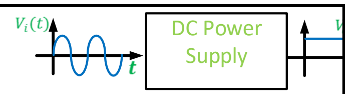
ENEE2360

Analog Electronics

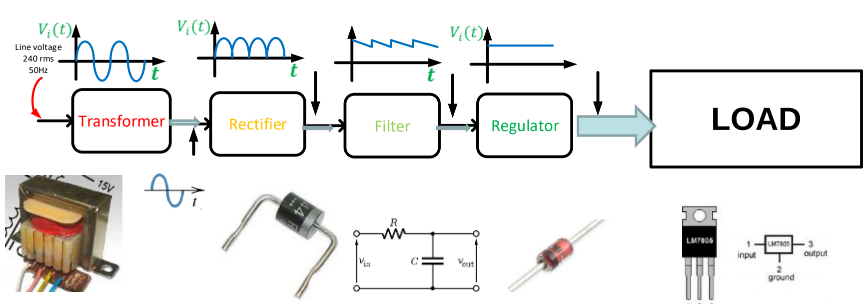
T4:
Diode Applications
DC power Supply

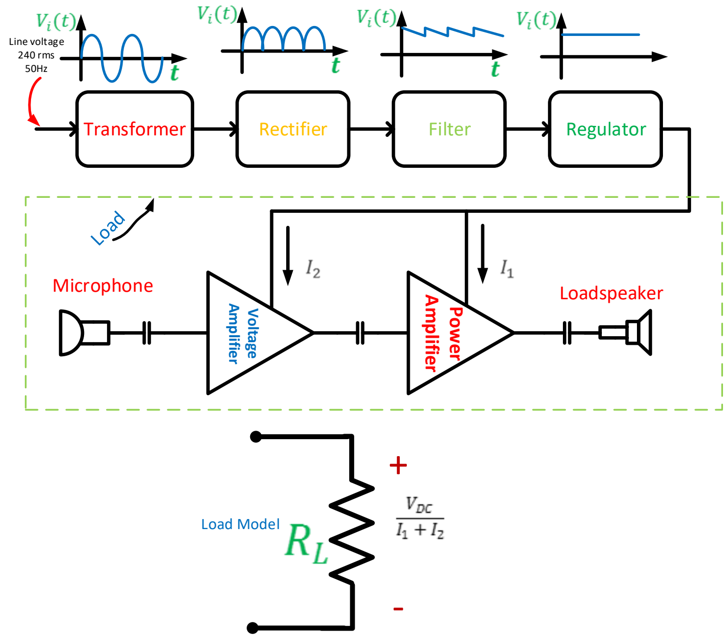
Instructor: Nasser Ismail

Dc Power Supply

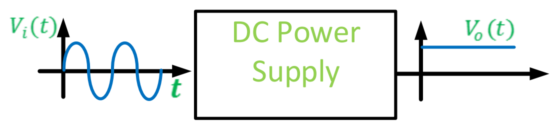


- All electronic circuits and systems require a stable source of dc voltage and current (or dc power) to operate correctly.

