

ENEE2360

Analog Electronics

T4:

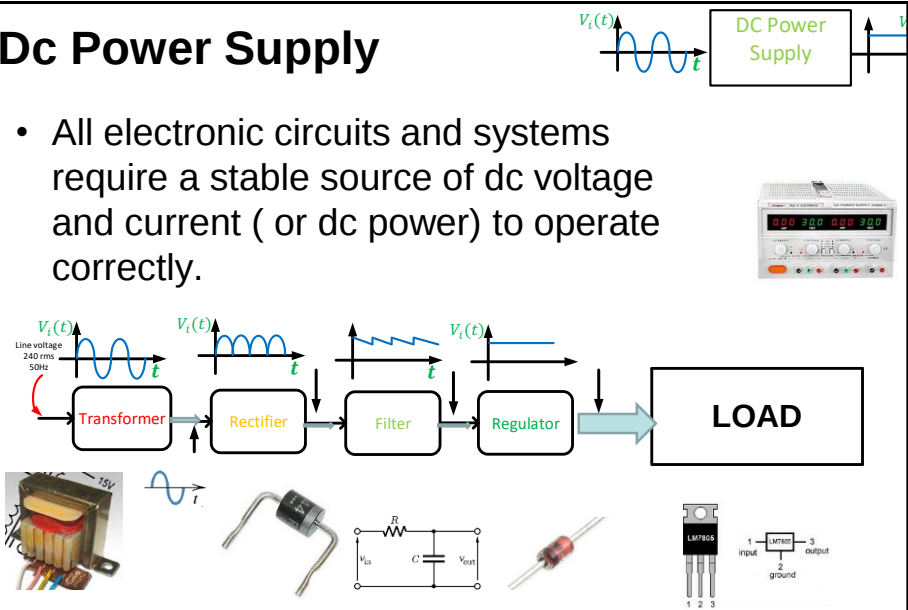
Diode Applications

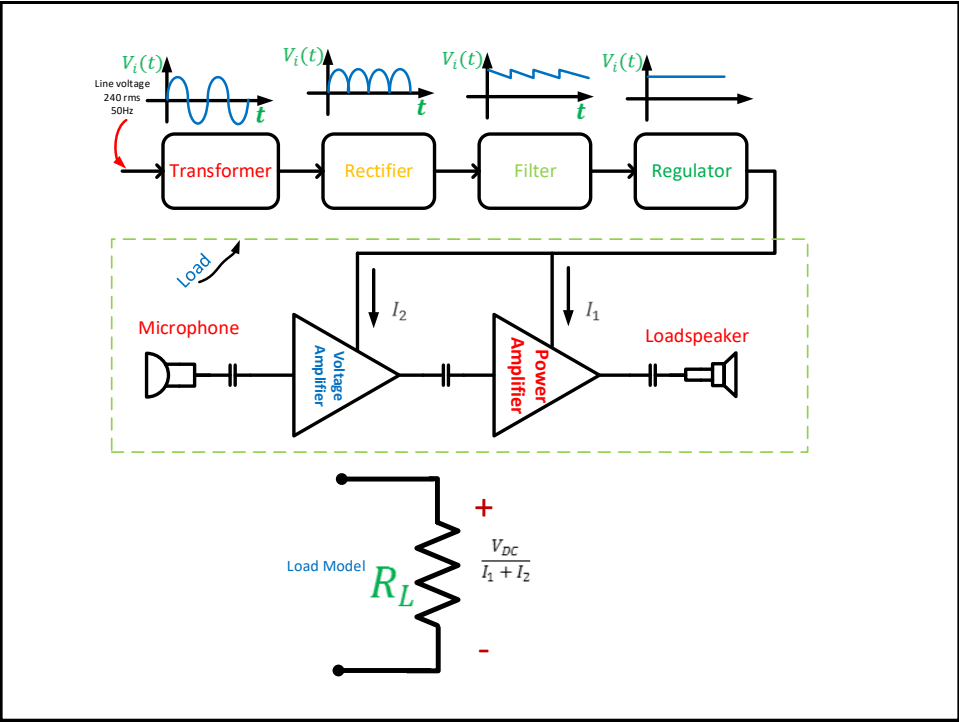
DC power Supply

Instructor: Nasser Ismail

Dc Power Supply

- All electronic circuits and systems require a stable source of dc voltage and current (or dc power) to operate correctly.





