ENEE236 & 241

Analog Electronics

L5 Diode Applications 3
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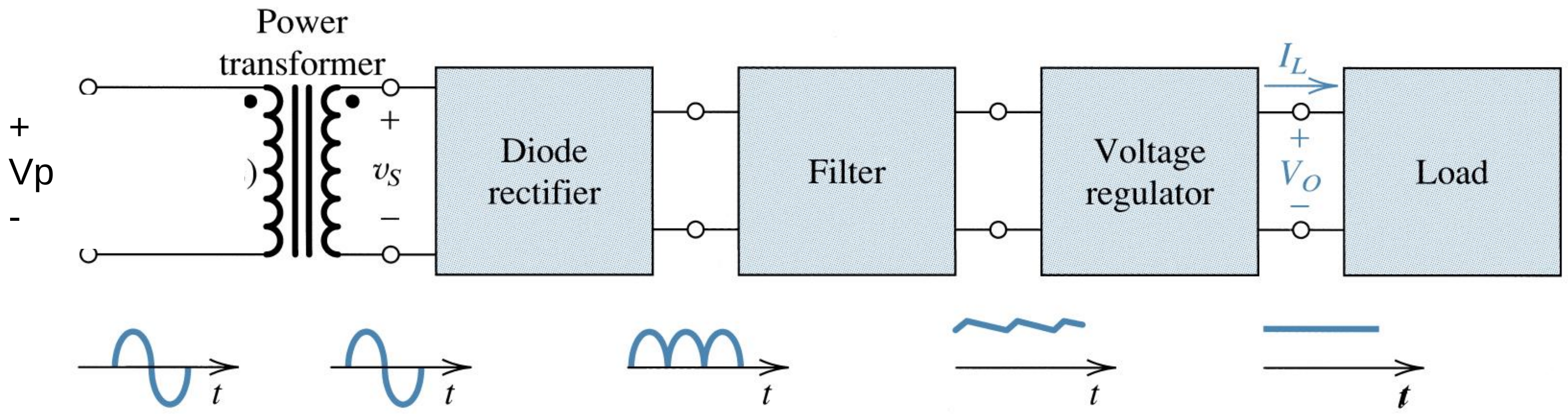
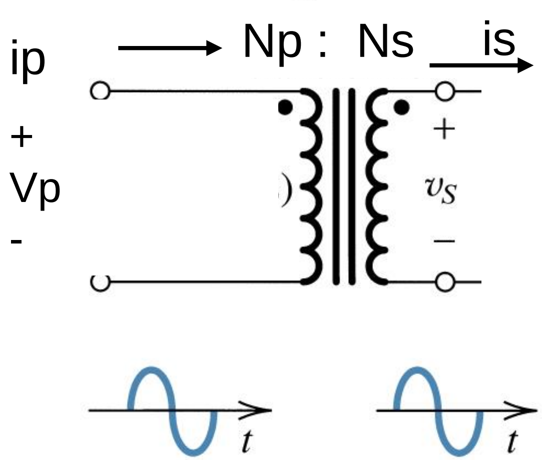
Designing a power supply



Block diagram of a dc power supply.

Designing a power supply

1) Transformer



Usually steps down type to decrease the amplitude of the ac line voltage

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

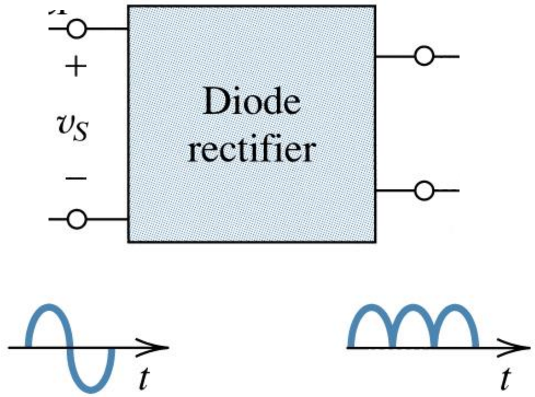
$$\frac{i_s}{i_p} = \frac{N_p}{N_s}$$

$$n = \frac{N_s}{N_p} \quad \text{transformer turns ratio}$$

$$\Rightarrow V_s = nV_p$$

Designing a power supply

2) Rectifier



- ➢ Used to convert ac voltage (with zero average value) to pulsating dc voltage (non zero average

- ➢ Rectifiers are two types:

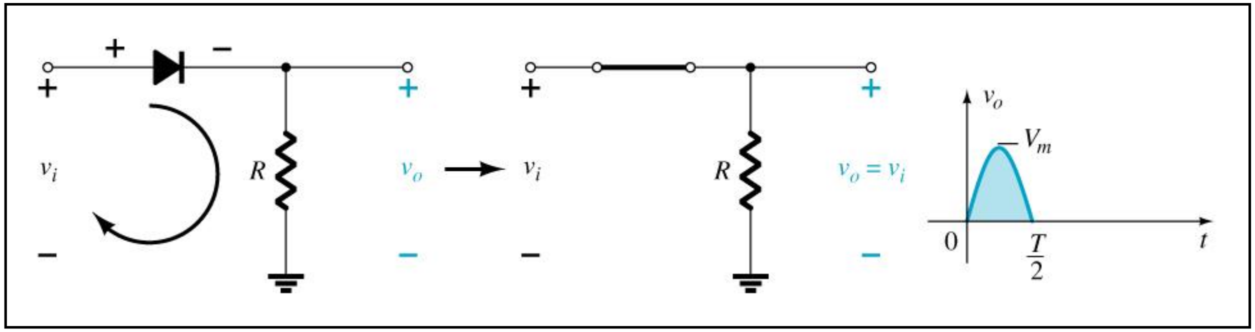
a) Half Wave Rectifier
b) Full Wave Rectifier
- Bridge Full Wave Rectifier
- Center Tapped Transformer Full Wave Rectifier

Half Wave Rectifier

1)When Vi(t) > 0,

Diode is ON

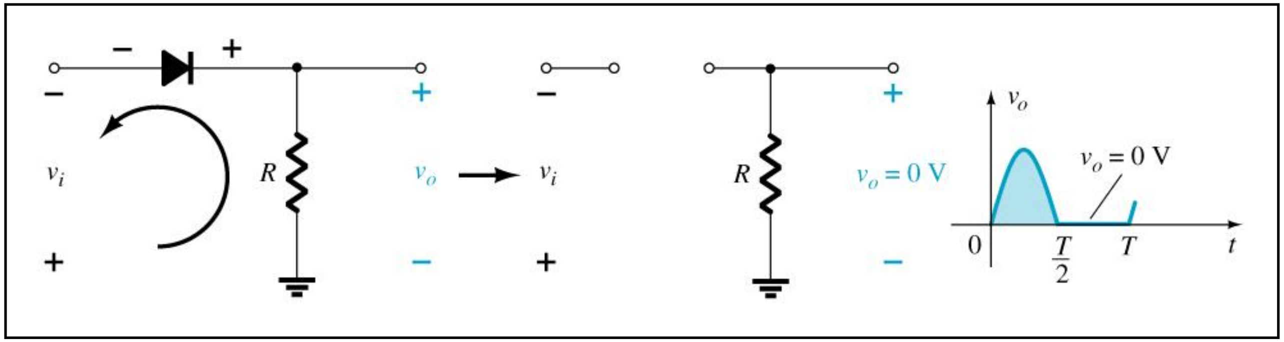
Vo = Vi



2)When Vi(t) < 0,

Diode is OFF

Vo = 0



The diode conducts only when it is forward biased, therefore only half of the AC cycle passes through the diode to the output.