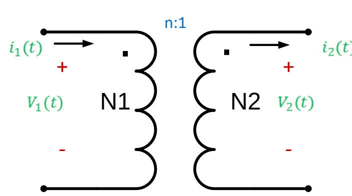




Dc Power Supply



- 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



- $$V_2(t) = \frac{1}{n} V_1(t)$$

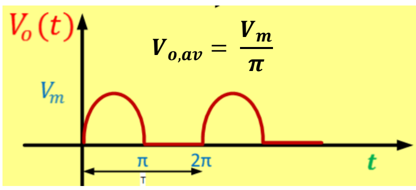
$$i_2(t) = n\, i_1(t)$$

$$\frac{V2(t)}{V1(t)} = \frac{N2}{N1}$$

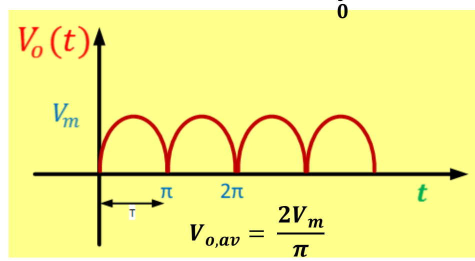
$$n = \frac{N1}{N2}$$

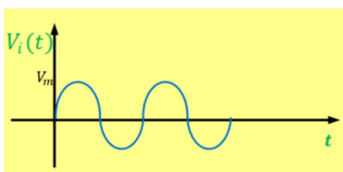
Dc Power Supply

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



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

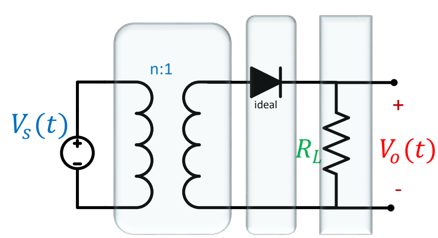




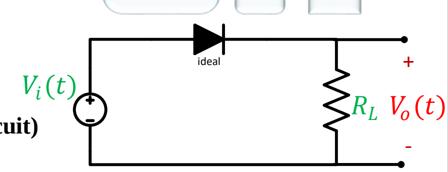
$$V_{i,av} = \frac{1}{T}\int_0^T V_i(t)dt = 0$$

Dc Power Supply

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



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

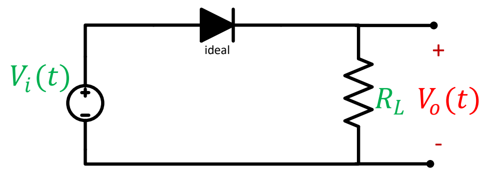


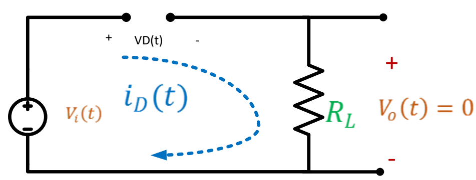
- **A)** when $V_i(t) > 0$, Diode is on (short circuit)

