Transistor

1-Characteristics of common base configuration

For common base (CB) connection, the input terminal is emitter, and the output terminal is collector, while the base terminal is grounded as shown in figure (1).

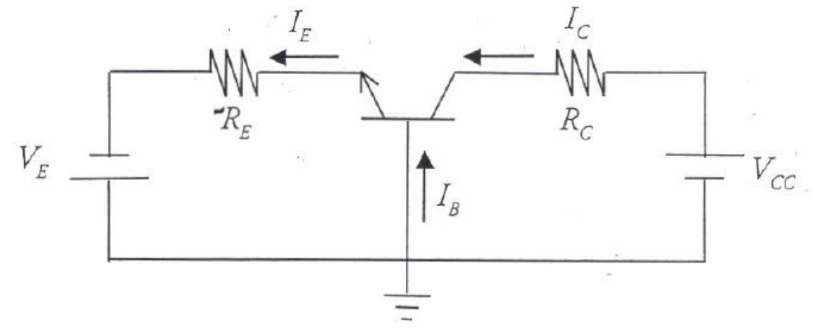


Figure (1)
Circuit with NPN transistor biased with common base configuration.

1-1 Input characteristics of common base configuration

To get input characteristics, voltage V_{CB} is set to value (V_{CC} fixed) and record the current I_E for some different values of V_{BE} (V_{EE} changes). The circuit to get these characteristics as shown in figure (2).

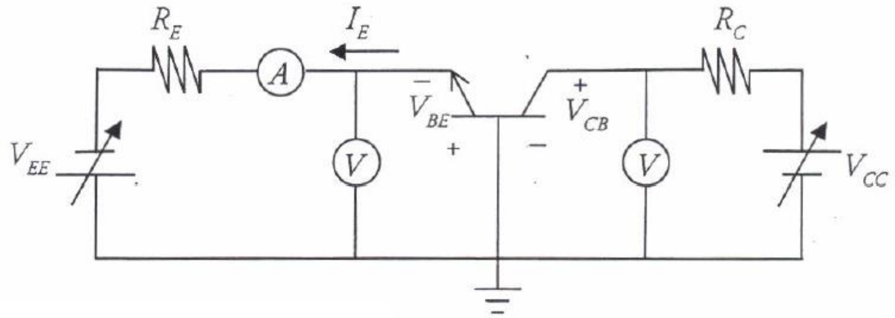


Figure (2)
Circuit to get common base input characteristics

The input characteristics graph plotted using input current I_E versus input voltage V_{BE} and V_{CB} as fixed parameter as shown in figure (3). In this graph, for a fixed value of V_{CB}, the voltage (V_{BE}) to increment will cause current (I_E) to increase exponentially after one voltage level. This voltage is 0.7V for Si transistor while 0.3 for Ge. Before that the value of I_E is very small or can be said that there is no current flow. This is same as diode condition when forward biased. At one fixed V_{BE} value of I_E is larger if V_{CB} larger.

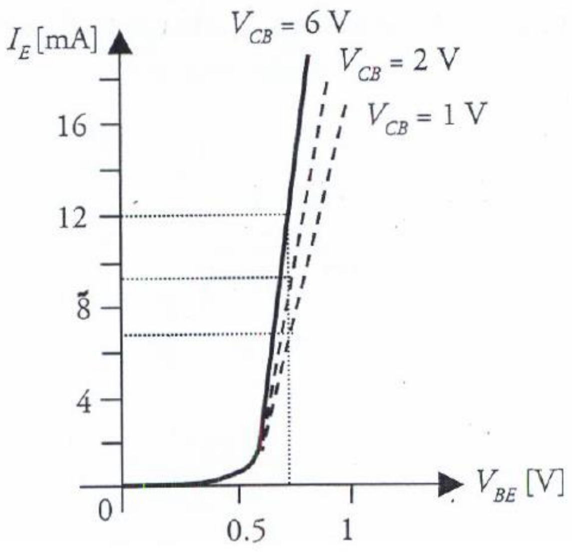


Figure (3)
Input characteristics graph of NPN with common base

1-2 Output characteristics of common base configuration

Graphs of output characteristic for common base configuration can be obtained by drawing output current I_C versus voltage V_{CB} with input current I_E , as a fixed parameter. This circuit to get this characteristic is shown in figure (4)

