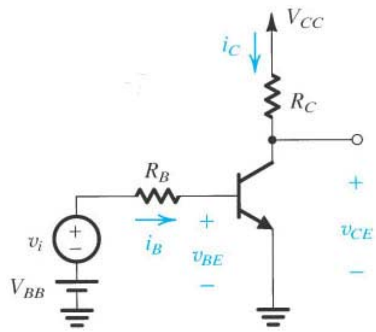
Lecture 16: Graphical Analysis of a BJT Small-Signal Amplifier.

We can use graphical analysis to approximately analyze the response of simple transistor amplifier circuits. This technique is primarily useful to develop physical insight.

Consider once again the "conceptual BJT amplifier" circuit:



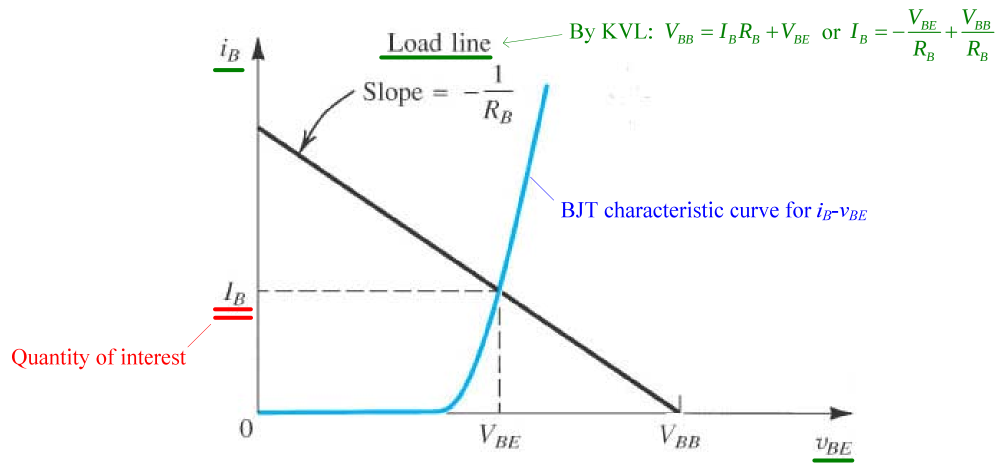
(Fig. 7.20a)

Similar to the analytical solution, there are two primary steps to the graphical solution of such small-signal amplifiers:

1. DC basis analysis
2. AC small-signal analysis.

DC Bias

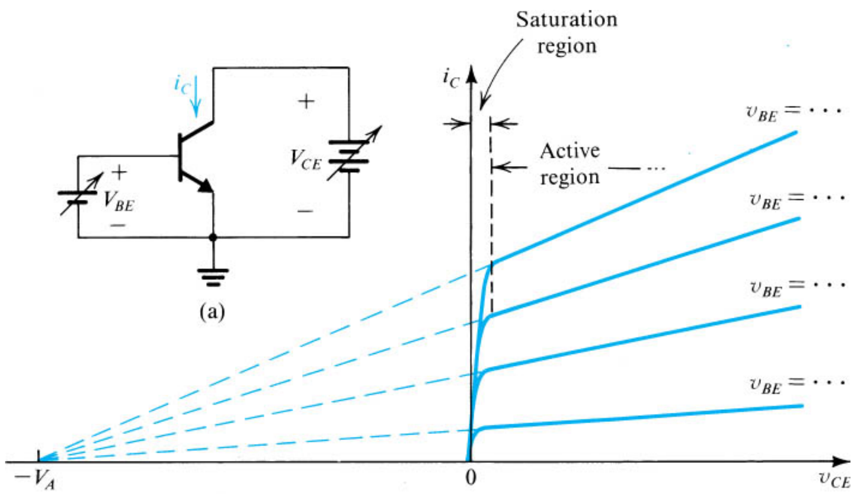
The first step in the bias calculations is to determine I_B. This is done with the i_B-v_{BE} characteristic curve and the load line:



(Fig. 1)
(Sedra and Smith, 5th ed.)

Once I_B has been determined we can compute I_C knowing that $I_C = \beta I_B$ for a BJT in the active mode. With this I_C value and the i_C-v_{CE} characteristic curve of the transistor, we can determine V_{CE}.

We haven't yet seen the i_C-v_{CE} characteristic curve of the BJT. This can be measured using the circuit in Fig. 2 below. v_{BE} is fixed at some value, then v_{CE} is swept while measuring i_C. The results are shown below for different values of v_{BE}.



