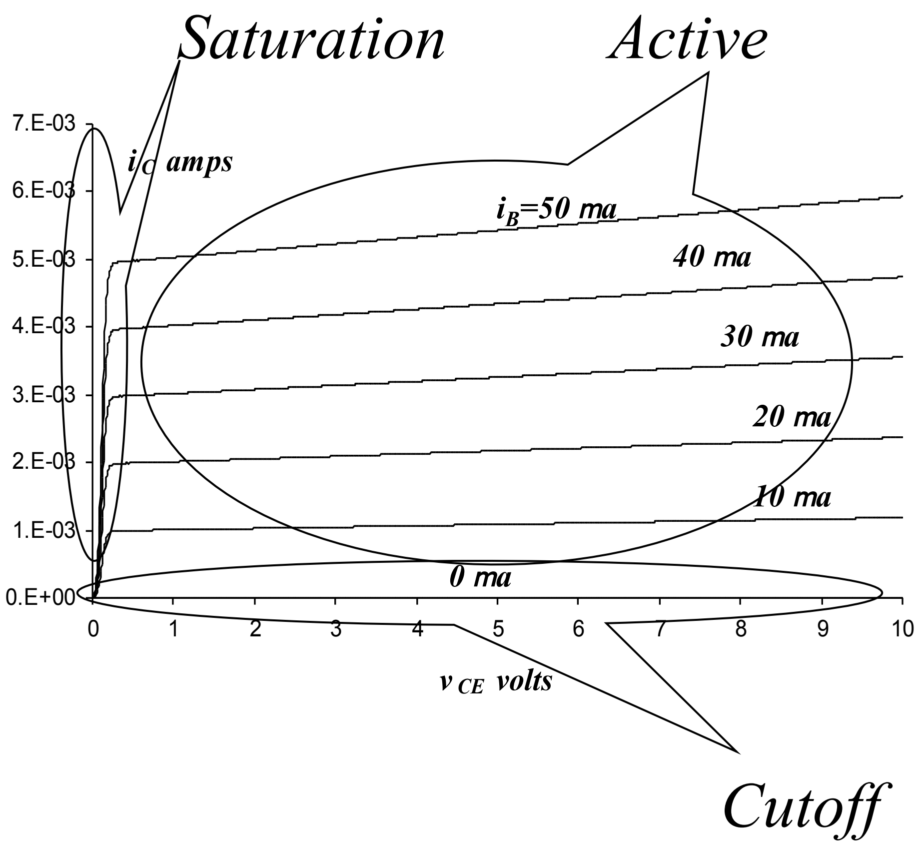
Transistors

Lesson #9

Chapter 4

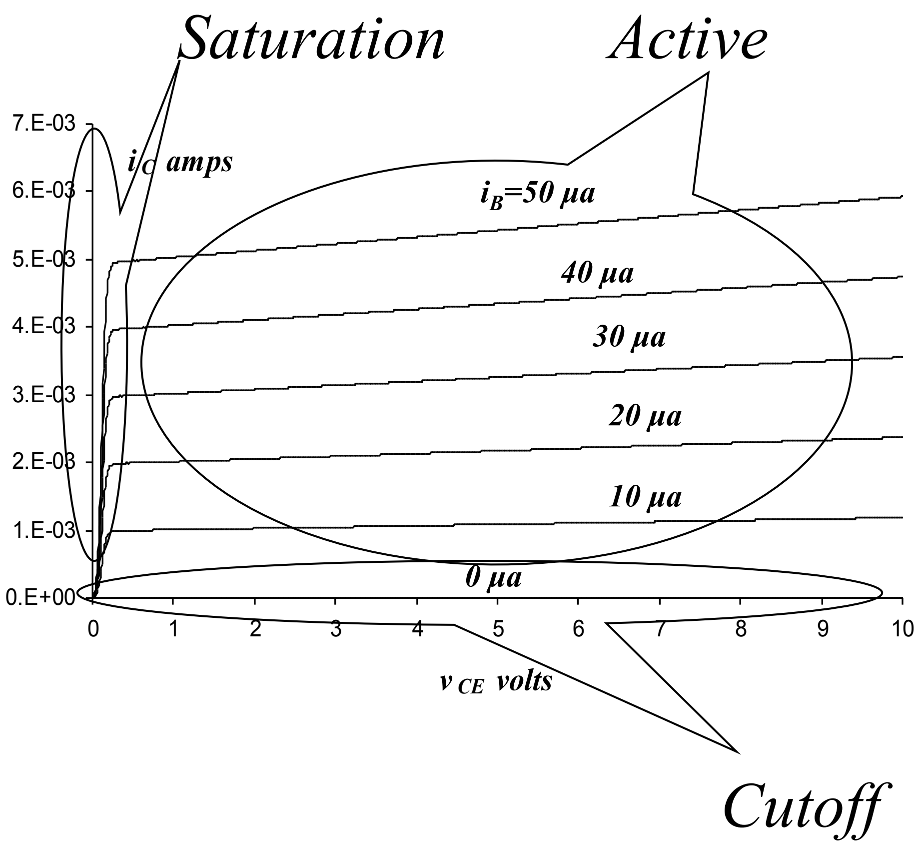
BJT Regions of Operation



There are three regions of operation for a BJT:

1. Cutoff Region – where no current flows in the collector or base circuits. When a transistor is in this state, we say that the transistor is OFF
2. Active Region – where amplification takes place
3. Saturation Region – where the maximum current flows in the collector for a given load.