$$V_{AVG} = \frac{1}{T}\int_0^T V_m Sin(\omega t)dt$$

Half Wave Rectifier

$$V_{AVG} = \frac{1}{T}\int_0^T V_m Sin(\omega t)dt$$

$$= \frac{1}{2\pi}\int_0^\pi V_m Sin(\theta)d\theta$$

$$= \frac{1}{2\pi}\left[-V_m Cos(\theta)\right]_0^\pi = \frac{V_m}{2\pi}\left[-Cos(\pi) - (-Cos(0))\right]$$

$$V_{AVG} = \frac{V_m}{2\pi}\left[-(-1) - (-1)\right]$$

$$= \frac{2V_m}{2\pi} = \frac{V_m}{\pi} \cong 0.318V_m$$

$T = T_o$ and $f = f_o$

(period and frequency of the rectified waveform is the same as ac input)

Important Electrical Ratings

I_{FM} - maximum Forward Current

I_{FM} - maximum average current that can be safely sustained by the diode in the forward region

$$I_{FM} = \frac{V_{AVG}}{R_L}$$

V_{RM} - Maximum Reverse voltage

V_{RM} - Maximum voltage that can be applied to the diode in the reverse bias polarity before voltage breakdown occure

PIV - Peak Inverse Voltage

$PIV = V_{RM}$

PIV (For Half Wave Rectifier)

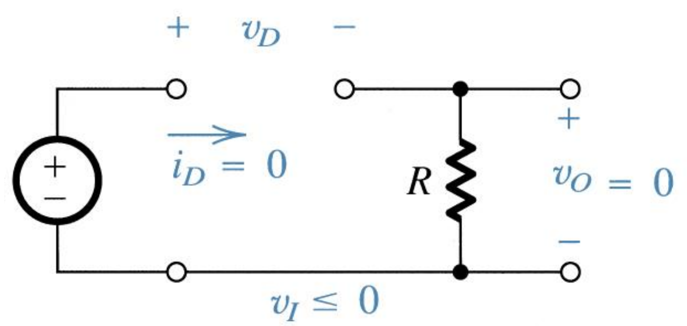
Because the diode is only forward biased for one-half of the AC cycle, it is also reverse biased for one-half cycle.

It is important that the reverse breakdown voltage rating of the diode be high enough to withstand the peak, reverse-biasing AC voltage.

$$V_D(t) = V_i(t)$$

$$V_D(t)_{max} = -V_m$$

$$PIV = -V_m$$



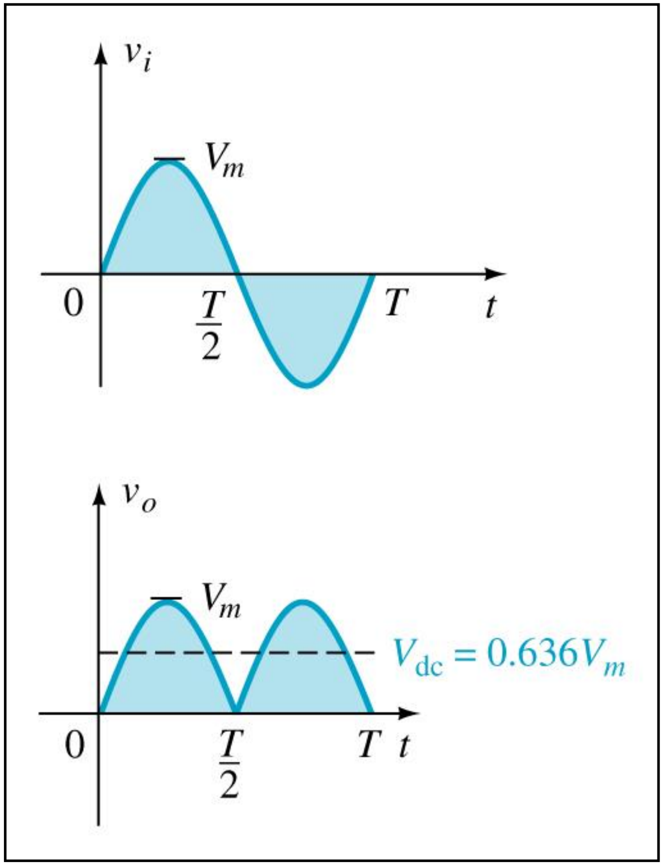
Full-Wave Rectification

The rectification process can be improved by using a full-wave rectifier circuit.

Full-wave rectification produces a greater DC output:

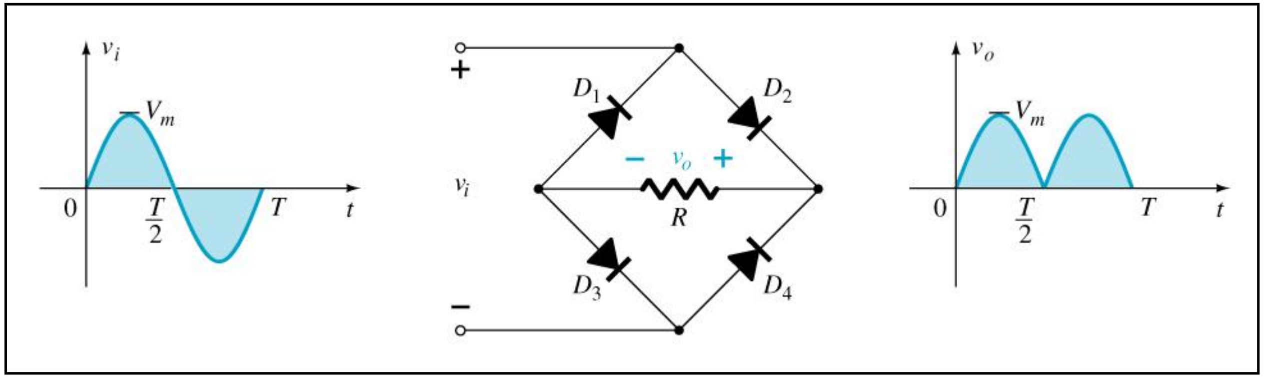
Half-wave: $V_{dc} = 0.318\,V_m$

Full-wave: $V_{dc} = 0.636\,V_m$



Bridge Full-Wave Rectifier

A full-wave rectifier with four diodes that are connected in a bridge configuration

