UNIT 2

SIA GROUP

PART-A
SHORT QUESTIONS WITH SOLUTIONS

Q1. What is a rectifier? List different types of rectifiers.

Ans:

Rectifier is a circuit made up of one or more diodes. It converts alternating supply into pulsating DC.

Different types of rectifiers are available for converting AC supply into pulsating DC. They are,

1. Half wave rectifier
2. Full wave rectifier
3. Bridge rectifier.

Q2. Define the following terms,

(a) Peak inverse voltage of a diode

(b) Transformer utility factor.

(Model Paper-1, Q3 | July-16, Q3)

Ans:

(a) Peak Inverse Voltage

The maximum reverse bias voltage that the diode can withstand without entering into the breakdown region is known as peak inverse voltage. PIV is maximum voltage that occurs during a part of the cycle when the diode is non-conducting.

(b) Transformer Utility Factor

TUF of a rectifier circuit is defined as the ratio of D.C power delivered to the load to the A.C power rating of transformer. The expression for Transformer Utilization Factor (TUF) in bridge rectifier is given by,

$$TUF = \frac{P_{d.c}}{P_{a.c(\text{Rated})}}$$

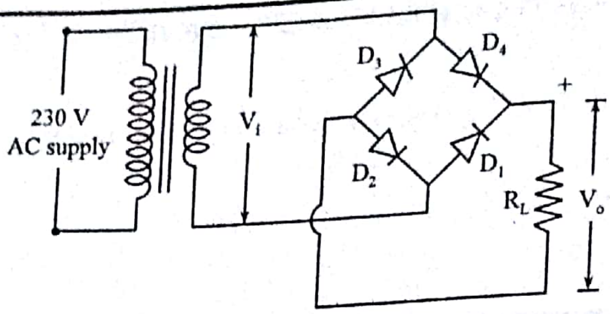
Where, $P_{d.c}$ – D.C power delivered to load

$P_{a.c(\text{Rated})}$ – A.C rating of secondary of transformer.

Q3. Draw the circuit of full-wave bridge rectifier.

Ans:

The circuit diagram of full wave bridge rectifier is shown in figure,



Figure

Q4. Define ripple factor. What is the value of ripple factor for a half-wave and full wave rectifier?

Ans:

For a rectifier circuit, "ripple factor" is defined as the ratio of RMS value of AC component of the output to the component of output. It is denoted with 'γ'. Mathematically, it is written as,

$$\gamma = \frac{\text{rms value of AC component of output}}{\text{DC component of output}} = \frac{I_{ac}}{I_{dc}}$$

$$\boxed{\therefore \gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}}$$

A rectifier circuit is said to be more efficient if its ripple factor is low.

Q5. What is early ripple 2V on average of 50 V? June-1

Ans:

Given that,

For a rectifier,

Peak voltage, $V_m = 2$ V

Average voltage, $V_{dc} = 50$ V

Ripple factor, $\gamma = ?$

Then, the expression for ripple factor is given by,

$$\gamma = \frac{V_{rms}}{V_{dc}}$$

$$= \frac{V_m}{\sqrt{2}\,V_{dc}} = \frac{2}{50\sqrt{2}}$$

$$= 0.0283$$

$$\boxed{\therefore \gamma = 0.0283}$$

Q6. Compare half-wave and center tapped full-wave rectifiers.

Ans:

The comparison between half wave and center tapped full wave rectifier are mentioned in table:

	Halfwave Rectifier		Fullwave Rectifier
1.	The output occurs only during positive half cycle.	1.	The output occurs during both positive and negative half cycle.
2.	Average current $I_{avg} = \frac{I_m}{\pi}$	2.	Average current $I_{avg} = \frac{2I_m}{\pi}$
3.	RMS current $I_{rms} = \frac{I_m}{2}$	3.	RMS current $I_{rms} = \frac{I_m}{\sqrt{2}}$

Table

Q7. State advantages and disadvantages of bridge rectifier circuit. Dec.-15, Q1

(or)

List the merits and demerits of bridge rectifier over a centre tapped full-wave rectifier.

(or)

What are the drawbacks of bridge rectifier over centre-tap rectifiers? Jan.-12, Q2

(Refer Only Demerits)

Ans:

Merits

1. The requirement of center-tapped transformer is eliminated or removed.
2. For the same secondary voltage, the output produced by bridge rectifier is twice that of the center-tap rectifier.
3. The PIV of the diodes posses is one-half that of the center-tap circuit.

Demerits

1. It needs four diodes.
2. The bridge circuit is not efficient for low voltages because the current flow in the two diodes connected in series results in a large power dissipation.
3. Bridge circuits are not convenient with vacuum diodes of directly heated cathode since they don't have same potential.

Q8. Explain the need for a filter in power supplies.

Ans:

The rectifier produces a DC output that is pulsating. But the output should have a constant value over time, like the output of a battery. This is achieved using a filter circuit. The filter eliminates the pulsations and generates a constant output. Filters are constructed using inductors and capacitors.

Q9. List different types of filters.

Ans:

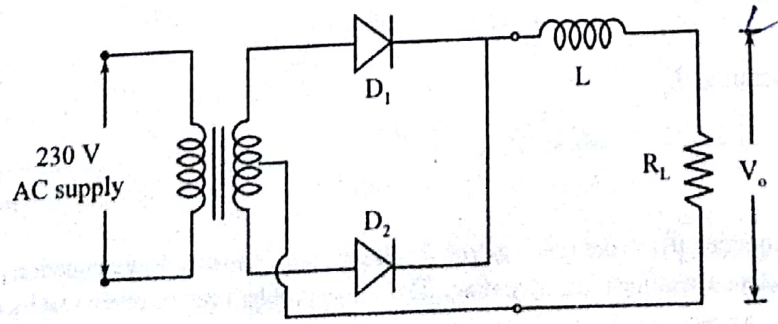
Filters are used in rectifier circuits to eliminate the ripples in the output dc. The following filters are frequently used in rectifier circuits,

1. Inductor filter
2. Capacitor filter
3. L-section filter
4. π-section filter.

Q10. Draw the circuit of FWR with inductor filter.

Ans:

The circuit diagram of full wave rectifier with inductor filter is shown in figure:

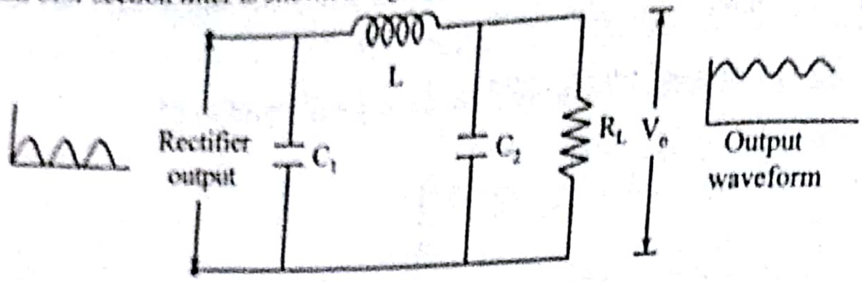


Figure

Q11. Draw the circuitry of π-section filter.

Ans:

The circuit diagram of π-section filter is shown in figure:



Figure

Q12. Explain the significance of bleeder resistor in a rectifier circuits. (Model Paper-II, Q3 | July-

(or)

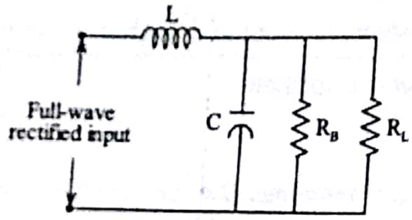
What is bleeder resistance? Why it is used in L- filter. Dec.-

(or)

What is the purpose of bleeder resistance in a rectifier circuit using L-C filter? Jan.-12, Q

Ans:

Figure shows the circuit arrangement of a *L*-section filter with bleeder resistor.



Figure

For a critical value of an inductor, current does not fall to zero i.e., either of the diodes is always conducting. The two components of the incoming current are,

(i) $I_{D.C} = \dfrac{V_{D.C.}}{R_L}$

(ii) A sinusoidal varying components with peak value of $\dfrac{4V_m}{3\pi X_L}$.

And always, $\sqrt{2}I_{r.m.s} \leq \dfrac{V_{D.C.}}{R_L}$

Since, for *L*-section filter, $I_{r.m.s} = \dfrac{\sqrt{2}}{3}\dfrac{V_{D.C.}}{X_L}$

Then,

$$\frac{2V_{D.C.}}{3X_L} \leq \frac{V_{D.C.}}{R_L}$$

$$\boxed{X_L \geq \frac{2}{3}R_L} \quad \text{... (6)}$$

But, for the critical inductance, L_C

$$\boxed{L_C = \frac{R_L}{3\omega}} \quad \text{... (7)}$$

The expression shown in equation (6), is not going to true for all load requirements. From equation (7), the value of inductance will tend to infinity, when the load resistance is infinity i.e., at no-load. The above problem can be overcome by connecting a resistance parallel to the load resistance called as bleeder resistor, R_B. Thus, for the optimum operation of the inductor, minimum current is required.

The bleeder resistor, R_B not only improves regulation but also provides safety by acting as a discharging path for capacitor.

Q13. Why series inductor and L-section filters cannot be used with half-wave rectifiers.

June/July-11, Q2

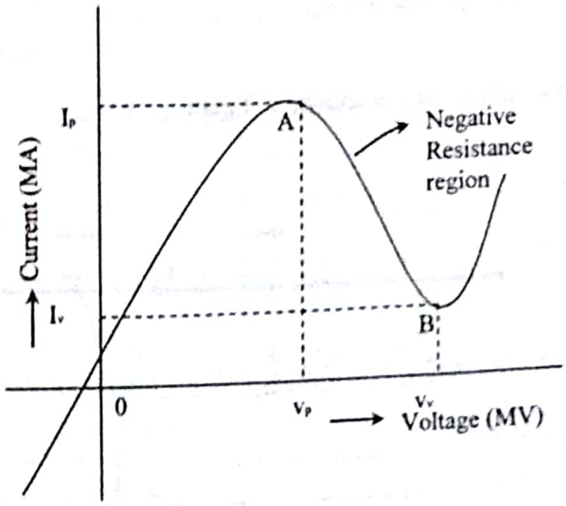
Ans:

Series inductor and L-section filters cannot be used with half-wave rectifiers, because their operation depends upon the current flowing through it and a minimum current to be flown at each and every instant of time.

Q14. Draw the V-I characteristics of Tunnel diode.

Ans:

The V-I characteristics of tunnel diode are shown in figure:



Figure

Q15. List applications of tunnel diode.

Ans:

Tunnel diode is used as,

1. Ultra high speed switch (under of ns (or) ps)
2. As logic memory storage device
3. As microwave oscillatory
4. In relaxation oscillator circuit
5. As an amplifier.

Q16. What is varactor diode?

(Model Paper-I, Q4 | Dec.-15, Q12(b))

Ans:

A p-n junction diode that acts as a voltage variable capacitor under reverse bias condition is known as varactor diode. The symbol of varactor diode as show in figure.

Figure

Q17. Explain the working principle of varactor diode.

Ans:

A *p-n* junction diode that acts as a voltage variable capacitor under reverse bias condition is known as varactor diode. The depletion layer created in the *p-n* junction acts as an insulator and the *p*-region and *n*-region act as plates of the capacitor. When the reverse voltage increases, the width of depletion layer increases and capacitance becomes smaller.

Q18. Mention the applications of varactor diode.

Ans:

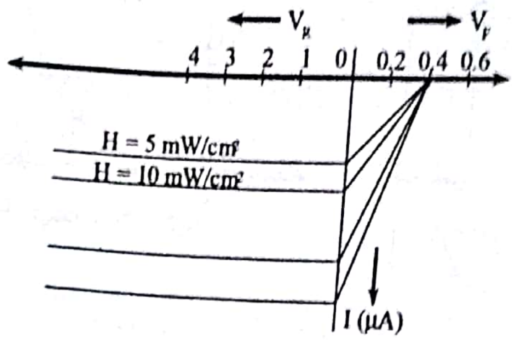
The applications of varactor diode are,

1. Voltage controlled oscillators
2. RF filters
3. Self balancing bridge circuits
4. Automatic frequency control circuits and
5. Voltage tuning of LC resonant circuits.

Q19. Draw the V-I characteristics of photo diode.

Ans:

The typical Photo diode characteristics are as shown in figure.



Figure

When there is no light is applied the current flow through the diode is zero and that current is known as dark curr plots are observed at different illumination levels.

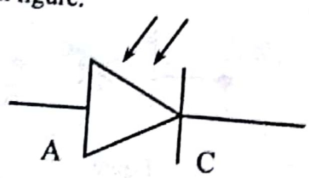
Q20. Write the applications of photo diode and draw its symbol.

Ans:

The applications of photodiode are,

1. Light detectors
2. Optical detector (or) demodulators
3. Sound track films
4. Electronic control circuits
5. Light operated switches
6. Computer punching cards and paper
7. Encoders

The symbol of photo diode is as shown in figure.



Figure

Q21. Draw the symbol and write the applications of LED.

Ans:

Light emitting diode is an light sensitive diode which emits light when it is forward biased. Figure shows the symbol of LED.

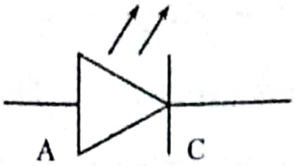


Figure: Symbol of LED

The applications of LED include,

1. Digital watches
2. Optical communication system
3. Microprocessor systems
4. Digital computers
5. Calculators
6. Multimeters.

Q22. Compare LED and LCD.

(Model Paper-II, Q4 | Dec.-15, Q10)

Ans:

The comparison between LED and LCD are mentioned below,

	LED		LCD
1.	LEDs Consume more power than LCDs.	1.	LCD Consumes very less power.
2.	Due to high power requirement, LED requires external interface circuits (called as LED driver circuit) when driven from ICs.	2.	LCD can be driven directly from IC chips. Driver
3.	LEDs have a very good brightness level.	3.	LCDs have moderate brightness level.
4.	The operating temperature range of commercially available LEDs is about –40 to 85 degree celsius.	4.	The operating temperature range of commercially available LCDs is about -20 to 60 degree celsius.
5.	Life time is around 1,00,000 hours.	5.	Due to chemical degradation the life time is 50,000 hours.
6.	Operating voltage range is 1.5 to 5 V.	6.	Operating voltage range is 3 to 20 V.

Q23. What is a CRO?

Ans:

Cathode Ray Oscilloscope (CRO) is a versatile electronic measuring instrument, which is used to display the signal waveforms based on applied input. It is used to measure frequencies, voltage and phase shift of any signal.