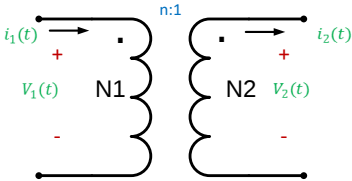
Dc Power Supply



- ▶ The basic power supply consists of a transformer, rectifier, filter, and a regulator.
- ▶ **Transformer:** Used to increase or decrease the amplitude of the line voltage

▶ $V_2(t) = \frac{1}{n} V_1(t)$

$i_2(t) = n i_1(t)$

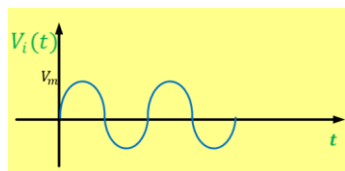
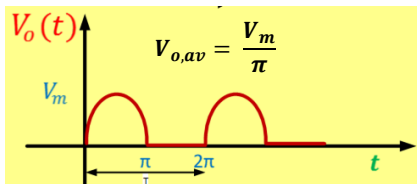


$\frac{V_2(t)}{V_1(t)} = \frac{N_2}{N_1}$

$n = \frac{N_1}{N_2}$

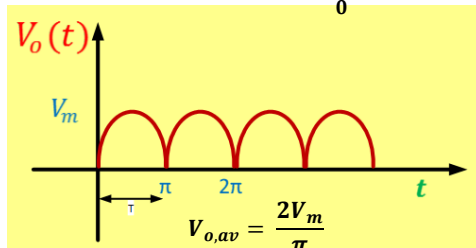
Dc Power Supply

- **Rectifier:** used to convert the ac voltage (zero- average value) into either positive and negative pulsating dc.



$$V_{i,av} = \frac{1}{T} \int_0^T V_i(t) dt = 0$$

$$V_{o,av} = \frac{1}{T} \int_0^T V_o(t) dt$$



Dc Power Supply

- **Rectifier:** used to convert the ac voltage (zero- average value) into either positive and negative pulsating dc.

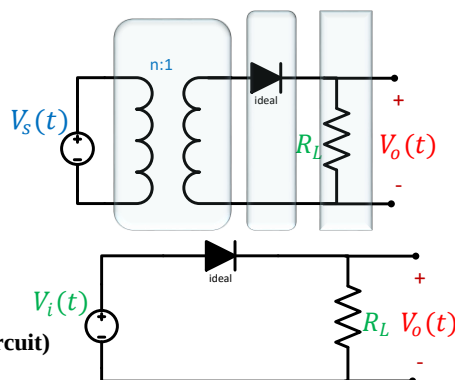
- 1) Half- Wave Rectifier

$$V_i(t) = \frac{V_s(t)}{n}$$

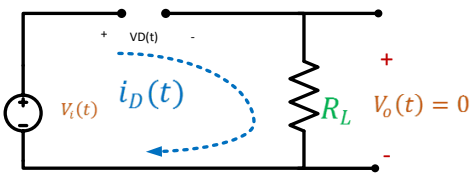
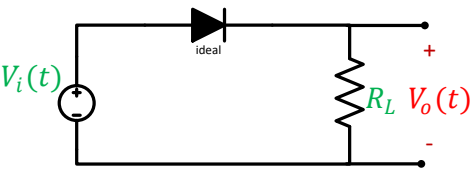
- **A)** when $V_i(t) > 0$, Diode is on (short circuit)

