BJT Overview
Characteristics (H.2)

20170421-2

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References

Based

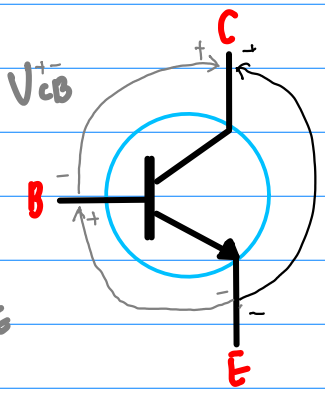
[1] Floyd, Electronic Devices 7th ed
[2] Cook,

[2] en.wikipedia.org

V_{BE} V_B measured from E

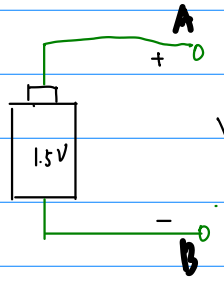
V_{CB} V_C measured from B

npn

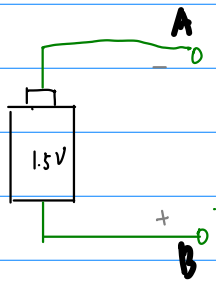


V_{CE}

$V_{CE} = V_{CB} + V_{BE}$

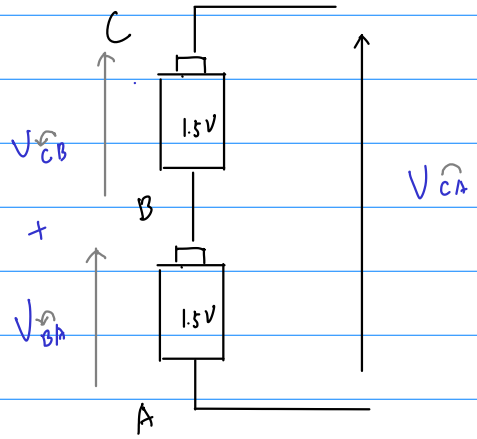


$V_{AB} = 1.5V$

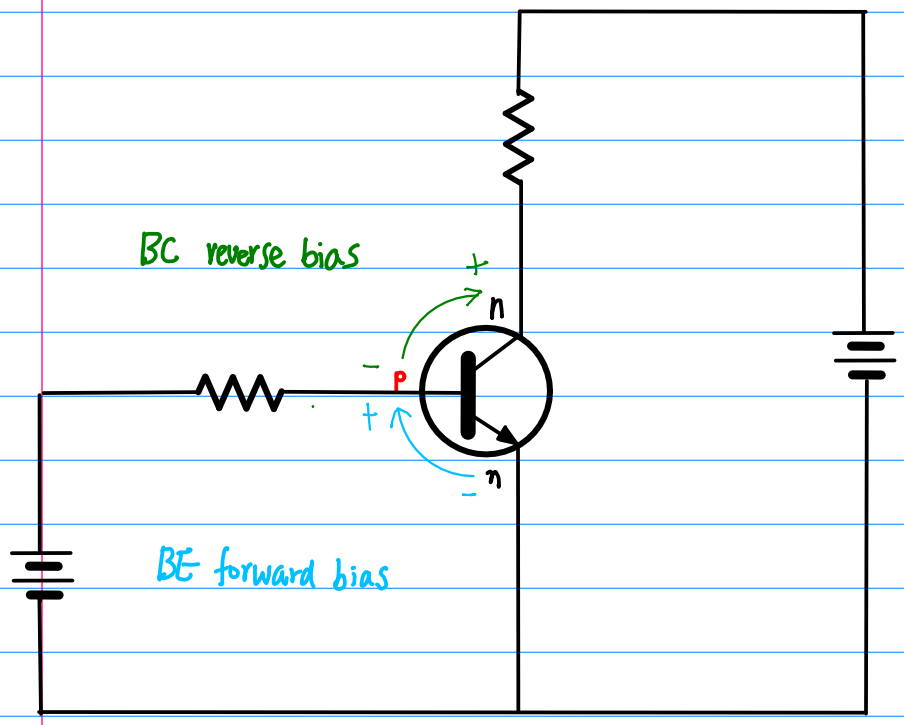