BJT Regions of Operation

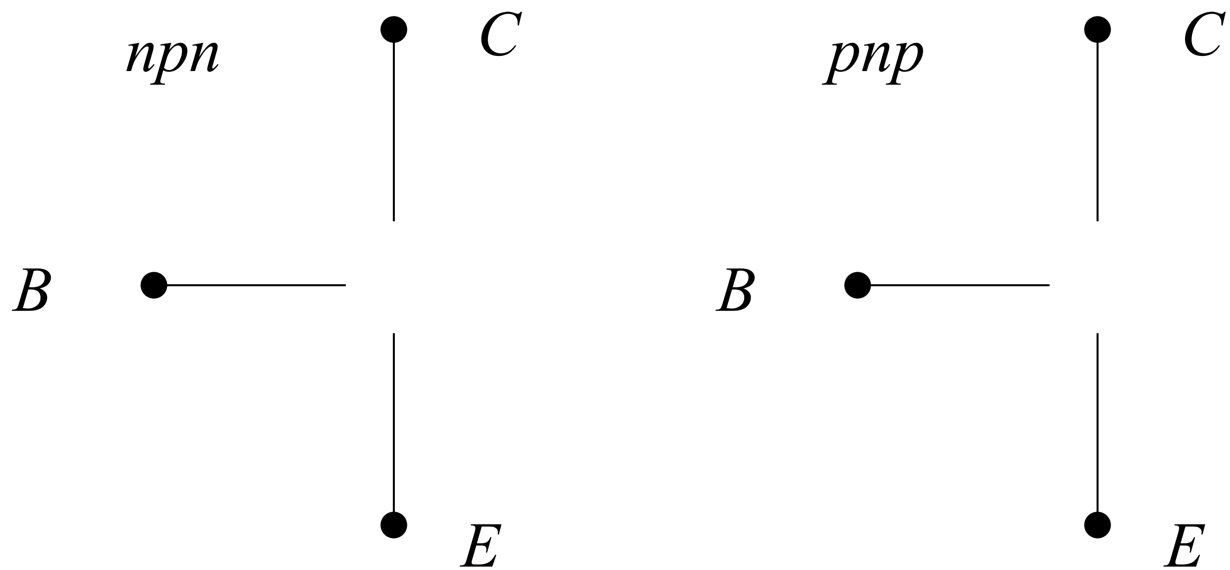


1. Cutoff: both junctions are reverse biased , $i_B = 0$, $v_{BE} < V_{FBThreshold}$, $i_C = 0$, $v_{CE} = V_{CC}$
2. Active: Emitter-Base junction forward biased, Collector Base junction reverse biased, $i_B > 0$, $v_{BE} \approx V_{FBThreshold}$, $i_C = \beta i_B > 0$, $v_{CE} = V_{CC} - i_C R_C$, where R_C is the series (load) resistor in the collector circuit.
3. Saturation: both junctions are forward biased, $i_B > 0$, $v_{BE} \approx V_{BEThreshold}$, $v_{CE} = V_{CESaturation} \approx 0 < v_{BE}$, $i_C = (V_{CC} - V_{CESaturation})/R_C$, $i_C < \beta i_B$, where R_C is the series (load) resistor in the collector circuit.

Large Scale DC Models

- For each of these regions, we can define an analysis model to aide in the DC operation of the transistor

Large Scale DC Models
Cutoff Region



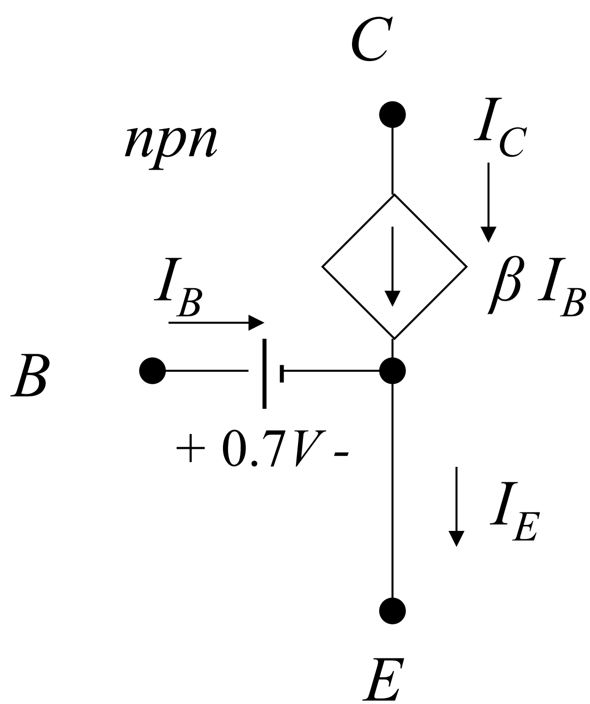
$V_{BE} < V_{FBThreshold} \approx$ 0.6 V

