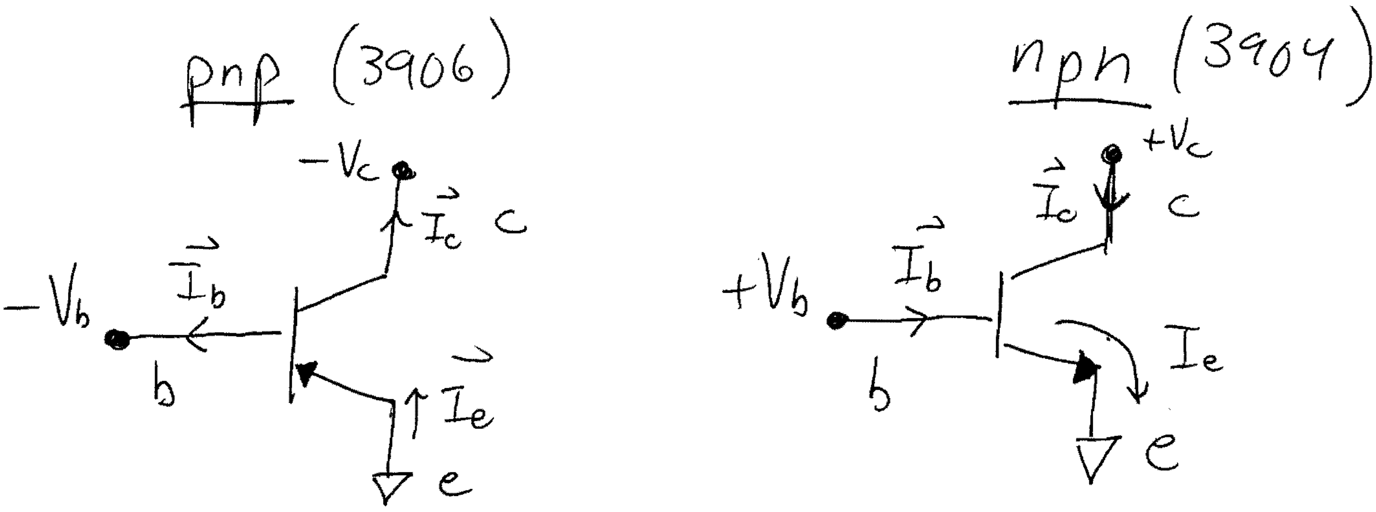
# Bipolar Junction Transistors:

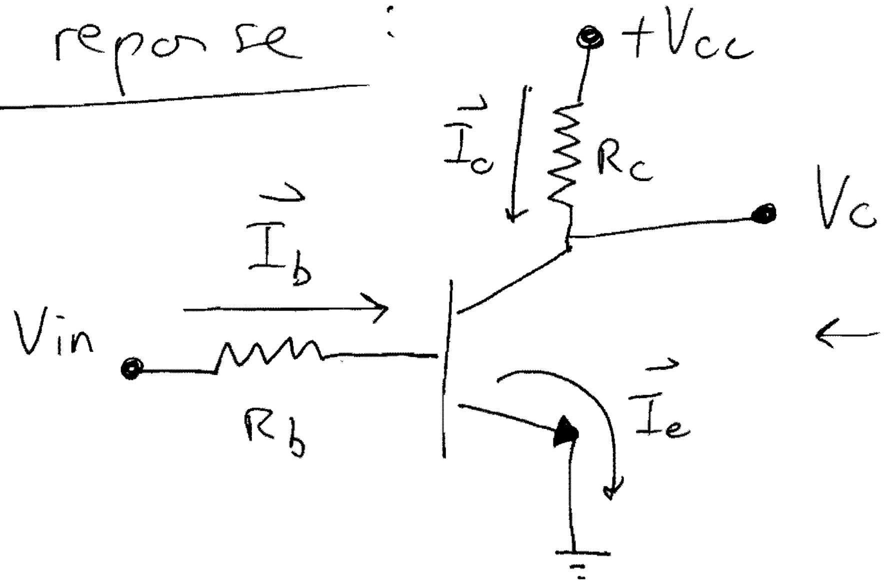
Bipolar junction transistors (BJT's) are npn or pnp devices.