Q24. List the applications of CRO.

Ans:

Some of the applications of CRO are as follows,

1. Cathode Ray Oscilloscope (CRO) is basically used to measure voltage, current, frequency and phase shift of alternating quantity.
2. It is used in examining the waveforms of electrical signals.
3. It acts as an indicator in radar receivers.
4. It adjusts the frequency in FM receivers.
5. It is used to study microwave spectroscopy, standing waves in transmission lines and vibrations of machinery.
6. It is used to analyze engine pressure, faulty components or diode testing in various circuits.
7. It is used to trace the transistor curves or B-H curves (for Hysteresis loop).
8. CROs measure capacitance and inductance and also compares phase and frequency.

PART-B

ESSAY QUESTIONS WITH SOLUTIONS

2.1 HALF WAVE, FULL WAVE AND BRIDGE RECTIFIERS - THEIR OPERATION - PERFORMANCE CHARACTERISTICS AND ANALYSIS

Q25. What is a rectifier? What are the different types of rectifiers available and how the performance of different rectifiers is evaluated?

Ans:

Rectifier is a circuit made up of one or more diodes. It converts alternating signal into pulsating DC signal.

Types of Rectifiers

Different types of rectifiers are available for converting AC signal into pulsating DC signal. They are,

1. Half-wave rectifier
2. Full-wave rectifier
3. Bridge rectifier.

To evaluate the performance of different rectifier circuits several parameters are defined. They are,

1. Average value or output 'DC' value
2. RMS value or effective value
3. Ripple factor
4. Efficiency
5. Peak inverse voltage.

1. Average Value

The average value of any current or voltage is the value indicated on a DC meter. In other words, over a complete cycle of a sinusoid, the average value is the equivalent DC value.

In the analysis of rectifier circuits, evaluation of average value of output signal (voltage or current) determines the DC component of voltage or current in the output.

Definition

The average value of a sinusoidal voltage or current (figure (1)) is defined as the ratio of area of one cycle to the length of the cycle. Mathematically, it is written as,

$$I_{avg} \text{ (or) } I_{dc} = \frac{\int_0^{2\pi} i \, d\alpha}{2\pi} \quad \text{...(1)}$$

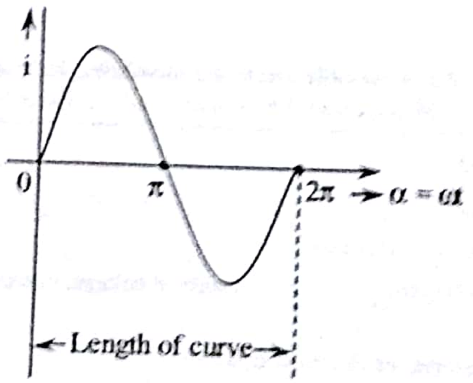
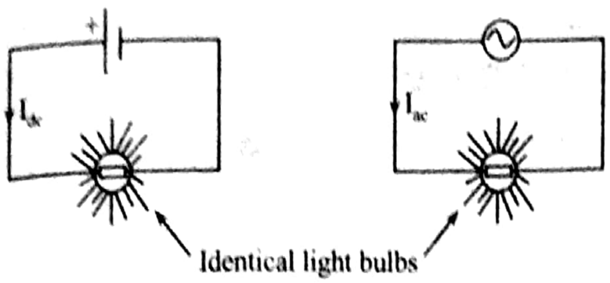


Figure (1): A Sinusoidal Current Waveform

2. RMS or Effective Value

The rms (or) effective value of any current or voltage is the value indicated on the ac meter. In other words, RMS value of a sinusoidal current or voltage is the DC voltage that delivers the same average power to a resistor as the sinusoidal signal.

For example, observe the two circuits shown in figures 2(a) and 2(b). The bulbs in the two circuits (having same resistance) light with same brightness indicating that, they are working at the same power. This signifies or necessitates the current I_{ac} is equivalent to current I_{dc}.



(a): Bulb Glowing with DC Supply **(b): Bulb Glowing with AC Supply**

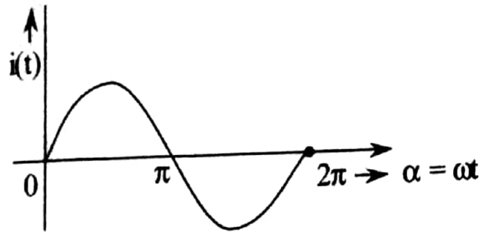
Figure (2)

The equivalent I_{dc} value for the signal I_{ac} is obtained by taking square-root of the mean square value of I_{ac} known as the RMS value of I_{ac}.

Definition

The RMS value of a sinusoidal signal is defined as the square root of area of one cycle of a squared signal divided by the length of the cycle. Mathematically, it is written as,

$$I_{rms} = \sqrt{\frac{\int_0^{2\pi} i^2(t)\,d\alpha}{2\pi}} \quad \text{... (2)}$$



Figure

3. Ripple Factor

For a rectifier circuit "ripple factor" is defined as the ratio of RMS value of ac component of the output to the dc component of output. It is denoted with 'γ'. Mathematically, it is written as,

$$\gamma = \frac{\text{rms value of ac component of output}}{\text{dc component of output}} = \frac{I_{ac}}{I_{dc}} \quad \text{... (3)}$$

I_{ac} is obtained using the expression,

$$I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2} \quad \text{... (4)}$$

Using equation (4), equation (3) can be written as,

$$\gamma = \frac{I_{ac}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}} = \sqrt{\frac{I_{rms}^2 - I_{dc}^2}{I_{dc}^2}}$$

$$\boxed{\therefore \gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}} \quad \text{... (5)}$$

A rectifier circuit is said to be more efficient if its ripple factor is low.

4. Efficiency

Efficiency of a rectifier circuit is defined as the ratio of dc output power to the ac input power. It is denoted by 'η' and mathematically written as,

$$\eta = \frac{P_{dc\,out}}{P_{ac\,in}} \quad \text{... (6)}$$

5. Peak Inverse Voltage

The maximum voltage that a diode can withstand without entering into the breakdown region is known as peak inverse voltage. PIV is the maximum voltage which occurs during a part of the cycle when the diode is non conducting.

Q26. Define form factor and ripple factor and establish relation between them.

Ans:

Ripple Factor

The ripple factor is defined as the ratio of the r.m.s value of the ripple voltage to the absolute value of the D.C component of the output voltage.

$$\gamma = \frac{\text{R.M.S value of A.C component}}{\text{D.C component value}}$$

$$= \frac{V_{r,\text{r.m.s}}}{V_{dc}}$$

$$V_{r,\text{r.m.s}} = \sqrt{V_{\text{r.m.s}}^2 - V_{dc}^2}$$

$$\gamma = \frac{\sqrt{V_{\text{r.m.s}}^2 - V_{dc}^2}}{V_{dc}}$$

$$\gamma = \sqrt{\left(\frac{V_{\text{r.m.s}}}{V_{dc}}\right)^2 - 1} \quad \text{... (1)}$$

Form Factor

The form factor is defined as the ratio of the r.m.s value to the average value,

$$F = \frac{\text{R.M.S value}}{\text{Average value}} = \frac{V_{\text{r.m.s}}}{V_{dc}} \quad \text{... (2)}$$

Using equation (2), equation (1) can be written as

$$\gamma = \sqrt{F^2 - 1}$$

∴ The relation between ripple factor and form factor is

$$\gamma = \sqrt{F^2 - 1}$$

Q27. Write a short note on halfwave rectifiers.

(Model Paper-I, Q12(a) | June-13, Q17(a))

(or)

Explain the operation of HWR with neat sketches.

Ans:

Halfwave Rectifier

The circuit diagram of a halfwave rectifier is as shown in figure (1). It contains a step down transformer and a diode in series with a load resistance (R_L). A 230 V ac supply is given as input to the primary side of the step down transformer.

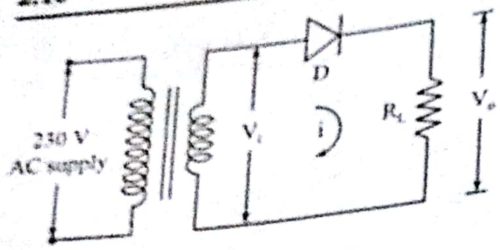


Figure (1): Halfwave Rectifier

Operation

The transformer converts the 230 V AC supply to a desired lower level 'V_i'. The output of the transformer (V_i) is as shown in figure (2). This acts as input to the diode "D".

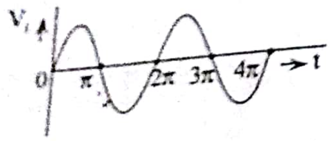


Figure (2): Voltage Across Transformer Secondary that Acts Input to Diode 'D'

Assuming the diode to be ideal.

For positive half cycle of the input voltage 'V_i', the diode is forward biased and acts as short circuit (or) closed switch and the equivalent circuit is as shown in figure (3).

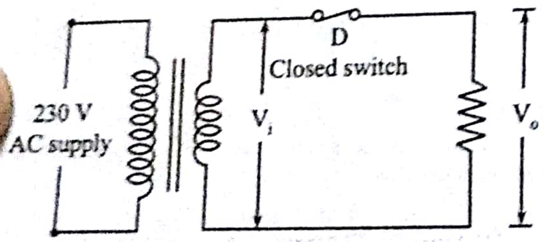


Figure (3): Equivalent Circuit of Halfwave Rectifier when Diode is Forward Biased

For negative half cycle of the input voltage 'V_i', the diode is reverse biased and it acts as open circuit (or) open switch. The equivalent circuit is as shown in figure (4).

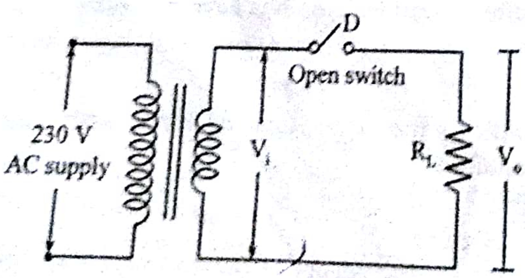


Figure (4): Equivalent Circuit of HWR when Diode is Reverse Biased

From the above operations, it is observed that the diode is conducting only during positive half cycles of input voltage 'V_i' and in negative half cycles the diode is not conducting. As a result, the output voltage 'V_o' across the load R_L for the input 'V_i' is as shown in figure (5).

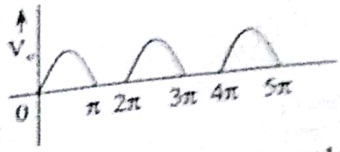


Figure (5): Output of HWR Across Load R_L

In figure (5), only positive half cycles are present because the diode conducts only in one direction. The negative half cycle is clipped off because the diode is non conducting in the other direction.

Disadvantages

1. Only one half of the input waveform reaches the output. Therefore the output is low.
2. Much more filtering is needed to eliminate harmonics of the AC frequency from the output and produce a steady DC voltage.

Q28. Derive the expression for average value, rms value, ripple factor and efficiency of HWR.

Ans:

The current $i(t)$ flowing across the load 'R_L' of a halfwave rectifier in figure (a) is as shown in figure (b).

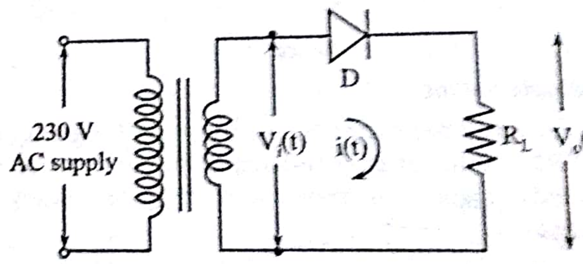


Figure (a): Half-wave Rectifier

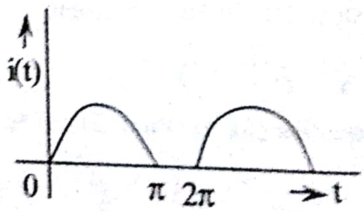


Figure (b): Current i(t) Flowing Across the Load R_L in figure (a)

Mathematically, the current $i(t)$ can be written as,

$$i(t) = \begin{cases} I_m \sin \omega t & 0 \le \omega t \le \pi \\ 0 & \pi \le \omega t \le 2\pi \end{cases} \quad \text{...(1)}$$

Where, I_m is the peak value of the current $i(t)$.

1. Average Value

The average value of current is also known as dc value. It is evaluated using the expression.

$$I_{avg} = \frac{1}{2\pi}\int_0^{2\pi} i(t)\,d(\omega t) \quad ...(2)$$

Using equation (1), equation (2) can be written as,

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

$$= \frac{I_m}{2\pi}\left[\int_0^{\pi} \sin \omega t\,d(\omega t)\right]$$

$$= \frac{I_m}{2\pi}[-\cos\omega t]_0^{\pi}$$

$$= \frac{I_m}{2\pi}\times 2$$

$$\boxed{\therefore I_{avg} = \frac{I_m}{\pi}} \quad ...(3)$$

Average voltage value is evaluated from I_{avg} using the expression.

$$V_{avg} = I_{avg}\,R_L \quad ...(4)$$

$$\boxed{\therefore V_{avg} = \frac{I_m}{\pi}R_L} \quad ...(5)$$

2. RMS Value

The RMS value of current is also known as effective value. It is evaluated using the expression,

$$I_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2(t)\,d(\omega t)} \quad ...(6)$$

Using equation (1), equation (6) can be written as,

$$I_{RMS} = \sqrt{\frac{1}{2\pi}\left[\int_0^{2\pi} I_m^2 \sin^2(\omega t)\,d(\omega t) + \int_{\pi}^{2\pi}(0)\,d(\omega t)\right]}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{2\pi} I_m^2 \sin^2(\omega t)\,d(\omega t)\right]}$$

Since, $\sin^2\omega t = \left(\frac{1-\cos 2\omega t}{2}\right)$, the above equation is written as,

$$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi}\left(\frac{1-\cos 2\omega t}{2}\right)d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\int_0^{\pi}\frac{1}{2}\,d(\omega t) - \int_0^{\pi}\frac{\cos 2\omega t}{2}\,d(\omega t)\right]}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\left(\frac{\omega t}{2}\right)_0^{\pi} - \frac{1}{4}(\sin 2\omega t)_0^{\pi}\right]}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left(\frac{\pi}{2}\right) - 0}$$

$$= \sqrt{\frac{I_m^2}{4}} = \frac{I_m}{2}$$

$$\boxed{\therefore I_{RMS} = \frac{I_m}{2}} \quad ...(7)$$

The RMS voltage is given as,

$$V_{RMS} = I_{RMS}\,R_L$$

$$\boxed{\therefore V_{RMS} = \frac{I_m R_L}{2}} \quad ...(8)$$

3. Ripple Factor

Ripple factor for a half-wave rectifier is obtained using the expression,

$$\gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} \quad ...(9)$$

Using equations (3) and (7), equation (9) can be written as,

$$\gamma = \sqrt{\frac{\left(\frac{I_m}{2}\right)^2}{\left(\frac{I_m}{\pi}\right)^2} - 1}$$

$$= \sqrt{2.467 - 1} = \sqrt{1.467}$$

$$\boxed{\therefore \gamma = 1.21} \quad ...(10)$$

4. Efficiency

The efficiency of a rectifier circuit is obtained using the expression,

$$\eta = \frac{P_{dcout}}{P_{acin}}\times 100 \quad ...(11)$$

$P_{dc\,out}$ is given as,

$$P_{dc\,out} = I_{dc}^2 R_L = \left(\frac{I_m}{\pi}\right)^2 R_L \quad ...(12)$$

P_{ac} is given as,

$$P_{ac} = I_{RMS}^2(R_L + r_d)$$

Where, r_d is forward diode resistance. Since, diode is assumed to be ideal $r_d = 0$.

$$\therefore\ P_{ac} = I_{RMS}^2(R_L) = \left(\frac{I_m}{2}\right)^2 R_L \quad ...(13)$$

Substituting equations (12) and (13) in equation (11), we get,

$$\eta = \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{2}\right)^2 R_L} \times 100 \qquad \cdots (4)$$

$$\boxed{\therefore \eta = 40.52\%}$$

Q29. What is a rectifier? Explain the operation of a full wave centre-tapped rectifier with necessary diagrams and waveforms.