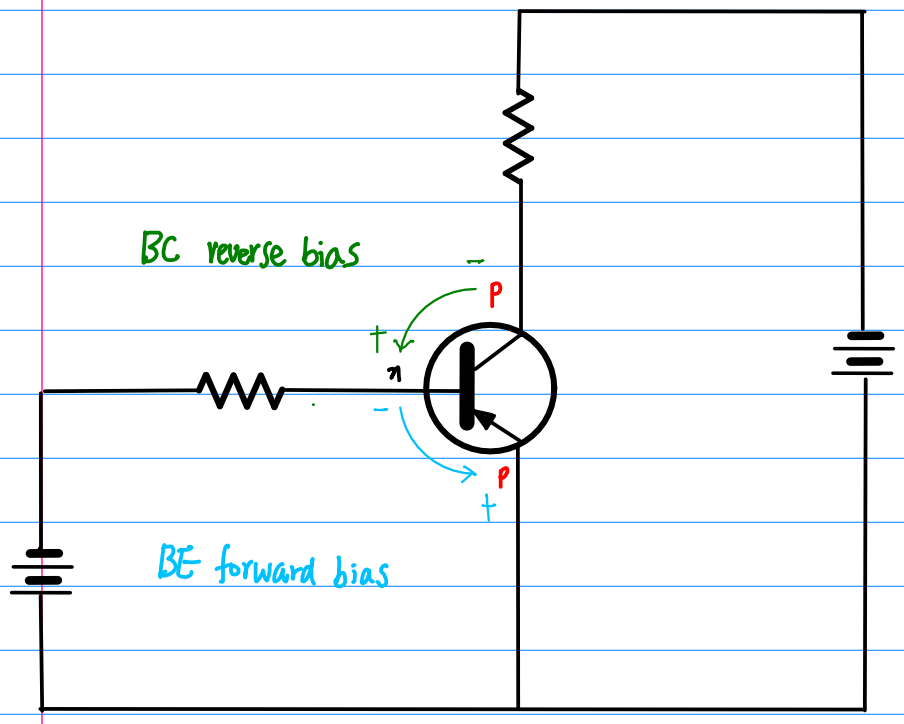
$V_{BA} = -1.5V$

$V_{AB} = -V_{BA}$

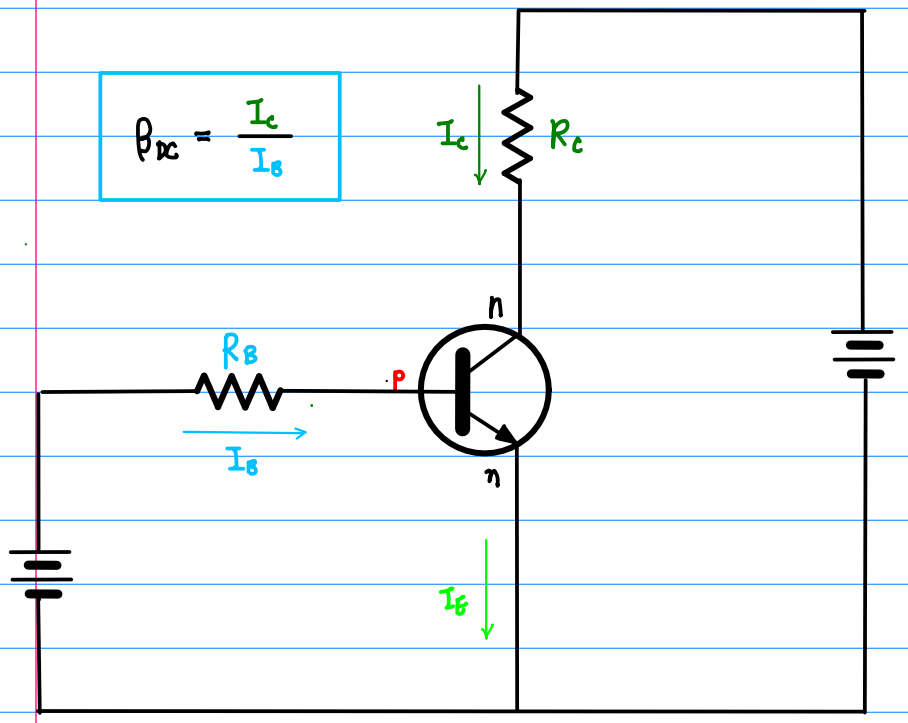


Active Region



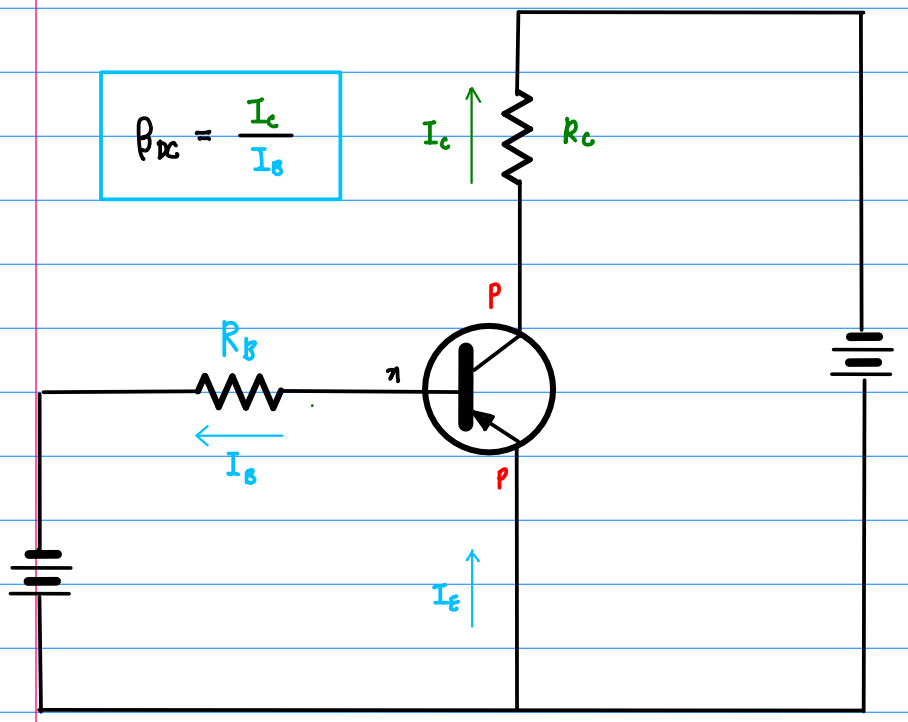


$\beta_{DC} = \frac{I_C}{I_B}$



$\alpha_{DC} = \frac{I_C}{I_E}$

$\beta_{DC} = \frac{I_C}{I_B}$

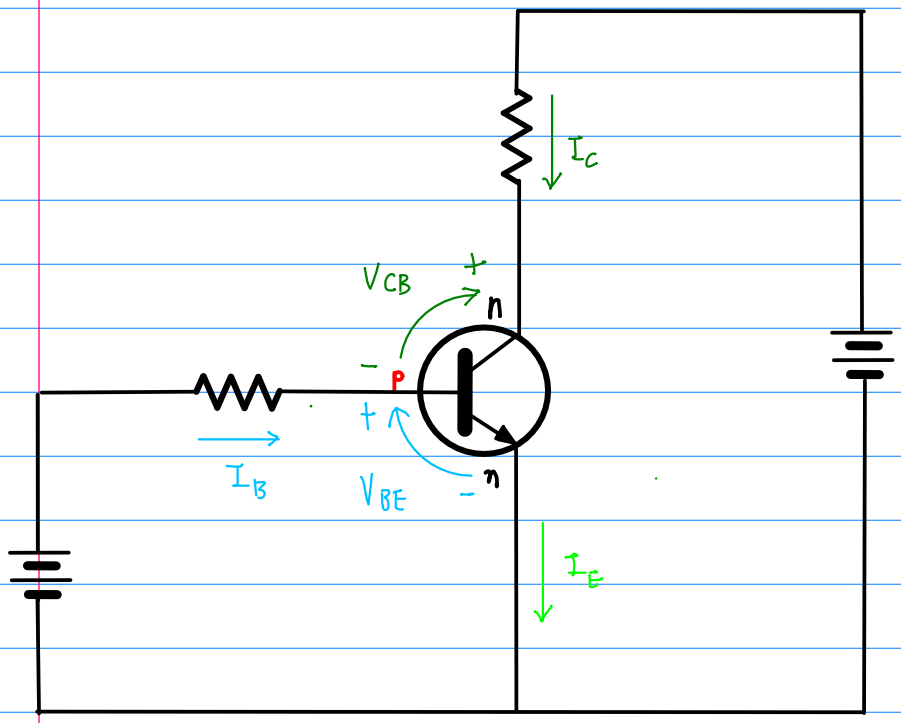


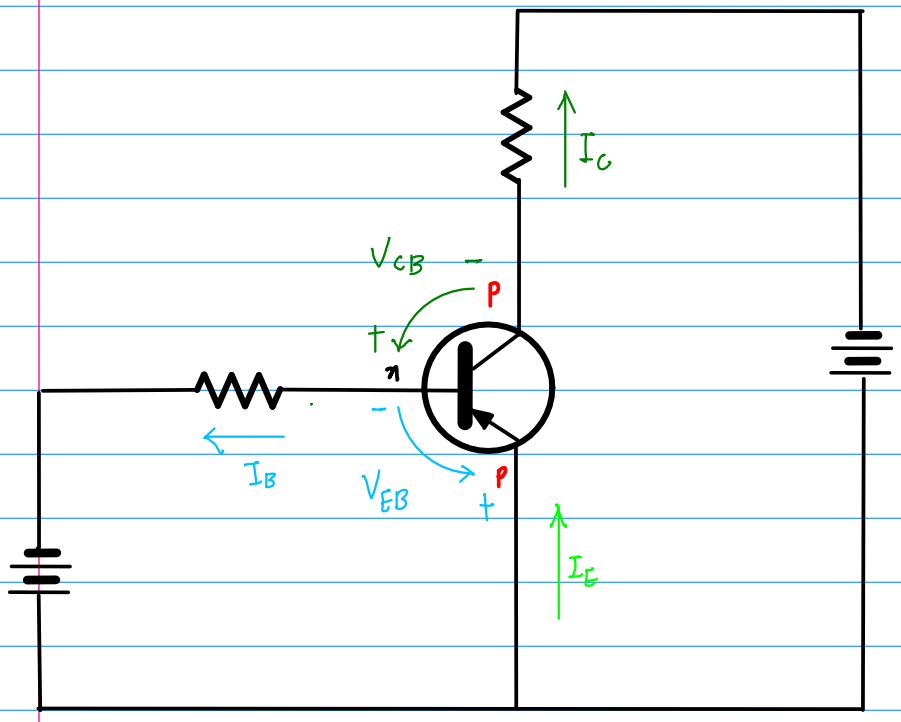
$\alpha_{DC} = \frac{I_C}{I_E}$

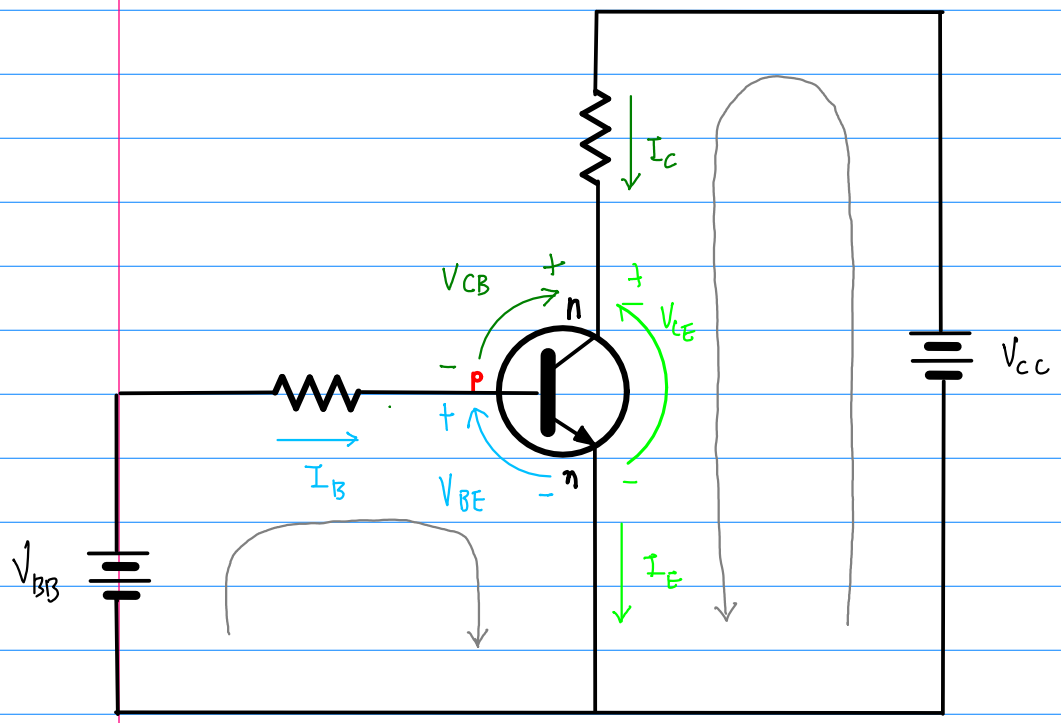
$$\beta_{DC} = \frac{I_C}{I_B}$$ 20 ~ 200