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

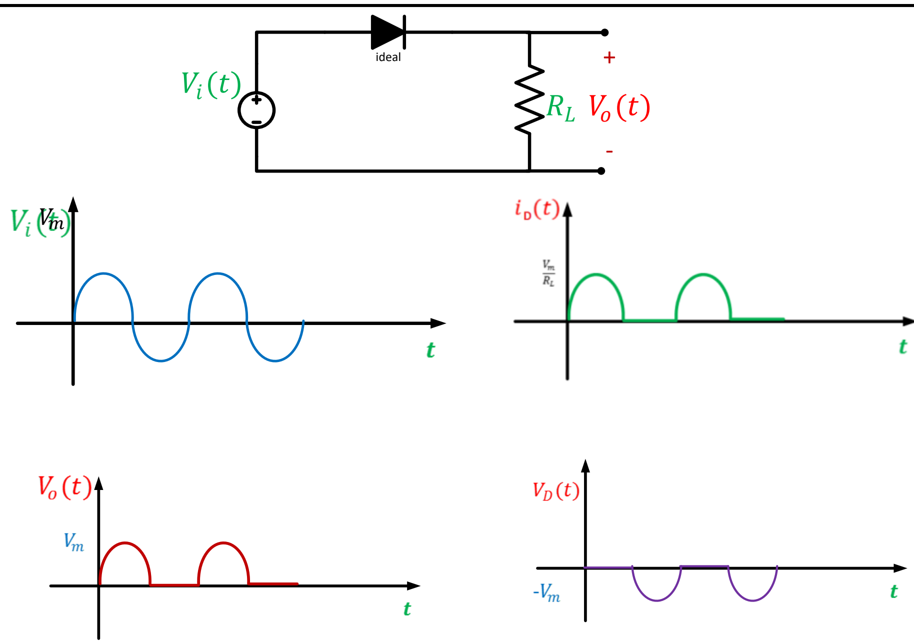
$$\therefore V_D(t) = 0$$

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



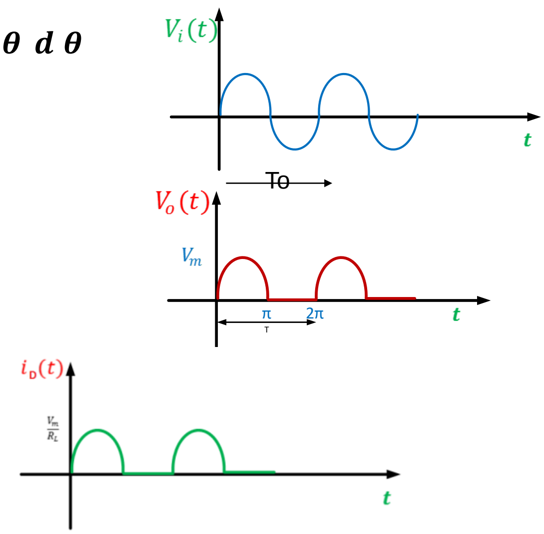


$$\therefore \boldsymbol{V_o(t) = 0}$$
$$\therefore \boldsymbol{V_D(t) = V_i(t)}$$



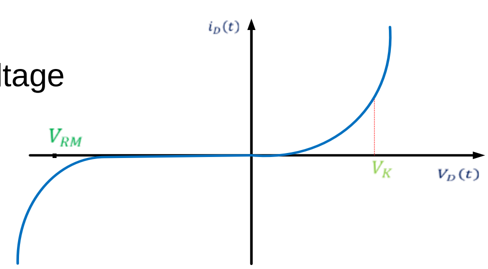
- $V_{o,av} = \frac{1}{T} \int_0^T V_o(t)dt$

  $= \frac{V_m}{2\pi} \int_0^{\pi} \sin\theta \ d\theta$
- $V_{o,av} = \frac{V_m}{\pi}$
- $\mathrm{T} = T_o$
- $f = f_o$
- $i_{D(t),av} = \frac{V_m}{\pi R_L}$



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 ≡ Peak Inverse Voltage
- PIV = V_{RM}



- ∴ **For the have-wave rectifier**

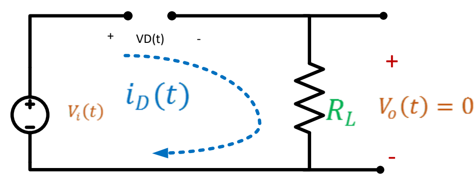
$$V_{o,av} = \frac{V_m}{\pi}$$

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

PIV $= -V_m$ **Prove ????**

To calculate PIV

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



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

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

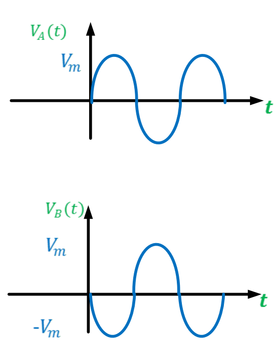
Full-Wave Rectifier

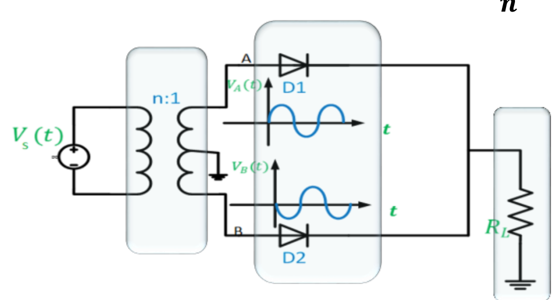
- A) Center-tapped transformer full-wave **Rectifier**
  - $V_A(t)$, $V_B(t)$ have the same amplitude but 180° out of phase