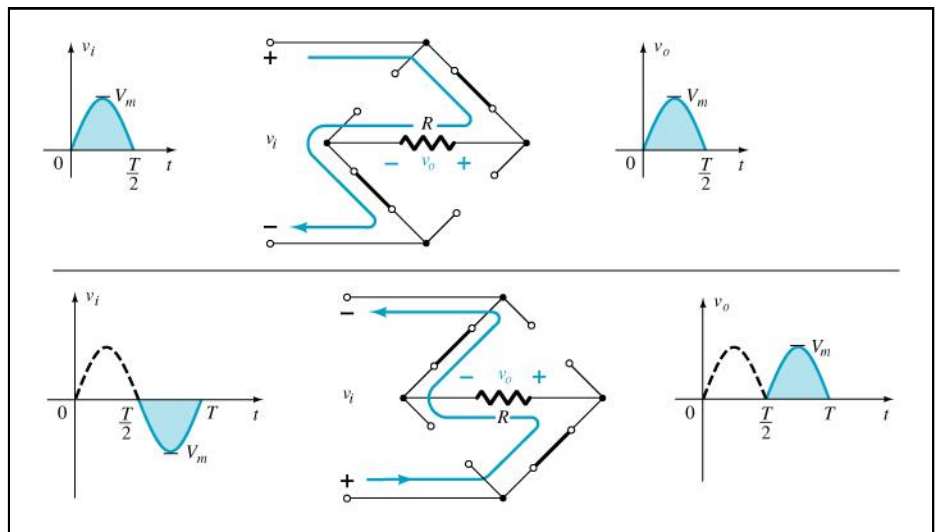


1)When $Vi(t) > 0$,

D2 , D3 are ON

D1 , D4 are OFF

$$\Rightarrow Vo(t) = Vi(t)$$



2)When $Vi(t) < 0$,

D2 , D3 are OFF

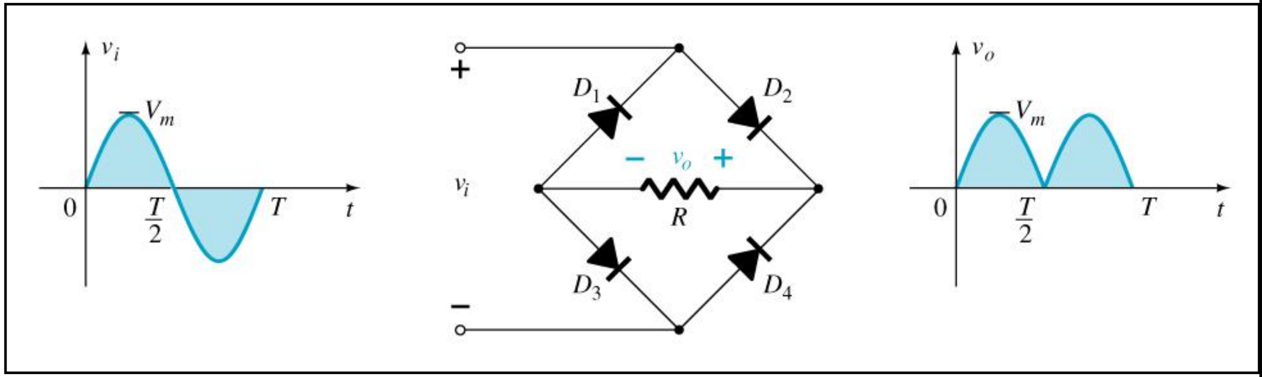
D1 , D4 are ON

$$\Rightarrow Vo(t) = -Vi(t)$$

Bridge Full-Wave Rectifier

$$V_{AVG} = \frac{1}{T}\int_0^T V_m Sin(\omega t)dt$$

$$= \frac{1}{\pi}\int_0^\pi V_m Sin(\theta)d\theta$$



$$V_{AVG} = \frac{2V_m}{\pi} \cong 0.636V_m$$

$$T = \frac{T_o}{2} \text{ and } f = 2f_o$$

(period and frequency of the rectified waveform is not the same as ac input)

