

RADIO AMATEUR EXAM
GENERAL CLASS

By **4S7VJ****CHAPTER-4**4.1 **VACUUM TUBE (VALVE)**

Vacuum tube is a completely vacuum sealed glass tube containing number of electrodes. The outstanding difference between the vacuum tube and most other electrical devices is the electric current flow through empty space or vacuum. Free electrons in an evacuated space will be attracted to a positively charged object within the same space, or will be repelled by a negatively charged object. The movement of the electrons under the attraction or repulsion of such charged objects constitutes the current in the vacuum.

4.1.1 **THERMIONIC EMISSION**

If a metal plate or thin wire is heated to red-hot in a vacuum, electrons near the surface are given enough energy of motion to fly off into the surrounding space. The higher the temperature, the greater the number of electrons emitted. This emission of electrons called thermionic emission. The name for the emitting metal is cathode. Usually the cathode is made out of a thin metal tube and the filament is installed inside this tube without electrical contact. For small valves there is no separate cathode, filament itself acting as the cathode.

4.1.2 **CLASSIFICATION OF VALVES**

There are several types of valves according to the number of electrodes. (normally filament and cathode count as one electrode)

1. diode (two electrodes)
2. triode (three electrodes)
3. tetrode (four electrodes)
4. pentode (five electrodes)
5. Double diode (two separate diodes in the same tube)
6. Diode triode (a diode and a triode in the same tube)
7. Triode pentode

4.1.2.1 **DIODE VALVE**

There are two electrodes in the diode valve. One is the filament or cathode and the other one is the anode or plate, placed surrounding the cathode. As indicated in the diagram (Fig 4.1) the cathode is heating by the battery "A". "B" battery is supply the positive voltage to the anode.

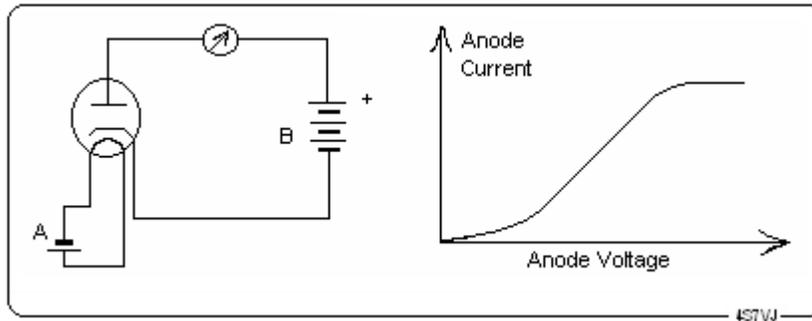


Fig. 4.1

The anode current increases with increasing the anode voltage. Anode current is zero with no anode voltage and the curve rises until a saturation point is reached.

The anode voltage multiplied by the anode current is the power input to the valve.

4.1.2.1.1 **RECTIFICATION**

Since current can flow through a valve in only one direction, a diode can be used to change a.c. into d.c.

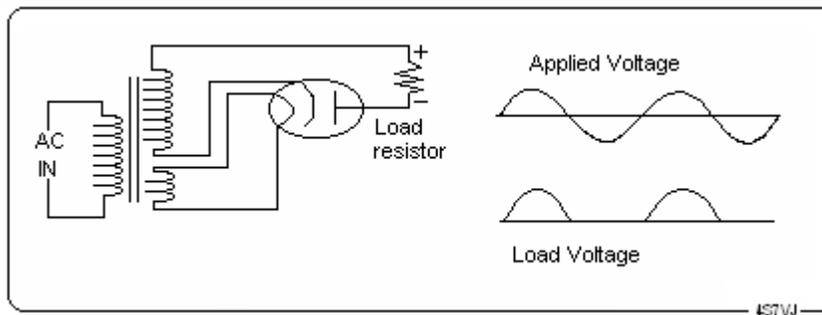


Fig 4.2

4.1.2.2 **TRIODE VALVE**

The third electrode, called the control grid or, simply grid is inserted between the cathode and plate as a coil or wire mesh. It can be used to control the effect of the valve if the grid is given a positive voltage with respect to the cathode the flow of electrons will be accelerated and anode current will be increase. If it is negative the electrons flow will be retard and anode current will be decrease.

