EEEE lec 32 1/11/23

Diode application : Rectifier

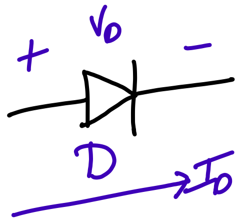
- Half-wave rectifier
- Full-wave center tap rectifier
- Full-wave bridge rectifier

only with 'R' load

+ Filters (Capacitor filter)

1. ckt diagm
2. working
3. I/p-o/p w/fs w.r.t time
4. Analysis:-
   a) $V_{out\,avg}$
   b) $V_{out\,rms}$ { $I_{out\,avg}$, $I_{out\,rms}$ }
   c) Rectificatn eff (η)
   d) Ripple factor (γ)
   e) TUF

Diode basics:-



D. is F.B (ON)

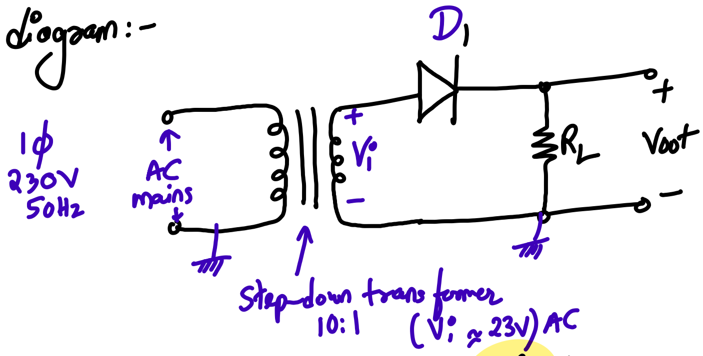
S.C

D is R.B (OFF)

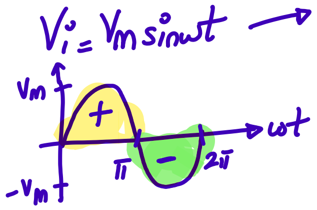
O.C

Half-wave Rectifier with 'R' load:

Circuit diagram :-

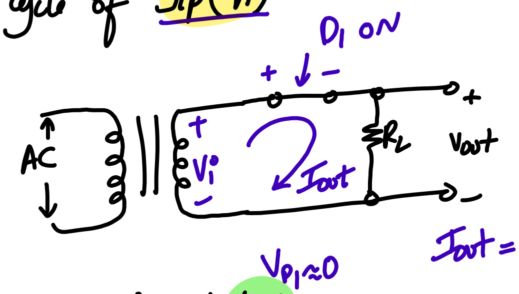


$V_i = V_m \sin\omega t$ → Secondary voltage of transformer



Case ①:- During +ve half cycle of I/p (V_i)

D_1 is F.B i.e ON



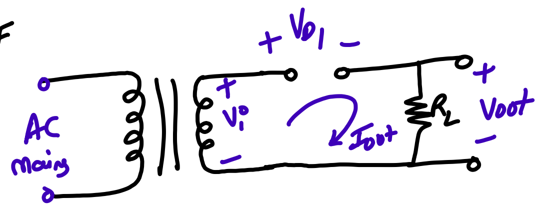
$V_{out} = V_i$

o/p follows I/p voltage

$I_{out} = \frac{V_{out}}{R_L}$

Case ②:- During −ve half cycle of I/p (V_i)

D_1 is R.B i.e OFF



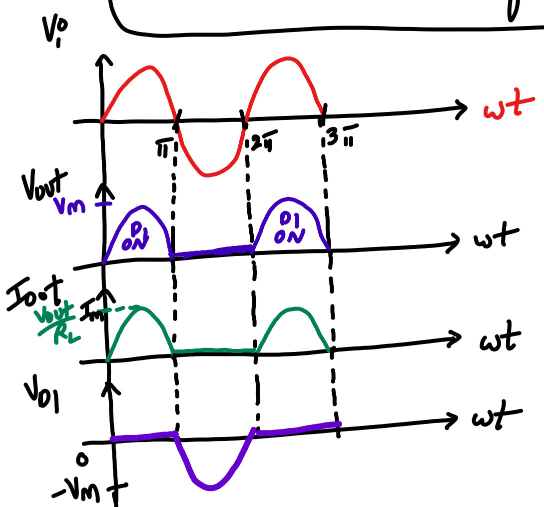
$I_{out} = 0$

$V_{out} = 0$

$V_{D_1} \neq 0$ "PIV rating"