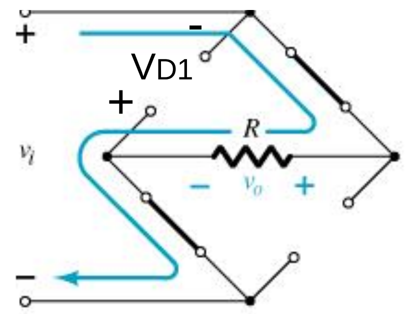
PIV for each of the 4 diodes

For ideal diode

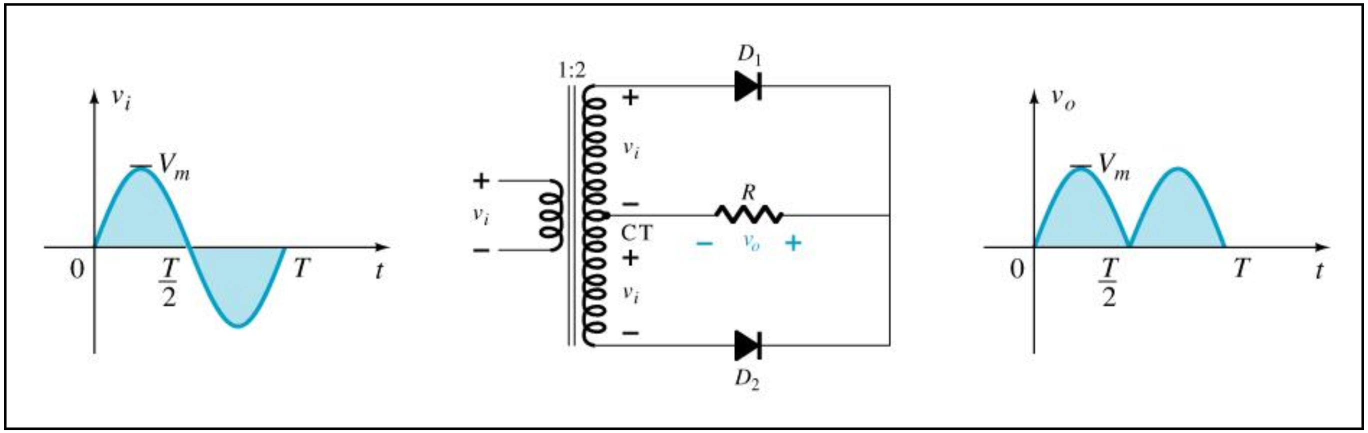
$$V_{D1}(t) = -V_i(t)$$

$$V_{D1}(t)_{max} = -V_m$$

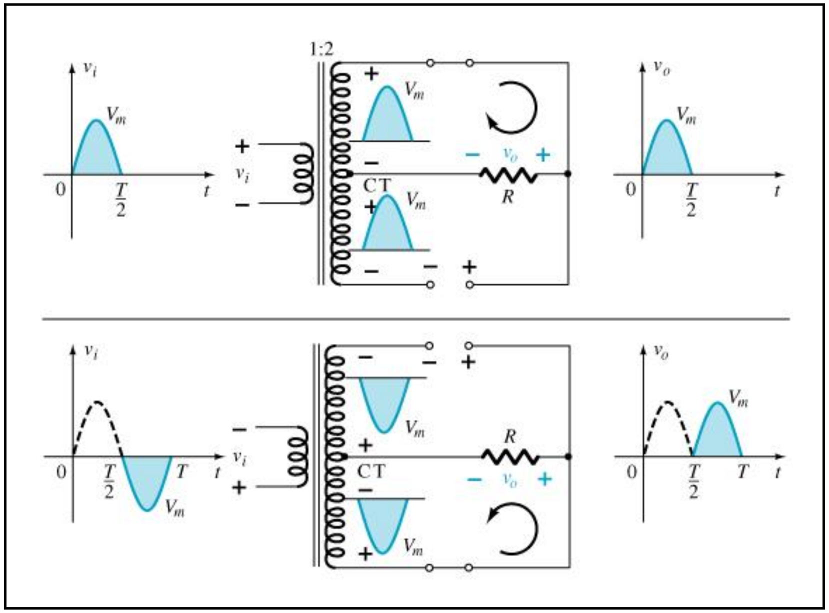
$$PIV = - V_m$$



Center Tapped Transformer Full-Wave Rectifier



Requires two diodes and a center-tapped transformer



CT Transformer Full-Wave Rectifier

1) When $Vi(t) > 0$,

D1 is ON

D2 is OFF

$$\Rightarrow Vo(t) = Vi(t)$$

2) When $Vi(t) < 0$,

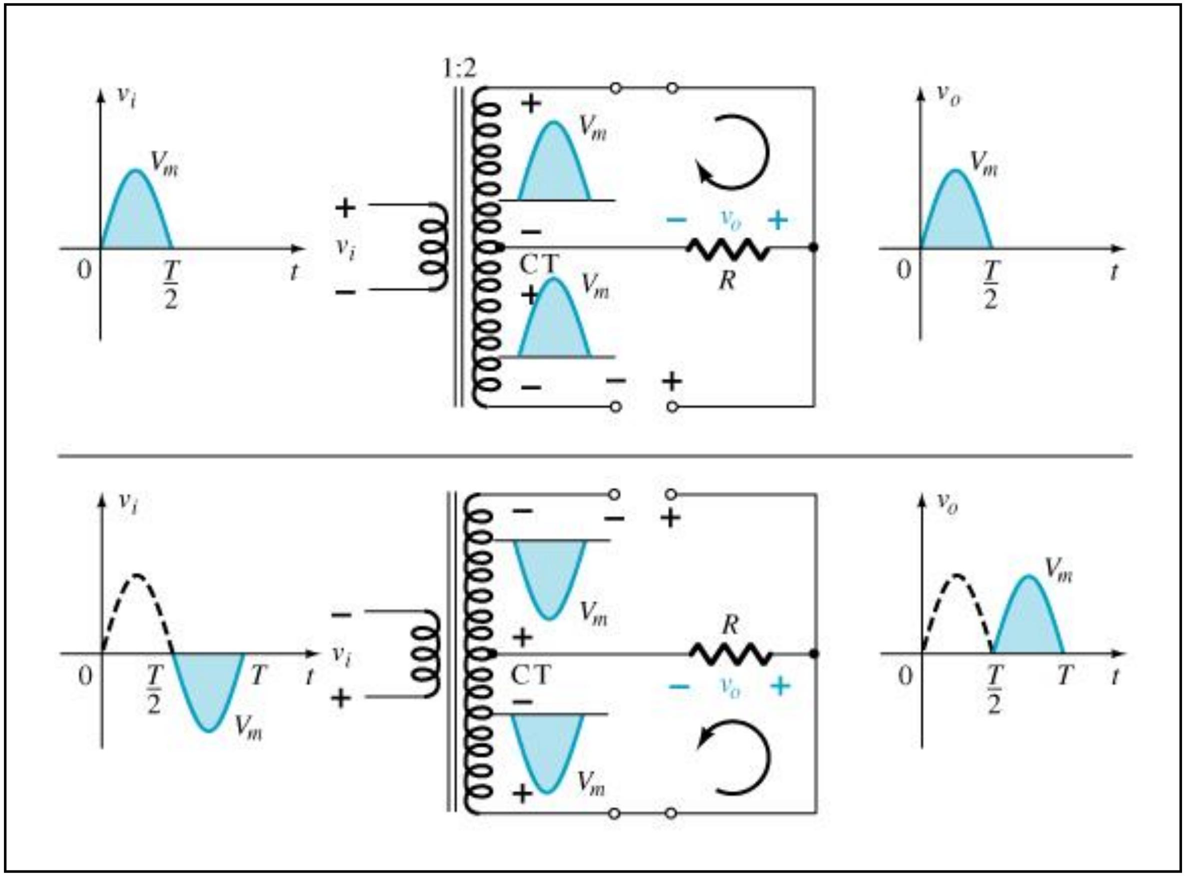
D1 is OFF

D2 is ON

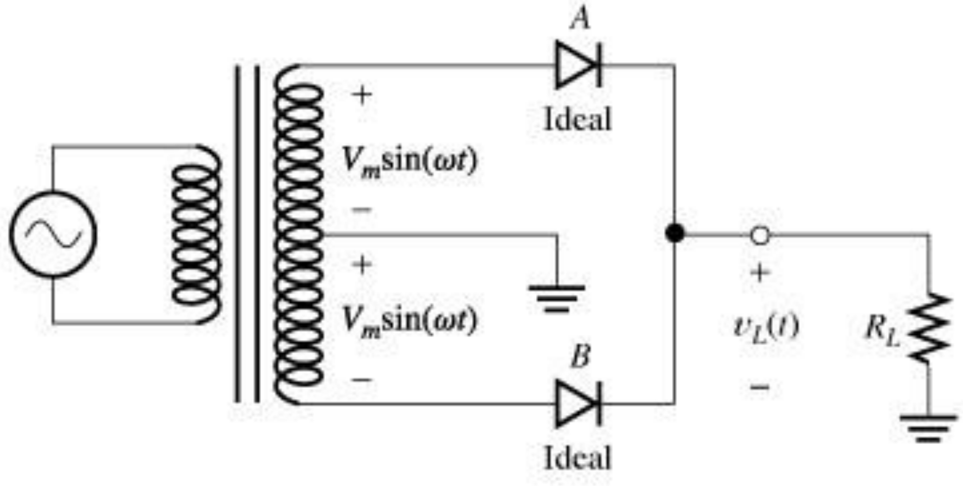
$$\Rightarrow Vo(t) = -Vi(t)$$

$$V_{AVG} = \frac{2V_m}{\pi} \cong 0.636V_m$$

