CIRCUITOS CON DIODOS.

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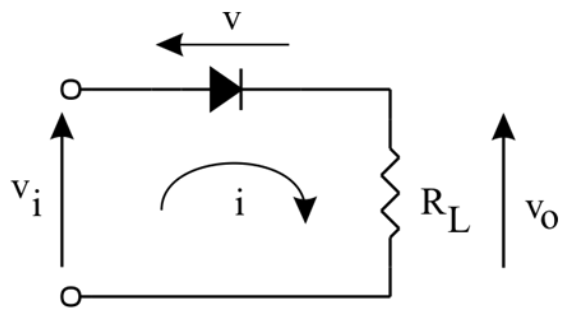
Pasos a seguir en la resolución de circuitos con diodos

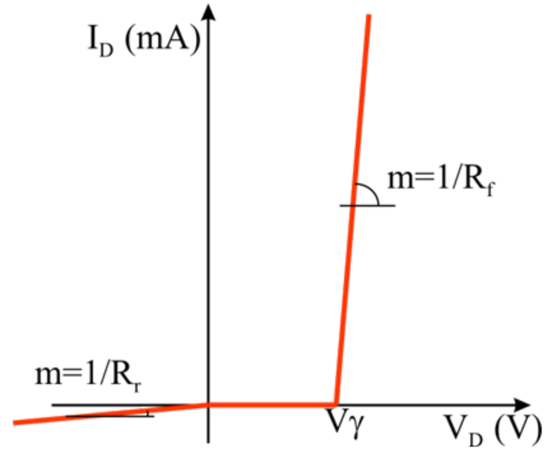
1.- **Suponer un estado del diodo**

2.- **Sustituir el diodo por su modelo y resolver el circuito**
(Cálculo de tensiones y corrientes)

3.- **Comprobar que condición debe de cumplir la entrada para que el diodo esté en el estado supuesto**

1.- Aplicación elemental.

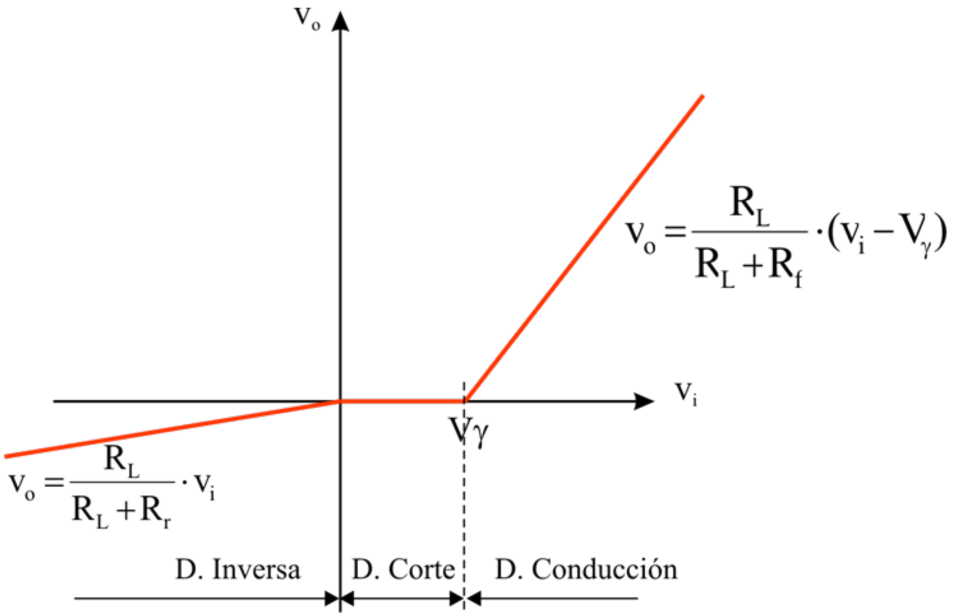




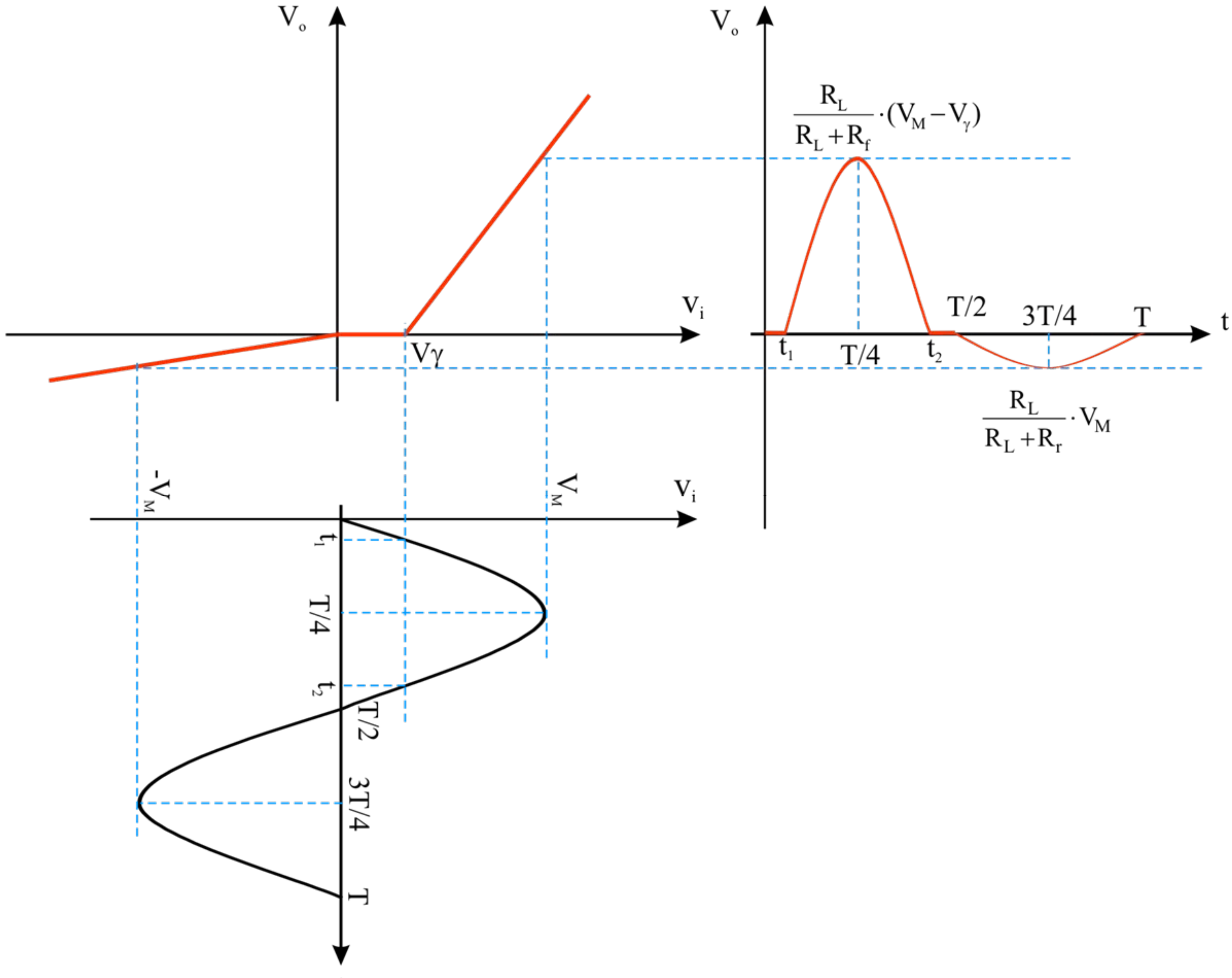
$$\text{Si} \quad v_i \le 0 \Rightarrow v_o = \frac{R_L}{R_L + R_r} \cdot v_i$$

$$\text{Si} \quad 0 \le v_i \le V_\gamma \Rightarrow v_o = 0$$

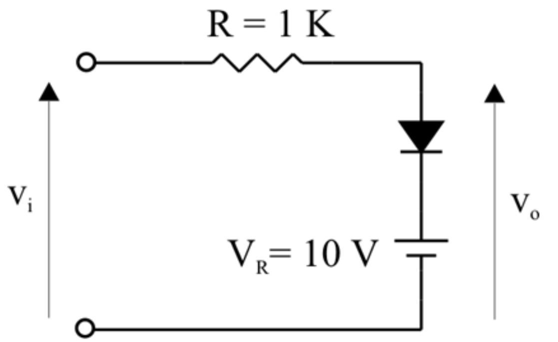
$$\text{Si} \quad v_i \ge V_\gamma \Rightarrow v_o = \frac{R_L}{R_L + R_f} \cdot (v_i - V_\gamma)$$



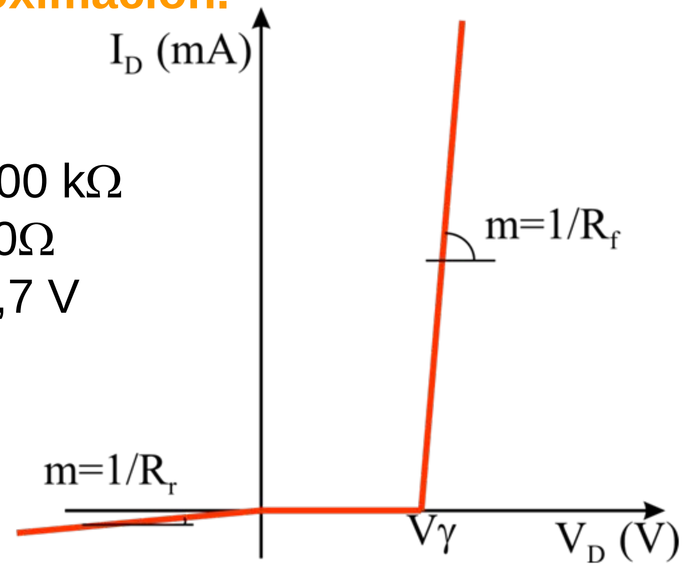
1.- Aplicación elemental.

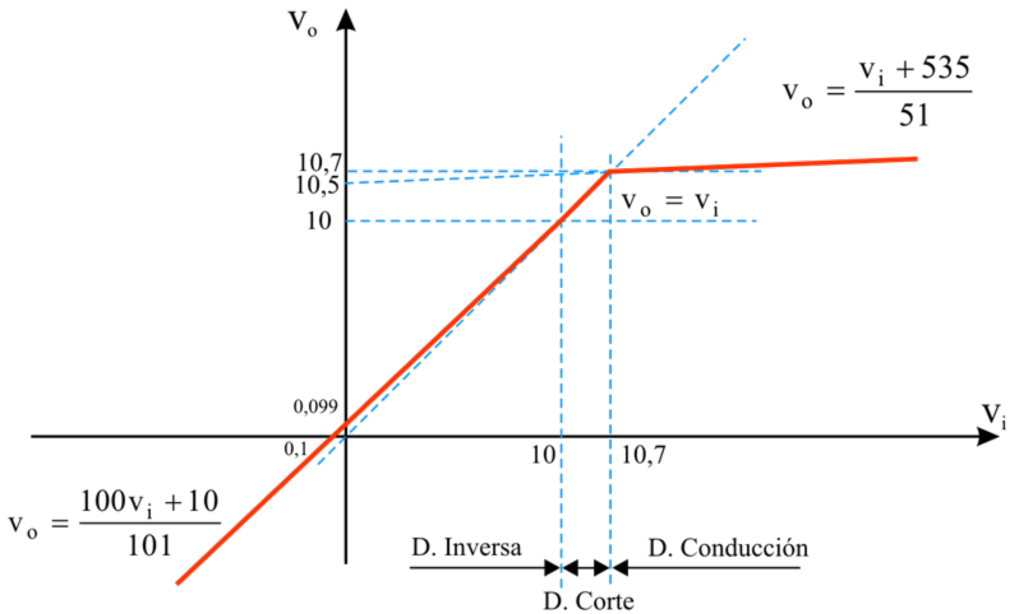


2.1.1.- Resolución utilizando la 1ª aproximación.



R_r = 100 kΩ
R_f = 20Ω
V_γ = 0,7 V



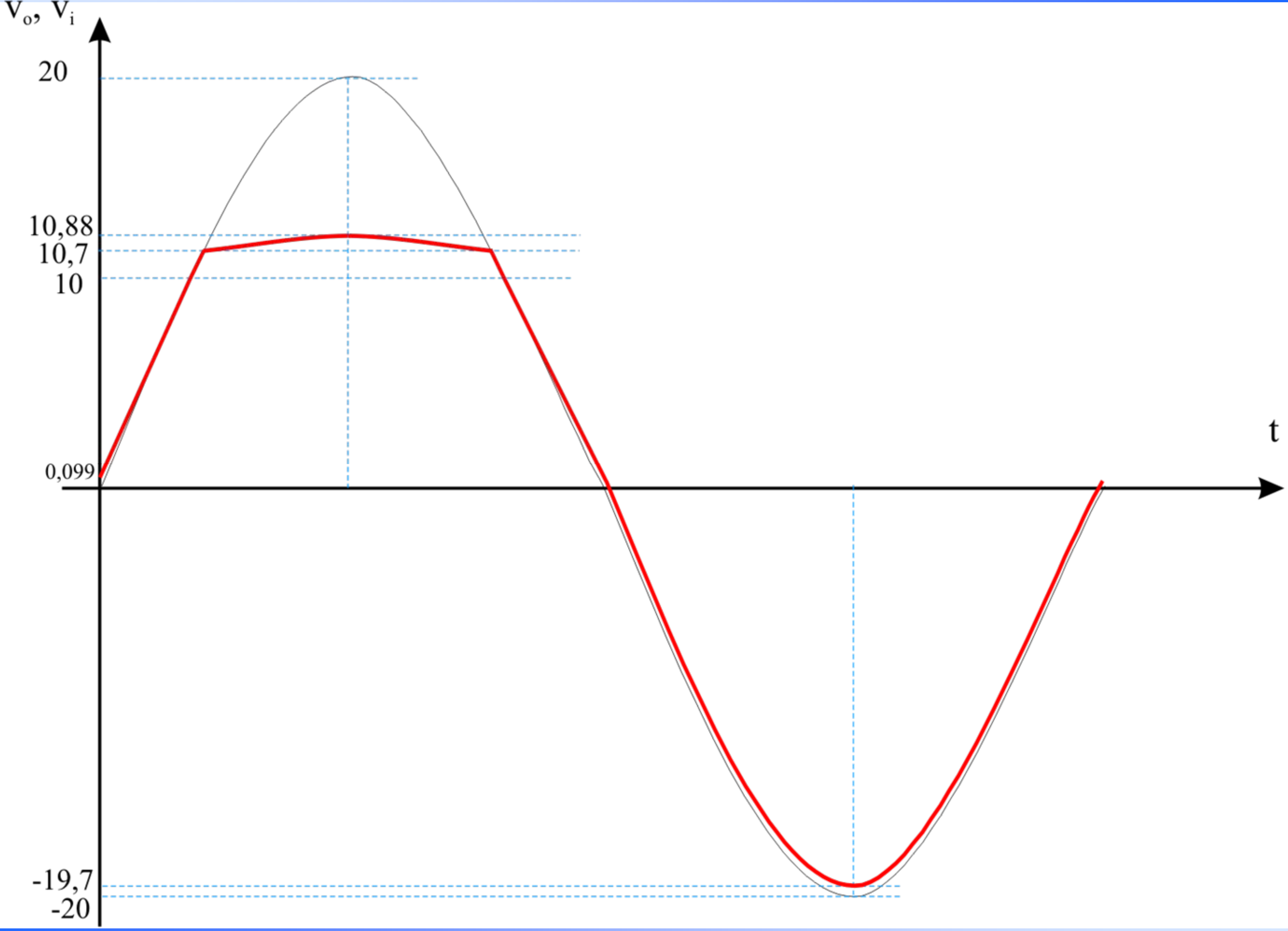


$$\text{Si } v_i \le 10 \text{ V} \Rightarrow v_o = \frac{100 v_i + 10}{101}$$

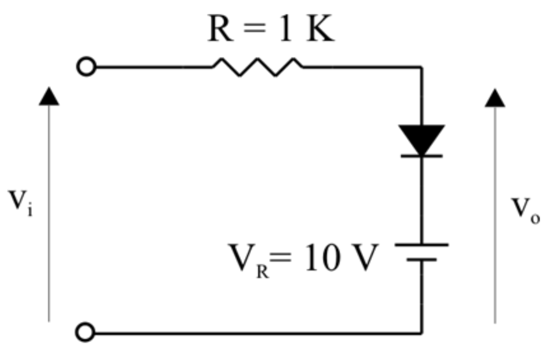
$$\text{Si } 10 \le v_i \le 10,7 \text{ V} \Rightarrow v_o = v_i$$

$$\text{Si } v_i \ge 10,7 \text{ V} \Rightarrow v_o = \frac{v_i + 535}{51}$$

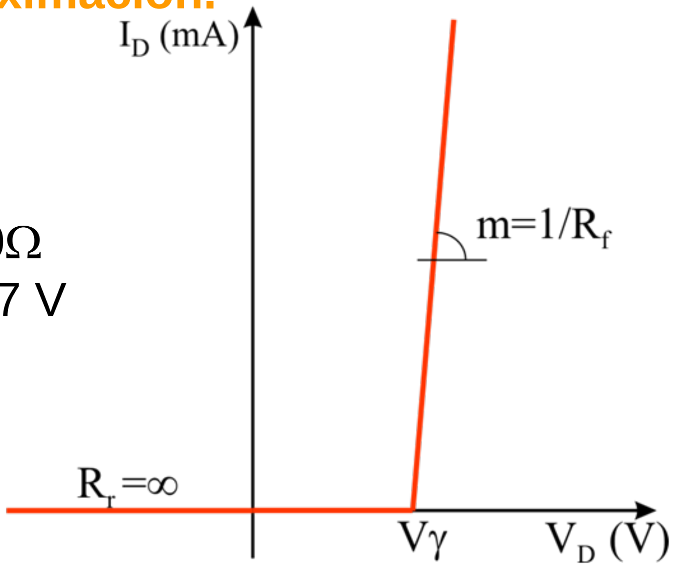
2.1.1.- Resolución utilizando la 1ª aproximación.

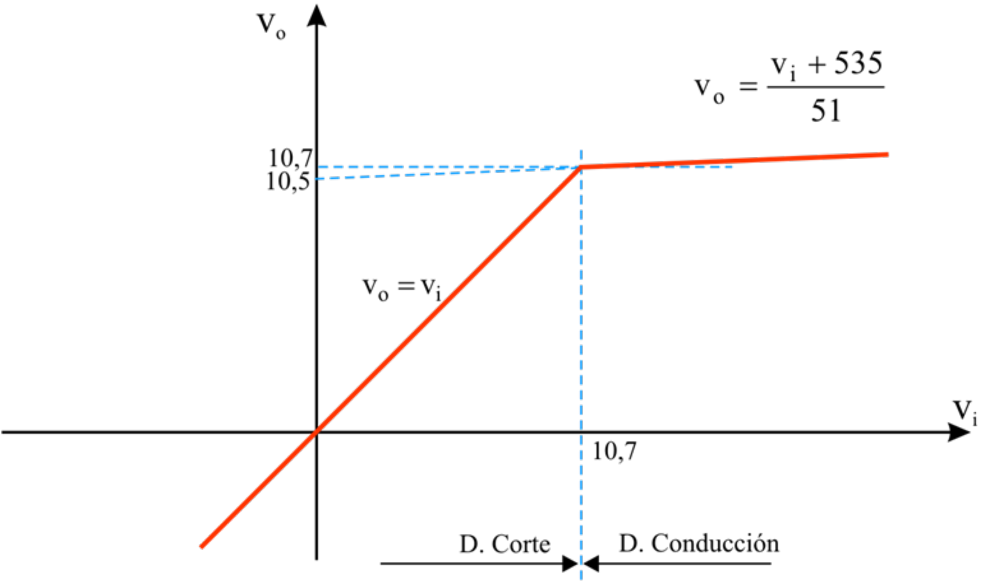


2.1.2.- Resolución utilizando la 2ª aproximación.