Ans: (Model Paper-II, Q12(a) | Dec.-13, Q11(a))

Rectifier

Rectifier is a circuit made up of one or more diodes. It converts alternating supply into pulsating DC.

Center Tapped Full-wave Rectifier

The circuit diagram of a "center tapped full-wave rectifier" is as shown in figure (1). It contains a center tapped step down transformer, two diodes D_1 and D_2 and a load resistance 'R_L'. A 230 V ac supply is given as input to the primary side of the transformer.

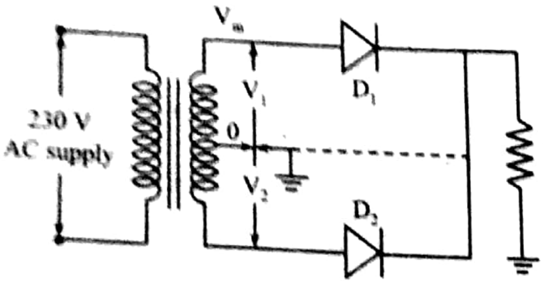


Figure (1): Full-wave Rectifier Circuit Diagram

Operation

The transformer converts the 230 V AC supply to a desired lower level. The 'center tap' across secondary of the transformer generates two separate voltages V_1 and V_2 that are equal in magnitude but opposite in polarity as shown in figure (2).

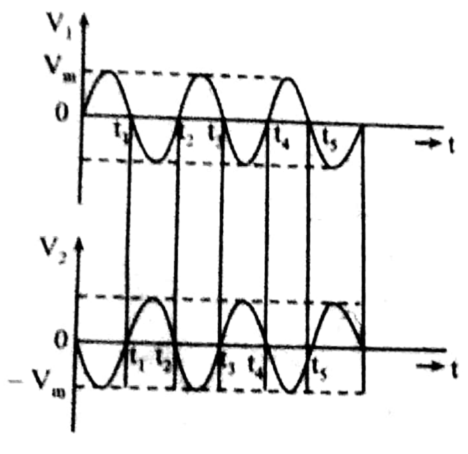


Figure (2): Voltages V_1 and V_2 Generated by Center Tap of the Transformers

The voltage V_1 acts as input to diode D_1 and voltage V_2 acts as input to diode D_2.

Assuming the diodes to be ideal,

1. For the time period 0 to t_1 of the voltages V_1 and V_2 shown in figure (2). The diode D_1 is forward biased because of the positive half cycle, and diode D_2 is reverse biased because of the negative half cycle. The forward biased diode D_1 acts as a short circuit and the reverse biased D_2 acts as an open circuit. The equivalent circuit is as shown in figure (3).

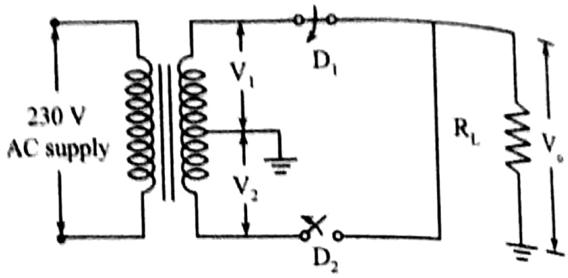


Figure (3): Equivalent Circuit of Center Tapped FWR When D_1 is Forward Biased and D_2 is Reverse Biased

2. For the time period 't_1' to 't_2' of the voltages V_1 and V_2 shown in figure (2). The diode D_1 is reverse biased because use of the negative half cycle, and diode D_2 is forward biased because of the positive half cycle. The reverse biased diode D_1 acts as an open switch, and the forward biased diode D_2 acts as a closed switch. The equivalent circuit is as shown in figure (4).

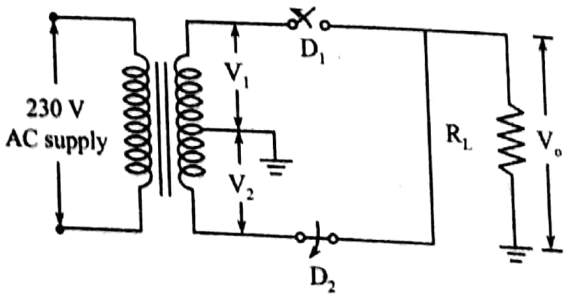


Figure (4): Equivalent Circuit of Center Tapped FWR When D_1 is Reverse Biased and D_2 is Forward Biased

From the above operation it is observed that the diode D_1 is ON for the time intervals in which diode D_2 is OFF. Similarly, diode D_2 is ON for the time intervals in which diode D_1 is OFF. As a result, the output voltage V_o across the load 'R_L' for the input voltage is as shown in figure (5).

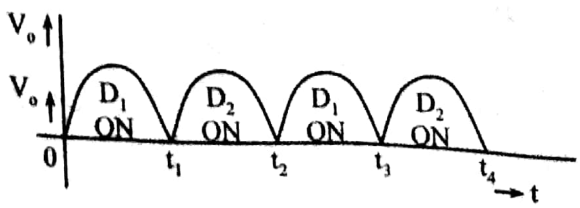


Figure (5): Output Voltage V_o Across Load R_L

In the figure (5), the ... and negative half cycles of ... in one direction and diode ...

Advantage

Output is present ... cycles of the inpu... half wave rectifie...

Disadvantages

1. It is hard and tr... center tap on the...
2. Each diode in t... secondary volta... low.
3. The diodes em... must have hig...

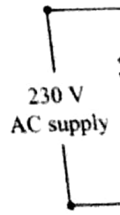
Q30. Write short...

Explain th... neat wave...

Ans:

Bridge Rectifier

The circu... as shown in figu... four diodes D_1, ... diodes D_1, D_2, ... illustrated in fig... the primary sid...



Operatio...

Th... desired lo... shown in... circuit.

Fig...

In the figure (5), the output is present for both positive and negative half cycles of input because diode D_1, is conducting in one direction and diode D_2 is conducting in other direction.

Advantage

- Output is present for both positive and negative half cycles of the input waveform. Therefore, compared to half wave rectifier output is high.

Disadvantages

1. It is hard and troublesome to trackdown (locate) the center tap on the secondary winding.
2. Each diode in the circuit utilizes only one-half of the secondary voltage. As a result, the output d.c voltage is low.
3. The diodes employed in the center-tap full wave rectifier must have high Peak Inverse Voltage (PIV).

Q30. Write short note on bridge rectifiers.

July-12, Q17(a)

(or)

Explain the operation of bridge rectifier with neat waveforms.

Ans:

Bridge Rectifier

The circuit diagram of a full-wave bridge rectifier is as shown in figure (1). It contains a step down transformer, four diodes D_1, D_2, D_3, and D_4 and a load resistance 'R_L'. The diodes D_1, D_2, D_3, and D_4 are connected in a bridge pattern as illustrated in figure (1). A 230 V ac supply is given as input to the primary side of the transformer.

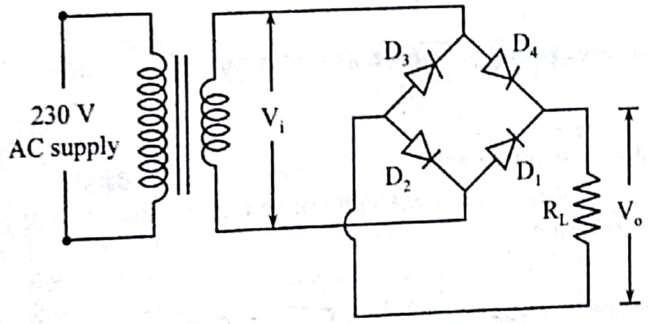


Figure (1): Bridge Rectifier

Operation

The transformer converts the 230 V AC supply to a desired lower level 'V_i'. The output of the transformer is as shown in figure (2). This acts as input to the diodes bridge circuit.

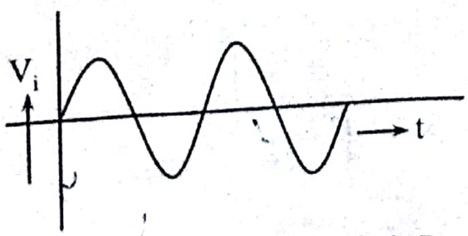


Figure (2): Voltage Across the Secondary of the Transformer

Assuming the diodes to be ideal,

1. For positive half cycle of input voltage (V_i), the diodes D_1 and D_3 are forward biased and the diodes D_2 and D_4 are reverse biased. So, the diodes D_1, D_3 acts as a closed switches and D_2, D_4 acts as open switches and the equivalent circuit diagram is as shown in figure (3).

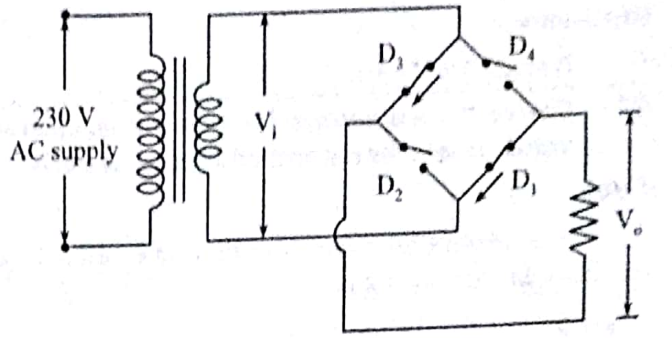


Figure (3): Equivalent Circuit of the Bridge Rectifier for the Positive Half Cycle of Input Voltage V_i

2. For negative half cycle of input voltage 'V_i', the diodes D_1 and D_3 are reverse biased and the diodes D_2 and D_4 are forward biased. So the diodes D_1 and D_3 acts as open switches and D_2 and D_4 acts as closed switches and the equivalent circuit diagram is as shown in figure (4).

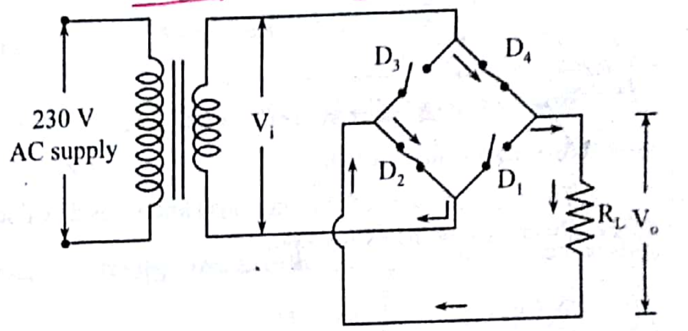


Figure (4): Equivalent Circuit of the Bridge Rectifier for the Negative Half Cycle of Input Voltage V_i

From the above operations it is observed that the diodes D_1 and D_3 are conducting for positive half cycle and D_2 and D_4 are conducting for negative half cycles of the input voltage 'V_i'. As a result the output voltage 'V_o' across the load 'R_L' for the input voltage V_i is as shown in figure (5).

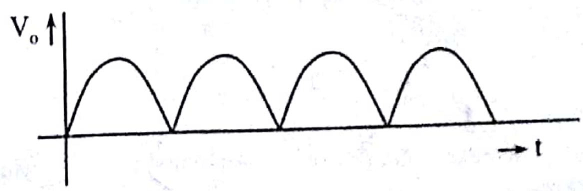


Figure (5)

In figure (5), both positive and negative half cycles are present because the diodes D_1 and D_3 are conducting in one direction and D_2 and D_4 are conducting in other directions.

Advantages

1. The requirement of center-tapped transformer is eliminated or removed.
2. For the same secondary voltage, the output produced by bridge rectifier is twice that of the center-tap rectifier.
3. The PIV of the diodes posses is one-half that of the center-tap circuit.

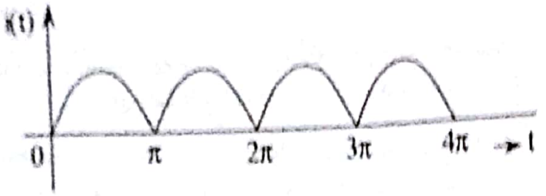
Disadvantage

- It needs four diodes.

Q31. Derive the equations for rms value, average value, ripple factor and efficiency of FWR.

Ans:

The current $i(t)$ flowing across the load R_l of a full-wave rectifier is as shown in figure.



Figure

Mathematically, it is written as,

$$i(t) = \begin{cases} I_m \sin \omega t & 0 \le \omega t \le \pi \\ -I_m \sin \omega t & 0 \le \omega t \le 2\pi \end{cases} \quad \dots (1)$$

Where, I_m is the peak value of current $i(t)$.

