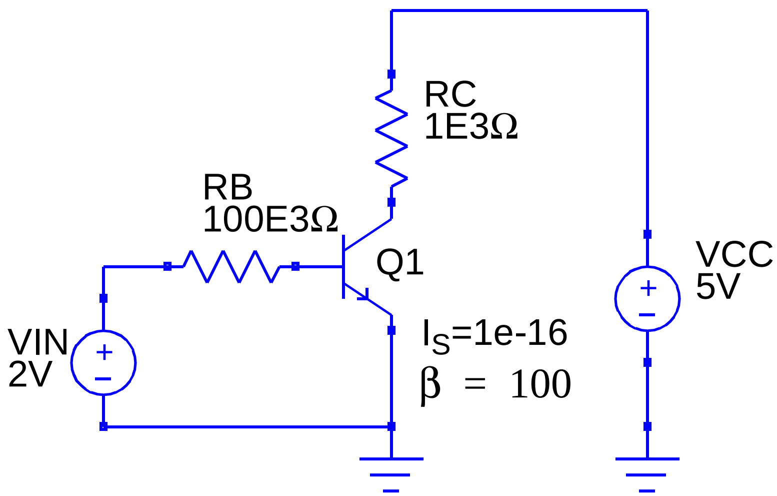
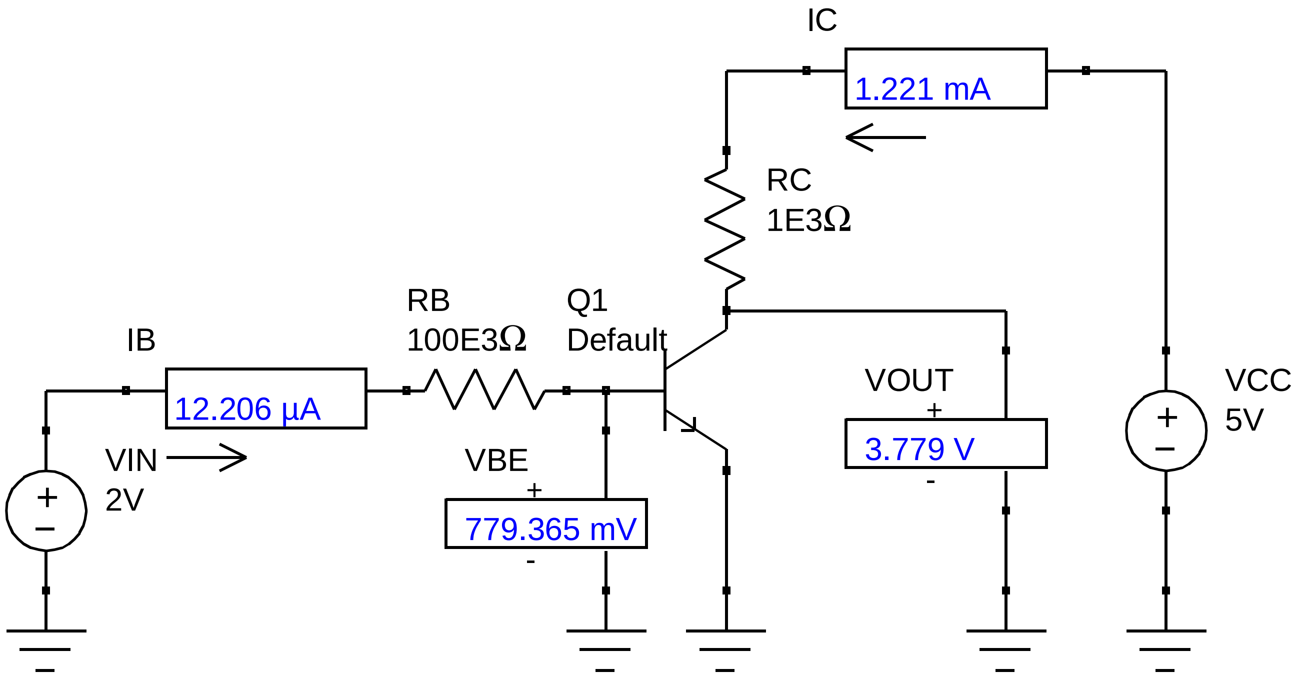
BJT Circuit Analysis

- *Assuming that the transistor is in the active region*, solve for the voltages and currents --- why this assumption?
- In general, the problem requires solution of a set of nonlinear equations:



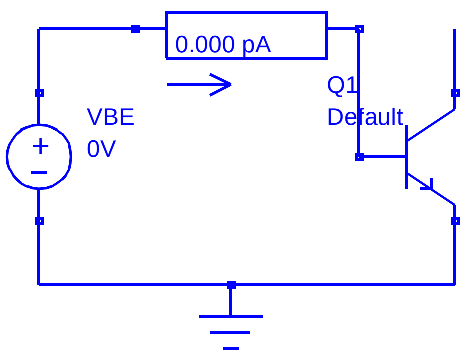
BJT Circuit Analysis

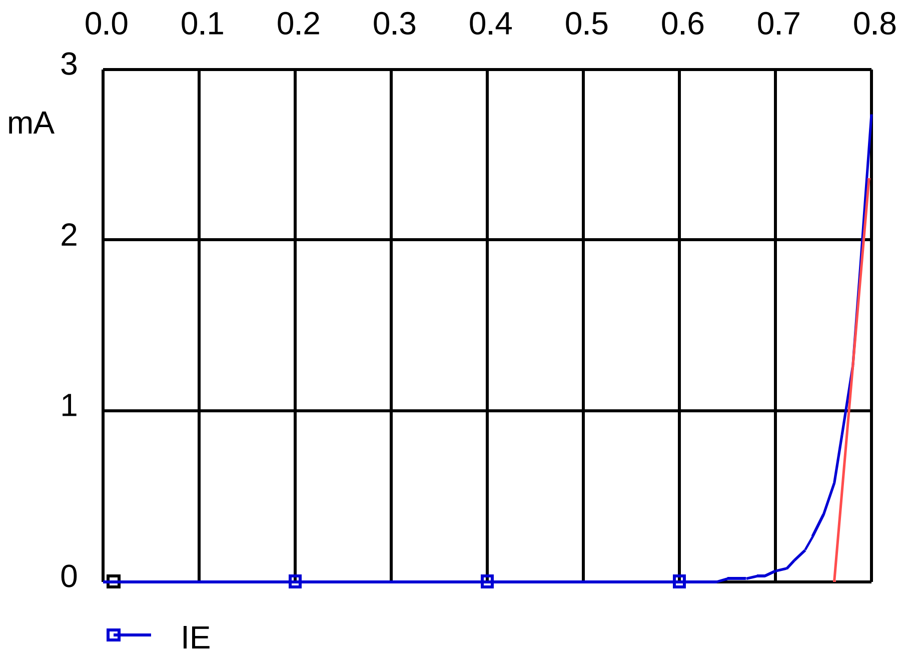
- SPICE solves the system of nonlinear equations to obtain the voltages and currents
- Is this circuit in the active region?