$R_r = \infty$
$R_f = 20\Omega$
$V_\gamma = 0,7$ V

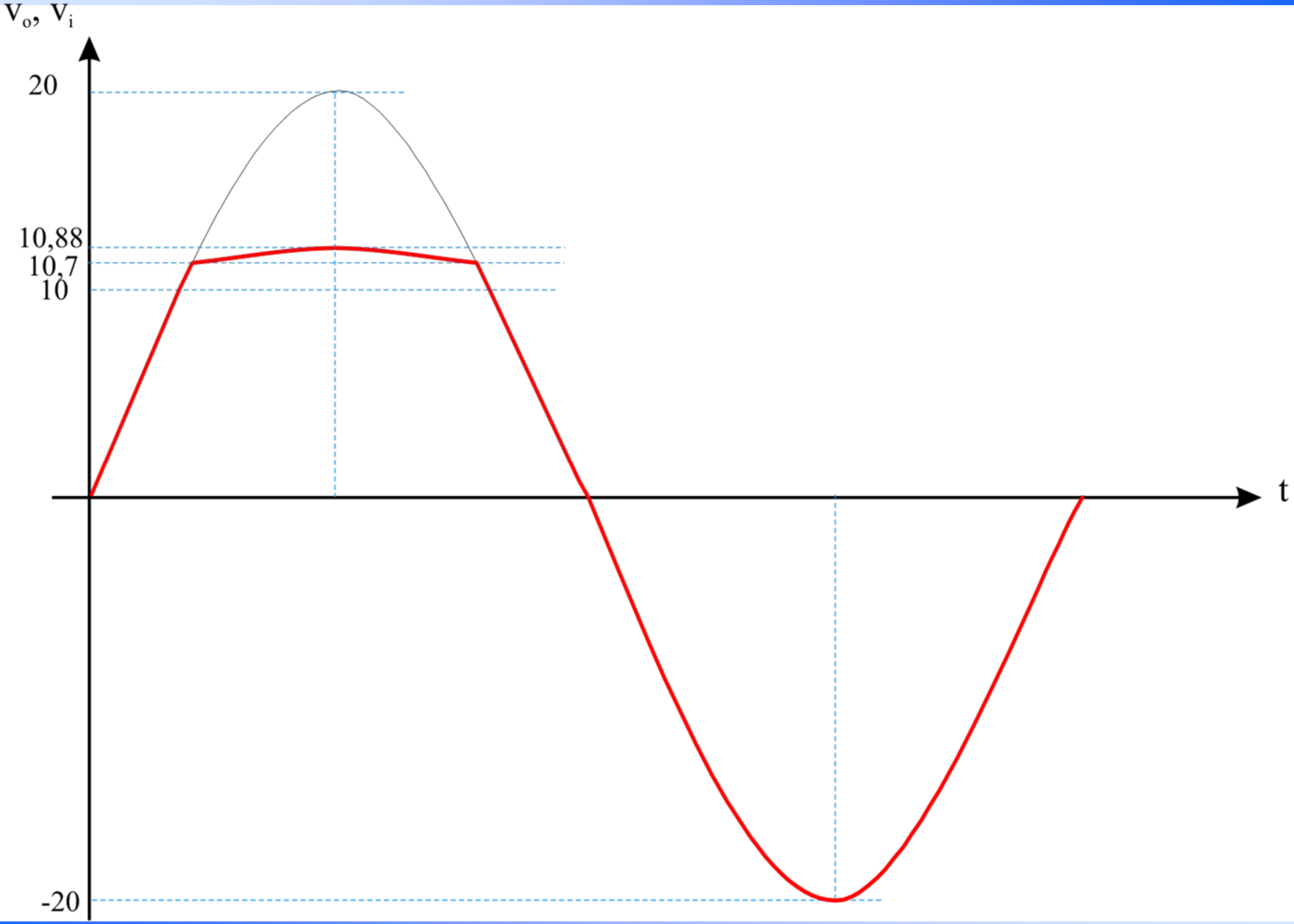




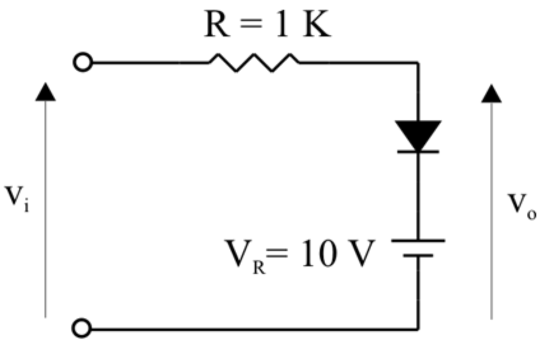
$$\text{Si} \quad v_i \le 10,7 \text{ V} \Rightarrow v_o = v_i$$

$$\text{Si} \quad v_i \ge 10,7 \text{ V} \Rightarrow v_o = \frac{v_i + 535}{51}$$

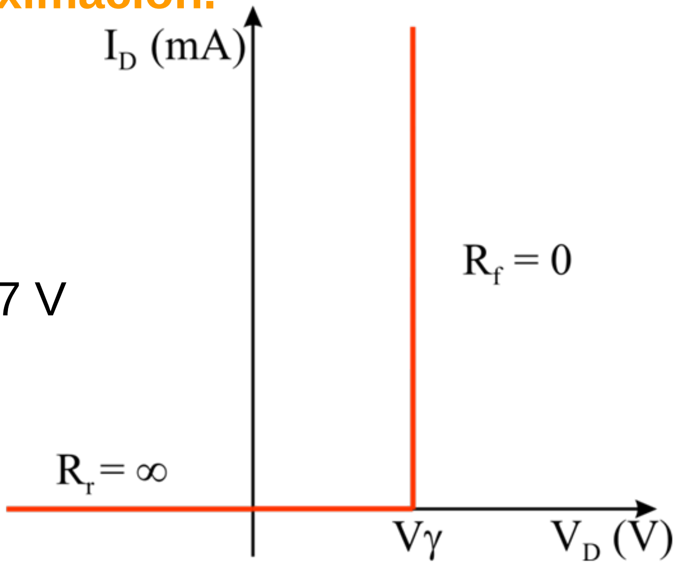
2.1.2.- Resolución utilizando la 2ª aproximación.

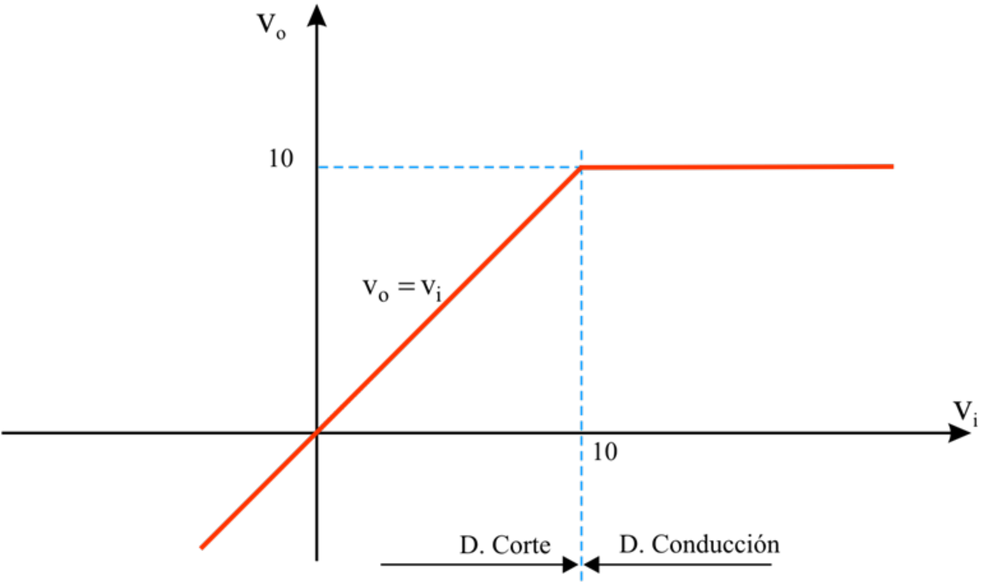


2.1.3.- Resolución utilizando la 3ª aproximación.



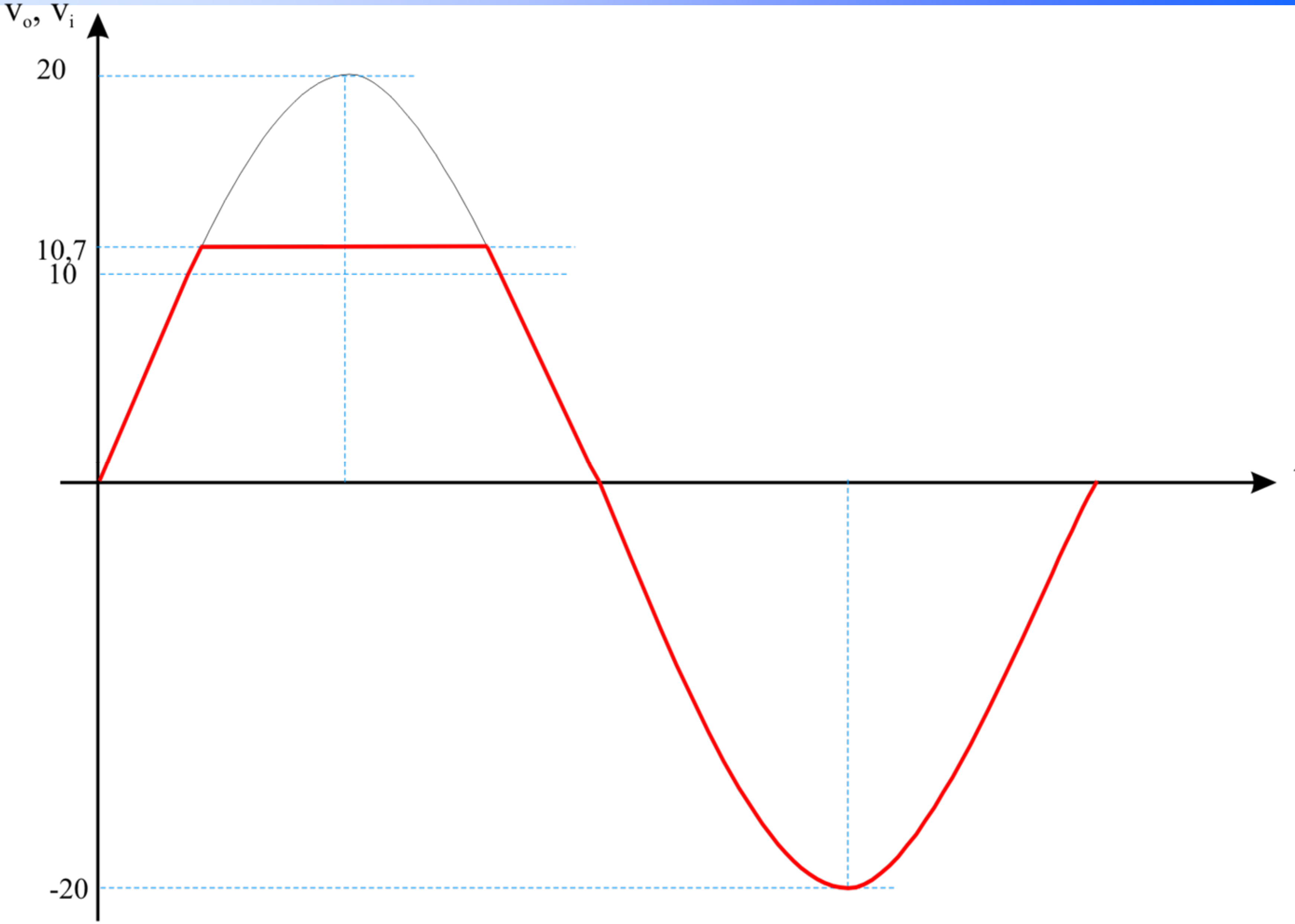
$R_r = \infty$
$R_f = 0$
$V_\gamma = 0{,}7$ V





$$\text{Si} \;\; v_i \leq 10{,}7 \;\; V \Rightarrow v_o = v_i$$

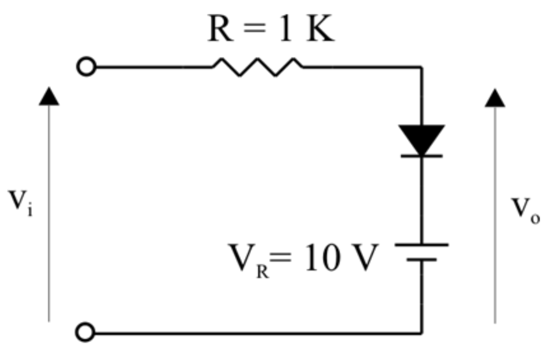
$$\text{Si} \;\; v_i \geq 10{,}7 \;\; V \Rightarrow v_o = 10{,}7 \;\; V$$



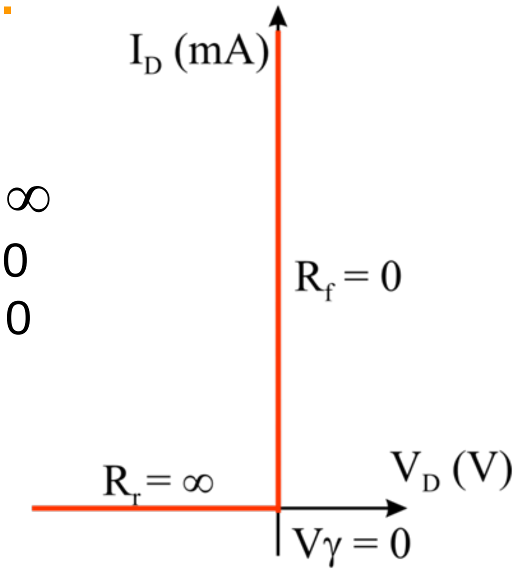
V_o, V_i
20
10,7
10
t
-20

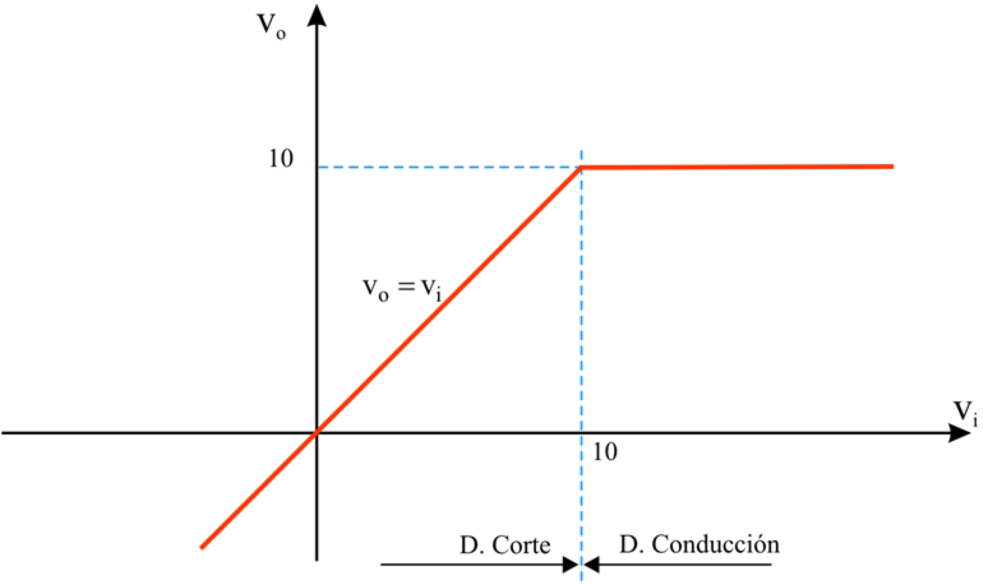
2.- Circuitos recortadores.

2.1.4.- Resolución utilizando la 4ª aproximación.



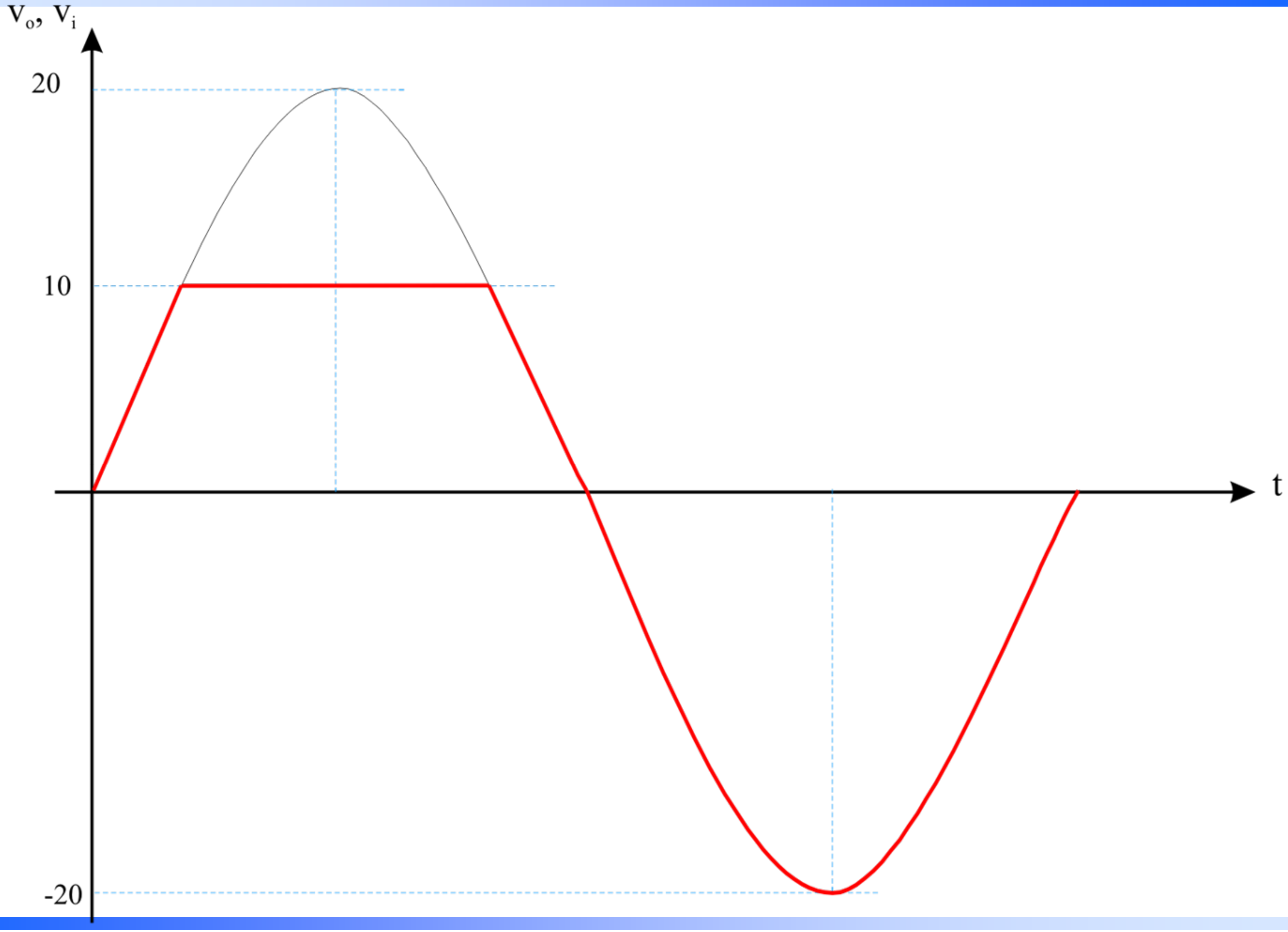
$R_r = \infty$
$R_f = 0$
$V_\gamma = 0$



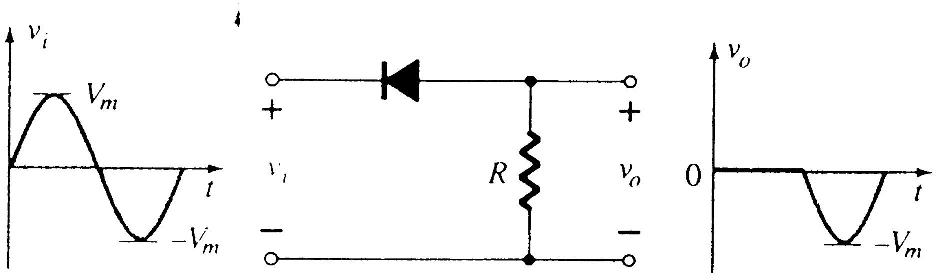


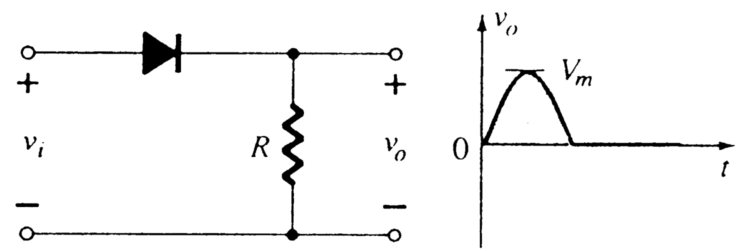
$$\text{Si } \; v_i \leq 10 \; \text{V} \Rightarrow v_o = v_i$$

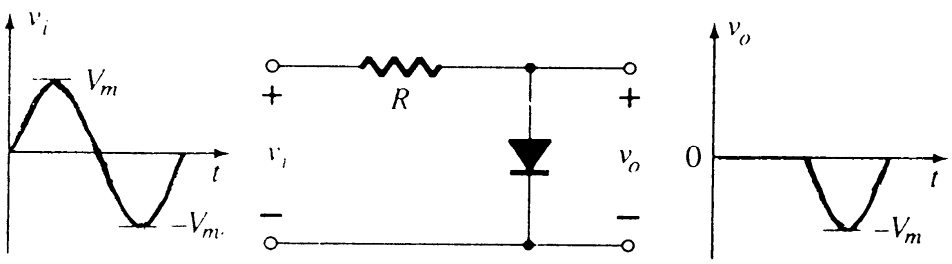
$$\text{Si } \; v_i \geq 10 \; \text{V} \Rightarrow v_o = 10 \; \text{V}$$

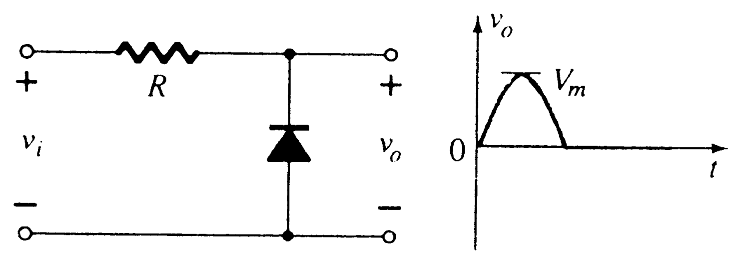

V_o, V_i
20
10
-20
t

2.2.- Otros circuitos recortadores.

