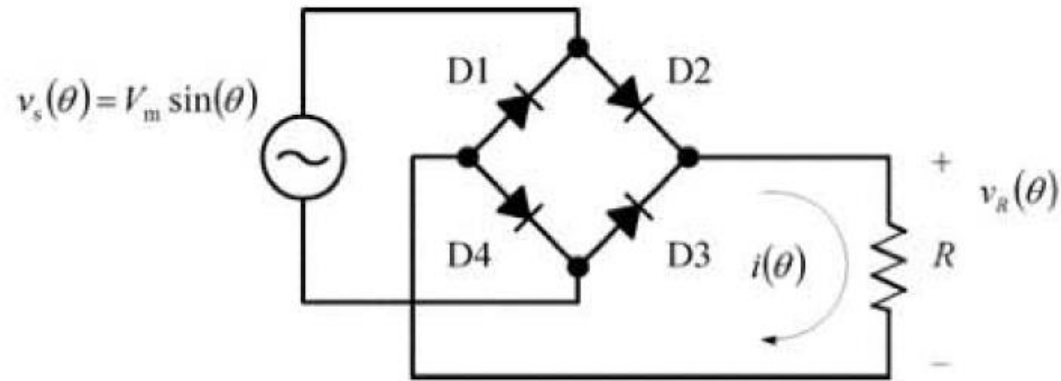
$$I_{DC} = \frac{2V_m}{\pi R}$$

- Valores RMS

$$V_{ORMS} = \frac{V_m}{\sqrt{2}}$$

$$I_{RMS} = \frac{V_{ORMS}}{R} = \frac{V_m}{\sqrt{2}R}$$

Rectificadores Monofásicos – Onda Completa



- Potencia de salida:

$$P_o = V_{oRMS} I_{RMS} = \frac{V_m^2}{2R}$$

- Eficiencia:

$$\eta = \frac{P_o}{P_o + P_{diodo}} = \frac{P_o}{P_i}$$

- Peak factor:

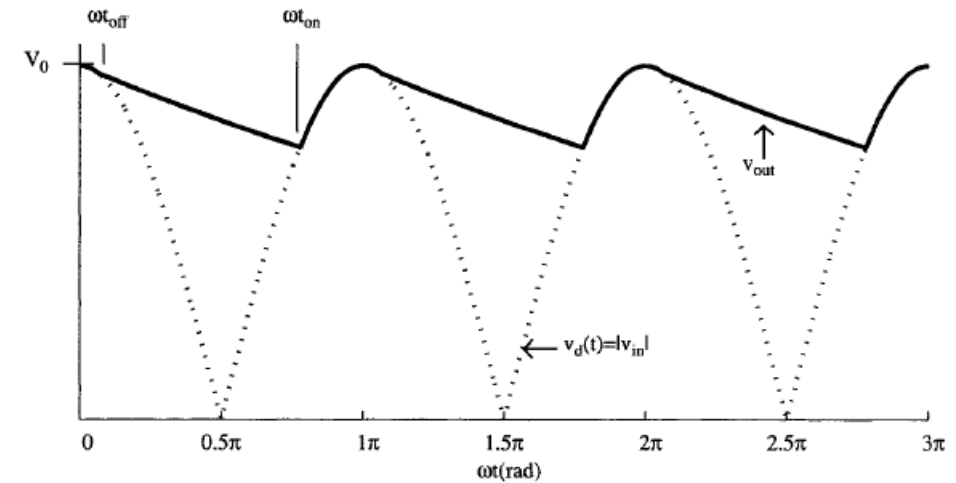
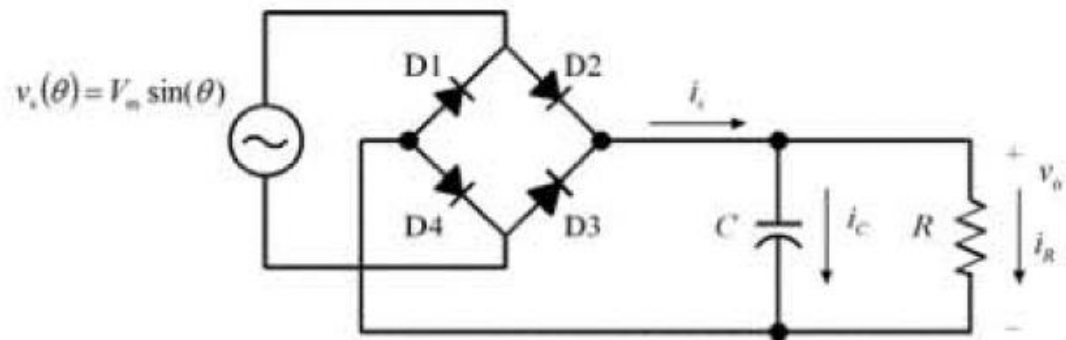
$$pf = \frac{Peak}{RMS} = \frac{\frac{V_m}{\sqrt{2}}}{\frac{V_m}{\sqrt{2}}} = \sqrt{2}$$