Notice how the emitter current flows forward bias for the b-e pn junction, and reverse bias for the c-b p-n junction.

Make sure you understand the "on" diagrams above before moving on.

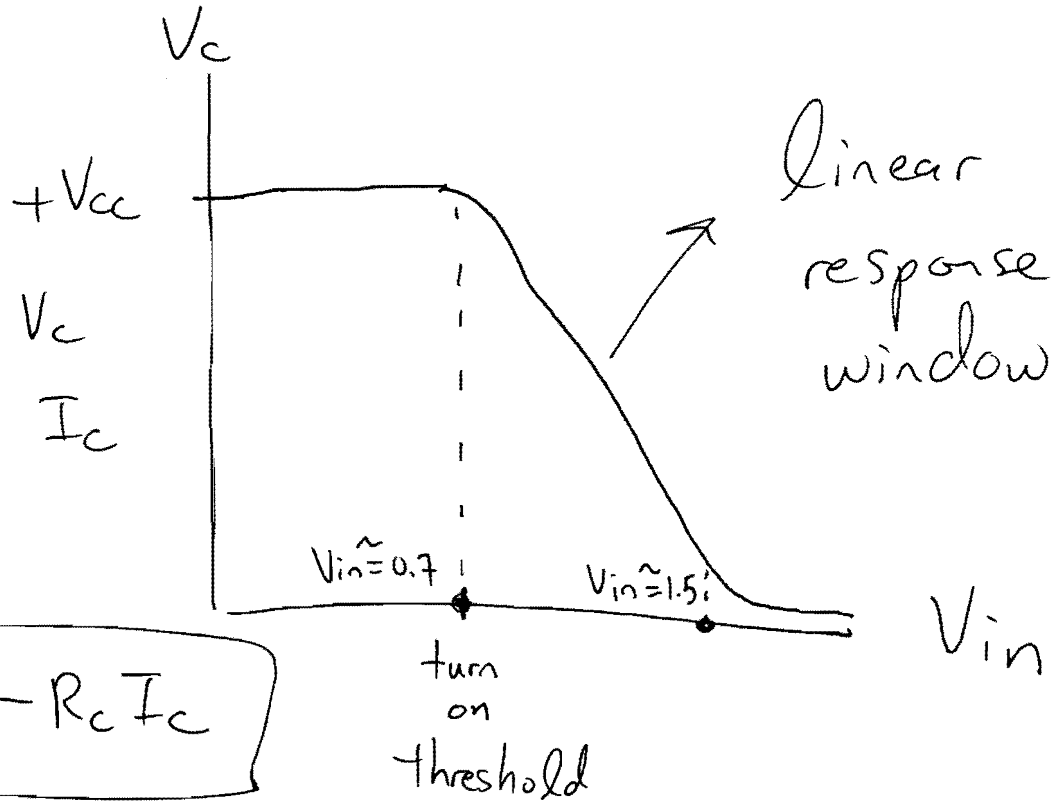
## BJT reponse :




$$\boxed{\frac{V_{cc} - V_c}{R_c} = I_c}$$

$\boxed{npn}$

Start off by applying a potential Vin to the base. Until you reach some threshold turn-on voltage $V_c = V_{cc}$ because the transistor is off and there is no potential drop on $R_c$.