1. Average Value

The average value of current is also known as dc value. It is evaluated using the expression.

$$I_{dc} \text{ (or) } I_{avg} = \frac{1}{2\pi}\int_0^{2\pi} i(t)\,d(\omega t) \quad \dots (2)$$

Using equation (1), equation (2) can be written as,

$$I_{avg} = \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin(\omega t)\,d(\omega t) - \int_{\pi}^{2\pi} I_m \sin(\omega t)\,d(\omega t)\right]$$

$$= \frac{1}{2\pi}\left[I_m[-\cos(\omega t)]_0^{\pi} + I_m[\cos \omega t]_{\pi}^{2\pi}\right]$$

$$= \frac{I_m}{2\pi}[(-(-2)) + 2] = \frac{4I_m}{2\pi}$$

$$\boxed{\therefore I_{dc} \text{ or } I_{avg} = \frac{2I_m}{\pi}} \quad \dots (3)$$

Average voltage value is evaluated from I_{avg} using the expression.

$$\therefore V_{avg} = I_{avg} R_L$$

$$\boxed{\therefore V_{avg} = \frac{2I_m R_L}{\pi}} \quad \dots (4)$$

2. RMS Value

The RMS value of current is also known as effective value. It is evaluated using the expression.

$$I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2(t)\,d(\omega t)} \quad \dots (5)$$

For the output of full-wave rectifier, the length of the curve is 0 to π and $i(t)$ is considered only for this period. Hence, equation (5) can be written as,

$$I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2(\omega t)\,d(\omega t)}$$

$$\cos 2\omega t = 1 - 2\sin^2 \omega t \Rightarrow \sin^2 \omega t = \frac{1-\cos 2\omega t}{2}$$

$$\Rightarrow I_{rms} = \sqrt{\frac{I_m^2}{\pi}\int_0^{\pi}\left(\frac{1-\cos 2\omega t}{2}\right)d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{\pi}\left|\int_0^{\pi}\frac{d(\omega t)}{2} - \int_0^{\pi}\frac{\cos 2\omega t}{2}\,d(\omega t)\right|}$$

$$= \sqrt{\frac{I_m^2}{\pi}\left(\left(\frac{\omega t}{2}\right)_0^{\pi} - \left(\frac{\sin 2\omega t}{4}\right)_0^{\pi}\right)}$$

$$= \sqrt{\frac{I_m^2}{\pi}\left(\frac{\pi}{2} - 0\right)}$$

$$= \sqrt{\frac{I_m^2}{2}}$$

$$\boxed{\therefore I_{rms} = \frac{I_m}{\sqrt{2}}} \quad \dots (6)$$

0.2323

3. Ripple Factor

Ripple factor for a rectifier circuit is obtained using the expression.

$$\gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} \quad \dots (7)$$

From equation (3) and equation (6), equation (7) can be written as,

$$\gamma = \sqrt{\frac{\left(\frac{I_m}{\sqrt{2}}\right)^2}{\left(\frac{2I_m}{\pi}\right)^2} - 1}$$

$$= \sqrt{1.233 - 1} = \sqrt{0.233}$$

$$\boxed{\therefore \gamma = 0.482} \quad \dots (8)$$

4. **Efficiency**

The efficiency of a rectifier circuit is obtained using the expression, ... (9)

$$\eta = \frac{P_{dc(out)}}{P_{ac(in)}}$$

DC power delivered to the load is,

$$P_{dc} = I_{dc}^2 R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

Total ac input power,

$$P_{ac} = I_{rms}^2 (r_d + R_L)$$

Where, r_d is forward diode resistance. Since, diode is assumed to be ideal $r_d = 0$

$$\therefore \quad P_{ac} = I_{rms}^2 R_L = \left(\frac{I_m}{\sqrt{2}}\right)^2 R_L$$

$\gamma = \sqrt{F^2-1}$

$\sqrt{(1.1)} = F^2-1$

Using P_{ac} and P_{dc} in equation (9), we get,

$$\eta = \frac{\left(\frac{2I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 R_L} \times 100$$

$$\boxed{\therefore \eta = 81.2\%}$$

Q32. Compare half wave, full wave and bridge rectifier in terms of theirs electrical characteristics.

(Model Paper-I, Q12(b) | July-16, Q2(b))

(or)

List out the differences between half wave, full wave and bridge rectifiers.

Dec.-13, Q11(b)

Ans:

	Half-wave Rectifier		Full-wave Rectifier		Bridge Rectifier
1.	The output occurs only during positive half cycle.	1.	The output occurs during both positive and negative half cycles.	1.	The output occurs during both + ve and – ve half cycles.
2.	Average current (I_{avg}), $I_{avg} = \frac{I_m}{\pi}$	2.	Average current (I_{avg}), $I_{avg} = \frac{2I_m}{\pi}$	2.	Average current (I_{avg}), $I_{avg} = \frac{2I_m}{\pi}$
3.	RMS current (I_{rms}), $I_{rms} = \frac{I_m}{2}$	3.	RMS current (I_{rms}), $I_{rms} = \frac{I_m}{\sqrt{2}}$	3.	RMS current (I_{rms}), $I_{rms} = \frac{I_m}{\sqrt{2}}$
4.	Form factor is 1.57.	4.	Form factor is 1.11.	4.	Form factor is 1.11.
5.	Ripple factor is 1.21.	5.	Ripple factor is 0.483.	5.	Ripple factor is 0.483.
6.	PIV is V_m.	6.	PIV is $2V_m$.	6.	PIV is $2V_m$.
7.	Maximum efficiency is 40.6%.	7.	Maximum efficiency is 81.2%.	7.	Maximum efficiency is 81.2%.
8.	It requires single diode.	8.	It requires two diodes.	8.	It requires four diodes.

2.2 FILTERS (L, C, LC AND CLC FILTERS) USED IN POWER SUPPLIES AND THEIR RIPPLE FACTOR CALCULATIONS

Q33. What is meant by filter and list the different types of filters?

Ans:

Filter

The rectifier produces a DC output that is pulsating. But the output should have a constant value over time, like the output of a battery.

This is achieved using a filter circuit. The filter eliminates the pulsations and generates a constant output. Filters are constructed using inductors and capacitors. Figure illustrates the functioning of a filter concisely.

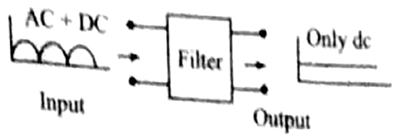


Figure: Concept of Filter

Types of Filters

Filters are used in rectifier circuits to eliminate the ripples in the output dc. The following filters are frequently used in rectifier circuits,

1. Inductor filter
2. Capacitor filter
3. L-section filter
4. π-section filter.

Q34. Explain about series inductor filter with neat circuit diagram.

Ans:

Series Inductor Filter

Basically, an inductor opposes sudden changes in the current (or) opposes the ac component. This property is utilized in converting the pulsating dc waveform into pure dc waveform. The circuit diagram for full-wave rectifier with inductor filter is as shown in figure (1). The inductor is connected in between the rectifier and the output load R_L.

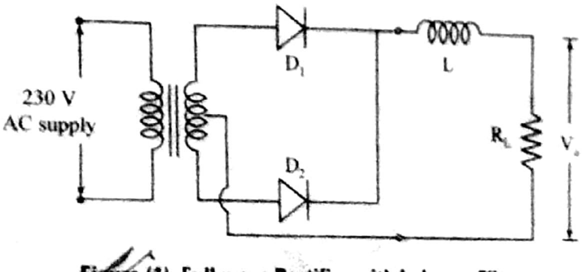


Figure (1): Full-wave Rectifier with Inductor Filter

When the output across the rectifier, which contains both dc and ac components as shown in figure 2(a) is applied to the inductor. The inductor oppposes ac component and allows only dc component through it by this we are getting pure form of dc, which is as shown in figure 2(b).

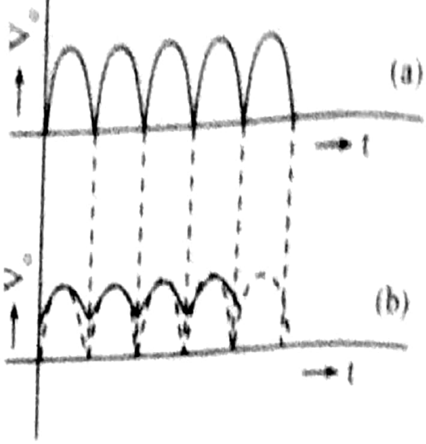


Figure (2): (a) Output Across the Rectifier

(b) Output Across the Load R_L

Q35. Draw the circuit diagram of FWR with inductor filter explain its operation and derive its ripple factor.

Ans:

The output of FWR contains D.C and A.C (ripples) components it can be represented mathematically as,

$$V_{out} = \frac{2V_m}{\pi} - \frac{4V_m \cos 2\omega t}{3\pi} - \frac{4V_m \cos 4\omega t}{15\pi} \ldots\ldots \quad \ldots(1)$$

Here second harmonic is dominant. Hence first ripple term is considered.

Therefore, from equation (1), it may be noted that two voltage sources are applied to filter section i.e., D.C voltage, A.C ripple voltage.

Inductor opposes the A.C (ripple current) and allows D.C current to pass to R_L. Hence, a reduced ripple is obtained in R_L. Therefore, improved D.C current is achieved in R_L.

Selection of inductor should be in such a way that $X_L >> R_L$.

Where, $X_L = \omega L = 2\pi f L$

I_{DC} due to $\frac{2V_m}{\pi}$ source is,

$$I_{DC} = \frac{\frac{2V_m}{\pi}}{R_L} = \frac{2V_m}{\pi R_L}$$

Ripple current is,

$$I'_{AC}\text{ ripple} = \frac{\frac{4V_m}{3\pi\sqrt{2}}}{\sqrt{R_L^2 + (2\omega L)^2}}$$

$$I'_{AC}\text{ ripple} = \frac{\frac{4V_m}{3\pi\sqrt{2}}}{\sqrt{R_L^2 + (2\omega L)^2}} = \frac{\frac{4V_m}{3\pi\sqrt{2}}}{2\omega L} = \frac{4V_m}{6\sqrt{2}\pi\omega L}$$

$[\because (2\omega L)^2 >> R_L^2]$

Ripple factor,

$$\gamma = \frac{I'_{A.C}}{I_{D.C}} = \frac{R_L}{3\sqrt{2}\omega L} = \frac{R_L}{3\sqrt{2}(2\pi f L)}$$

Consider $f = 50$ Hz.

Then,

$$\gamma = \frac{R_L}{3\sqrt{2}(2\pi \times 50 \times L)} = \frac{R_L}{(1332.86 \times L)}$$

The above equation indicates,

(i) $\gamma \propto \frac{1}{L}$, γ can be made small by increasing L, then good D.C regulation is obtained. But there is a limitation in using large value of L as its internal reactance comes into picture which cannot be neglected. Therefore, output D.C voltage is reduced.

(ii) $\gamma \propto R_L$, γ can be made small by reducing R_L but there is also limitation in decreasing R_L value. Therefore, within certain limitation semiconductor filter is good.

Q36. Explain the operation of HWR with capacitor filter with neat circuit diagram.

Ans:

Basically, a capacitor opposses the flow of dc signals and allows the flow of ac signals through it. This property is utilized to convert pulsating DC into pure form of DC. The circuit diagram for half wave rectifier with capacitive filter is as shown in figure (1),

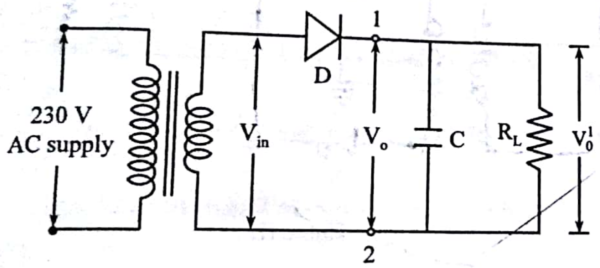
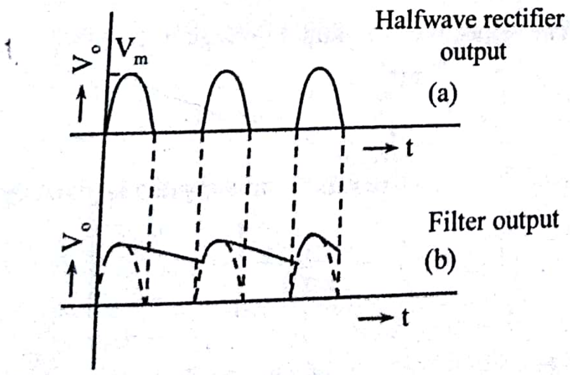


Figure (1): Half-wave Rectifier with Capacitor Filter

The output 'V_o' across the terminals 1 and 2 of the rectifier is as shown in figure 2(a).



(a) Output of Rectifier Across the Terminals 1 and 2

(b) Charging and Discharging of Capacitor Filter

Figure (2)

From figure 2(a) it is observed the output is not continuous, it contains periodic pulses. In other words, the output is present only for positive half cycles of input and absent for negative half cycles of the input. During the positive half cycle period, the capacitor charges itself to the peak value V_m of the positive cycle. During the negative half cycle period the capacitor is disconnected from the rectifier because diode is reverse biased or open circuited. As a consequence, the capacitor charged to 'V_m' starts discharging through load R_L. It means that capacitor provides current to the load R_L. This is as shown in figure 2(b).

The ripple factor for capacitor input filter is given by the expression,

$$\gamma = \frac{1}{2\sqrt{3}\omega CR_L}$$

Where,

C - Capacitance in 'F'

R_L - Load resistance in 'Ω'

Q37. With neat sketches explain the operation of FWR with shunt capacitor filter and derive the expression and its ripple factor.

(or)

Draw the circuit of full-wave rectifier with capacitor filter and explain the operation with necessary equations.

Ans:

Capacitor Filter

Basically, a capacitor opposses the flow of DC signals and allows the flow of ac signals through it. The circuit diagram for full-wave rectifier with capacitor filter is as shown in figure (1). The rectifier output across the terminals 1 and 2 in figure (1) is as shown in figure 2(a).

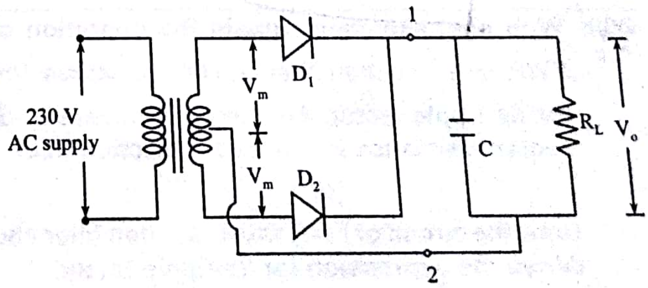


Figure (1): Fullwave Rectifier with C-Filter

This output, which contains both AC and DC components is applied to shunt capacitor (C).

The capacitor in the circuit allows only AC component and blocks DC component through it. The waveform of input and output are as shown in figure (2).