If any signal introduced to the grid, anode current will be vary according to the signal or in other word the input signal will be amplify.

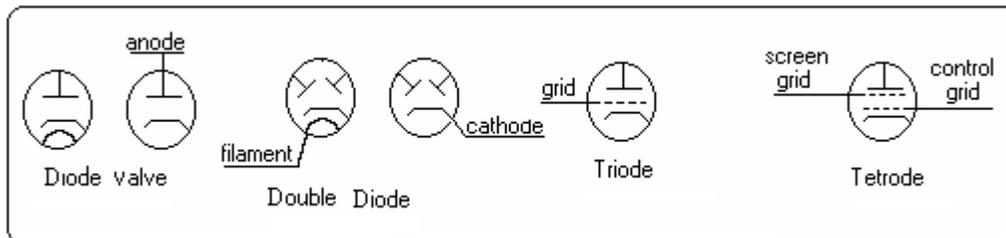


Fig 4.3

4.1.2.3 **TETRODE VALVE**

The fourth electrode, called the screen grid is inserted between the control grid and plate as a coil or wire mesh. The grid-plate capacitance can be reduced to a negligible value by inserting the screen grid. The grid-plate capacitance is very important for RF applications, because its reactance relatively low at RF, offers a path over which energy can be fed back from the plate to the grid and generates self-oscillations.

4.1.2.4 **CATHODE RAY TUBE**

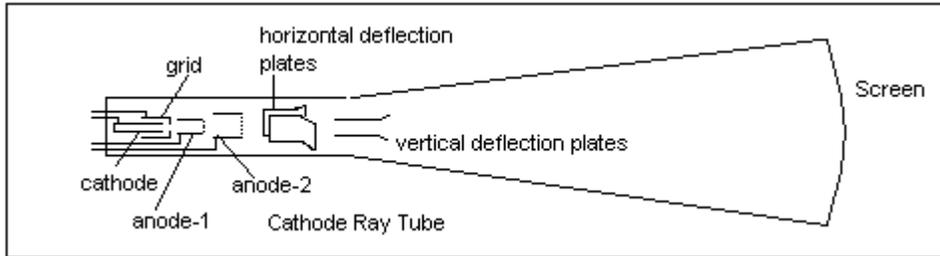


Fig 4.4

The heart of the Oscilloscope, Television and computer monitor is the Cathode Ray Tube (CRT). As with other vacuum tubes the filament heats the cathode (electron gun). The control grid influences the amount of current flow, as in standard vacuum tubes. Two cylindrical shaped anodes are employed, each having a positive voltage. These anodes accelerate the electron beam and focus into a narrow beam.

The intensity of the beam is varied according to the potential applied to the control grid. A high voltage is applied to the second anode so the electron stream will attain high velocity for increased intensity and visibility when it strikes the tube face.

As shown in the diagram two sets of plates are present in the tube beyond the second anode. These plates are for deflecting the electron beam both horizontally and vertically.

4.1.3 **VACUUM TUBE AMPLIFIER**

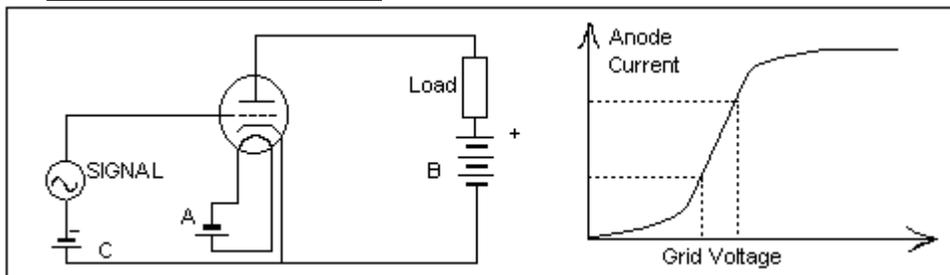


Fig 4.5

The diagram (Fig 4.5) shows a simple vacuum tube amplifier. Input signal connected to the control grid. The voltage supplied to the grid is called grid-bias (negative voltage). According to the input signal the voltage at the control grid is varying slightly. The same time anode current also varying considerable

amount according to the input signal. Therefore the input signal amplified by the vacuum tube.