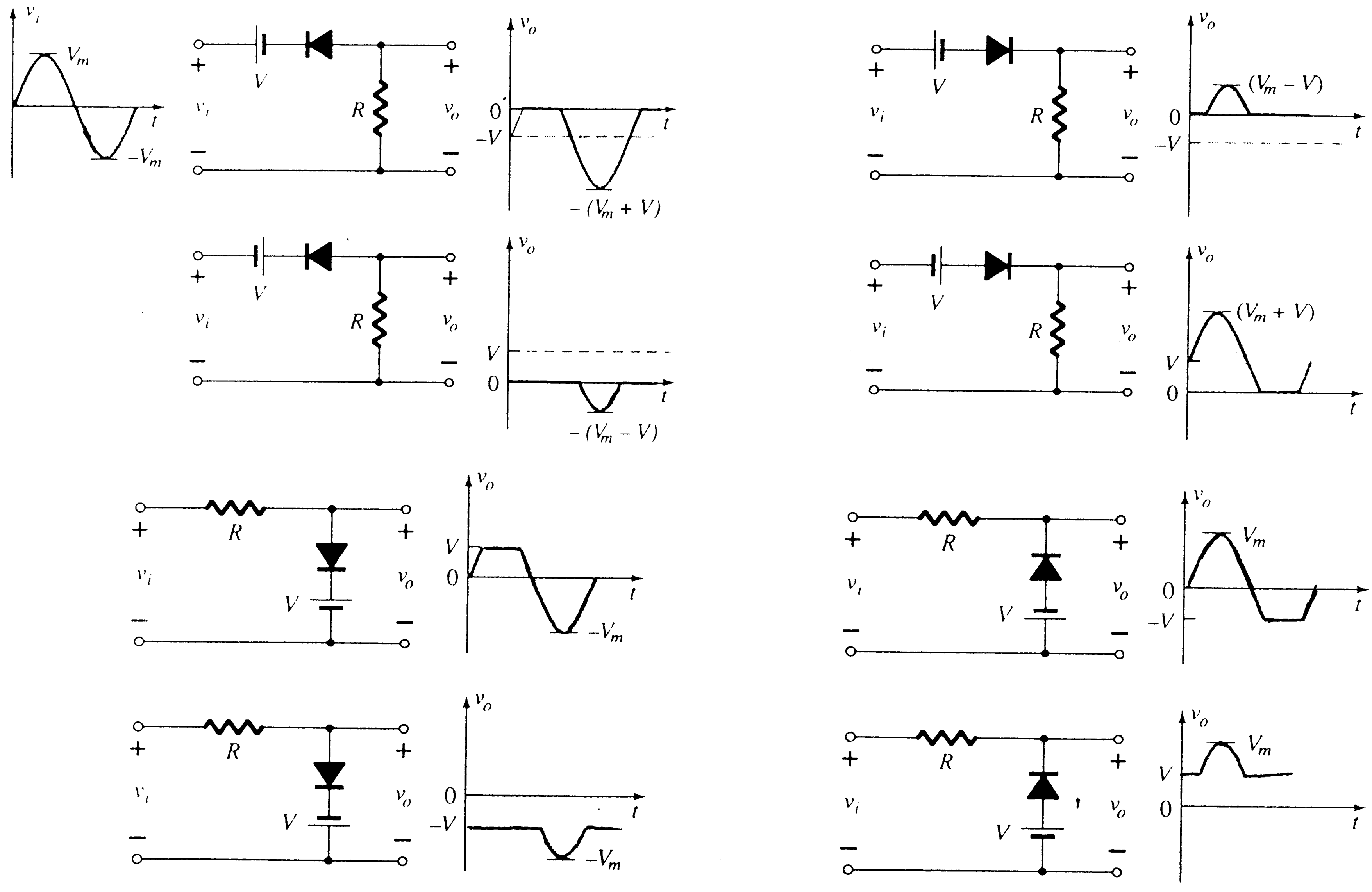






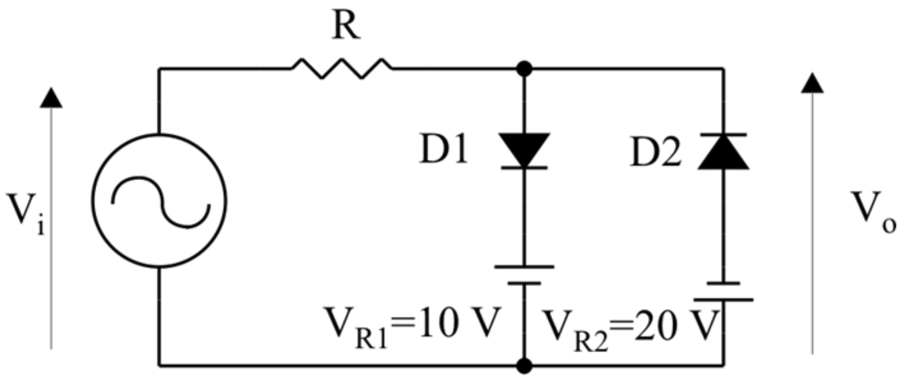


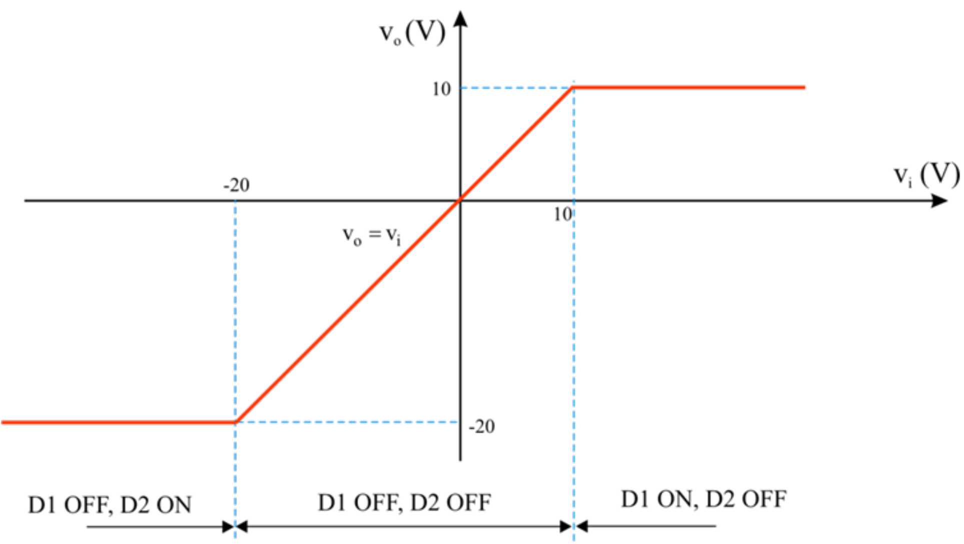
2.- Circuitos recortadores.

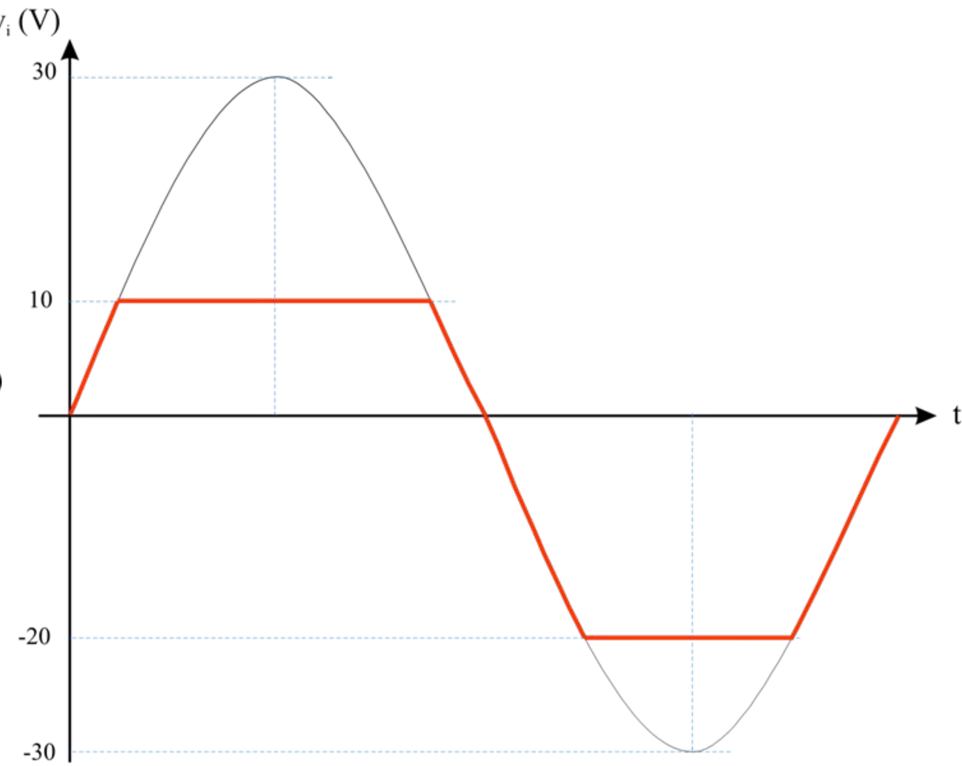


2.- Circuitos recortadores.

2.3.- Circuito recortador a dos niveles.

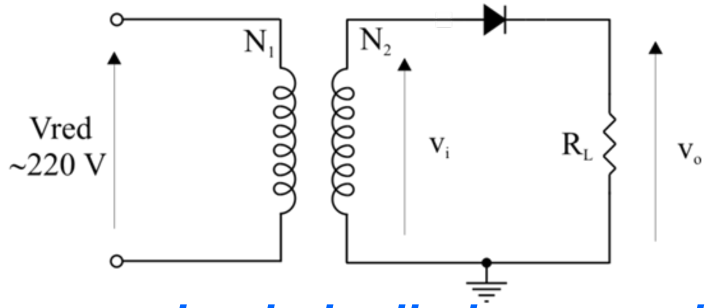






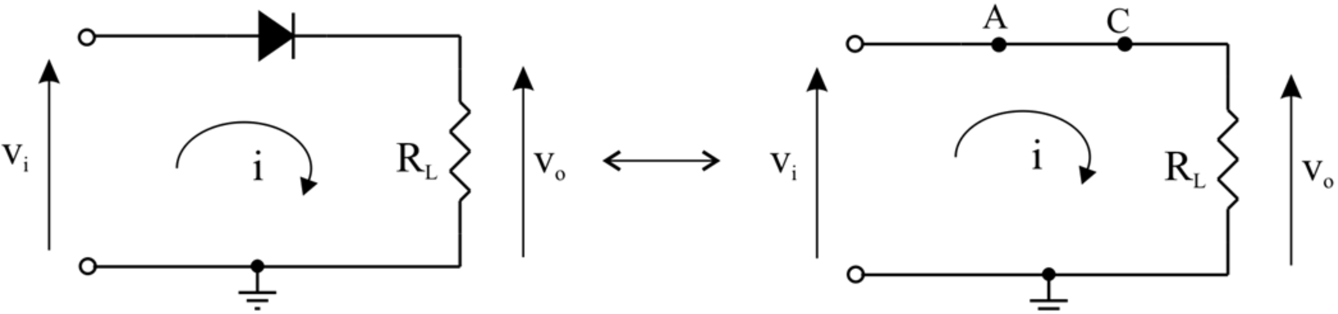
3.- Circuitos rectificadores.

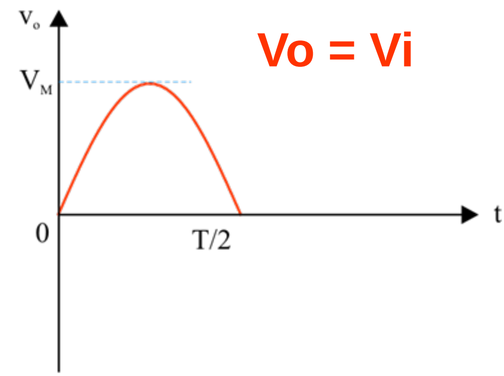
3.1.- Rectificador de media onda.



$$\frac{V_{red}}{V_i} = \frac{N_1}{N_2}$$

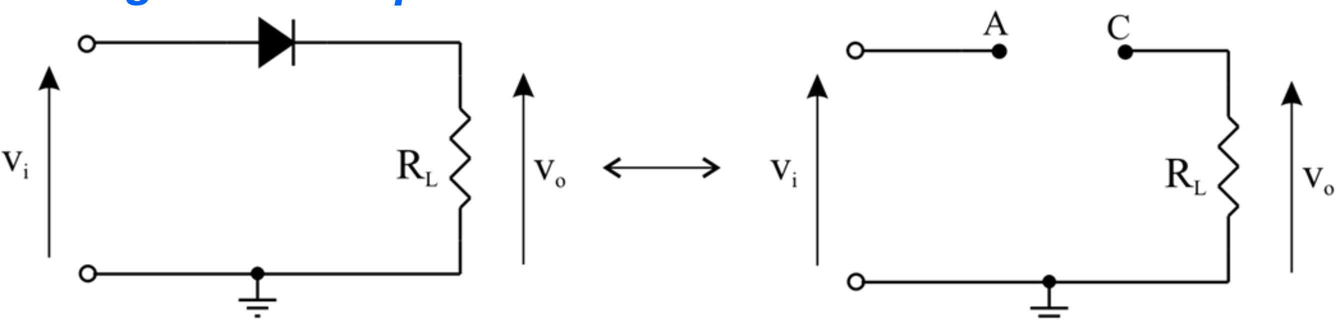
Primer semiperiodo diodo en conducción

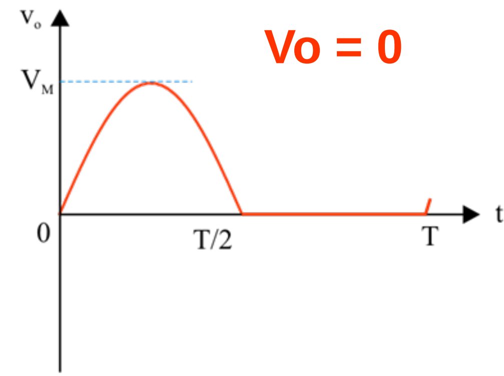




Vo = Vi

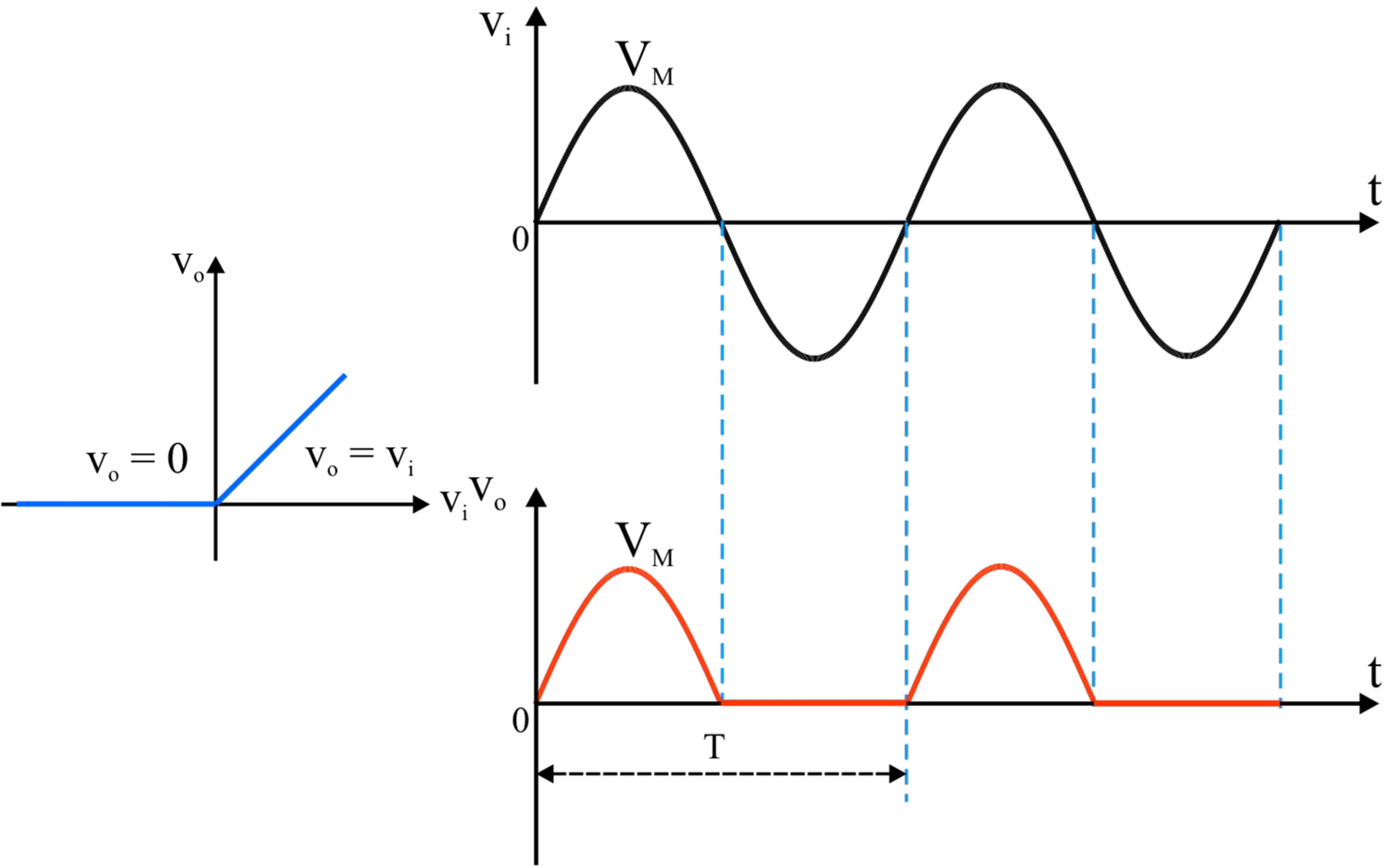
Segundo semiperiodo diodo en corte





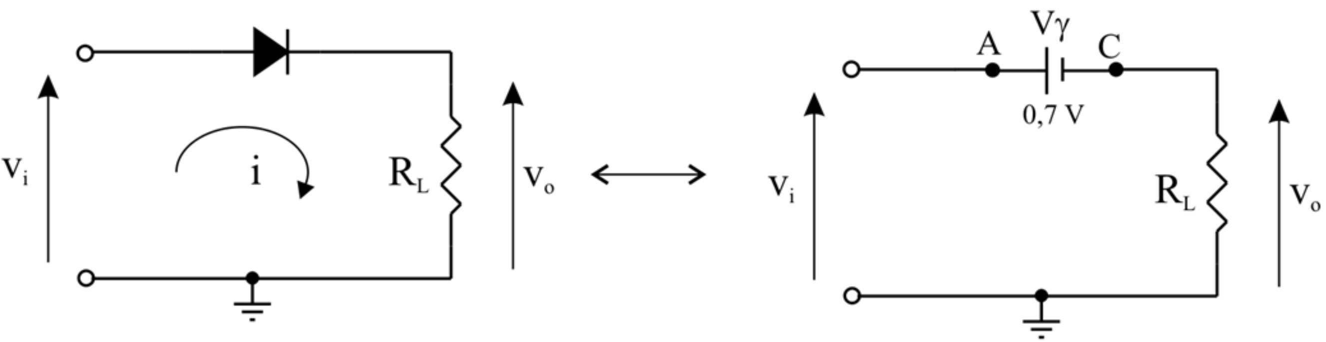
Vo = 0

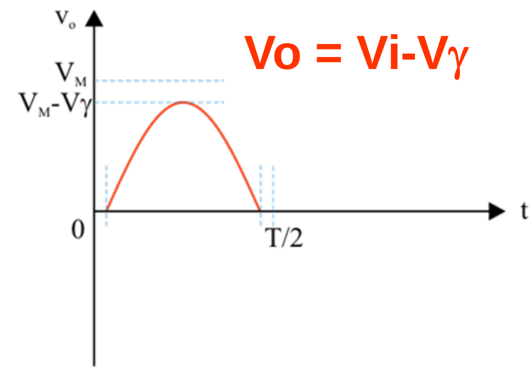
3.1.- Rectificador de media onda.