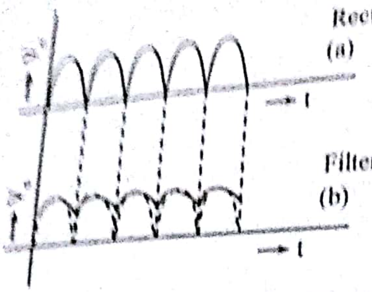


Figure (2): (a) Output Across Terminals 1 and 2 in figure (1)
(b) Output Across the load R_L Obtained by Charging and Discharging of Capacitor

Derivation for ripple factor

The output of the capacitor filter, that is, ripple voltage is a triangular wave.

Therefore r.m.s value of ripple voltage $= \dfrac{V_{pp}}{2\sqrt{3}}$

[For triangular wave]

$$\therefore V'_{r.m.s} = \frac{I_{D.C}}{4\sqrt{3}fC} \qquad \left(\because V_{pp} = \frac{I_{D.C}}{2fC}\right)$$

Since,

$$I_{D.C} = \frac{V_{D.C}}{R_L}$$

$$V'_{r.m.s} = \frac{V_{D.C}}{4\sqrt{3}fCR_L}$$

Ripple factor,

$$\gamma = \frac{V'_{r.m.s}}{V_{D.C}} = \frac{V_{D.C}}{4\sqrt{3}fCR_L}\cdot\frac{1}{V_{D.C}}$$

$$\boxed{\gamma = \frac{1}{4\sqrt{3}fCR_L}} \qquad \text{... (2)}$$

Q38. With neat sketches explain the operation of FWR with L-section filter and derive expression for its ripple factor. Also explain necessity of vector resistance in practical L-section filter.

(or)

Draw the circuit of FWR with L-section filter and derive the expression for its ripple factor.

Ans:

L-Section Filter

The filtering action of inductor and capacitor can be mixed into a single L-section filter as shown in figure (1). The output of the rectifier is applied across the inductor of the filter circuit (figure (1)), since the inductor opposes the ac component and allows dc component. Most of the ac component drops across the inductor and dc component passes through it.

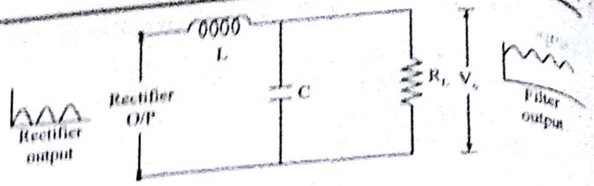


Figure (1): L-Section Filter

The output from inductor also contains some ripples. The capacitor which is in parallel to the load resistance (R_L) allows ac components to pass through it and block dc component. The dc component blocked by capacitor passes through the load (R_L). As a result, pure form of dc is obtained.

The ripple factor of L-section filter is given by expression:

$$r = \frac{\sqrt{2}}{12\omega^2 LC} = \frac{1}{6\sqrt{2}\omega^2 LC} = \frac{1.19}{LC}$$

Where,

L - Inductance in 'H'

C - Capacitance in 'F'.

Expression for γ

The basic circuit arrangement for full-wave rectifier with LC filter or L-section filter is shown in figure (2).

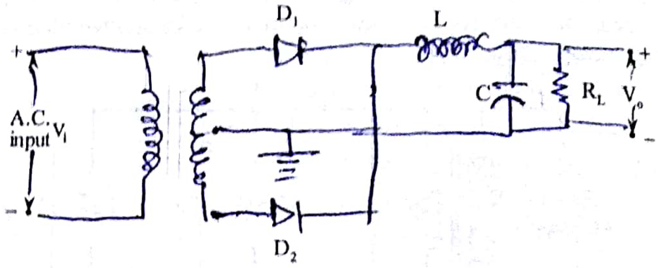


Figure (2)

Using Fourier series, the output of the L-section filter can be expressed as,

$$V_o = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi}\cos 2\omega t \qquad \text{... (1)}$$

The respective D.C output voltage is given by,

$$V_{D.C} = \frac{2V_m}{\pi} \qquad \text{... (2)}$$

And the respective r.m.s output current is given by,

$$I_{r.m.s} = \frac{I}{\sqrt{2}} = \frac{V}{\sqrt{2}X_L} \quad \left[\because I = \frac{V}{X_L}\right]$$

Here, V is A.C component amplitude i.e., $\dfrac{4V_m}{3\pi}$

$$\therefore \quad I_{r.m.s} = \frac{4V_m}{3\sqrt{2}\pi X_L} \qquad \text{... (3)}$$

The ripple voltage in the output is created by the current that flows through X_C. Then the respective r.m.s value of an A.C component is given by,

$$V_{\gamma,r.m.s} = I_{r.m.s} \cdot X_c = \frac{4V_m X_c}{3\sqrt{2}\pi X_L}$$

Substituting equation (2) in above equation, we have,

$$V_{\gamma,r.m.s} = \frac{4X_C}{3\sqrt{2}\pi X_L} \times \frac{\pi V_{D.C}}{2}$$

$$\Rightarrow \quad V_{\gamma,r.m.s} = \frac{2V_{D.C}}{3\sqrt{2}} \cdot \frac{X_C}{X_L} \qquad \text{... (4)}$$

Then, the ripple factor, γ is defined as the ratio of r.m.s value of A.C component to the D.C component in the output i.e.,

$$\gamma = \frac{\text{R.M.S. value of A.C component}}{\text{D.C value of component}} = \frac{V_{\gamma,r.m.s}}{V_{D.C}}$$

From equation (4), we have,

$$\gamma = \frac{\sqrt{2}}{3} \frac{X_C}{X_L} \qquad \text{... (5)}$$

Where,

X_C - Reactance of the capacitor at the second harmonic frequency.

X_L - Reactance of the inductor at the second harmonic frequency.

i.e., $X_C = \frac{1}{2\omega C}$, $X_L = 2\omega L$

Then, equation (5), becomes as,

$$\boxed{\gamma = \frac{1}{6\sqrt{2}\omega^2 LC}}$$

Q39. Write a short note on pi section filters. June-13, Q17(c)

(or)

Explain the working of a π-filter for full wave rectifier. July-12, Q11(b)

(or)

Discuss in detail about π-section filter.

Ans:

π-section filter is as shown in figure, it contains two capacitors C_1 and C_2 and one inductor (L), which are connected in the form of Greek letter 'π'.

π-section filters are used if,

1. The required voltage is higher than that can be obtained from L-section filter.
2. The required ripple factor is lower than that can be obtained from simple capacitor (or) L-section filter.

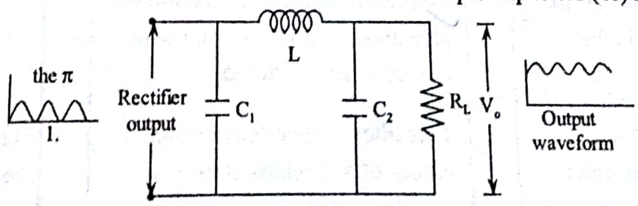
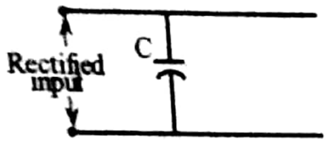
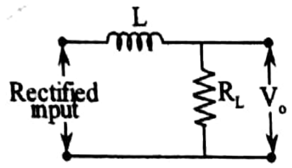
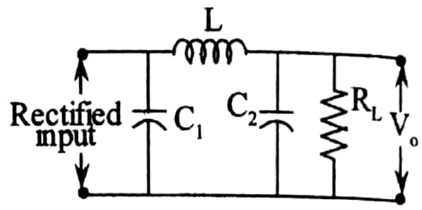


Figure: CLC Filter

The output of the rectifier is applied across the capacitor of the filter circuit (figure (1)), since the capacitor blocks dc component and allows ac component. The output from capacitor 'C_1' contains ac component and some sort of dc component which passes through inductor (L). Inductor (L) opposes the ac component and allows dc component through it. Most of the ac component drops across the inductor and dc component passes through it. The output from inductor also contains some ripples. The capacitor (C_2) which is in parallel to the load resistance (R_L) allows ac components to pass through it and blocks dc component. The dc component blocked by capacitor is passes through 'R_L'. As a result pure form of dc is obtained.

Compare the filtering characteristics of capacitor, inductor type and π-type filters.

The comparison of capacitor, inductor type and π-section filters is mentioned below:

S.No.	Capacitor Filter	Inductor or Choke Filter	CLC or π Filter
1.	The circuit arrangement for capacitor filter is shown in figure (1).  **Figure (1)**	The circuit arrangement for inductor filter is shown in figure (2).  **Figure (2)**	The circuit arrangement for π-section filter is shown in figure (3).  **Figure (3)**
2.	The expression for ripple factor is, $$RF = \frac{1}{4\sqrt{3} f C R_L} \left[\begin{array}{l} For \\ full \\ wave \end{array}\right]$$ $$RF = \frac{1}{2\sqrt{3} f C R_L} \left[\begin{array}{l} For \\ half \\ wave \end{array}\right]$$ The ripple factor depends on the circuit whose output is being filtered by the capacitor filter.	The expression for ripple factor is, $$RF = \frac{R_L}{3\sqrt{2}\omega L}$$ The ripple factor of choke filter also depends on the circuit whose output is being filtered.	The expression for ripple factor is, $$RF = \frac{\sqrt{2}}{8\omega^2 L C_1 C_2 R_L}$$
3.	This filter is operated at large values of C and R_L because the ripple factor is very small at these values.	This filter is operated at small values of R_L because it gives a very less ripple factor and requires very high values of L (for less ripple factor) which increases the cost.	This filter depends on load resistance R_L. This filter is generally preferred to operate at very high values of L, C_1 C_2, R_L R_L for small RF value.
4.	The ripple voltage depends on load current. (and load resistance)	The ripple voltage depends on load current.	The ripple voltage depends on load current, i.e., load resistance.

2.3 DESIGN OF RECTIFIERS WITH AND WITHOUT FILTERS

Q41. A diode with forward voltage 0.7 volts is connected as half wave rectifier. The load resistance 500 ohms and rms ac input is 22 volts. Determine the peak output voltage, peak load current and diode peak reverse voltage.

Ans: (Model Paper-I, Q13(a) | July-16, Q12(a))

Given that,

For an half wave rectifier,

Diode forward voltage, $V_D = 0.7$ V

Load resistance, $R_L = 500\ \Omega$

RMS ac input, $V_{rms} = 22$ V

Peak output voltage, $V_m = ?$

Peak load current, $I_L = ?$

Diode peak reverse voltage, $PIV = ?$

Then, the peak output voltage of an half wave rectifier is obtained as,

$$V_m = \sqrt{2}\, V_{rms}$$
$$= \sqrt{2} \times 22$$
$$= 31.113 \text{ V}$$
$$\boxed{\therefore V_m = 31.113 \text{ V}}$$

And the peak load current flowing through R_L is obtained as,

$$V_{rms} = I_L(R_f + R_L)$$
$$\Rightarrow V_{rms} = I_L R_f + I_L R_L$$
$$\Rightarrow V_{rms} = V_D + I_L R_L$$
$$\Rightarrow I_L R_L = V_{rms} - V_D$$
$$= 22 - 0.7$$
$$= 21.3$$
$$\Rightarrow I_L = \frac{21.3}{R_L}$$
$$= \frac{21.3}{500}$$
$$= 0.043 \text{ A}$$
$$\boxed{\therefore I_L = 0.043 \text{ A}}$$

And the diode peak reverse voltage of an half wave rectifier is given by,

$$PIV = V_m$$
$$= 31.113 \text{ V}$$
$$\boxed{\therefore PIV = 31.113 \text{ V}}$$

Q42. A full wave rectifier uses a diode with forward resistance of 1 ohm. The transformer secondary is centre tapped with output of 10-0-10 V rms and has resistance of 5 ohms for each half section. Calculate no load DC voltage. DC output voltage at 100 mA and % regulation at 100 mA.

Ans: (Model Paper-II, Q13(a) | Dec.-15, Q12(a))

Given that,

For a full wave rectifier with centre tapped transformer,

Diode forward resistance = 1 Ω

RMS voltage, $V_{rms} = 10$ V

Resistance of each half section, $R_s = 5\ \Omega$

No load DC voltage, $V_{DC(NL)} = ?$

For $I_{DC} = 100$ mA, DC output voltage, $V_{DC} = ?$

For $I_{DC} = 100$ mA, %regulation = ?

Then, the peak output voltage of a centre tapped full wave rectifier is obtained as,

$$V_m = \sqrt{2}\, V_{rms}$$
$$= \sqrt{2} \times 10$$
$$= 10\sqrt{2} \text{ V}$$

And the expression for no load DC voltage is given by,

$$V_{DC(NL)} = \frac{2V_m}{\pi}$$
$$= \frac{2 \times 10\sqrt{2}}{\pi}$$
$$= 9.0032 \text{ V}$$
$$\boxed{\therefore V_{DC(NL)} = 9.0032 \text{ V}}$$

And the DC output voltage for $I_D = 100$ mA is obtained as,

$$I_{DC} = \frac{2I_m}{\pi}$$
$$\Rightarrow I_m = \frac{\pi I_{DC}}{2}$$
$$= \frac{\pi \times 100}{2}$$
$$= 50\pi \times 10^{-3}$$

$$\text{But, } I_m = \frac{V_m}{R_f + R_s + R_L}$$
$$\Rightarrow R_f + R_s + R_L = \frac{V_m}{I_m}$$
$$\Rightarrow 5 + 1 + R_L = \frac{10\sqrt{2}}{50\pi \times 10^{-3}}$$
$$= 90.032$$
$$\Rightarrow R_L = 90.032 - 6$$
$$= 84.032\ \Omega$$

Then,

$$V_{DC} = I_{DC} R_L$$
$$= 100 \times 10^{-3} \times 84.032$$
$$= 8.4032 \text{ V}$$
$$\boxed{\therefore V_{DC} = 8.4032 \text{ V}}$$

And the % regulation is given by,

$$\%\text{regulation} = \frac{V_{DC(NL)} - V_{DC}}{V_{DC}} \times 100$$

$$= \frac{9.0032 - 8.4032}{8.4032} \times 100$$

$$= 7.14$$

$$\boxed{\therefore \%\text{ regulation} = 7.14}$$

Q43. A centre-tapped transformer has a 220 V primary winding and a secondary winding rate at 12-0-12 V and is used in a full-wave rectifier circuit with a load of 100 Ω. What is d.c output voltage d.c load current and the PIV rating required for diodes?