$$\therefore V_o(t) = V_i(t)$$

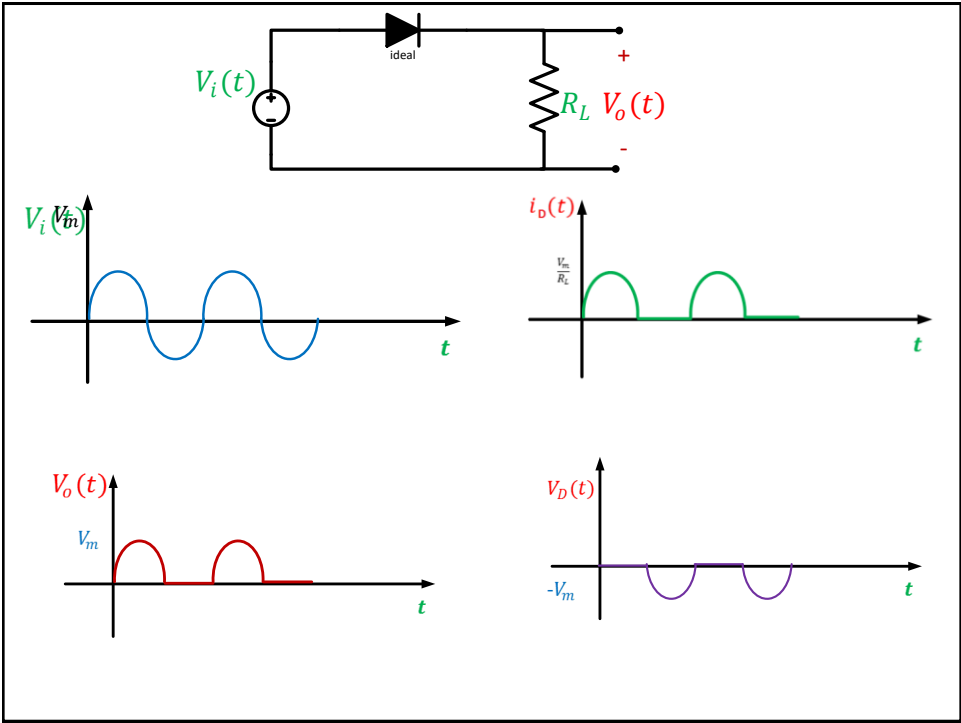
$$\therefore V_D(t) = 0$$



B) when $V_i(t) < 0$, Diode is off (open circuit)



$\therefore V_o(t) = 0$
 $\therefore V_D(t) = V_i(t)$



- $V_{o,av} = \frac{1}{T} \int_0^T V_o(t) dt$

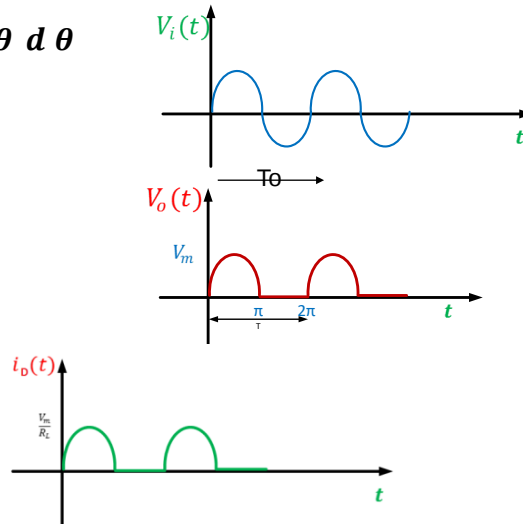
$$= \frac{V_m}{2\pi} \int_0^\pi \sin \theta d\theta$$

- $V_{o,av} = \frac{V_m}{\pi}$

- $T = T_o$

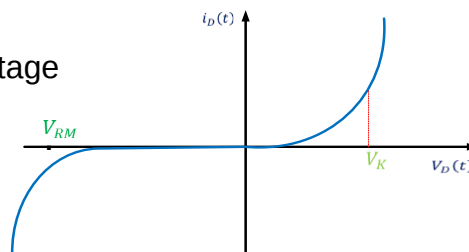
- $f = f_o$

- $i_D(t)_{av} = \frac{V_m}{\pi R_L}$



Important Electrical Ratings

- I_{FM} = Maximum Forward Current
- I_{FM} = Maximum average current that can safely be sustained by the diode when it is forward biased
- V_{RM} = Maximum Reverse Voltage
- V_{RM} = Maximum voltage that can be applied to the diode in the Reverse bias polarity before voltage break down occur
- $PIV \equiv$ Peak Inverse Voltage
- $PIV = V_{RM}$



