

## DEPARTMENT OF ELECTRONICS &amp; COMMUNICATION ENGINEERING, KITSW

COURSE: U14EI 205 - BASIC ELECTRONICS ENGINEERING | ECE-I, Semester-II, 2015-16

**ASSIGNMENT-3 HINTS & SOLUTIONS**

1. Draw the block diagram of an adapter (also called "Regulated Power Supply") and explain the function of each block.

*Refer to class notes for details...*

*If asked as a short answer question...*

- Draw the block diagram (*Refer to class notes*)
- Starting from an AC supply, the adapter
  - will be using a step down transformer to bring it to the desired level of AC voltage
  - then rectifier circuit to rectify the AC into pulsating unipolar voltage; (*mention ripple factors of HWR and FWR*)
  - then there will be filtering circuit to smoothen out the pulsating DC voltage which we get after rectification; (*mention C,L,LC and CLC filters*)
  - then a voltage regulator circuit will be there to finally keep it at a constant voltage level. (*Mention Zener voltage regulator circuit*)

*If asked in long answer type questions, you need to elaborate on each of the blocks*

### Rectifier

- Rectifier: Rectifier is a circuit that converts AC voltage into DC voltage
  - DC is a constant voltage signal.
  - Diode rectifiers convert the AC into unidirectional pulsating signal (*not pure DC*)
- Types of rectifiers: HWR, FWR
  - Draw HWR circuit and sketch the input - output waveforms
  - Say what happens during positive half cycle of the input and during negative half cycle of the input.
  - Mention that the output of HWR has high ripple 121%. This is undesirable. Hence there is need for FWR
  - Draw Centre-tapped FWR circuit and sketch the input - output waveforms
  - Say what happens during positive half cycle of the input and during negative half cycle of the input.
  - Mention here that the ripple in the output of full-wave rectified signal is 48.2%. Considerable improvement in the ripple.

Filter:

Filter reduces the ripple content to produce almost DC

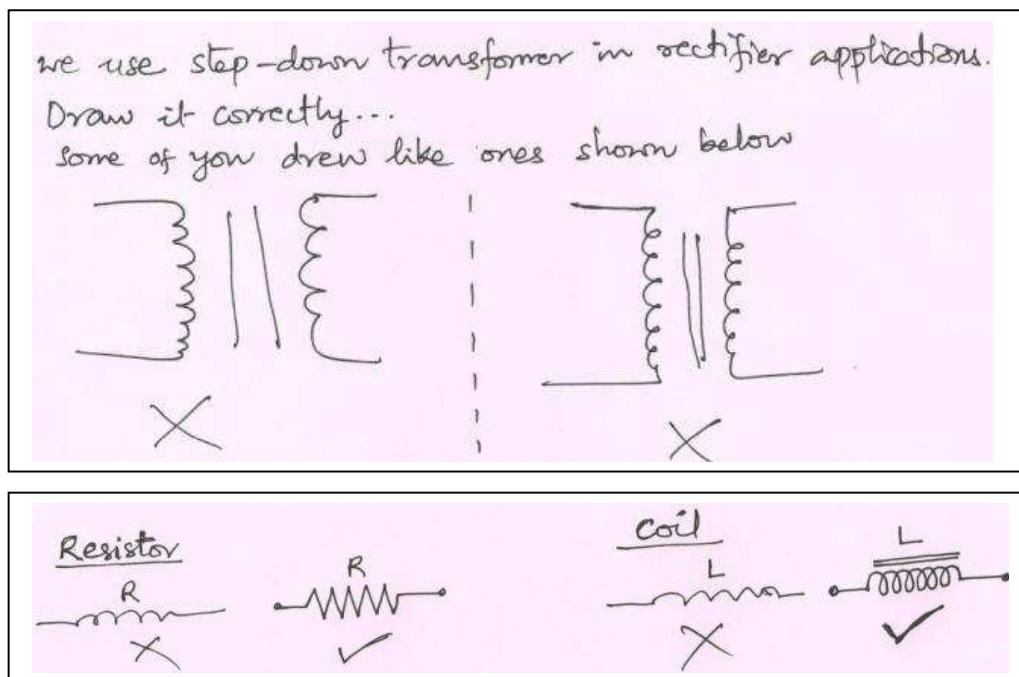
- Filters are basically made up of C or L or combination of L & C
- Types of filters:
  - Shunt capacitor filter (draw the circuit & also mention expression for the ripple factor)
  - Series inductor filter (draw the circuit & also mention expression for the ripple factor)
  - LC filter (draw the circuit & also mention expression for the ripple factor)
  - CLC filter (draw the circuit & also mention expression for the ripple factor)

Voltage Regulator:

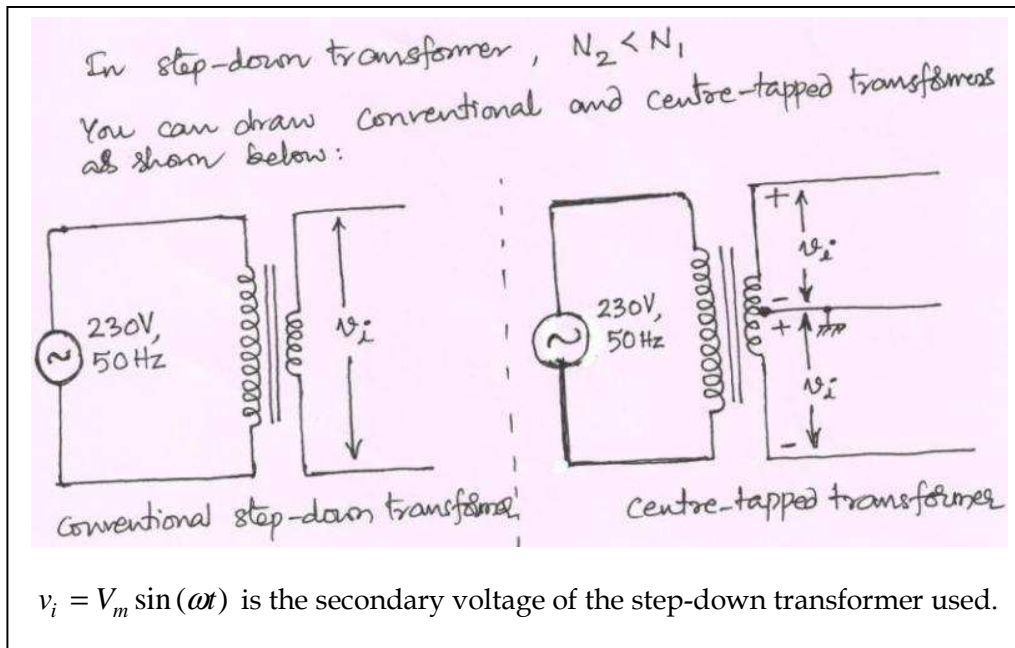
- Voltage regulator gives a constant ( DC) output
- Zener diode is used as voltage regulator.
- Draw the circuit diagram of voltage regulator circuit : It provides both line and load regulation.