4.2 **SOLID-STATE BASICS**

The conductivity of a material is proportional to the number of free electrons in the material. Pure germanium and pure silicon crystals have relatively free electrons. If however, carefully controlled amount of impurities are added, the number of free electrons, and consequently the conductivity, is increased. When certain other impurities are introduced an electron deficiency, or hole, is produced.

Semiconductor material having more free electrons called N-type material; material having more electron deficiency is called P-type material.

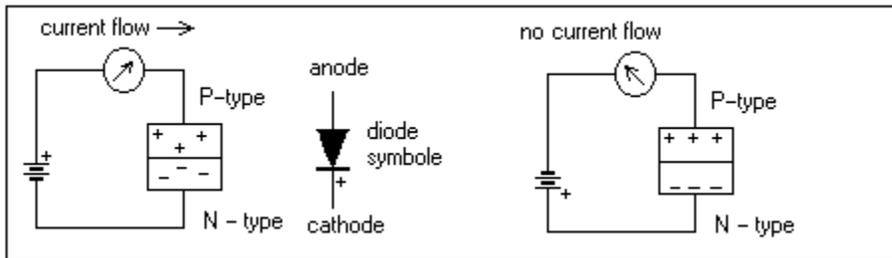


Fig 4.6

4.2.1 **SEMICONDUCTOR DIODE**

The vacuum tube diode has been replaced by the semiconductor diode in modern equipment designs. Advantages of solid state diode are as follows:-

1. More efficient because they do not consume filament power
2. They are very much smaller
3. They operate into the micro wave region, while most vacuum tube diodes are inactive above 50 MHz.

4.2.1.1 **TYPES OF DIODES**

There are three main types of diode

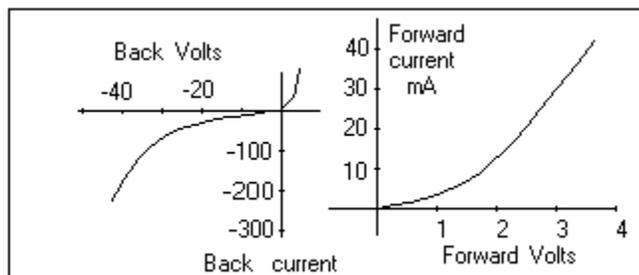
1. Selenium diode
2. Germanium diode
3. Silicon diode

SELENIUM DIODE

Selenium diodes used as rectifiers in early stages (before 1965). This is very low efficiency.

GERMANIUM DIODE

The Germanium diode is normally use for RF applications. Characteristic curve shown in the diagram. (Fig 4.7) The forward resistance is the order of 200 Ohms and reverse is around 100 k to one Megohm. The junction barrier voltage is about 0.3 volts.



SILICON DIODE

Most of power rectifier diodes are Silicon Junction Diodes. Forward current will be several milli amperes to about 100 Amperes. PIV (Peak Input Voltage) is 1000 V or greater. The junction barrier voltage is about 0.7 volts. The device temperature is one of the important parameters. Heat sinks are used with diodes that must handle large amount of power, thereby holding the diode junction temperature at a safe level.

4.2.1.2 VARIOUS APPLICATIONS OF DIODE

1. Diode as a rectifier
2. Diode as a gate
3. Zener Diode
4. Light Emitting Diode (LED)
5. Diode Detector (demodulator)
6. Switching diode
7. Varicap diode (variable capacitance)
8. Diode Frequency Multiplier
9. Gunn Diode
10. Solar-Electric Diode
11. Tunnel Diode
12. Current Regulator Diode

We will discuss only a few from the above list for the novice class.