Ans: July-12, Q11(a)

Given that,

For a centre-tapped full wave rectifier circuit,

Voltage across primary windings, $V_{primary} = 220$ V

RMS value of output voltage , $V_{rms} = 12$ V

Load resistance, $R_L = 100\ \Omega$

DC output voltage, $V_{dc} = ?$

DC load current, $I_{dc} = ?$

Peak inverse voltage rating, PIV = ?

Then, the expression for peak output voltage of a centre-tapped full wave rectifier is given by,

$$V_m = \sqrt{2}\, V_{rms}$$

$$= \sqrt{2} \times 12$$

$$= 12\sqrt{2}\text{ V}$$

And the expression for DC output voltage is given by,

$$V_{dc} = \frac{2V_m}{\pi}$$

$$= \frac{2 \times 12\sqrt{2}}{\pi}$$

$$= 10.804\text{ V}$$

$$\boxed{\therefore V_{dc} = 10.804\text{ V}}$$

And the expression of DC load current is given by,

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

$$= \frac{10.804}{100}$$

$$= 0.108 \times 10^{-3}$$

$$\boxed{\therefore I_{dc} = 0.108\text{ mA}}$$

And the expression for peak inverse voltage of a centre-tapped full wave rectifier is given by,

$$PIV = V_m$$

$$= 12\sqrt{2}$$

$$= 16.97\text{ V}$$

$$\boxed{\therefore PIV = 16.97\text{ V}}$$

Q44. A 230 V, 60 Hz voltage is applied to the primary of a 5:1 step-down transformer used in a bridge rectifier having a load resistance of 400 Ω. Assuming the diodes to be ideal. Determine,

(a) D.C output voltage

(b) D.C power delivered to the load

(c) PIV

(d) Output frequency.

Ans:

Given that,

For a bridge rectifier using a step-down transformer,

Input primary voltage, $V_1 = 230$ V

Frequency, $f = 60$ Hz

Transformer's turns ratio, $N_1 : N_2 = 5:1$

Load resistance, $R_L = 400\ \Omega$

(a) D.C output voltage, $V_{d.c} = ?$

(b) D.C power delivered to the load, $P_{d.c} = ?$

(c) Peak inverse voltage, PIV = ?

(d) Output frequency, $f_0 = ?$

(a) **D.C Output Voltage**

The D.C output voltage is given as,

$$V_{d.c} = \frac{2V_m}{\pi} \quad \text{... (1)}$$

Where,

V_m – Maximum of secondary voltage

$$V_m = \sqrt{2}\ V_2 \quad \text{... (2)}$$

Where,

V_2 – Secondary voltage

The secondary voltage can be determined as,

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

$$V_2 = \frac{V_1 N_2}{N_1}$$

$$= \frac{230 \times 1}{5}$$

$$\therefore V_2 = 46\text{ V}$$

On substituting 'V_2' value in equation (2), we get,

$$V_m = \sqrt{2} \times 46$$

$$\therefore V_m = 65.05\text{ V}$$

On substituting 'V_m' value in equation (1), we get,

$$V_{d.c} = \frac{2 \times 65.05}{\pi}$$

$$\boxed{\therefore V_{d.c} = 41.41\text{V}} \quad \text{... (3)}$$

D.C Power Delivered to the Load

(b) The D.C power delivered to the load is given as,

$$P_{dc} = \frac{V_{dc}^2}{R_L} = \frac{(41.41)^2}{400} = \frac{1714.78}{400}$$

$$\boxed{\therefore P_{dc} = 4.286 \text{ W}} \quad \text{... (4)}$$

Peak Inverse Voltage

(c) The peak inverse voltage of bridge rectifier is given as,

$$PIV = V_m \quad \text{... (5)}$$

$$\boxed{\therefore PIV = 65.05 \text{ V}} \quad \text{... (6)}$$

Output Frequency

(d) The output frequency is given as,

$$f_0 = 2f \quad \text{... (7)}$$

$$= 2 \times 60$$

$$\boxed{\therefore f_0 = 120 \text{Hz}} \quad \text{... (8)}$$

Q45. A full-wave rectifier has a peak output voltage of 20 volts at 50 Hz and uses a shunt capacitor filter with C = 25 μF. The connected load is of 5 kΩ. Determine

(i) D.C load current

(ii) D.C output voltage

(iii) Ripple voltage and

(iv) Ripple factor.

June-13, Q11(a)

Ans:

Given that,

For a full wave rectifier with shunt capacitor filter,

Peak output voltage, $V_m = 20$ V

Operating frequency, $f = 50$ Hz

Capacitance, $C = 25$ μF

Load resistance, $R_L = 5$ kΩ

(i) DC load current, $I_{dc} = ?$

(ii) DC output voltage, $V_{dc} = ?$

(iii) Ripple voltage, $V_r = ?$

(iv) Ripple factor, $\gamma = ?$

(i) The expression for DC load current is given by,

$$I_{dc} = \frac{V_{dc}}{R_L} = \frac{18.518}{5\times10^3}$$

$$= 3.704 \times 10^{-3}$$

$$\boxed{\therefore I_{dc} = 3.704 \text{ mA}}$$

(ii) The expression for DC output voltage of a full wave rectifier with shunt capacitor filter is given by,

$$V_{dc} = \frac{V_m}{1 + \frac{1}{2fCR_L}}$$

$$= \frac{20}{1 + \frac{1}{2\times50\times25\times10^{-6}\times5\times10^3}}$$

$$= \frac{20}{1+0.08} = 18.518 \text{ V}$$

$$\boxed{\therefore V_{dc} = 18.518 \text{ V}}$$

(iii) The expression ...

$$V_r = \frac{V_{dc}}{2fCR_L}$$

$$= \frac{18.518}{2\times50\times25\times10^{-6}\times5\times10^3}$$

$$= \frac{18.518}{12.5}$$

$$= 1.481 \text{ V}$$

$$\boxed{\therefore V_r = 1.481 \text{ V}}$$

(iv) The expression for ripple factor is given by,

$$\gamma = \frac{1}{4\sqrt{3}fCR_L}$$

$$= \frac{1}{4\sqrt{3}\times50\times25\times10^{-6}\times5\times10^3}$$

$$= 0.0231$$

$$\boxed{\therefore \gamma = 0.0231}$$

Q46. A full-wave rectifier uses filter inductance L = 20 H and resistance R_L = 20 kΩ. A sinusoidal voltage V = 300 sin 314t is a applied to the input. Assuming rectified output to contain second harmonic only find,

(i) D.C load current

(ii) D.C output voltage

(iii) Ripple factor

(iv) Ratio of this ripple to that without inductor filter.

July-10, Q16(a)

Ans:

Given that,

For a full wave rectifier with inductor filter,

Inductance, $L = 20$ H

Resistance, $R_L = 20$ kΩ

Input sinusoidal voltage, $V_{in} = 300 \sin 314t$

(i) DC load current, $I_{dc} = ?$

(ii) DC output voltage, $V_{dc} = ?$

(iii) Ripple factor, $\gamma_{with} = ?$

(iv) Ratio of ripple factors with and without inductor filter, $\frac{\gamma_{with}}{\gamma_{without}} = ?$

It is assumed that rectified output contains second harmonic only.

(i) The expression for DC load current is given by,

$$I_{DC} = \frac{V_{dc}}{R_L}$$

$$= \frac{190.986}{20\times10^3}$$

$$= 9.549 \times 10^{-3}$$

$$\boxed{\therefore I_{DC} = 9.549 \text{ mA}}$$

(ii) Then, the expression for DC output voltage of a full wave rectifier with inductor filter is given by,

$$V_{dc} = \frac{2V_m}{\pi}$$

$$= \frac{2\times 300}{\pi} \quad [\because V_m = 300\text{ V}]$$

$$= 190.986\text{ V}$$

$$\boxed{\therefore V_{dc} = 190.986\text{ V}}$$

(iii) The expression for ripple factor is given by,

$$\gamma_{with} = \frac{R_L}{3\sqrt{2}\,\omega L} = \frac{20\times 10^3}{3\sqrt{2}\times 314\times 20}$$

$$= 0.751$$

$$\boxed{\therefore \gamma_{with} = 0.751}$$

(iv) The ripple factor for full wave rectifier without inductor filter is, $\gamma_{without} = 0.482$.

Then, the ratio of ripple factors with and without inductor filter is given by,

$$\frac{\gamma_{with}}{\gamma_{without}} = \frac{0.751}{0.482}$$

$$= 1.558.$$

$$\boxed{\therefore \frac{\gamma_{with}}{\gamma_{without}} = 1.558}$$

Q47. A single phase full-wave rectifier uses 300-0-300 V, 5 Hz transformer. For a load current of 60 mA, design L-filter using 10 H coil and a suitable capacitor to ensure a ripple factor of not more than 1%.

Ans: Dec.-12, Q11(a)

Given that,

For a single phase full wave rectifier with L-section filter,

RMS value of output voltage, $V_{rms} = 300$ V

Operating frequency, $\phi = 50$ Hz

Load current, $I_L = 60$ mA

Inductance of the coil, $L = 10$ H

Ripple factor, $\gamma \leq 0.01$

Capacitance, $C = ?$

Load resistance, $R_L = ?$

The, the expression for ripple factor of a single phase full wave rectifier with L-section filter is given by,

$$\gamma = \frac{1}{6\sqrt{2}\,\omega^2 LC}$$

But, $\gamma \leq 0.01$

$$\Rightarrow 0.01 \geq \frac{1}{6\sqrt{2}\,\omega^2 LC}$$

$$\Rightarrow C \geq \frac{1}{6\sqrt{2}\,\omega^2 L\times 10^{-2}}$$

$$\Rightarrow C \geq \frac{1}{6\sqrt{2}\times(2\pi\times 50)^2\times 10\times 10^{-2}}$$

$$\Rightarrow C \geq 11.94\times 10^{-6}\text{ F}$$

$$\boxed{\therefore C \simeq 11.94\,\mu\text{F}}$$

And the critical value of inductance for 50 Hz supply frequency is given by,

$$L \geq \frac{R_L}{943}$$

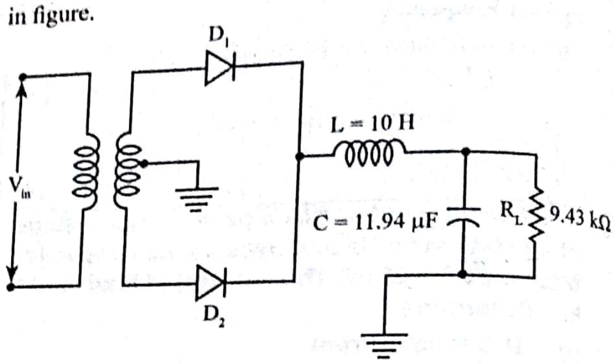
$$\Rightarrow R_L \leq 943L$$

$$\Rightarrow R_L \leq 943\times 10$$

$$\Rightarrow R_L \leq 9.43\text{ k}\Omega$$

$$\boxed{\therefore R_L \simeq 9.43\text{ k}\Omega}$$

Then, the circuit diagram of a single phase full wave rectifier using L-section filter with the designed values is shown in figure.



Figure

Q48. A single phase full wave rectifier makes use of π-section filter with two 10 μF capacitors and a choke of 10 H. The secondary voltage is 280 with respect to centre tap. If the load current is 100 mA. Determine the D.C output voltage and percentage ripple in the output. Assume supply frequency of 50 Hz. Jan.-12, Q11(a)

(or)

A single phase full-wave rectifier makes use of π-section filter with two 10 μF capacitors a choke of 10 H secondary voltage is 280 V_{rms} with respect to centre tap. If the load currents is 100 mA, determine the D.C voltage and percentage ripple in the output. Assume supply frequency of 50 Hz.

Ans: Dec.-10, Q11(a)

Given that,

For a single phase full wave rectifier with π-section filter,

Capacitances, $C_1 = C_2 = 10\,\mu$F

Choke, $L = 10$ H

Secondary voltage with respect to centre tap,

$V_{rms} = 280$ V

Load current, $I_L = 100$ mA

Supply frequency, $f = 50$ Hz

DC output voltage, $V_{dc} = ?$

Percentage ripple, $\gamma = ?$

Then, the expression for peak output voltage of a single phase full wave rectifier with π-section filter is given by,

$$V_m = \sqrt{2}\, V_{rms}$$
$$= \sqrt{2} \times 280$$
$$= 280\sqrt{2} \text{ V}$$

And the expression for DC output voltage is given by,

$$V_{dc} = \frac{2V_m}{\pi}$$
$$= \frac{2\times 280\sqrt{2}}{\pi}$$
$$= 252.09 \text{ V}$$

$$\boxed{\therefore V_{dc} = 252.09 \text{ V}}$$

And the expression for ripple factor is given by,

$$\gamma = \frac{\sqrt{2}}{8\omega^3 C_1 C_2 L R_L}$$

But, $R_L = \dfrac{V_{dc}}{I_L}$

$$= \frac{252.09}{100\times 10^{-3}}$$
$$= 2.521 \text{ k}\Omega$$

Then,

$$\gamma = \frac{\sqrt{2}}{8\times(2\pi\times 50)^3 \times 10\times 10^{-6}\times 10\times 10^{-6}\times 10\times 2.521\times 10^3}$$
$$= 2.262 \times 10^{-3}$$
$$= 0.226\%$$

$$\boxed{\therefore \gamma = 0.226\%}$$

Q49. A centre-tapped transformer has a 220 V primary winding and a secondary winding rate at 12-0-12 V and is used in a full-wave rectifier circuit with a load of 100 Ω. What is d.c output voltage d.c load current and the PIV rating required for diodes?

Ans: **June/July-11, Q11(a)**

Given that,

For a bridge rectifier with π-section filter,

Load current, $I_L = 200$ mA

DC output voltage, $V_{dc} = 30$ V

Choke, $L = 0.5$ H

Capacitance, $C_1 = C_2 = 80\ \mu$F

Supply frequency, $f = 50$ Hz

(i) Input rms voltage of the secondary of the transformer, $V'_{ac(r.m.s)} = ?$

(ii) Percentage ripple in the output, $\gamma = ?$

(i) Then, the expression for input r.m.s voltage of the secondary of the transformer in a bridge rectifier with π-section filter is given by,

$$V'_{ac(r.m.s)} = \frac{\sqrt{2}\, I_{dc}}{\omega^3 C_1 C_2 L}$$
$$= \frac{\sqrt{2}\times 200\times 10^{-3}}{(2\pi\times 50)^3\times 80\times 10^{-6}\times 80\times 10^{-6}\times 0.5}$$
$$= 2.851 \text{ V}$$

$$\boxed{\therefore V'_{ac(r.m.s)} = 2.851 \text{ V}}$$

(ii) The expression for percentage ripple in the output is given by,

$$\gamma = \frac{V'_{ac(r.m.s)}}{V_{dc}}\times 100$$
$$= \frac{2.851}{30}\times 100$$
$$= 9.503\%$$

$$\boxed{\therefore \gamma = 9.503\%}$$

Q50. A bridge rectifier is supplying a load of 200 mA at 30 V. It uses a π-section filter with a choke of 0.5 H an capacitors each of 80 μF. Assume supply frequency of 50 Hz. Find,

(i) The input r.m.s voltage of the secondary of the transformer and

(ii) The percentage ripple in the output.