- Factor de ripple:

$$r = \frac{\sqrt{V_{RMS}^2 - V_{DC}^2}}{V_{DC}} \approx 0.48$$

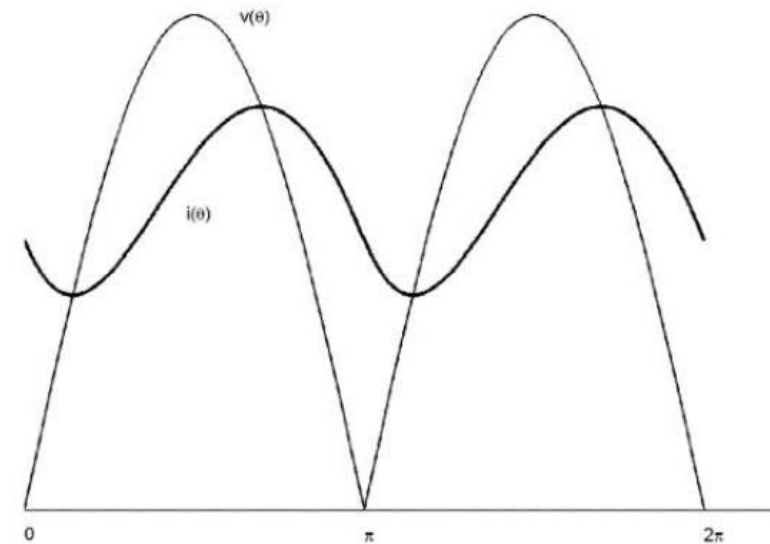
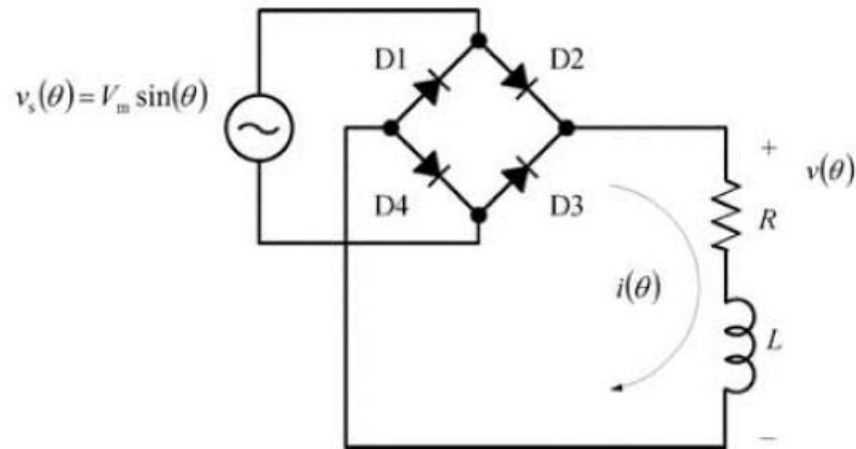
Rectificadores Monofásicos – Onda Completa