- ∴ For the half-wave rectifier

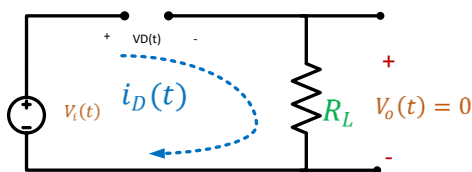
$$V_{o,av} = \frac{V_m}{\pi}$$

$$I_{FM} = \frac{V_m}{\pi R_L}$$

$$PIV = -V_m \quad \text{Prove ???}$$

To calculate PIV

When $V_i(t) < 0$, Diode is off



$$V_D(t) = V_i(t) < 0$$

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

Full-Wave Rectifier

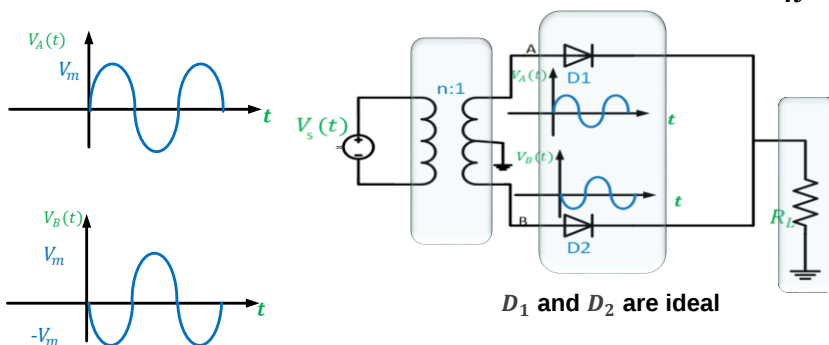
- A) Center-tapped transformer full-wave Rectifier

- $V_A(t)$, $V_B(t)$ have the same amplitude but 180° out of phase

$$V_A(t) = -V_B(t)$$

$$V_A(t) = \frac{1}{n} V_s(t)$$

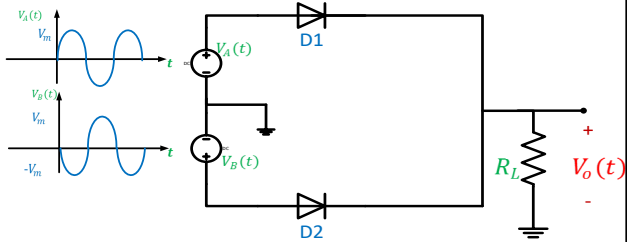
$$V_B(t) = -\frac{1}{n} V_s(t)$$



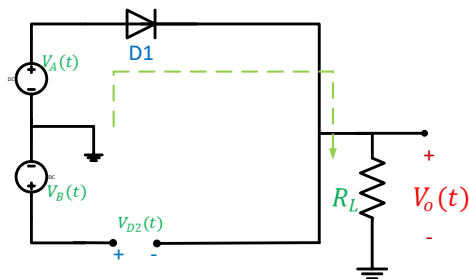
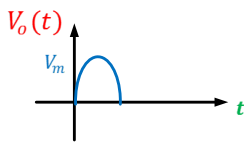
Simplified Circuit

D_1 and D_2 are ideal

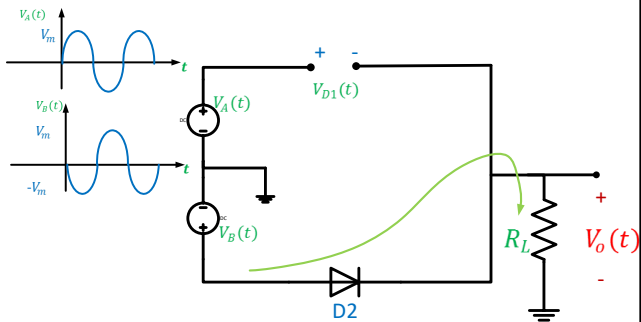
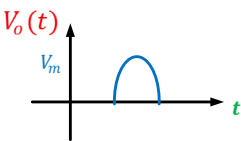
- 1) when $V_s(t) > 0$
 $V_A(t) > 0$, D_1 is on
 $V_B(t) < 0$, D_2 is off



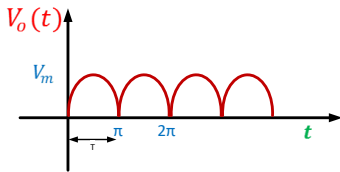
- $V_o(t) = V_A(t)$



- 2) when $V_s(t) < 0$
 $V_A < 0$; D_1 is off
 $V_B > 0$; D_2 is on
► $\therefore V_o(t) = V_B(t) > 0$