Ans: **(Model Paper-II, Q12(b) | June/July-11, Q11(a))**

Given that,

For a bridge rectifier with π-section filter,

Load current, $I_L = 200$ mA

DC output voltage, $V_{dc} = 30$ V

Choke, $L = 0.5$ H

Capacitance, $C_1 = C_2 = 80\ \mu$F

Supply frequency, f = 50 Hz

(i) Input rms voltage of the secondary of the transformer, $V'_{ac(r.m.s)} = ?$

(ii) Percentage ripple in the output, $\gamma = ?$

(i) Then, the expression for input r.m.s voltage of the secondary of the transformer in a bridge rectifier with π-section filter is given by,

$$V'_{ac(r.m.s)} = \frac{\sqrt{2}\, I_{dc}}{\omega^3 C_1 C_2 L}$$
$$= \frac{\sqrt{2}\times 200\times 10^{-3}}{(2\pi\times 50)^3\times 80\times 10^{-6}\times 80\times 10^{-6}\times 0.5}$$
$$= 2.851 \text{ V}$$

$$\boxed{\therefore V'_{ac(r.m.s)} = 2.851 \text{ V}}$$

(ii) The expression for percentage ripple in the output is given by,

$$\gamma = \frac{V_{ac(r.m.s)}}{V_{dc}} \times 100$$

$$= \frac{2.851}{30} \times 100$$

$$= 9.503\%$$

$$\boxed{\therefore \gamma = 9.503\%}$$

2.4 ELEMENTARY TREATMENT ON THE FUNCTIONING OF TUNNEL DIODE, VARACTOR, PHOTO, LIGHT EMITTING DIODES - LIQUID CRYSTAL DISPLAY

Q51. Discuss briefly about tunnel diode and its characteristics.

Ans: Model Paper-I, Q13(b)

Tunnel Diode

Tunnel diode is a two terminal PN junction diode which is having high conductivity and high doping density. The doping density is 103 times greater than normal PN junction diode. This was first introduced by DR. Iw Esaki in 1958, hence it is also Esaki diode. The circuit symbol of tunnel diode is as shown in figure (1).

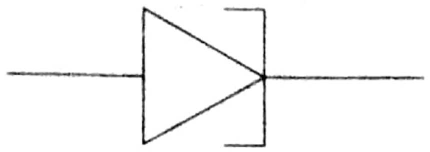


Figure (1): Symbol of Tunnel Diode

Explanation with Energy Band Diagrams

The operation of tunnel diode is explained with the help of energy band diagrams. Tunnel diode exhibit three distinct levels with respect to biasing and those are explained as follows,

Zero Bias Voltage

At zero biasing voltage, the energy levels are at the same heights until the electrons are excited (or) activated from the external source. The energy of electrons in N-side is insufficient to cross the junction barrier for reaching P-side. According to quantum mechanics, there is finite probability for electrons reaching one side to another side through junction provided there is allowed empty energy status in P-side of the junction at the same energy level therefore forward current is zero and it is shown in figure (2).

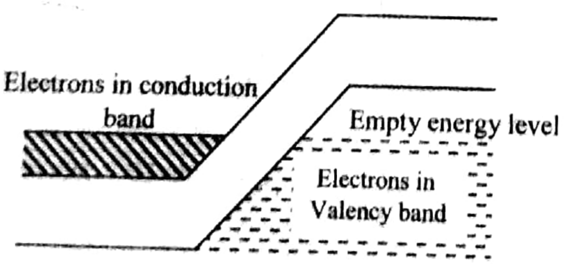


Figure (2): Zero Bias Voltage

Forward Bias Voltage

When small forward bias voltage is applied to junction the energy levels of N-side are higher than P-side to empty energy levels in P-side, tunneling of electrons takes place from N side to P side. Tunneling in reverse direction is not possible because the valency band electrons on P-side are opposite to the forbidden energy gap on the N-side. The energy levels diagram during forward bias is as shown in figure (3).

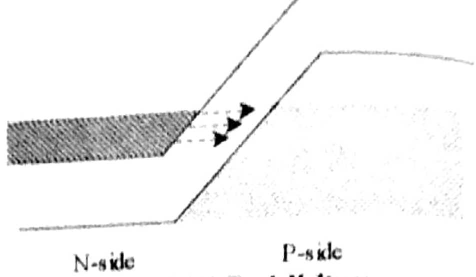


Figure (3): Peak Voltage

High Forward Bias Voltage: (Negative Resistance)

When the forward bias is increased beyond the limit the process of tunneling will decrease. The energy of P-side is depressed and it results fewer conduction electrons on N-side are opposite to the unoccupied electrons on P-side energy levels and it leads to decline of forward bias current, this results in the negative resistance region in diode characteristics. The energy level diagram as shown in figure (4),

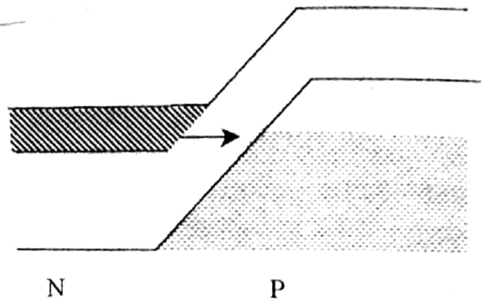


Figure (4): Valley Voltage

V-I Characteristics of Tunnel Diode

Figure (5) illustrates the typical characteristic of tunnel diode.

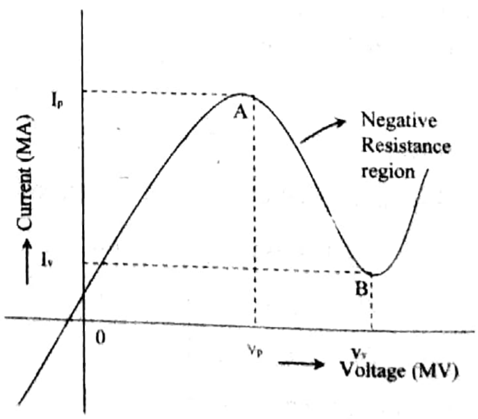


Figure (5): V-I Characteristics of Tunnel Diode

Forward current increases sharply in accordance with increase in applied voltage and it reaches the maximum point. The voltage (or) current at maximum point (or) peak point is referred as peak voltage (or) peak current.

After attaining peak point the forward current decreases slowly due to tunneling phenomenon, this region is indicated by points *A* and *B* in figure (5) and is referred as "*Negative Resistance Region*". After reaching certain point it again start to increase, the voltage at that point is referred as valley voltage and it is shown in figure (5).

Applications

Tunnel diode is used as,

1. Ultra high speed switch
2. As logic memory storage device
3. As microwave oscillatory
4. In relaxation oscillator circuit
5. As an amplifier.

Q52. Explain the working principle of varactor diode and draw its characteristics.

Ans:

A p-n junction diode that acts as a voltage variable capacitor under reverse bias condition is known as varactor diode. The symbol of varactor diode as show in figure (1).

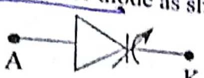


Figure (1)

Working Principle

Junction capacitance present in all reverse biased diodes because of depletion region is optimized in a varactor diode and used in high frequencies and switching applications. In other words, the dependence of junction capacitance C_j on the reversed bias voltage V_R is made useful in a number of applications.

Concept

The depletion layer created in the p-n junction acts as an insulator and the p-region and n-region act as plates of the capacitor. When the reverse voltage increases, the width of depletion layer increases and capacitance becomes smaller. The capacitance C_T of a varactor diode is determined using the equation.

$$C_T = \varepsilon \frac{A}{W_d} \quad \text{... (1)}$$

Where,

ε – Permittivity of semiconductor material

A – Cross-sectional area of the junction

W_d – Width of the depletion layer

The characteristic of varactor diode are as shown in figure (2),

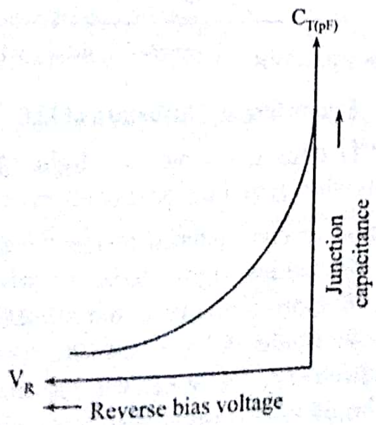


Figure (2)

Applications

1. Voltage controlled oscillators
2. RF filters
3. Self balancing bridge circuits
4. Automatic frequency control circuits and
5. Voltage tuning of LC resonant circuits.

Q53. Explain the construction and working of photo diode.

Ans:

Photo Diode

Photo diode is an opto electronic device in which light signals are converted into electrical signals by using photo omissive effect. When the light is incident on the material the electrons are ejected from the surface of the material is known as photo emissive effect. The symbol of photo diode is as shown in figure (1)

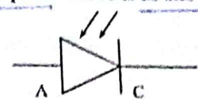


Figure (1): Symbol of Photo Diode

Construction

Figure (2) illustrates that the cross sectional view of photo diode. A thin heavily doped P-type layer is placed on the top of lightly doped n- type layer. The depletion region is formed between the p-type and n-type layer and it is deeply penetrates into n-type layer. The p-type layer is exposed to the light as shown in figure (2).

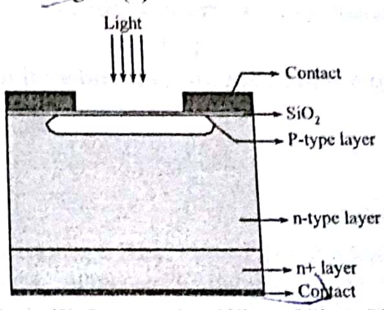


Figure (2): Constructional View of Photo Diode

Operation

When the light is illuminated on P-type layer, The photons from light energy will collides with valency electrons. From this the valency electrons gets sufficient energy to separate from the parent atoms In this manner electron hole pair are generated at PN junction, and there minority charge carriers results a reverse current flow . From this point it is clear that increasing the illumination causes increases in minority charge carriers and it results raise in reverse current flow the operation is briefly explained with the diagram as shown in figure (3).

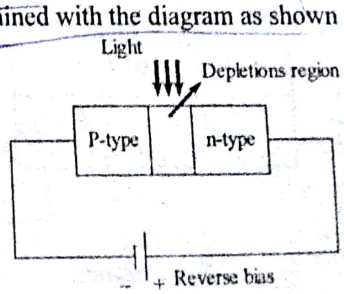


Figure (3): Operation of Photo Diode

Characteristics

Typical Photo diode characteristics are as shown in figure (4).

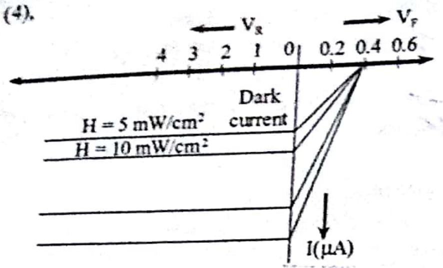


Figure (4)

When there is no light is applied the current flow through the diode is zero and that current is known as dark current. The plots are observed at different illumination levels .

Applications

1. Light detectors
2. Optical detector (or) demodulators
3. Sound track films
4. Electronic control circuits
5. Light operated switches
6. Computer punching cards and paper
7. Encoders.

Q54. Explain the operation of LED.

(or)

Explain the construction and working of LED.

Ans:

LED

Construction

A Light Emitting Diode (LED) is generally made up of elements such as Gallium, Phosphorus, which produce different types of LEDs with the emission of different coloured lights. For instance, LEDs made of Gallium Arsenide (GaAS) emit invisible infrared light while those constructed using Gallium Arsenide Phosphide (GaAsP) emit a red or yellow light. Similarly, LEDs formed using Gallium Phosphide (GaP) emit red or green light.

The cross-sectional view of a typically diffused LED is as shown in figure below.

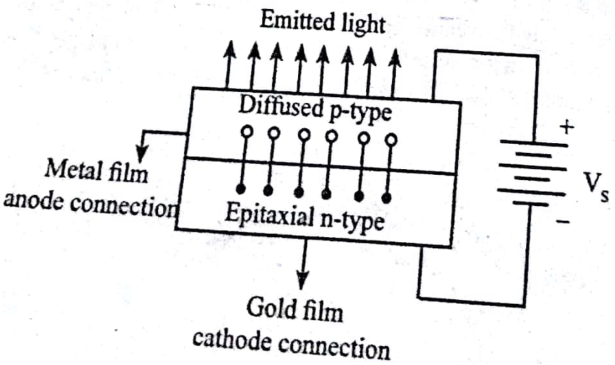


Figure: Construction of LED

An LED is constructed using semiconducting material. The N-region is formed by growing an N-type epitaxial layer over the substrate. The P-region is produced at the top through diffusion process. This P-region acts as the surface of device where actual recombination of charge carriers takes place. The outer edges of P-layer are connected to a metal film (anode) to increase the surface area for light emission. On the other hand, the bottom of the substrate is coated with a gold film (cathode), which reflects maximum possible light towards the device surface.

Working

A Light Emitting Diode (LED) works on the principle of electroluminance (i.e., when an electric field is applied to a semiconductor, light is emitted from it).

When the PN-junction of LED is forward biased, the free electrons from N-region diffuse into the P-region to recombine with holes present in it. Generally free electrons lie in the conduction band (higher energy level), whereas holes lie in the valence band (low energy level). Therefore, when an electron from a higher energy level combines with a hole belonging to low energy level, energy is released. This energy is emitted in the form of light. Hence, the name light emitting diode.

Q55. Explain the operation of an LCD.

(or)

Describe the working of LCD.

Ans:

An LCD is a Liquid Crystal Display, which comprises of a thin liquid crystal layer (of nearly 10 μm). This layer is placed between two glass sheets, which have transparent electrodes deposited on their inner faces.