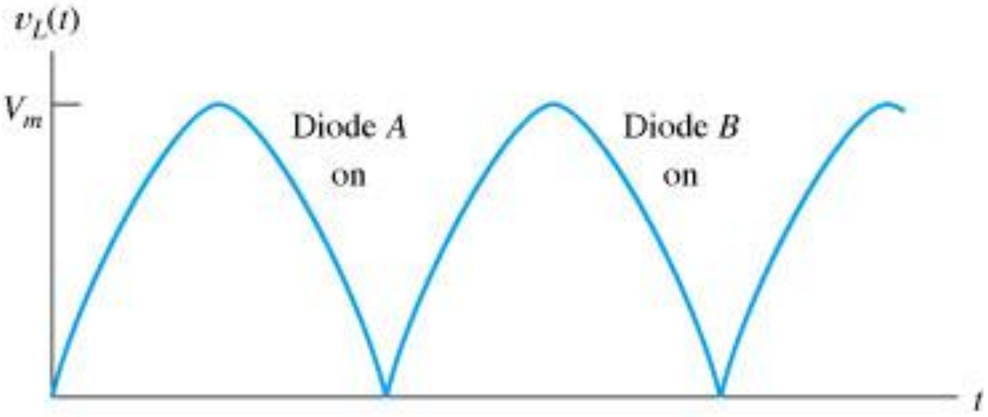
$$T = \frac{T_o}{2} \text{ and } f = 2f_o$$



CT Full-wave rectifier



(a) Circuit diagram



(b) Output voltage

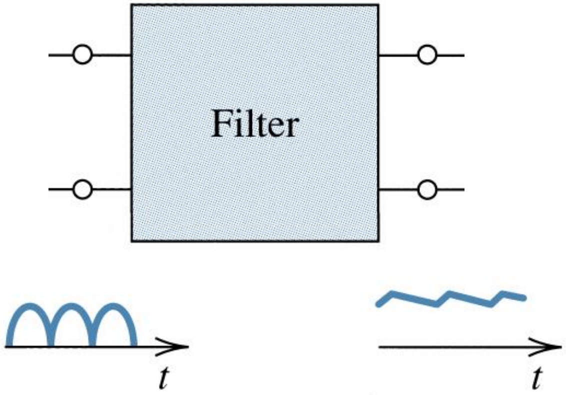
Summary of Rectifier Circuits

In the center tapped transformer rectifier circuit, the peak AC voltage is the transformer secondary voltage to the tap.

Rectifier	Ideal V_{DC}	Realistic V_{DC}
Half Wave Rectifier	$V_{DC} = 0.318\, V_m$	$V_{DC} = 0.318\, V_m - 0.7$
Bridge Rectifier	$V_{DC} = 0.636\, V_m$	$V_{DC} = 0.636\, V_m - 2(0.7\text{ V})$
Center-Tapped Transformer Rectifier	$V_{DC} = 0.636\, V_m$	$V_{DC} = 0.636\, V_m - 0.7\text{ V}$