For a complete cycle of $V_s(t)$



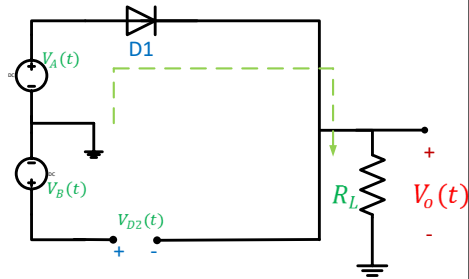
To calculate PIV for D2

$$V_{D2}(t) = V_B(t) - V_A(t)$$

$$V_{D2}(t)_{max} = -V_m - V_m$$

$$V_{D2}(t)_{max} = -2V_m$$

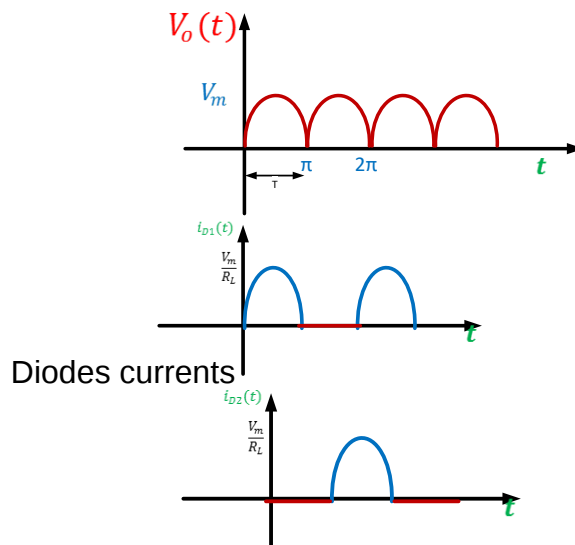
$$\therefore \text{PIV} = -2V_m$$



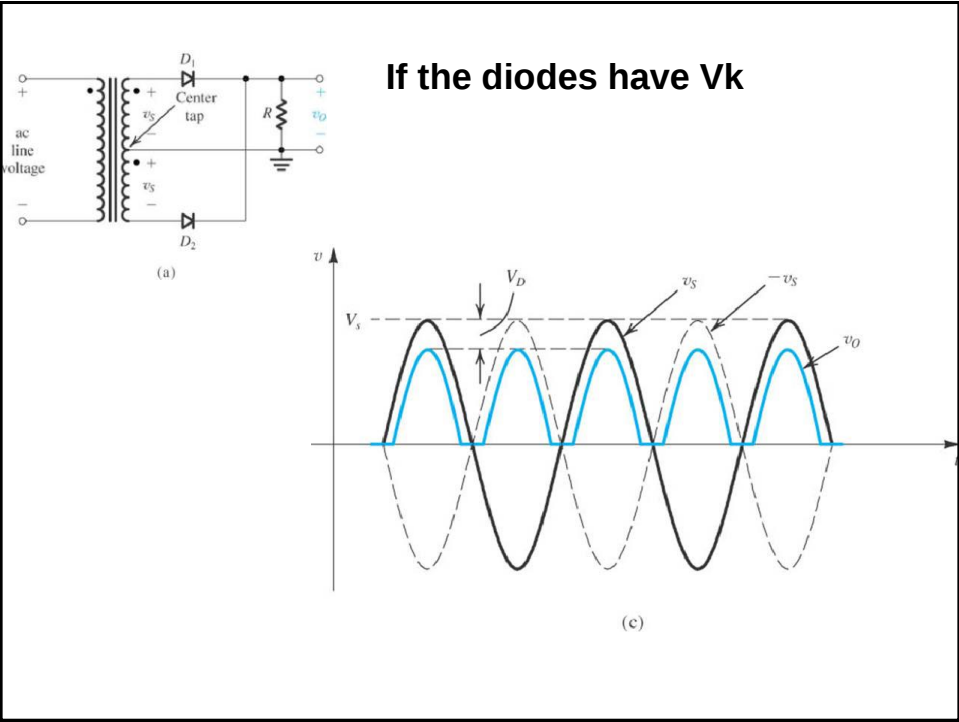
$V_A(t) > 0$, D_1 is on

$V_B(t) < 0$, D_2 is off

- $V_{o,av} = \frac{2V_m}{\pi}$
- $\text{PIV} = -2V_m$
- $T = \frac{1}{2}T_o$
- $f = 2f_o$