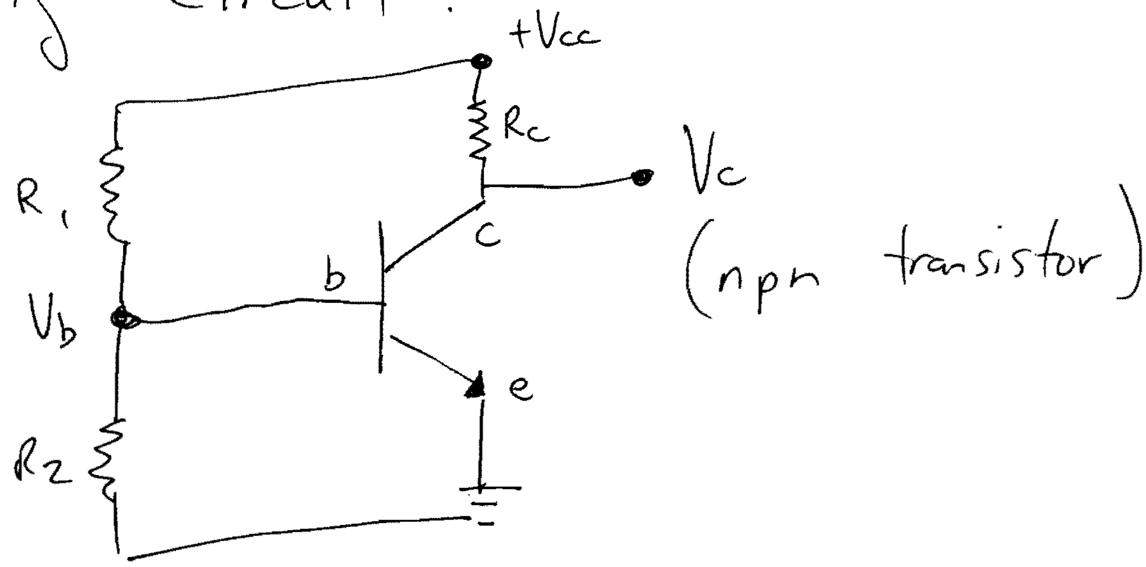



Measure $V_c$ leads to $I_c$ via,

$$\boxed{V_c = V_{cc} - R_c I_c}$$

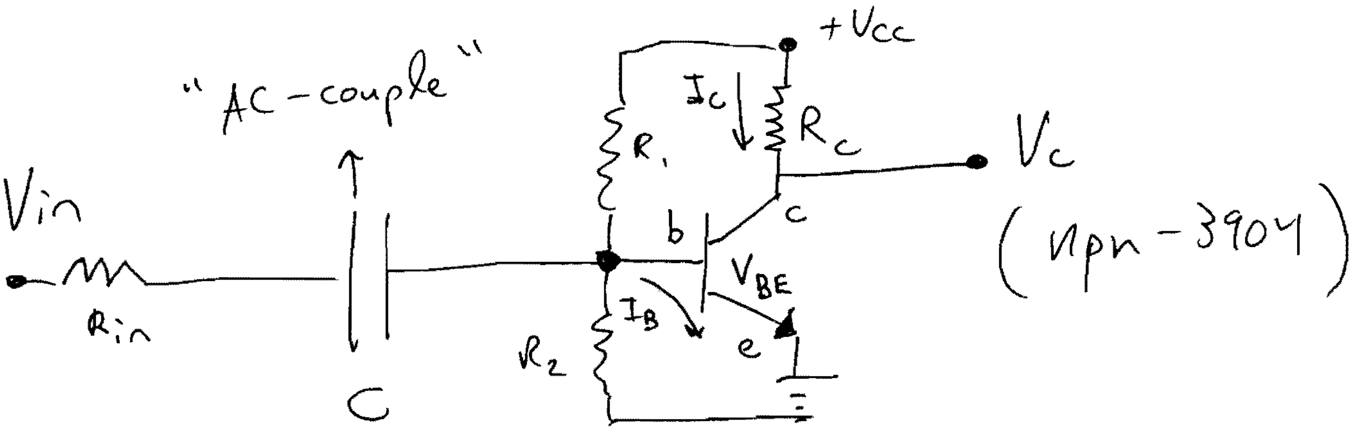
# Common Emitter Amplifyer :

First you want to establish a DC Bias condition by making the following circuit.




The goal is to make $V_c = \frac{V_{cc}}{2}$ so that you're operating right in the middle of the linear response window. Note that $V_b = F V_{cc}$ where $F = \dfrac{R_2}{R_1 + R_2}$.

Now that the proper DC-Bias condition is set up AC couple a signal (Capacitor) into the Comon Emitter Amp.




what is $Z_{BE}$ ?