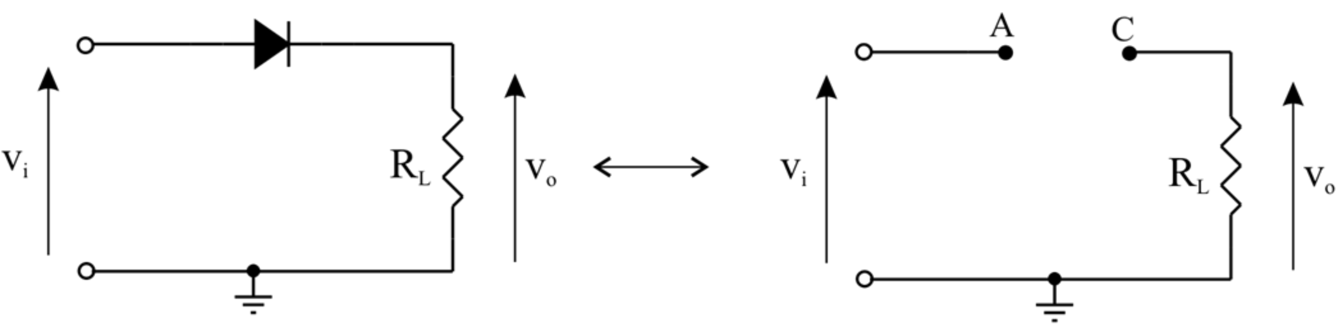
Utilizando la 3ª aproximación

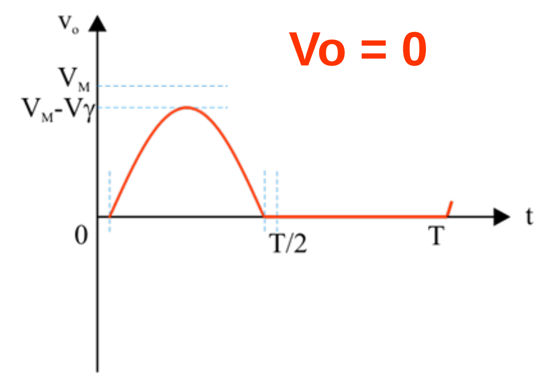
Primer semiperiodo diodo en conducción



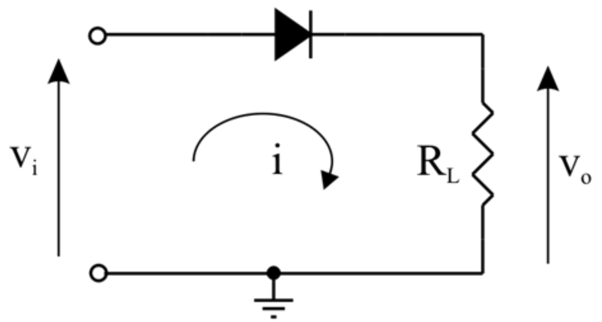


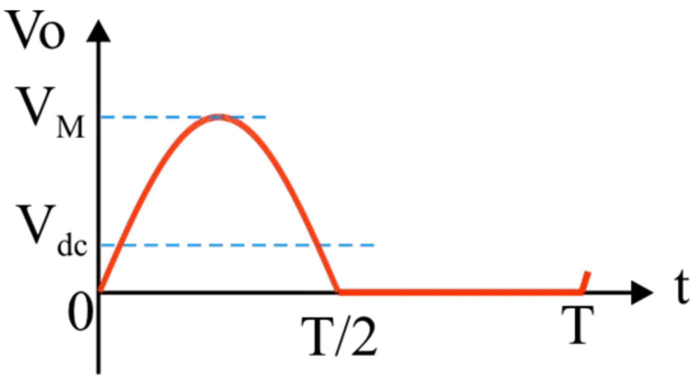
Segundo semiperiodo diodo en corte





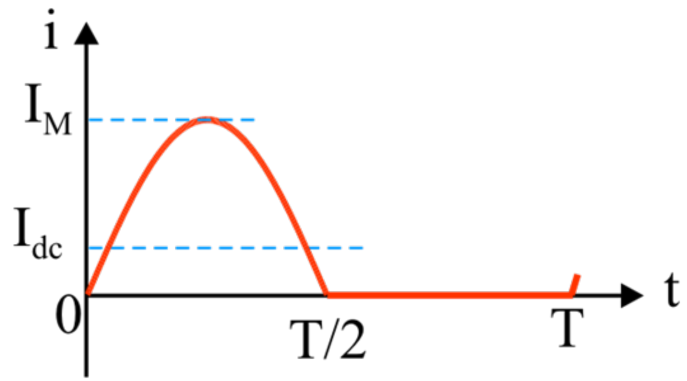
3.1.1.- Cálculo de la corriente.





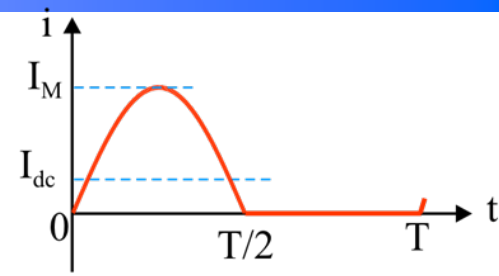
$$\boxed{i = \frac{v_o}{R_L}}$$

$$\begin{cases} 0 \le t \le \dfrac{T}{2} \rightarrow i = \dfrac{V_M}{R_L} \cdot \text{sen}\ (\omega t) \\ \dfrac{T}{2} \le t \le T \rightarrow i = 0 \end{cases}$$



3.1.- Rectificador de media onda.

3.1.1.- Cálculo de la corriente.



Valor medio o de continua

$$I_{dc} = \frac{1}{T}\left[\int_0^{\frac{T}{2}} i \; dt + \int_{\frac{T}{2}}^{T} i \; dt\right] = \frac{1}{T}\int_0^{\frac{T}{2}} I_M \cdot \mathrm{sen}\;(\omega t)\; dt = \frac{I_M}{T}\cdot\frac{(-1)}{\omega}\left[\cos\;(\omega t)\right]_0^{\frac{T}{2}}$$

$$\boxed{I_{dc} = \frac{I_M}{\pi}}$$

Valor eficaz

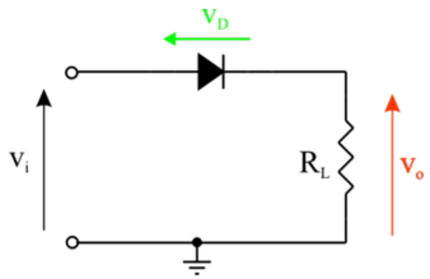
$$I^2 = \frac{1}{T}\left[\int_0^{\frac{T}{2}} i^2 dt + \int_{\frac{T}{2}}^{T} i^2 dt\right] = \frac{1}{T}\int_0^{\frac{T}{2}} i^2 dt = \frac{1}{T}\int_0^{\frac{T}{2}} I_M^2\; \mathrm{sen}^2(\omega t)\; dt = \frac{I_M^2}{T}\int_0^{\frac{T}{2}} \mathrm{sen}^2(\omega t)\; dt =$$

$$= \frac{I_M^2}{T}\int_0^{\frac{T}{2}} \frac{1-\cos\;(2\omega t)}{2}\; dt = \frac{I_M^2}{2\,T}\left[t - \frac{1}{2\omega}\mathrm{sen}\;(2\omega t)\right]_0^{\frac{T}{2}} =$$

$$= \frac{I_M^2}{2\,T}\left[\frac{T}{2} - 0 - \frac{1}{2\omega}\mathrm{sen}\;2\pi + \frac{1}{2\omega}\mathrm{sen}\;0\right] = \frac{I_M^2}{4}$$

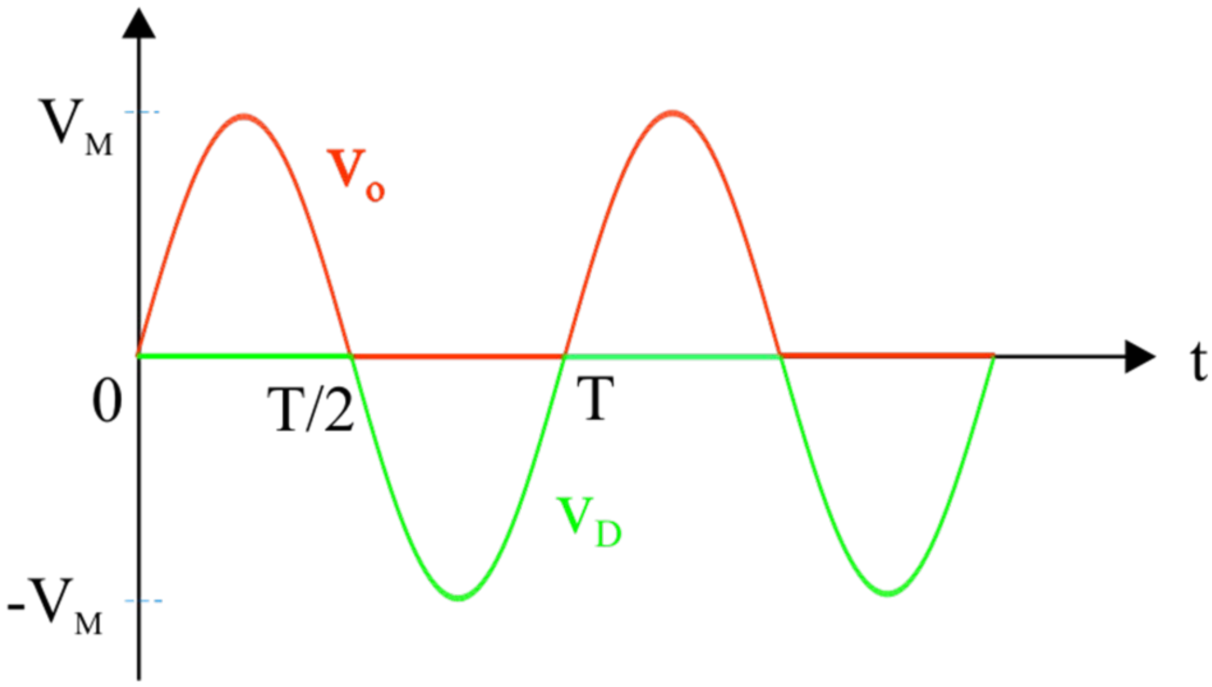
$$\boxed{I = \frac{I_M}{2}}$$

3.1.2.- Cálculo de la tensión en el diodo.



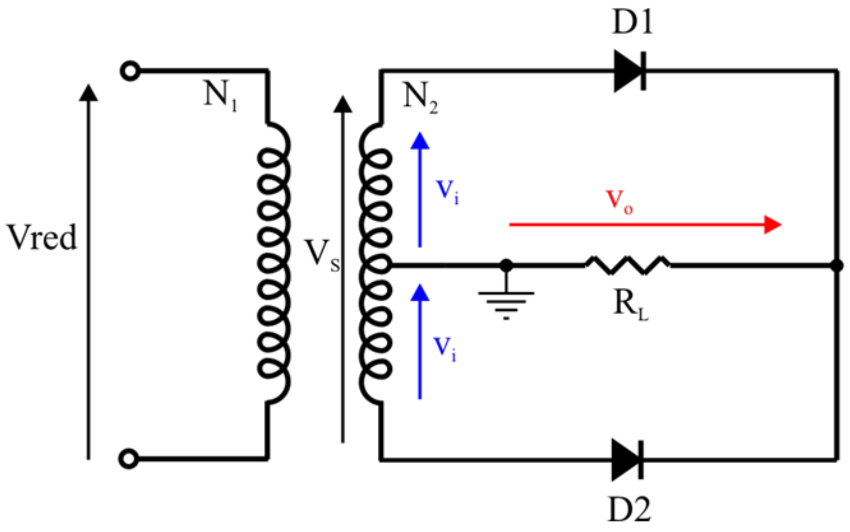
$$v_D = v_i - v_o$$

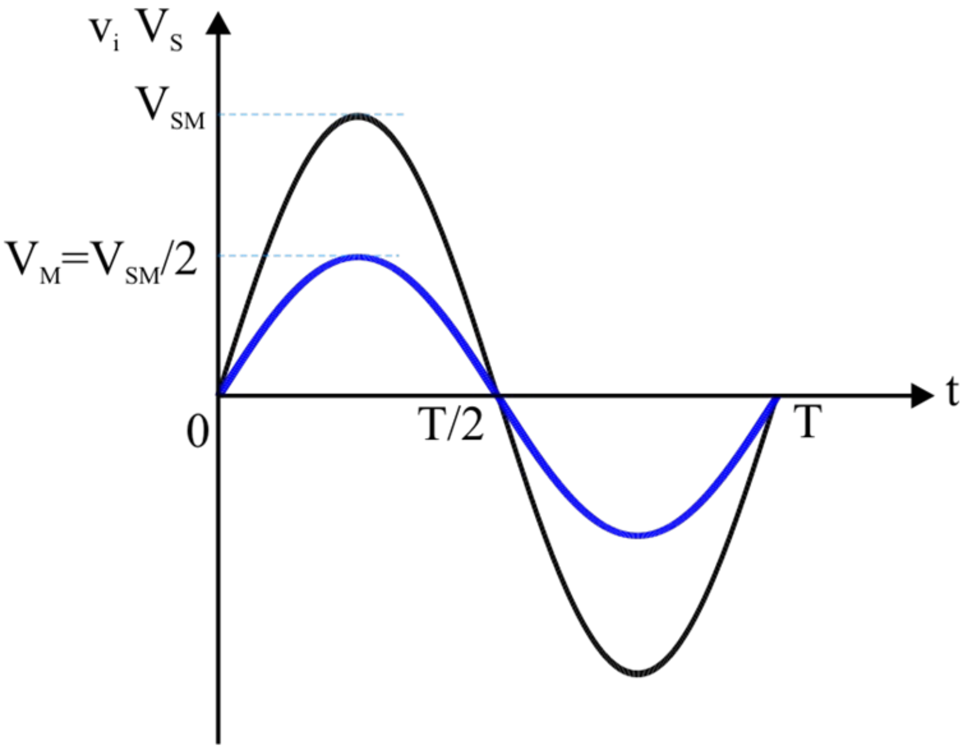
$$\begin{cases} 0 \le t \le \dfrac{T}{2} & v_o = v_i \Rightarrow v_D = 0 \\ \dfrac{T}{2} \le t \le T & v_o = 0 \Rightarrow v_D = v_i \end{cases}$$



3.2.- Rectificador de onda completa.

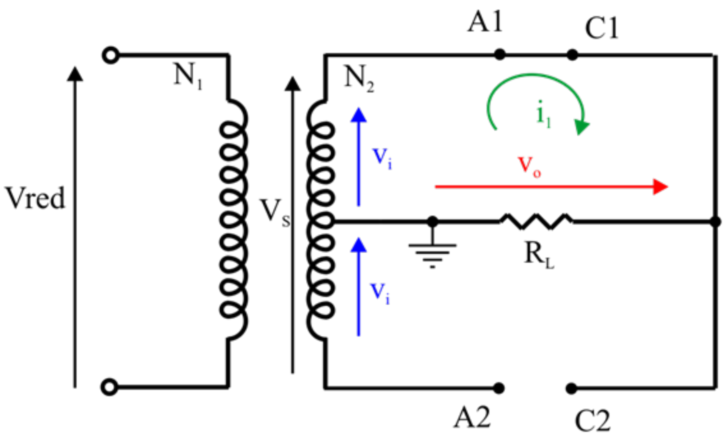
3.2.1.- Circuito con dos diodos.