BE Diode Characteristic

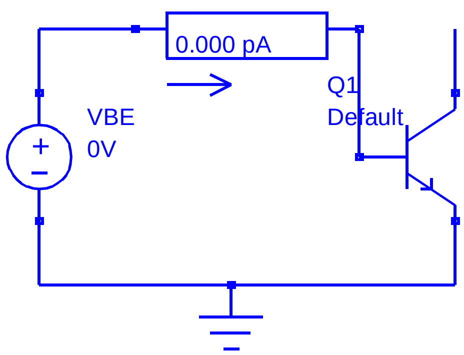
- We can effectively use a simplified model for the diode if we know the approximate operating range of the BE diode characteristic

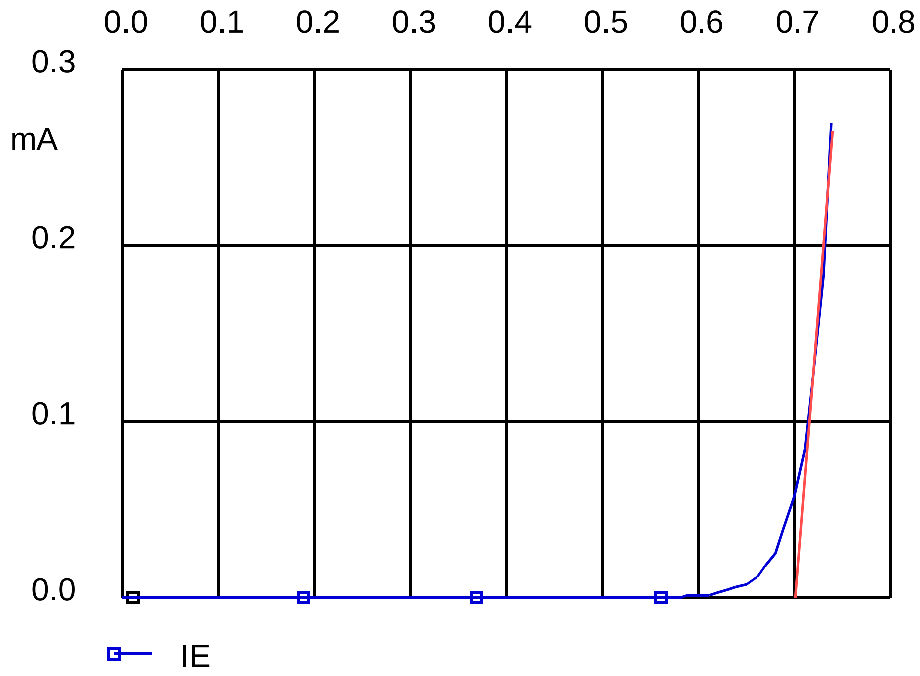




BE Diode Characteristic

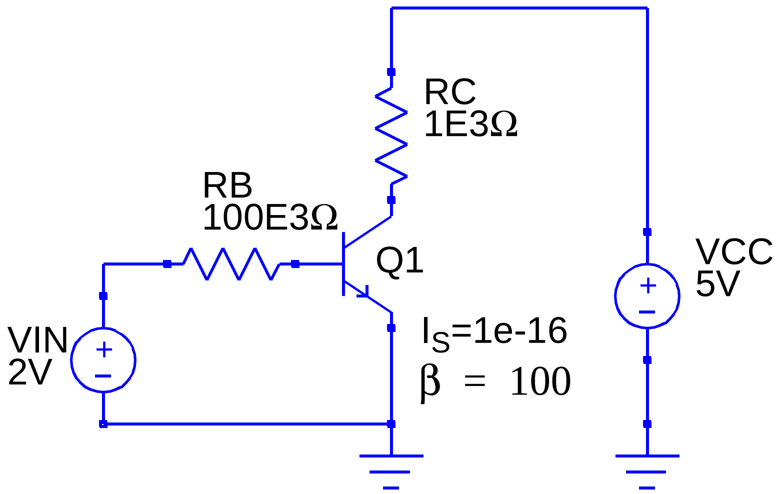
- Note that "V_{ON}" changes if we're analyzing an order of magnitude less current
- So how do we know what the real "V_{ON}" is?





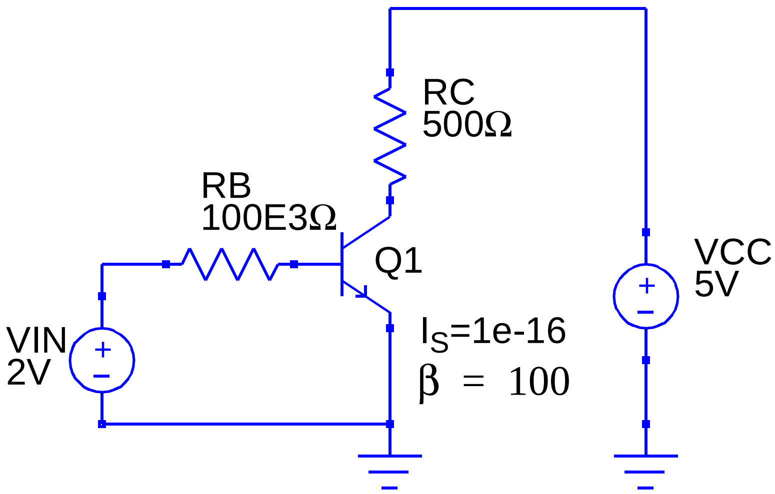
Simplified BJT Circuit Analysis

- Assuming V_{BE} is 0.78 volts, we can approximate this circuit solution by hand analysis