① $V_{cc} - V_c = I_c R_c$

② $\beta = \frac{I_c}{I_B}$

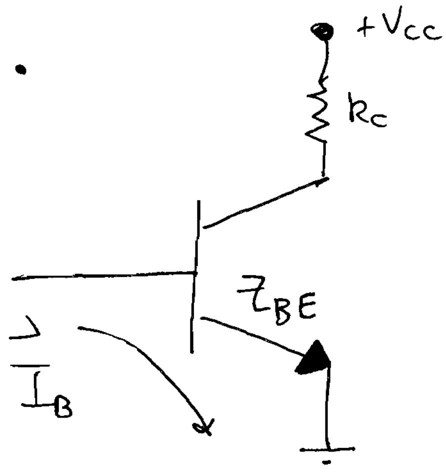
③ so therefore $V_{cc} - V_c = \beta I_B R_c$

$$\boxed{\begin{array}{ll} V_c = -\beta I_B R_c & \text{(AC coupled)} \\ V_c = \underbrace{V_{cc}}_{\text{"DC term"}} - \beta I_B R_c & \text{(DC coupled)} \end{array}}$$

Q: what is $Z_{BE}$?

Soln:

zoom in on the common emitter amplifyer.




$Z_{BE}$ is a diode impedance.

$I_D = I_o\left(e^{\alpha V_D} - 1\right)$ so, $\frac{1}{Z_D} = \frac{\partial I_D}{\partial V_D}$

$$y_D = \frac{1}{Z_D} = \frac{1}{\alpha I_o e^{\alpha V_D}} \cong \frac{1}{\alpha I_D}$$

$$\boxed{\frac{1}{Z_D} \cong \frac{1}{\alpha I_D}}$$ → measure $\vec{I}_B$ gives you $Z_{BE}$!

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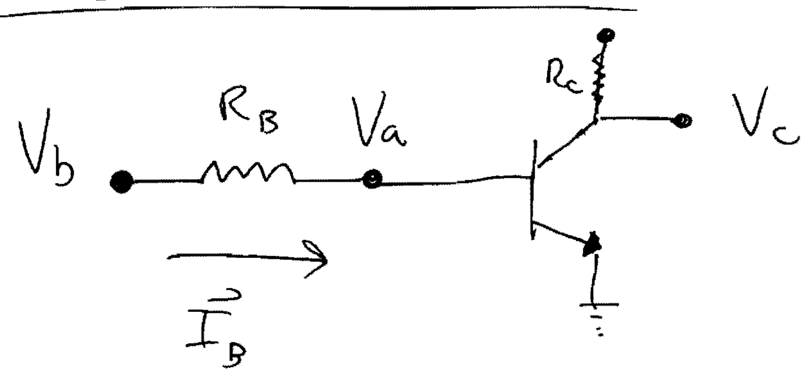
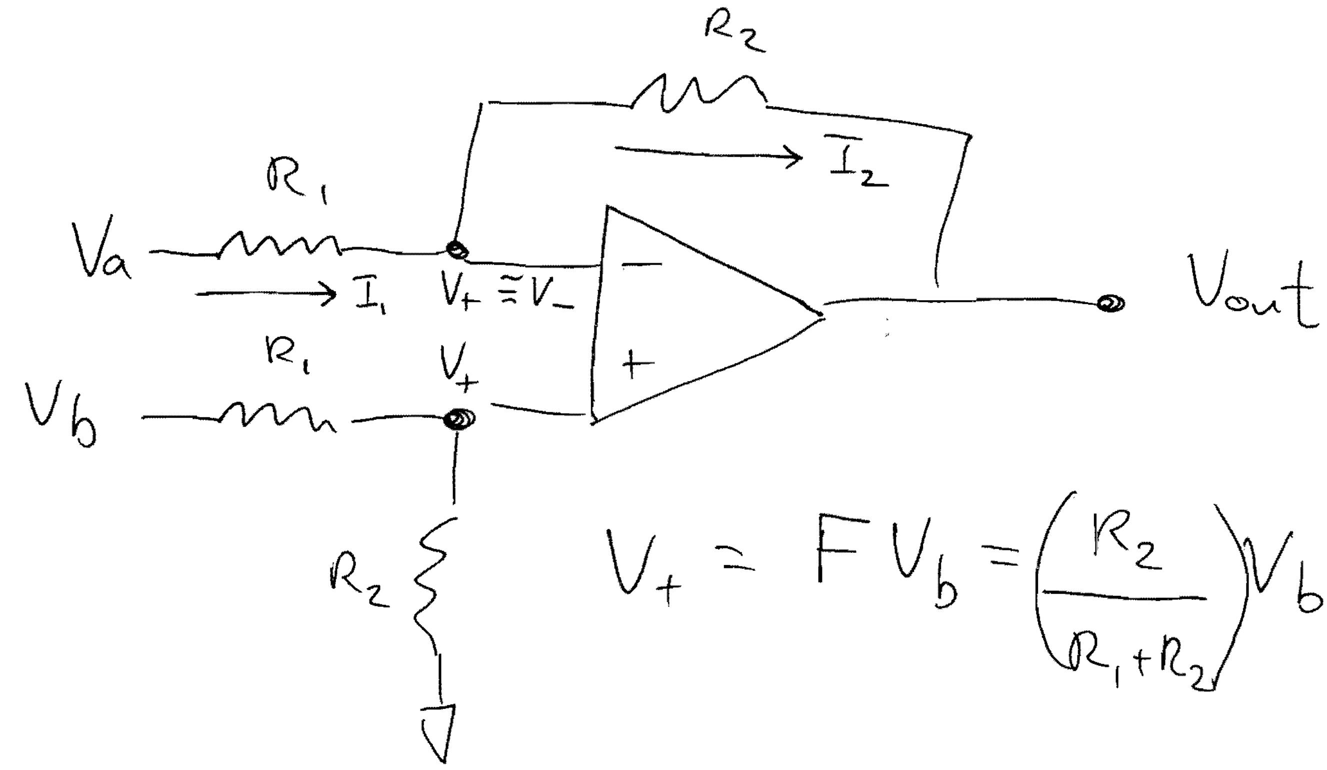
## Measuring Base Current :




