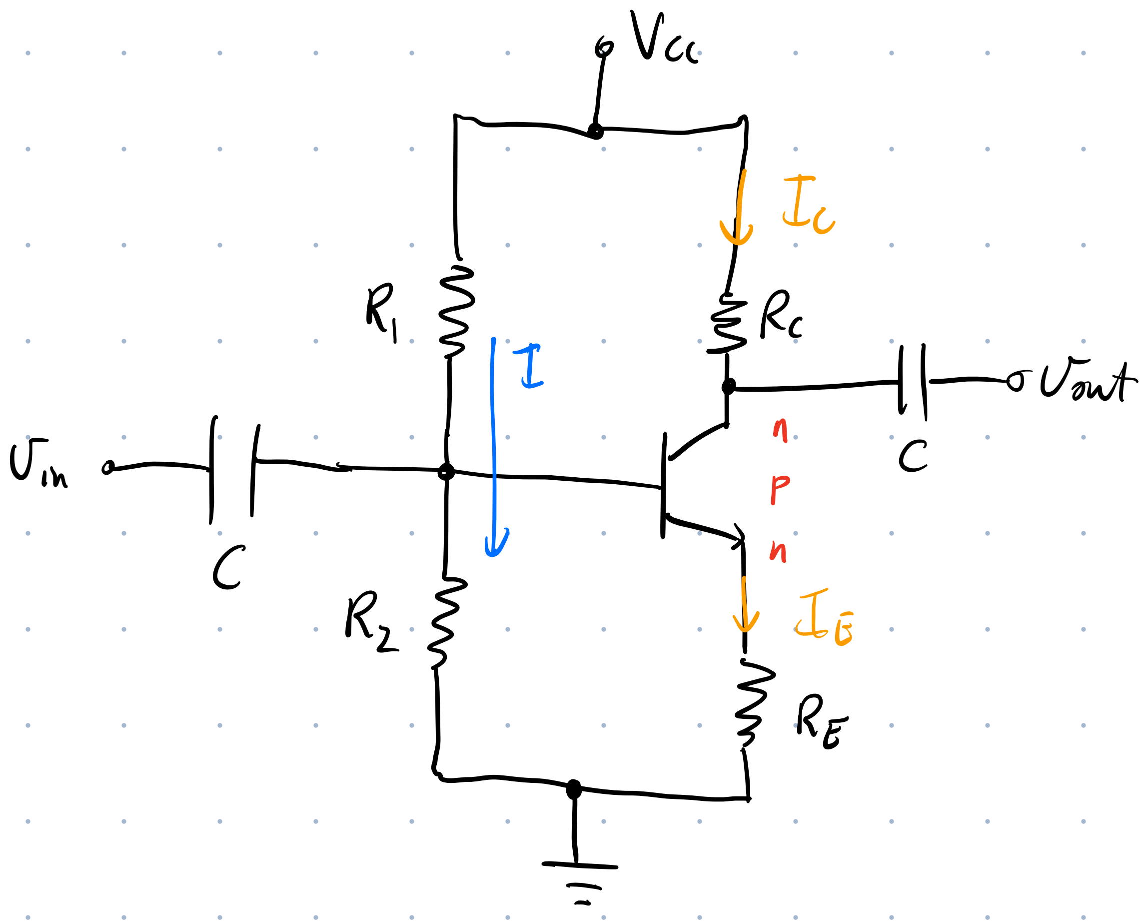
PHYS 231 : Supplementary Notes — Nov. 25, 2024

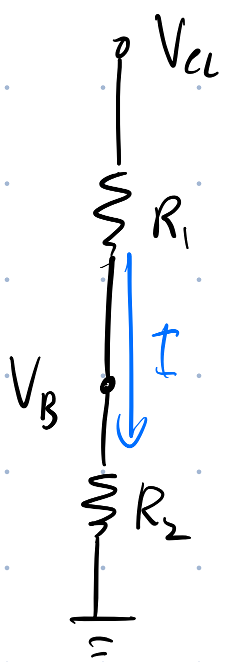
Bipolar Junction Transistor (npn configuration) Voltage Amplifier

Consider the following transistor circuit known as the "common emitter amplifier".