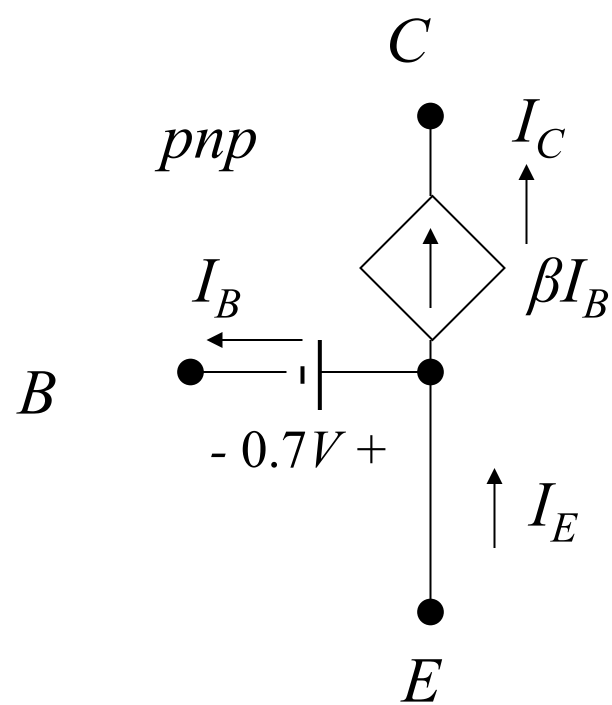
$V_{CE} < V_{FBThreshold} \approx$ 0.6 V

$V_{BE} > V_{FBThreshold} \approx$ -0.6 V

$V_{CE} > V_{FBThreshold} \approx$ -0.6 V

Large Scale DC Models
Active Region

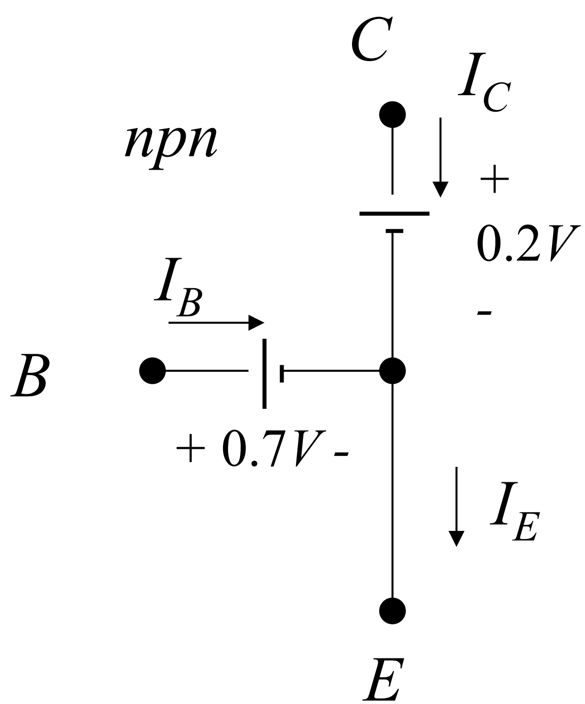


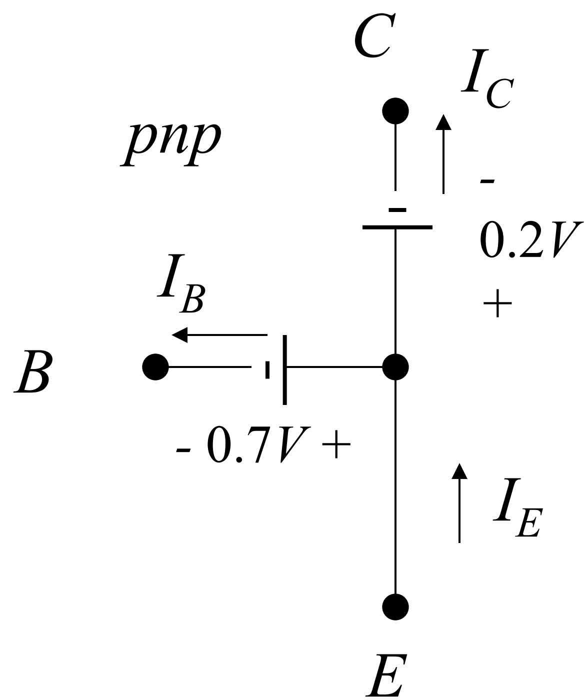


$I_B > 0;\ V_{BE} \approx\ 0.7V > V_{FBThreshold}$ $\quad$ $I_B > 0;\ V_{BE} \approx\ -0.7V > V_{FBThreshold}$

$I_C = b\ I_B;\ V_{CE}\ > 0.2\ \mathrm{V}$ $\quad$ $I_C = b\ I_B;\ V_{CE}\ < -\ 0.2\ \mathrm{V}$