**2. Draw the circuit diagram and explain the working of Half Wave Rectifier (HWR).**

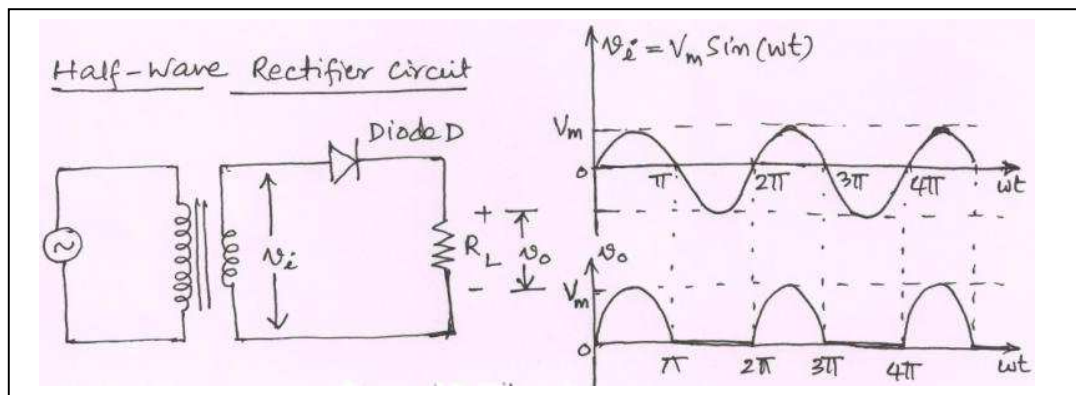
[You are expected to cover: (i) Ckt diagram of HWR, (ii) Ckts showing current conduction path through Load during +ve and -ve half cycles of  $v_i$  (iii) Input  $v_i$  and Output voltage  $v_o$  waveforms, (iv) derive  $V_{dc}$  and  $v_{rms}$ , (v) calculate ripple factor (vi) calculate rectification efficiency, (vii) comment on PIV]



Draw the circuit diagram carefully ...



The circuit diagram of half-wave rectifier is shown below



- Rectifier: Rectifier is a circuit that converts AC voltage into DC voltage
  - DC is a constant voltage signal.
  - Diode rectifiers convert the AC into unidirectional pulsating signal (*not pure DC*)

Assume ideal diode

- Cut-in voltage=0 Volts
- When forward biased: Acts as short circuit
- When reverse biased: Acts as open circuit

During positive half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D is forward biased and acts as a short.
- Hence a current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_o$

During negative half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D is reverse biased and acts as open.
- Hence practically no current flows through the load  $R_L$  and no voltage across the load.
- The output of HWR is not a perfect DC, but at least unidirectional.
- For HWR, the typical parameters are:

- $V_{dc} = \frac{V_m}{\pi}$

- $V_{rms} = \frac{V_m}{2}$

- $Ripple\ factor = r = \frac{v_{r,rms}}{V_{dc}} = \sqrt{\left(\frac{v_{rms}}{V_{dc}}\right)^2} - 1 = 1.21$

- The output of HWR has high ripple 121%. The ripple content exceeds the DC content. This is undesirable. Hence there is need for FWR
- *Rectification efficiency:*

$$\text{Rectification efficiency } \eta = \frac{\text{Power delivered to the load}}{\text{Total input AC power}} = \frac{P_{dc}}{P_{ac}}$$

- *The rectification efficiency of a HWR = 40.6 %*  
*Under best conditions, only 40.6 % of the input power is converted into DC power. The rest 59.4% % remains as AC power in the load. This is highly undesired*
- **PIV:** *The peak inverse voltage is the maximum reverse voltage the diode should withstand without breakdown.*

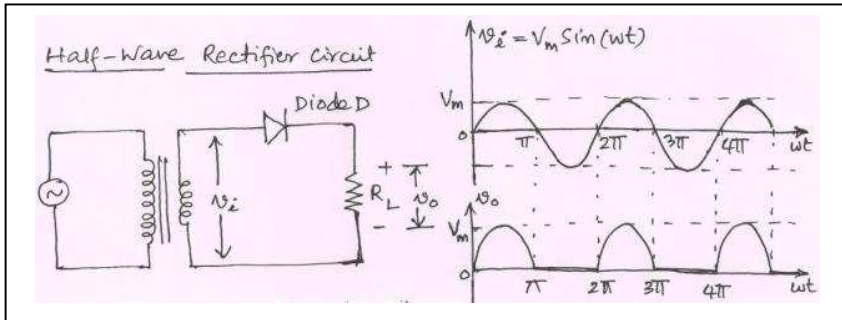
In HWR, when the diode D is reverse biased, the maximum voltage across it would be  $V_m$

- *In HWR, the PIV of the diode should be  $V_m$*

**Note:** *If asked as long answer question, you need to derive values of  $V_{dc}$ ,  $v_{rms}$  ripple factor rectification efficiency and PIV*