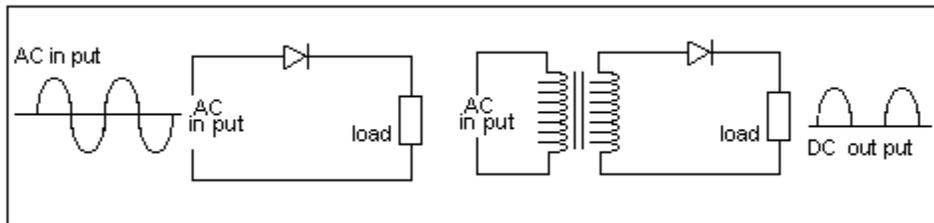
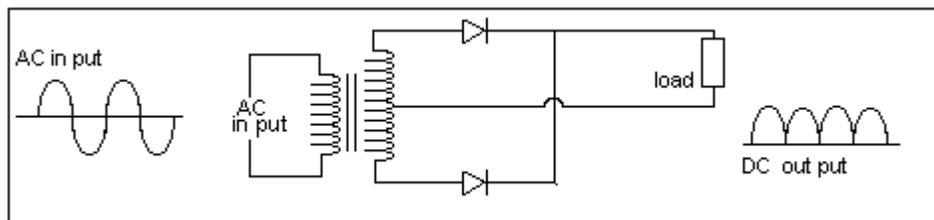
4.2.1.3 Diode as a rectifier**Half-wave rectifier**

Fig 4.8

The diagram (Fig 4.8) shows a simple half wave rectifier circuit. A diode will be conduct current in one direction but not the other. During one half of the A.C. cycle the diode will conduct and current will flow through the diode to the load. During the other half cycle the diode is reverse biased and no current will flow.

Full-wave rectifier**Center tap type**

A commonly used rectifier circuit is shown in the diagram. (Fig 4.9) A transformer with a center tapped secondary is required for this circuit.

Bridge rectifier

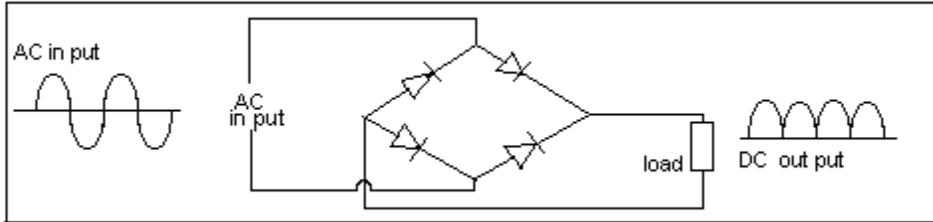


Fig 4.10

Another commonly used rectifier circuit is illustrated in the diagram (Fig 4.10) IN this arrangement two diodes operate in series on each half cycle.

4.2.1.4 Diode as a gate

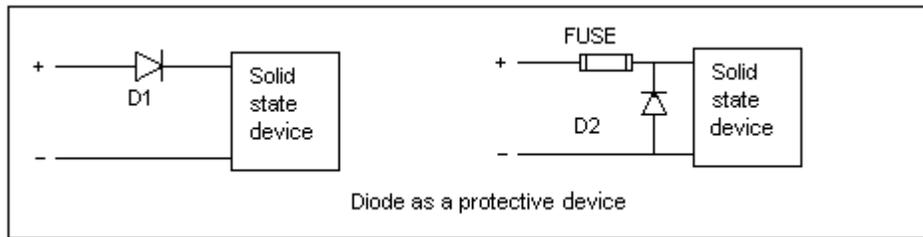


Fig 4.11

Diode can be placed in series with D.C. leads to function as a gate. It is active as a protective device. Should the operator mistakenly connect the supply leads in reverse the current will not flow through D1 (Fig 4.11-A).

A power type diode D2 can be used in shunt with the supply line (Fig 4.11-B) to the solid state device for protector purposes. If the supply polarity reversed accidentally, the fuse will be blown off due to the high current flow through D2.

4.2.1.5 ZENER DIODE

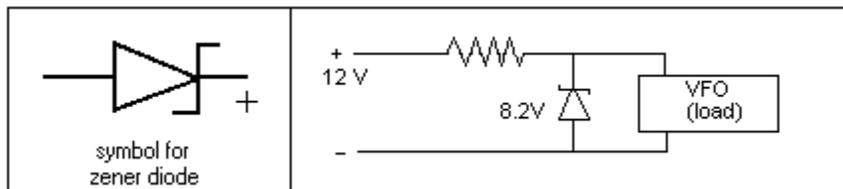


Fig 4.12

Some electronic devices needs a stable voltage, otherwise it will not function properly. For example VFO stage of transceiver

Zener diode can be used as a voltage regulator.