Large Scale DC Models
Saturation Region





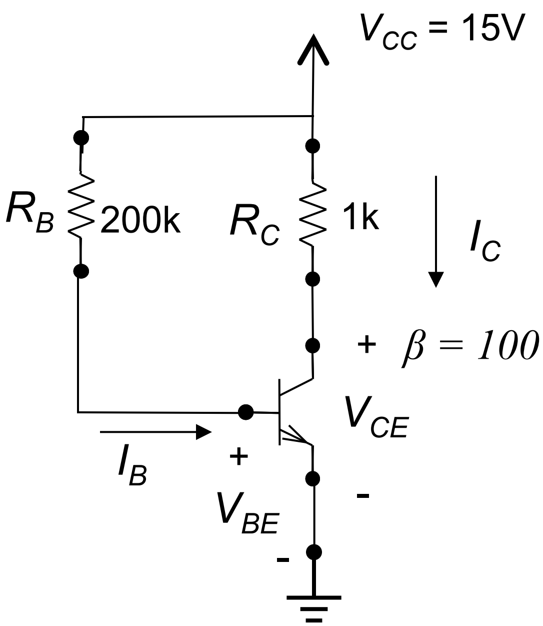
$I_B > 0;\ V_{BE} \approx 0.7V > V_{FBThreshold}$

$0 < I_C < \beta I_B;\ V_{CE} \approx 0.2\text{ V}$

$I_B > 0;\ V_{BE} \approx -0.7V > V_{FBThreshold}$

$0 < I_C < \beta I_B;\ V_{CE} \approx -0.2\text{ V}$

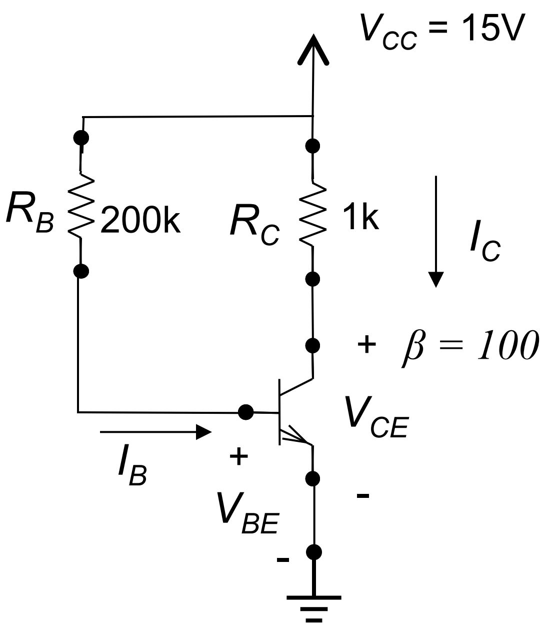
An Example



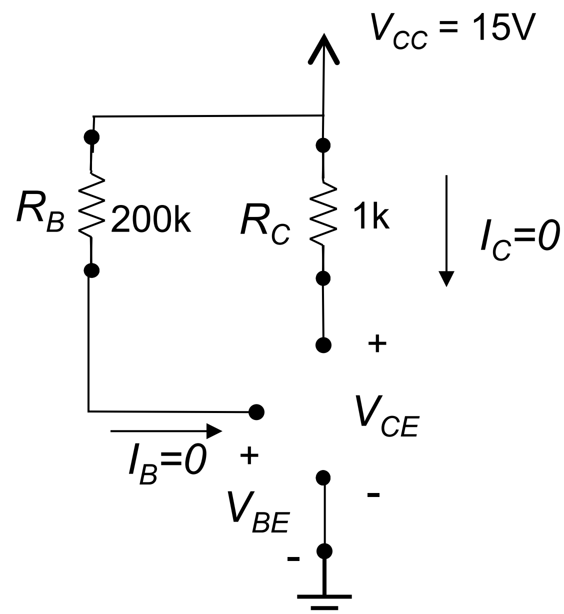
- This circuit uses one DC source to set the Q-point.
- The term, Bias point, is synonymous with Q-point.
- Therefore we call this circuit a self-bias circuit

- Let's first assume that this circuit is in cutoff.
- We will use the model for cutoff

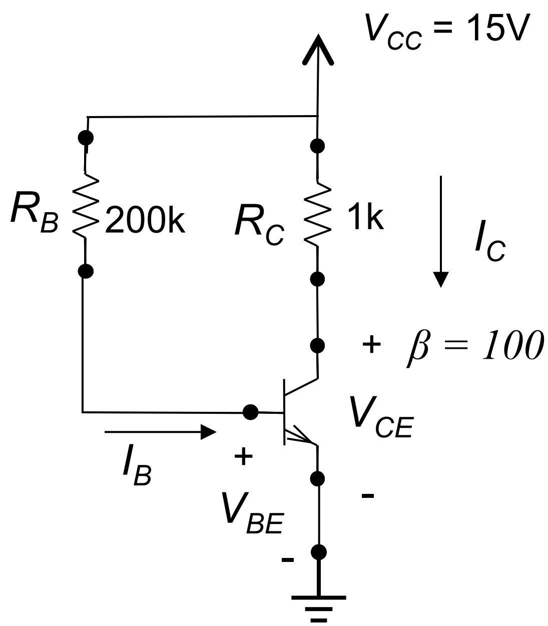
An Example



- If this is in cutoff, then $V_{BE} = 15V$.
- But this can't be since to be in cutoff $V_{BE} < V_{FBThreshold} \approx 0.5$