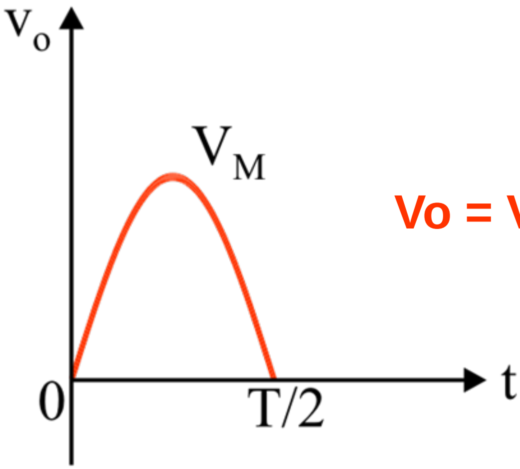




La tensión a rectificar es $v_i = \frac{V_{SM}}{2}\,\text{sen}(\varpi t)$

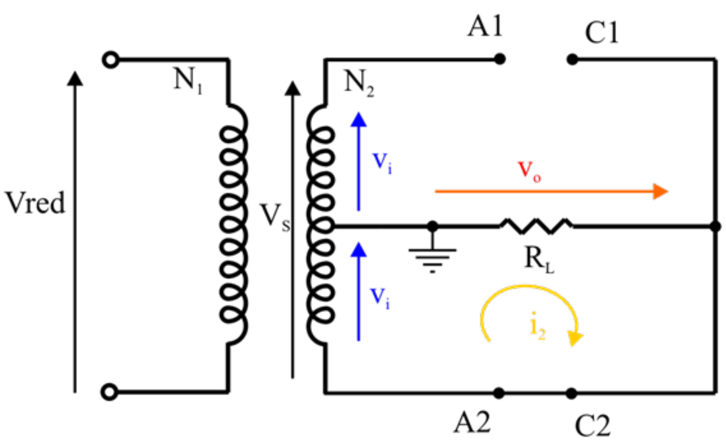
D1 ON, D2 OFF

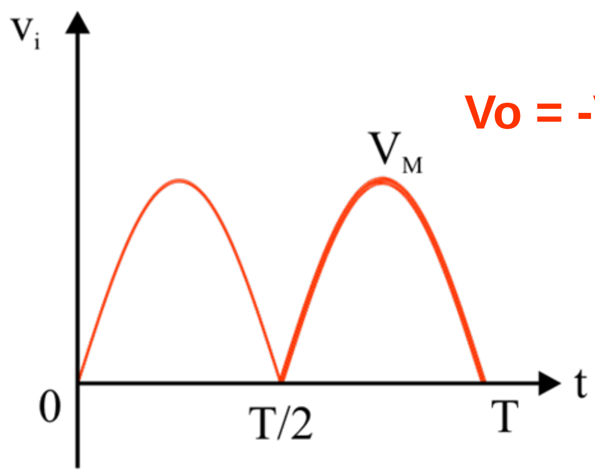




Vo = Vi

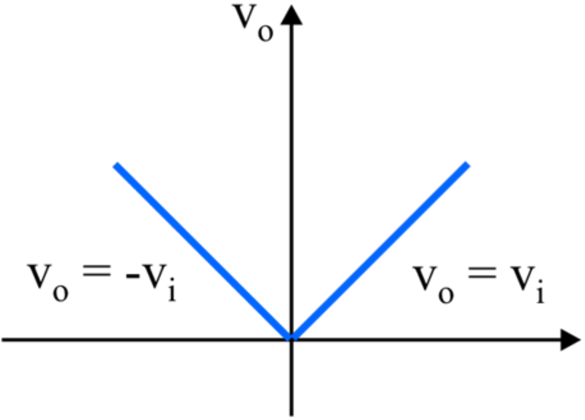
D1 OFF, D2 ON

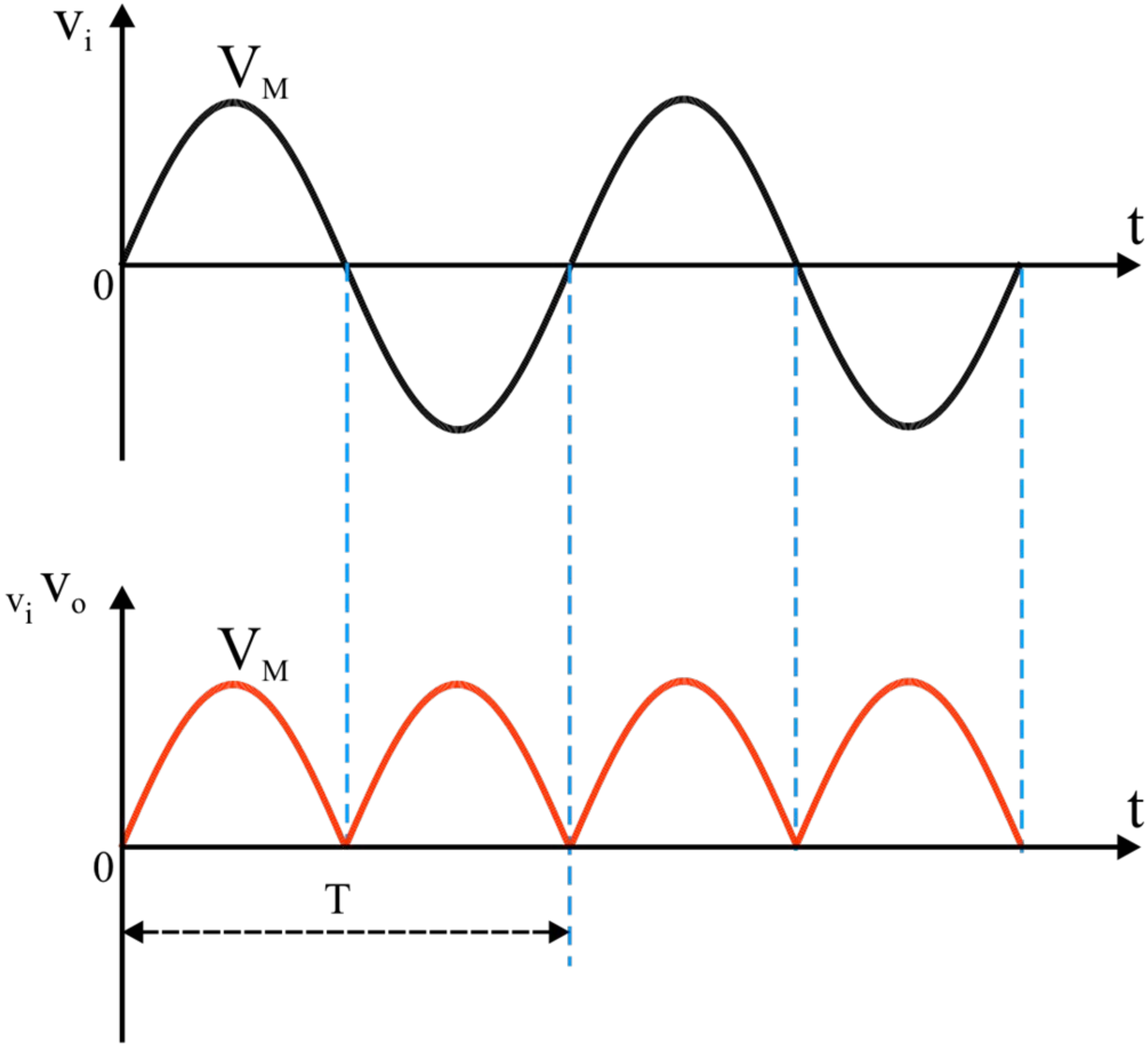




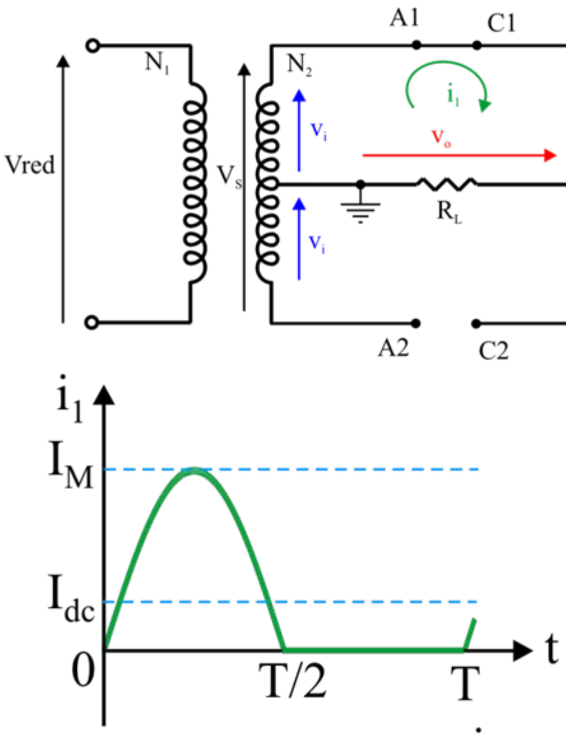
Vo = -Vi

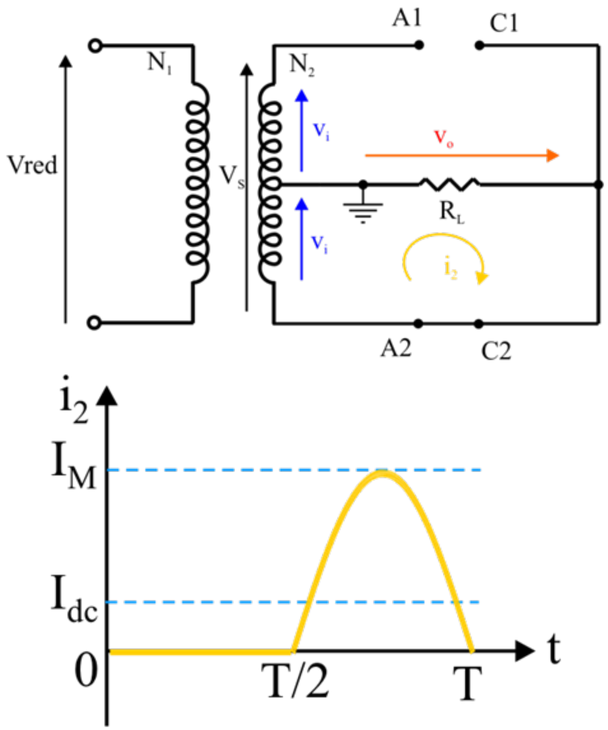
3.2.1.- Circuito con dos diodos.





3.2.1.1.- Cálculo de las corrientes.

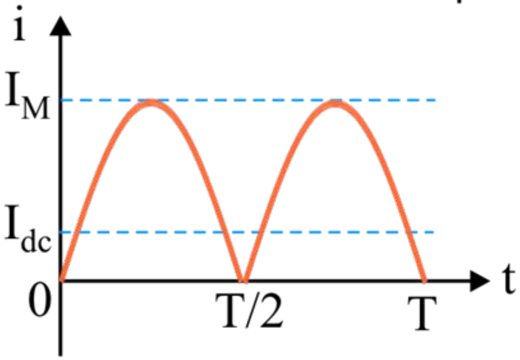




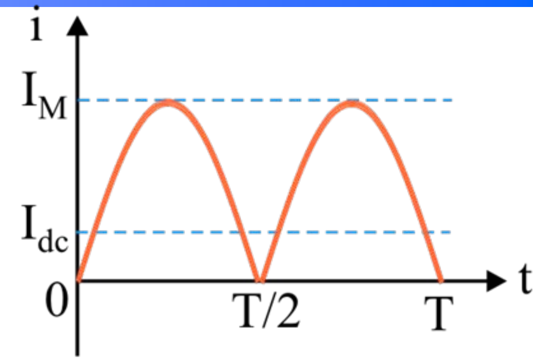
$$I_{dc} = \frac{I_M}{\pi}$$

$$I = \frac{I_M}{2}$$

$$i = \frac{v_o}{R_L}$$



3.2.1.1.- Cálculo de las corrientes.



Valor medio o de continua

$$I_{dc}=\frac{1}{T}\left[\int_0^{\frac{T}{2}} i\ \ dt+\int_{\frac{T}{2}}^{T} i\ \ dt\right]=\frac{2}{T}\int_0^{\frac{T}{2}} I_M\cdot\text{sen}\ \ (\omega t)\ \ dt=\frac{2\cdot I_M}{T}\cdot\frac{(-1)}{\omega}\ \left[\cos\ \ (\omega t)\right]_0^{\frac{T}{2}}$$

$$\boxed{I_{dc}=\frac{2\cdot I_M}{\pi}}$$

Valor eficaz

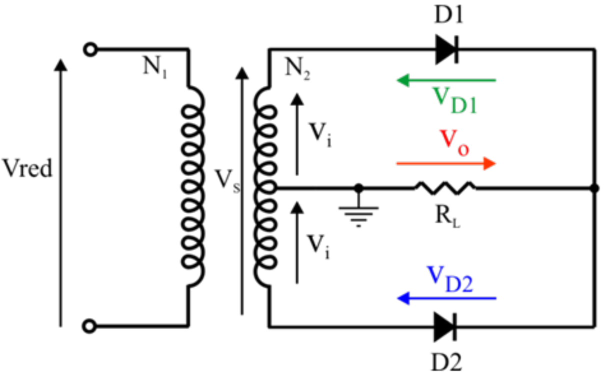
$$I^2=\frac{1}{T}\left[\int_0^{\frac{T}{2}} i^2 dt+\int_{\frac{T}{2}}^{T} i^2 dt\right]=\frac{2}{T}\int_0^{\frac{T}{2}} i^2 dt=\frac{2}{T}\int_0^{\frac{T}{2}} I_M^2\ \ \text{sen}^2(\omega t)\ \ dt=\frac{2\cdot I_M^2}{T}\int_0^{\frac{T}{2}}\text{sen}^2(\omega t)\ \ dt=$$

$$=\frac{2\cdot I_M^2}{T}\int_0^{\frac{T}{2}}\frac{1-\cos\ \ (2\omega t)}{2}\ \ dt=\frac{I_M^2}{T}\left[t-\frac{1}{2\omega}\text{sen}\ \ (2\omega t)\right]_0^{\frac{T}{2}}=$$

$$=\frac{I_M^2}{T}\left[\frac{T}{2}-0-\frac{1}{2\omega}\text{sen}\ \ 2\pi+\frac{1}{2\omega}\text{sen}\ \ 0\right]=\frac{I_M^2}{2}$$

$$\boxed{I=\frac{I_M}{\sqrt{2}}}$$

3.2.1.1.- Cálculo de las tensiónes en los diodos.

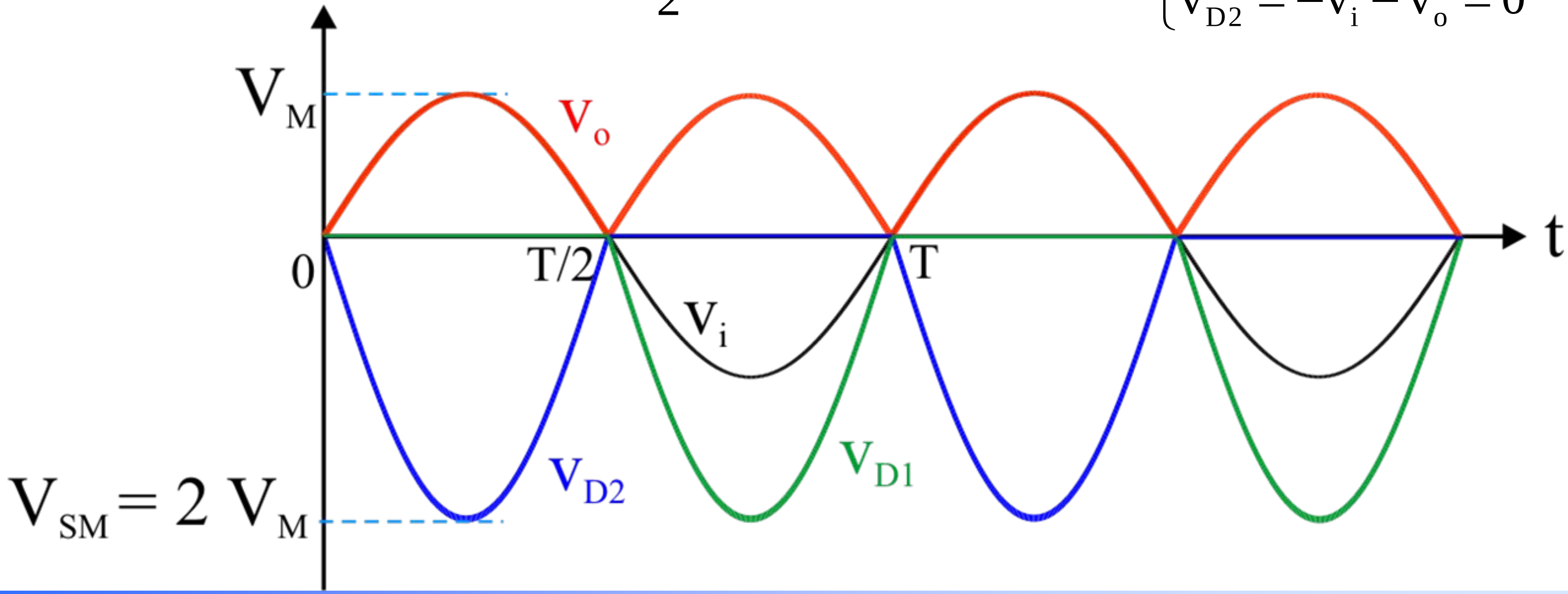


$$v_{D1} = v_i - v_o$$

$$v_{D2} = -v_i - v_o$$

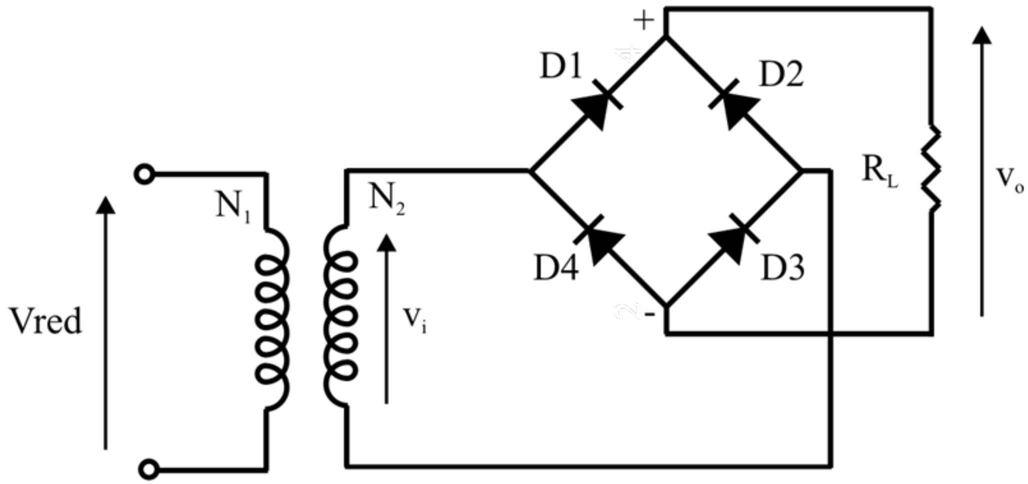
$$0 \le t \le \frac{T}{2} \rightarrow v_o = v_i \Rightarrow \begin{cases} v_{D1} = v_i - v_o = 0 \\ v_{D2} = -v_i - v_o = -2\ v_i \end{cases}$$

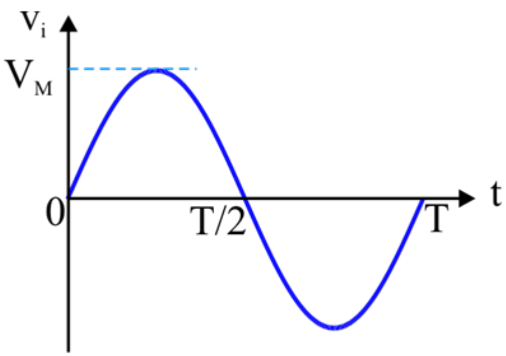
$$\frac{T}{2} \le t \le T \rightarrow v_o = -v_i \Rightarrow \begin{cases} v_{D1} = v_i - v_o = 2\ v_i \\ v_{D2} = -v_i - v_o = 0 \end{cases}$$

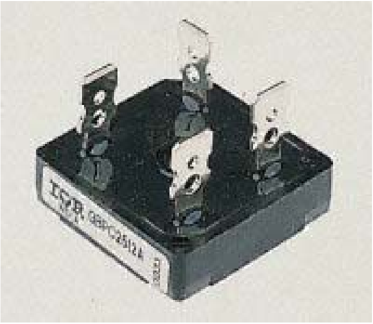


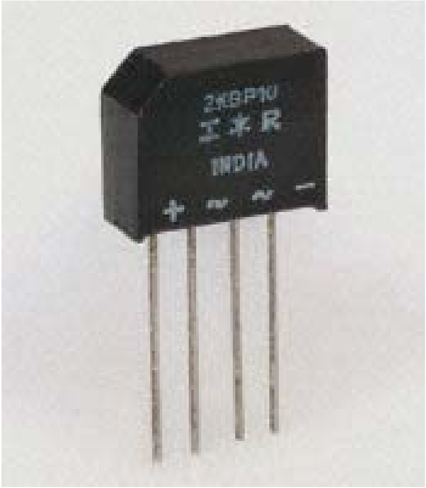
3.2.- Rectificador de onda completa.

3.2.2.- Circuito con puente de diodos.