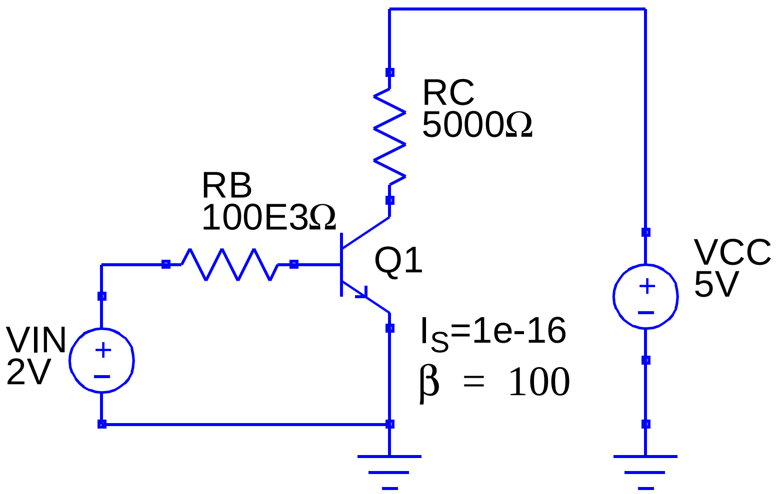
Simplified BJT Circuit Analysis

- What happens as R_C is decreased?
- Will it remain in the active region?



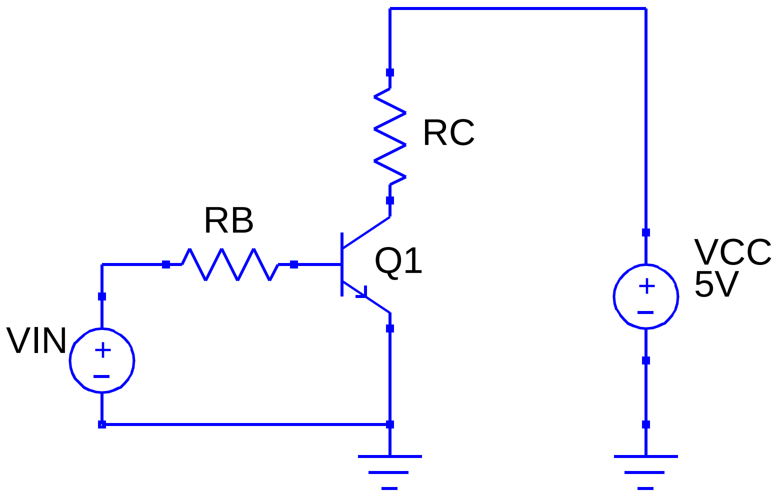
Simplified BJT Circuit Analysis

- What happens as R_C is increased?
- Will it remain in the active region?



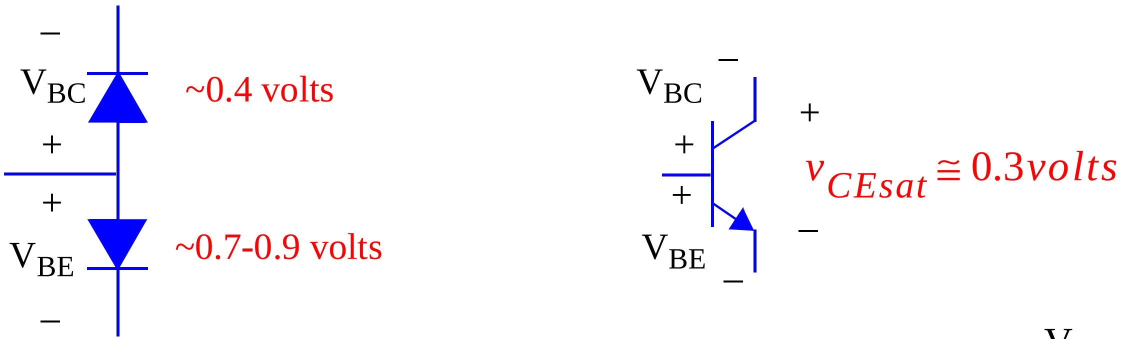
Saturation

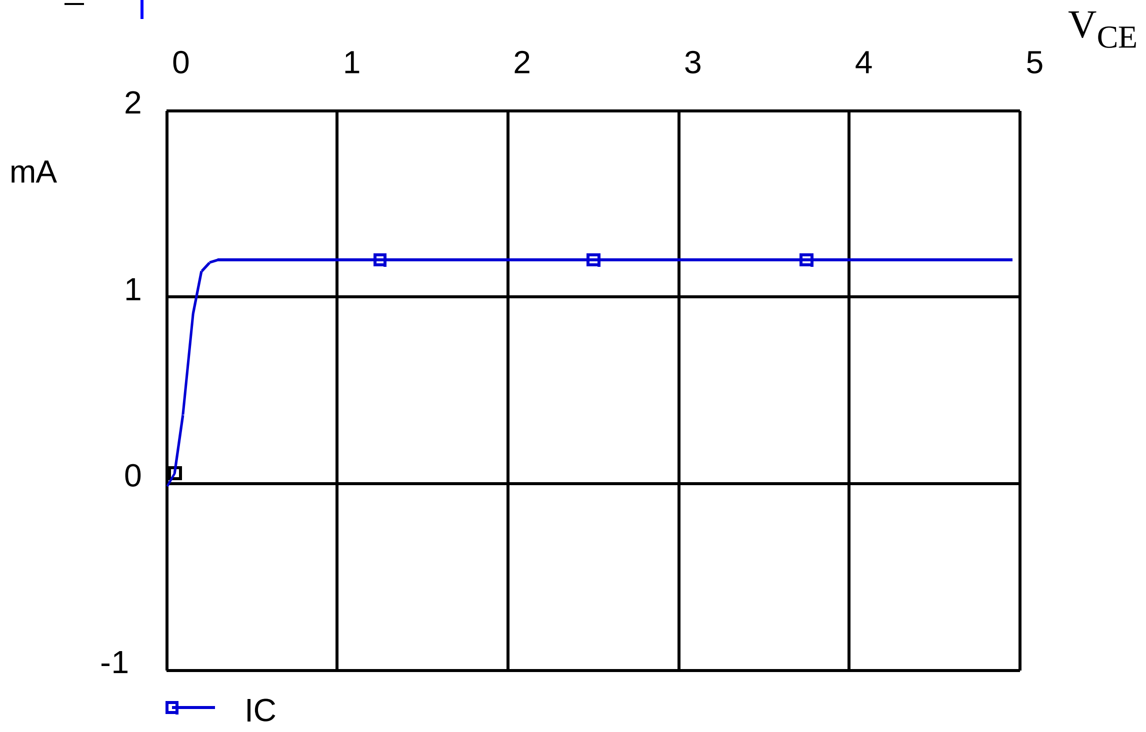
- When both the EBJ and CBJ are forward biased, the transistor is no longer in the active region, but it is in the saturation region of operation
- We can *easily* solve for the maximum i_C that we can have before we reach saturation *for this circuit*