**3. Derive expressions for ripple factor ( $r$ ), rectification efficiency ( $\eta$ ) of HWR and PIV of the diodes to be used.**

Draw Ckt diagram of HWR, and Input  $v_i$  and Output voltage  $v_o$  waveforms,



Explain working principle:

- Rectifier: Rectifier is a circuit that converts AC voltage into DC voltage
  - DC is a constant voltage signal.
  - Diode rectifiers convert the AC into unidirectional pulsating signal (*not pure DC*)

Assume ideal diode

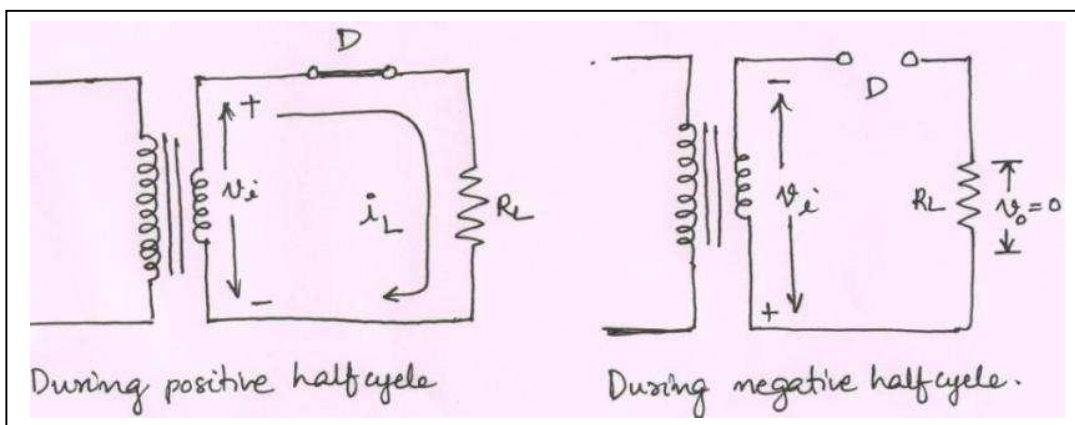
- Cut-in voltage=0 Volts
- When forward biased: Acts as short circuit
- When reverse biased: Acts as open circuit

During positive half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D is forward biased and acts as a short.
- Hence a current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_o$

During negative half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D is reverse biased and acts as open.
- Hence practically no current flows through the load  $R_L$  and no voltage across the load.



- show that  $V_{dc} = \frac{V_m}{\pi}$  (refer to class notes)
- Show that  $V_{rms} = \frac{V_m}{2}$  (refer to class notes)
- Show that Ripple factor =  $r = \frac{v_{r,rms}}{V_{dc}} = \sqrt{\left(\frac{v_{rms}}{V_{dc}}\right)^2} - 1 = 1.21$  (refer to class notes)

- The output of HWR has high ripple 121%. The ripple content exceeds the DC content. This is undesirable. Hence there is need for FWR

- Rectification efficiency:

$$\text{Rectification efficiency } \eta = \frac{\text{Power delivered to the load}}{\text{Total input AC power}} = \frac{P_{dc}}{P_{ac}}$$

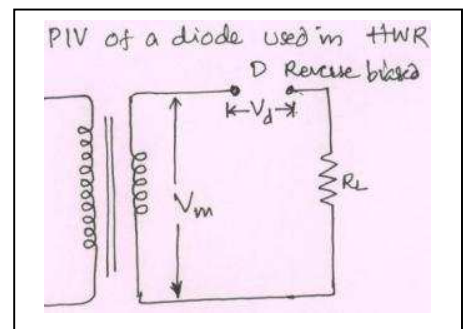
- Show that the rectification efficiency of a HWR = 40.6% (refer to class notes)
  - Under best conditions, only 40.6% of the input power is converted into DC power. The rest 59.4% remains as AC power in the load. This is highly undesired

- PIV: The peak inverse voltage is the maximum reverse voltage the diode should withstand without breakdown.

- In HWR, when the diode D is reverse biased, the maximum reverse voltage across it would be  $V_m$

In HWR, the diode must withstand  $V_m$  voltage, when it is reverse biased

- In HWR, the PIV of the diode  $V_d = V_m$



4. The primary to secondary turns ratio of a transformer used in a HWR is 20:1. If the primary is connected to the power mains: 220V, 50Hz, calculate D.C voltage across the 1KΩ load resistor. Also find the diode current. [Ans: 4.95V, 4.95mA]

④ Calculate DC voltage across 1KΩ resistor and the diode current.

$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

$$\frac{220}{E_2} = \frac{20}{1} \Rightarrow E_2 = 11 \text{ V (rms)}$$

∴ Secondary rms voltage = 11V.

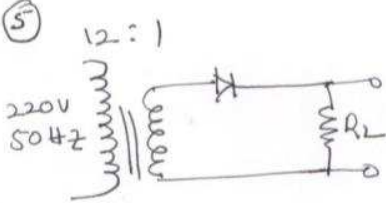
$$V_m = \sqrt{2} \times 11 = 15.556 \text{ V}$$

$$V_{dc} = \frac{V_m}{\pi} = \frac{15.556}{\pi} = 4.95 \text{ V}$$

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{4.95}{1K\Omega} = 4.95 \text{ mA (Diode current)}$$

5. The primary to secondary turns ratio of a transformer used in a HWR is 12:1. The primary is connected to the power mains: 220V, 50Hz. Assuming the diode resistance in forward bias to be zero, calculate the D.C voltage across the load resistor. What is the PIV of the diode? [Ans:  $V_{dc}=8.24V$ ,  $PIV=25.9V$ ]

⑤ 12:1



Calculate of p D.C voltage and PIV of the diode.