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

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

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





D_1 **and** D_2 **are ideal**

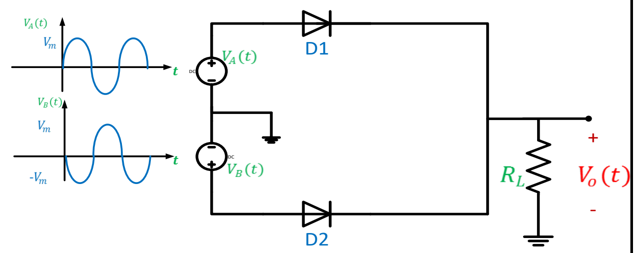
Simplified Circuit

D_1 and D_2 are ideal

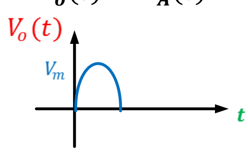
- 1) when $V_s(t) > 0$

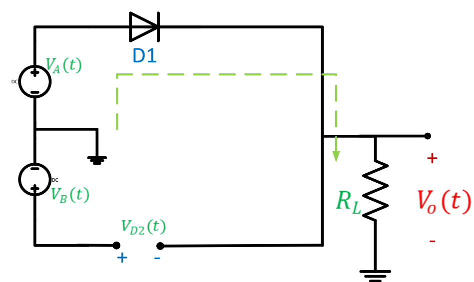
  $V_A(t) > 0$, D_1 is on

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



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



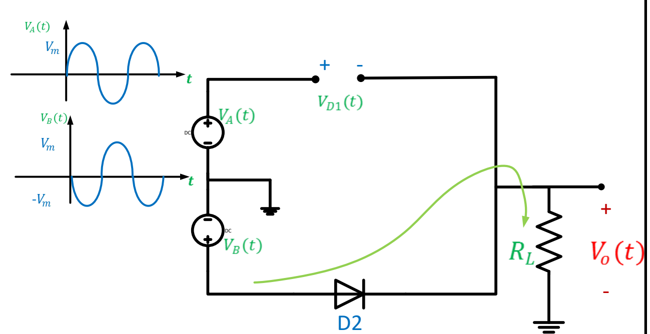


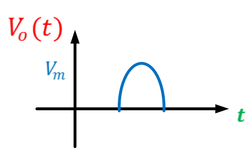
- 2) when $V_s(t) < 0$

  $V_A < 0$; D_1 is off

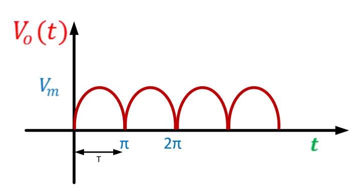
  $V_B > 0$; D_2 is on

- $\therefore V_o(t) = V_B(t) > 0$



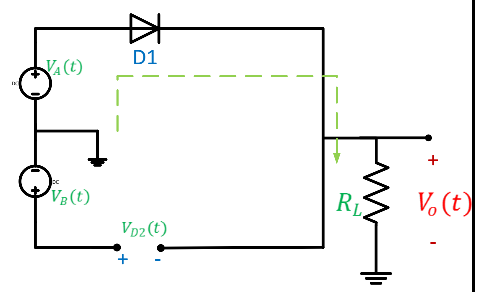


For a complete cycle of $V_s(t)$



To calculate PIV for D2

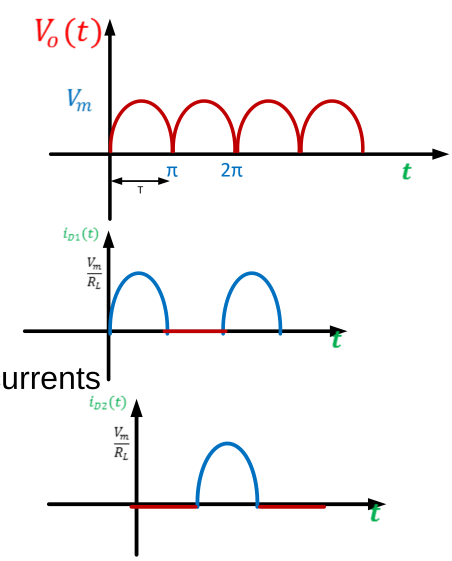
$$V_{D2}(t) = V_B(t) - V_A(t)$$
$$V_{D2}(t)_{,max} = -V_m - V_m$$
$$V_{D2}(t)_{,max} = -2V_m$$
$$\therefore \text{PIV} = -2V_m$$