$$h_{FE} = \beta_{DC}$$

$$\alpha_{DC} = \frac{I_C}{I_E}$$ 0.95 ~ 0.99


I_C
V_{CB}
+
n
−
P
+
I_B
V_{BE}
−
n
I_E

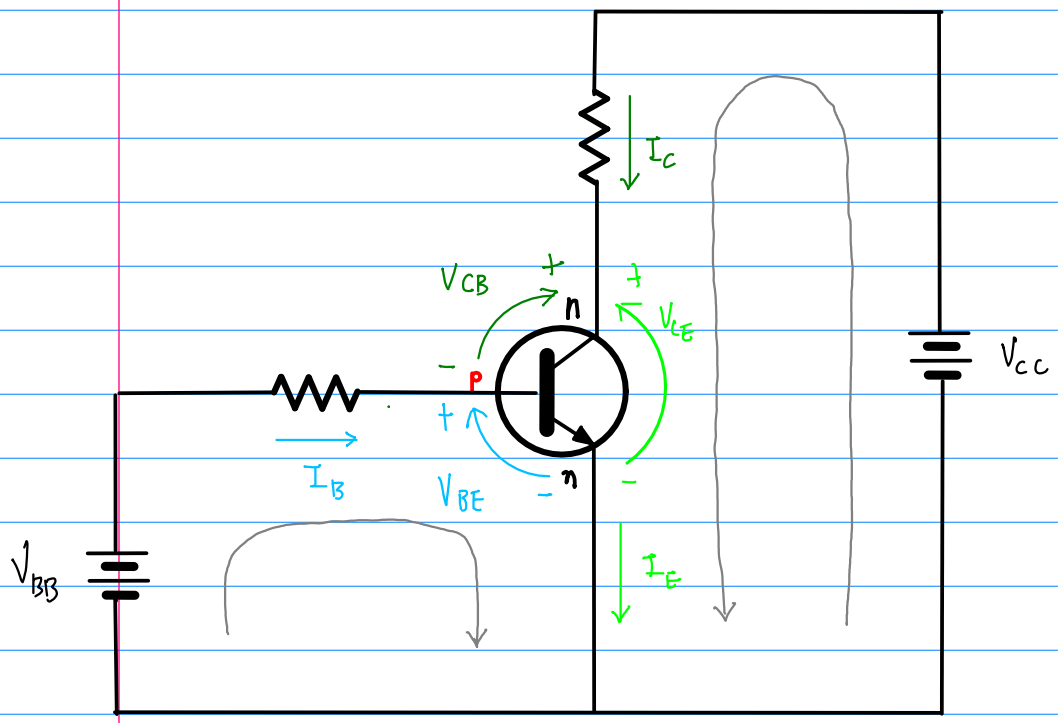

I_C
V_{CB}
−
P
+
n
−
I_B
V_{EB}
+
P
I_E

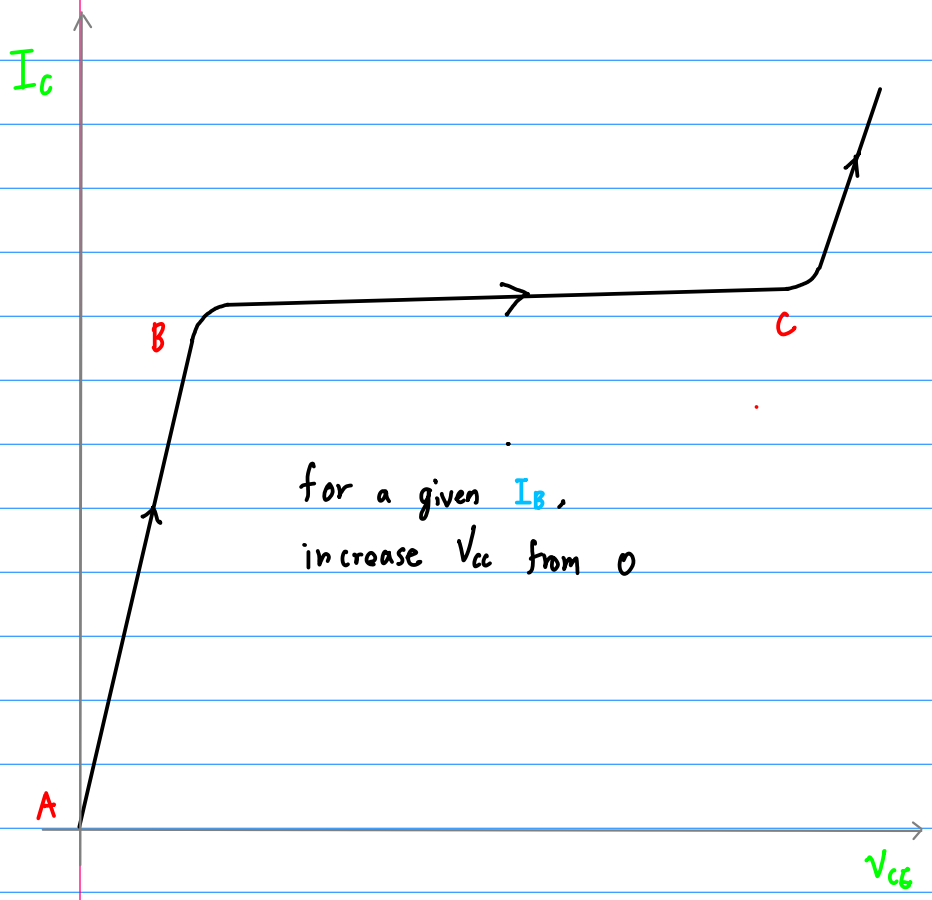


$$V_{BB} = I_B R_B + V_{BE} \qquad V_{CC} = I_C R_C + V_{CE}$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} \qquad I_C = \frac{V_{CC} - V_{CE}}{R_C} \qquad V_{CE} = V_{CC} - I_C R_C$$

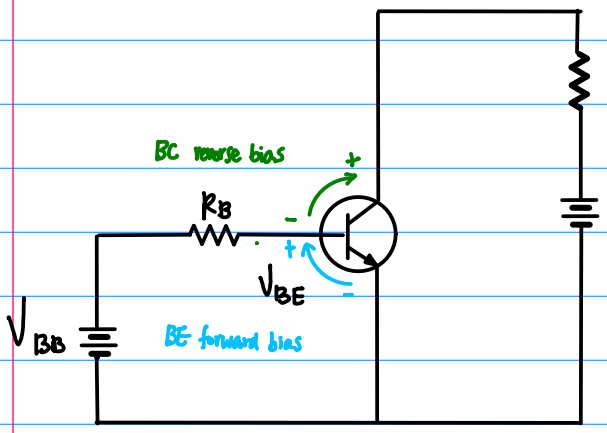
$$I_C = \beta \cdot I_B \qquad V_{CE} = V_{CC} - \beta \cdot I_B \cdot R_C$$





for a given I_B,
increase V_{cc} from 0

BJT Input Characteristic



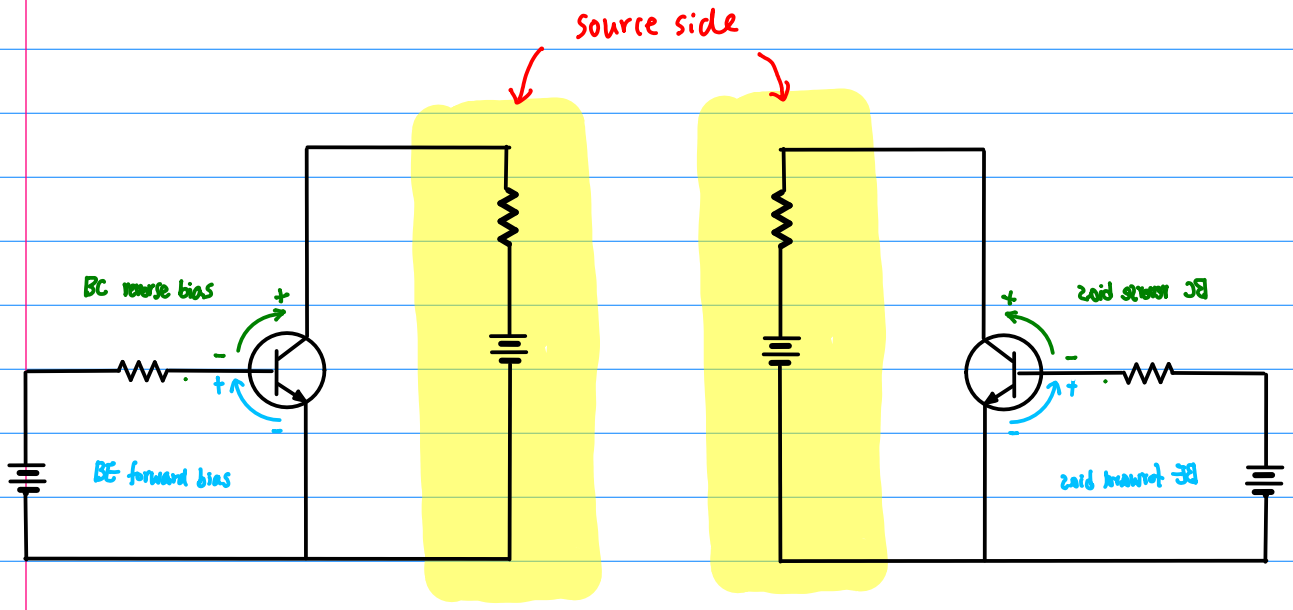
$$V_{BB} = I_B R_B + V_{BE}$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$V_{BE} = 0.7\,V$ in active region