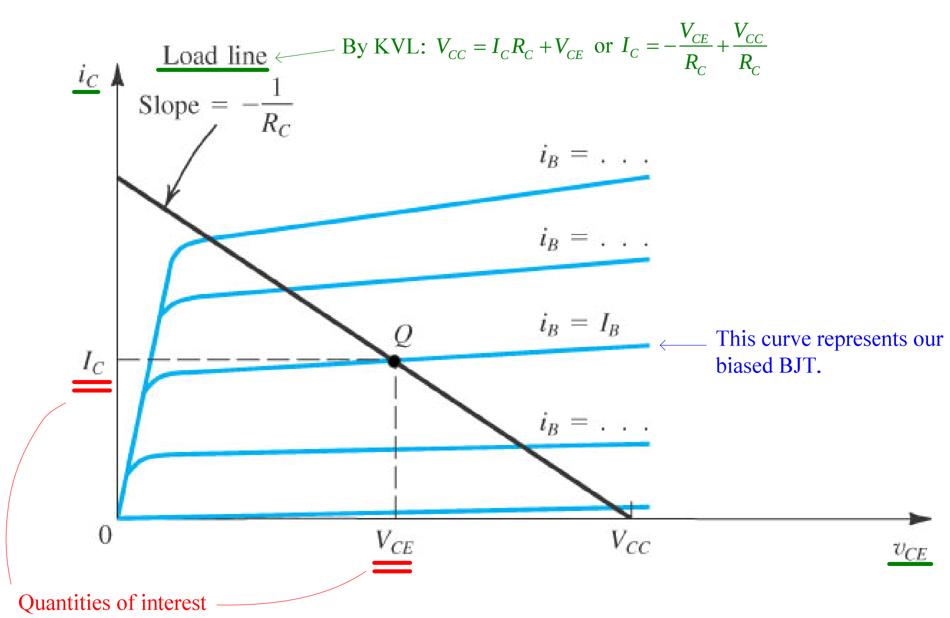
(Fig. 2)
(Sedra and Smith, 5th ed.)

(Curve tracers are pieces of equipment that will measure and display families of i_C-v_{CE} characteristic curves for transistors.)

When v_{CE} is very small, i_C is nearly zero. This is the cutoff mode of the BJT. As v_{CE} increases but is still small, the CBJ is forward biased and the BJT is in the saturation mode. When v_{CE} becomes large enough, the CBJ becomes reversed biased and the BJT enters the active mode.

The slopes of the lines in Fig. 2 in the active mode are quite exaggerated in this figure.

So, back to the graphical solution. With the $I_C = \beta I_B$ value from Fig. 1, the i_C-v_{CE} characteristic curve of the transistor from Fig. 2, and the load line representing the effects of the collector circuit, we can determine V_{CE}:

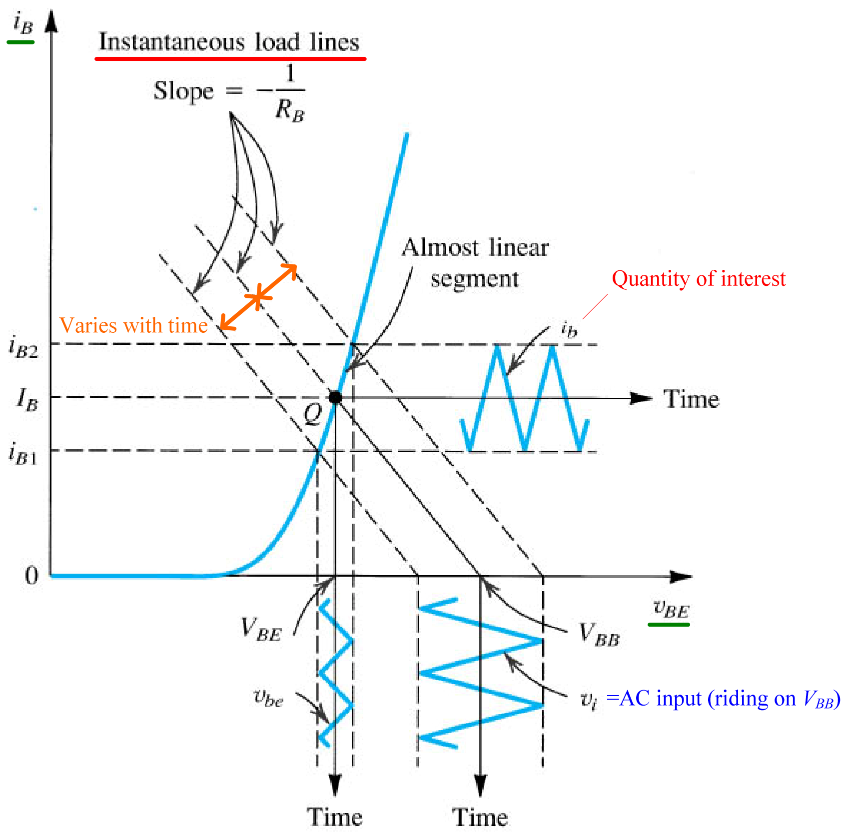


(Fig. 3)

(Sedra and Smith, 5th ed.)