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

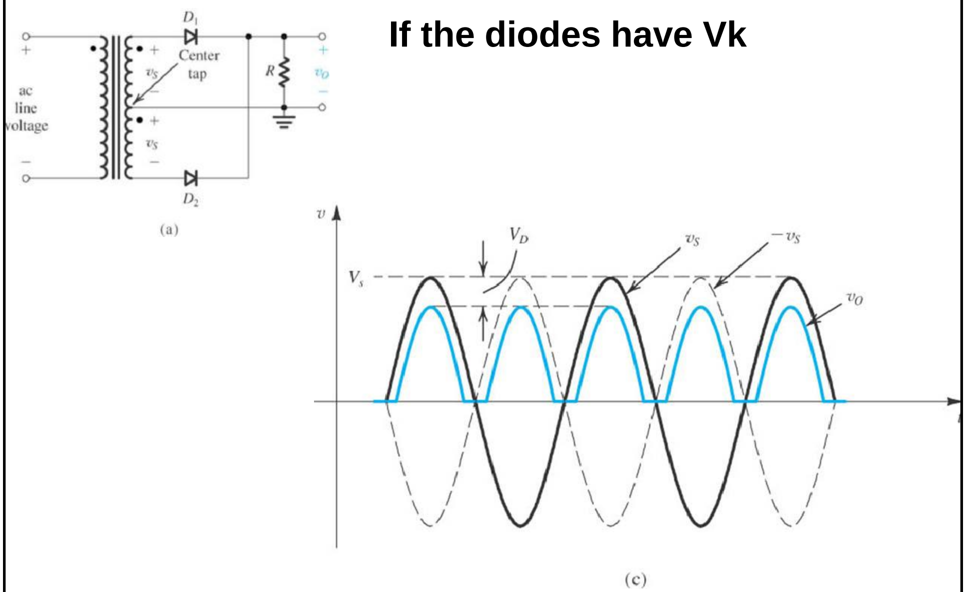
$V_B(t) < 0$, D_2 is off

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



Diodes currents

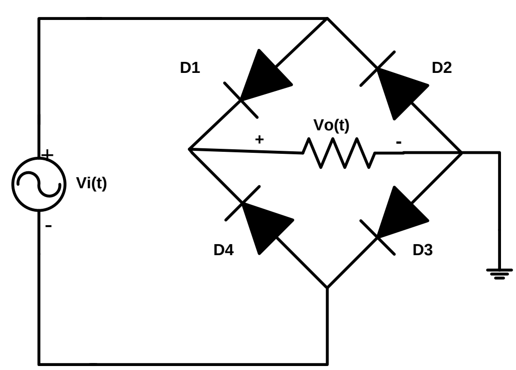
If the diodes have Vk



b) Bridge full-wave rectifier

- Simplified circuit

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



b) Bridge full-wave rectifier

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

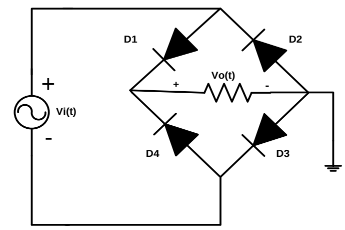
- 1) when $V_s(t) > 0$

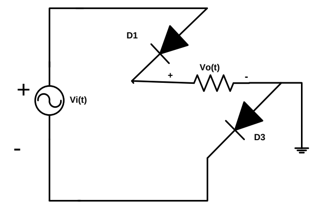
  $\therefore V_i(t) > 0$

  $\therefore$ D_1 and D_3 are on

  $\therefore$ D_2 and D_4 are off

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





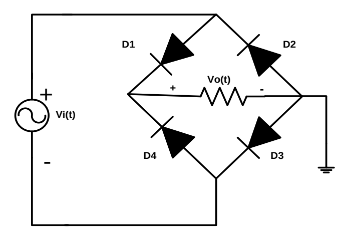
- 2) when $V_s(t) < 0$

  $\therefore V_i(t) < 0$

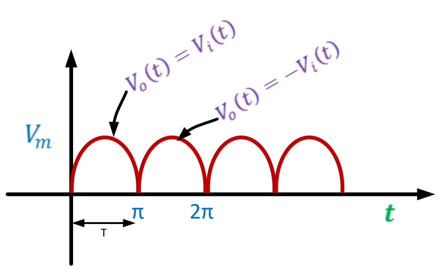
  $\therefore$ D_1 and D_3 are off

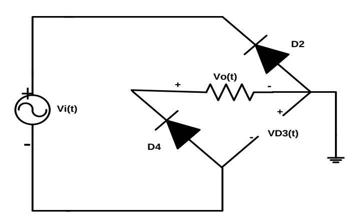
  $\therefore$ D_2 and D_4 are on

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



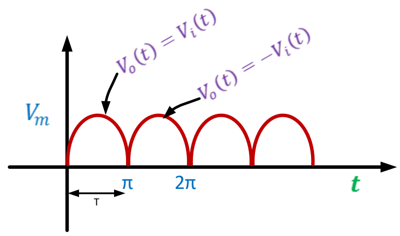
$\therefore$ For the complete cycle of $V_i(t)$