Input-Output w/fs :-

$$\boxed{\begin{aligned} V_{out} &= V_i\ (V_m \sin\omega t) && \text{if } 0 < \omega t < \pi \\ &= 0 && \text{if } \pi < \omega t < 2\pi \end{aligned}} \quad \text{—— ①}$$



HWR I/p & o/p waveforms.

$$\boxed{I_m = \frac{V_m}{R_L}}$$

PIV rating → $-V_m$

Analysis (HWR):

Derive
a) Expression for $V_{out\,avg}$
b) —"— for $V_{out\,rms}$
c) —"— for rectification efficiency (η)
d) —"— for ripple factor (γ)
e) —"— for TUF

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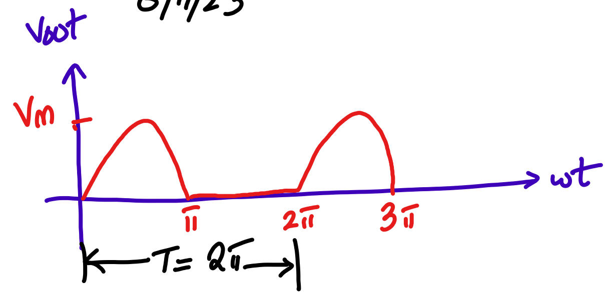


a) $V_{out(avg)} / V_{dc}$:

$$V_{out}(avg) = \frac{1}{T}\int_0^T V_{out}\, d\omega t$$

$$V_{out}(avg) = \frac{1}{2\pi}\int_0^{2\pi} V_{out}\, d\omega t$$

$V_i = V_m \sin\omega t$

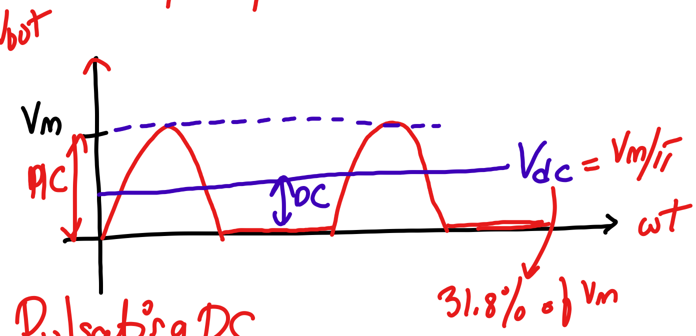
$$V_{out}(avg) = \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\omega t\, d\omega t + \int_{\pi}^{2\pi} 0\, d\omega t\right]$$

$$V_{out}(avg) = \frac{V_m}{2\pi}\Big[-\cos\omega t\Big]_0^{\pi} = -\frac{V_m}{2\pi}\Big[\underbrace{\cos\pi}_{-1} - \underbrace{\cos 0}_{1}\Big]$$

$$V_{out}(avg) = \frac{V_m}{2\pi}(2)$$

$$\boxed{V_{out}(avg) = \frac{V_m}{\pi}}$$

i.e $V_{dc} = 0.318 V_m$



o/p of HWR : Pulsating DC
(AC + DC)

$$I_{out}(avg) = I_{dc} = \frac{V_{out}(avg)}{R_L} = \frac{V_{dc}}{R_L} = \frac{V_m}{\pi R_L}$$

