35

APPLICATIONS OF SEMICONDUCTOR DEVICES

35.1 INTRODUCTION

In the previous lesson we have learnt about the construction and properties of semiconductor devices like p-n junction diodes, zener diodes, LEDs and transistors. Their properties are so interesting that they find wide applications in items of everyday use which have become indispensable for modern life. Think of a common item like radio set, tape recorder, sound amplifier, T.V., telephone, intercom, automatic washing machine, electronic fan regulator and emergency light etc. Transistors and Diodes find application in each one of them.

Here we shall study only simple basic applications of these devices in power supplies, amplifier, and oscillator. We will also study about the working and simple circuit diagrams to realize the logic gates in this lesson.

35.2 OBJECTIVES

After studying this lesson, you should be able to:

- *use the diode as a rectifier;*
- *use the Zener Diode to stabilize the out put of a power supply;*
- *use a transistor as an amplifier;*
- *use a transistor as an oscillator to generate sine wave from a DC source;*
- *differentiate between analog and digital signals;*
- *explain the working of logic gates and their truth tables;*
- *design simple circuits using transistors and diodes to realize the logic gates; and*
- *use basic logic gates to design combination logic circuits;*

35.3 APPLICATIONS OF DIODES

As you know a semiconductor diode is an electronic device having two electrodes Anode and Cathode. They have asymmetric conducting property. In diodes the current is not proportional to the applied voltage like a resistance hence they are called non-linear devices. It is highly conducting when forward biased and non conducting when reverse biased. Depending upon the design of a diode they find different applications.

1. The p-n junction diode can pass large current and withstand high reverse voltages hence they are used as ***rectifiers***.
2. A diode with highly doped p and n regions and extremely thin depletion layer has low reverse breakdown voltage, hence it is used as a voltage stabilizer.

We shall consider the applications of these two types of diodes.

35.3.1 Diode as a Rectifier

Our domestic power is supplied at 220 V 50 Hz A.C. But all electronic devices need low voltage DC for their operation. So, for operating these devices from A.C. mains we use a step down transformer for lowering the A.C. voltage and a p-n junction diode for converting this AC into DC. ***A diode used for converting A.C. into D.C. is called a rectifier.***

(a) Half Wave Rectifier

A.C. from the mains supply is fed to a suitable step-down transformer. The desired low voltage A.C. is obtained across the secondary terminals X, Y. The load resistance R through which we want to pass D.C. is connected to X, Y terminals through the diode 'D' as shown in fig. 35.1.

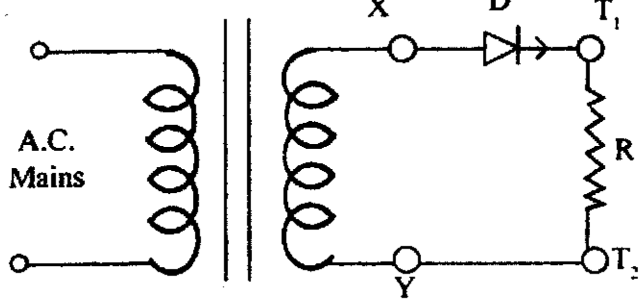


Fig. 35.1 : The half wave rectifier circuit

The potential of terminal X with respect to Y varies as a ***sine*** function with time as shown in fig. 35.2. Here we see that the polarity of X alternately becomes positive and negative with time. When the terminal X of the secondary is positive during the time 0 to $T/2$ the diode D is forward biased and current flows through R from T_1 to T_2. During the next half cycle i.e. from $T/2$ to T, the terminal X will be negative thereby making the diode reverse biased. Hence, the diode will not conduct and current through the load resistance will be zero as shown in the fig. 35.3. This process will be repeated during the next cycles.

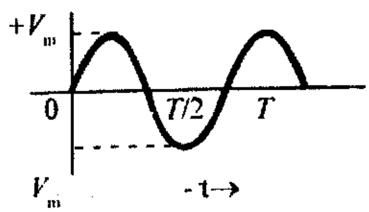


Fig. 35.2: *A.C input wave form.*

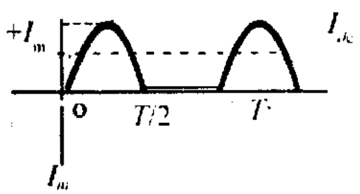


Fig. 35.3: *The H.W. rectified AC*

During the non conducting half cycle the maximum reverse voltage appearing across the diode, which has to be opposed by it to stop the flow of reverse current, is equal to the peak A.C. voltage that is 'V_m'. The maximum reverse voltage which a diode can oppose with out break down is called its **Peak Inverse Voltage** 'PIV'. For rectification we must choose a diode having PIV > peak A.C. voltage to be rectified by it, otherwise it will get damaged. This type of rectifier circuit in which the current flows only for half the cycle is called a **Half Wave Rectifier.** The D.C. voltage 'V_{dc}' across R as measured by a voltmeter is given by

$$V_{dc} = V_m / \pi \tag{35.1}$$

where V_m is the peak A.C. voltage. The D.C. current I_{dc} through the load resistance R is given by

$$I_{dc} = V_{dc} / R \tag{35.2}$$

The unidirectional current flowing through the load resistance due to rectified A.C. is not a pure D.C., but it is a fluctuating D.C. The fluctuating D.C. is a mixture of A.C. and D. C. The A.C. present in it, is called 'Ripple'. The ratio of the rms value of A.C. component to the D.C. component is called the ***ripple factor*** 'r'. For H.W. rectifier the ripple factor has been found to be 'r = 1.21'.

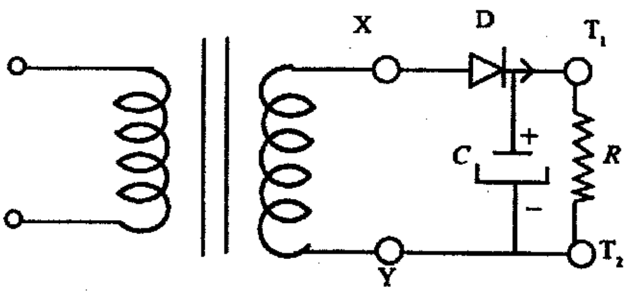


Fig. 35:4 : H.W. Rectifier with a capacitor filter

The fluctuating D.C. through the load can be converted into a more constant D.C. by connecting a large capacitor C across the load resistance as shown in fig. 35.4. The capacitor 'C' will get charged nearly to V_m during the conduction of diode and it will supply current to the load when diode is non conducting. Hence, the current through the load will never fall to zero and remain nearly constant with much less fluctuations as shown in fig. 35.5. The larger the value of the condenser and the load resistance the lower will be the fluctuations in the rectified D.C. The condenser C connected across the load to reduce the fluctuations in the rectified A.C. is called a filter condenser. When a filter condenser is used the peak inverse voltage to be opposed by the diode is ($2V_m$).