$$\uparrow I_B = \frac{V_{BB} - 0.7}{R_B \downarrow}$$

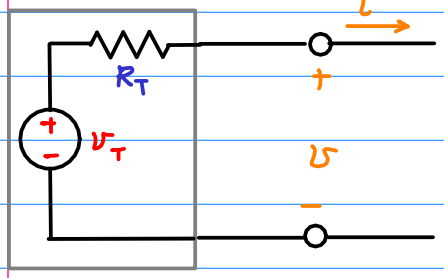
BJT Output Characteristics



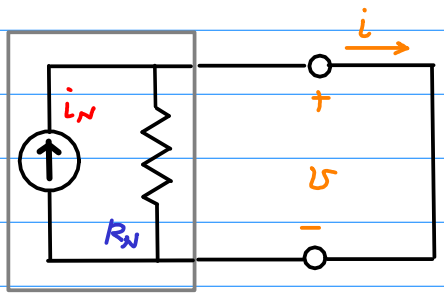
Active Region assumed

Source Side Equation R_T

max v ← $R_L = \infty$



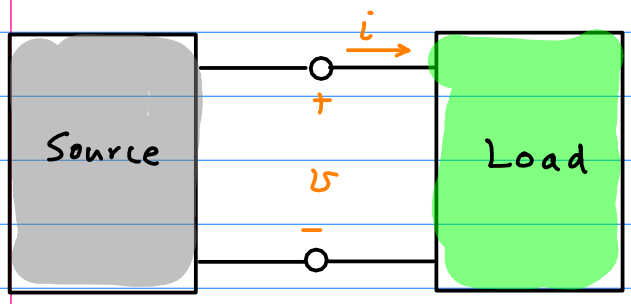
max i ← $R_L = 0$

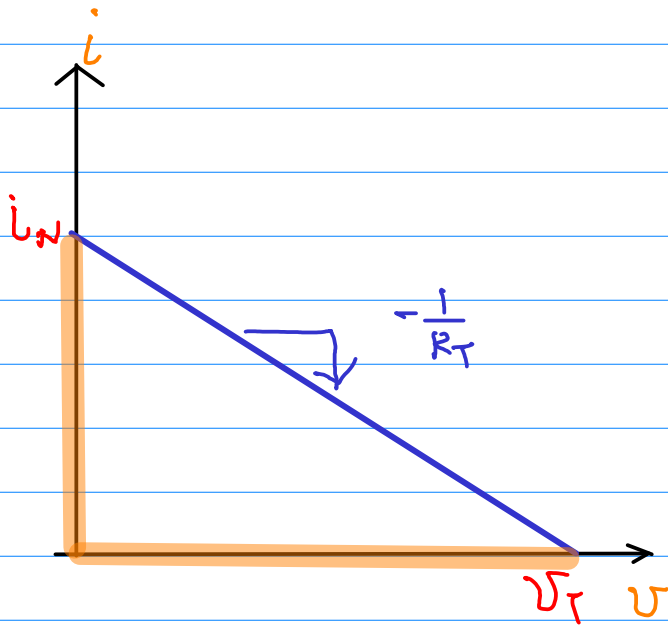


$i < i_N$