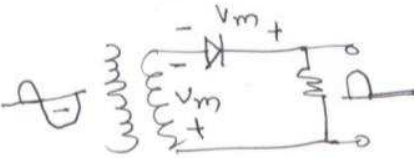
$$\frac{220}{E_2} = \frac{12}{1} \Rightarrow E_2 = \frac{220}{12}$$

$$E_2 = 18.33 \text{ V (rms)}$$

$$V_m = \sqrt{2} \times 18.33 = 25.92 \text{ V}$$

$$V_{dc} = \frac{V_m}{\pi} = \frac{25.92}{\pi} = 8.25 \text{ V}$$

PIV of diode in HWR is  $V_m$ . PIV is the maximum voltage which appears across the diode in reverse bias.



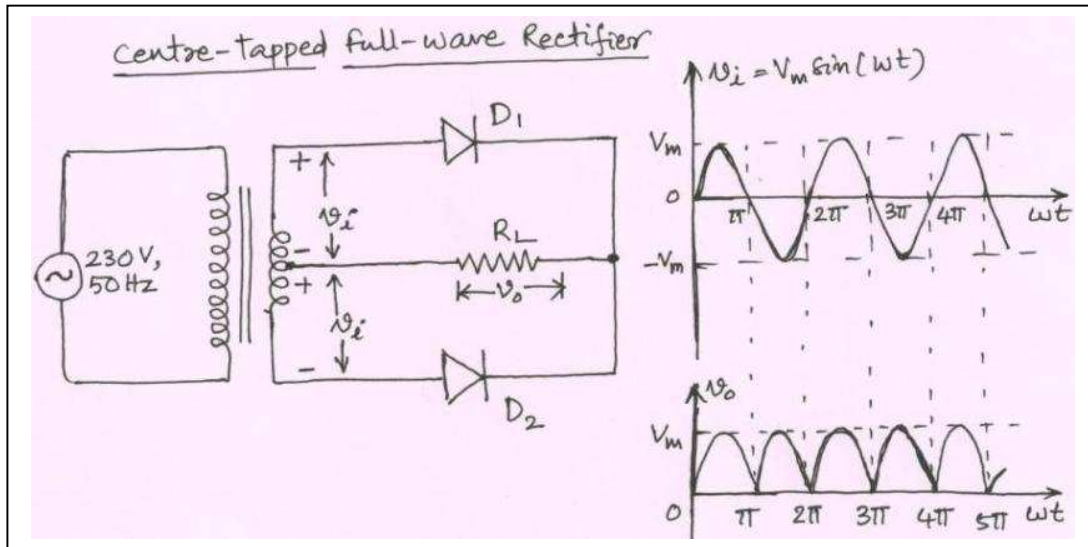
The diode is in reverse bias during negative half cycle. During -ve half cycle the maximum secondary voltage is  $V_m$  and the output voltage is zero, therefore the maximum voltage which appears across the diode is  $V_m = 25.92 \text{ V}$

6. With the help of a neat circuit diagram explain the working principle of a centre tapped Full Wave Rectifier.

[You are expected to cover: (i) Ckt diagram of FWR, (ii) Ckts showing current conduction path through Load during +ve and -ve half cycles of  $v_i$  (iii) Input  $v_i$  and Output voltage  $v_o$  waveforms, (iv) derive  $V_{dc}$  and  $v_{rms}$  (v) compute ripple factor (vi) calculate rectification efficiency (vii) comment on PIV]

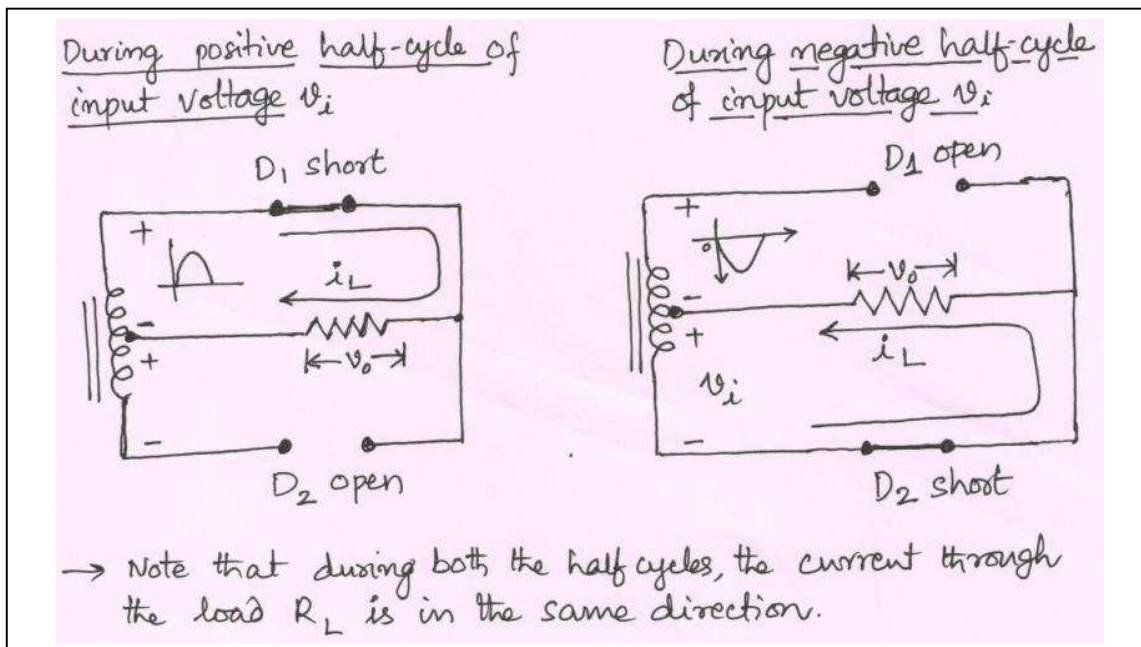
- Rectifier: Rectifier is a circuit that converts AC voltage into DC voltage
  - DC is a constant voltage signal.
  - Diode rectifiers convert the AC into unidirectional pulsating signal (not pure DC)

The centre-tapped full-wave rectifier is shown below:



Assume ideal diodes

- Cut-in voltage=0 Volts
- When forward biased: Acts as short circuit
- When reverse biased: Acts as open circuit



During positive half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D1 is forward biased and acts as a short.
- So, the current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_o$
- The diode D2 is reverse biased and acts as open.