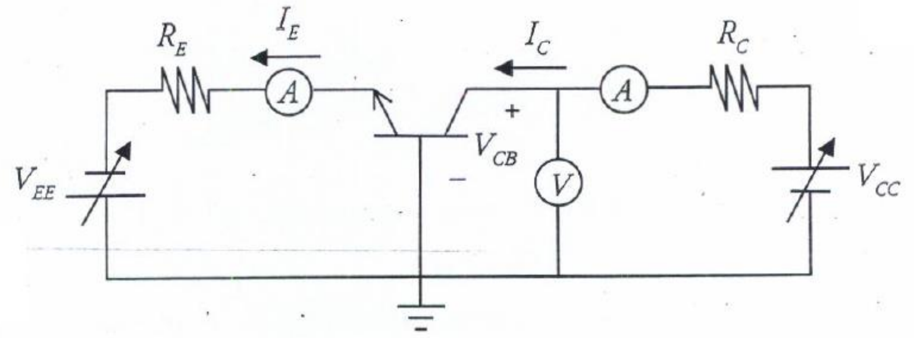


Figure (4)
Circuit to get common base output characteristics

Figure (5) shows the output characteristics. In this graph when I_E =0, the collector current I_C, is very small (i.e., the same as leakage current, I_{CBO}), thus I_C =I_{CBO}. This is when an emitter-base junction is reverse biased (in an active region). In this region when I_E increase (I_E > 0) , I_C increases too, but I_C value is almost similar to I_E ($I_C \approx I_E$) . In an active region, it is also found that I_C does not depend on V_{CB} . Thus, it produces a relatively flat line, which is almost parallel to V_{CB} axis. Active region is a good for a transistor to work as an amplifier.