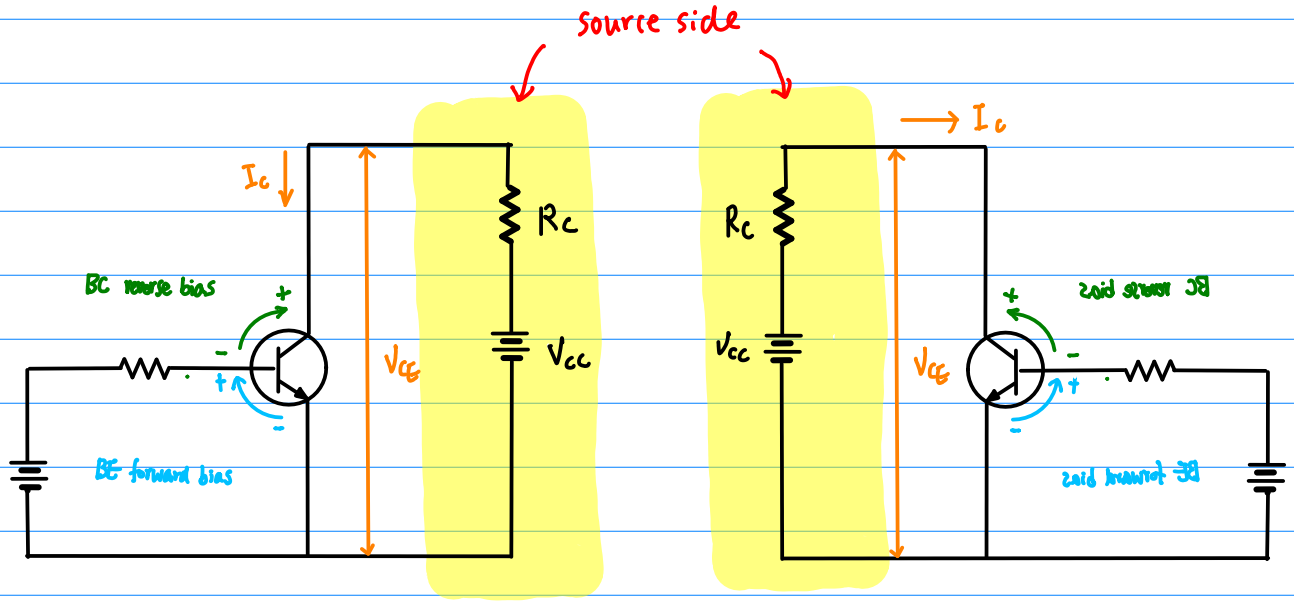
$v < v_T$

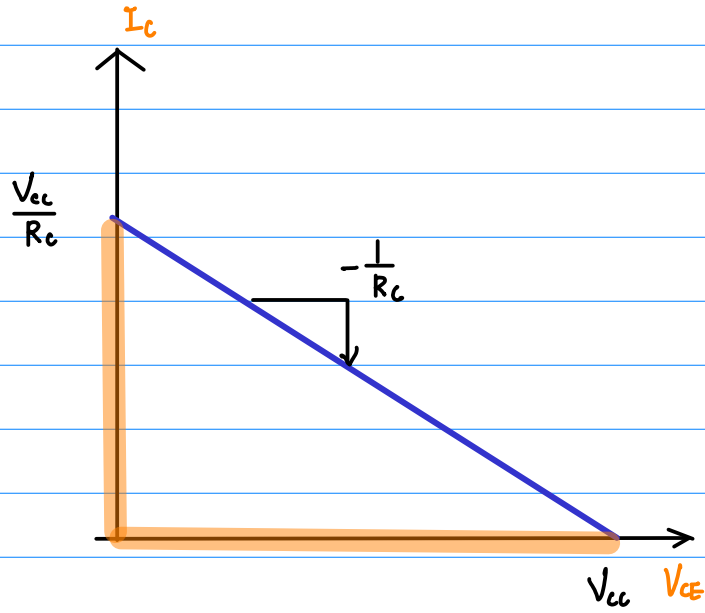
$0 < R_L < \infty$

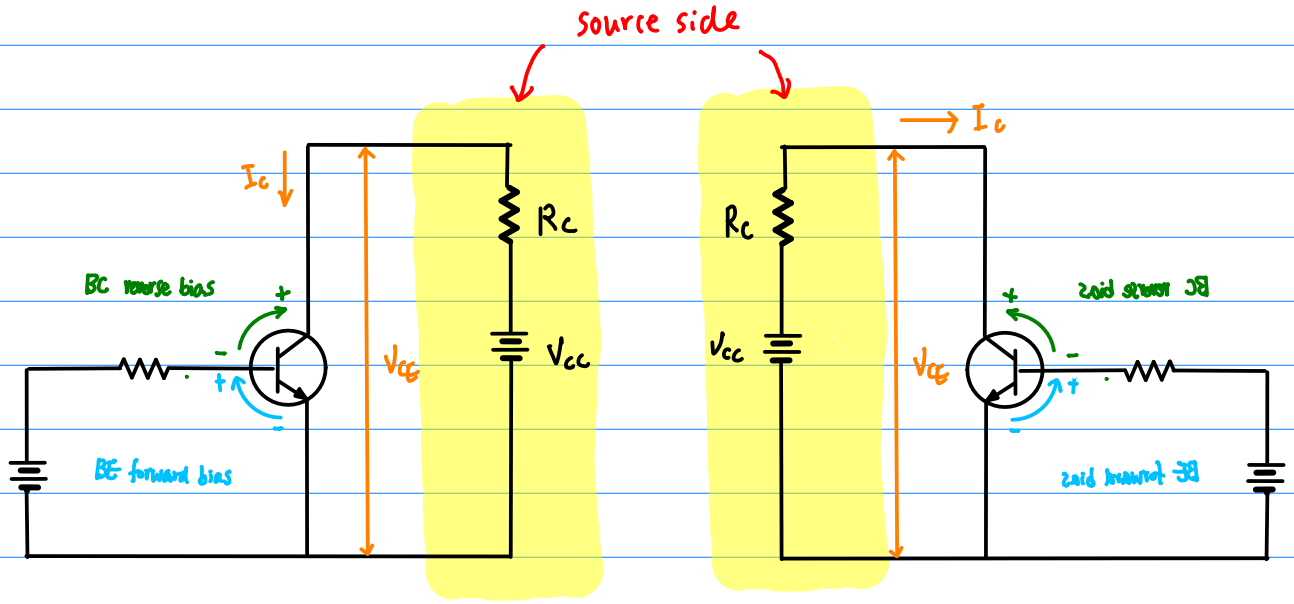


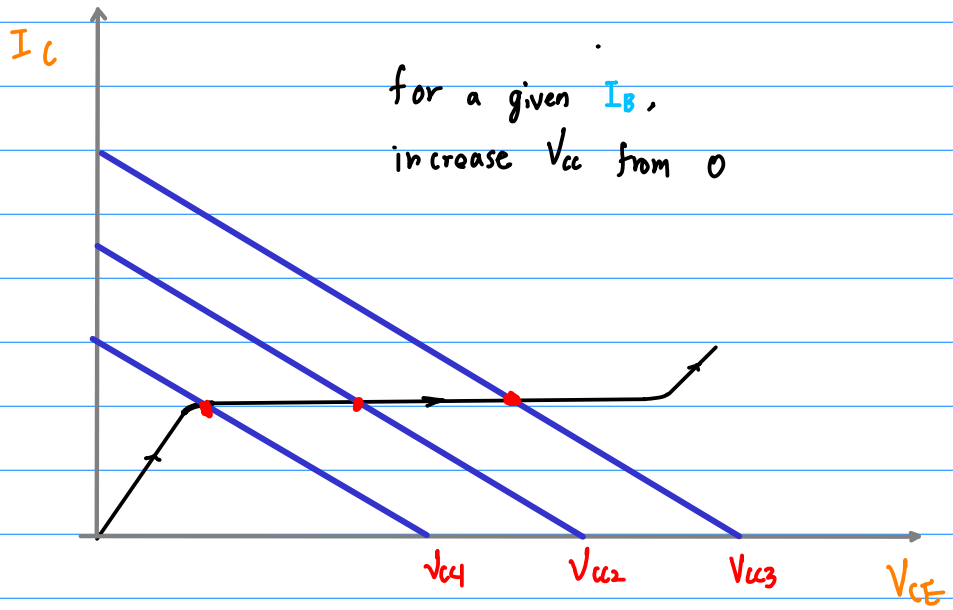


$$i = \frac{1}{R_T}(v_T - v)$$

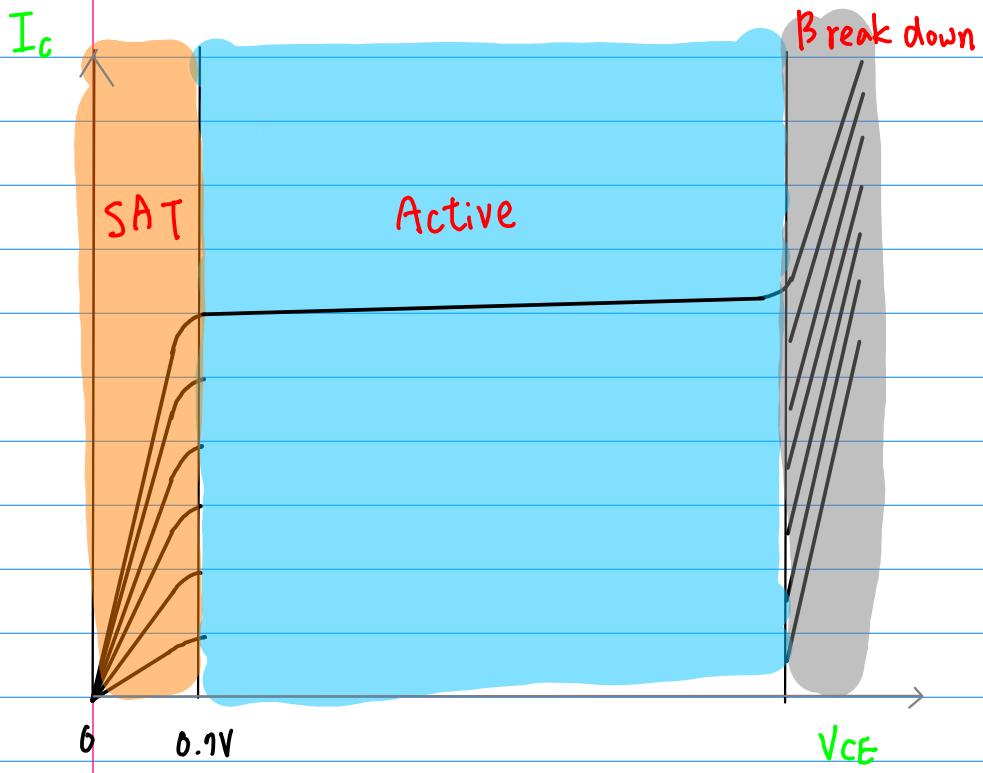

source side
I_c
R_c
V_{cc}
V_{CE}
BC reverse bias
BE forward bias
I_c
R_c
V_{cc}
V_{CE}
BC reverse bias
BE forward bias