4.2.1.6 **Light-Emitting Diode (LED)**

The primary component in optoelectronics is the LED. This diode contains a P-N junction of crystal material that produces light around the junction when forward bias is applied. LED

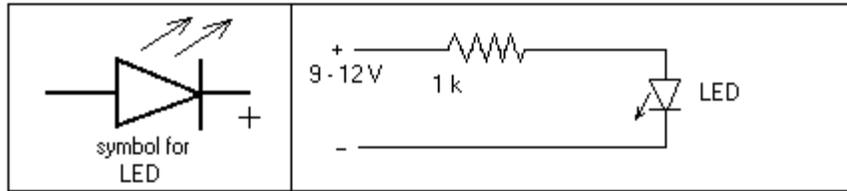


Fig 4.13

junctions are made from gallium arsenide (GaAs) , gallium phosphide (GaP) or a combination of both materials. The commonly available LED colors are red, green and yellow. Recently developed White and blue LEDs, and also multi coloured.

There are valuable advantages to the use of LEDs. Notable among them are the low current drain, long life and small size. They are useful as visual indicators. One of their most common applications is in digital display units , where arrays of tiny LEDs are arranged to provide illuminated segments in numeric display assemblies. The forward bias current for a typical LED ranges between 10 and 20 mA.

4.2.2 **TRANSISTOR**

The transistor was invented by Shockley, Bardeen and Brattain at Bell laboratories in 1947. It has become a standard amplifying device in electronic equipment.

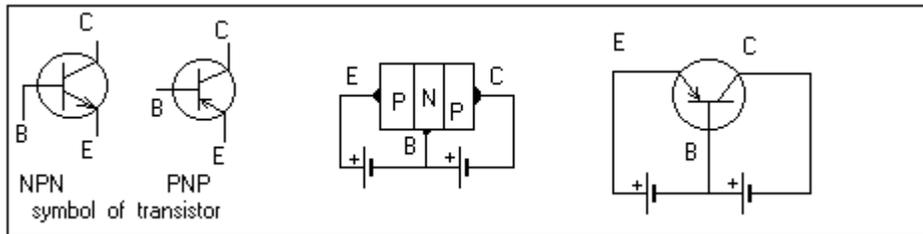


Fig 4.14

There are three terminals in the transistor called Collector, Emitter and Base.

The diagram shows a sandwich made from two layers of P-type material with a thin layer of N-type between. There are in effect two PN junction diodes back-to-back. If a positive bias is applied to the P-type material at the left, current will flow through the left hand junction to the right. That means holes moving from left to right and electrons moving from right to left. Some of the holes moving into the N-type material will combine with the electrons there and be neutralized, but some of them also will travel to the region of the right hand junction.

If the PN combination at the right is biased negatively ,as shown there would normally be no current flow in this circuit. However, there are now additional holes available at the junction to travel to point C (collector) and electrons can travel toward point E (emitter) so current can flow even though this section of sandwich is bias to prevent condition. Most of the current is between E and C and does not flow out through the common connection to the N-type material in the sandwich.

There are various types of transistors. Some of them are

1. Point-contact transistor
2. Junction transistor
3. Bipolar transistor
4. Field effect transistor (FET)
5. Metal oxide FET (MOSFET)

Normally transistor has three terminals (emitter, collector, base) FET also has three terminals named as gate, drain and source. MOSFET has more than one gate. These gates are very sensitive to static charges which can quickly puncture the insulation and cause a short circuit between the junctions. Similar care must be exercised when soldering a MOSFET. Power transistors need to be mounted on a heat sink. Small signal transistors (low power) do not require heat sinks.

TRANSISTOR CHARACTERISTICS

4.2.2.1 POWER AMPLIFICATION

According to the diagram (Fig 4.14) collector is reverse biased. So collector-base resistance is high. On the other hand the emitter and collector currents are substantially equal. So the power in the collector circuit is larger than the power in the emitter circuit. The powers are proportional to the respective resistances because the currents (I_e and I_c) are almost same and

$$\text{Power, } P = I^2 R$$

In practical transistors emitter resistance is on the order of a few Ohms while the collector resistance is hundred or thousand times higher, so power gain of 20 or 40 dB or even more are possible.