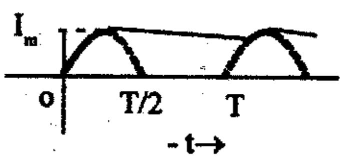


Fig. 35.5: wave form of current flowing through the load with a capacitor filter

(b) Full Wave Rectifier

For full wave rectification of A.C. we have to use a step down transformer with two identical secondary windings connected in series and two diodes D_1 and D_2 as shown in fig. 35.6. One end of the load resistance R is connected to the central point 'Y' of the secondary windings. The other end of R is connected to the cathode terminals of the two diodes D_1 and D_2. The anodes of the two diodes are connected to the two outer ends 'X and Z' of the secondary windings as shown in fig. 35.6. The potentials of ends X and Z with respect to Y are in phase opposition that is when potential of X is positive that of Z will be negative and vice versa. It is shown graphically in fig. 35.6 (a) and 35.6(b).

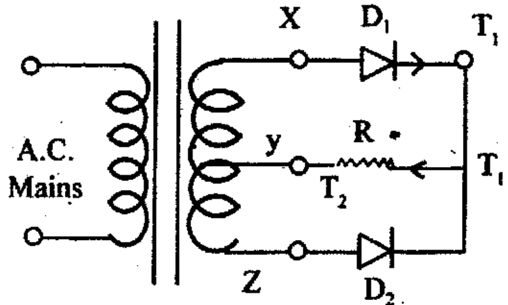


Fig. 35.6: Full wave rectifier circuit

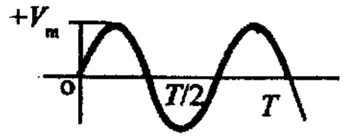
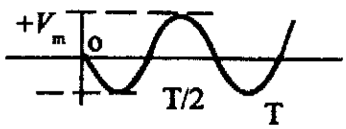


Fig. 35.6 (a) Potential of point X wrt Y



(b) Potential of point Z wrt Y.

To start with, say terminal 'X' is positive, 'Y' will be negative. Under this condition diode D_1 will conduct and D_2 will not conduct. Current will flow through the load from T_1 to T_2 as shown in fig. 35.7a. During next half cycle terminal 'X' will be negative and 'Y' will be positive. Under this condition diode D_2 will conduct and D_1 will not conduct and current will again pass through the load resistance in the same direction that is from T_1 to T_2 as shown in fig. 35.7 b.

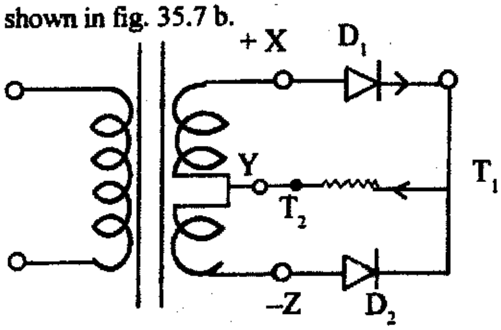


Fig. 35.7(a) when D_1 conducts.

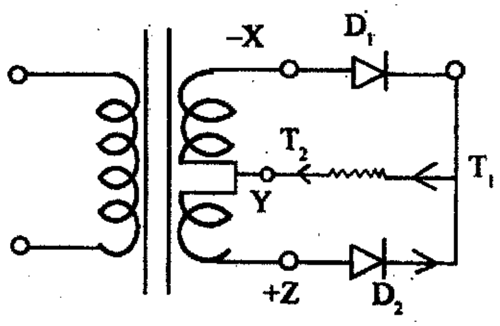


Fig. 35.7(b) when D_2 conducts.

The wave form of the current flowing through the load is shown in fig. 35.8. The fig. 35.7 (a) and 35.7 (b) show that the current flowing through the load resistance is uni-directional that is D.C. but again it is fluctuating as in H.W. rectifier. But the fluctuation in this case is much less and I_{dc} is much higher. The ripple factor 'r' for F.W. rectifier is found to be 'r = 0.482'. The D.C. voltage V_{dc} and D.C. current I_{dc} are given by

$$V_{dc} = 2 \times V_m / \pi \qquad (35.4)$$

$$I_{dc} = 2 \times V_{dc}/R \qquad (35.5)$$

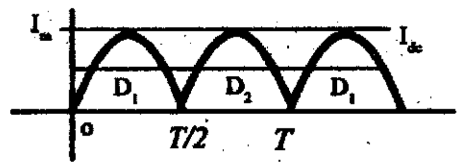


Fig. 35.8 : The current wave form through the load due to alternating condition of D_1 & D_2

Filter condenser can be used here as well to reduce the fluctuations and get purer D.C. as in the case of H.W. Rectifier. The current wave form with filter condenser in a F.W. rectifier is given in fig. 35.9.

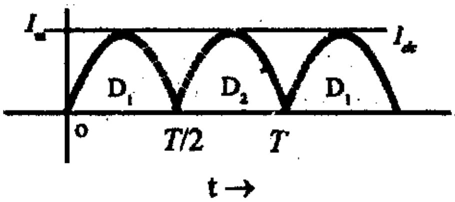


Fig. 35.9 : The current wave in a F.W. rectefied with a capacitor filter

Also when diode D_1 is conducting it behaves like a short circuit and brings the cathode of D_2 to the potential of terminal X whose maximum potential is $+V_m$ and the anode of D_2 is connected to terminal Y whose maximum potential is $-V_m$. Therefore, in this case the maximum reverse potential appearing across the non conducting diode will be 2 X V_m. The filter capacitor will not change the situation in this case.

35.3.2 Zener Diode as a Voltage Regulator

The H.W. and F.W. rectifiers with large filter capacitors described earlier are the simplest type of power supplies. They do provide almost pure D.C. but they suffer from a serious defect. When the load current is increased by decreasing the load resistance the output voltage falls and vice versa. Similarly if the A.C. input changes then also the D.C. output voltage varies. This type of D.C. supply with varying output voltage, affects the performance of the device being operated with it. If our device operated is, say an amplifier, the quality of sound reproduced by it gets deteriorated. The use of a Zener Diode with these simple power supplies removes this defect and gives constant D.C. output voltage against variation of both load current and A.C. input.