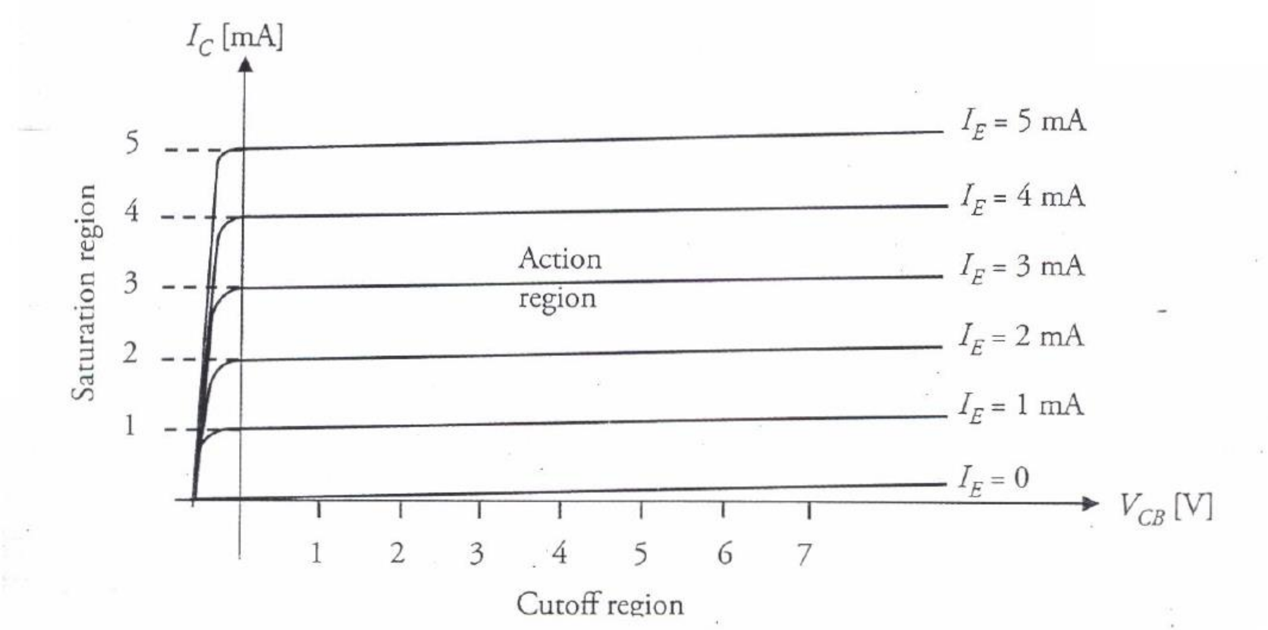


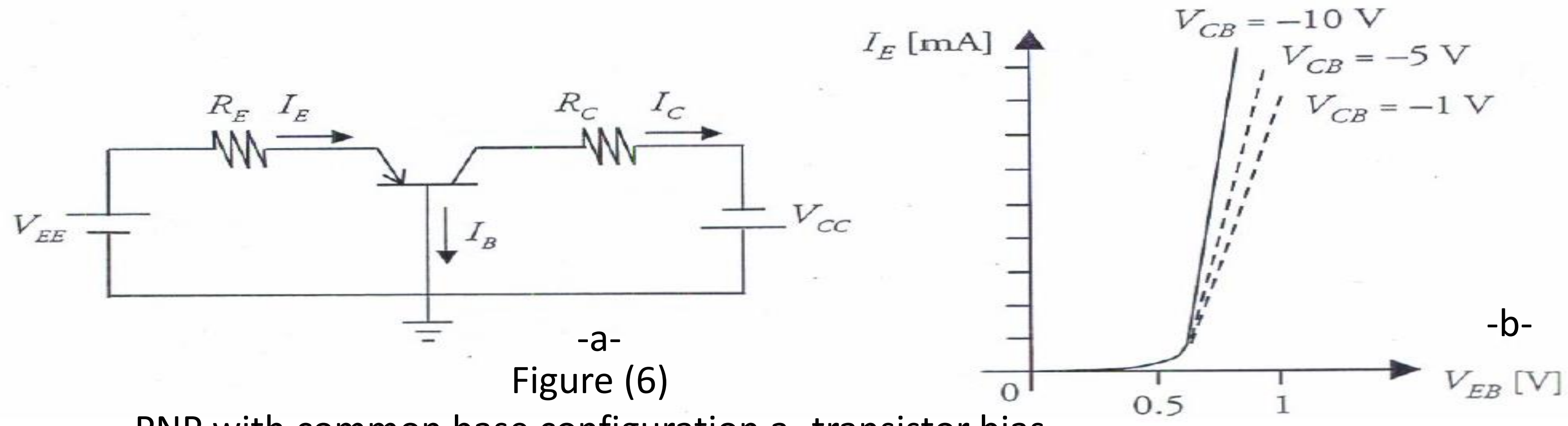
Figure (5)
Output characteristics graph of an NPN transistor with common base connection

Besides active region, there are two more regions that must be observed in CB output's characteristic graph, which are cutoff and saturation. In a cutoff region, which is below the I_E = 0 curve, both emitter-base and collector-base junctions are reverse biased. In this condition, there is almost no current at the collector, except I_{CBO} which has very small value.

For saturation, the emitter-base and collector-base junction are forward biased. In this region, small changes at V_{CB} cause very big change in I_C.

If voltage V_{CB} (voltage to reverse bias collector-base junction) is allowed to exceed the maximum limit determined by transistor manufacture, breakdown will occur. Consequently, collector current I_C increase drastically and this will damage the transistor. Breakdown occurs because of two conditions; first is due to the same reason as diode breakdown. Second is caused by punch-through effect or reach through ; which is when CB junction's depletion region is beyond deeply into base part and combined with the EB-junction depletion region.