$$I_B = \frac{(V_b - V_a)}{R_B}$$ , but we don't know $V_a$.

Answer = Use Difference Amplifier.

## Difference Amplifier :




$$V_+ = F V_b = \left(\frac{R_2}{R_1 + R_2}\right) V_b$$

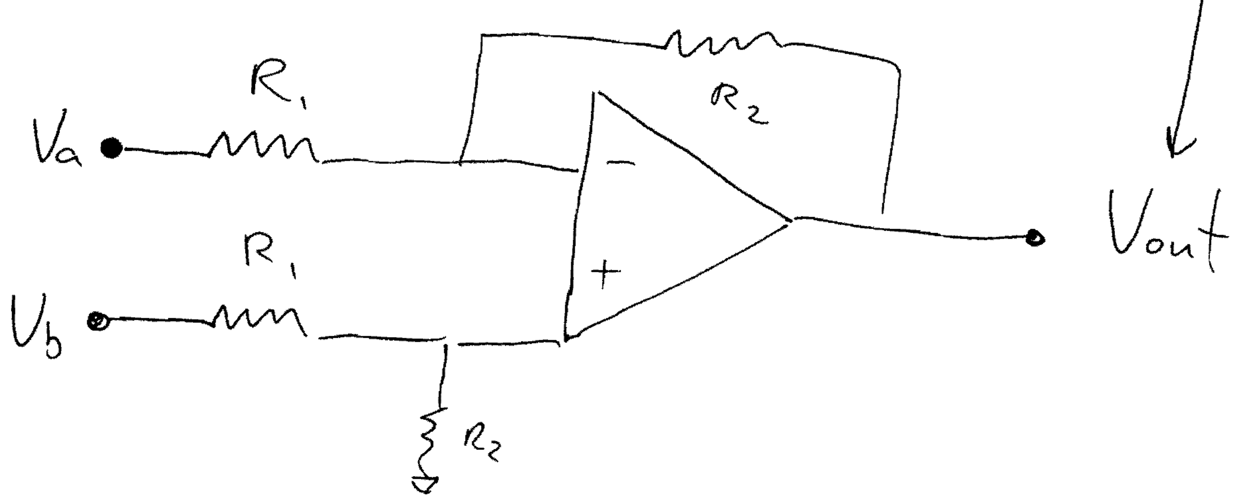
$$\underline{\underline{I_1 = I_2}} \Rightarrow \frac{V_a - V_+}{R_1} = \frac{V_+ - V_{out}}{R_2}$$

and $V_+ = F V_b$, therefore

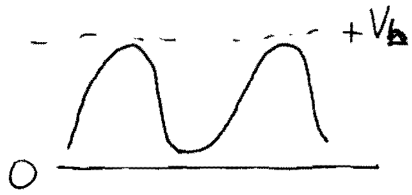
$$\frac{V_a - F V_b}{R_1} = \frac{F V_b - V_{out}}{R_2}$$