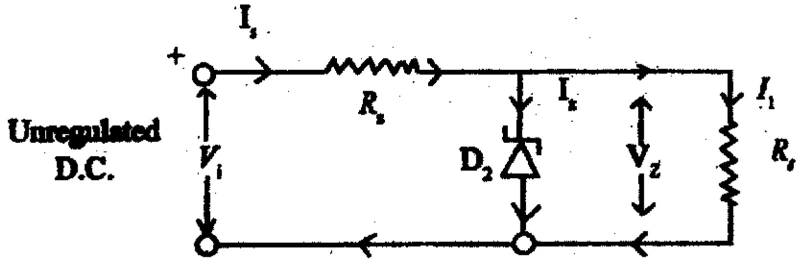


Fig. 35.10 : Zener diode used as a stablizer

The zener diode stabilizer circuit consists of a suitable series resistance 'R_s' and a zener diode with break down voltage 'V_Z' equal to the required stabilized output voltage V_O. The anode of zener diode is connected to the negative terminal of the input supply and the cathode is connected in series with R_s to the positive terminal of the input supply. The load resistance is connected across the zener diode as shown in fig.(35.10). The zener regulator will only operate if 'V_i' the input supply voltage to the regulator is greater than V_Z. After break down in the zener diode, the voltage across it remains nearly constant and the current through it rises very rapidly. This you have already learnt in section 35.7(a). The series resistance 'R_s' keeps it with in safe limit. The current 'I_s' flowing through R_s is given by the equation

$$I_s = (V_i - V_z)/R_s \tag{35.6}$$

This current divides in two parts, the zener current I_z and and the load current I_l. Applying Kirchoff's law we get

$$I_s = I_z + I_l \tag{35.7}$$

or $$I_z = I_s - I_l \tag{35.8}$$

For zener diode to operate, some current should always flow through it. Therefore, the load current I_l should always be less than the main current I_s.

If the load current is zero, the entire I_s will pass through the zener diode and output voltage V_O across T_1 and T_2 will be equal to V_Z. When we draw some load current say I_l, the zener current will decrease by the same amount and output voltage will again be equal to V_Z. Hence we see that output voltage is independent of load current. Similarly if the A.C. mains voltage increases or decreases the input voltage V_i will increase or decreases accordingly. It will result in change of I_s given by the equation (35.6). Due to change in I_s, the change in V_i will appear as a drop across the series resistance R_s and the zener voltage V_Z and hence V_O will remain almost unchanged. Thus we see that the output voltage has been stabilized against the variations of both the load current and the input voltage.

The power dissipation in zener diode is given by the equation

$$P_d = V_Z \times I_Z \tag{35.9}$$

This dissipation should never be allowed to exceed the maximum power dissipation recommended by the manufacturer for the zener diode. Due to this dissipation the diode gets heated up. Therefore, it should be cooled by using a proper heat sink.

Example 35.1: *If you are given that the load current varies from 0 to 100 mA Max and input supply voltage varies from 16.5 V to 21 V. How will you design a stabilized D.C. supply of 6 V.*

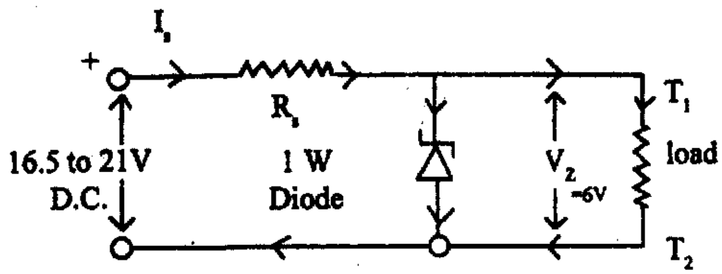


Fig. 35.11 Circuit of a 6V stabilizer

Solution :

For this purpose we should choose a zener diode of 6 V.

Let the current through the zener be (100+5) mA, when $I_l = 0$ mA.

Therefore $R_S = (16.5 - 6)/0.105 = 100$ ohm.

The current through the zener diode will be max, when input voltage is max, that is 21 V and $I_l = 0$.

Therefore the max. zener current $I_{max} = (21-6)/100 = .15$ A.

The max. power dissipation in the diode is $= 6 \times .15 = .9$ W.

Therefore we should use a zener diode of 6 V , 1 Watt. Provide it with proper cooling and connect the circuit as shown in fig.(35.11). It will give an output of 6 V stabilized against both load and input variations with in given limits.

INTEXT QUESTIONS 35. 1.

1. *In a half wave rectifier the diode conducts for*
   - a. *less than half a cycle of A.C.*
   - b. *half a cycle of A.C.*
   - c. *more than half a cycle of A.C.*
   - d. *full cycle of A.C.*
2. *In a F.W. rectifier the current flows through the load*
   - a. *for half cycle of A.C.*
   - b. *for full cycle of A.C.*
   - c. *for less than half a cycle of A.C*
   - d. *none of the above.*
3. *The D.C. voltage in a full wave rectifier is*
   - a. *equal to that in H.W. rectifier.*
   - b. *twice of that in H.W. rectifier.*
   - c. *less than that in H.W. rectifier.*
   - d. *zero.*
4. *What is the value of the ripple factor in a H.W. rectifier ?*
   - a. *1.21*
   - b. *0.482*
   - c. *0*
   - d. *2.*

35.4 APPLICATIONS OF A TRANSISTOR

We have studied about the construction and properties of transistors in details in the last lesson. Normally the collector is reverse biased and no current flows in collector emitter circuit. If we pass a very small current in the base circuit a very large current starts flowing in the collector circuit. It is this property which has made this tiny device indispensable for vast electronic applications. But here we shall consider only two basic applications. That is transistor as an amplifier and as an oscillator.

35.4.1 Use of Transistors as an Amplifier

The electrical signal is an electrical quantity like voltage or current which is coded with some useful information. For example when some one speaks in front of a microphone its diaphragm vibrates and induces a very weak voltage in its coil which varies in accordance with the sound. This induced voltage is the signal. It is generally very weak and can not operate a loud speaker to reproduce the sound. To make it intelligible it is fed to a device called an amplifier. **The amplifier increases the level of weak input signal and gives out strong magnified output.** If V_i is the input signal voltage fed to the amplifier and V_o the amplified output then the voltage gain of the amplifier is

$$A_V = V_o / V_i, \qquad (35.10)$$

similarly the current & power gains are

$$A = \frac{i_o}{i_i} \quad (35.11)$$

$$A_p = \frac{P_o}{P_i} \quad (35.12)$$

'Decibel' The Unit of power gain

Human ear can hear right from an extremely feeble whisper having a level of few micro watt to the strong output of thousands of watts of a powerful amplifier. The ratio of these two power levels is 10^9. To be able to hear such a wide range of power level the response of our ear is logarithmic and not linear. So, the power gain is measured in terms of a new logarithmic unit called a 'decibel or db' it is defined as

$$\text{db} = 10 \log_{10}(P_o / P_i) \quad (35.13)$$

For example, if for an amplifier the output power is twice the input power then the power gain is 3 db. If power output is 100 times then the gain is 20 db.