Saturation

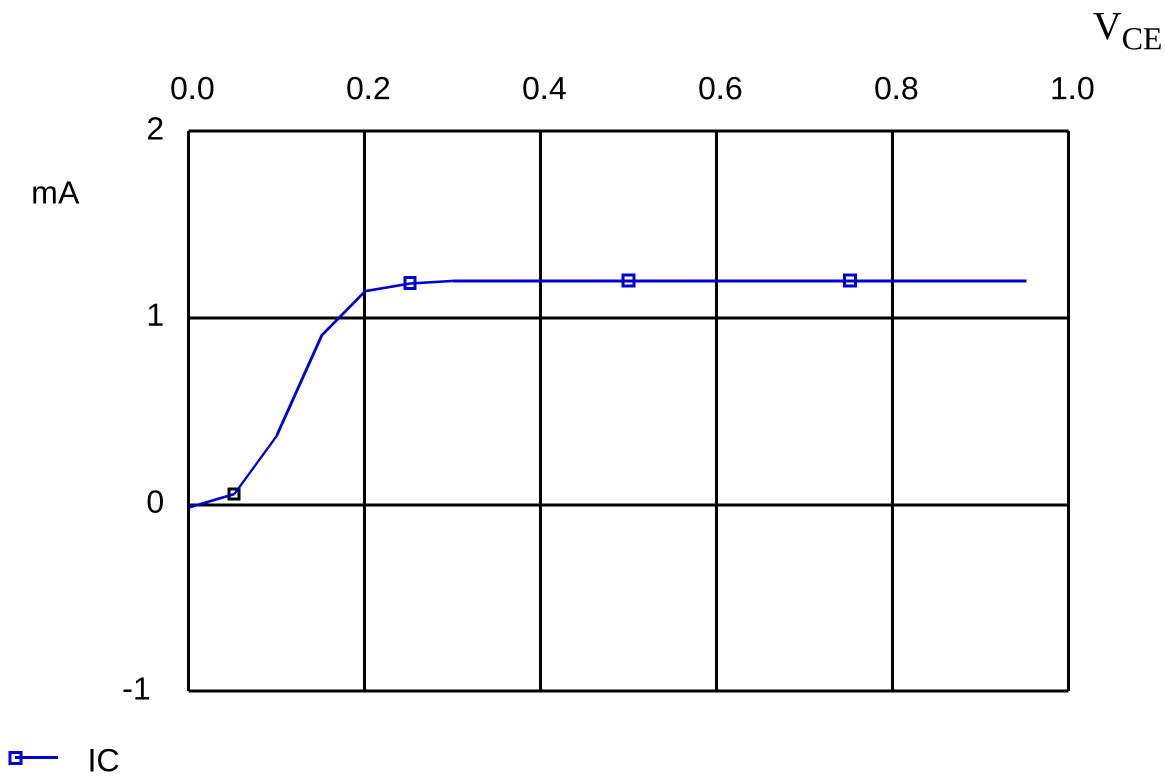
- With both diodes forward biased, the collector-to-emitter voltage, v_{CE}, saturates toward a constant value





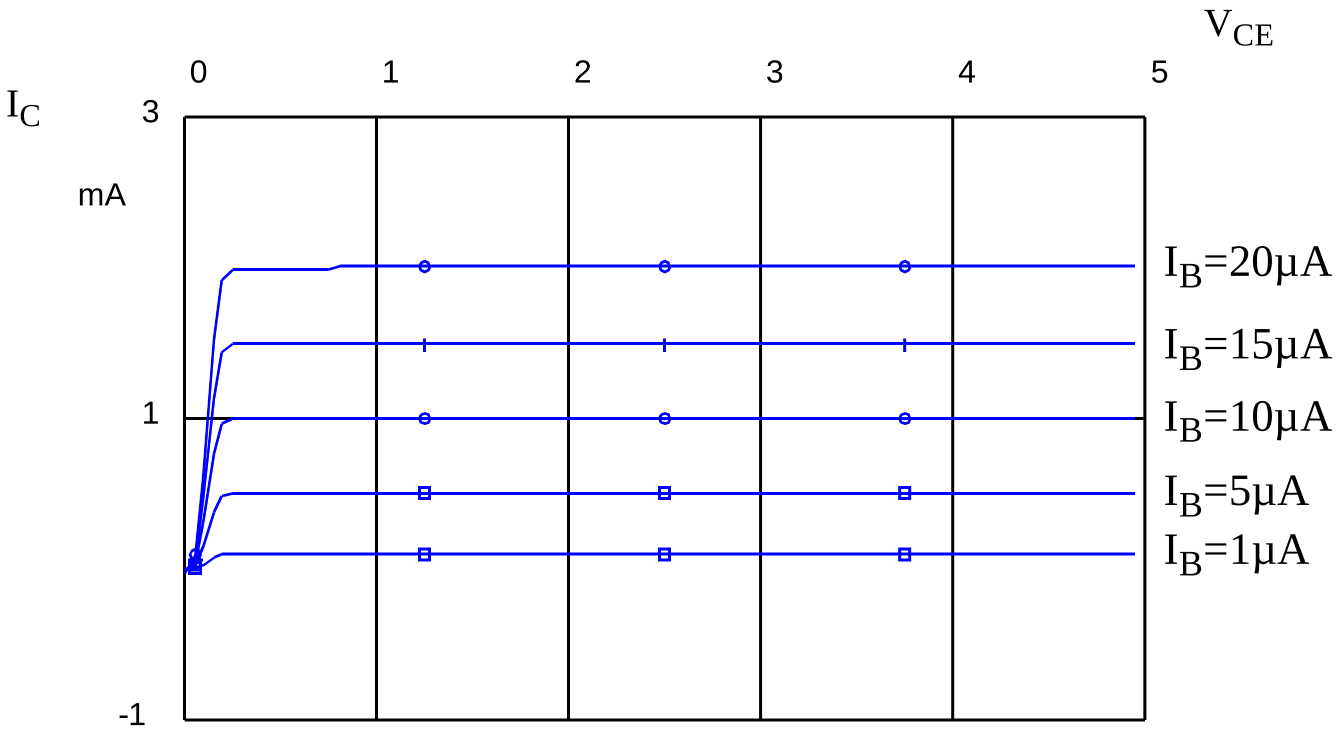
Saturation

- In saturation, increasing i_C shows little increase in i_B. Why?