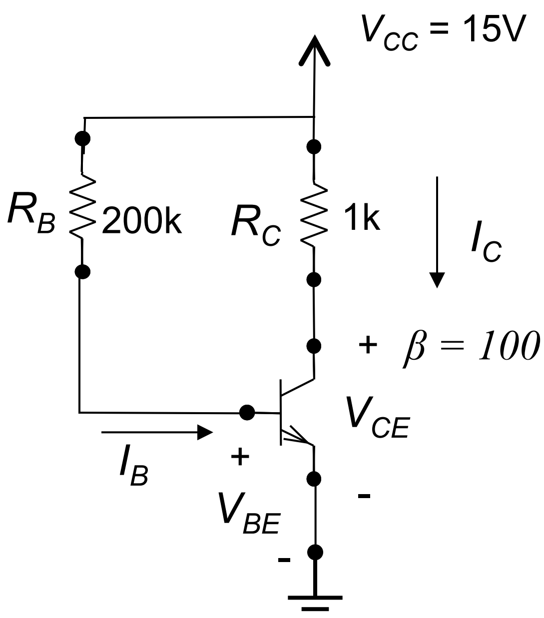


An Example

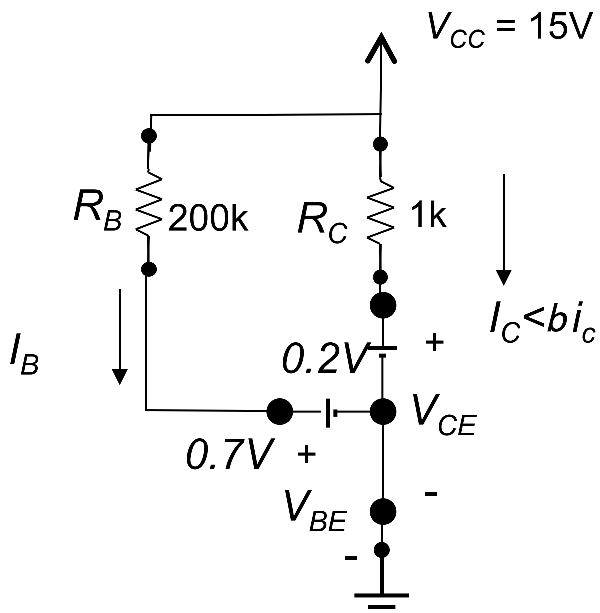


- Now let's assume that this circuit is in the saturation region.
- And we will use the model for the saturation region

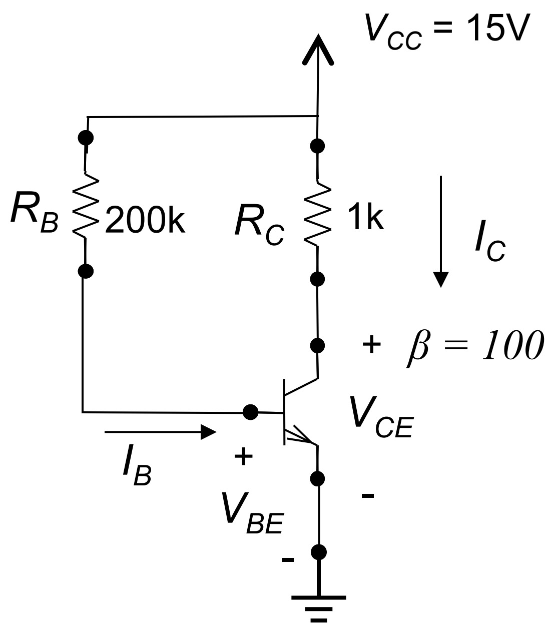
An Example



- If this is in the saturation region, then
  $i_B = (15 - 0.7) / 200k = 71.5m\,A$
  $i_C = (15 - 0.2) / 1k = 14.8\text{ m}A$
  $\beta I_B = 100 * 71.5m = 7.15\text{ mA} < i_C$
- NOT OK !!!!