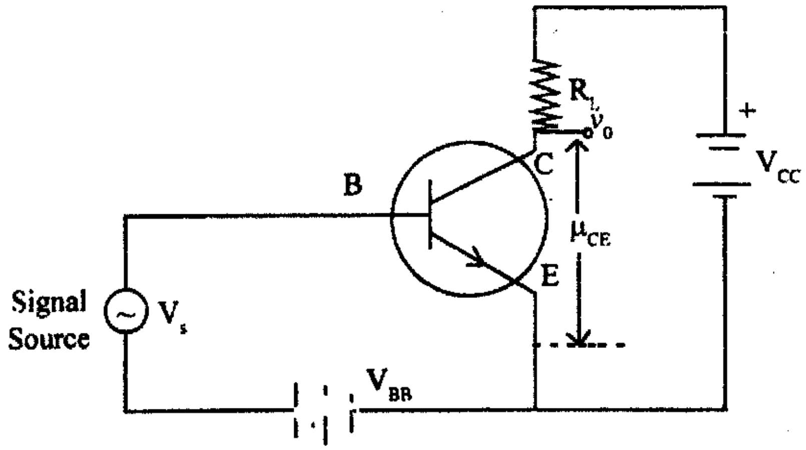


Fig. 35.12: Basic amplifier circuit using a n-p-n transistor in CE mode

To use the transistor as an amplifier the circuit is connected as shown in fig.(35.12). Here an n-p-n transistor is used in CE mode. Its collector is reverse biased through the load resistance R_L by the battery V_{CC}. When a base current I_b is passed by forward biasing the base some collector current I_c will start flowing. On decreasing I_b a stage will be reached when I_c becomes almost zero and stops decreasing. This is the lower limit of variation of I_b. Similarly on increasing I_b again a stage of saturation is reached and I_c stops increasing. This is the upper limit of variation of I_b. For faithful amplification of the input signal a base current equal to the mean of these two limiting I_bs is passed through the base by forward biasing it with the battery V_{BB}. This is called biasing of the base. A signal source providing an input signal of amplitude V_s is connected in series with the V_{BB} as shown.

Due to addition of oscillating signal voltage V_s to V_{BB} the base current changes by an amount i_b around the D.C. biasing current I_b. Care is taken to keep the signal voltage low so that the signal current i_b added and subtracted from I_b does not cross the upper and lower limits of the base current variation. Otherwise the transistor will go into saturation region and the amplified output will be highly distorted and noisy. The signal current i_b is given by

$$i_b = V_s/r_i \text{ where } r_i \text{ is the input impedance.} \tag{35.14}$$

This change in base current results in a large change of collector current say i_c, given by

$$i_c = \beta i_b = \beta V_s/r_i \tag{35.15}$$

where β is the A.C. current amplification factor given by 'I_c/I_b'. From (35.15) we get

$$V_s = i_c \times r_i/\beta \tag{35.16}$$

By Kirchoff's Law we have

$$V_{cc} = V_{ce} + I_c \times R_L \tag{35.17}$$

differentiating (35.17) gives

$$dV_{cc} = dV_{ce} + dI_c \times R_L = 0; \text{ because } V_{cc} \text{ is constant.}$$

therefore $dV_{ce} = -dI_c \times R_L$ (35.18)

but dV_{ce} is the output V_o and dI_c is i_c

therefore $V_o = -i_c \times R_L$ (35.19)

The voltage gain A_v of the amplifier will be given by

$$A_v = v_o/v_s = -(i_c \times R_L)/(i_c \times r_i/\beta) \tag{35.20}$$

$$= -\beta \times R_L/r_i \tag{35.21}$$

The ratio 'β/r_i' is called the transconductance 'g_m' of the transistor. Putting this in (35.21) gives

$$A_v = -g_m \times R_L \tag{35.22}$$

Negative sign indicates that input and output are in opposite phase that is they differ in phase by 180 degrees. The power gain is given by

$$A_p = A_i \times A_v = \beta \times A_v \tag{35.23}$$

Power gain does not mean that the law of conservation of energy is violated in an amplifier. The A.C. power output of the amplifier is more than the A.C. signal power input but this gain is achieved at the cost of D.C. power supplied by the battery.

35.4.2 Transistor as an Oscillator

An electronic oscillator is a device which generates continuous electrical oscillations. There are many types of electronic oscillators. Here we shall consider a tuned base oscillator. In this case a parallel LC circuit is used as a resonant circuit and a coil L_f is used to feed back energy to the resonant circuit. It can generate vide range of frequencies from audio to radio frequencies depending upon the choice of L, C and other components.

We know that when a charged capacitor is connected across an inductance the charge oscillates. But due to loss of energy by radiation and heating of wires the amplitude of oscillations decays with time and finally stops. In a transistor oscillator a part of oscillating current from the LC circuit is fed to the transistor amplifier. The amplified oscillating current feeds back energy to the LC circuit in phase to make good the loss of energy and produce continuous oscillations as explained below.