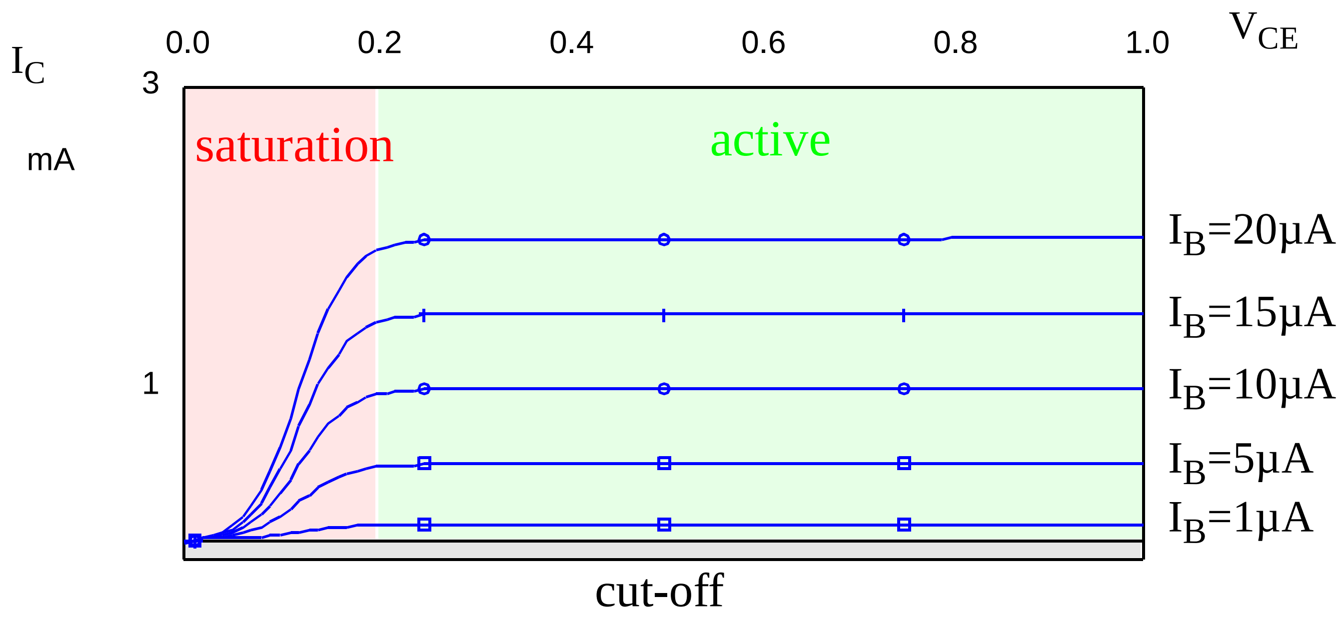


Regions of Operation

- The complete i-v characteristic is:

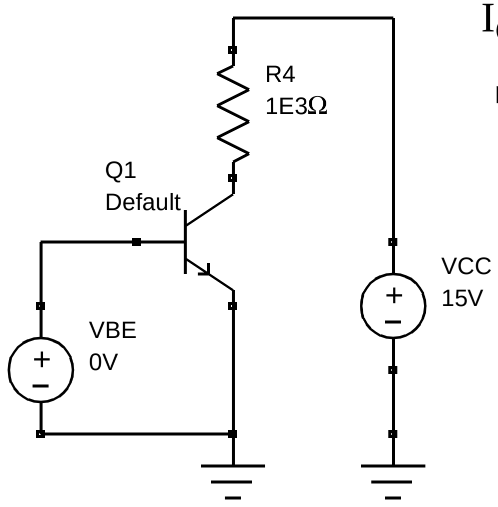


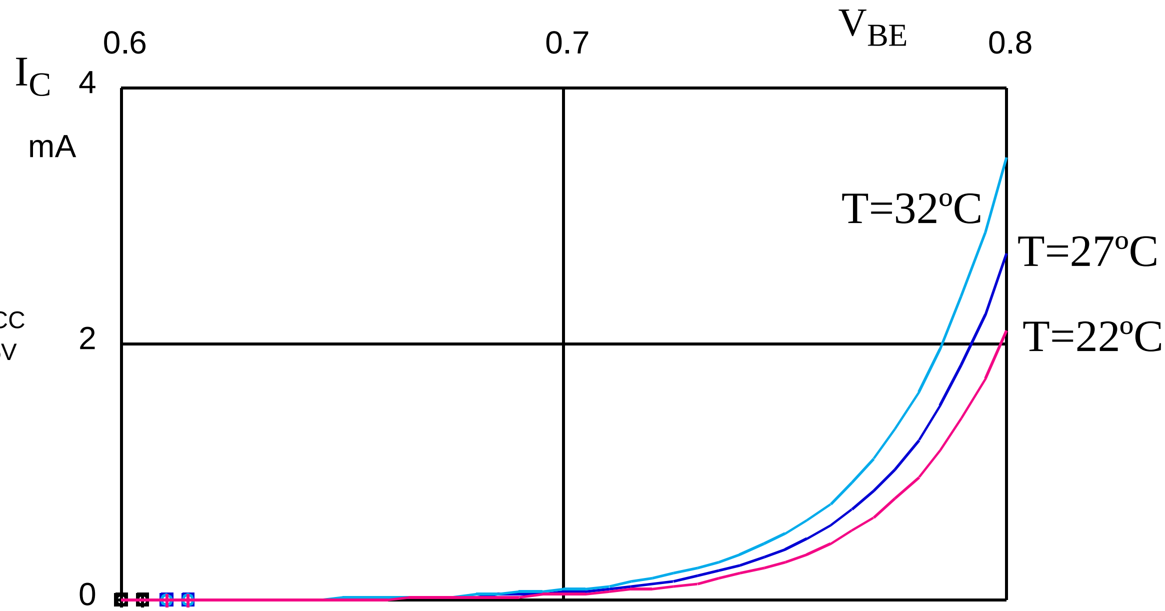
Regions of Operation



Temperature Variations

- The collector current vs. the base-emitter voltage follows a diode characteristic, which like a diode, is temperature dependent

