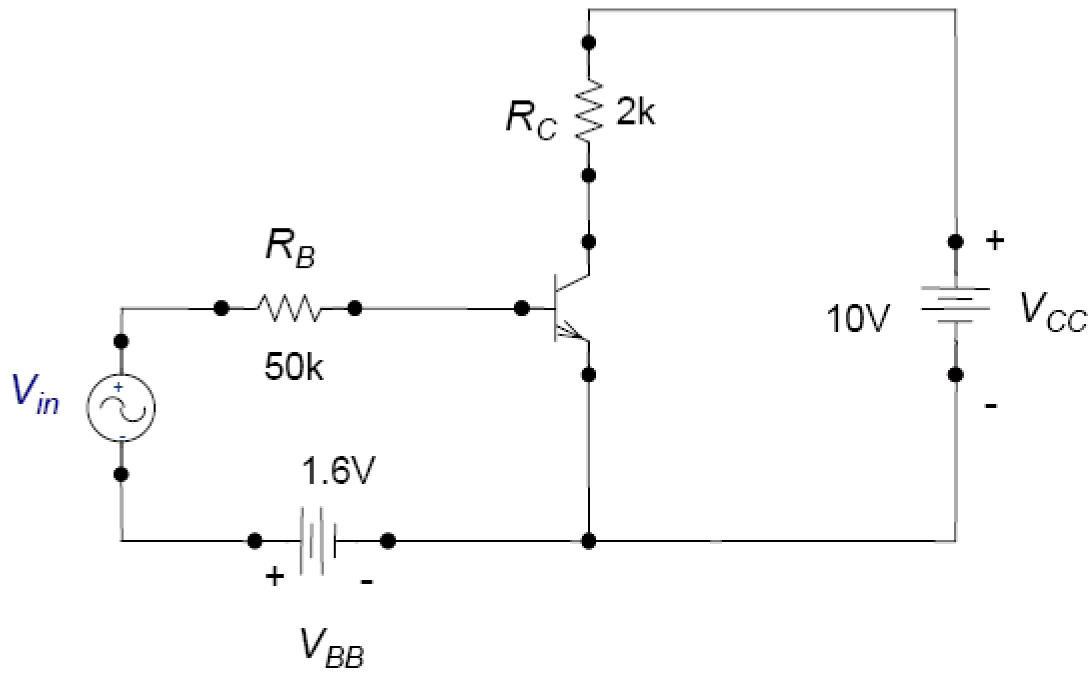
Lecture 18

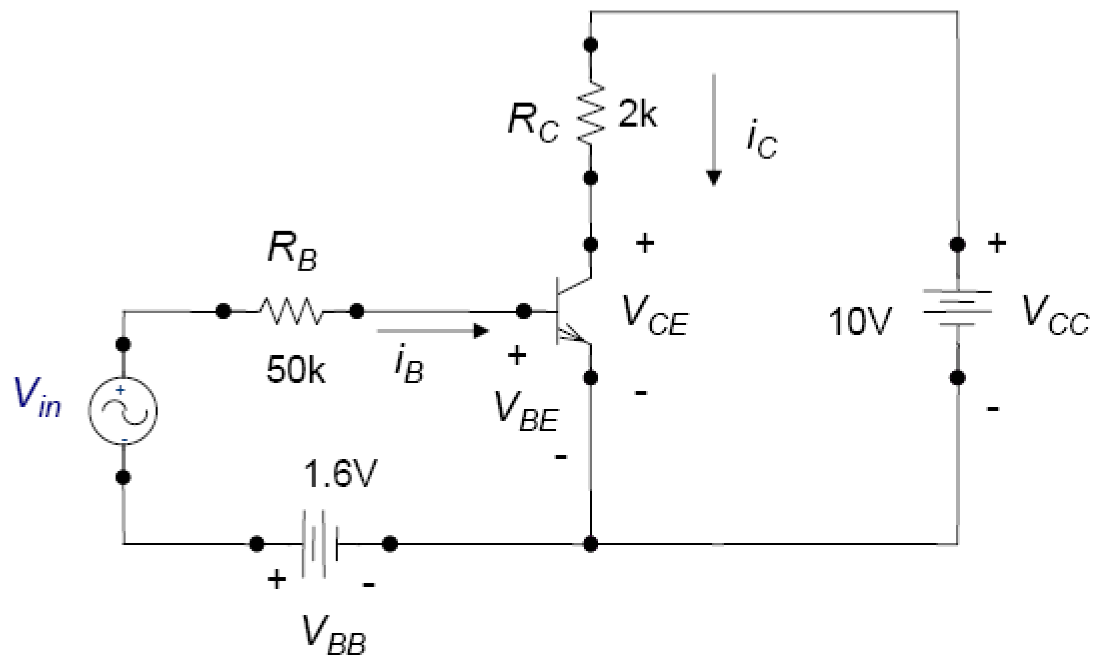
BJT

BJT Analysis

- Here is a common emitter BJT amplifier:
- What are the steps?