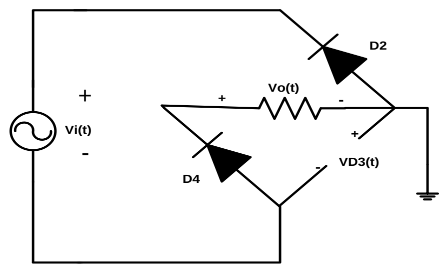




- ∴ **For Bridge full-wave rectifier**
- $V_{o,av} = \frac{1}{T}\int_0^T V_o(t)dt$

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

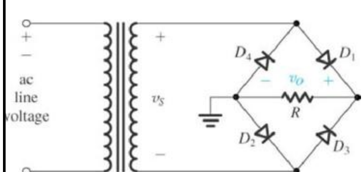




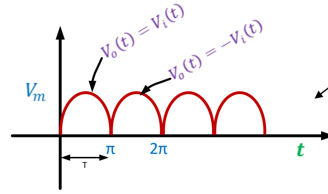
- **To calculate the PIV of the D3**
- $V_i(t) < 0$

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

  ∴ $V_{D3}(t)_{,max} = -V_m$ ∴ **PIV** $= -V_m$

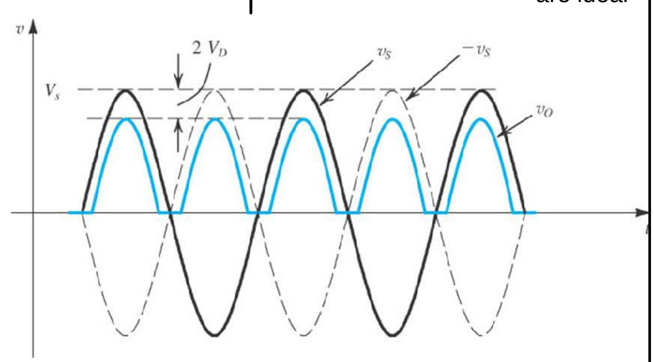


(a)



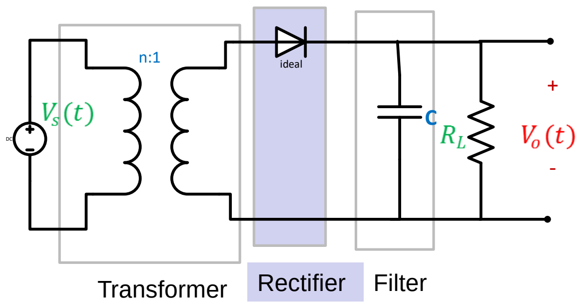
If the Diodes are ideal

If the diodes have Vk

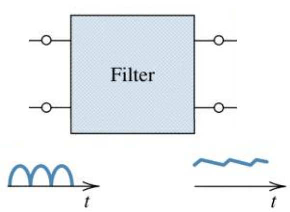


(b)

- 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)**



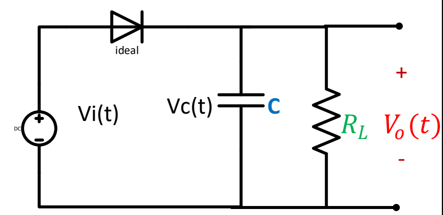
3) Filter

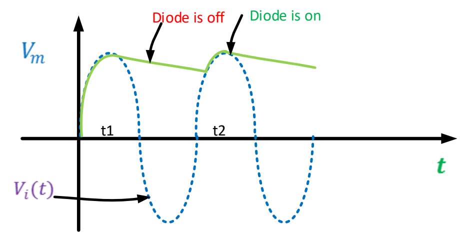


- One of dc power supply components
- Used to smooth out (remove) the pulsating DC produced by the rectifiers and to pass only the DC component (average value; mean value)