$\boxed{I_{out}(avg) = \frac{I_m}{\pi}}$ where $I_m = \frac{V_m}{R_L}$

b) $V_{out}(rms)$ → RMS value of AC component of o/p

$$V_{out}^2(rms) = \frac{1}{T}\int_0^T V_{out}^2(\omega t)\, d\omega t \quad ; T = 2\pi$$

$V_i = V_m \sin\omega t$

$$V_{out}^2(rms) = \frac{1}{2\pi}\int_0^{2\pi} V_{out}^2(\omega t)\, d\omega t$$

$$V_{out}^2(rms) = \frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2\omega t\, d\omega t = \frac{V_m^2}{2\pi}\int_0^{\pi}\left(1 - \frac{\cos 2\omega t}{2}\right) d\omega t$$

$$V_{out}^2(rms) = \frac{V_m^2}{2\pi}\left[\frac{\omega t}{2} - \frac{\sin 2\omega t}{4}\right]_{\omega t = 0}^{\pi}$$

$$V_{out}^2(rms) = \frac{V_m^2}{2\pi}\left\{\left(\frac{\pi}{2}-0\right) - \frac{\cancel{\sin 2\pi}^{\,0}}{4} - \frac{\cancel{\sin 0}^{\,0}}{4}\right\}$$

$$V_{out}^2(rms) = \frac{V_m^2}{2\pi} \times \frac{\pi}{2} = \frac{V_m^2}{4}$$

$$\boxed{V_{out}(rms) = \frac{V_m}{2}}$$

$$I_{out}(rms) = \frac{I_m}{2}$$

$$I_m = \frac{V_m}{R_L}$$

c) Rectifier efficiency (η): $\rightarrow$ It is the ratio of DC power at the o/p to the applied o/p AC power

$$\%\eta = \frac{P_{DC}}{P_{AC}} \times 100$$

$$P_{DC} = V_{dc} I_{dc} = \frac{V_{dc}^2}{R_L} = I_{dc}^2 R_L$$

$$P_{AC} = V_{out(rms)} I_{out(rms)} = V_{rms} I_{rms} = \frac{V_{rms}^2}{R_L} = I_{rms}^2 R_L$$

$$P_{DC} = \frac{V_{dc}^2}{R_L} = \frac{\left(\frac{V_m}{\pi}\right)^2}{R_L} = \frac{V_m^2}{\pi^2 R_L} \quad -(a)$$

$$P_{AC} = \frac{V_{rms}^2}{R_L} = \frac{\left(\frac{V_m}{2}\right)^2}{R_L} = \frac{V_m^2}{4R_L} \quad -(b)$$

$$\%\eta = \frac{P_{DC}}{P_{AC}} \times 100 = \frac{\frac{\cancel{V_m^2}}{\pi^2 \cancel{R_L}}}{\frac{\cancel{V_m^2}}{4\cancel{R_L}}} \times 100$$

$$\%\eta = \frac{4}{\pi^2} \times 100$$

$$\boxed{\%\eta = 40.56\%}$$ HWR

d) Ripple factor (γ): $\rightarrow$ It is the ratio of rms value of o/p AC component to the DC component of rectifier o/p

$$\gamma = \frac{I_{ac}}{I_{dc}} \qquad I_{ac} = \sqrt{I_{out(rms)}^2 - I_{dc}^2}$$

$$\text{i.e } \frac{I_{ac}}{I_{dc}} = \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}$$

$$\text{i.e } \boxed{\gamma = \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}}$$

For HWR, $I_{rms} = \frac{I_m}{2}$, $I_{dc} = \frac{I_m}{\pi}$

$$\gamma = \sqrt{\frac{\frac{\cancel{I_m^2}}{4}}{\frac{\cancel{I_m^2}}{\pi^2}} - 1} = \sqrt{\frac{\pi^2}{4} - 1}$$

$$\boxed{\gamma = 1.21}_{HWR}$$

—x—