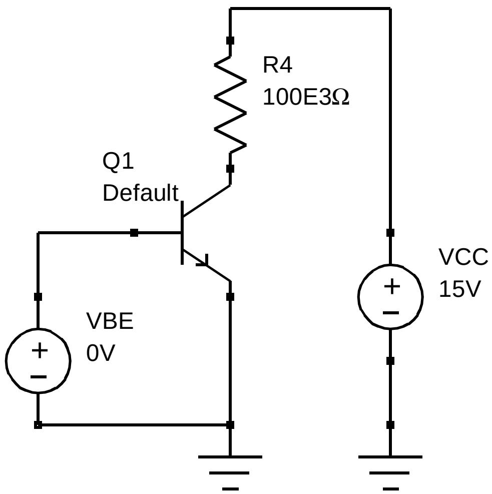


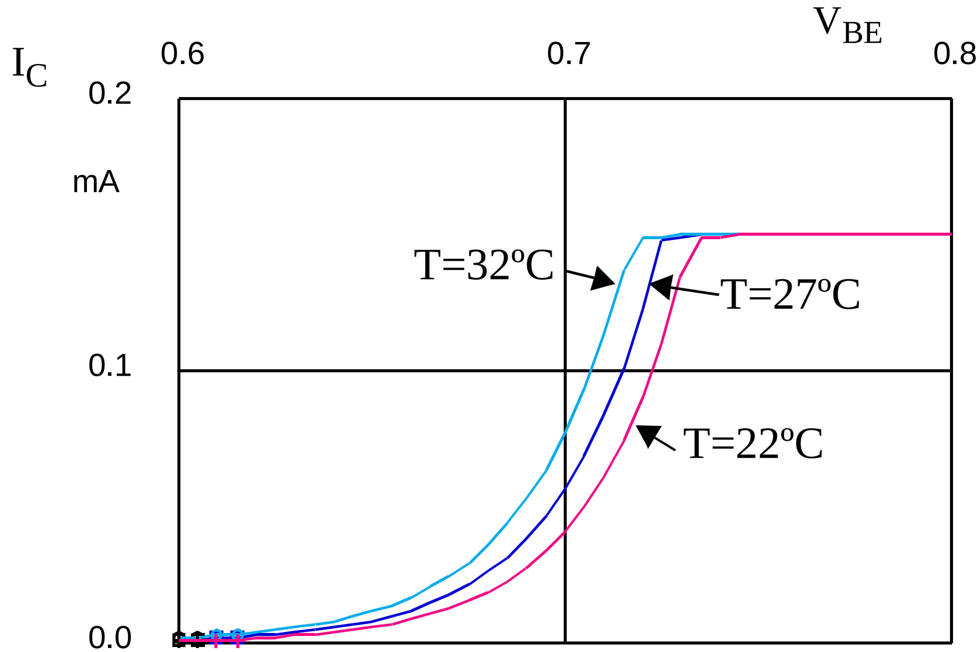


- Does this value of R_C significantly impact the values for i_C in this example?

Temperature Variations

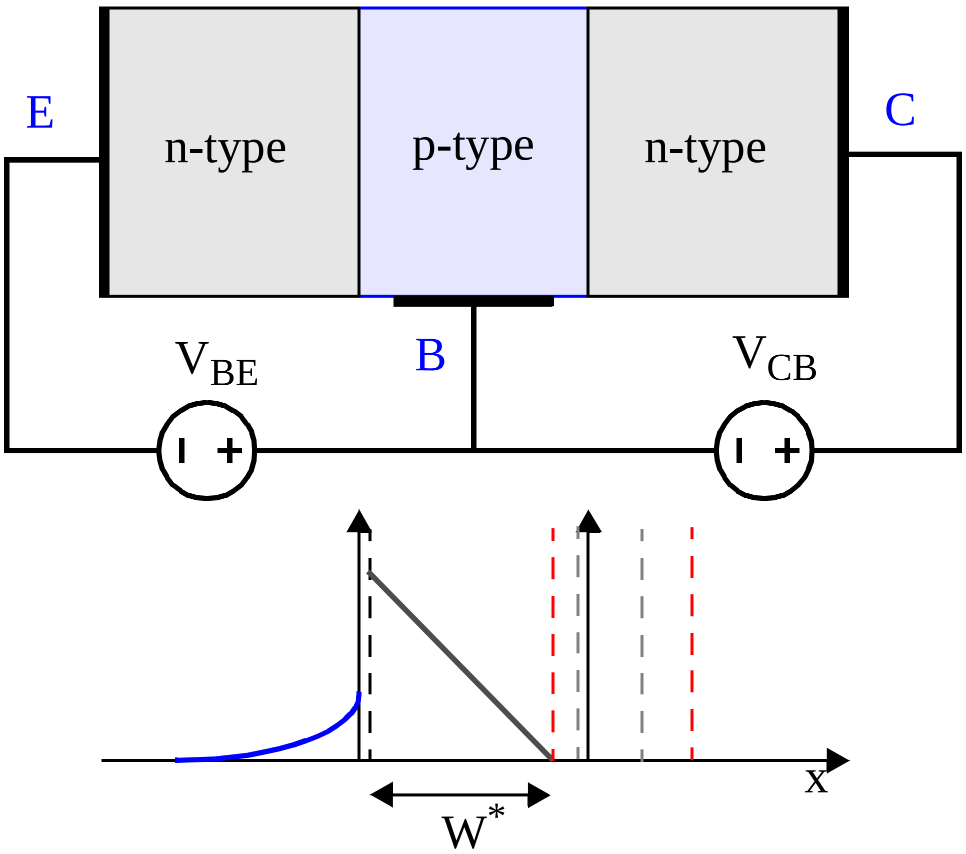
- In saturation, the collector current no longer increases with increasing V_{BE}. Why not?