- Rectificador Onda Completa con filtro RC



Rectificadores Monofásicos – Onda Completa

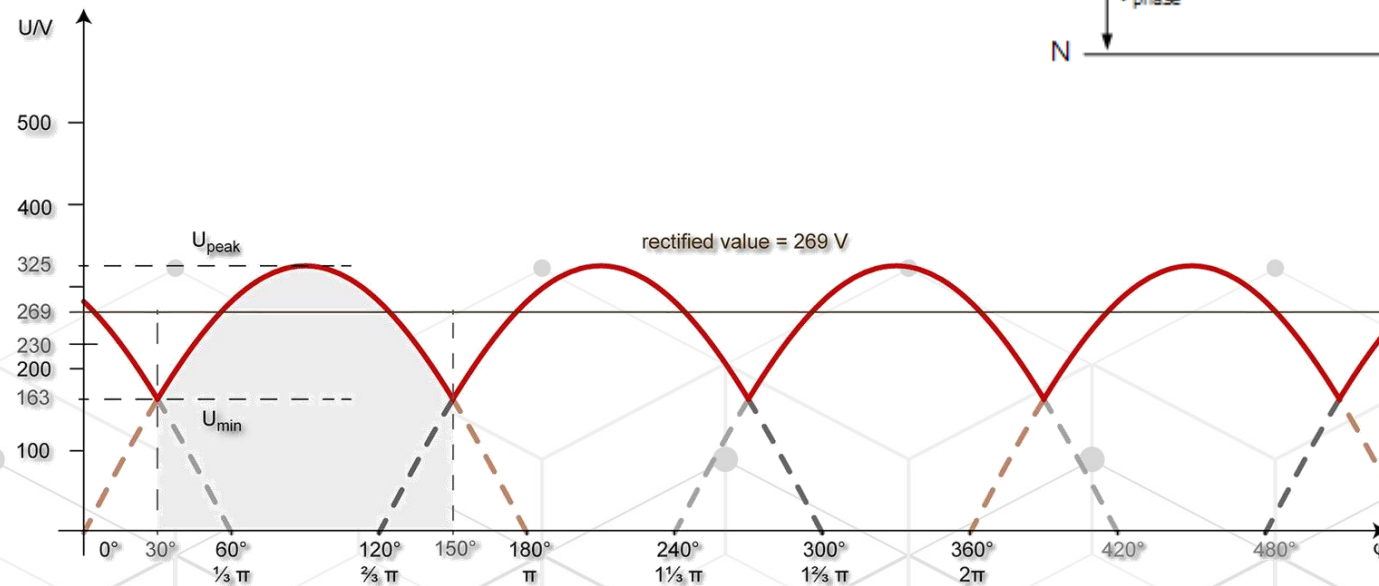
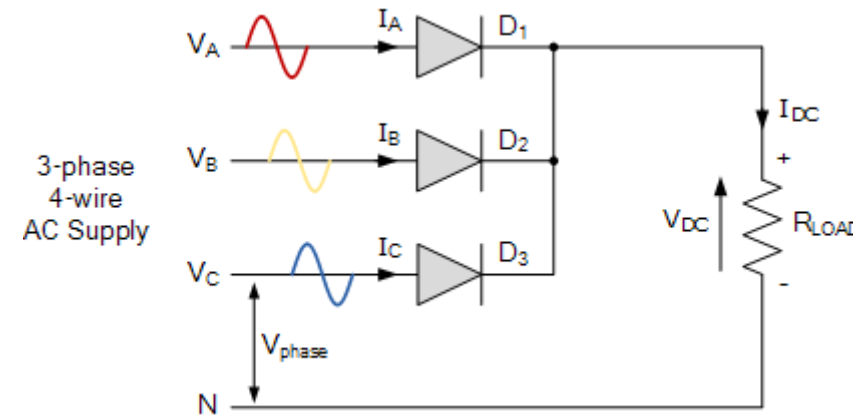
- Rectificador Onda Completa con filtro RL



Rectificador Trifásico - Media Onda

- Medio Salida:

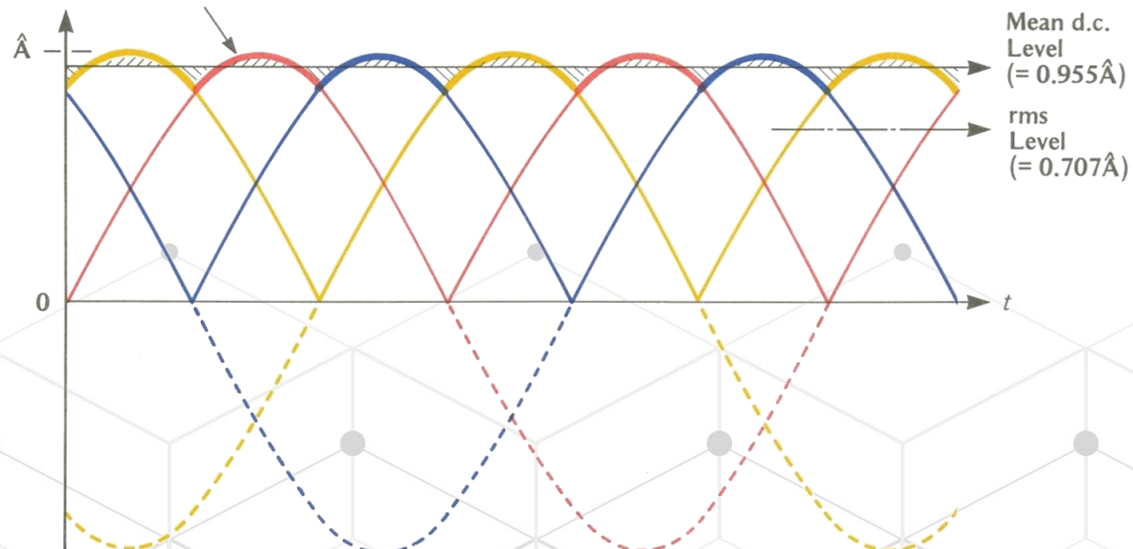
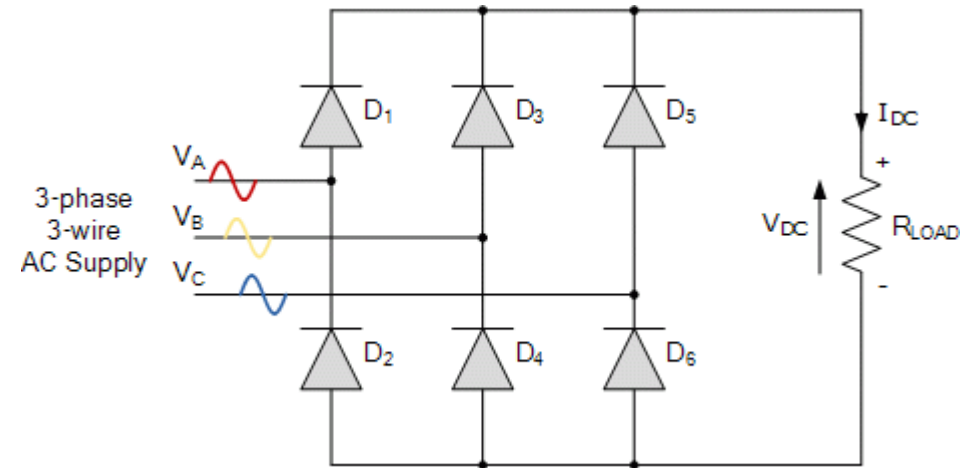
$$V_{DC} = \frac{3\sqrt{3}V_{peak}}{2\pi} = 1.17V_{LN}$$



Rectificador Trifásico – Onda Completa

- Medio Salida:

$$V_{DC} = \frac{3\sqrt{3}V_{peak}}{\pi} = 2.34V_{LN}$$



Referencias



- R. W. Erickson and D. Maksimović, *Fundamentals of Power Electronics*. Springer US, 2001.
- N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*, 3rd Editio. John Wiley & Sons, Ltd, 2002.
- R. Shaffer, *Fundamentals Of Power Electronics With Matlab*, 1st Editio. Charles River Media, 2006.

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