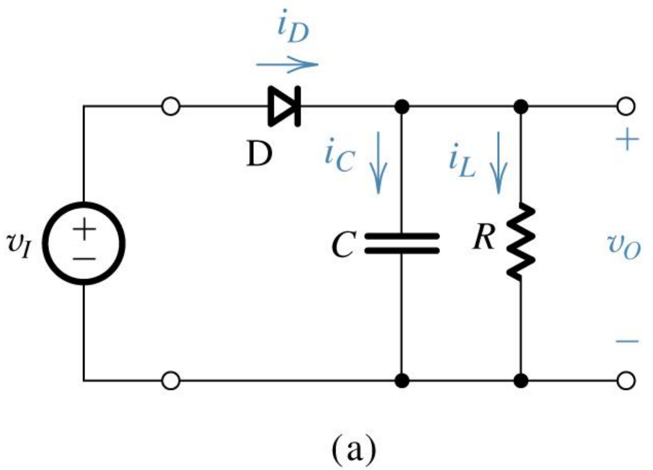
V_m = the peak AC voltage

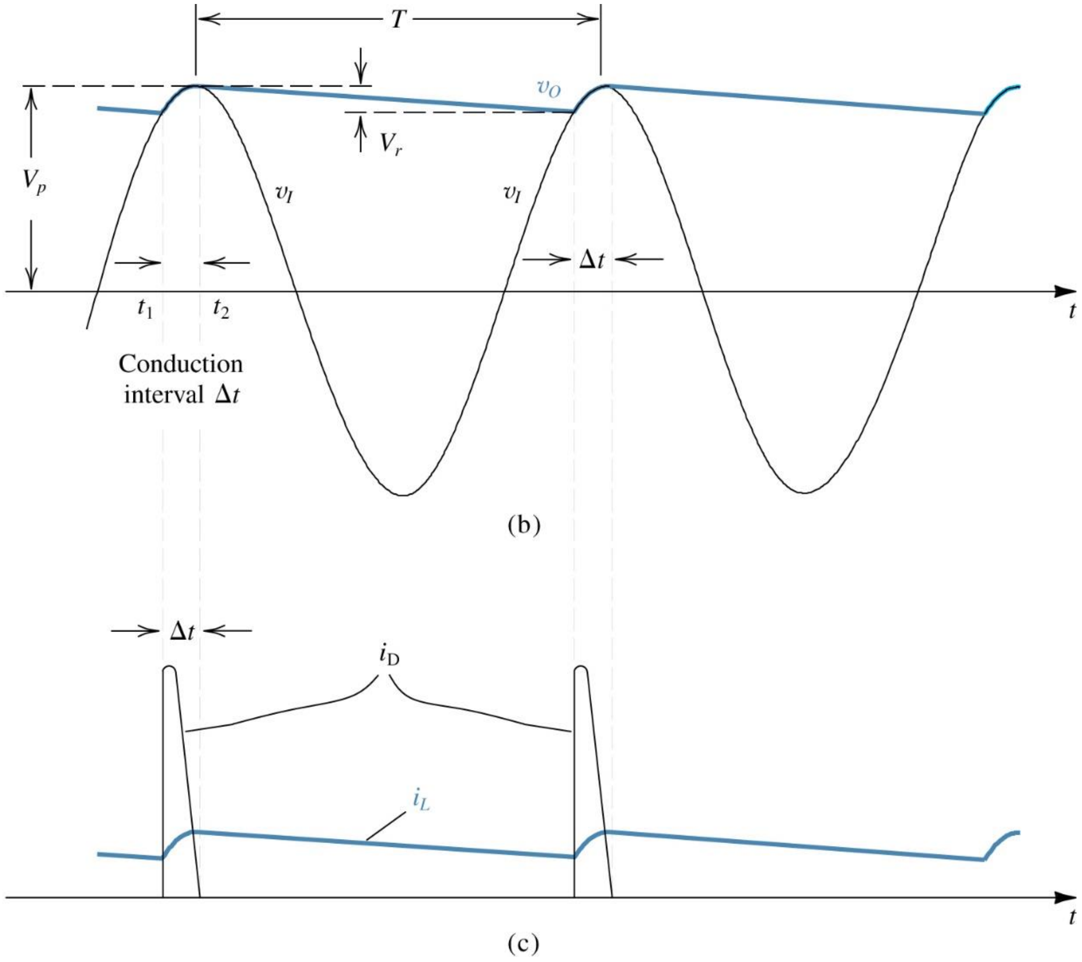
3) Filter



- One of dc power supply components
- Used to smooth out (remove) the pulsating DC produced by the rectifiers and to pass only the DC component

Half-wave rectifier with smoothing (Filter) capacitor



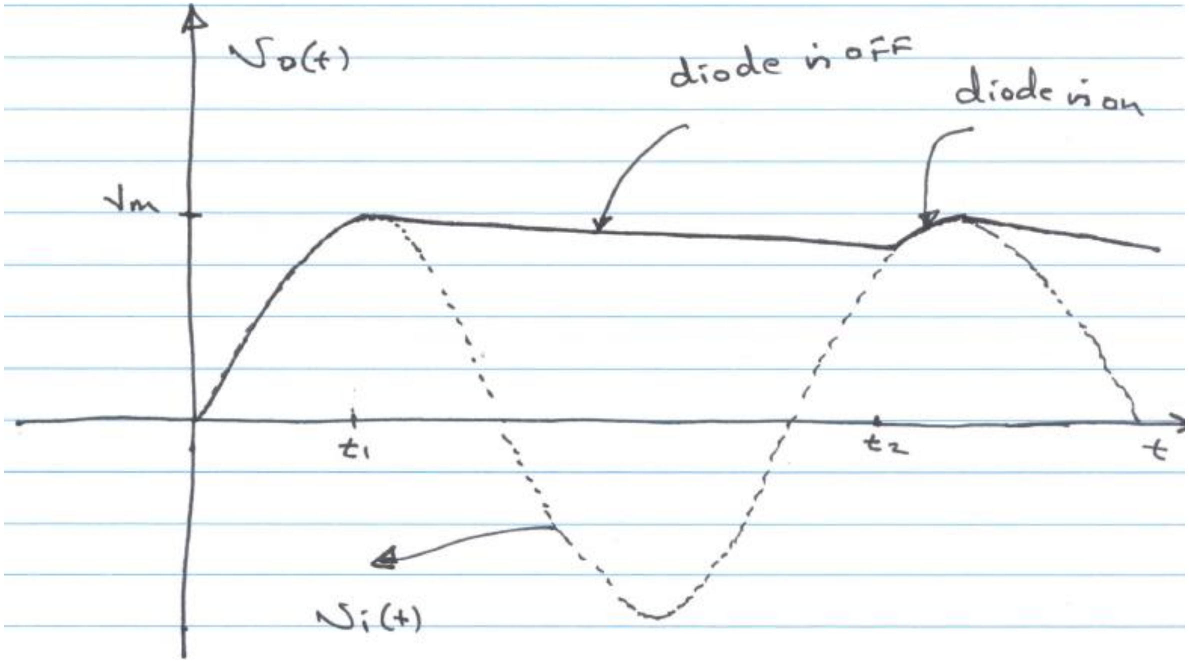


1) When Vi(t) > Vc(t), diode is ON and capacitor is charged
2) When Vi(t) < Vc(t), diode is OFF and capacitor is discharged through R

Voltage and current waveforms in half wave rectifier (peak detector) with $CR \gg T$. (The diode is assumed ideal)