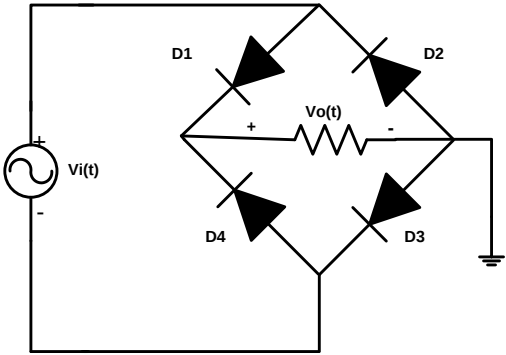
Diodes currents



b) Bridge full-wave rectifier

- Simplified circuit

$$V_i(t) = \frac{V_s(t)}{n}$$



b) Bridge full-wave rectifier

$$V_i(t) = \frac{V_s(t)}{n}$$

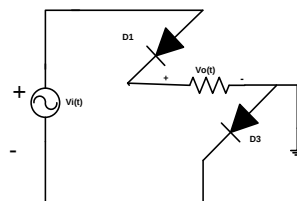
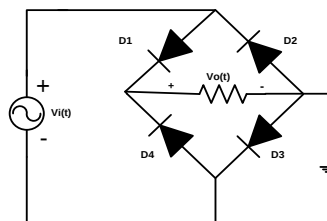
► 1) when $V_s(t) > 0$

$$\therefore V_i(t) > 0$$

$\therefore D_1$ and D_3 are on

$\therefore D_2$ and D_4 are off

► $V_o(t) = V_i(t)$



• 2) when $V_s(t) < 0$

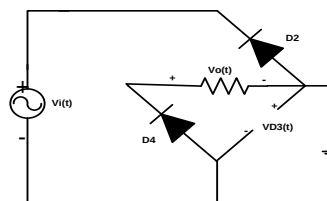
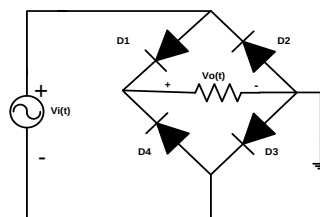
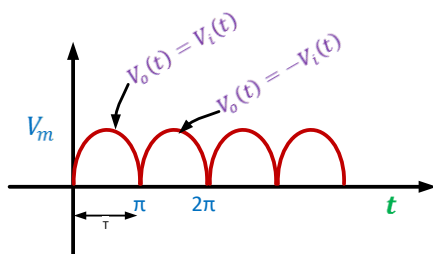
$$\therefore V_i(t) < 0$$

$\therefore D_1$ and D_3 are off

$\therefore D_2$ and D_4 are on

$$\therefore V_o(t) = -V_i(t)$$

$\therefore$ For the complete cycle of $V_i(t)$



- $\therefore$ For Bridge full-wave rectifier

- $V_{o,av} = \frac{1}{T} \int_0^T V_o(t) dt$

$$V_{o,av} = \frac{2V_m}{\pi}$$

- $T = \frac{1}{2} T_o$

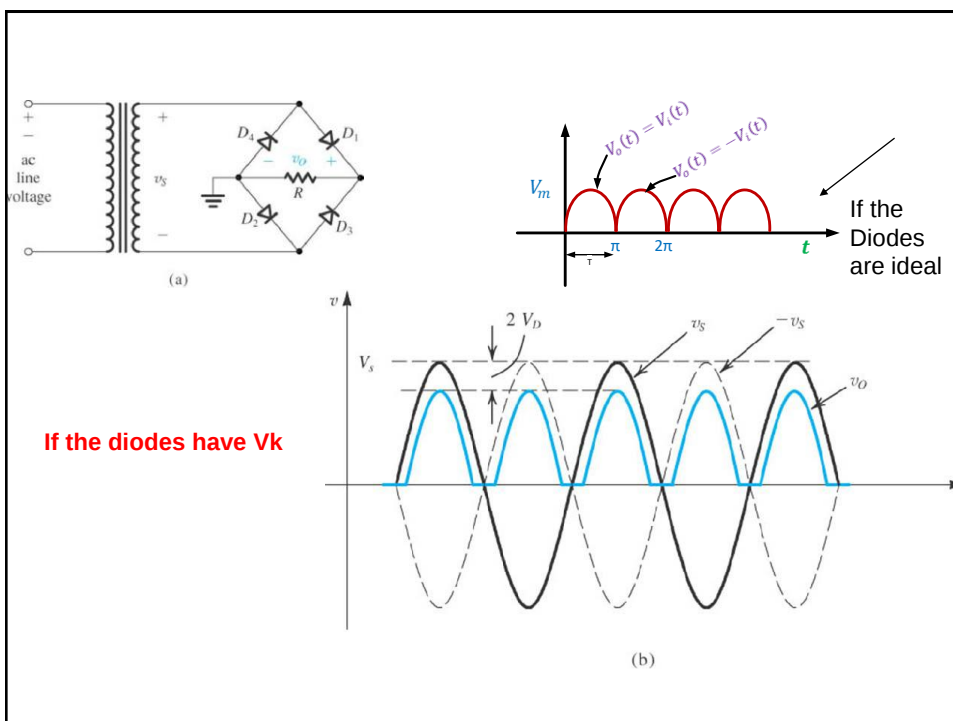
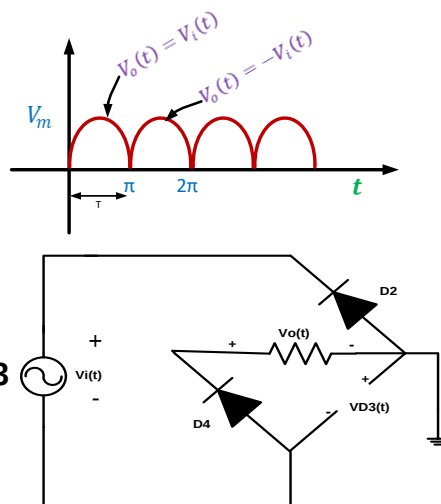
- $f = 2f_o$