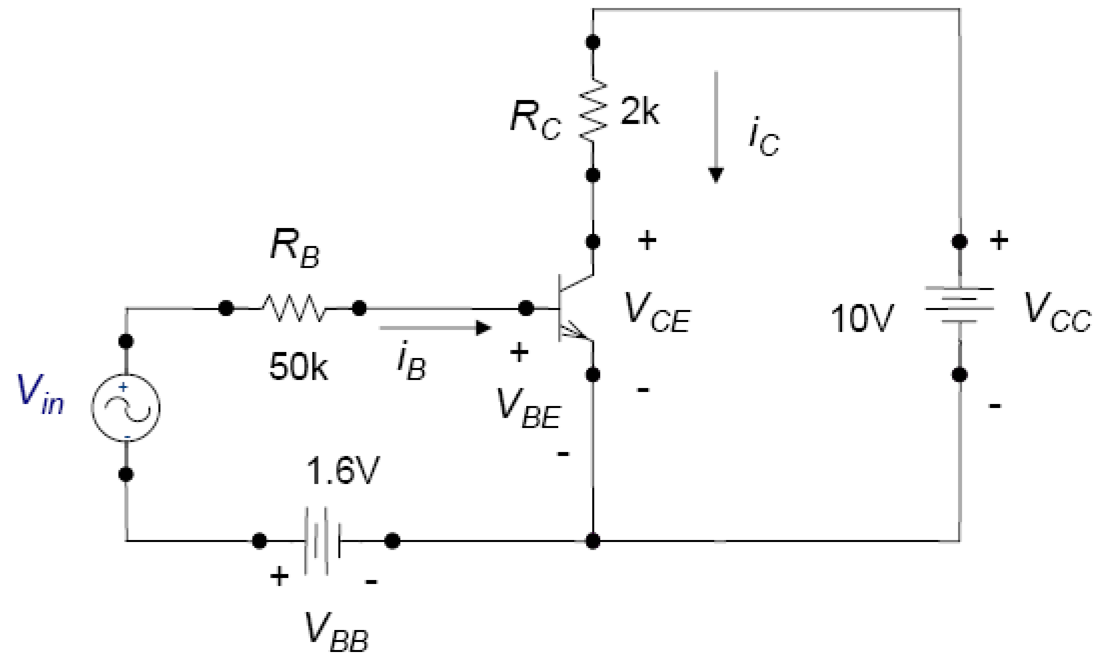


Input & Output



- We would want to know the collector current (i_C), collector-emitter voltage (V_{CE}), and the voltage across *RC*.
- To get this we need to fine the base current (i_B) and the base-emitter voltage (V_{BE}).