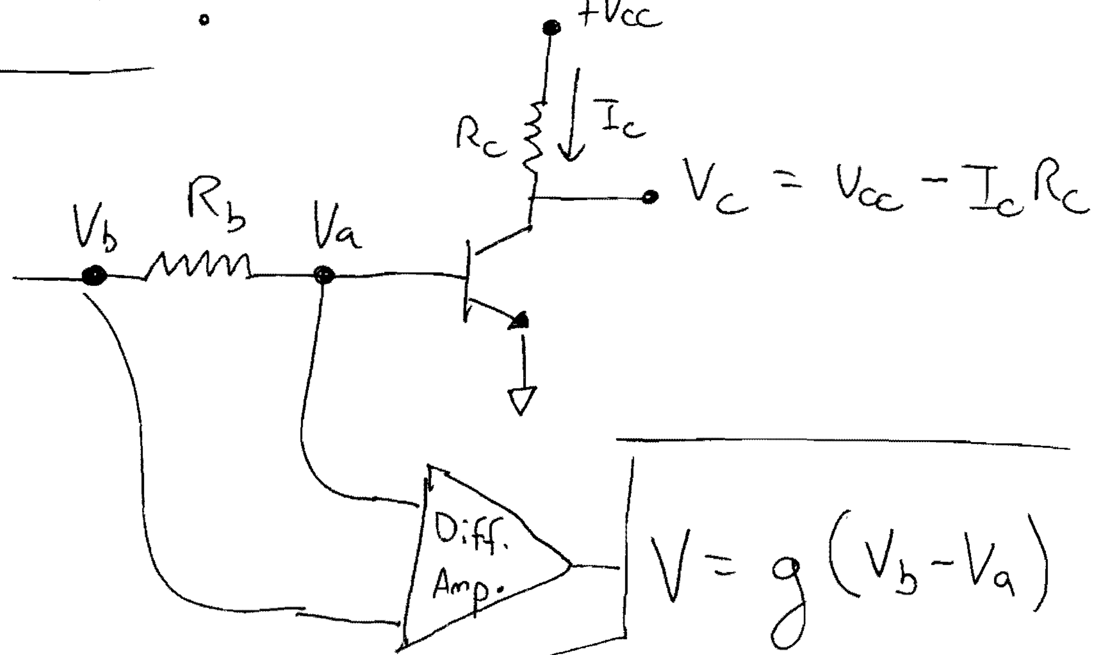
$$V_{out} = -\frac{R_2}{R_1} V_a + F\left(1 + \frac{R_2}{R_1}\right) V_b$$