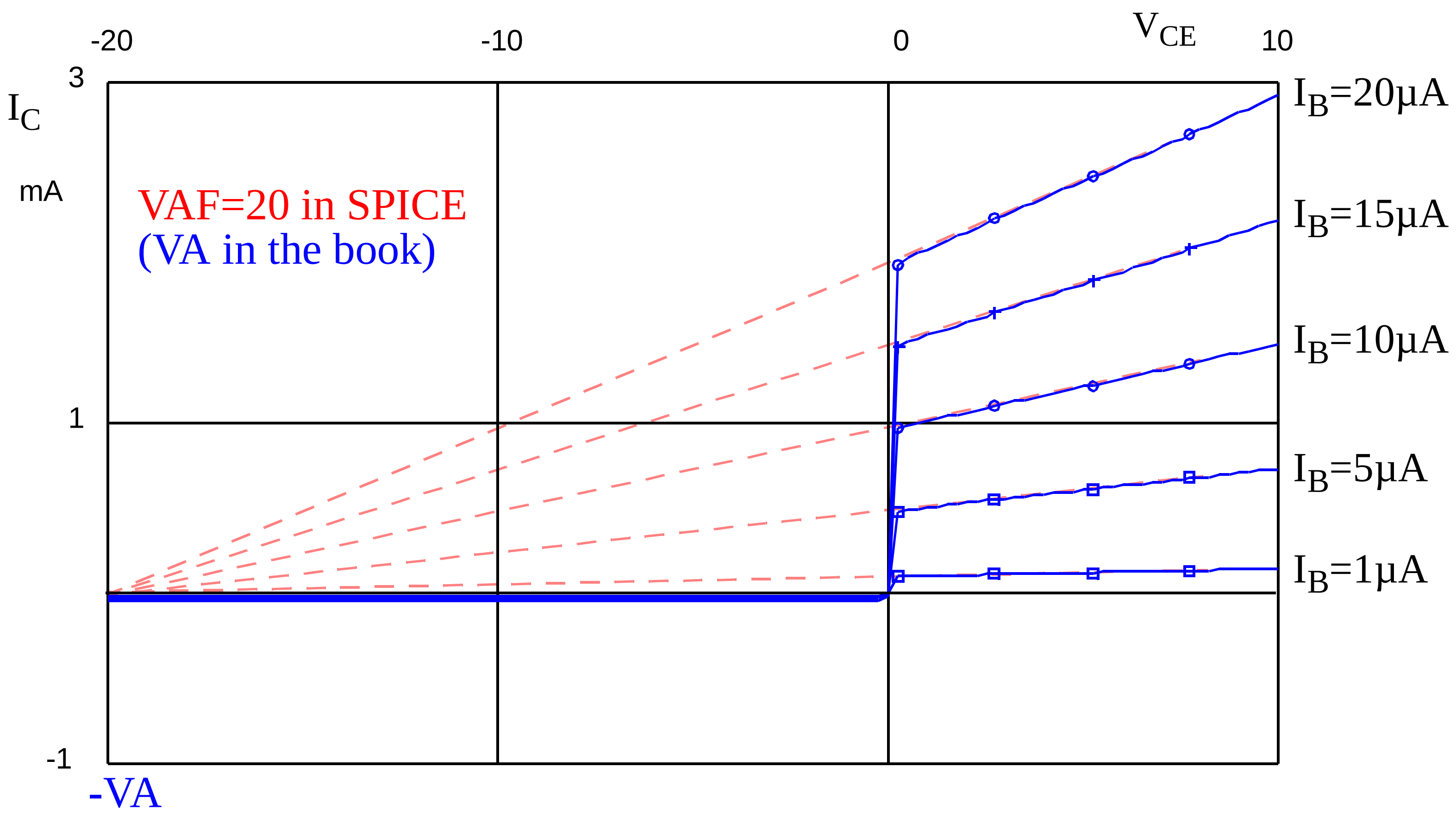
Base Width Variation

- In the active region, i_C does vary somewhat with V_{CB} (hence R_C in our previous examples) due to the variation it causes in the base width.
- Effective base width, W^*, decreases with increasing V_{CB}
- What do you expect would happen to i_C as W^* decreases?



Early Voltage

- The I_C vs. V_{CE} curves in the active region have a finite slope to them due to this i_C dependence on V_{CB}
- *Early* showed that these slopes all converge to one negative voltage point

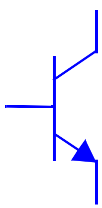


Early Voltage

- The finite slope in the active region due to decreasing base width can be approximated by

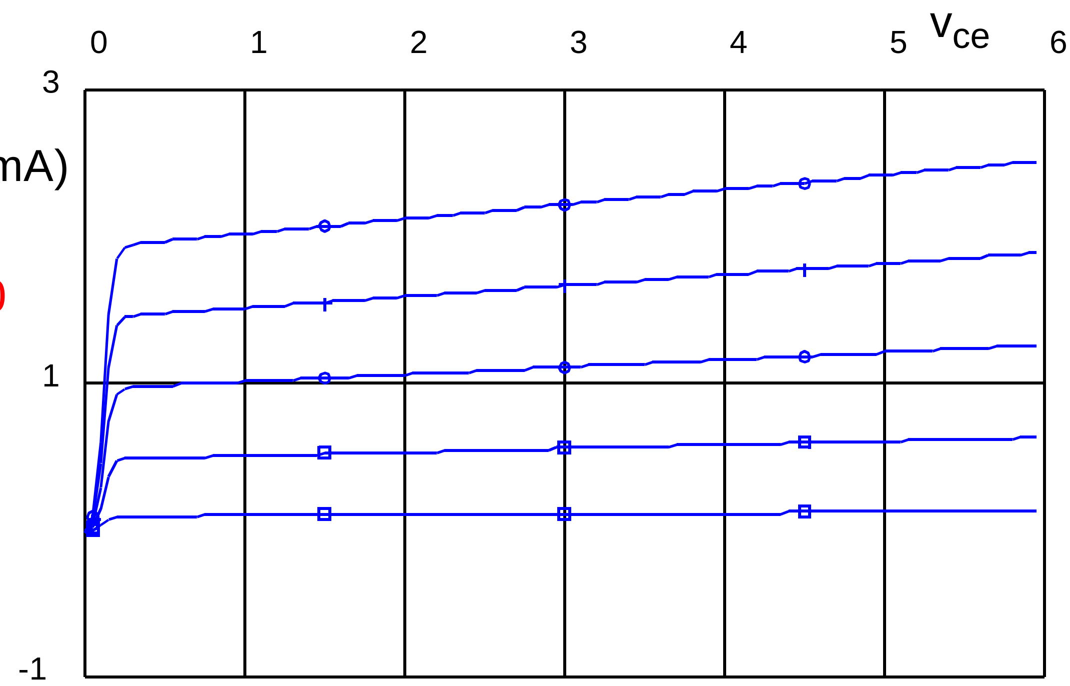
$$i_c = I_s e^{v_{be}/V_T}\left(1 + \frac{v_{ce}}{V_A}\right)$$