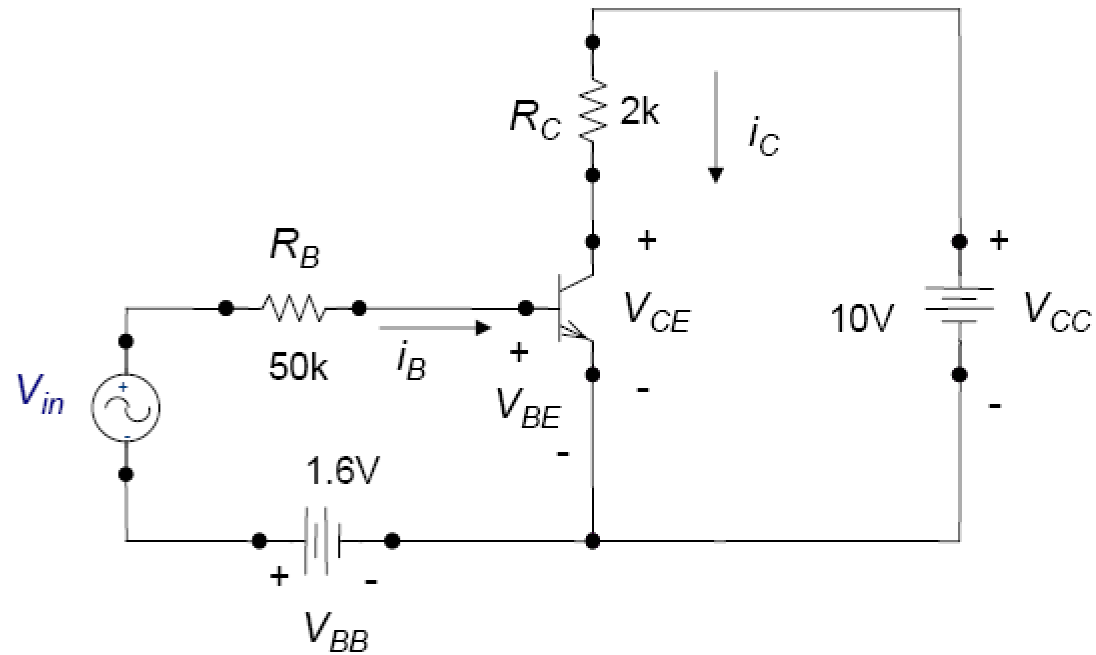
Input Equation



- To start, let's write Kirchoff's voltage law (KVL) around the base circuit.

$$V_{in}(t) + V_{BB} = i_B(t)R_B + V_{BE}(t)$$

Output Equation



Likewise, we can write KVL around the collector circuit.

$$V_{CC} = i_C(t)R_C + V_{CE}(t)$$

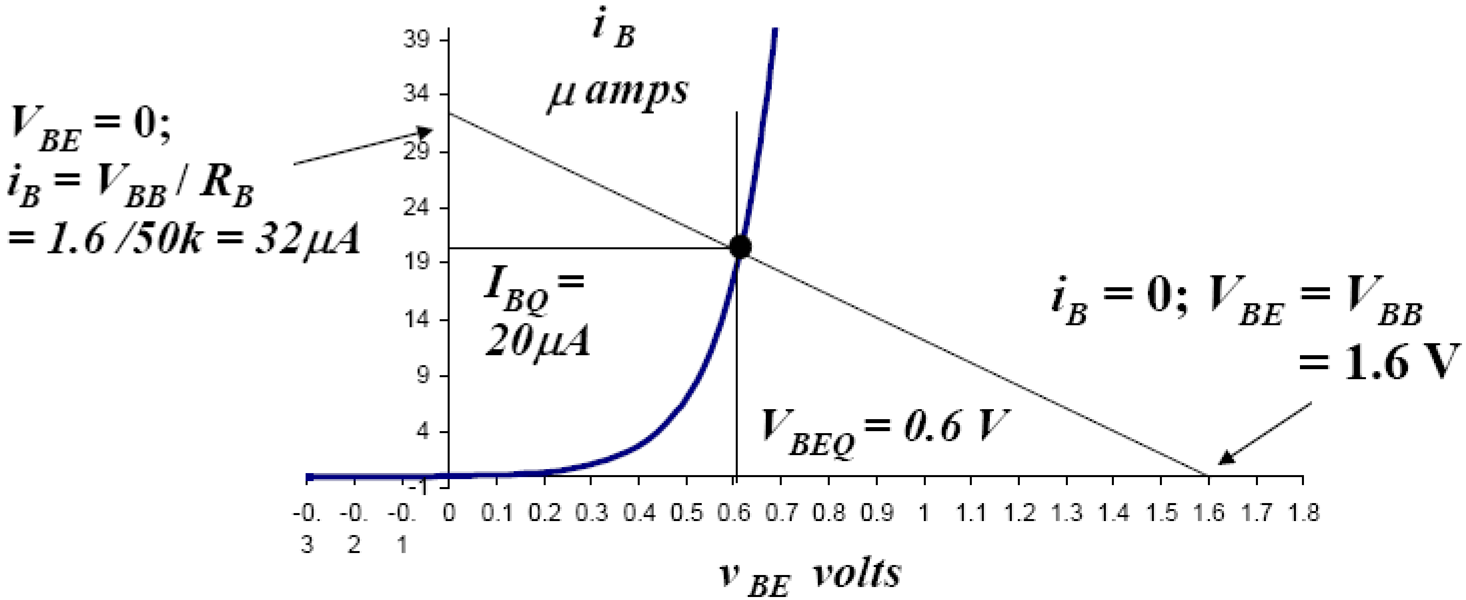
Use Superposition: DC & AC sources

- Note that both equations are written so as to calculate the transistor parameters (i.e., base current, base-emitter voltage, collector current, and the collector-emitter voltage) for both the DC signal and the AC signal sources.
- Use superposition, calculate the parameters for each separately, and add up the results:
  - First, the **DC analysis to calculate the DC Q-point**
    - Short Circuit any AC voltage sources
    - Open Circuit any AC current sources
  - Next, the **AC analysis to calculate gains of the amplifier**.
    - Depends on how we perform AC analysis
      - Graphical Method
      - Equivalent circuit method for small AC signals