- Figure (6) is a common base connection for PNP type transistor with its input and output characteristics graphs.

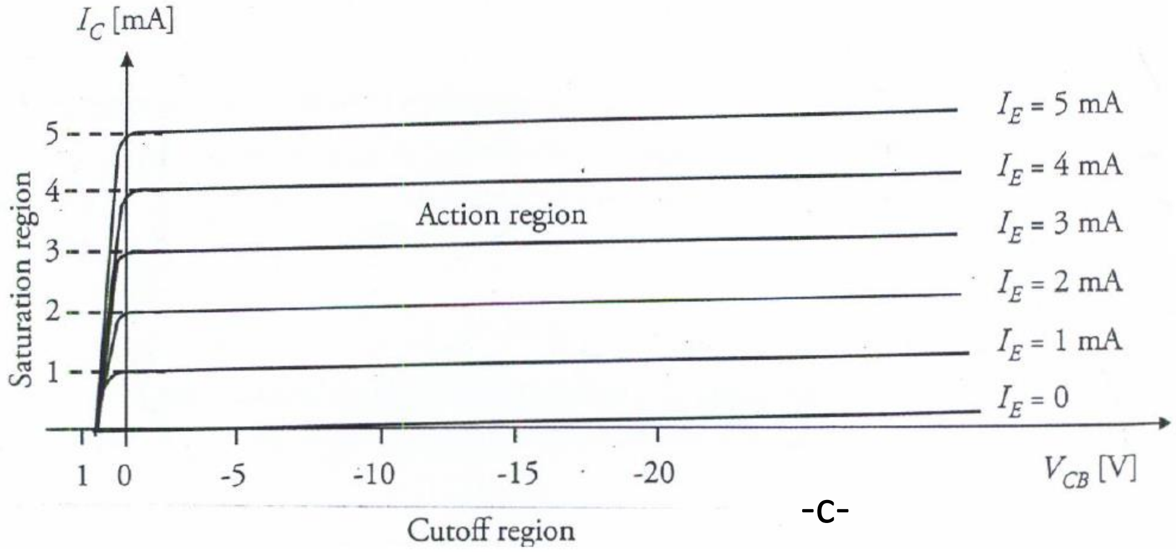


-a-

-b-

Figure (6)

PNP with common base configuration a- transistor bias circuit b- input characteristics graph



-c-

Figure (7)
PNP with common base configuration c- output characteristics graph

2- Common emitter configuration

For a common emitter (CE) connection, an emitter is the reference and connected to base (input) and collector (output). Most transistor that are used as an amplifier are biased with CE connection, because they have high voltage current gain. For a transistor which is connected as a common emitter figure (8), the V_{cc} value must be greater than V_{BB} so the CB junction will be reverse biased. As shown in figure (8), the BE junction must be forward biased in order to turn a transistor into an amplifier.