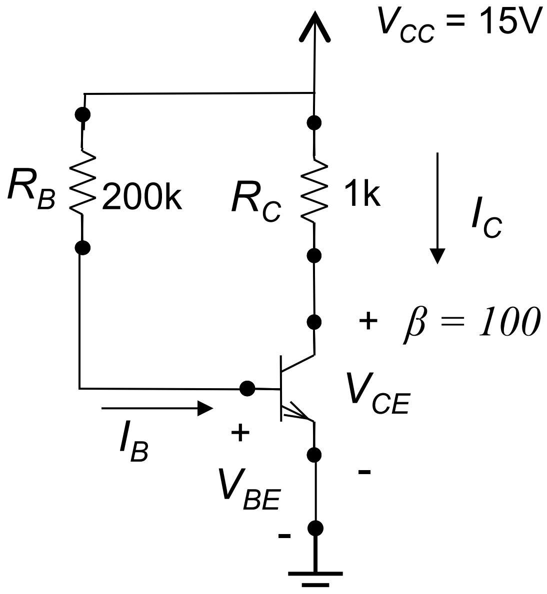
An Example

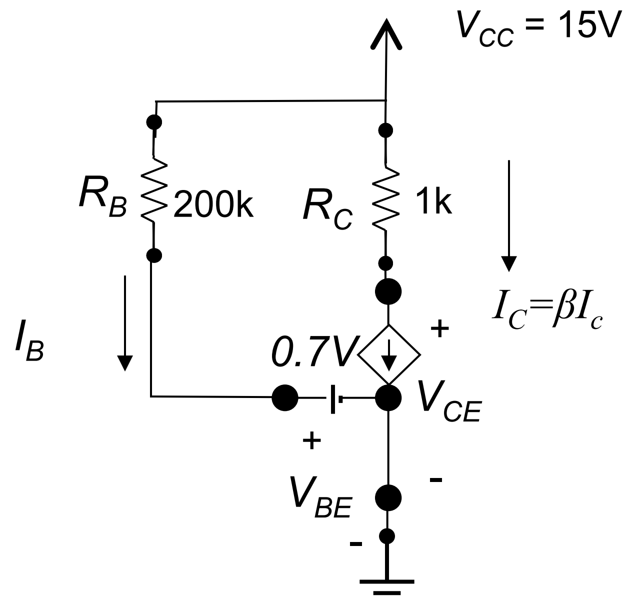


- Now let's assume that this circuit is in the active region.
- And we will use the model for the active region

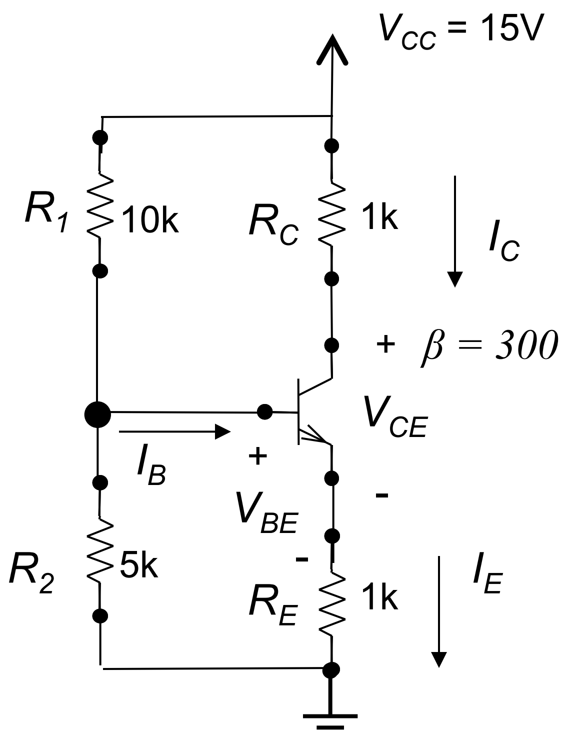
An Example

- If this is in the active region, then
  $i_B = (15 - 0.7) / 200k = 71.5 m A$
  $i_C = 100 * 71.5 m A = 7.15\ mA$
  $V_{CE} = 15 - (7.15\ m * 1k)$
  $= 7.85\ V > 0.2V$
- OK !!!!