The internal structure of an LCD is as shown in figure below:

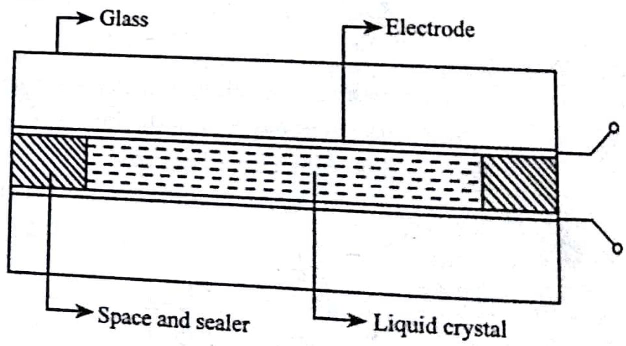


Figure: Internal Structure of LCD

The LCD does not have any light of its own, but displays visuals when light falls on it from any external source.

The liquid crystal material inside the cell is normally transparent to the incident light. However, when subjected to electric field, the molecules inside the crystal gets disturbed and polarizes the liquid. As a result, the transparent crystal turns into an opaque crystal. When the applied electric field is removed, the liquid crystal regains its original form and again becomes transparent to the incident light.

Depending on the method of construction employed, LCD's are classified as,

1. Dynamic scattering type LCD
2. Field effect type LCD.

1. **Dynamic Scattering Type LCD**

A dynamic scattering type LCD consists of a liquid crystal cell, which uses two glass plates. These glass plates are coated with tin oxide (TO_2) and are deposited with transparent electrodes at their inner faces. These electrodes are separated by a thin layer of liquid crystal (nearly 5 to 50 μm). In the absence of electric field, the liquid inside the crystal (with properly oriented molecules) shows transparency towards the incident light. But, when an electric field is applied to it, the molecules inside the liquid gets disrupted and scatter the incident light in all directions. As a result, the display gives a frosted glass appearance with a silver display.

2. **Field Effect Type LCD**

A field effect type LCD uses two polarizers (front and back) which are placed perpendicular to each other. In the absence of electric field, the light is incident in the front polarizer, which rotates it by 90^{o}. The rotated light reaches the back polarizer and is reflected back. But on application of electric field, the molecules (inside the crystal) rotated by 90^{o}, which prevents the rotation of light in the fluid. As a result, light absorbed by the back polarizer, creating a dark appearance on the display.

Q56. Explain about Liquid Crystal displays (LCD's).

Ans:

Liquid Crystal Displays (LCD)

The displays are made from liquid crystals are known as liquid crystal displays . Liquid crystals are the liquids, which exhibits properties of solid. Generally the orientation of molecules in liquid is in random nature, Where as in liquid crystals in some crystalline pattern.

Construction and Working: Figure below Illustrates that the cross sectional view of liquid crystal cell as shown in below

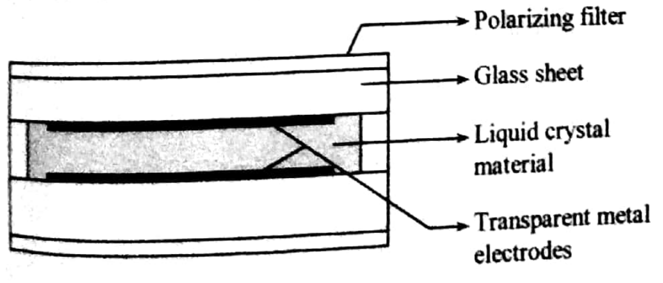


Figure: Cross-sectional View of Liquid Crystal Cell

A liquid crystal cell contains a liquid crystal material sandwiched between the two glass sheets. The transparent metal film electrodes are deposited on the inner sides of glass sheets . In twisted noematic all (frequently use liquid crystal) the two polarizing optical filters of size in thin manner are situated on the surfaces of glass sheets.

In twisted nematic all, the liquid crystal is employed in twisted manner. When the cell is not energized the light is passing through twists. These twists allows the light through polarizing filters so that the cell became a semi transparent when the all is energized the molecules in liquid crystal cell are reorientation , it results no twists in the cell so that no light is passed through the liquid crystal. Due to this the energized cell will appear as dark in the bright back ground . Even some cells are designed to appear bright against dark background.

Applications:

1. Calculators
2. Digital watches
3. Computer
4. Television
5. Higher end CRO's
6. All potable instrument displays.

2.5 CRO : STUDY OF BLOCK DIAGRAM OF CRO

Q57. Write short notes on Cathode Ray Oscilloscope (CRO).

(Model Paper-II, Q13(b) | July-16, Q17(c) | Dec.-15, Q17(b))

(or)

Draw the block diagram of CRO and explain each block in detail.

Ans:

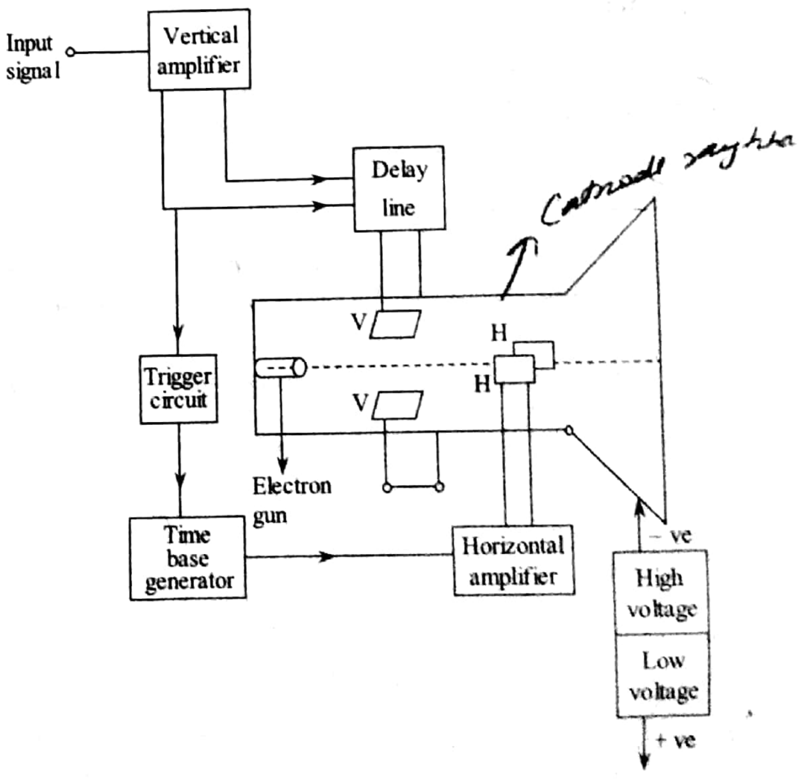


Figure: Basic Block Diagram of a CRO

The block diagram of a general purpose oscilloscope is illustrated in figure. It comprises,

1. Cathode ray tube
2. Vertical amplifier

3. Delay line
4. Time base circuit
5. Horizontal amplifier
6. Trigger circuit
7. Power supply

1. **Cathode Ray Tube**

Cathode ray tube (CRT) is the heart of the oscilloscope. When the electrons emitted by the electron gun strikes the phosphor screen of the CRT, a visual signal is displayed on it.

2. **Vertical Amplifier**

Vertical amplifier (or y-amplifier) is a wide band amplifier. It amplifies the input signals in the vertical section. As the input signals are not strong enough to drive the deflection plates, vertical amplifier is used to amplify the input signal to such an extent which can drive the deflection plates.

3. **Delay Line**

The delay line circuit is used to introduce a delay in feeding the output of vertical amplifier to the vertical deflection plates.

The horizontal deflection system is triggered by the output of the vertical amplifier. It takes certain amount of time (about 80 ns) for the signal to be processed through the circuitry of horizontal deflection system. Hence, the horizontal deflection plates receive the signal after a certain delay of time. As a result, the vertical deflection starts before the horizontal deflection (sweep). Due to this, the trace of leading edge of the input waveform will be missed. To avoid this problem, a delay line of 200 ns delay time is introduced between the vertical amplifier and vertical deflection plates.

4. **Time Base Circuit**

Time base circuit is a sawtooth waveform generator. It uses a unijunction transistor to produce the sweep or sawtooth voltage. The sawtooth voltage produced by the time base circuit is required to deflect the beam in the horizontal section.

5. **Horizontal Amplifier**

Horizontal amplifier is a circuit used to amplify the sawtooth voltage produced by the time base circuit before applying to horizontal deflection plates.

6. **Trigger Circuit**

Trigger circuit converts the incoming signals into corresponding trigger pulses. It is required to synchronize the input signal with the sweep frequency.

7. **Power Supply**

There are two voltages namely negative high voltage (HV) supply and positive low voltage (LV) supply are generated in the CRO. High voltage supply circuit generates high voltage power supply to accelerate, deflect and sweep the electron beam.

The range of negative high voltage supply is from – 1000 V to – 1500 V. The range of positive voltage supply is from 300 V to 400 V.

From ... that

1. The reverse saturation current I_s is a strong function of temperature. As a rule of thumb, the value of I_s double for every 7°C rise the temperature.

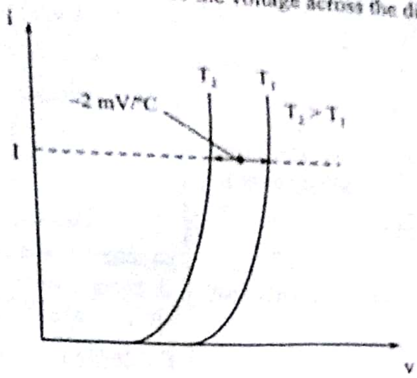
2. The thermal voltage V_T is given by, $V_T = \frac{T}{11,600}$

Where,

T is the absolute temperature in Kelvin.

Therefore, V_T is also a strong function of temperature.

Because both I_s and V_T are functions of temperature, the characteristics in forward region varies with temperature as shown in figure. At constant current, for every 1°C rise in temperature the voltage across the diode drops by 2 mV.



$C_J = \frac{dQ}{dV} = \frac{\epsilon A}{W}$

Figure: Temperature Dependence of V-I Characteristics of Diode

1.8 ZENER DIODES, ZENER VOLTAGE REGULATOR AND ITS LIMITATIONS

Q29. What is Zener diode?

July-15, Q11(b)

(or)

Explain the operation of Zener diode and mention its applications.

~~The power~~ dissipated at the junction of a normal PN diode operating

Ans:

Zener Diode

A heavily doped PN-junction diode, which always remains in reverse-biased condition is known as zener diode.

A zener diode is represented by the symbol as shown in figure (1).

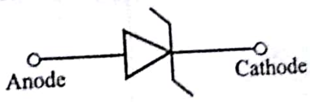


Figure (1): Zener Diode

Operation of Zener Diode

A zener diode always operates in the reverse biased condition. It is a heavily doped diode which reduces the width of depletion layer at the PN junction.

The V-I characteristics of a zener diode is as shown in figure (2).

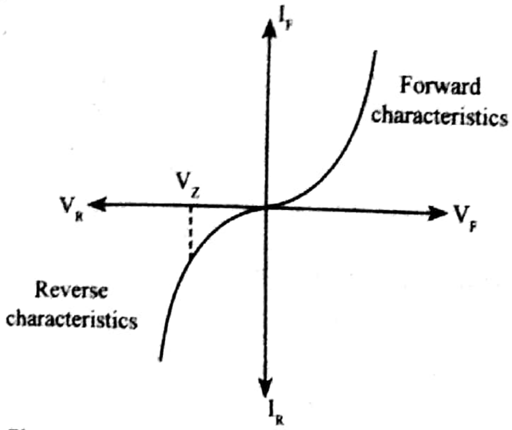


Figure (2): V-I Characteristics of Zener Diode

It can be observed from figure (2) that under forward biased condition, a zener diode operates like an ordinary diode. Under reverse-biased condition, an increase in reverse voltage (V_R), decreases the reverse current (I_R). A further increase in V_R, causes a sharp breakdown in I_R. Such breakdown in zener diode is called zener breakdown and the voltage at which breakdown occurs is called zener voltage (V_Z). After, the breakdown, zener diode operates with a constant voltage.

The breakdown in voltage largely depends on the amount of doping. If the diode is heavily doped, the width of depletion layer decreases and the breakdown occurs at a lower reverse voltage. On the other hand, if diode is lightly doped, a higher breakdown of voltage occurs.

Applications of Zener Diode

The important applications of zener diode are listed below:

1. Voltage regulator.
2. Clippers
3. Clamping circuits
4. Surge processors.

Q30. Explain why Zener diode is used as voltage regulator.

(Dec.-15, Q11(a) | June-13, Q11(b))

(or)

Draw the circuit of Zener voltage regulator. Explain its operation with neat characteristics and also derive the expression for maximum and minimum values of source resistor for the zener diode to work as regulator.

Ans:

Zener Regulator

A simple regulator circuit is constructed using Zener diode and it is as shown in figure. For the regulation operation zener diode is operated in break down (or) zener region. In the zener region, the voltage across the zener diode is constant for large variations of current passing from one side to other side of the diode.

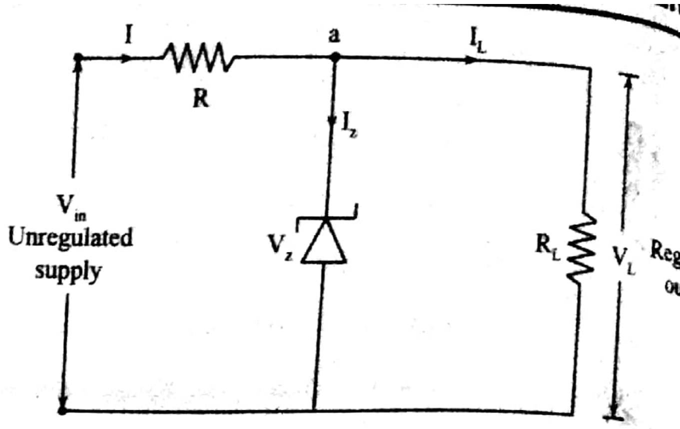


Figure: Simple Zener Diode Regulator

As seen from figure, until the input voltage 'V_{in}' t zener regulator is greater than breakdown voltage 'V_z' the function in the zener region and keeps the voltage acros load constant.

Apply KCL at node 'a' circuit shown in figure (1) get,

$$I = I_L + I_Z$$

And voltage across the load resistance is given as,

$$V_L = V_z + I_z R_z$$

Where,

V_L – Load voltage

V_Z – Zener voltage.

Small variations in the output voltage are observed d to zener resistance 'R_Z'. Changes in load current causes chang in zener current. Since $V_L = V_Z + I_Z R_Z$ changes in I_Z caus changes in output voltage or load voltage.

Limitation

This circuit is used only when the changes in the loa current and line voltage are small.