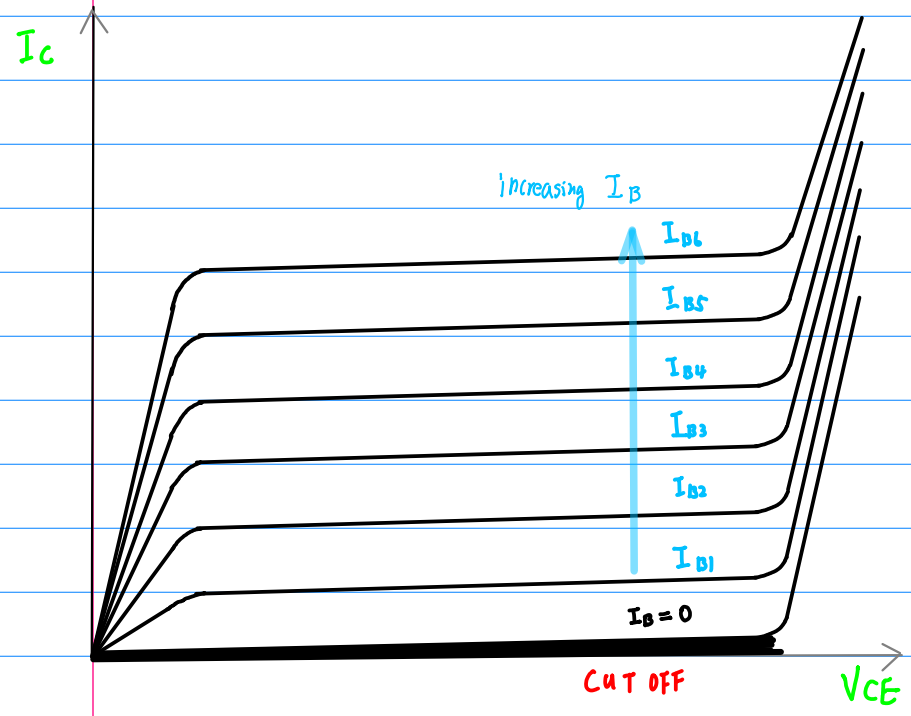

I_c
$\frac{V_{cc}}{R_c}$
$-\frac{1}{R_c}$
V_{cc}
V_{CE}



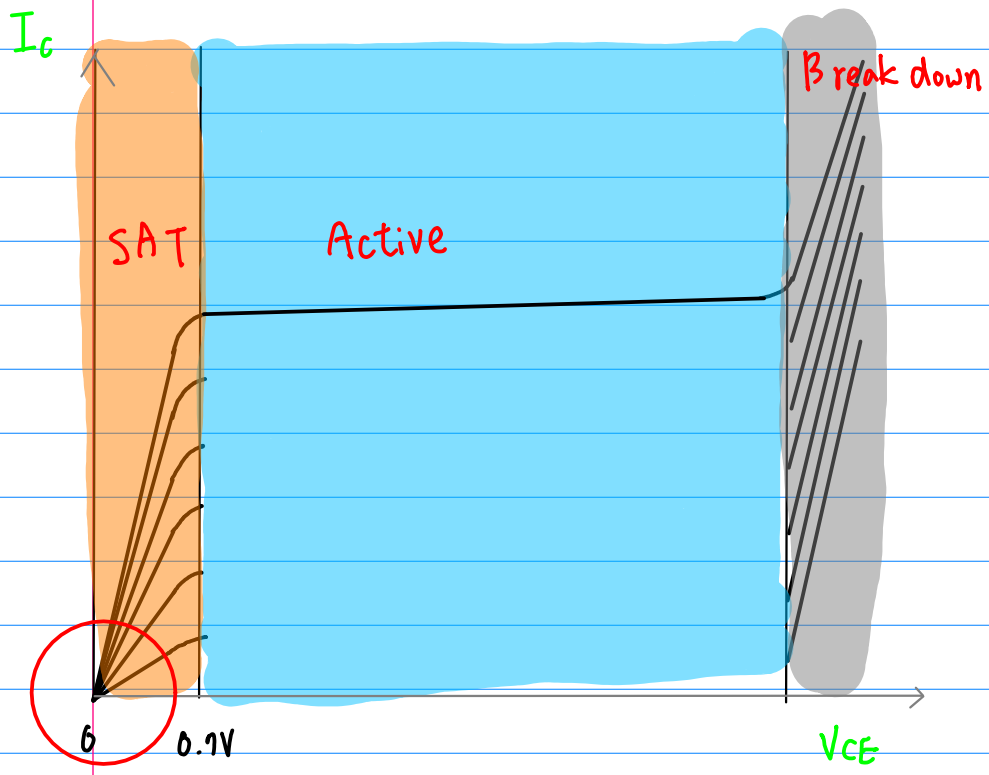


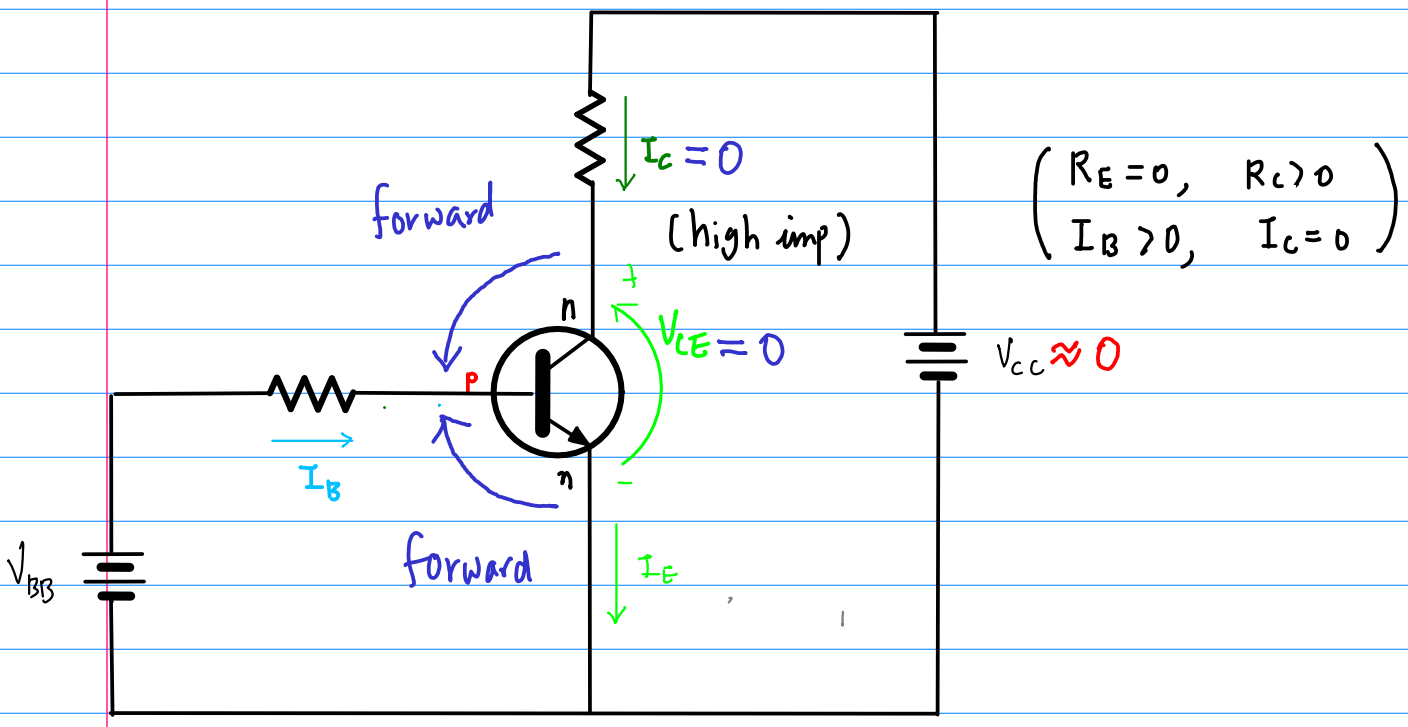
for a given I_B,
increase V_{cc} from 0


I_C
Break down
SAT
Active
0
0.7V
V_{CE}


I_C
Increasing I_B
I_{B5}
I_{B4}
I_{B3}
I_{B2}
I_{B1}
$I_B = 0$
CUT OFF
V_{CE}

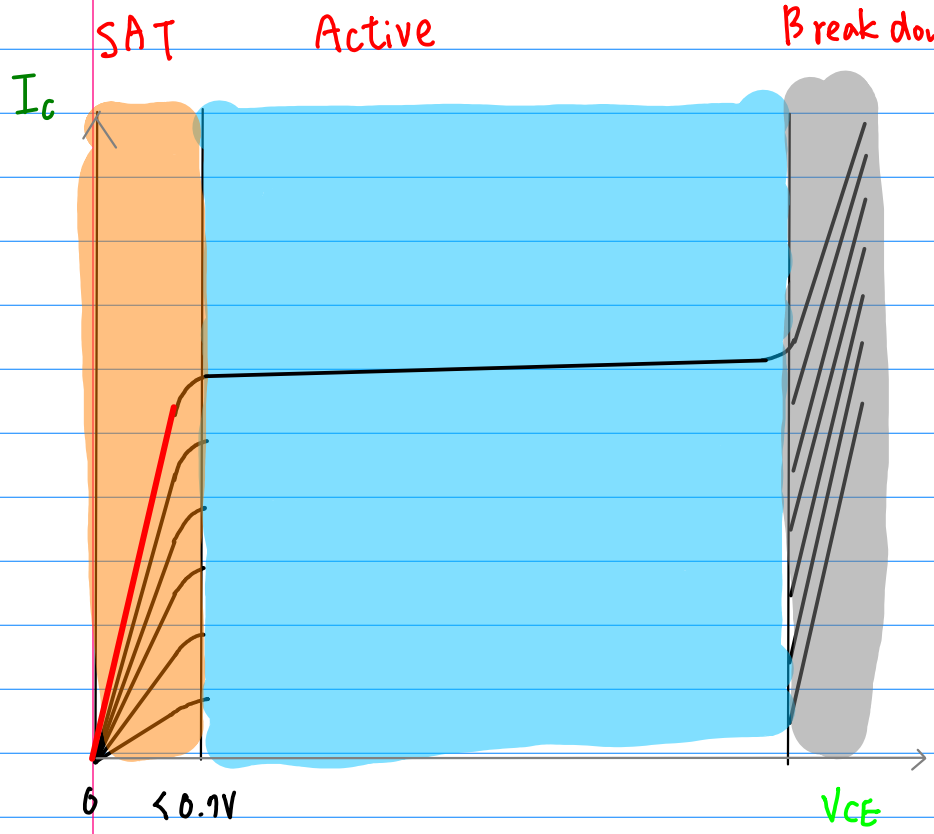
(A) At the origion

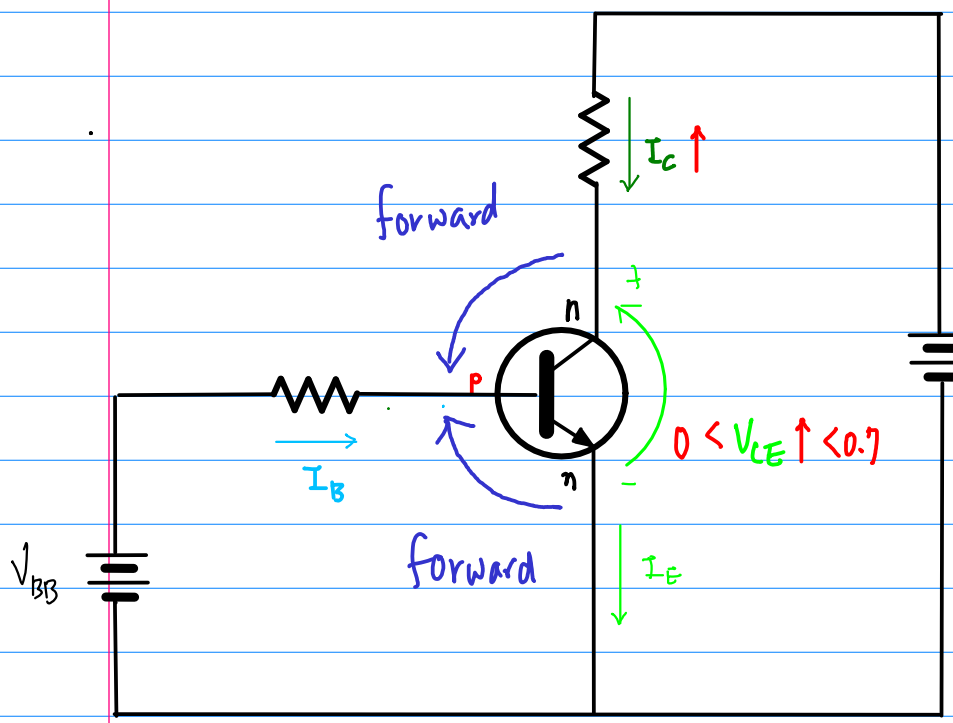




$$\left(\begin{array}{ll} R_E = 0, & R_C > 0 \\ I_B > 0, & I_C = 0 \end{array} \right)$$