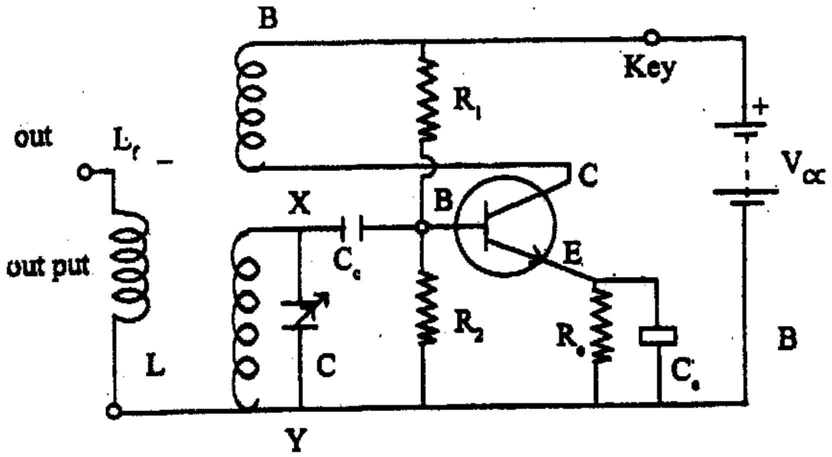


Fig. 35.13 : Oscillator cercuit using a n-p-n Transistor

The circuit diagramme of a tuned base oscillator is given in fig.(35.13). Here an n-p-n transistor is connected as a common emitter amplifier. The collector is reverse biased and connected to the battery V_{CC} through the feed back coil L_f. The potential divider consisting of R_1 and R_2 is used to forward bias the base and to fix its working point in the centre of the load line. Load line should be explained or this part should be moved the emitter is grounded through the resistance R_e. When the emitter current increases the potential drop across R_e increases too, which brings down the base potential and hence avoid the thermal run away of the transistor. A large by pass capacitor C_e is connected in parallel to Re in order to provide an easy path to the oscillating current. The LC circuit is coupled to the base through a small capacitor C_c . It allows an easy flow for the oscillating current from LC circuit to the base for amplification but does not allow the D.C. potential at the base to be shorted through L.

To start with, when the battery supply is switched on the collector current I_c starts increasing from zero. This increasing I_c induces a growing magnetic flux in the feedback coil L_f which links the inductance L of the tank circuit and induces emf in it such that its end X becomes positive and charges the condenser C with upper plate becoming positive. This positive potential coupled to the base of the transistor increases its base current and helps I_c to rise more rapidly till saturation stage is reached and I_c stops rising.

At this moment the magnetic flux in L_f becomes const.nt and there is no induction of emf. The capacitor now starts discharging through L and the potential of end X falls. The decreasing potential of X makes the I_c decrease which produces a decreasing magnetic flux in L_f. The decreasing flux induces a negative potential at the end X which in turn makes the I_c to fall more rapidly till the stage of cutoff is reached.

At this moment the condensur C is fully charged in opposite direction and starts discharging. The negative potential of X starts decreasing. This makes I_c to start rising again and the process goes on and on. Continuous oscillations are generated in the LC circuit. The oscillating current can be taken out from the output coil inductively coupled with the coil L.

The frequency of oscillation '*f*' is given by

$$f = \frac{1}{2\pi\sqrt{L \times C}} \tag{35.24}$$

Where L is the inductance of the coil in Henry and C is the capacity of condenser in farads.

INTEXT QUESTIONS 35.2.

1. *For a CE mode amplifier v_i is 20 mV and v_o is 1 V, then what will be the voltage gain?*

2. *The P_o of an amplifier is 200 times the P_i. How much will be the power gain ?*

3. *What is the value of the phase difference between v_i & i_c in a CE amplifier ?*

4. *For a CE amplifier $R_o = 2000\ \Omega$, $R_i = 500\ \Omega$ and $\beta = 50$. Compute the voltage gain and current gain for the amplifier.*

5. *An oscillator is producing 1000 H_z. If the feedback coil is rotated through 180° wrt resonant coil, then what will be the effect on oscillator ?*

35.5 LOGIC GATES

In the preceding sections we have considered the applications of diodes & transistors in the circuits dealing with analog signals. Now we shall consider applications in an another important fields in electronics that is digital circuits, which find wide applications in Digital Computers.

35.5.1 Analog and Digital signals

a) The Analog Signal: ***A signal which varies continuously with time between its minimum and maximum values is called analog signal.*** For example when a thermocouple is heated its output varies continuously with the rise of temperature. This is an example of analog signal. We come across this type of signal very often in every day life. It is highly susceptible to noise. The radio signal received in the aerial consists of variation of electrical potential. When there is lightening additional voltage is induced in the aerial which modifies the radio signal in an irregular manner and we get noise in the radio reception.

b) The Digital Signal: In contrast to the analog signal ***the digital signal varies in steps and has only two widely separated values '0 and 1'. These are called the 'bits'.*** 0 ± 1 V corresponds to bit '0' and 5 ± 1 V corresponds to bit '1'. A noise can not vary the signal beyond such large amounts of allowed variation in the bits, hence these signals are completely free from susceptibility to noise. A digital computer is based on these signals. It is free from errors due to noise and is highly reliable. ***The digital signal is coded with information by a series of bits arranged in different order.***

35.5.2 Concept of Gates

Gates are the devices which have one or more inputs and one output. They give different output when the input digits differ in their arrangement. The output produced by these gates follows the laws of Boolean logic. They find wide application in digital circuits.
Following are the three basic types of logic gates.

1. AND GATE 2. OR GATE 3. NOT GATE

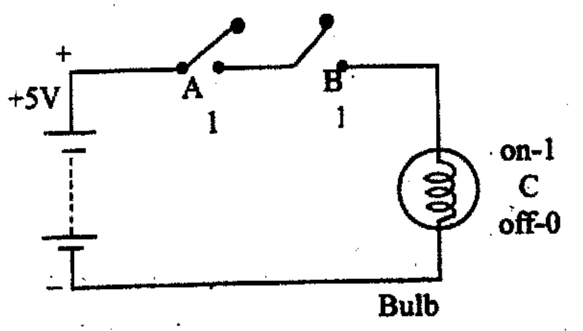
By combining these gates other gates obtained are

1. NAND GATE 2. NOR GATE 3. XOR GATE

Complex digital circuits are also formed by their combination.

(i) THE AND GATE

The AND GATE can have two or more inputs and only one output. The logic symbol of a two input AND GATE is given in fig.(35.14a). We can explain the behavior of an AND GATE with the help of a number of electrical switches connected in series. For a two input AND GATE two switches are connected as shown in fig.(35.14b) The switches A and B are the two inputs of the gate and bulb gives the output 'C'. The 'ON' switch stands for logic input '1' and 'OFF' switch stands for logic input '0'. The glowing bulb stands for logic output '1' and the non glowing bulb for logic output '0'. The input output correlation for an AND GATE is derived as explained below and shown pictorially in tabular form termed as the 'Truth Table' given in fig. (35.14c).