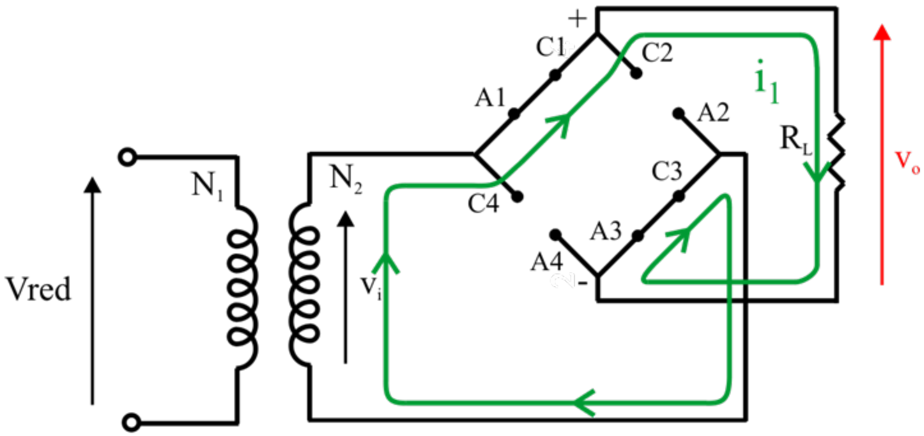


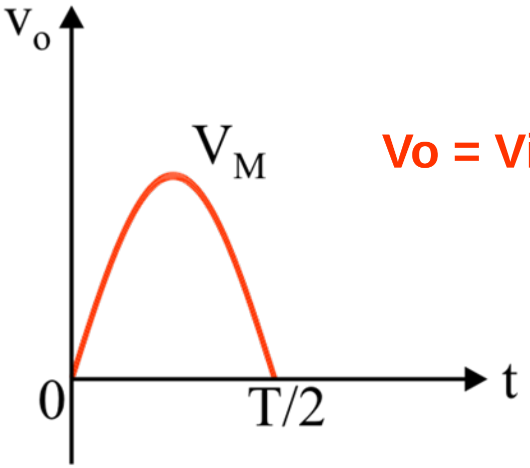






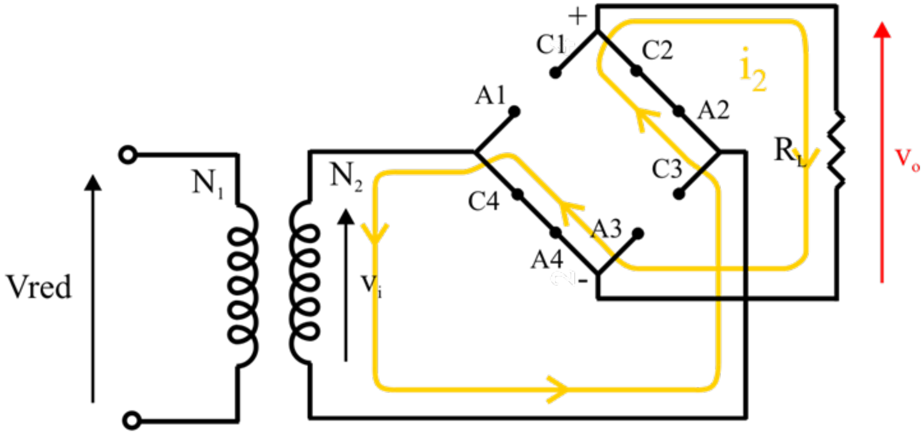
D1 y D3 ON, D2 y D4 OFF

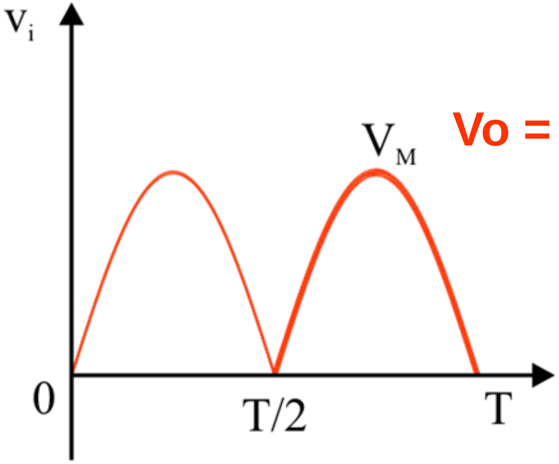




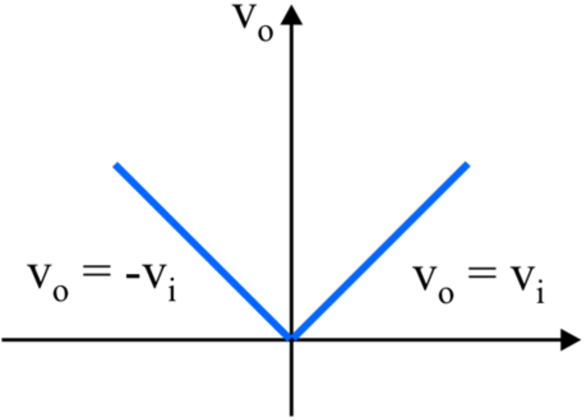
Vo = Vi

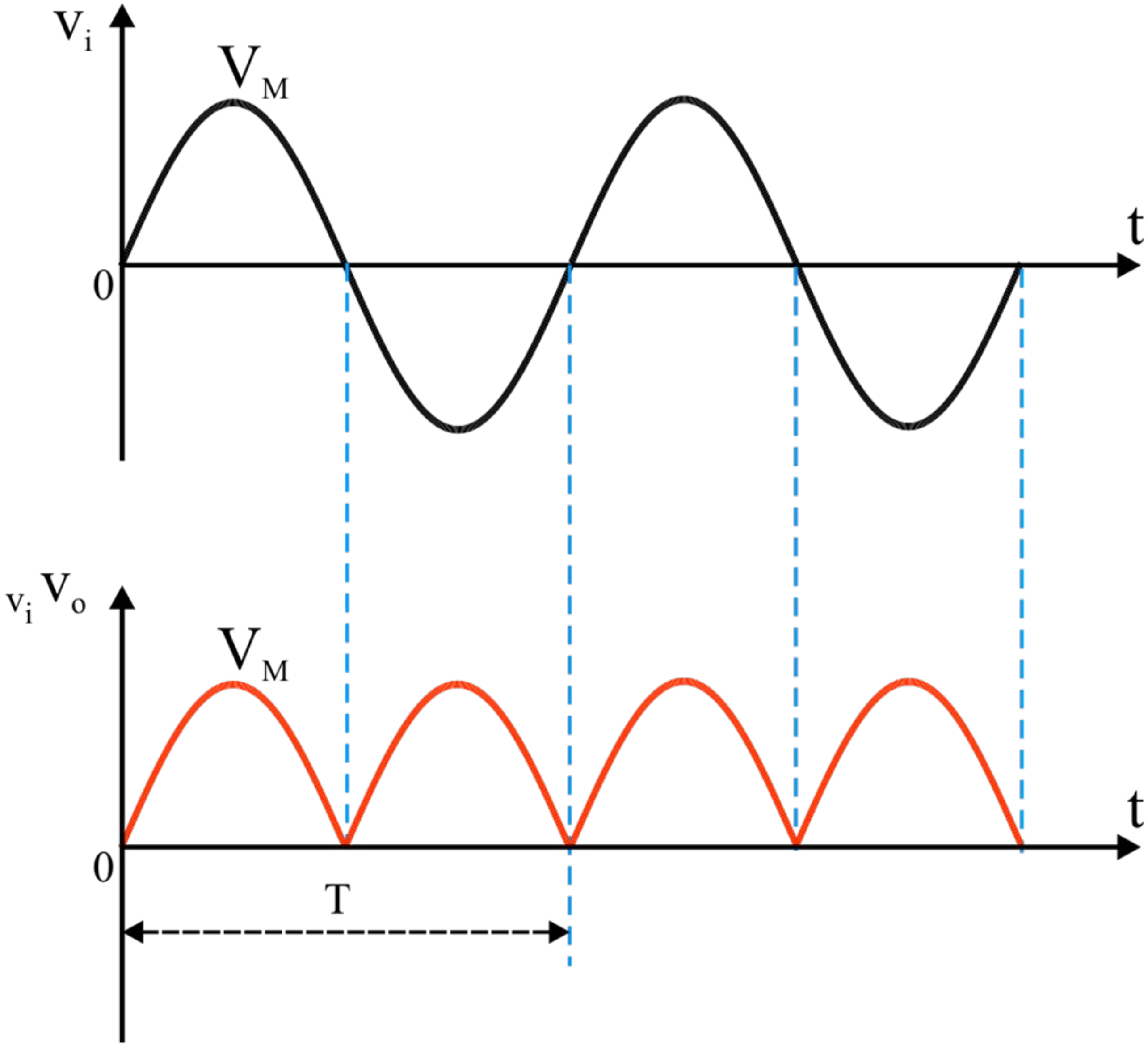
D1 y D3 OFF, D2 y D4 ON



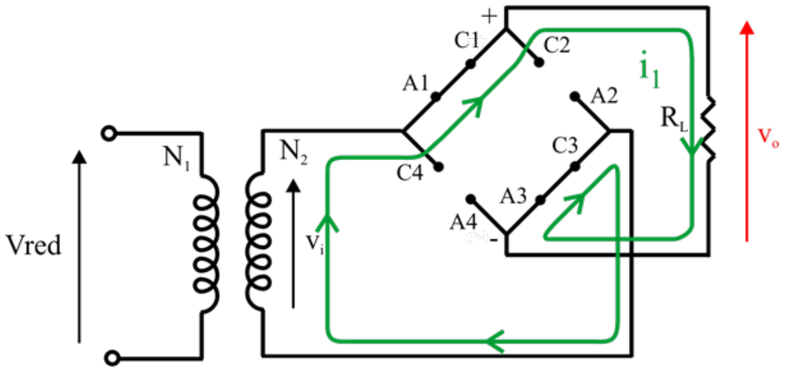


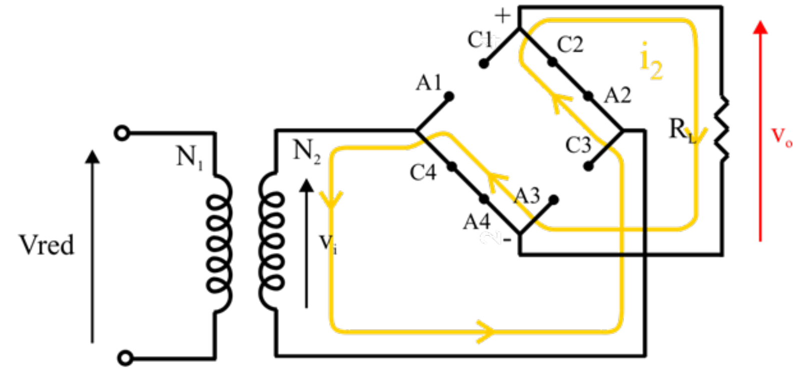
Vo = -Vi

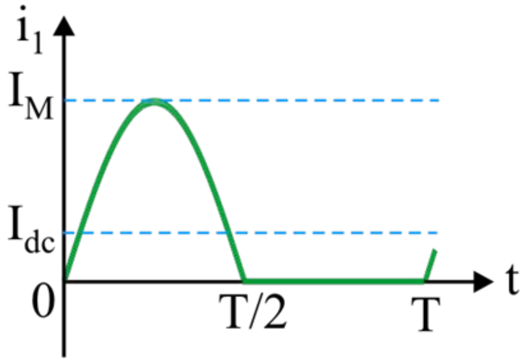

v_o
v_o = -v_i
v_o = v_i
v_i


v_i
V_M
t
0
v_o
V_M
t
0
T

3.2.2.1.- Cálculo de las corrientes.

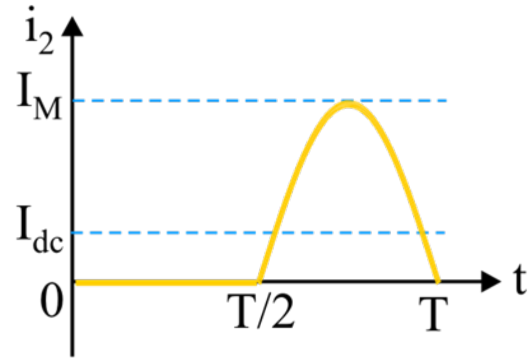




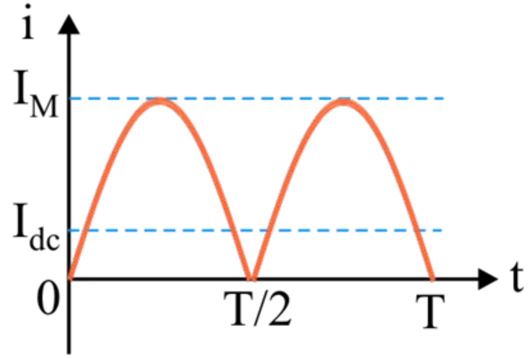


$$I_{dc} = \frac{I_M}{\pi}$$

$$I = \frac{I_M}{2}$$



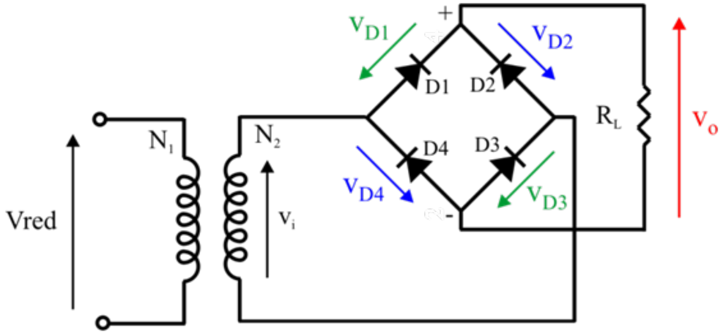
$$i = \frac{v_o}{R_L}$$



$$I_{dc} = \frac{2 \cdot I_M}{\pi}$$

$$I = \frac{I_M}{\sqrt{2}}$$

3.2.2.2.- Cálculo de las tensiónes en los diodos.

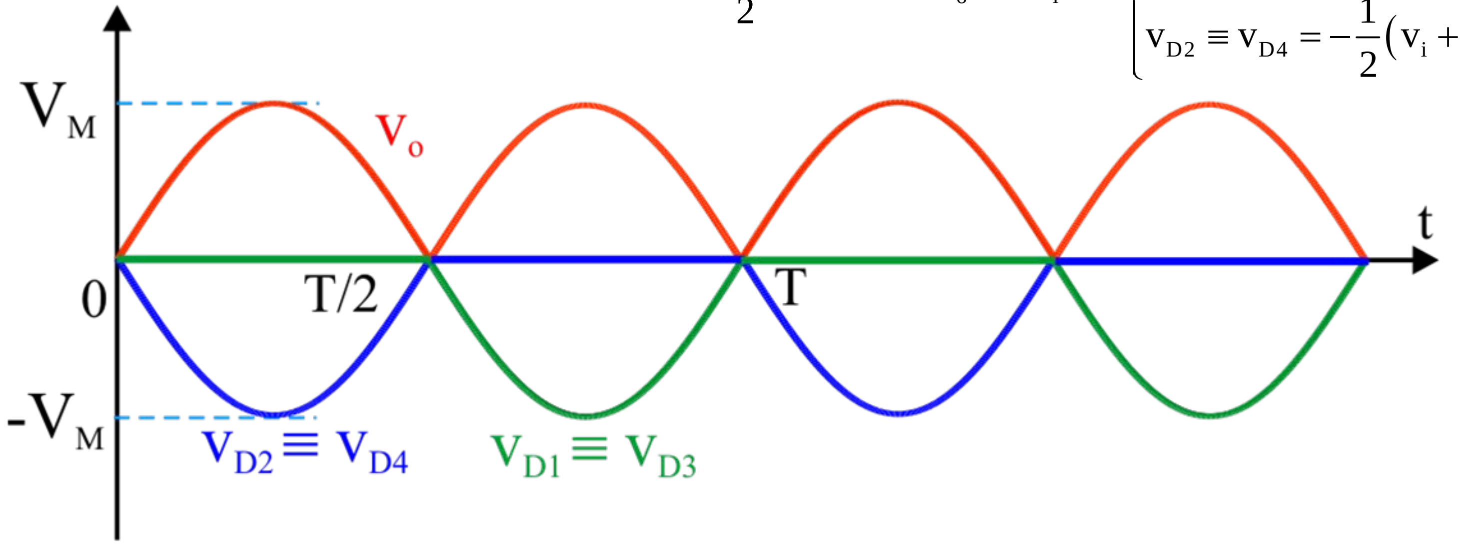


$$v_{D1} \equiv v_{D3} = \frac{1}{2}(v_i - v_o)$$

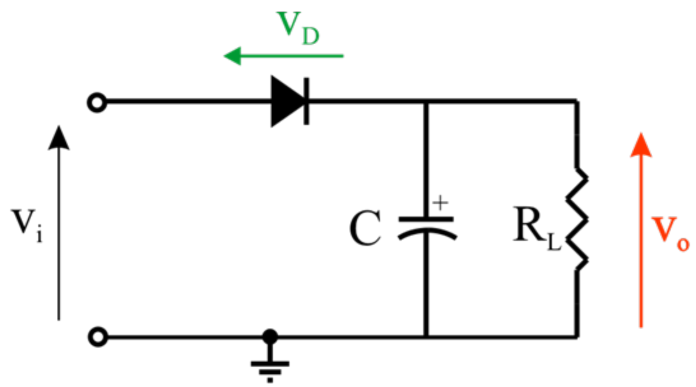
$$v_{D2} \equiv v_{D4} = -\frac{1}{2}(v_i + v_o)$$

$$0 \le t \le \frac{T}{2} \rightarrow v_o = v_i \Rightarrow \begin{cases} v_{D1} \equiv v_{D3} = \frac{1}{2}(v_i - v_o) = 0 \\ v_{D2} \equiv v_{D4} = -\frac{1}{2}(v_i + v_o) = -v_i \end{cases}$$

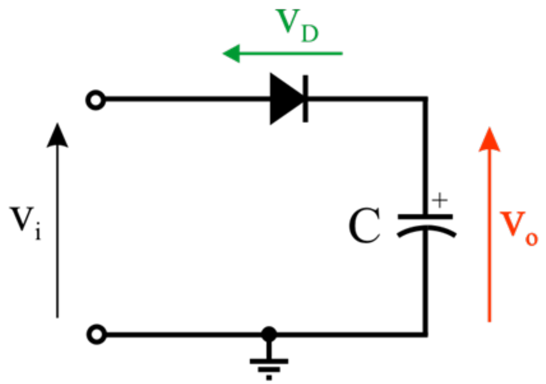
$$\frac{T}{2} \le t \le T \rightarrow v_o = -v_i \Rightarrow \begin{cases} v_{D1} \equiv v_{D3} = \frac{1}{2}(v_i - v_o) = v_i \\ v_{D2} \equiv v_{D4} = -\frac{1}{2}(v_i + v_o) = 0 \end{cases}$$

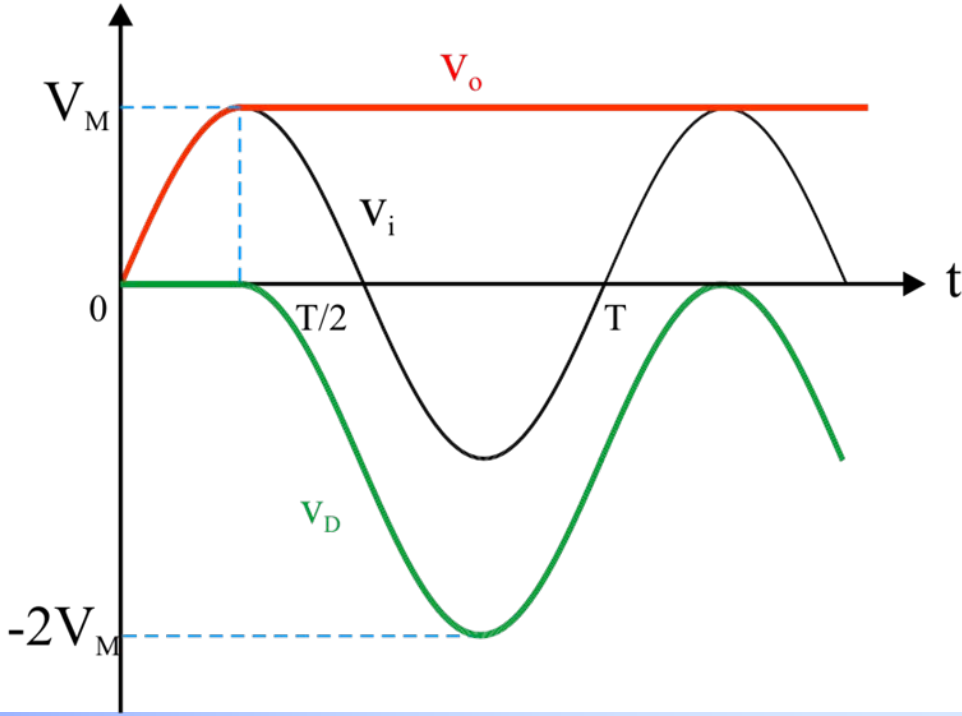


A los circuitos rectificadores vistos hasta ahora vamos añadirles un condensador en paralelo con la carga

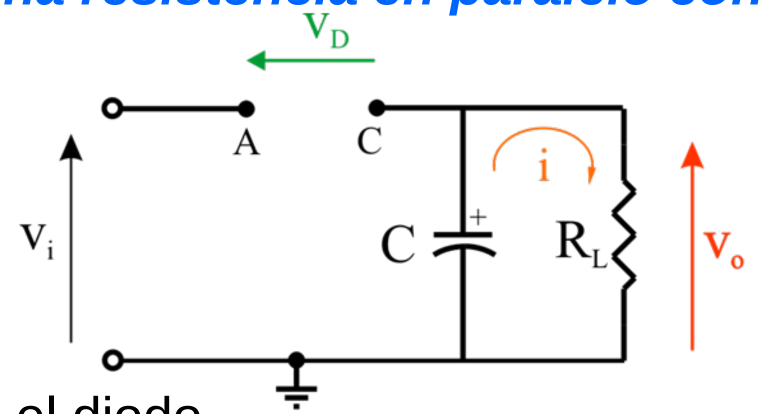


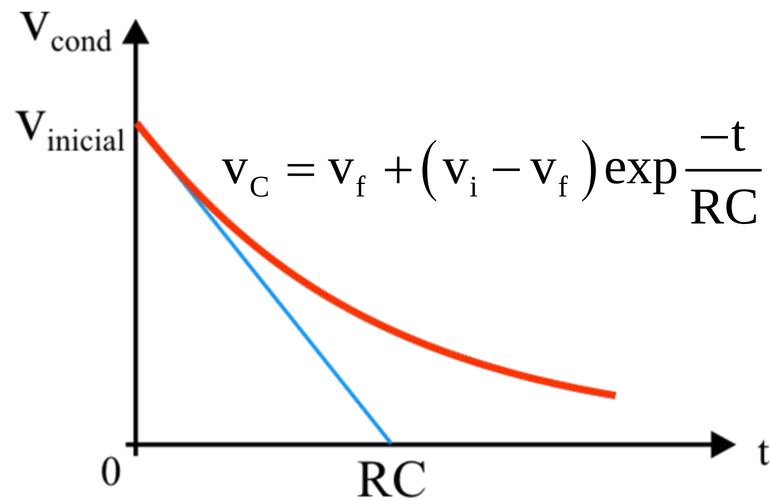
En un primer análisis suponemos $R_L = \infty$