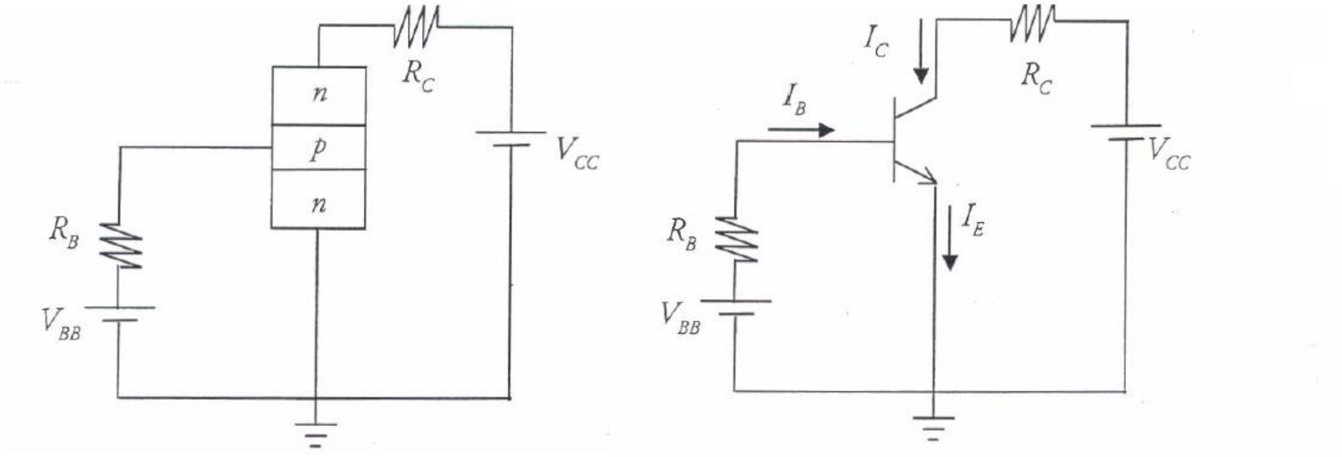


Figure (8) NPN transistor with CE connection

The operation of circuit in figure (8) :emitter will inject electrons to base and this will produce I_E . These electrons which are majority carrier from an emitter will be pulled to be greater at collector (pushed by V_{cc}). These electrons will flow through base and only a small part will combine with holes at base and exit through base (pulled by V_{BB}). Hence, a base current I_B is produced. Most electrons will reach the collector and produced current I_c. This current is the majority electrons that can reach the collector that can reach the collector and is known as αI_c .

V_{BB} voltage control total number of electrons that flow from emitter to base with forward bias increment or decrement at the BE junction. Directly this also controls current I_c . A good transistor has an I_B value which is smaller than I_c.At the same time the CB junction that reverse biased will cause minority carrier movement from base to collector (base is a P-type material and its minority carrier is electron). This minority current or leakage current is known I_{CEO}.

2-1 Input characteristics of common emitter configuration

The input characteristics for a common emitter can be explained through current graph at input terminal , I_B versus V_{BE} but V_{CE}, as a fixed parameter. This graph can be plotted using current I_B with the change in value of V_{BE} but V_{CE} is fixed to one value. The circuit to get these values is shown in figure (9).

