DC LOAD LINE AND OPERATING POINT

For the transistor to properly operate it must be biased. There are several methods to establish the DC operating point. We will discuss some of the methods used for biasing transistors as well as troubleshooting methods used for transistor bias circuits.The goal of amplification in most cases is to increase the amplitude ofan ac signal without altering it.

Biasing in electronics is the method of establishing predetermined voltages or currents at various points of an electronic circuit for the purpose of establishing proper operating conditions in electronic components. Many electronic devices whose function is signal processing time-varying (AC) signals also require a steady (DC) current or voltage to operate correctly. The AC signal applied to them is superposed on this DC bias current or voltage. Other types ofdevices, for example magnetic recording heads, require a time- varying (AC) signal as bias. **The operating point of a device, also known as bias point, quiescent point, or Q-point**, is the steady-state voltage or current at a specified terminal of an active device (a transistor or vacuum tube) with no input signal applied

Most often, bias simply refers to a fixed DC voltage applied to the same point in a circuit as an alternating current (AC) signal, frequently to select the desired operating response of a semiconductor or other electronic component (forward or reverse bias). For example, a bias voltage is applied to a transistor in an electronic amplifier to allow the transistor to operate in a particular region of its transconductance curve. For vacuum tubes, a (much higher) grid bias voltage is also often applied to the grid electrodes for precisely the same reason. This bias point is called the quiescent or **Q-point** as it gives the values of the voltages when no input signal is applied. To determine the Q-point we need to look at the range of values for which the transistor is in the active region.

For bipolar junction transistors the bias point is chosen to keep the transistor operating in the active mode, using a variety of circuit techniques, establishing the Q-point DC voltage and current. A small signal is then applied on top of the Q-point bias voltage, thereby either modulating or switching the current, depending on the purpose of the circuit.

The quiescent point of operation is typically near the middle of the DC load line. The process of obtaining a certain DC collector current at a certain DC collector voltage by setting up the operating point is called biasing.

After establishing the operating point, when an input signal is applied, the output signal should not move the transistor either to saturation or to cut-off. However, this unwanted shift still might occur, due to the following reasons:

1. Parameters of transistors depend on junction temperature. As junction temperature increases, leakage current due to minority charge carriers (I_{CBO}) increases. As I_{CBO} increases, I_{CEO} also

   increases, causing an increase in collector current I_C. This produces heat at the collector junction. This process repeats, and, finally, the Q-point may shift into the saturation region. Sometimes, the excess heat produced at the junction may even burn the transistor. This is known as thermal runaway.
2. When a transistor is replaced by another of the same type, the Q-point may shift, due to changes in parameters of the transistor, such as current gain (β) which varies slightly for each unique transistor.

To avoid a shift of Q-point, bias-stabilization is necessary. Various biasing circuits can be used for this purpose.

A **load line** is used in graphical analysis of nonlinear electronic circuits, representing the constraint other parts of the circuit place on a non-linear device, like a diode or transistor. It is usually drawn on a graph of the current vs the voltage in the nonlinear device, called the device's characteristic curve. A load line, usually a straight line, represents the response of the linear part of the circuit, connected to the nonlinear device in question. The operating point(s) of the circuit are the points where the characteristic curve and the load line intersect; at these points the current and voltage parameters of both parts of the circuit match.[1]

The example at right shows how a load line is used to determine the current and voltage in a simple diode circuit. The diode, a nonlinear device, is in series with a linear circuit consisting of a resistor, R and a voltage source, V_{DD}. The characteristic curve (curved line), representing current I through the diode versus voltage across the diode V_D, is an exponential curve. The load line (diagonal line) represents the relationship between current and voltage due to Kirchhoff's voltage law applied to the resistor and voltage source, is

$$V_D = V_{DD} - IR$$

Since the current going through the three elements in series must be the same, and the voltage at the terminals of the diode must be the same, the operating point of the circuit will be at the intersection ofthe curve with the load line.

In a BJT circuit, the BJT has a different current-voltage (I_C-V_{CE}) characteristic depending on the base current. Placing a series of these curves on the graph shows how the base current will affect the operating point of the circuit.

Transistor load line

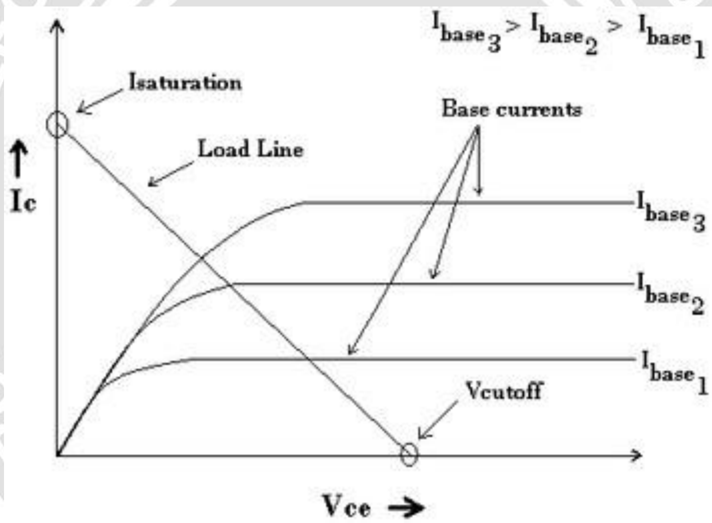

Fig.1 Common emitter transistor load line

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain

The load line diagram at right is for a transistor connected in a common emitter circuit. It shows the collector current in the transistor I_C versus collector voltage V_{CE} for different values of base current I_{base}. The load line represents a particular value of collector loadresistor (R_C). The intersections of the load line with the transistor characteristic curve represent the different values of I_C and V_{CE} at different base currents.

The point on the load line where it intersects the collector current axis is referred to as saturation point. At this point, the transistor current is maximum and voltage across collector is minimum, for a given load. For this circuit, $I_{C\text{-}SAT}= V_{CC}/R_C$.

The cutoff point is the point where the load line intersects with the collector voltage axis. Here the transistor current is minimum (approximately zero) and emitter is grounded. Hence $V_{CE\text{-}CUTOFF}=V_{cc}$.

The operating point of the circuit in this configuration is generally designed to be in the active region, approximately between middle of the load line and close to saturation point. In this region, the collector current is proportional to the base current, and hence useful for amplifier applications. a load line is normally drawn on I_c-V_{ce} characteristics curves for the transistor used in amplifier circuit.