V_{cc}, R_1, & R_2 are chosen to "bias" the transistor s.t. the B-E junction is forward biased & the B-C junction is reverse biased.

Because I_B is small, we have (approximately):



$$V_{cc} - I(R_1 + R_2) = 0$$

$$\therefore I = \frac{V_{cc}}{R_1 + R_2}$$

$$\therefore V_B = IR_2 = V_{cc} \frac{R_2}{R_1 + R_2}$$

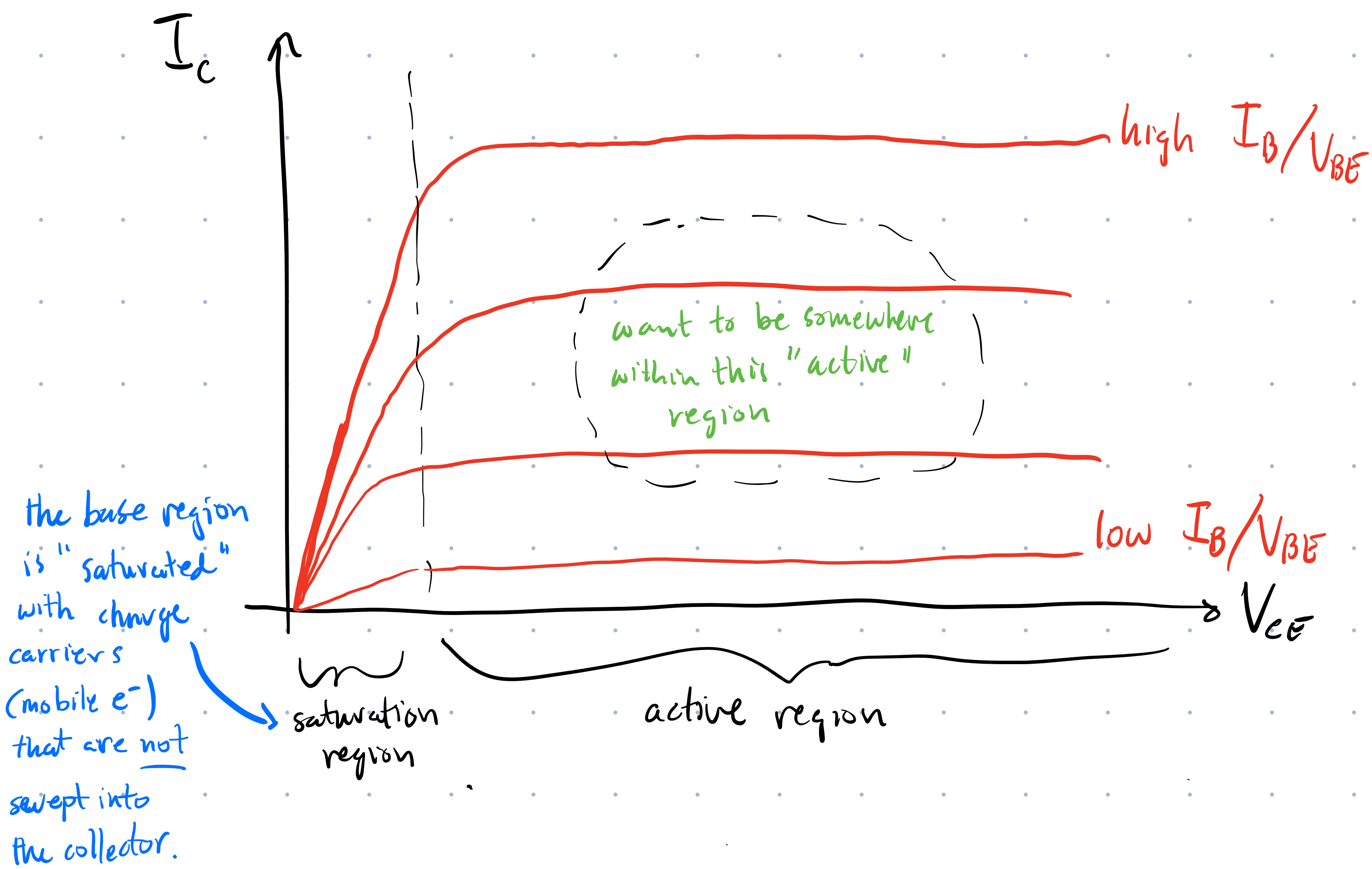
require $V_B = V_{cc} \frac{R_2}{R_1 + R_2} \gtrsim 0.7\,V$

to forward bias the B-E junction.