(A) - (B) Saturation

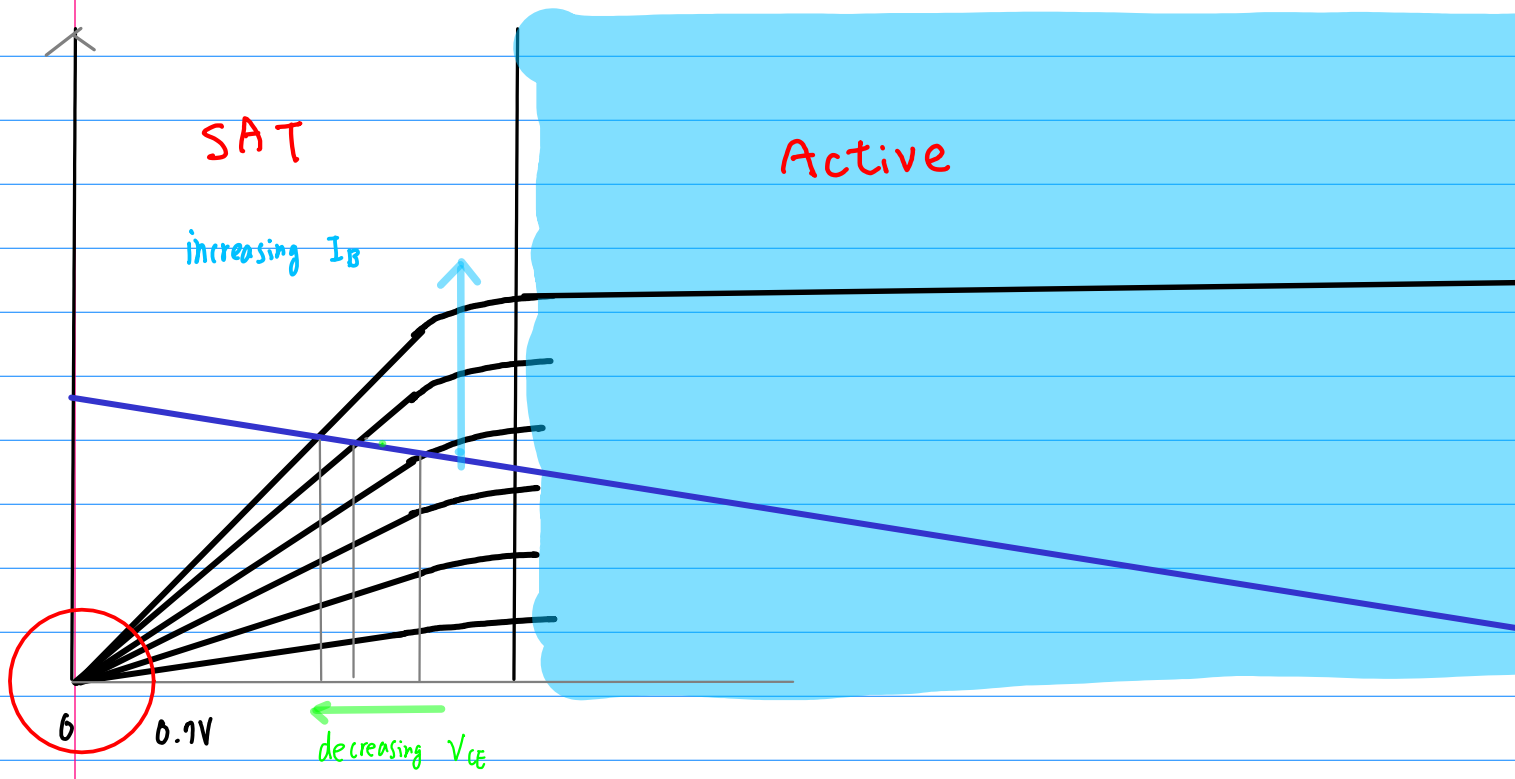




I_C ↑ large R_C > small R_{CE} large V_{drop} small V_{drop}

V_{CE} ↑ slowly

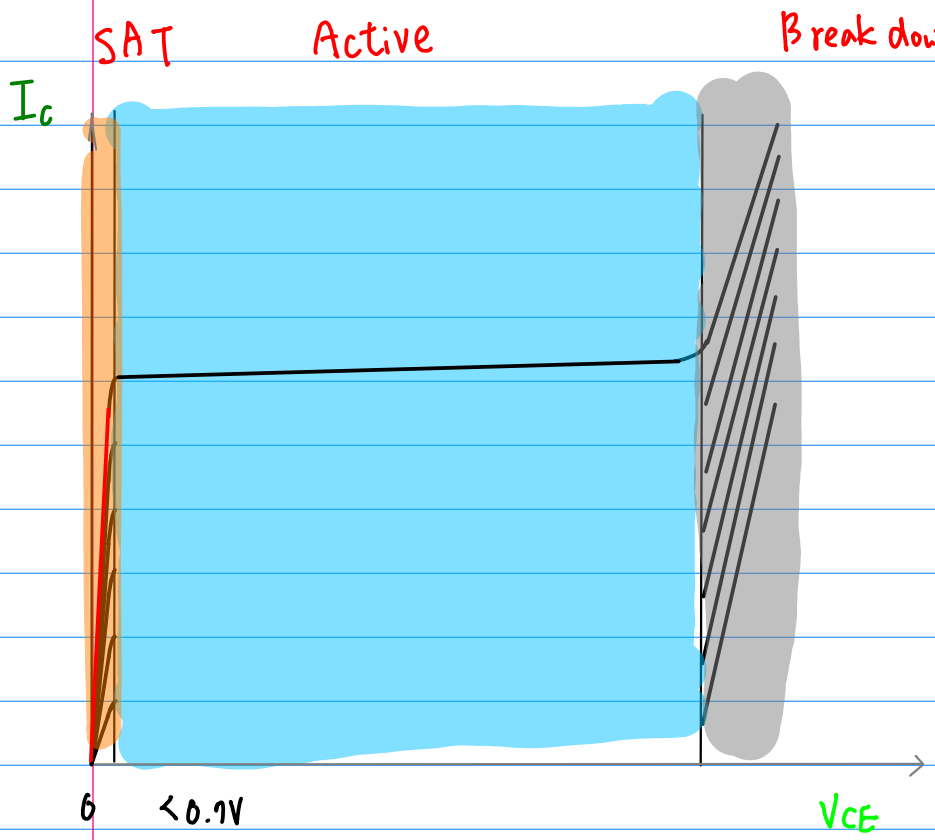
$V_{CE} < 0.7V$ for forward bias

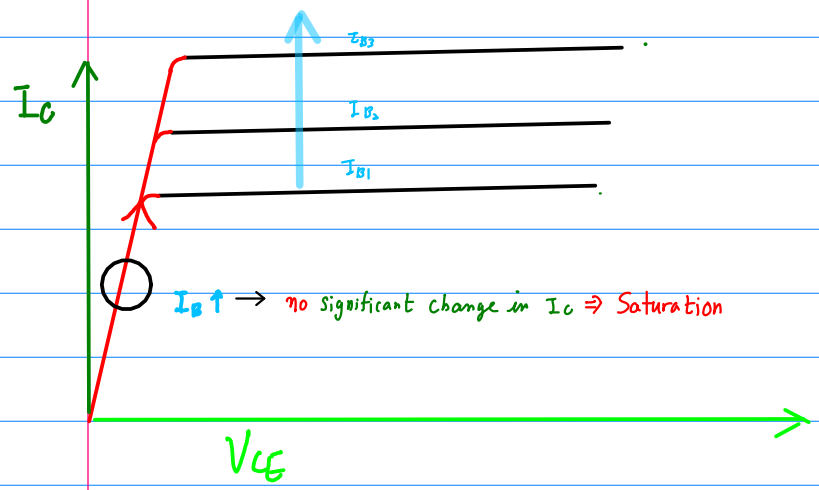


$I_B \uparrow \Rightarrow I_C \uparrow \Rightarrow$ more V_{drop} across R_C

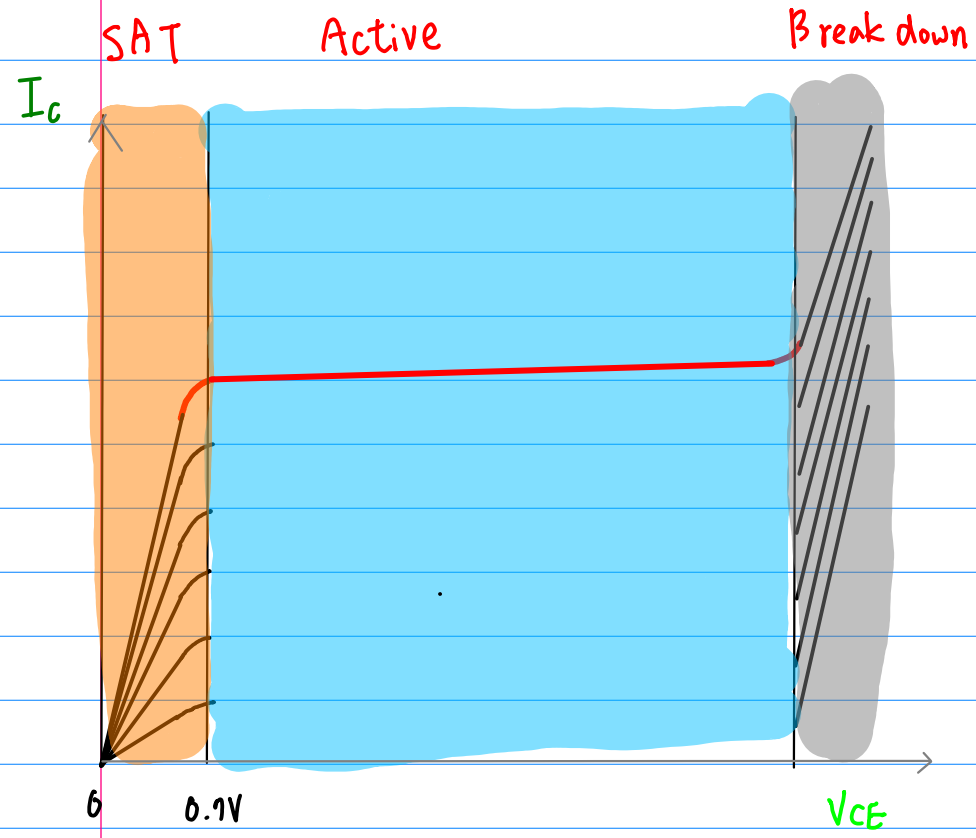
$\Rightarrow V_{CE} \downarrow$

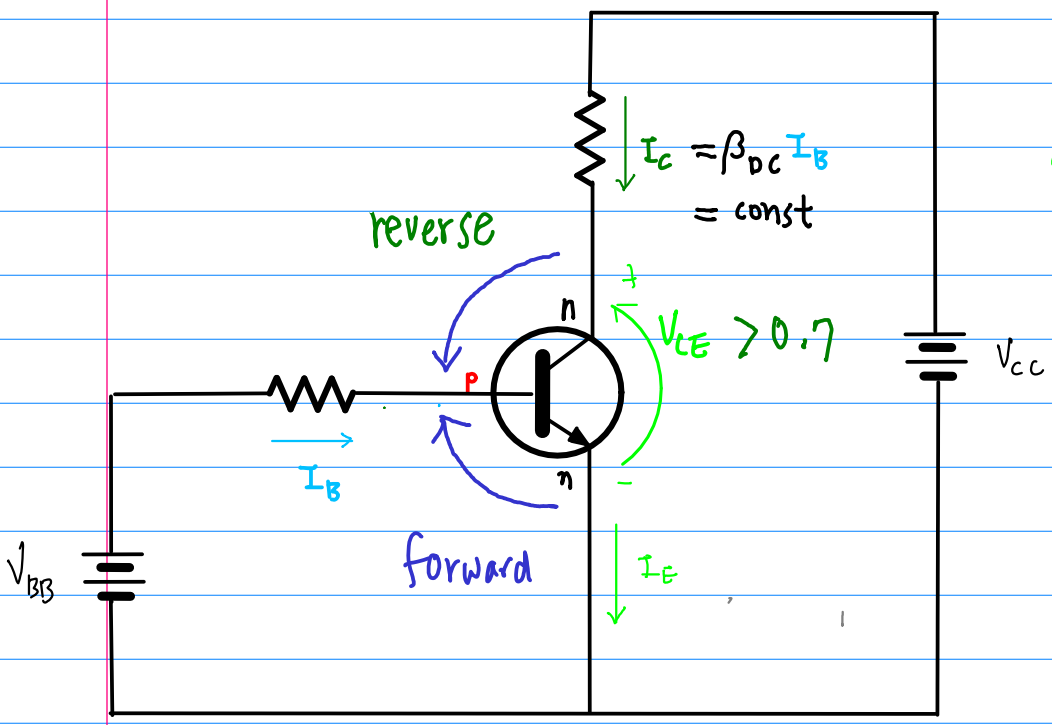
difference not much.. $V_{CE} \cong 0.3\,V$


SAT
Active
Break down
I_C
0
< 0.7V
V_{CE}

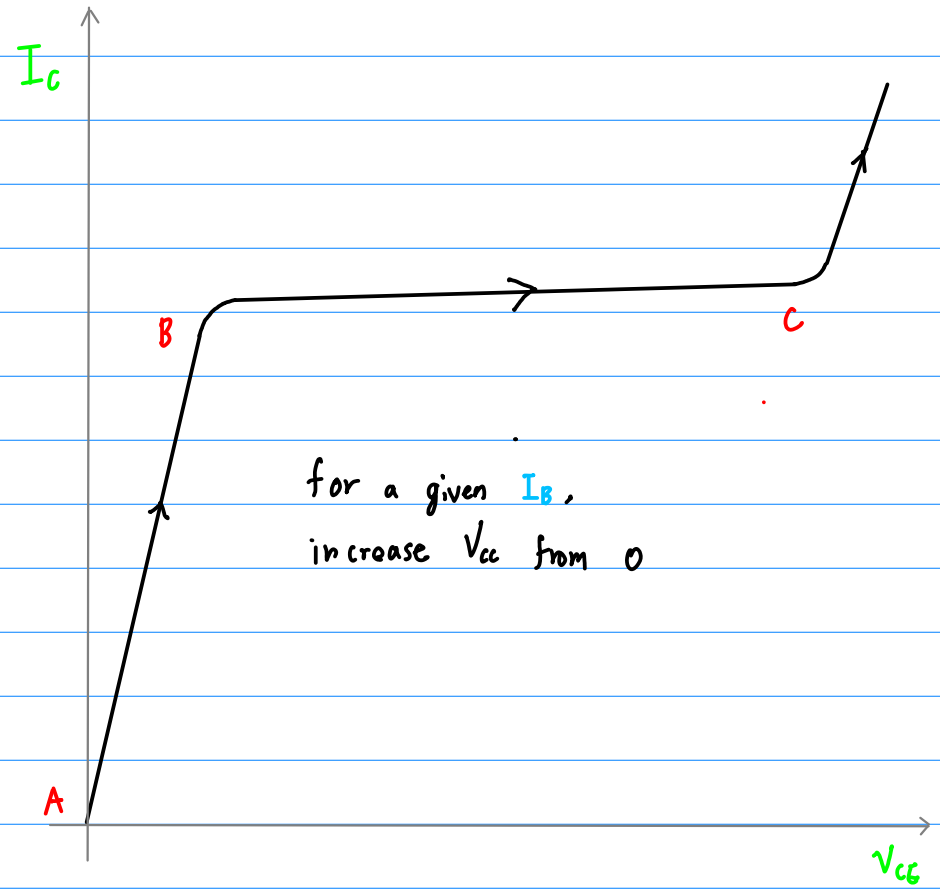

I_C
I_{B3}
I_{B2}
I_{B1}
$I_B \uparrow \rightarrow$ no significant change in $I_C \Rightarrow$ Saturation