(b) Switch implementation of AND gate

(a) Symbol of AND gate

A	B	C
0	0	0
1	0	0
0	1	0
1	1	1

(c) Truth table of an AND GATE

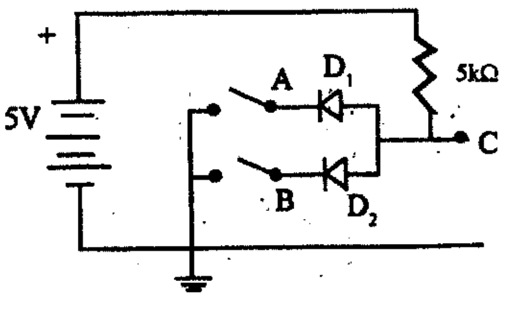


Fig. 35.14 *(d) Diode implementation of AND gate*

When both the switches are off the bulb is also off. The two inputs A & B are '0, 0' and output C is also '0'. This state is shown in column 1 of the truth table. When switch A is on and B off the bulb is off. The input A is '1', input B and output C are '0, 0'. This state is shown in column 2 of the table. When switch A is off and B on, input A is '0' and input B is '1' & C is '0'. This state is shown in column 3 of the table. When both the switches are on the bulb is also on. In this case both the inputs and the output are all '1'. It is shown in column 4 of the table. The truth table shows that an AND GATE gives output '1' only when both the inputs are '1'.

The *Boolean expression* for the AND operation is represented as
$C = A.B = AB = A \times B$ and read as A AND B.

Realization of AND GATE: The logic Gate realized by using diodes is called a DDL Gate (Diode -Diode Logic Gate). The diode implementation of a positive logic two-input AND GATE is shown in fig.(35.14d). The anodes of two diodes D_1 and D_2 connected in parallel are forward biased by a 6 V battery through a 5 KΩ resistance. The output is taken from the anode and the two cathode wires A & B serve as input terminals. When either A or B or both the terminals are grounded the respective diode will conduct and potential will drop across the resistance and output will be 0.7 V i.e. logic '0'. When both are up and connected to 5 V point no diode will conduct and output will be 5 V i.e. logic '1'.

(ii) OR GATE

The OR GATE can have two or more inputs and only one output. The logic symbol of a two input OR GATE is given in fig.(35.15a). We can explain the behavior of an OR GATE with the help of a number of electrical switches connected in parallel. For a two input OR GATE two switches are connected as shown in fig.(35.14b) The switches A and B are the two inputs of the gate and bulb gives the output 'C'. The 'ON' switch stands for logic input '1' and 'OFF' switch stands for logic input '0'. The glowing bulb stands for logic output '1' and the non glowing bulb for logic output '0'. The input output correlation for an OR GATE is derived as explained below and shown pictorially in the 'Truth Table' given in fig.(35.15c).

Fig. 35.15 (a) : Symbol of OR gate

A	B	C
0	0	0
1	0	1
0	1	1
1	1	1

Fig. 35.15(c): Truth table of an OR GATE.

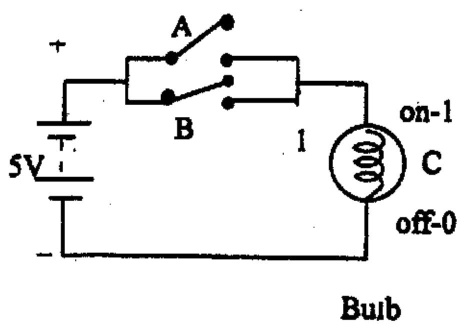


Fig. 35.15 (b) : Switch implementation of OR gate

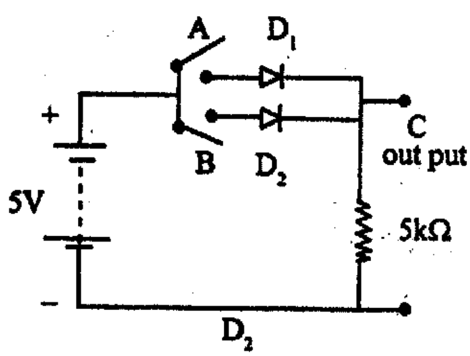


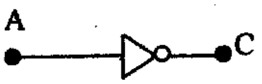
Fig. 35.15 (d) :Diode implementation of OR gate

When both the switches are off the bulb is also off. The two inputs A & B are '0, 0' and output C is also '0'. This state is shown in column 1 of the Truth Table. When switch A is on and B off the bulb is on. The input A is '1', input B is '0' and output C is '1'. This state is shown in column 2 of the table. When switch A is off and B on, input A is '0' and input B is '1' & C is '1'. This state is shown in column 3 of the table. When both the switches are on the bulb is also on. In this case both the inputs and the output are all '1'. It is shown in column 4 of the table. The Truth Table shows that an OR GATE gives output '1' when any or both of the inputs are '1'.

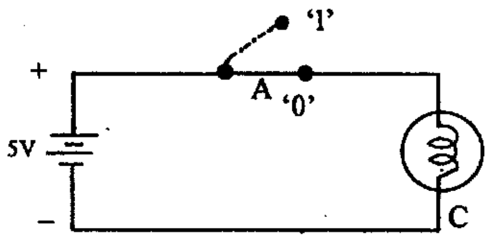
The Boolean expression for an OR operation is represented as
C = A + B and read as A OR B.

Realization of OR GATE: The diode implementation of a positive logic two-input OR GATE is shown in Fig.(35.15d). The cathodes of two diodes D_1 and D_2 connected in parallel are grounded through a 5 kΩ resistance. The output is taken from the cathode and the two anode wires A & B serve as input terminals. When either A or B or both the terminals are connected to the positive terminal of the 5V battery the respective deiode / deiodes will conduct and potential at the output will be 5.3 V e.i. logic '1'. When both are disconnected output will be 0 V i.e. logic '0'.

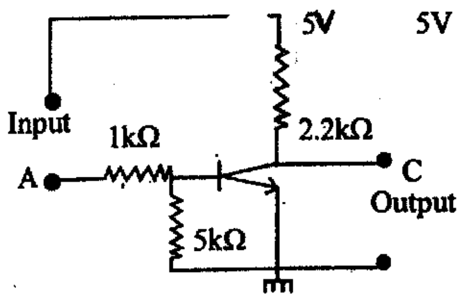
(iii) NOT GATE
A NOT GATE has one input and one output. It inverts the state of input hence it is also called an ***Inverter gate***. The logic symbol of a NOT GATE is given in Fig.(35.16a). Its behavior can be explained with the help of a switch connected as shown in Fig.(35.16b). Here the switch represent input 'A' and its value is taken as '0' when the switch is on and '1' when off. The bulb represents output with values assigned as in other gates.



(a) Logic symbol of a NOT Gate



(b) switch realizetion of a NOT Gate



(d) Transistor implementation

A	C
0	1
1	0

(c) : Truth Table of a NOT GATE.