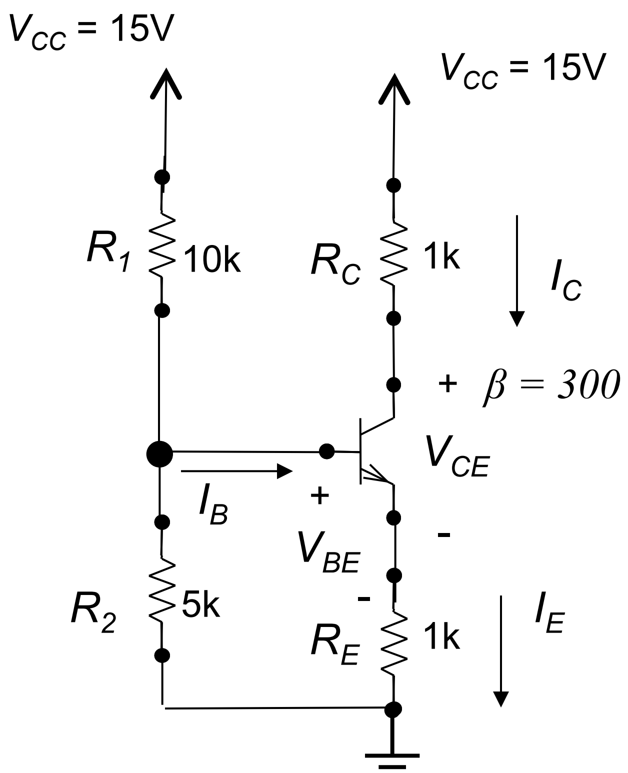
Another Self-Bias Circuit Example

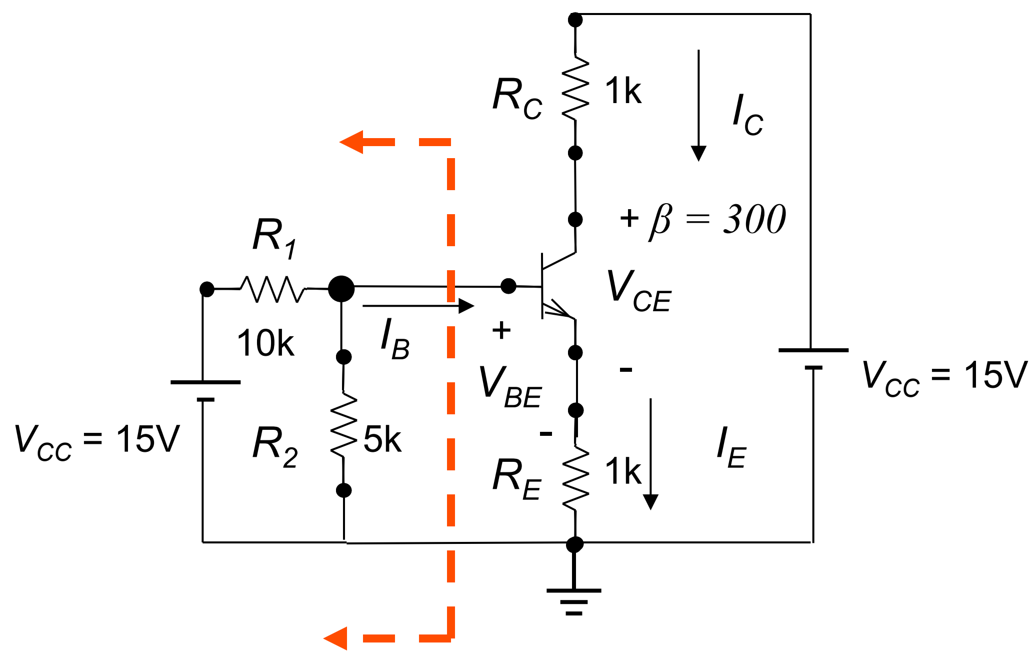


- This is another self-bias circuit which uses 4 resistors to set the Q-point.
- Let's redraw this circuit to see how to analyze it!

Another Self-Bias Circuit Example

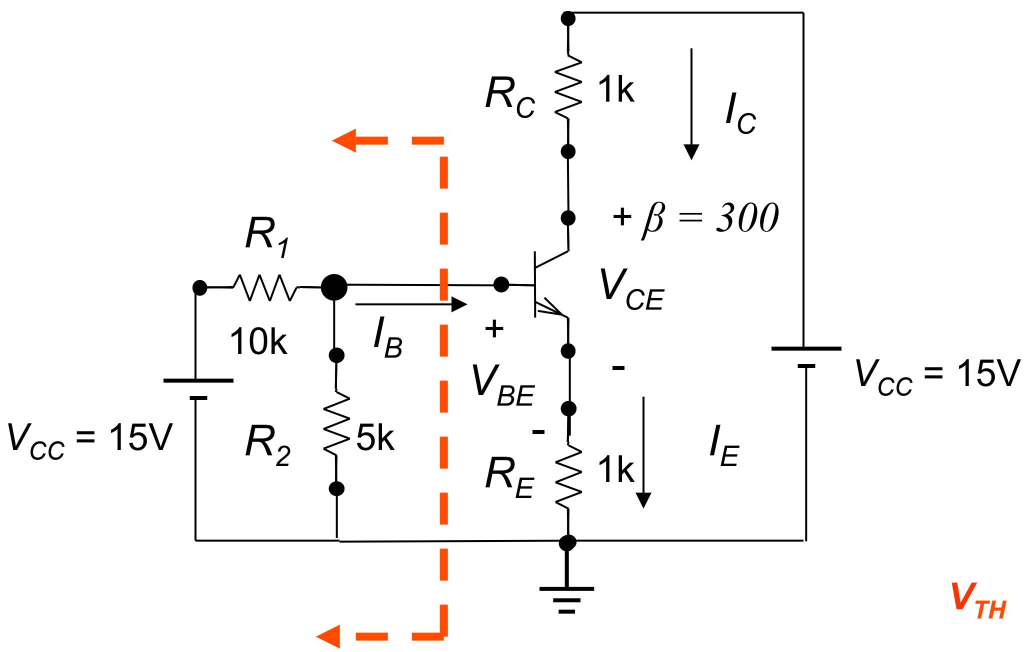
- Use Thevenin's equivalent on the redrawn circuit to yield another simpler circuit to analyze