- To calculate the PIV of the D3

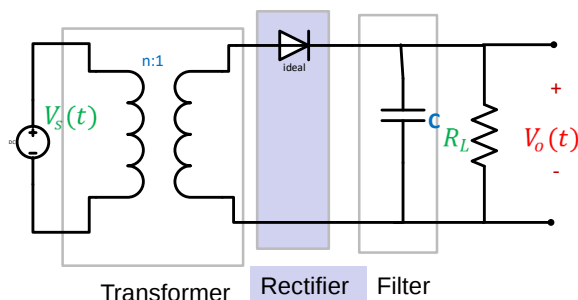
- $V_i(t) < 0$

$$V_{D3}(t) = V_i(t)$$

$$\therefore V_{D3}(t)_{max} = -V_m \therefore \text{PIV} = -V_m$$

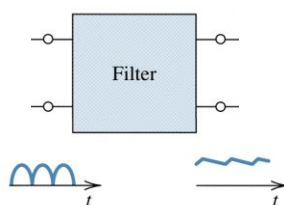


- **Filter:** used to smooth out the pulsating dc produced by the rectifier by removing its ac ripple contents and passing its dc component (average value)



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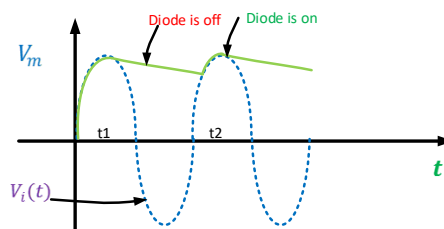
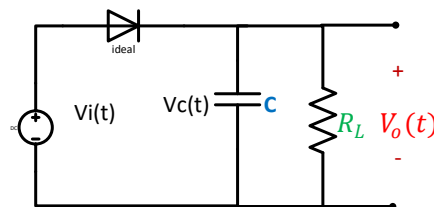
3) Filter



- 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 (average value; mean value)

Simplified Circuit

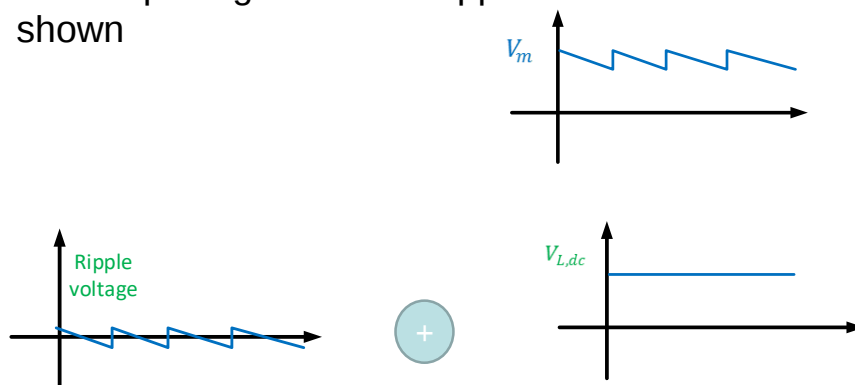
- A) when $V_i(t) > V_c(t)$;
Diode is on and $V_o(t) = V_c(t) = V_i(t)$
- B) when $V_i(t) < V_c(t)$;
Diode is off and the capacitor starts discharging