BJT - DC Analysis

- Using KVL for the input and output circuits and the transistor characteristics, the following steps apply:
  1. Draw the load lines on the transistor characteristics
  2. For the input characteristics determine the Q point for the input circuit from the intersection of the load line and the characteristic curve (Note that some transistor do not need an input characteristic curve.)
  3. From the output characteristics, find the intersection of the load line and characteristic curve determined from the Q point found in step 2, determine the Q point for the output circuit.

Base-Emitter Circuit Q point



First let's set $V_{in}(t) = 0$ to get the Q-point for the BJT.

We start with the base circuit.

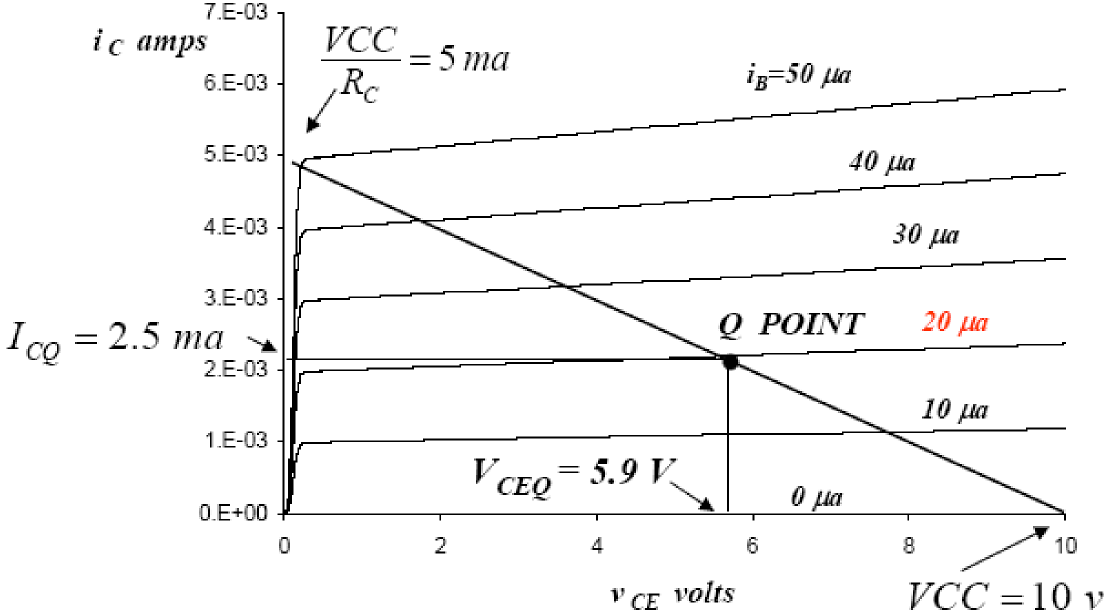
$$V_{BB} = i_B R_B + V_{BE}$$

And the intercepts occur at $i_B = 0;\ V_{BE} = V_{BB} = 1.6$ V

and at $V_{BE} = 0;\ i_B = V_{BB} / R_B = 1.6 / 50k = 32\mu A$

The Load Line intersects the Base-emitter characteristics at $V_{BEQ} = 0.6\ V$ and $I_{BQ} = 20\ \mu A$

Collector-Emitter Circuit Q point



Now that we have the Q-point for the base circuit, let's proceed to the collector circuit.

$$V_{CC} = i_C R_C + V_{CE}$$

The intercepts occur at $i_C = 0$; $V_{CE} = V_{CC} = 10$ V;

and at $V_{CE} = 0$; $i_C = V_{CC} / R_C = 10/2k = 5mA$

The Load Line intersects the Collector-emitter characteristic, $i_B = 20$ μA at $V_{CEQ} = 5.9\ V$ and $I_{CQ} = 2.5mA$, *then* $\beta = 2.5m/20$ μ = 125