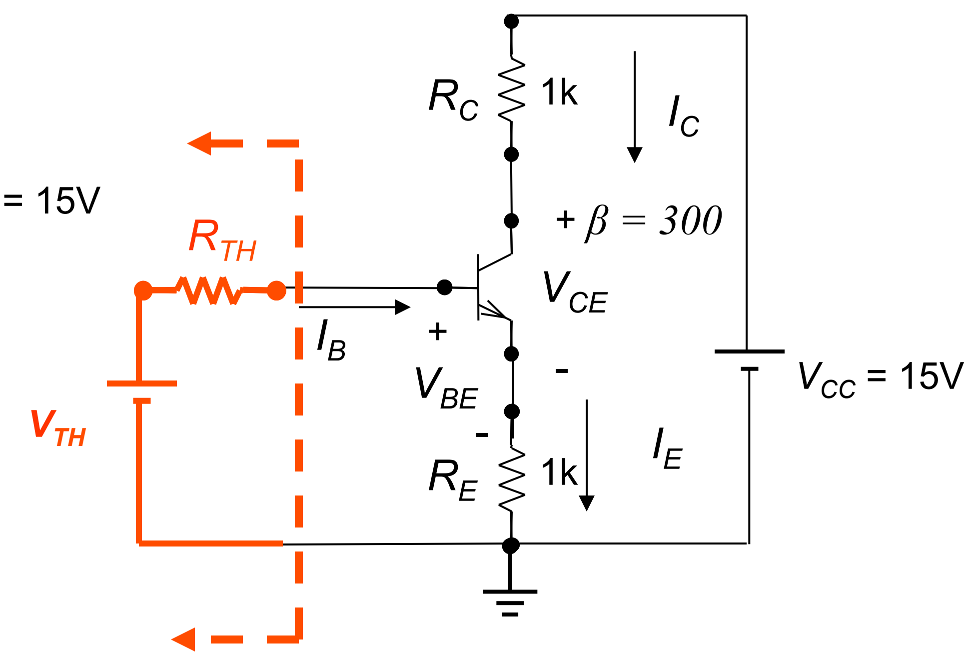




Another Self-Bias Circuit Example

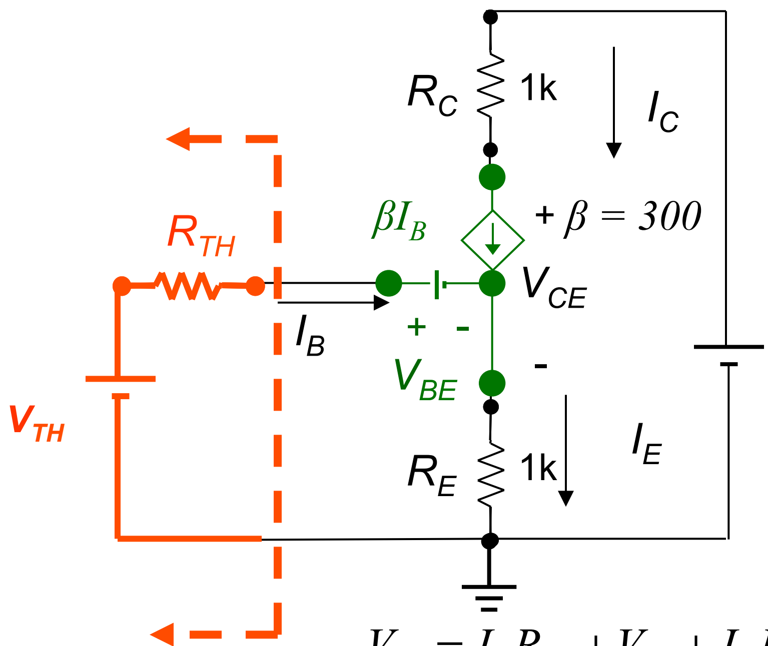
- Use Thevenin's equivalent on the redrawn circuit to yield another simpler circuit to analyze





Another Self-Bias Circuit Example

- Now let's assume the active region, replace the transistor with the active region model, and analyze the circuit.



- First, the Thevenin's Equivalent:

$$V_{TH} = \frac{R_2}{R_2 + R_1} V_{CC} = \frac{5}{5+10} 15 = 5V$$

$$R_{TH} = \frac{R_2 R_1}{R_2 + R_1} = \frac{5 \times 10k}{5+10} = 3.33k$$

- Next, applying KVL to the Base And Collector Circuits:

$$V_{TH} = I_B R_{TH} + V_{BE} + I_E R_E = I_B R_{TH} + V_{BE} + (I_B + I_C) R_E = I_B R_{TH} + V_{BE} + (1+\beta) I_B R_E$$

$$I_B = \frac{V_T - V_{BE}}{R_{TH} + (1+\beta) R_E} = \frac{5 - 0.7}{3.33k + (301)1k} = 14.1\mu A$$

$$I_C = \beta I_B = 4.24mA; I_E = 4.25mA$$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E = 15 - 4.24m \times 1k - 4.25m \times 1k = 6.51V$$

Homework

- Probs. 4.26, 4.27, 4.28, 4.29, 4.30, 4.33, 4.34, 4.35