During negative half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D1 is reverse biased and acts as open.
- The diode D2 is forward biased and acts as a short.
- So, the current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_o$

• show that  $V_{dc} = \frac{2V_m}{\pi}$  (refer to class notes)

• Show that  $V_{rms} = \frac{V_m}{\sqrt{2}}$  (refer to class notes)

• Show that Ripple factor =  $r = \frac{v_{r,rms}}{V_{dc}} = \sqrt{\left(\frac{v_{rms}}{V_{dc}}\right)^2} - 1 = 0.482$  (refer to class notes)

- The output of FWR has a ripple of 48.2%. The ripple content, though very much less than ripple of HWR, is undesired. This ripple can be removed/suppressed with the help of filters.

• Rectification efficiency:

$$\text{Rectification efficiency } \eta = \frac{\text{Power delivered to the load}}{\text{Total input AC power}} = \frac{P_{dc}}{P_{ac}}$$

• Show that the rectification efficiency of a FWR = 81.2 % (refer to class notes)

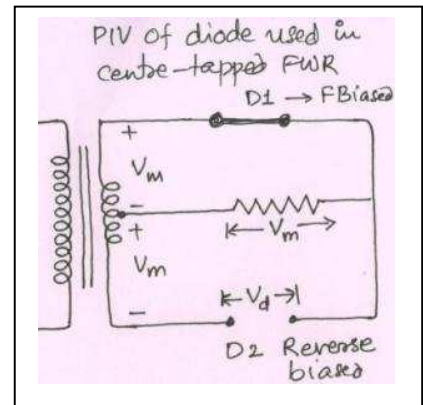
- Under best conditions, 81.2 % of the input power is converted into DC power. The rest 18.8 % remains as AC power in the load.

• **PIV:** The peak inverse voltage (PIV) is the maximum reverse voltage the diode should withstand without breakdown.

- In centre-tapped FWR, during positive half cycle of input, D2 will be reverse biased
- Considering the lower loop, voltage across D2 is  $V_d = V_m + V_m = 2V_m$

In CT-FWR, the diode must withstand  $2V_m$  voltage when it is reverse biased

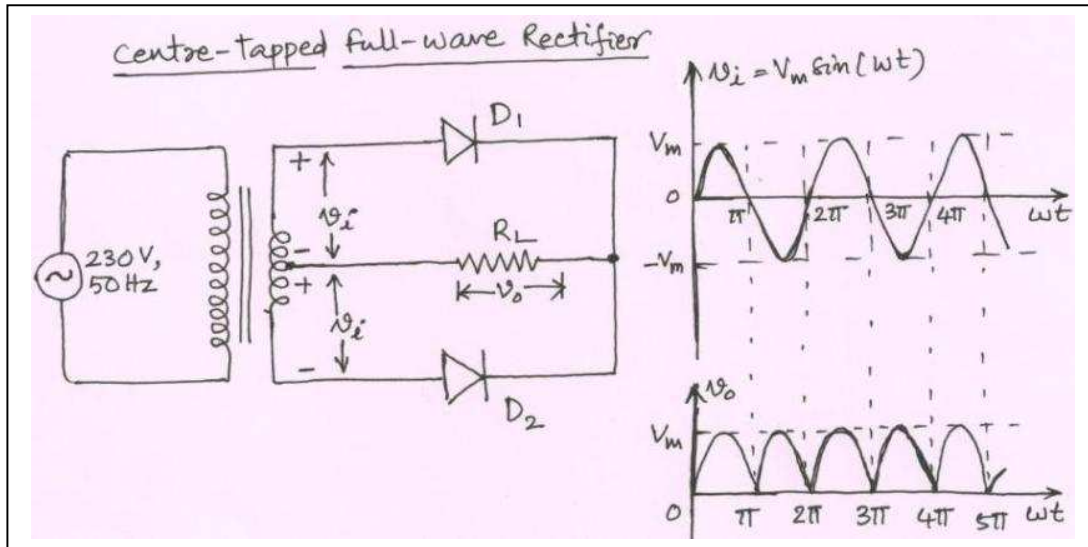
- PIV of diodes in CT-FWR =  $2V_m$



**7. Derive expressions for ripple factor ( $r$ ), rectification efficiency ( $\eta$ ) of a Full Wave Rectifier (FWR) and the PIV of the diodes to be used.**

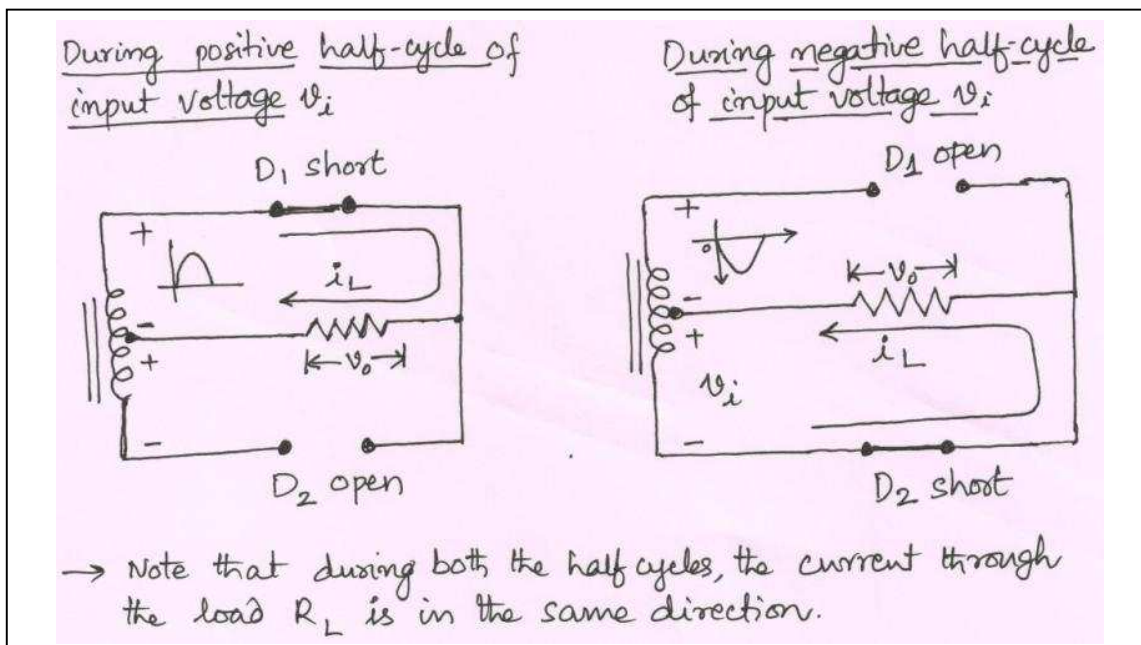
- Rectifier: Rectifier is a circuit that converts AC voltage into DC voltage
  - DC is a constant voltage signal.
  - Diode rectifiers convert the AC into unidirectional pulsating signal (not pure DC)