Fig. 35.16

When the switch is on the bulb glows. In this case input 'A' is '0' and output 'C' is '1'. It is shown in column one of the Truth Table in fig.(35.16c). When the switch is off the bulb is off. In this case input 'A' is '1' and output is '0'.
The Boolean expression for a NOT operation is represented as

$$C = A \quad \text{read as inverse of A.}$$

Realization of NOT Gate: We know that output and input in a common emither transistor amplifier are 180 degree out of phase. This property of transistor is utilized for implementing the NOT gate using a transistor. The circuit diagramme of a NOT gate is shown in fig.(35.16d). When input terminal is connected to V_{CC} i.e. input is '1' the transistor goes into saturation and almost entire V_{CC} will drop across the 2.2 KΩ resistance and output will be '0'. When input is open i.e. '0' transistor will not conduct and there will be no voltage drop across the 2.2 kW resistance. The output voltage will be 5V, i.e.'1'

35.5.3 The Combination Circuits

The combination circuits are obtained by combining two or more basic gates. The simplest examples are the realization of NAND, NOR and XOR Gates.

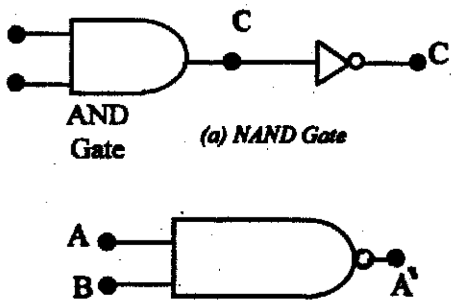
(i) The NAND GATE

The NAND GATE is obtained by combining an AND GATE and a NOT GATE as shown in fig.(35.17a). Here the output C' of AND GATE is inverted by the NOT GATE to get the final output C. The Logic symbol of a NAND GATE is given in fig.(35.17b). The Truth Table of a NAND GATE, given in fig.(35.17c) can be arrived at by inverting the output of the Truth Table of an AND GATE drawn earlier. The Truth Table of a NAND GATE shows that it gives output '1' only when both the inputs are together not '1'.
The Boolean expression for a NAND operation is represented as

$$C = \overline{A.B} = \overline{A \times B} = \overline{AB}.$$

A	B	C'	C
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0

(c) The Truth Table of a NAND GATE



(a) NAND Gate

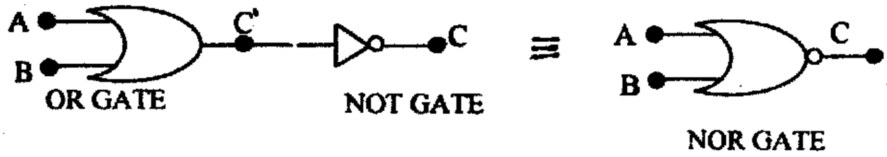
(b) Symbol of NAND gate

Fig.35.17

(ii) The NOR GATE

The NOR GATE is obtained by combining an OR GATE and a NOT GATE as shown in Fig.(35.18a). Here the output of OR GATE C' is inverted by the NOT GATE to get the final output C. The Logic symbol of a NOR GATE is given in fig.(35.18b). The Truth Table of a NOR GATE given in fig.(35.18c) can be arrived at by inverting the output of the Truth Table of an OR GATE drawn earlier. The Truth Table of a NOR GATE shows that it gives output '1' only when both the inputs are together '0'.

The Boolean expression for a NOR operation is represented as $C = \overline{A+B}$



(a) *(b)*

A	B	C'	C
0	0	0	1
1	0	1	0
0	1	1	0
1	1	1	0

(c) *Truth Table of NOR gate* (c)

Fig. 35.18 a, b, c

(iii) EXCLUSIVE OR GATE or EX-OR GATE

The Ex-OR GATE is a combination logic gate which gives output '1' if and only if one of the two inputs is '1'. Therefore, the simplest way of designing this gate from the basic logic gates is to draw the truth table for the EX-OR gate satisfying the above condition. Its logic symbol is given in fig.(35.19a).

The Truth Table satisfying the above condition for giving an output '1' is given below in the fig.(35.19b)

A	B	C
0	0	0
1	0	1
0	1	1
1	1	0

Fig. 35.19 (a) Logic symbol of an exclusive -OR gate *(b) Truth table of an exclusive-OR gate.*

This Truth Table can be realized from the following operations,

A	B	$A\bar{B}$	$\bar{A}B$	$A\bar{B}+\bar{A}B$
0	0	0	0	0
1	0	1	0	1
0	1	0	1	1
1	1	0	0	0

Fig. 3.19 (c) : Detailed operations for an EX-OR gate.

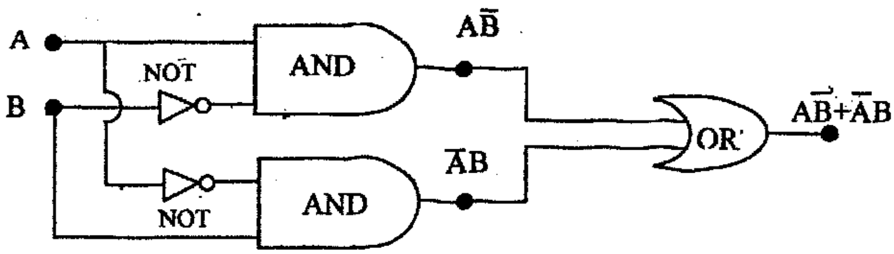


Fig. 35.19 (d): Implementation of X-OR Gate using basic gates.

This Truth Table is implemented by using five basic logic gates as shown in the circuit diagramme given in fig. (35.19d).
The Boolean expression for EX-OR Gate is $C = A\bar{B} + \bar{A}B$

35.5.4 REALIZATION OF BASIC GATES FROM NAND GATE:

The NAND GATE is considered to be a universal gate because all other gates can be realized by using this Gate along as shown below.

b) Realization of a NOT GATE using NAND GATE : If the two input leads of a NAND GATE are shorted together as shown in fig.(35.20a), the resulting gate is a NOT GATE.

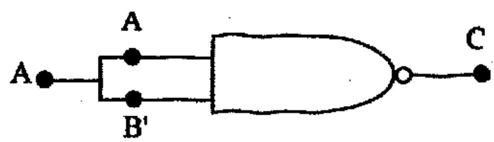


Fig. 35.20(a) NAND gate connected as NOT gate

c) Realization of an AND GATE using NAND GATE.: The AND GATE can be realized by using two NAND GATEs. The output of one NAND GATE is inverted by the second NAND GATE connected as an inverter as shown in fig.(35.20b). The combination acts as an AND GATE.