$$\boxed{V_{out} = \frac{R_2}{R_1}\left(V_b - V_a\right)}$$



# $\beta$ measurements :



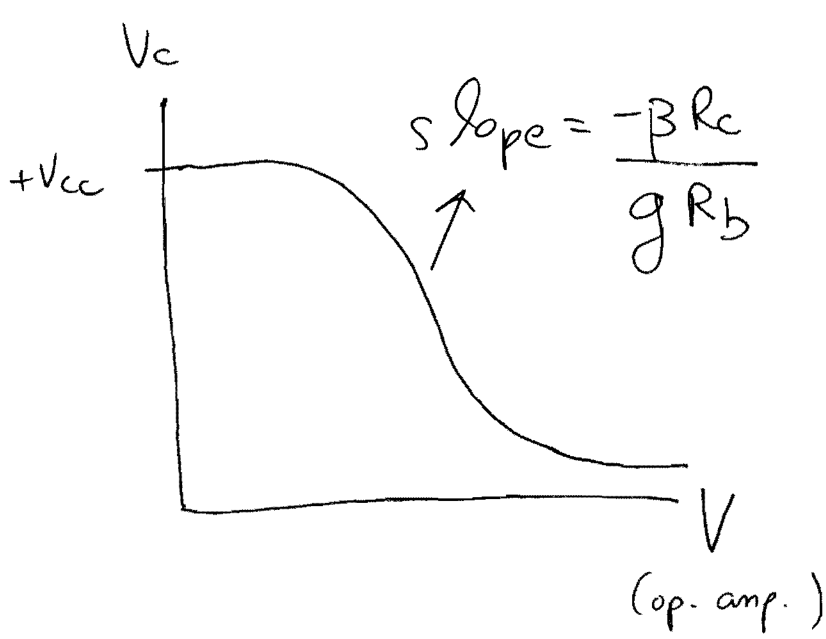

$$\boxed{V = g(V_b - V_a)}$$

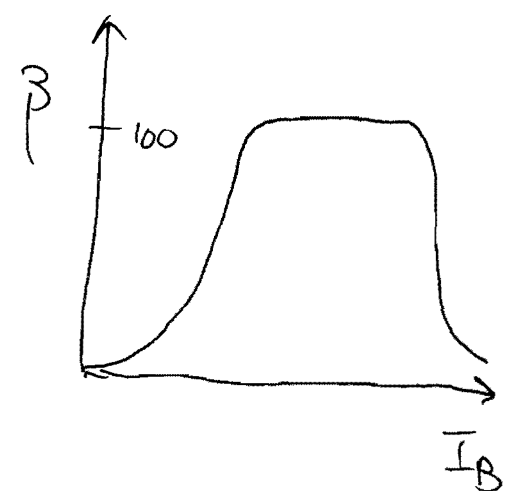
$$\boxed{I_B = \frac{V_b - V_a}{R_b} = \frac{V}{g R_b}}$$

$V_c = V_{cc} - I_c R_c$ ,

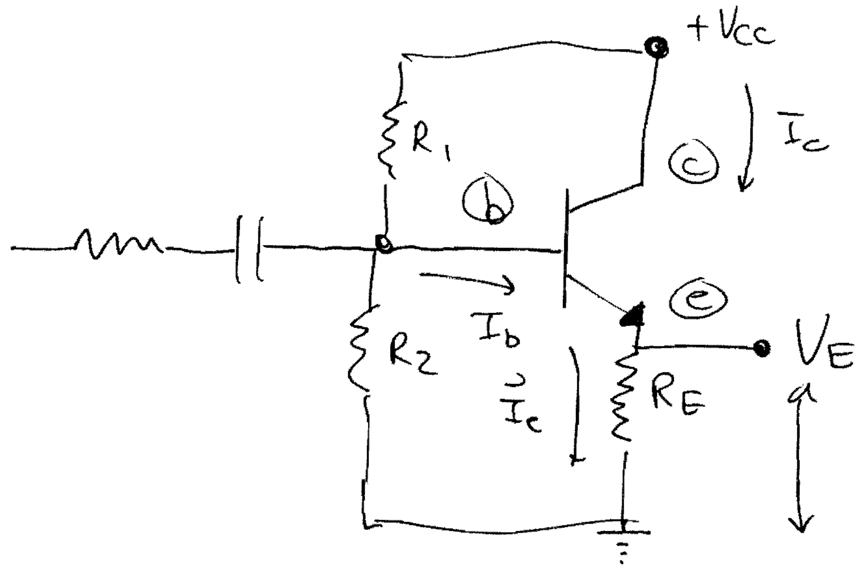
and $\beta = \dfrac{I_c}{I_B}$ , so ,

$$V_c = V_{cc} - \beta I_B R_c = \boxed{V_{cc} - \frac{\beta V R_c}{g R_b} = V_c}$$



# Common Collector Amplifier :




$$I_B \cong I_o e^{\alpha (V_B - V_E)}$$

$$I_e = I_c + I_b \cong I_c$$

$$V_E = I_c R_E$$

## E-potential = ?

$$V_E = I_c R_E = \beta I_B R_E = \beta R_E \underbrace{I_o e^{\alpha (V_B - V_E)}}_{= I_B}$$

$$\downarrow$$

$$\ln V_E = \ln (\beta R_E I_o) + \alpha (V_B - V_E)$$

$$\downarrow$$

$$\boxed{V_E = V_B \pm \delta}$$

$$\boxed{V_E = V_B - \frac{\ln V_E}{\alpha} + \frac{\ln \beta R_E I_o}{\alpha}}$$

ⓐ