On the other hand, $V_c = V_{cc} - I_c R_c$

Require $V_c > V_B$ to keep B-C jcn reverse biased.

Once proper biasing has been acheived, we are in the so-called "active" region of the I-V characteristic.

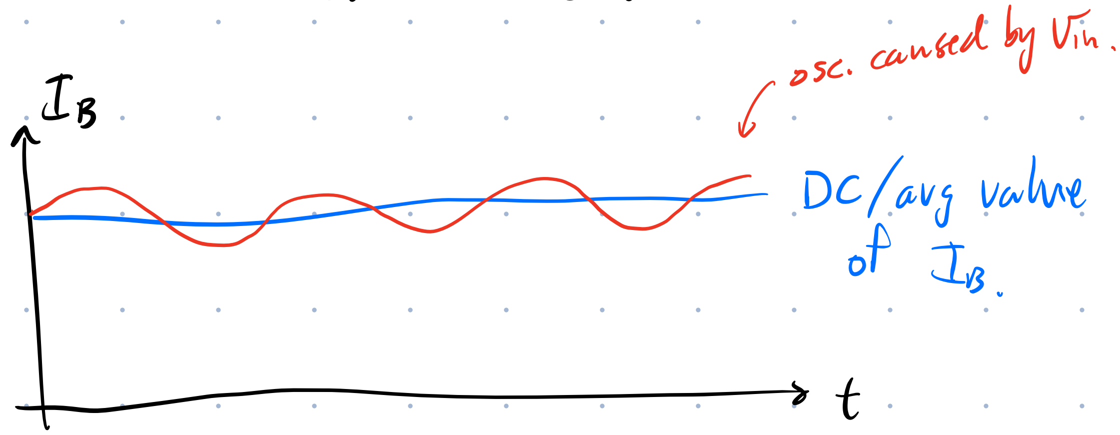


The purpose of the capacitors is to "decouple" the transistor from DC voltages at the input & output of the amplifier. Recall that the impedance of a capacitor is $Z_C = \frac{1}{j\omega C}$

$\therefore$ If $\omega \to 0$ (DC), then $Z_C \to \infty$. $\therefore$ The capacitors pass AC signals, but block DC.

Suppose $v_{in} = V_0 \sin \omega t$, where V_0 is assumed to be much smaller than V_{cc}.

In this case, v_{in} causes the base voltage and, therefore, current to osc. about it's DC value.



Here, I've exaggerated the osc. amp. for I_B.

Recall that small changes in I_B result in large changes to I_C (current amplifier)

Aside:

Some people like to think of the transistor as effectively a variable resistor. The "knob" that we use to tune the resistance is I_B. As $I_B \uparrow$, the resistance of the transistor decreases.

Because the B-E jcn is forward biased, the AC components of the voltages at the base & emitter are equal.

$$\therefore \quad v_{in} = v_B = v_E \qquad \left(\text{I'm using lower case } v/i \text{ for AC voltages/currents} \right)$$

$$\therefore \quad v_E = i_E R_E \Rightarrow i_E = \frac{v_E}{R_E} = \frac{v_B}{R_E}$$

If we assume $\alpha \approx 1$ (recall $I_C = \alpha I_E$ & $\alpha \approx 0.99$), then we can write:

$$i_c \approx \frac{v_B}{R_E} = \frac{v_{in}}{R_E} \quad \otimes$$

We also know that the voltage at the collected is given by $V_C = V_{CC} - I_C R_C$

But I_c has an AC component s.t. :

$$v_{out} = v_c = -i_c R_c$$

we get a neg. sign b/c as $I_c \uparrow$, $V_c = V_{cc} - I_c R_c \downarrow$

sub in ⊗ for i_c to find

$$v_{out} = -\frac{R_c}{R_E} v_{in}$$

∴ The common-emitter amplifier is an <u>inverting</u> amplifier w/ gain

$$G = \frac{v_{out}}{v_{in}} = -\frac{R_c}{R_E}$$