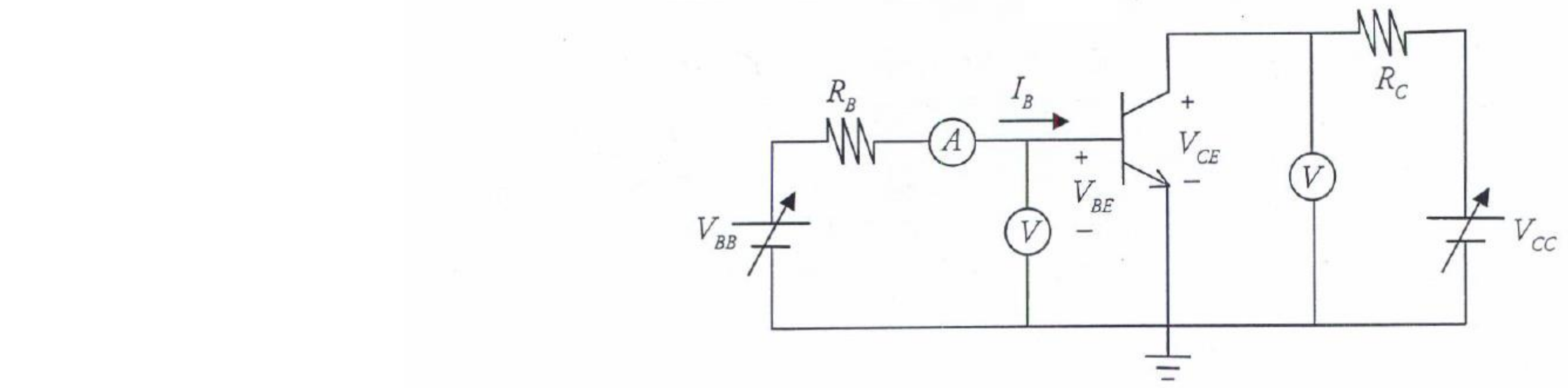


Figure (9)
Circuit layout to get a common emitter input characteristic

The CE input characteristics is almost the same as CB input characteristics . Curves that produced, as shown in figure (10), can be explained using diode analogy. Base-emitter (BE)junction is forward biased. Same as a diode that forward bias, I_B will only flow when $V_{BE} > 0.7$ for silicon transistor and 0.3 for germanium type transistor. Before this V_{BE} value, only a minor or no current I_B present. The value of I_B is small which in μA range.

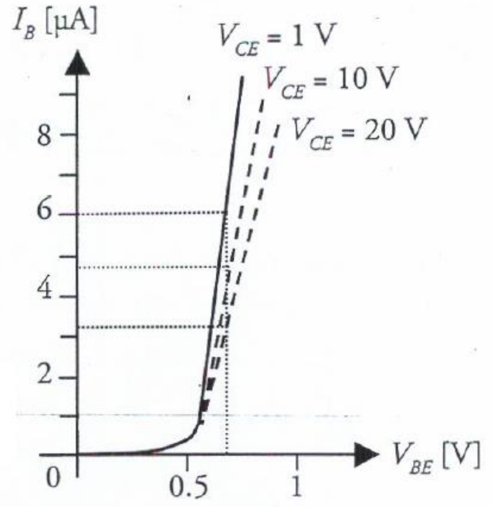


Figure (10)
Input characteristic graph of an NPN transistor with common emitter configuration

This graph also shows that V_{CE} increment give an I_B value that decreased for certain values of V_{BE}. This is because V_{CE} increment give a big reverse bias at the CB-junction with a wide depletion region . Thus, the distance between the CB and EB depletion regions becomes thinner. Therefore, most of the current majority carrier from E flow to C and only a few that can flow out through base B.

2-2 Output characteristics of common emitter configuration

The output characteristics for a transistor with a common emitter configuration can be explained with output current, I_c , versus output voltage, V_{CE}, and input current, I_B becomes a fixed parameter. Figure (11) shows the circuit to get output characteristics for a transistor with a common emitter configuration.