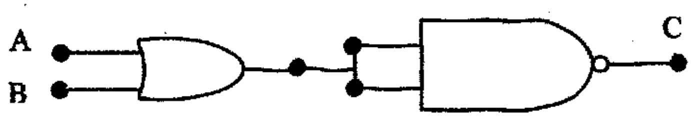


Fig. 35.20 (b) NAND gates connected to impliment AND gate

d) Realization of an OR GATE using NAND GATE: The OR GATE can be realized by using three NAND GATEs. Two NAND GATEs are connected as Inverter and their outputs of thered NAND GATE are fed to the the two inputs as shown in fig.(35.19c). The combination acts as an OR GATE.

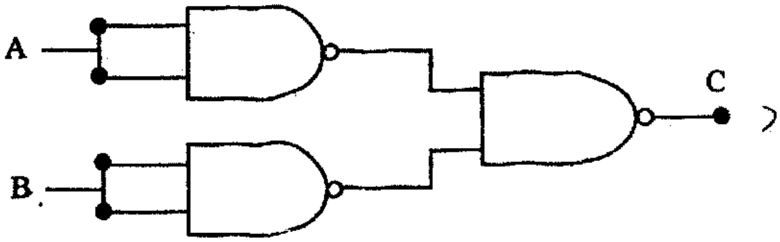


Fig. 35.20 (c) 3 NAND gates connected as OR gate

INTEXT QUESTIONS - 35.3

1. *The analog signal has*
   - *a. two discrete values.*
   - *b. only one value.*
   - *c. continuously varying values*
   - *d. none of the above.*
2. *AND Gate gives high output when*
   - *a. both inputs are zero.*
   - *b. one input is zero.*
   - *c. both inputs are one.*
   - *d. none of the above.*
3. *OR Gate give zero out put when*
   - *a. one input is zero.*
   - *b. both inputs are zero.*
   - *c. both inputs are one.*
   - *d. none of the above.*
4. *X-OR Gate give '1' output when*
   - *a. one input is zero.*
   - *b. both inputs are zero.*
   - *c. both inputs are one.*
   - *d. none of the above.*

35.6 WHAT YOU HAVE LEARNT

- A pn junction diode can be used as a rectifier to change A.C. into D.C.
- A H.W. rectified D.C. contains more A.C component than the F.W. rectified D.C.
- Filter capacitor reduces the A.C. component of rectified D.C.
- The output of an ordinary power supply changes with load and line variation.
- A zener diode stabilizes the output of a power supply against both load and input variation.
- A zener diode dissipates more power when the current taken by load is less.
- For amplification a transistor needs input current.
- A transistor has to be properly biased to get undistorted output.
- 'db' is the logarithmic unit of measuring power gain.
- 'db' = $10 \log_{10} (P_o/P_i)$.
- Transistor produces continuous oscillations due to its amplifying property.
- There are three basic logic gates called AND, OR & NOT.
- NAND gate is a universal gate because with it we can implement other gates easily.
- From the Truth Table of AND gate we see that
  $A.0 = 0$, $A.1 = A$ & $A.A = 0$.
- From the Truth Table of OR gate we see that
  $A + 0 = A$, $A + 1 = 1$ & $A + A = 1$.

35.7 TERMINAL QUESTIONS

1. Give the circuit diagramme of a F.W. rectifier. Explain its working.
2. How a capacitor makes a fluctuating D.C. purer D.C. ?
3. Explain how a zener diode is used to stabilze D.C.against load variation.
4. Why do we need biasing a transistor for using it as an amplifier ?

5. What should be the range of variation of amplitude of input signal for proper working of an amplifier ?
6. Can we go on increasing the gain of an amplifier by increasing the load resistance ?
7. Explain the working of a tuned base oscillator with necessary diagramme.
8. Give the circuit diagramme for realization of a NOT gate. Explain its working.
9. How do we realize the AND gate with NAND gates ?
10. How do we define an X-OR gate ? Give its truth table.
11. Implement an X-OR gate using basic gates.
12. Why NAND gate is called universal gate ?
13. How many inputs and outputs does a NOT gate have ?
14. If the value of L of a resonant circuit in doubled, then to keep the frequency unchanged what should be the change in the value of C ?
15. What is the value of phase difference between V_i and V_o in a CE amplifier ?
16. Why the signal voltage in an amplifier is taken very small ?
17. True - False
    a) Input capacitor in an amplifier is used for blocking D.C.
    b) CE amplifier provide both i and p gain but no v gain.
    c) In a CE amplifier if i_b increases then i_e also increases
    d) In a CE amplifier $i_b \simeq i_e$
18. The reverse voltage at which breakdown occurs is
    a) higher in zener diodes. b) lower in rectifier diodes.
    c) higher in rectifier diodes. d) same in the two diodes.
19. The peak A.C. voltage across the secondary of a transformer in a H.W. rectifier is V_m. The max. reverse voltage across the diode with out a filter capacitor is
    a) V_m. b) $V_m/2$.
    c) $2V_m$. d) none of the above.
20. The peak A.C. voltage across the secondary of a transformer in a H.W. rectifier is V_m. The max. reverse voltage across the diode with a filter capacitor is
    a) V_m b) $V_m/2$.
    c) $2V_m$. d) none of the above.
21. The peak A.C. voltage across one of the secondary windings of a transformer in a F.W. rectifier is V_m. The max. reverse voltage across the diode with a filter capacitor is
    a) V_m. b) $V_m/2$.
    c) $2V_m$. d) none of the above.
22. The peak A.C. voltage across one of the secondary windings of a transformer in a F.W. rectifier is V_m. The max. reverse voltage across the diode with out a filter capacitor is
    a) V_m. b) $V_m/2$.
    c) $2V_m$. d) none of the above.
23. The current flowing through a 5 V zener diode is 50 mA and a load current is 40 mA. The power dissipation in the zener
    a) 50 mW. b) 200 mW.
    c) 250 mW. d) 450 mW.

ANSWER TO INTEXT QUESTIONS

Intext Questions 35.1

1. b. 2. b. 3. b. 4. 1.21
5. 250 mw.

Intext Questions 35.2

1. Voltage gain is 50
2. Power gain is 23 db.
3. 0°
4. Voltage gain 200 and current gain 50.
5. The oscillator will stop working.

Intext Questions 35.3

1. a. 2. c. 3. b. 4 a.