The centre-tapped full-wave rectifier is shown below:



Assume ideal diodes

- Cut-in voltage=0 Volts
- When forward biased: Acts as short circuit
- When reverse biased: Acts as open circuit



During positive half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D1 is forward biased and acts as a short.
- So, the current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_0$

- The diode D2 is reverse biased and acts as open.

During negative half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diode D1 is reverse biased and acts as open.
- The diode D2 is forward biased and acts as a short.
- So, the current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_o$

• show that  $V_{dc} = \frac{2V_m}{\pi}$  (refer to class notes)

• Show that  $V_{rms} = \frac{V_m}{\sqrt{2}}$  (refer to class notes)

• Show that Ripple factor =  $r = \frac{v_{r,rms}}{V_{dc}} = \sqrt{\left(\frac{v_{rms}}{V_{dc}}\right)^2} - 1 = 0.482$  (refer to class notes)

- The output of FWR has a ripple of 48.2%. The ripple content, though very much less than ripple of HWR, is undesired. This ripple can be removed/suppressed with the help of filters.

• Rectification efficiency:

$$\text{Rectification efficiency } \eta = \frac{\text{Power delivered to the load}}{\text{Total input AC power}} = \frac{P_{dc}}{P_{ac}}$$

• Show that the rectification efficiency of a FWR = 81.2 % (refer to class notes)

- Under best conditions, 81.2 % of the input power is converted into DC power. The rest 18.8 % remains as AC power in the load.

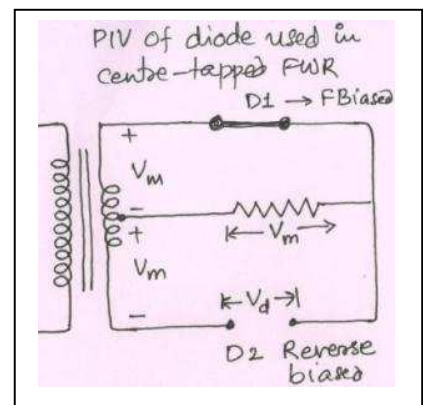
**PIV:** The peak inverse voltage (PIV) is the maximum reverse voltage the diode should withstand without breakdown.

- In centre-tapped FWR, during positive half cycle of input, D2 will be reverse biased.
- Considering the lower loop, voltage across D2 is

$$V_d = V_m + V_m = 2V_m$$

In CT-FWR, the diode must withstand  $2V_m$  voltage, when it is reverse biased.

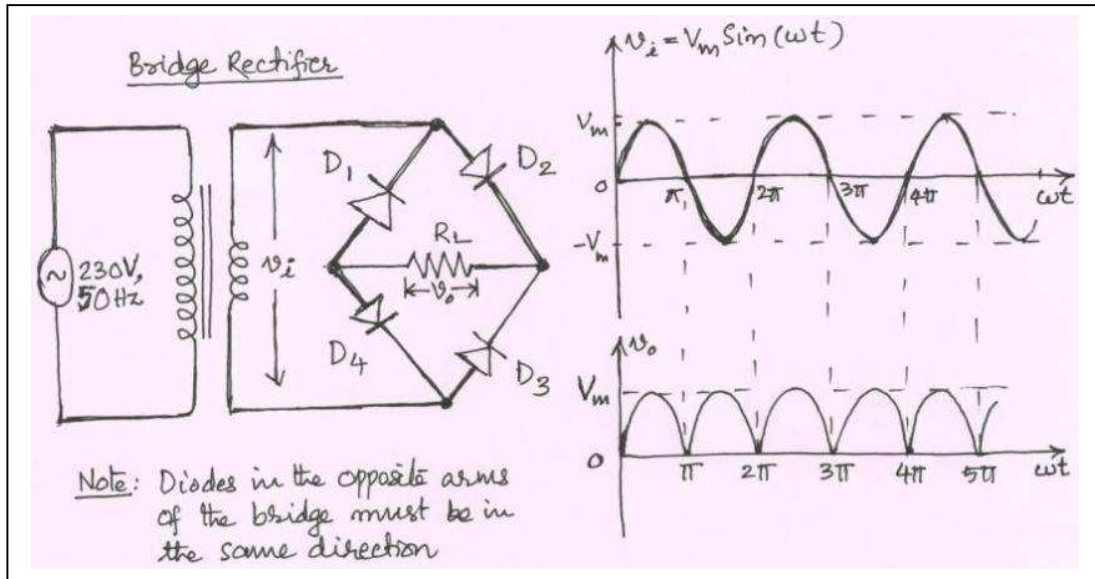
- PIV of diodes in CT-FWR =  $2V_m$



**8. With the help of a neat circuit diagram explain the operation of a Bridge Rectifier. Also define PIV and find PIV for HWR, Center tapped FWR and Bridge Rectifier.**