BJT DC Analysis - Summary

- Calculating the Q-point for BJT is the first step in analyzing the circuit
- To summarize:
  - We ignored the AC (variable) source
    - Short circuit the voltage sources
    - Open Circuit the current sources
  - We applied KVL to the base-emitter circuit and using load line analysis on the base-emitter characteristics, we obtained the **base current Q-point**
  - We then applied KVL to the collector-emitter circuit and using load line analysis on the collector-emitter characteristics, we obtained the **collector current and voltage Q-point**
- This process is also called DC Analysis
- We now proceed to perform AC Analysis

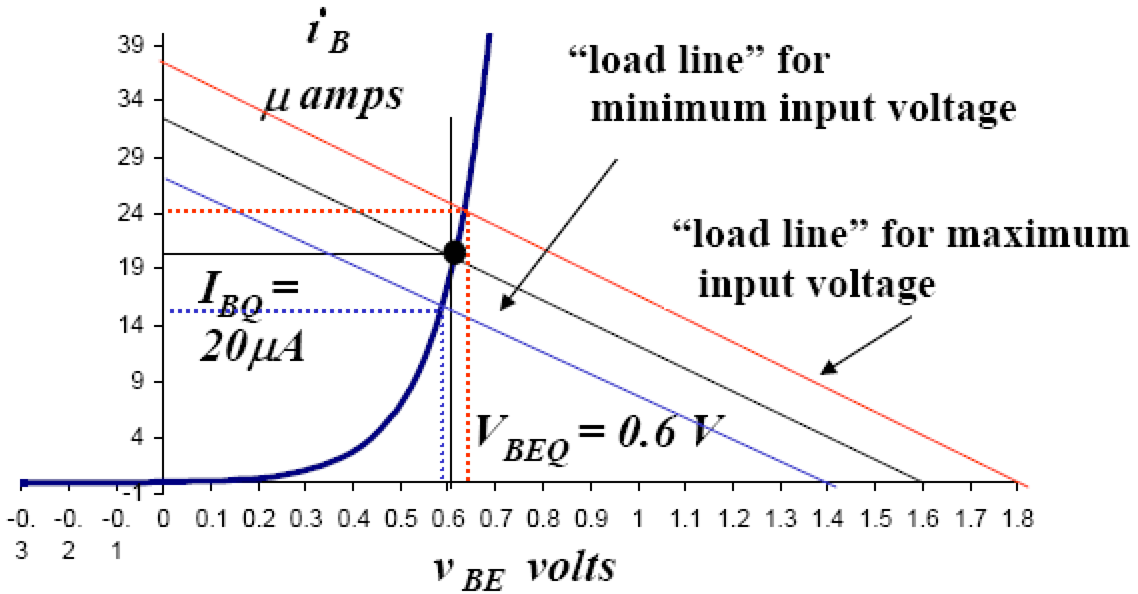
BJT - AC Analysis

- How do we handle the variable source $V_{in}(t)$?
- When the variations of $V_{in}(t)$ are large we will use the base-emitter and collector-emitter characteristics using a similar graphical technique as we did for obtaining the Q-point.
- When the variations of $V_{in}(t)$ are small we will shortly use a linear approach using the BJT small signal equivalent circuit.

BJT - AC Analysis

- Let's assume that $V_{in}(t) = 0.2 \sin(\omega t)$.
- Then the voltage sources at the base vary from a maximum of 1.6 + 0.2 = 1.8 V to a minimum of 1.6 -0.2 = 1.4 V
- We can then draw two "load lines" corresponding the maximum and minimum values of the input sources
- The current intercepts then become for the:
  - Maximum value: 1.8 / 50k = 36 μA
  - Minimum value: 1.4 / 50k = 28 μA

AC Analysis Base-Emitter Circuit



From this graph, we find:

At Maximum Input Voltage:

V_{BE} = 0.63 V, i_B = 24 μA

At Minimum Input Voltage:

V_{BE} = 0.59 V, i_B = 15 μA

Recall: At Q-point:

V_{BE} = 0.6 V, i_B = 20 μA

Note the asymmetry around the Q-point of the Max and Min Values for the base current and voltage which is due to the non-linearity of the base-emitter characteristics

$\Delta i_{Bmax} = 24\text{-}20 = 4\ \mu A;$

$\Delta i_{Bmin} = 20\text{-}15 = 5\ \mu A$

AC Analysis Base-Emitter Circuit