- Ripple factor is an indicator for the effectiveness of the filter

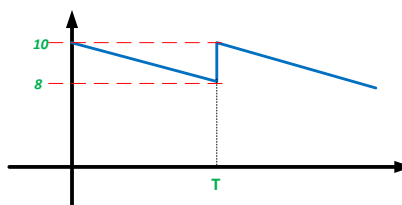
$$r = \frac{\text{RMS(ripple of output voltage)}}{\text{Average value of the output signal}} \times 100\%$$

- The output signal can be approximated as shown



Example

Find average output voltage?



$$\begin{aligned} V_{O,DC} &= V_{O,AVG} = \frac{1}{T} \int_0^T V_O(t) dt \\ &= \frac{1}{T} (\text{Area}) \\ &= \frac{1}{T} \left(8T + \frac{2T}{2} \right) = 9 \text{ V} \end{aligned}$$

OR

$$\begin{aligned} V_{O,DC} &= V_m - \frac{1}{2} V_{Lr,p-p} \\ \text{where } V_m &= 10 \\ V_{Lr,p-p} &= 2 \end{aligned}$$

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

- Also for a triangular signal,

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

OR

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

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

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

Ripple Factor

For $t_2 > t > t_1$

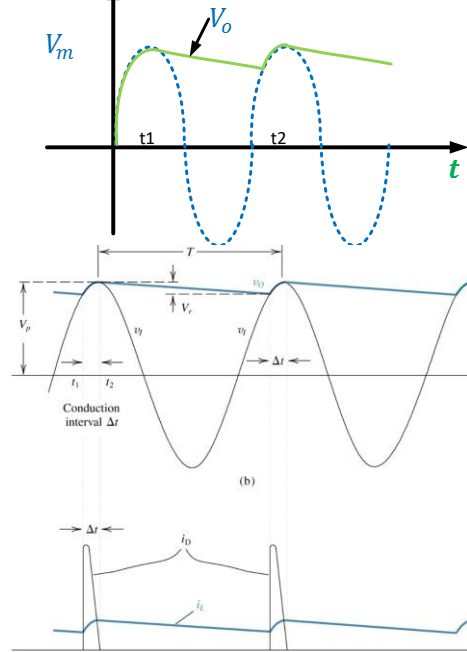
$$V_L(t) = V_m e^{\frac{-(t-t_1)}{RC}}$$

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

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

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

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



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

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

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

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a) For Half Wave Rectifier

$$t_2 - t_1 \cong T_o = \frac{1}{f_o}$$

$$V_{Lr,p-p} = V_m \left(\frac{T_o}{RC} \right) = V_m \left(\frac{1}{f_o RC} \right)$$

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

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

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

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

$$\therefore r \% = \frac{1}{\sqrt{3}[2f_o RC - 1]} 100\%$$

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b) For Full Wave Rectifier

$$t_2 - t_1 \cong \frac{1}{2} T_o = \frac{1}{2f_o}$$

$$V_{Lr,p-p} = V_m \left(\frac{T_o}{RC} \right) = V_m \left(\frac{1}{2f_o RC} \right)$$

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

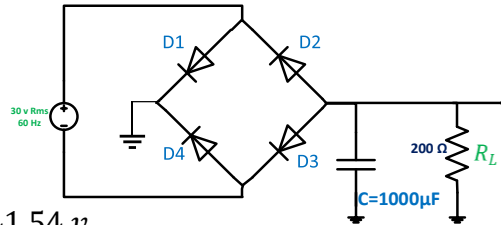
$$(V_{L,r})_{RMS} = \frac{V_{Lr,p-p}}{2\sqrt{3}}$$

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

$$\therefore r \% = \frac{1}{\sqrt{3}[4f_o RC - 1]} 100\%$$

Example

- Find the ripple factor $r\%$
- Input=30V RMS
- $F=60$ Hz



- $V_{L,dc} = V_m - \frac{1}{2} \frac{V_m}{2f_o R_{Lc}} = 41.54 \text{ v}$

$$V_{Lr,p-p} = \frac{V_m}{2f_o R_{Lc}} = 1.7677 \text{ v}$$

- RMS (ripple voltage) = $\frac{V_{Lr,p-p}}{2\sqrt{3}} = 0.51 \text{ v rms}$

$$\therefore r = \frac{0.51}{41.54} \times 100\%$$

$$r = 1.2277 \%$$