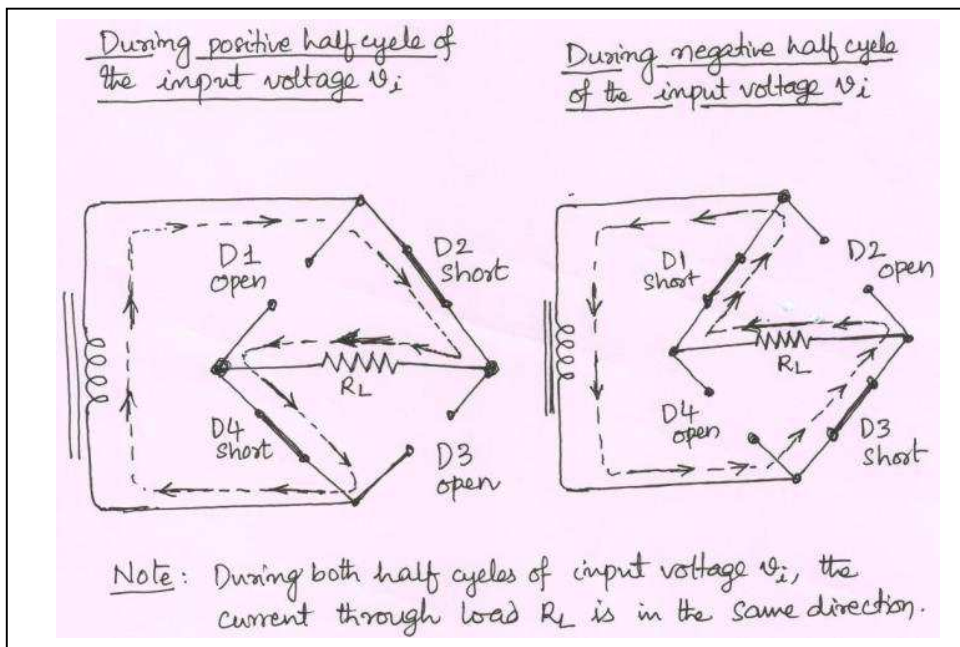
- Rectifier: Rectifier is a circuit that converts AC voltage into DC voltage
  - DC is a constant voltage signal.
  - Diode rectifiers convert the AC into unidirectional pulsating signal (not pure DC)

The bridge full-wave rectifier is shown below:



Assume ideal diodes

- Cut-in voltage=0 Volts
- When forward biased: Acts as short circuit
- When reverse biased: Acts as open circuit



During positive half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diodes D2 & D4 are forward biased and act as shorts.
- So, the current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_o$
- The diodes D1 & D3 are reverse biased and act as open ckts.

During negative half cycle of the input signal  $v_i = V_m \sin(\omega t)$

- The diodes D3 & D1 are forward biased and act as shorts.
- So, the current  $i_L$  flows through the load  $R_L$  and produces load voltage  $v_0$
- The diodes D4 & D2 are reverse biased and act as open ckt.

• show that  $V_{dc} = \frac{2V_m}{\pi}$  (refer to class notes)

• Show that  $V_{rms} = \frac{V_m}{\sqrt{2}}$  (refer to class notes)

• Show that Ripple factor =  $r = \frac{v_{r,rms}}{V_{dc}} = \sqrt{\left(\frac{v_{rms}}{V_{dc}}\right)^2} - 1 = 0.482$  (refer to class notes)

- The output of FWR has a ripple of 48.2%. The ripple content, though very much less than ripple of HWR, is undesired. This ripple can be removed/suppressed with the help of filters.

• Rectification efficiency:

$$\text{Rectification efficiency } \eta = \frac{\text{Power delivered to the load}}{\text{Total input AC power}} = \frac{P_{dc}}{P_{ac}}$$

• Show that the rectification efficiency of a FWR = 81.2 % (refer to class notes)

- Under best conditions, 81.2 % of the input power is converted into DC power. The rest 18.8 % remains as AC power in the load.

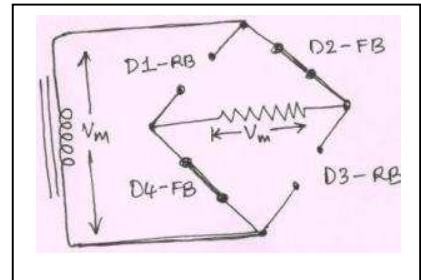
• PIV: The peak inverse voltage (PIV) is the maximum reverse voltage the diode should withstand without breakdown.

- In bridge FWR, during positive half cycle of input, D1 & D3 will be reverse biased
- Considering the upper triangular loop in the bridge, voltage across D1 is

$$V_d = V_m$$

- Considering the lower triangular loop in the bridge, voltage across D3 is

$$V_d = V_m$$



In bridge-FWR, the diodes must withstand  $V_m$  voltage, when they are reverse biased.

- PIV of diodes in bridge-FWR =  $V_m$

9. Compare the performance of HWR, Center-tapped FWR and Bridge Rectifier. Mention the advantages and disadvantages of Center-tapped FWR and Bridge rectifiers

[You are expected to compare them based on parameters (i) Number of diodes required, (ii)  $V_{ac}$ , (iii)  $v_{rms}$ , (iv) ripple factor, (v) max.rectification efficiency, (vi) PIV of diodes, (vii) ripple frequency and (viii) other parameters, if any ]

If asked in short answer type questions...

Let  $v_i = V_m \sin(\omega t)$  be the secondary voltage of the step-down transformer used.