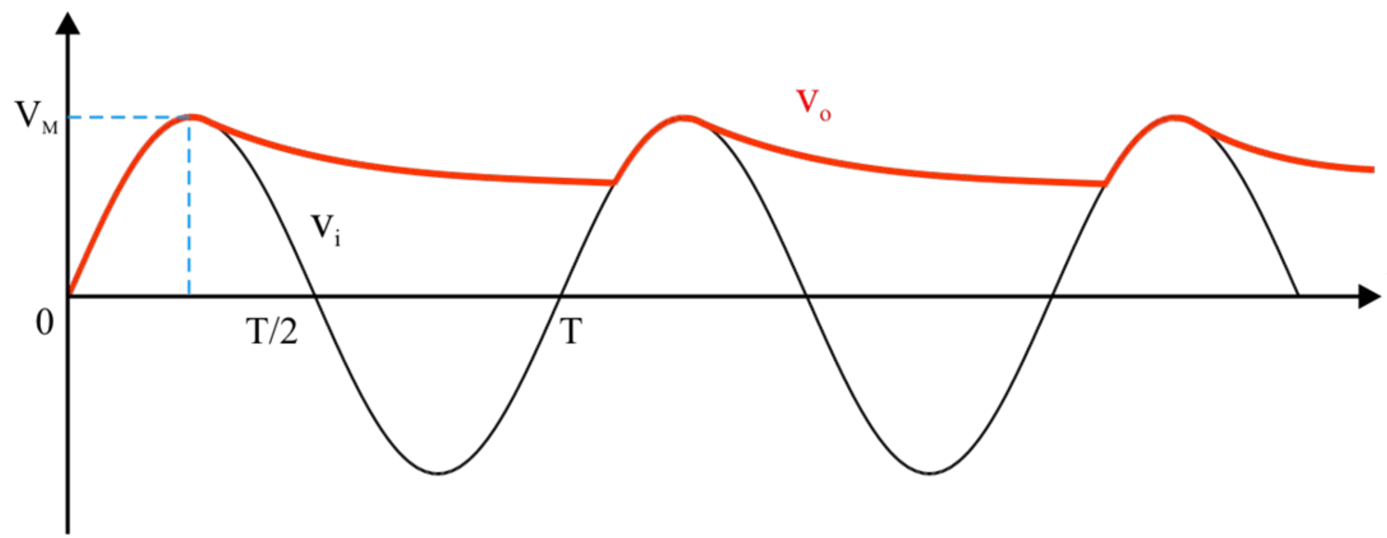


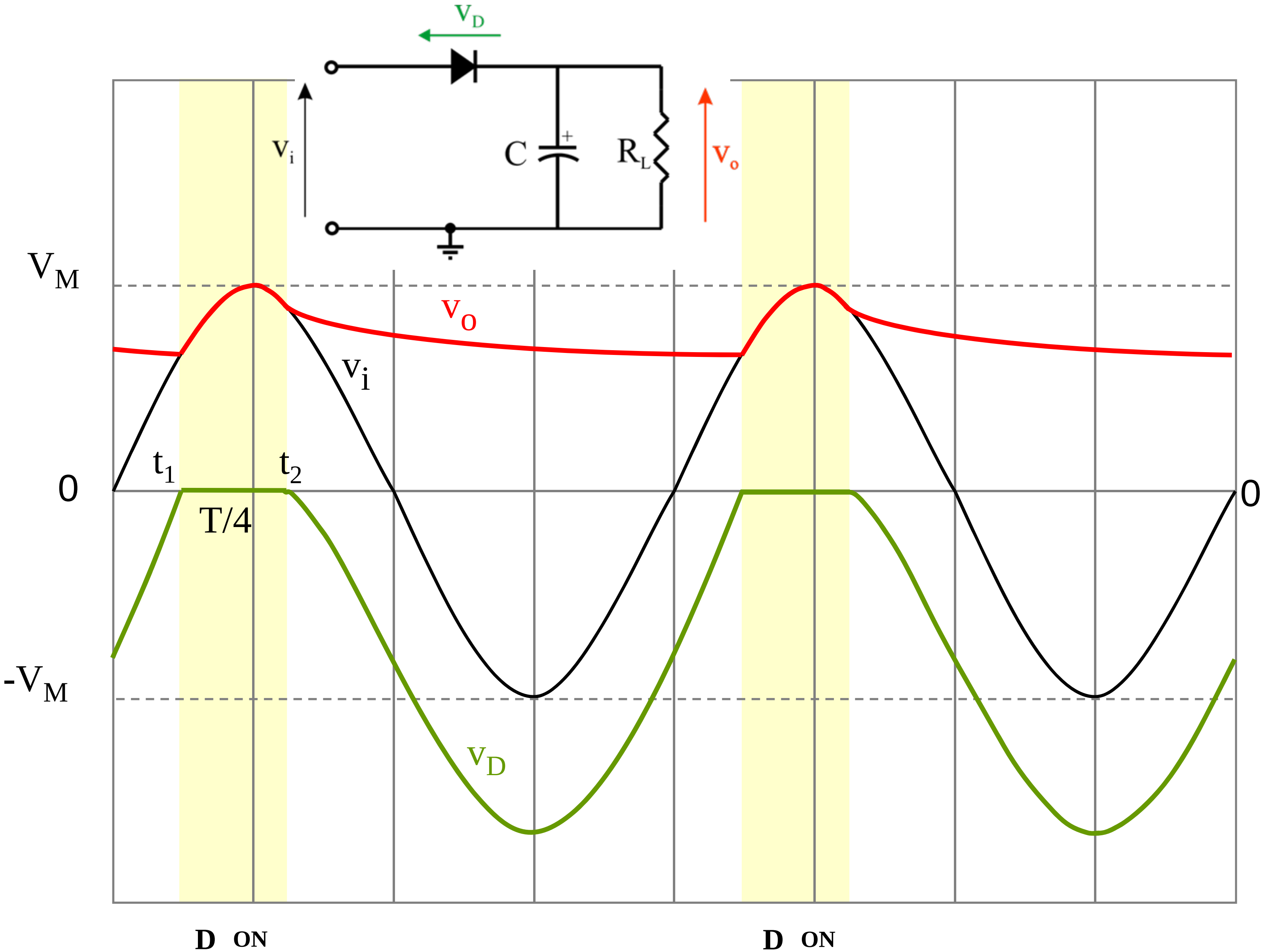
Ponemos una resistencia en paralelo con el condensador



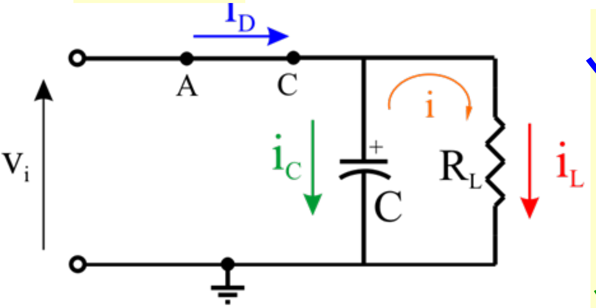


A partir de T/4 el diodo
se pone en OFF y el C
se descarga a través de R




v_D
v_i
C
R_L
v_o
V_M
v_o
v_i
t_1
t_2
0
T/4
0
$-V_M$
v_D
D ON
D ON

D ON

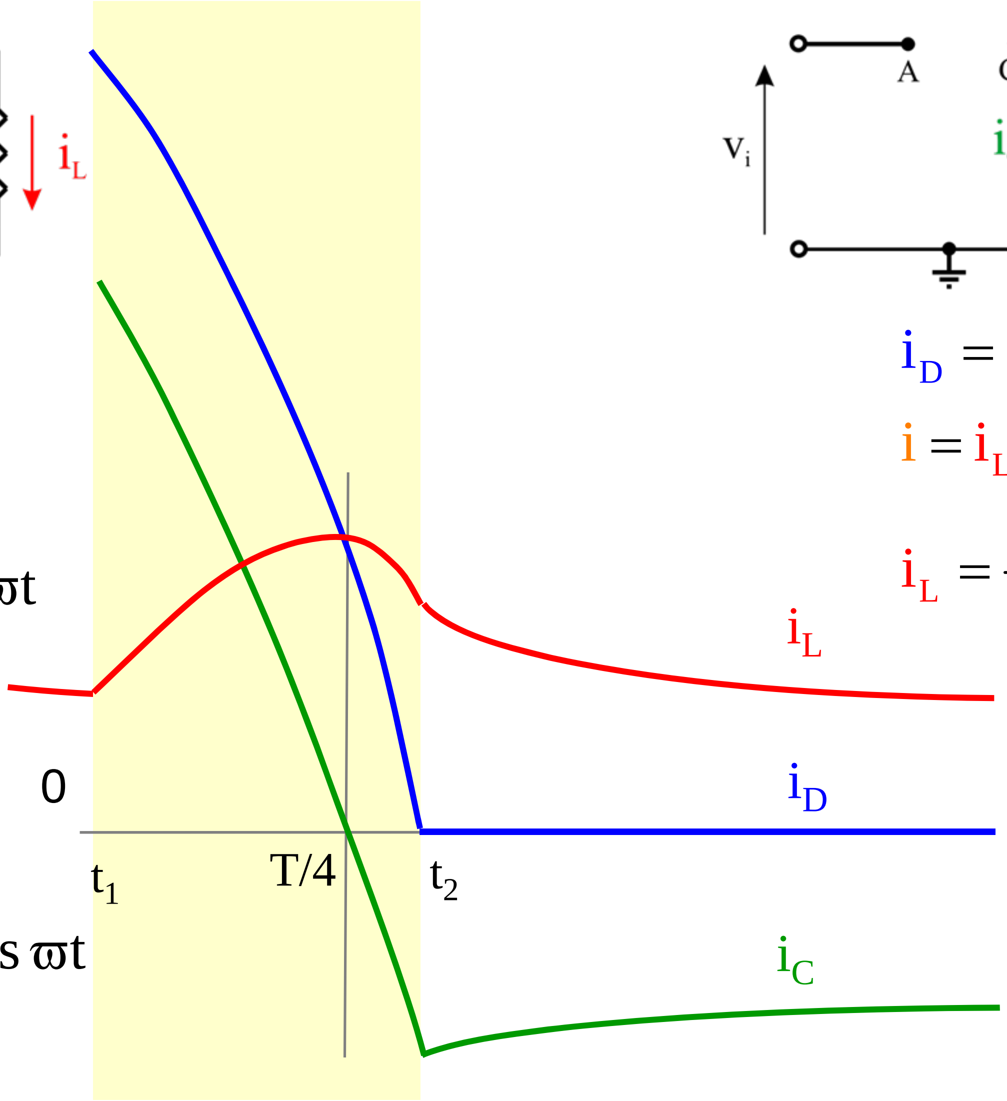


$$i_D = i_L + i_C$$

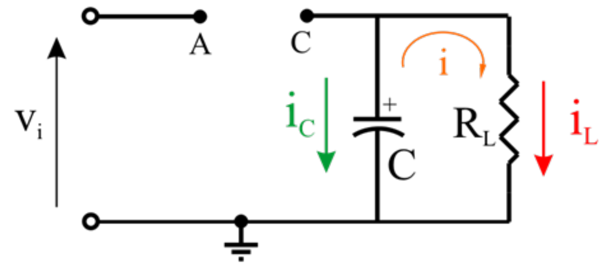
$$i_L = \frac{v_O}{R_L} = \frac{V_M}{R_L}\,\text{sen}\,\varpi t$$

$$i_C = C\frac{dv_O}{dt}$$

$$i_C = 2\pi f \cdot C \cdot V_M \cdot \cos \varpi t$$



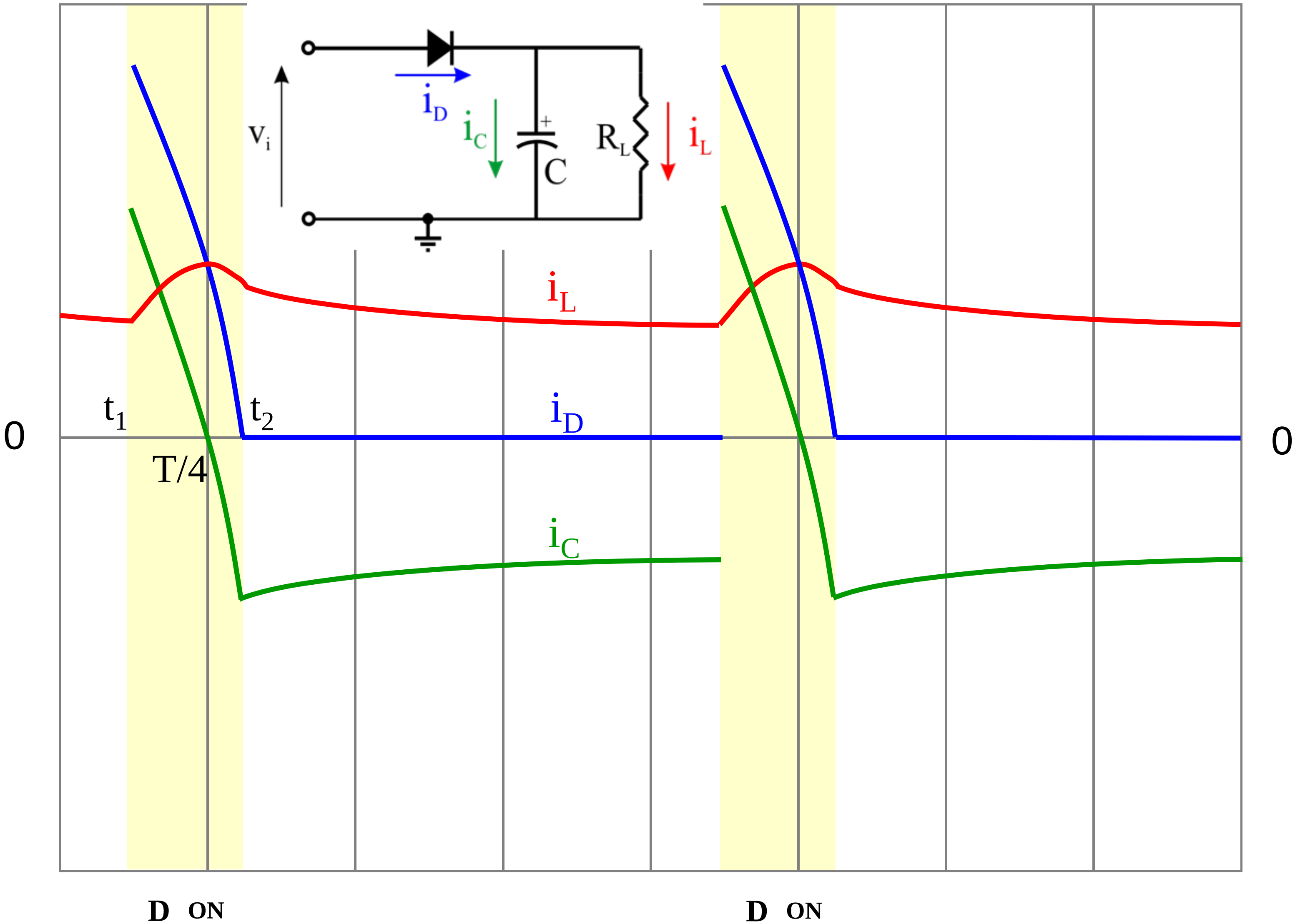
D OFF

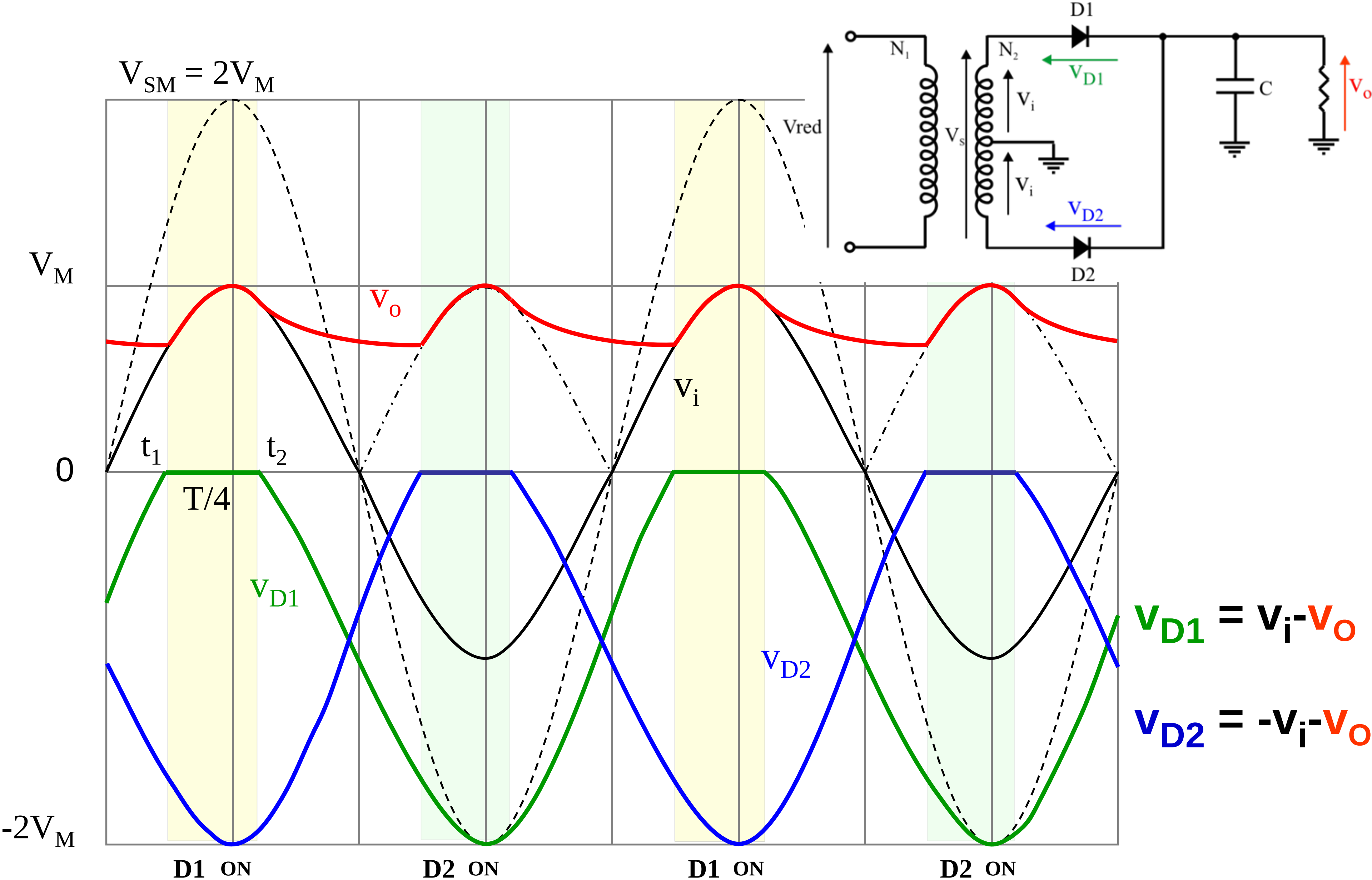


$$i_D = 0$$

$$i = i_L = -i_C$$

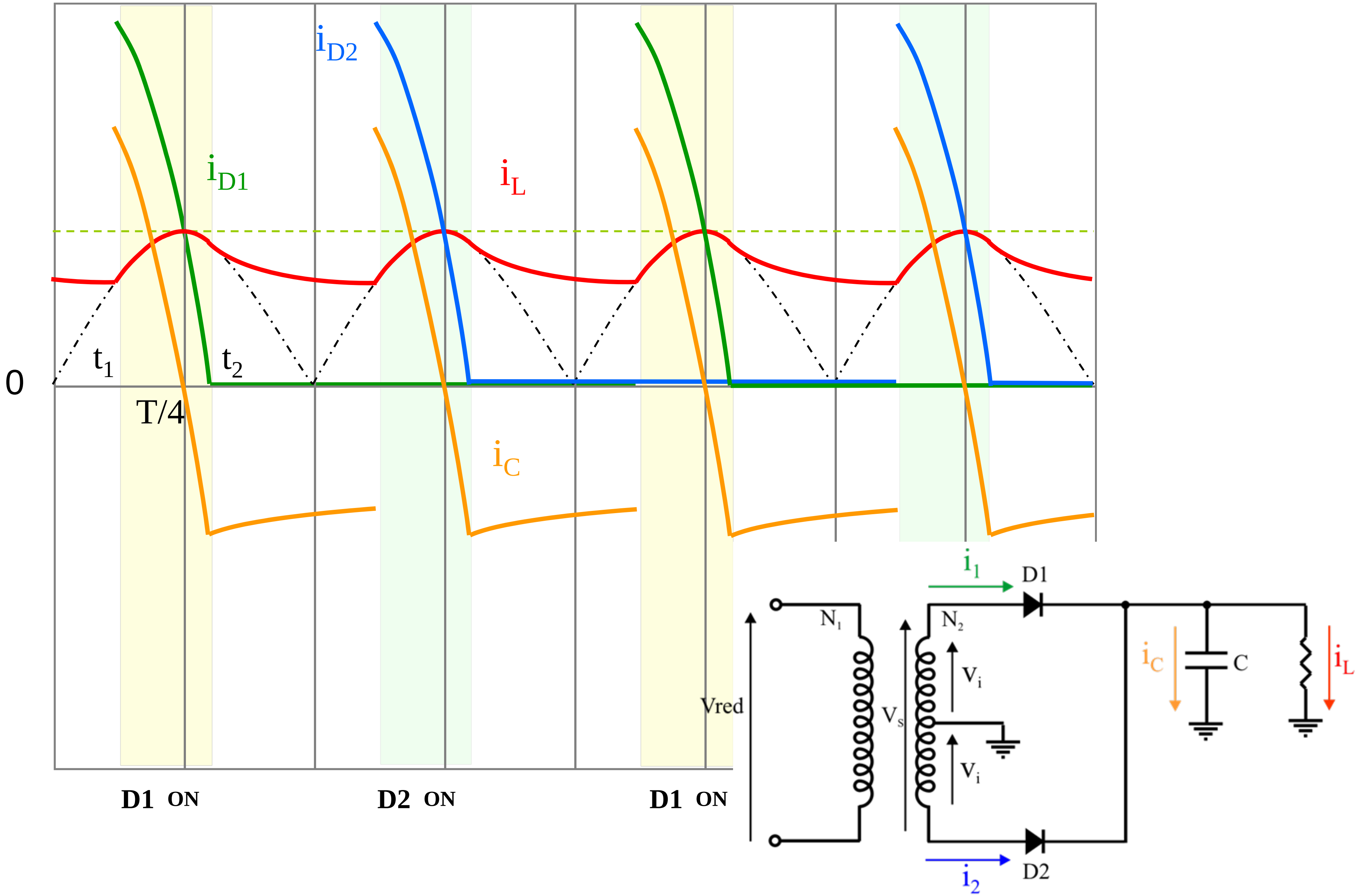
$$i_L = \frac{v_O}{R_L} = \frac{V_M}{R_L}\exp\frac{-t}{RC}$$