AC Small-Signal Analysis

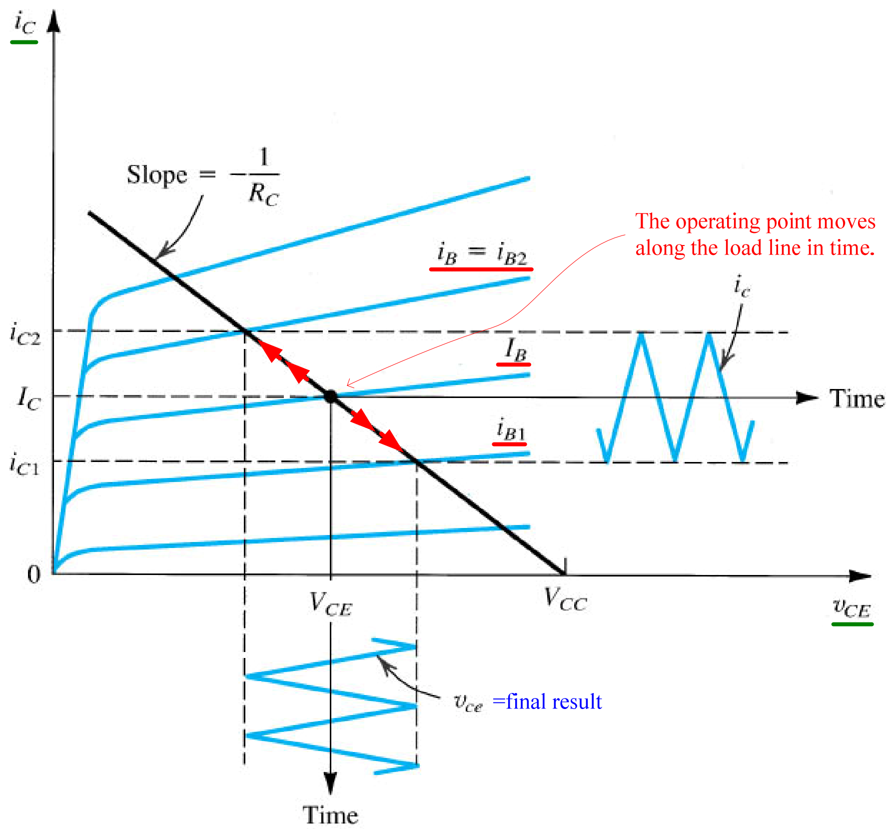
The first step in the AC small-signal analysis is to determine i_b. This is performed using a slightly complicated interaction of the input waveform v_i, the subsequent time variation of the load line, and the i_B-v_{BE} characteristic curve of the BJT:



(Fig. 4)
(Sedra and Smith, 5th ed.)

From this comes the small-signal quantities v_{be} and i_b.

With i_b known and $i_c = \beta i_b$, then we use these values on the i_C-v_{CE} characteristic curve to determine v_{ce}:



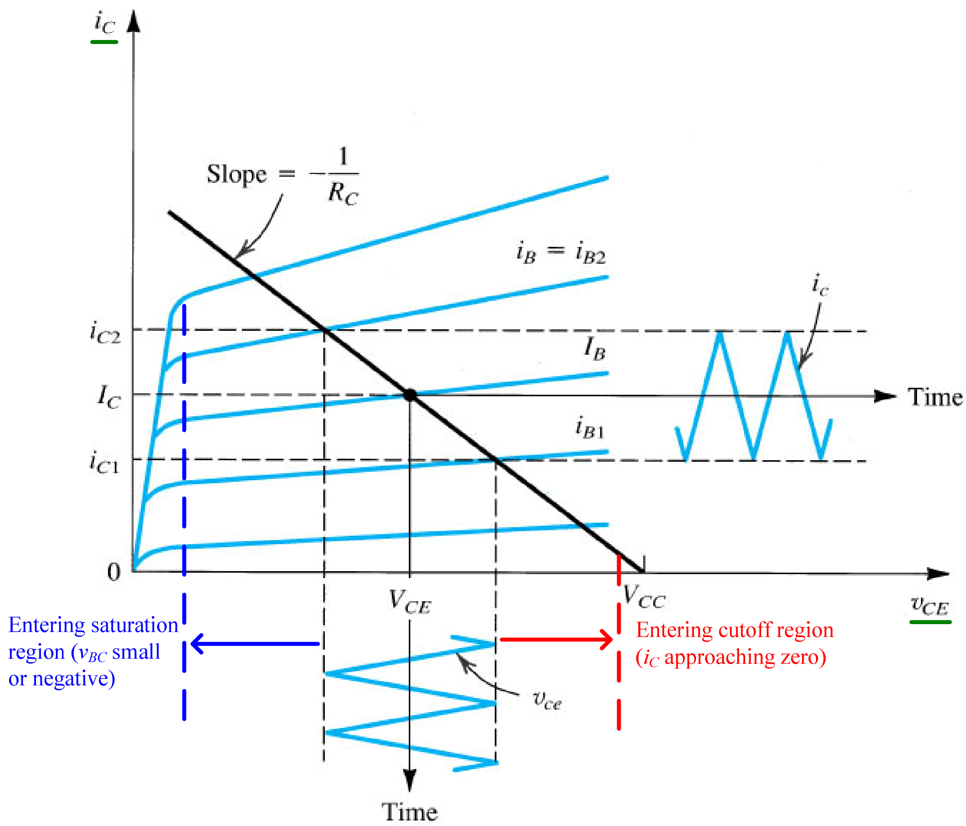
(Fig. 5)
(Sedra and Smith, 5th ed.)

Cutoff and Saturation

Notice that there are limits on v_{CE} in which the BJT remains in the active mode:

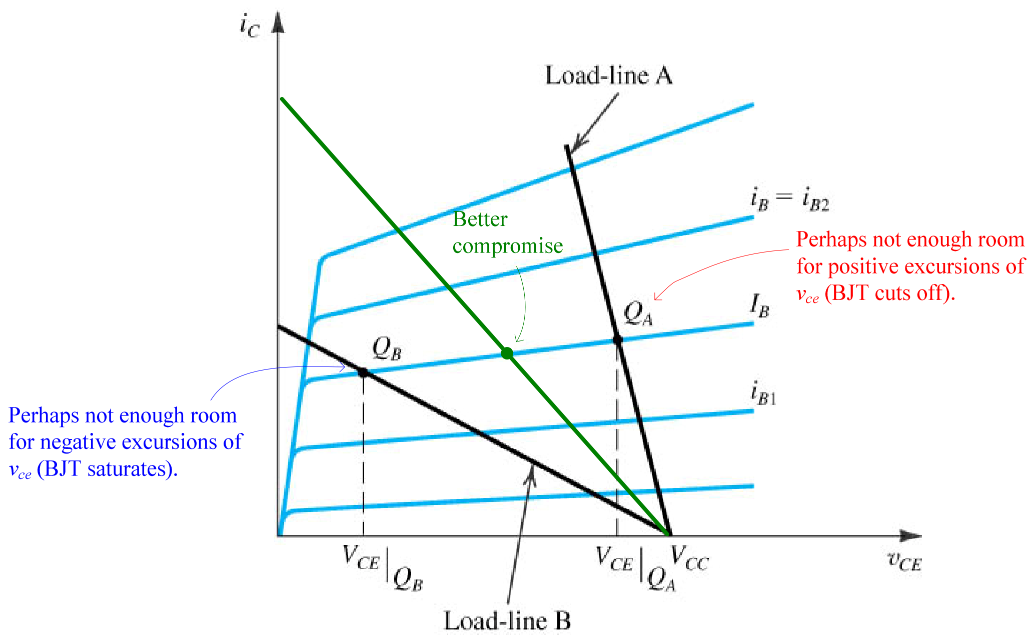
- Too large ($\geq V_{CC}$) and the BJT cuts off
- Too small (few tenths of a volt) and the transistor saturates.

These limits are readily apparent if we reexamine the previous figure of the small-signal variation:



(Fig. 6)
(Sedra and Smith, 5th ed.)

Because of these limits on v_{CE}, it is important to choose the Q point properly to all for the desired swing in the signal voltage (v_{ce}).



(Fig. 7)
(Sedra and Smith, 5th ed.)