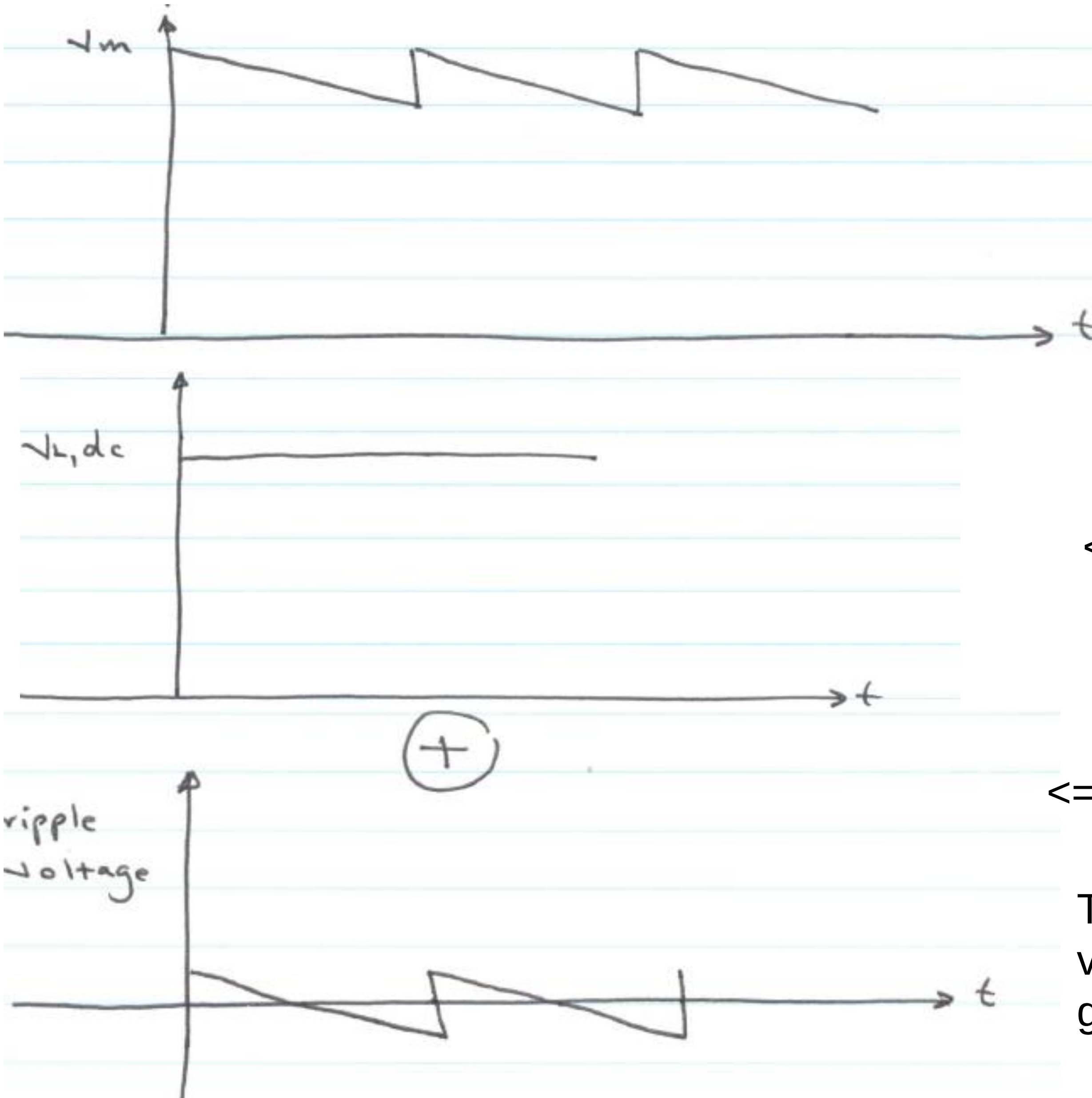
Ripple Factor

Is an indication of the effectiveness of the filter



$$r\% = \frac{\text{RMS value of ripple voltage}}{\text{Average Value of output signal}} .100\%$$

The Output Voltage can be approximated as

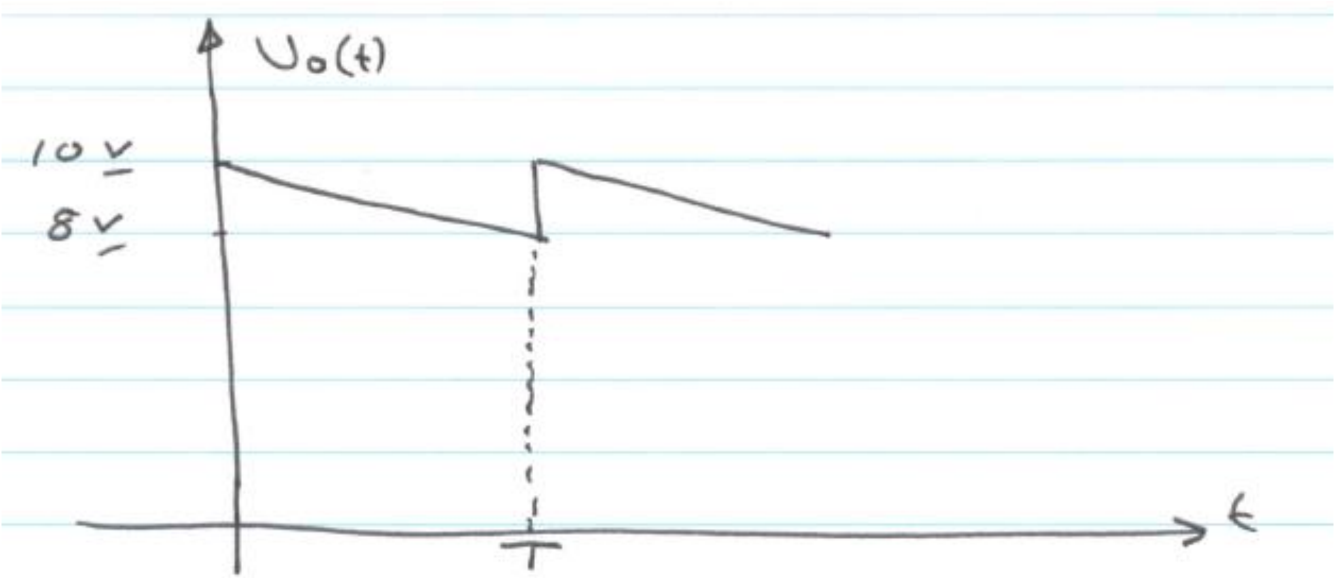


<== DC voltage

<== Ripple Voltage

The smaller the ripple voltage, the closer we get to DC

Example



$$V_{O,DC} = V_{O,AVG} = \frac{1}{T}\int_0^T V_O(t)dt$$

$$= \frac{1}{T}(\text{Area})$$

$$= \frac{1}{T}(8T + \frac{2T}{2}) = 9\text{ V}$$

OR

$$V_{O,DC} = V_m - \frac{1}{2}V_{Lr,p-p}$$

$$\text{where Vm} = 10$$

$$V_{Lr,p-p} = 2$$

$$V_{O,DC} = 10 - \frac{1}{2}.2 = 9\text{ V}$$

Also , for a triangular signal, the RMS value

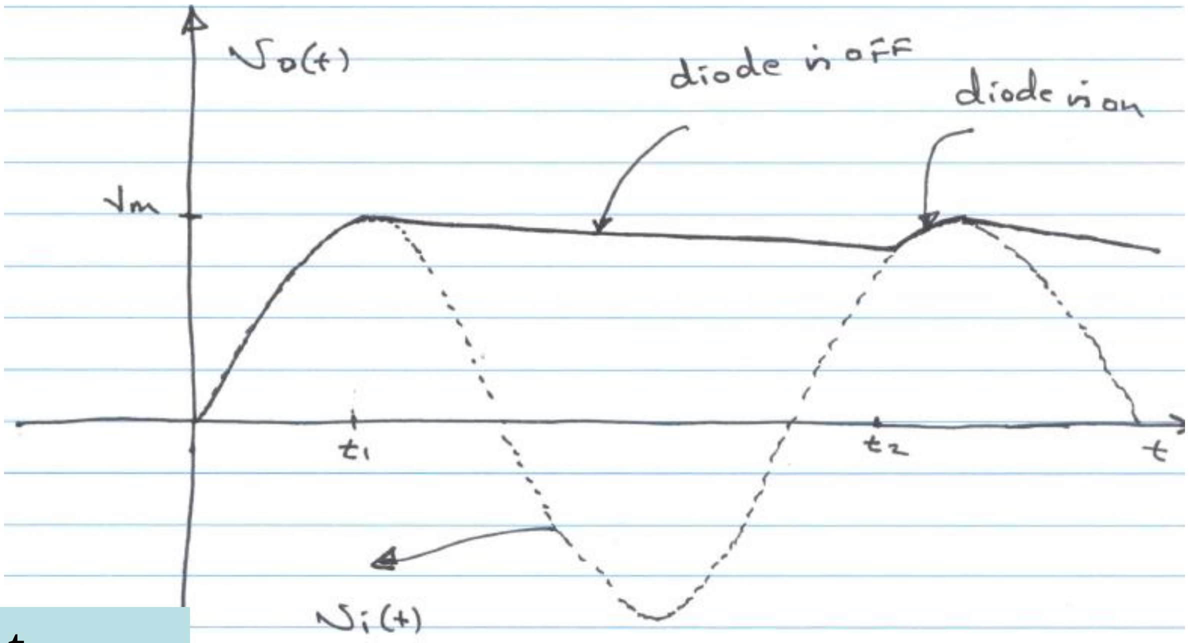
$$\text{RMS Value} = \frac{\text{Peak Value}}{\sqrt{3}}$$