4.2.2.2 CURRENT AMPLIFICATION FACTOR **(Beeta-Factor β or HFE)**

An important characteristic of a transistor is its current amplification factor or 'BEETA'. It is defined as the ratio of the collector current to the base current.

$$\beta = I_c / I_b$$

Thus if base current of 5 mA causes the collector current to rise to 200mA, the $\beta = 40$ Typical BEETAs for transistors range from as low as 10 to as high as several hundreds.

4.2.2.3 MAXIMUM RATINGS

We need to be ever mindful of maximum safe ratings for semiconductors. These are listed on the manufacturer's data sheets and in various transistor manuals. Let's use the 2N3904 npn silicon transistor as an example. The maximum V_{ce} (collector to emitter voltage with the base open) is +40. The maximum I_c (steady collector current) is 200 mA. Maximum power is 1.5 watts. Now, let's learn what these ratings mean to us.

Transistors are likely to self-destruct if the forgoing ratings are exceeded, even for a moment. We should never operate any semiconductor at its maximum ratings. Better to operate your transistors at about half of the maximum ratings. Keep in mind that the transistor V_{ce} rises to twice the supply voltage when ac or RF energy is being amplified.

Transistor should not be allowed to operate when it is hot. Heat is the most dangerous enemy of semiconductors. Reduce the operating

parameters or use a heat sink when a transistor is more than comfortably warm to the touch.

4.2.2.4 TRANSISTOR AMPLIFIER

Amplifier circuits used with transistors fall into one three types, known as the common emitter (grounded emitter) , common base(grounded base) and common collector (grounded collector) circuits.

COMMON EMITTER CIRCUITS

The grounded emitter circuit shown in the diagram (Fig 4.15-a) corresponds to the ordinary grounded cathode vacuum tube triode amplifier. Input signal apply to the base and amplified output is going out from the collector. The base current is small and the input impedance is therefor fairly high, several kilo Ohms in the average case. The phase of the output (collector) current is opposite to that of the input (base) current so such feedback as occurs through the small emitter resistance is negative feedback and the amplifier is stable.

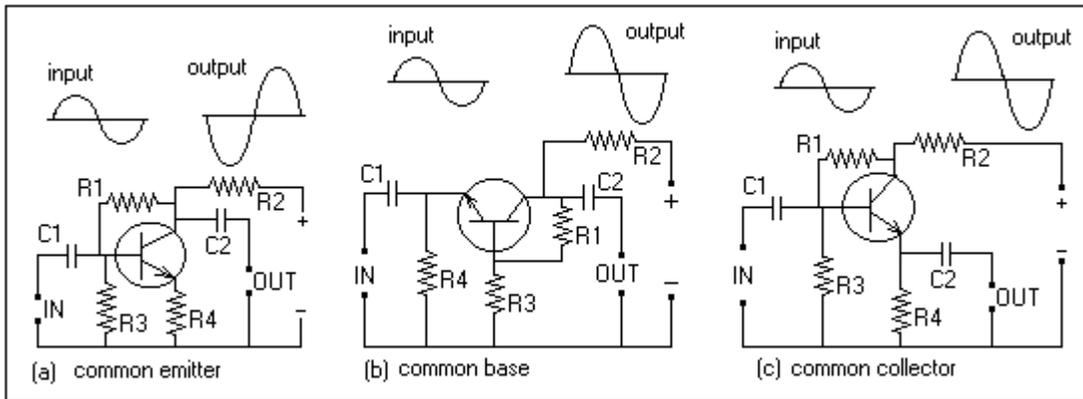


Fig. 4.15

COMMON BASE CIRCUIT

As shown in the diagram (Fig. 4.15-b) input signal is apply to the emitter for the common base amplifier and it is with low impedance. Output signal is going out from the collector, and the output impedance is few kilo Ohms. Input and output both are in phase.

COMMON COLLECTOR CIRCUIT

As shown in the diagram (Fig. 4.15-c) input signal is apply to the base and output is taking from the emitter. This amplifier has high input impedance and low output impedance.