Where  $V_m$  is peak secondary voltage,

$\omega = 2\pi f$  and  $f$  is the line frequency (50 Hz)

$R_L$  is the load resistor ;  $R_f$  is the diode forward resistance

Parameter	Half-wave rectifier	Full-wave rectifier (FWR)	
		Centre-tap FWR	Bridge FWR
Number of diodes	1	2	4
DC voltage	$V_m / \pi$	$2V_m / \pi$	$2V_m / \pi$
RMS voltage	$V_m / 2$	$V_m / \sqrt{2}$	$V_m / \sqrt{2}$
Ripple factor	1.21	0.482	0.482
Rectification efficiency(Max)	40.6%	81.2%	81.2%
Peak load current ( $I_m$ )	$V_m / (R_f + R_L)$	$V_m / (R_f + R_L)$	$V_m / (2R_f + R_L)$
PIV of diodes to be used	$V_m$	$2V_m$	$V_m$
Lowest ripple frequency	$f$	$2f$	$2f$

If asked in long answer type questions, you need to add following details before that table showing the comparison

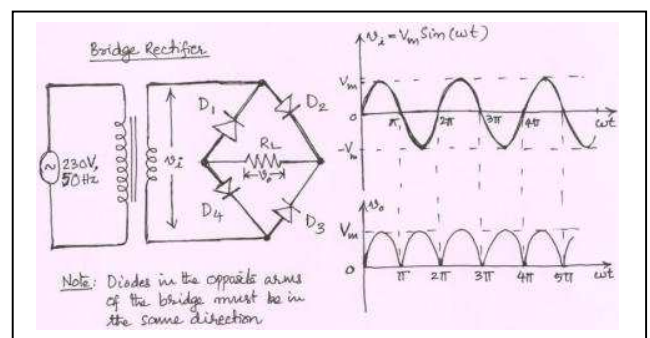
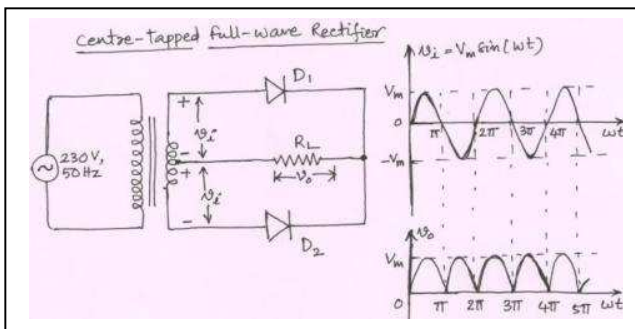
- Define rectifier:
- Mention types of rectifiers: (HWR, FWR)
- **Draw HWR circuit** and sketch the input - output waveforms
  - Say what happens during positive half cycle of the input and during negative half cycle of the input.
  - Mention that the output of HWR has high ripple 121%. This is undesirable. Hence HWR is not much of practical use.
- **Draw Centre-tapped FWR circuit** and sketch the input - output waveforms
  - Say what happens during positive half cycle of the input and during negative half cycle of the input.
  - Mention here that the ripple in the output of full-wave rectified signal is 48.2%. Considerable improvement in the ripple.

- Draw Bridge rectifier circuit and sketch the input - output waveforms
  - Say what happens during positive half cycle of the input and during negative half cycle of the input.

**The advantages and disadvantages of Center-tapped FWR and Bridge rectifiers**

- Rectifier: Rectifier is a circuit that converts AC voltage into DC voltage
  - DC is a constant voltage signal.
  - Diode rectifiers convert the AC into unidirectional pulsating signal (*not pure DC*)
- Rectifiers are of two types
  - Half-wave rectifiers,
  - Full-wave rectifiers
- Full-wave rectifiers are implanted in two forms
  - Centre-tapped full-wave rectifier
  - Bridge rectifier

The circuits and input-output waveforms are shown below:



- Bridge rectifier is most widely used full-wave rectifier
- It has many advantages over centre-tapped full-wave rectifier (FWR)

**Advantages of Bridge Rectifiers**

- It does not require centre-tapped transformer
- Peak inverse voltage (PIV) of the diode to be used = Peak secondary voltage  $V_m$
- Whereas the PIV of diode to be used with CT-FWR is  $2V_m$ 
  - So, when higher DC voltages are required, the diode used must withstand high voltage when reverse biased.
  - Hence, CT-FWR are not used for high voltage applications
  - The diodes meant for CT-FWR are costlier than those meant for bridge rectifier
- Bridge rectifiers are preferred over CT-FWR for high voltage applications

Disadvantages of Bridge Rectifiers

- The main disadvantage is that it requires four (4) diodes, two of which conduct during alternate half cycles
  - This poses a problem when low DC voltages are required.
  - Practically, two diodes will take almost 1.4 Volts from the secondary voltage, if Si diodes are employed (Cut-in voltage of Si diode = 0.7 V) for their operation/conduction.
- For this reason, bridge rectifiers are not used for low-voltage applications

Advantages of centre-tapped Rectifiers

- Only one diode will be in conduction mode during each half cycle of the input voltage
- So it takes only one diode drop of 0.7 V.
- This drop can be further reduced by using Ge diode instead of Si diode. Ge diode takes only 0.3V for its conduction.
- Centre-tapped FWR are used for low voltage applications.

10. The turns ratio of a transformer used in a Bridge Rectifier is 12:1. The primary is connected to the power mains: 220V, 50Hz. Assuming the diode voltage drops to be zero, (a) calculate the D.C voltage across the load resistor. (b) What is the PIV of the diode? If the same dc voltage is obtained by using Center tapped FWR, what is PIV?  
[Ans: (a)16.48V (b)25.9V (c)51.8V]

③

⑭ Bridge Rectifier

Transformer Turns ratio = 12:1

Primary voltage = 220V rms

DC output voltage  $V_{DC} = \frac{2V_m}{\pi}$

Secondary voltage =  $\frac{220}{12} = 18.33V$

$V_m = 18.33\sqrt{2} = 25.92V$

(a) DC output voltage  $V_{DC} = \frac{2V_m}{\pi} = \frac{2 \times 25.92}{\pi} = 16.5V$

(b) PIV for Bridge Rectifier <sup>diodes</sup> is  $V_m = 25.9V$

(c) PIV for Center Tapped FWR is  $2V_m = 25.9 \times 2 = 51.8V$ .