OR

$$\text{RMS Value} = \frac{\text{Peak to peak Value}}{2\sqrt{3}} = \frac{V_{Lr,p-p}}{2\sqrt{3}}$$

$$\therefore \quad r\,\% = \frac{\dfrac{V_{Lr,p-p}}{2\sqrt{3}}}{V_m - \dfrac{1}{2}V_{Lr,p-p}} 100\%$$

$\Rightarrow$ To Determine the ripple factor we need to find the peak to peak ripple $V_{Lr,p-p}$



For $t_2 > t > t_1$

$$V_L(t) = V_m\, e^{\frac{-(t-t_1)}{RC}}$$

$$V_{Lr,p\text{-}p} = V_m\left[1 - e^{\frac{-(t_2-t_1)}{RC}}\right]$$

For $t_2 > t > t_1$

$$V_{Lr,p\text{-}p} = V_L(t_1) - V_L(t_2)$$

$$V_{Lr,p\text{-}p} = V_m - V_m\, e^{\frac{-(t_2-t_1)}{RC}}$$

using $e^{-x} \cong 1 - x$

using $e^{-x} \cong 1 - x$

$$V_{Lr,p\text{-}p} = V_m\left[1 - e^{\frac{-(t_2 - t_1)}{RC}}\right] \Rightarrow V_{Lr,p\text{-}p} = V_m\left(\frac{(t_2 - t_1)}{RC}\right)$$

$$V_{L,dc} = V_m - \frac{1}{2}V_{Lr,p-p}$$

a) For Half Wave Rectifier

$$t_2 - t_1 \cong T_O = \frac{1}{f_O}$$

$$V_{Lr,p\text{-}p} = V_m\left(\frac{T_O}{RC}\right) = V_m\left(\frac{1}{f_O RC}\right)$$

$$V_{L,dc} = V_m\left(1 - \frac{1}{2f_O RC}\right)$$

$$\left(V_{L,r}\right)_{RMS} = \frac{V_{Lr,p\text{-}p}}{2\sqrt{3}}$$

$$\left(V_{L,r}\right)_{RMS} = \frac{V_m}{2\sqrt{3}f_O RC}$$

$$\therefore \quad r\,\% = \frac{\left(V_{L,r}\right)_{RMS}}{V_{L,dc}}100\%$$

$$\therefore \quad r\,\% = \frac{1}{\sqrt{3}\left[2f_O RC - 1\right]}100\%$$

b) For Full Wave Rectifier

$$t_2 - t_1 \cong \frac{1}{2} T_O = \frac{1}{2f_O}$$

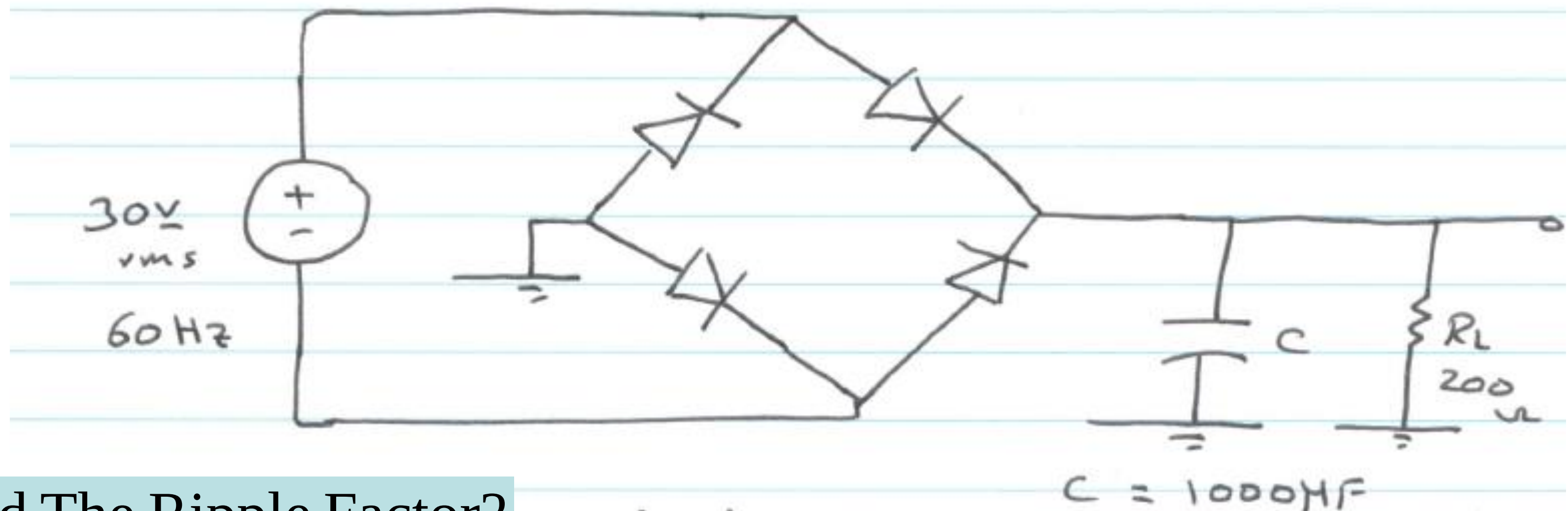
$$V_{Lr,p\text{-}p} = V_m\left(\frac{T_O}{2RC}\right) = V_m\left(\frac{1}{2f_O RC}\right)$$

$$V_{L,dc} = V_m\left(1 - \frac{1}{4f_O RC}\right)$$

$$\left(V_{L,r}\right)_{RMS} = \frac{V_{Lr,p\text{-}p}}{2\sqrt{3}}$$

$$\left(V_{L,r}\right)_{RMS} = \frac{V_m}{4\sqrt{3} f_O RC}$$

$$\therefore \quad r\,\% = \frac{1}{\sqrt{3}\left[4f_O RC - 1\right]} 100\%$$



Find The Ripple Factor?

$$V_{L,dc} = V_m\left(1-\frac{1}{4f_O RC}\right) = 30\sqrt{2}\left(1-\frac{1}{4*60*200*1000\mu 0}\right) = 41.54\ \mathrm{V}$$

$$V_{Lr,p\text{-}p} = V_m\left(\frac{T_O}{2RC}\right) = V_m\left(\frac{1}{2f_O RC}\right) = 1.7677\ \mathrm{V}$$

$$\left(V_{L,r}\right)_{RMS} = \frac{V_{Lr,p\text{-}p}}{2\sqrt{3}} = 0.51\ V_{RMS}$$

$$\therefore \quad r\,\% = \frac{0.51\ \mathrm{V}}{41.54\ \mathrm{V}}.100\% = 1.2272\ \%$$