4.2.2.5 CLASSES OF AMPLIFIERS

4.2.2.5.1 CLASS-A AMPLIFIER

A class-A amplifier is one operated so that the wave shape of the output is the same as the input. The operating region is in the linear portion of the curve.(Fig 4.16)

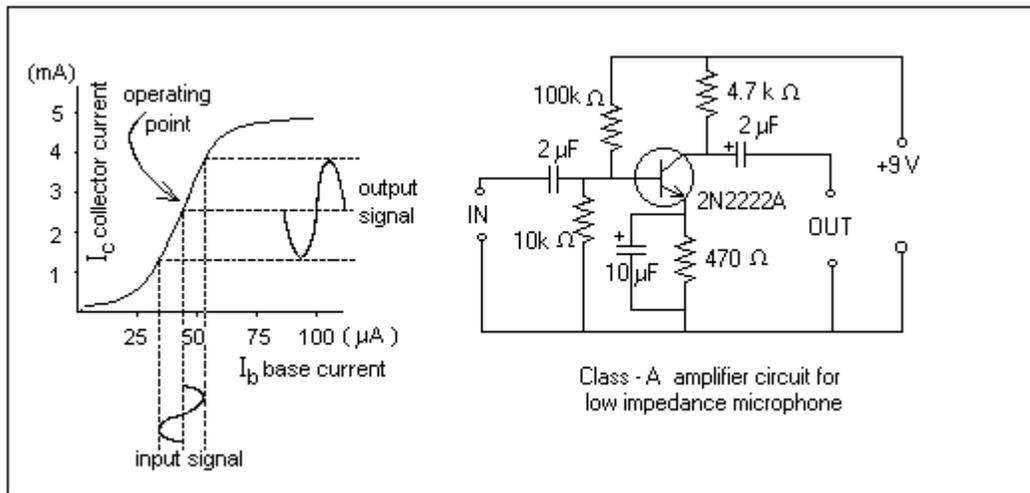


Fig 4.16

4.2.2.5.2 CLASS-B AMPLIFIER

The diagram (Fig 4.17) shows two npn transistors connected in push-pull circuit as a class-B amplifier. If the bias set at the point where the collector current just cut off (when no signal applied) then a signal can cause collector current to flow in either transistor only when the signal voltage applied to the particular transistor is positive with respect to the emitter. Since in the balanced base circuit the signal voltage in the base of the two transistors always have opposite polarization collector current flows only in one transistor at a time.

Upper half of the input signal is amplifying with one transistor and the other half is amplifying by the other transistor. The graph shows the operation of such an amplifier. At the operating point I_b and I_c both equals to zero. Only one half of the signal is amplifying and the other half is getting cut off completely.

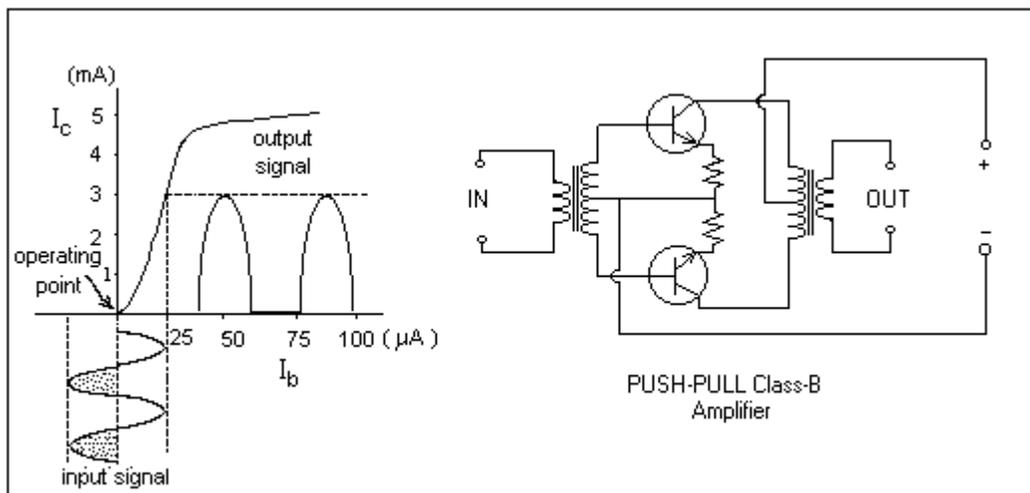


Fig 4.17