v$_i$
i$_D$
i$_C$
C
R$_L$
i$_L$
i$_L$
i$_D$
i$_C$
0
t$_1$
t$_2$
T/4
0
D ON
D ON



$$v_{D1} = v_i - v_O$$

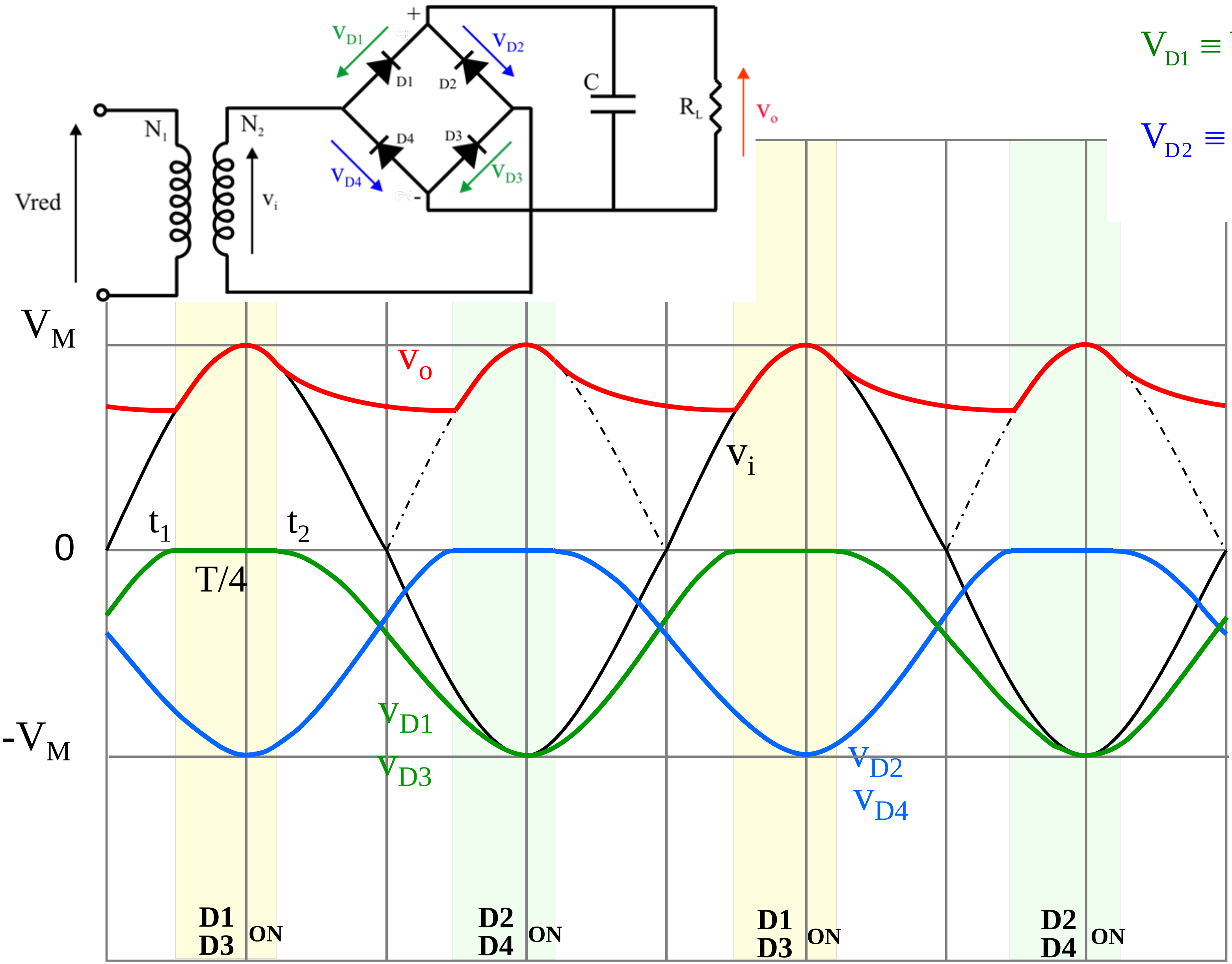
$$v_{D2} = -v_i - v_O$$

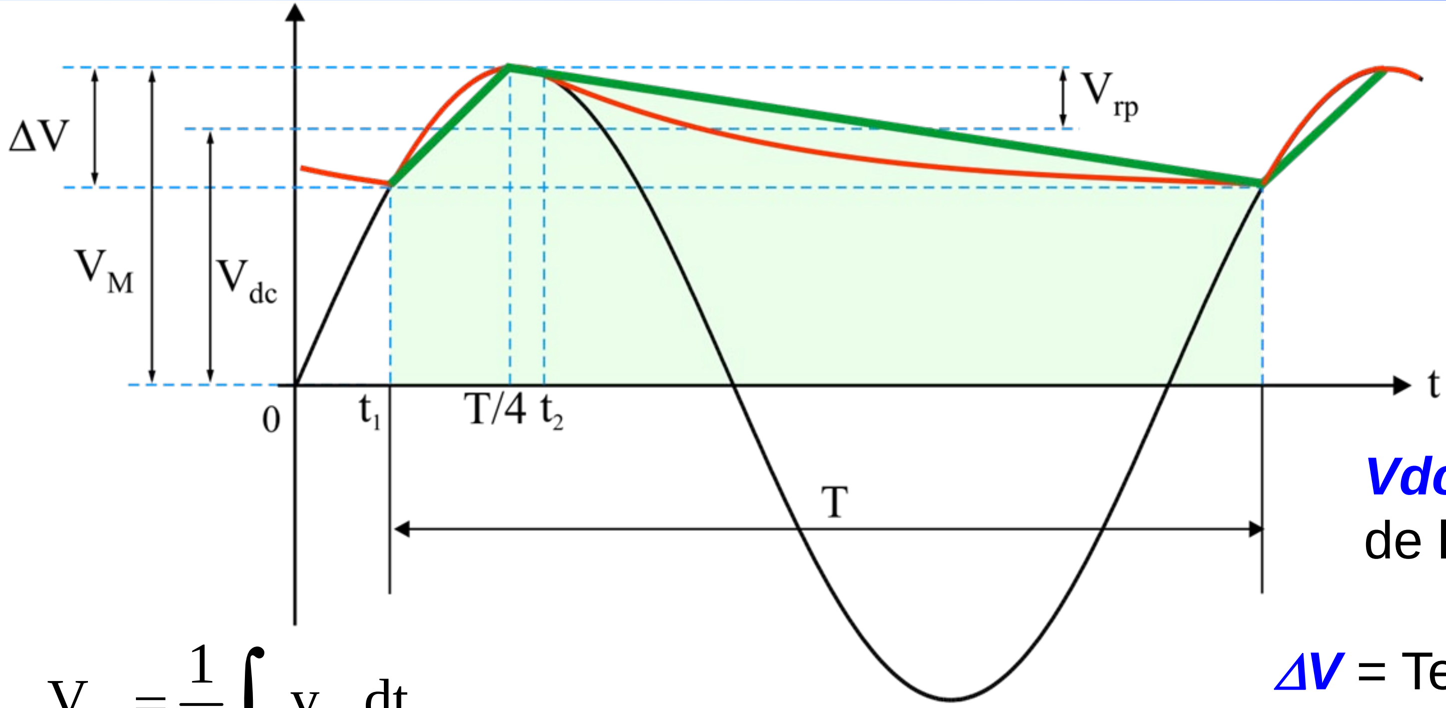


i_{D2}
i_{D1}
i_L
i_C
0
t_1
t_2
T/4
D1 ON
D2 ON
D1 ON
i_1
D1
N_1
N_2
V_i
V_i
Vred
V_s
i_C
C
i_L
i_2
D2

$$V_{D1} \equiv V_{D3} = \frac{1}{2}(v_i - v_o)$$

$$V_{D2} \equiv V_{D4} = \frac{1}{2}(-v_i - v_o)$$



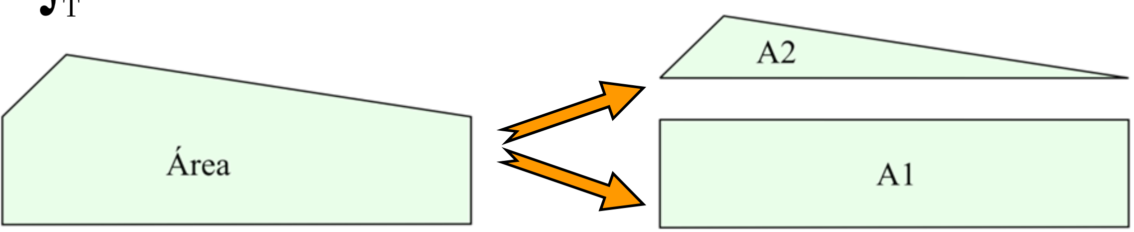


Vdc = Valor medio de la tensión de rizado

ΔV = Tensión de descarga del condensador

$$V_{dc} = \frac{1}{T}\int_T v_O\, dt$$

$\int_T v_O\, dt$ = Área encerrada por la curva = A1 + A2

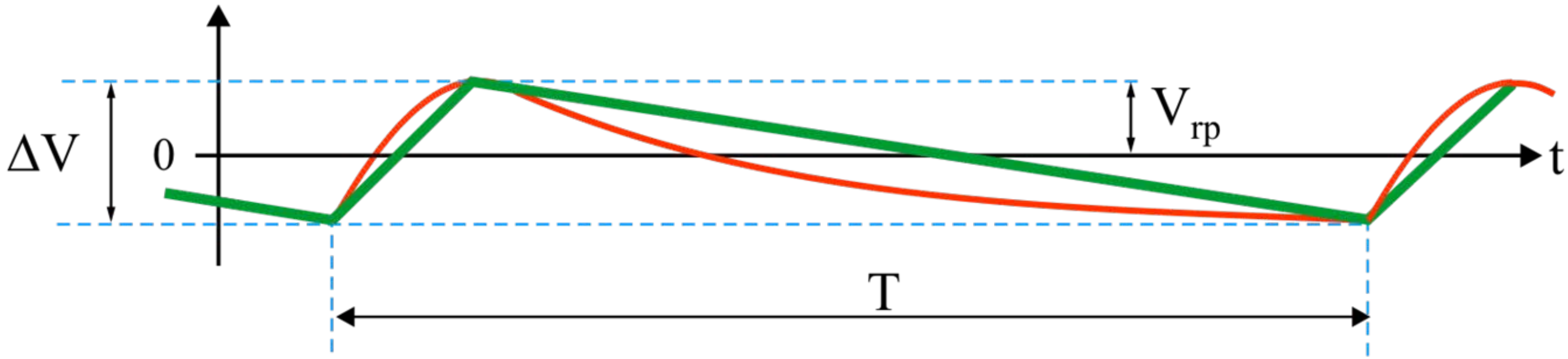


$$A2 = \frac{1}{2} T \cdot \Delta V$$

$$A1 = T \cdot \left(V_M - \Delta V\right)$$

$$V_{dc} = \frac{1}{T}\int_T v_O\, dt = \frac{1}{T}\left[T\left(V_M - \Delta V\right) + \frac{1}{2} T \Delta V\right]$$

$$\boxed{V_{dc} = V_M - \frac{\Delta V}{2}}$$



V_{rp} = Tensión de pico de rizado

$$\boxed{V_{rp} = \frac{\Delta V}{2}}$$

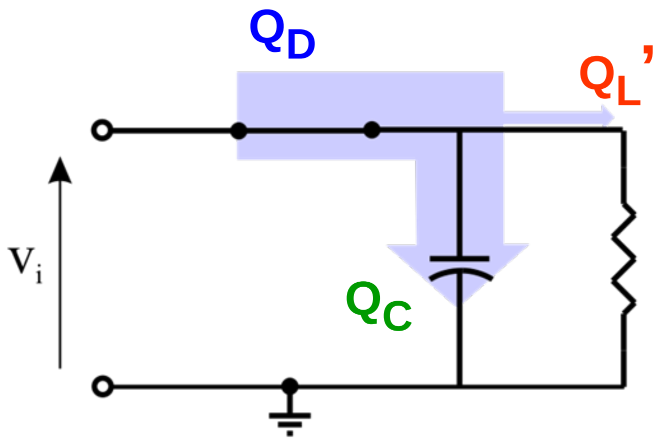
V_r = Tensión eficaz de rizado

$$\boxed{V_r = \frac{V_{rp}}{\sqrt{3}} = \frac{\Delta V}{2\sqrt{3}}}$$

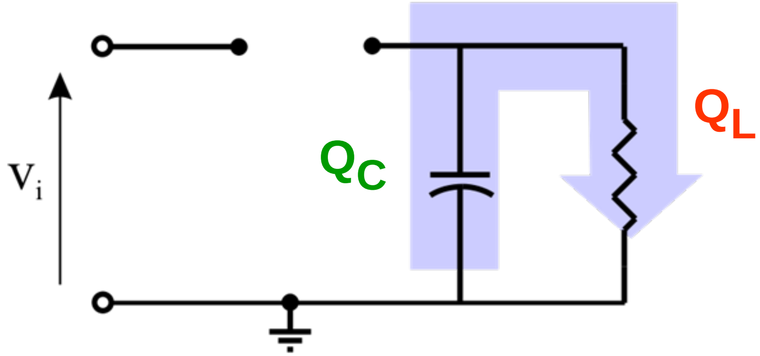
γ = Factor de ondulación

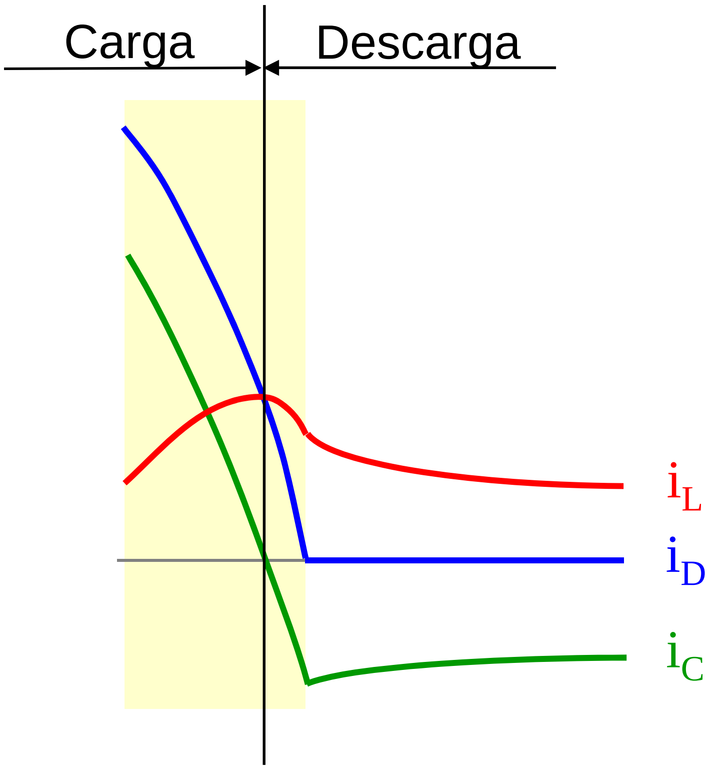
$$\boxed{\gamma(\%) = \frac{V_r}{V_{dc}} \cdot 100}$$

D. ON → Carga del condensador



D. OFF → Descarga del condensador





$$i = \frac{dQ}{dt}$$

$$Q = \int i\,dt$$

Cálculos.

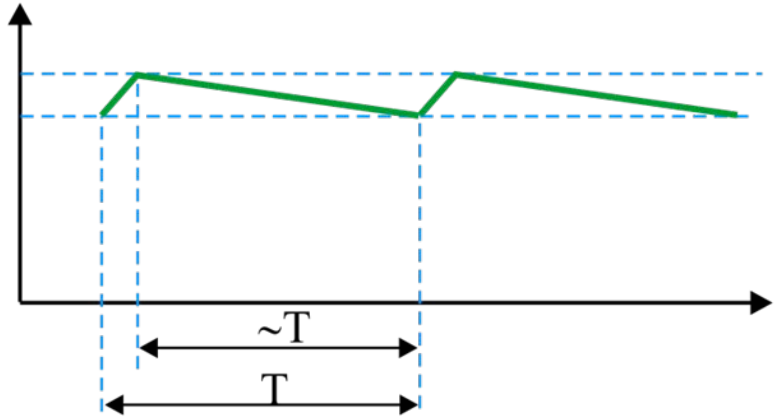
Q_C = Carga que almacena el condensador cuando el diodo está en conducción y que proporciona a la carga cuando el diodo deja de conducir

$$\boxed{Q_C = C \cdot \Delta V}$$

Q_L = Cargar que circula por la resistencia. *Se supone que toda la carga que circula por la resistencia la proporciona el condensador*, es decir, se desprecia Q_L'

$$Q_C = Q_L$$

Suponemos que el condensador se descarga en un tiempo igual al periodo T



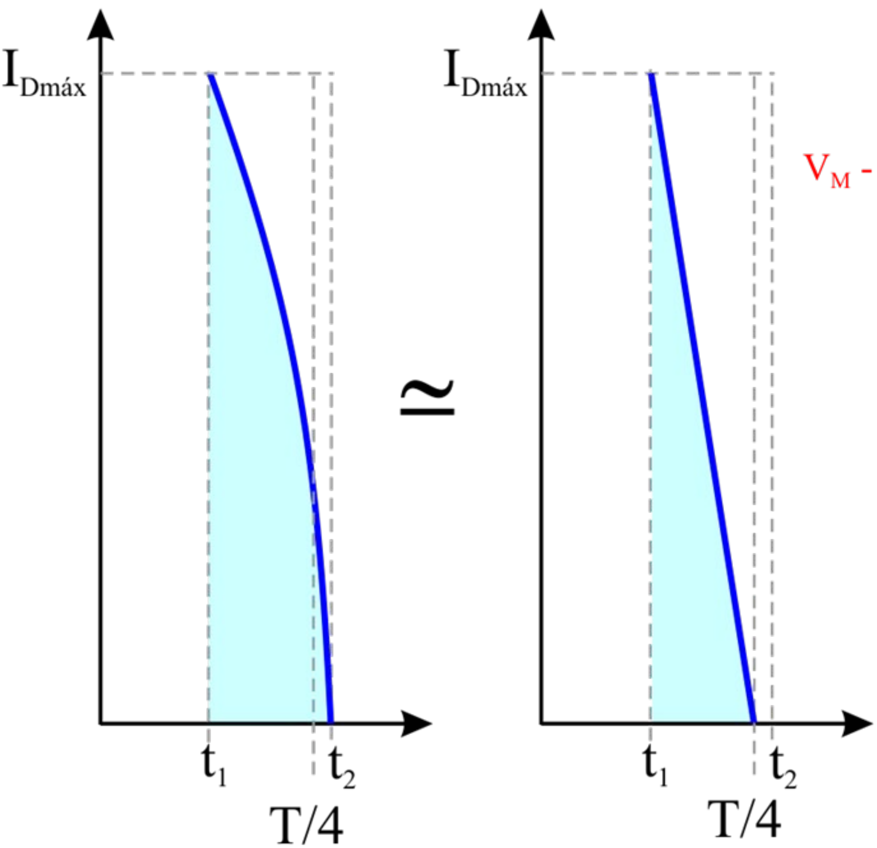
$$Q_L = \int i_L \, dt = I_{dc} \cdot T$$

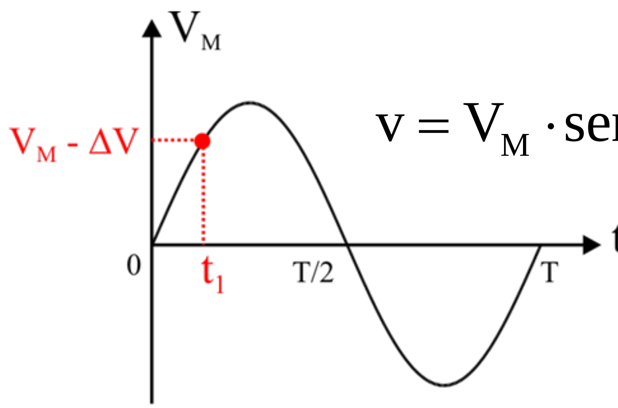
$$\boxed{Q_L = I_{dc} \cdot T}$$

Cálculos.

Q_D = Carga que atraviesa el diodo

$$Q_D = \int_T i_D\,dt = \int_{t_1}^{\frac{T}{4}} i_D\,dt = \text{ Area sombreada } \Rightarrow \boxed{Q_D = \frac{1}{2} I_{D\max}\left(\frac{T}{4} - t_1\right)}$$





$$v = V_M \cdot \operatorname{sen} \varpi t \begin{cases} t = t_1 \\ v = V_M - \Delta V \end{cases}$$

$$t_1 = \frac{1}{2\pi f} \operatorname{arc\,sen} \frac{V_M - \Delta V}{V_M}$$

$$\boxed{Q_C = Q_L = Q_D}$$

$$\boxed{V_{dc} = V_M - \frac{\Delta V}{2}}$$

$$\boxed{V_{rp} = \frac{\Delta V}{2}}$$

$$\boxed{V_r = \frac{V_p}{\sqrt{3}} = \frac{\Delta V}{2\sqrt{3}}}$$

$$\boxed{\gamma(\%) = \frac{V_r}{V_{dc}} \cdot 100}$$

$$\boxed{Q_C = C \cdot \Delta V}$$

$$\boxed{Q_L = I_{dc} \cdot T}$$

Para onda completa

$$\boxed{Q_L = I_{dc} \cdot \frac{T}{2}}$$

$$\boxed{Q_D = \frac{1}{2} I_{D\max} \left(\frac{T}{4} - t_1 \right)}$$

$$t_1 = \frac{1}{2\pi f} \arcsen \frac{V_M - \Delta V}{V_M}$$

$$\boxed{Q_C = Q_L = Q_D}$$