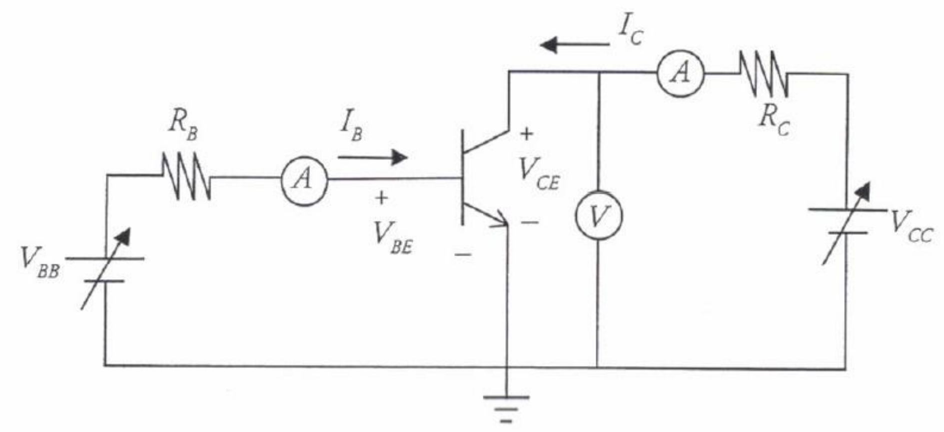


Figure (11)
Circuit to get common emitter output characteristics

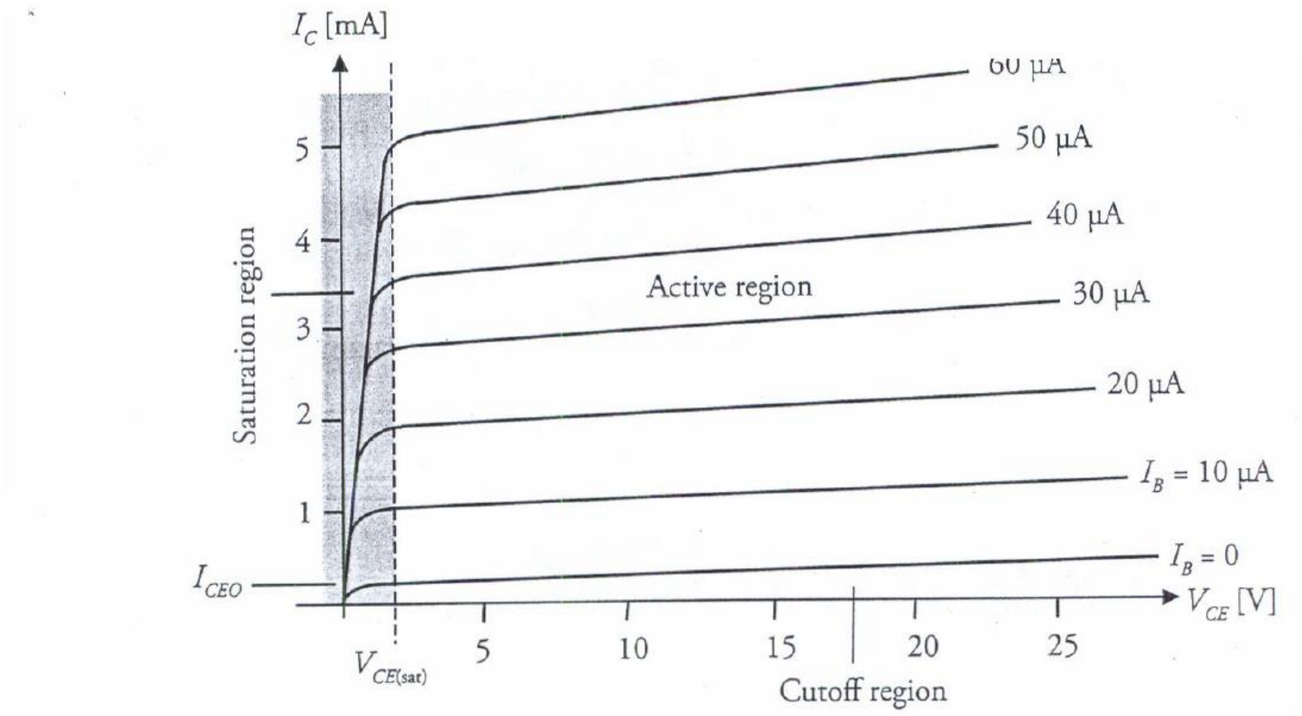


Figure (12)

Output characteristics graph for NPN transistor with common emitter configuration.

There are some items that can be seen from the output characteristics graph of a common emitter (CE) circuit (figure 12):

(1) For a small value of V_{CE} ($V_{CE} > V_{CE(sat)}$), collector current I_c will increase linearly with increment of V_{CE}.

(2) Once $V_{CE} > V_{CE(sat)}$, I_c is not affected with V_{CE} , and value of I_c becomes almost constant. This can be seen at the line that becomes more flattened at the curve. However, this I_c curve is not flat as I_E curve for CB connection. This shows V_{CE} has little effect on I_c which results from early effect.

(3) I_B value [in μA] is smaller than I_c [in $\mathrm{m}A$]. Small increment of input current, I_B causes a large increment of output current I_c .

(4) When I_B =0, there is a collector current with I_{CEO} .

There are three regions in a transistor output characteristics graph with common emitter connection, same as the common base connection, which are active, saturation, and cutoff region.