- This means that the output resistance between the collector and emitter is not infinite --- *very important for analog design*



$$\frac{\partial i_C}{\partial v_{ce}} = g_o \neq 0$$

at some fixed i_b point



Early Voltage

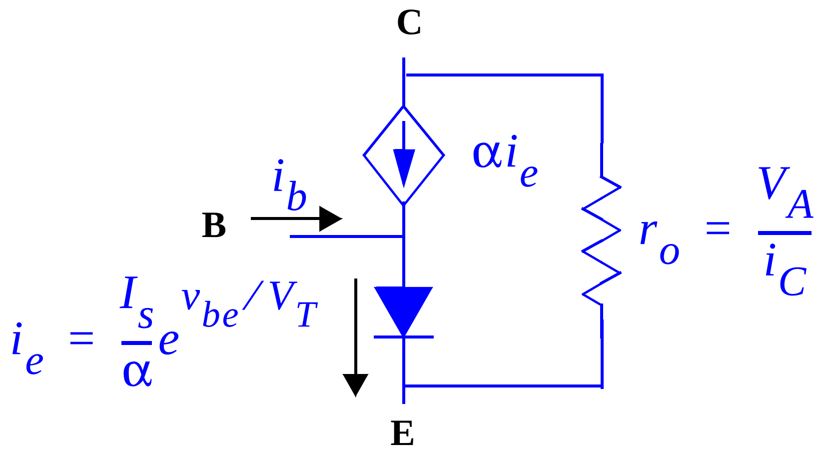
- The output conductance, or resistance, at a fixed i_b point represents the slope of the line tangent to that point on the curve:

$$i_c = I_s e^{v_{be}/V_T}\left(1 + \frac{v_{ce}}{V_A}\right)$$

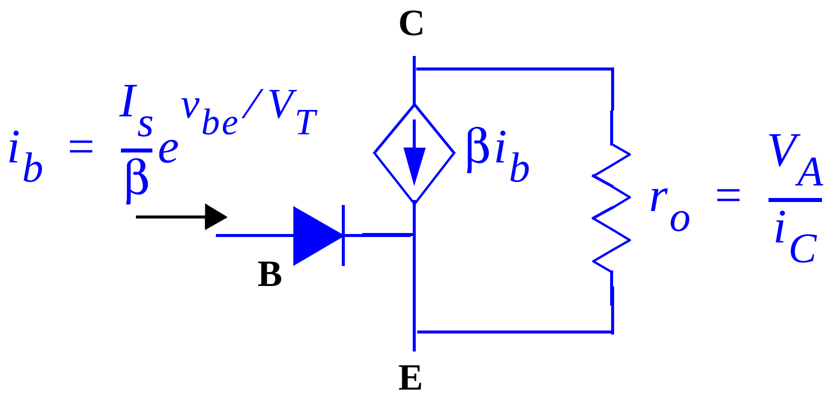
- Generally not considered for dc bias point calculations, but r_o can have a significant impact on a transistor amplifier gain

Early Voltage

- The equivalent circuit models can be modified accordingly:



<u>or</u>

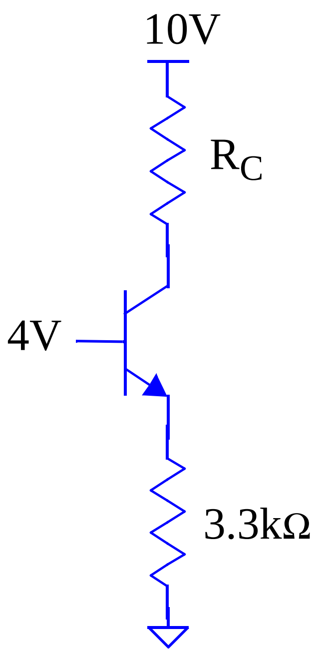


dc Bias Point Calculations

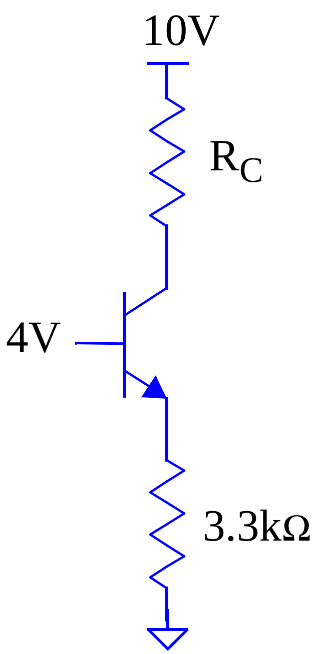
- r_o is generally not considered for hand calculations of dc bias point -- why?

- *For hand calculations:* use V_{BE}=0.7 and assume that the transistor is in the active region; Later verify that your assumptions were correct.

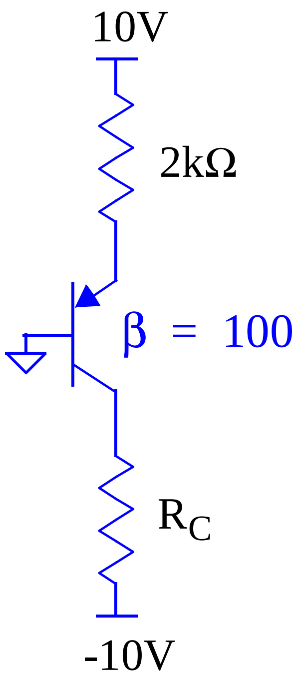
What's the maximum value that R_C can be without reaching saturation? Assume β=100.



dc Bias Point Calculationsdc Bias Point Calculations



- What value of R_C saturates the transistor?



dc Bias Point Calculations

- What value of VCC saturates the transistor for this same circuit?