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

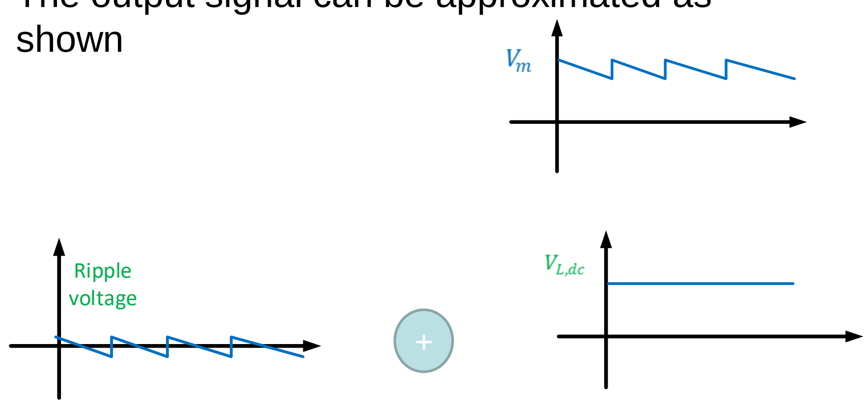




- Ripple factor is an indicator for the effectiveness of the filter

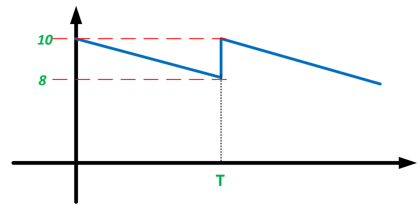
$$r = \frac{RMS(ripple\ of\ output\ \ voltage\ )}{Average\ value\ of\ the\ output\ signal} \times 100\%$$

- The output signal can be approximated as shown



Example

Find average output voltage?



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

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,

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

OR

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

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

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

Ripple Factor

For $t_2 > t > t_1$

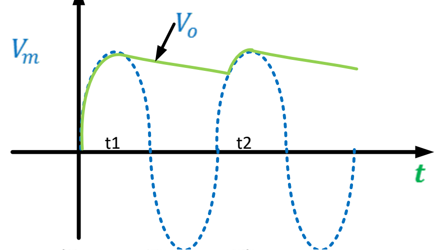
$$V_L(t) = V_m\, e^{\frac{-(t-t_1)}{RC}}$$

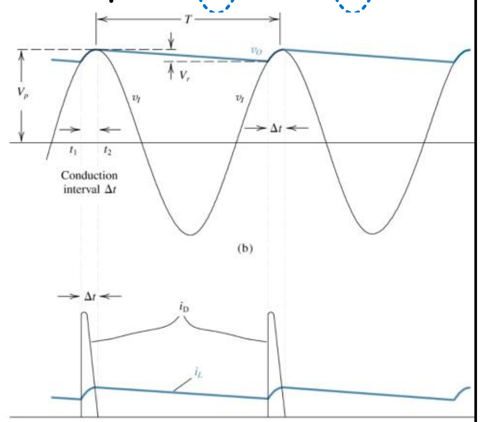
$$V_{Lr,p\text{-}p} = V_L(t_1) - V_L(t_2)$$

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

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

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

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

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

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

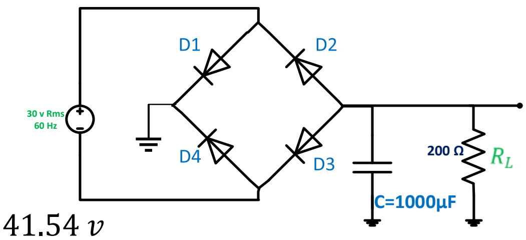
$$\left(V_{L,r}\right)_{RMS} = \frac{V_{Lr,p\text{-}p}}{2\sqrt{3}}$$

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

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

Example

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



- $V_{L,dc} = V_m - \frac{1}{2}\frac{V_m}{2f_oR_Lc} = 41.54\ v$

  $V_{Lr,p-p} = \frac{V_m}{2f_oR_Lc} = 1.7677v$

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

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

  $r = 1.2277\ \%$