V_{CE}

(B) — (C) Active



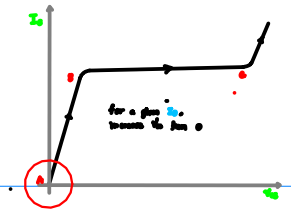


$$V_{CE} + V_{R_C} = V_{CC}$$

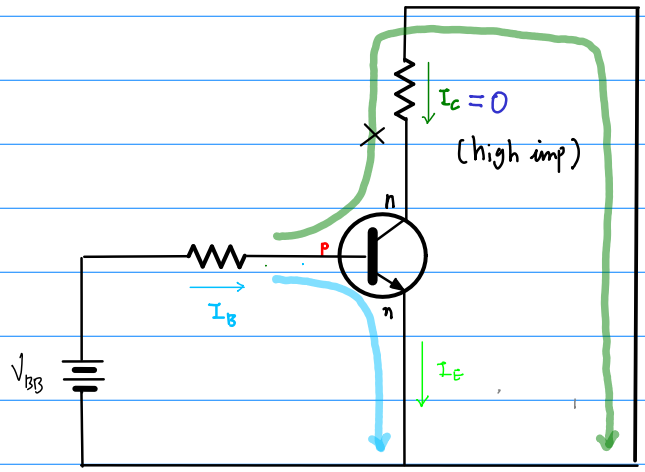


http://www.physics.csbsju.edu/trace/CC.html

(A) at the origin



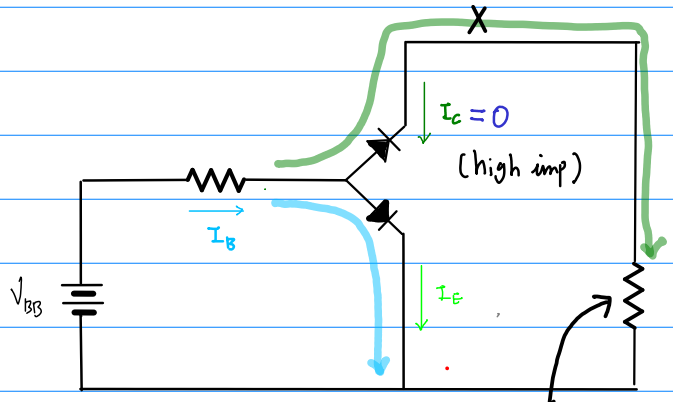
(A) $V_{CC} \approx 0$



2 paths

B → E very small R

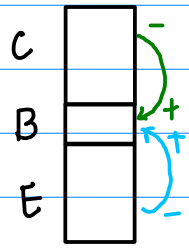
B → C (R_C) → $I_C = 0$

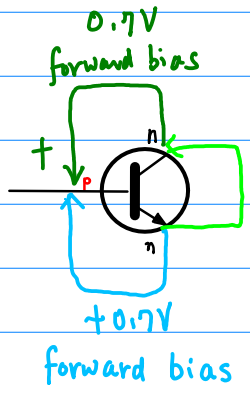


no voltage drop if $I_C = 0$

$V_{BC} = V_{BE}$

$-V_{CB} = V_{BE}$

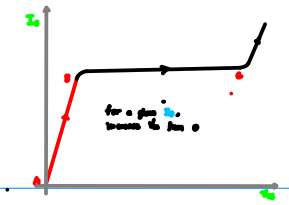


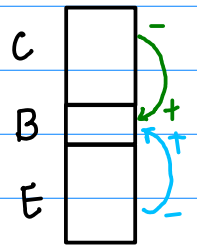


$V_{CE} = 0$ for saturation and $I_C = 0$

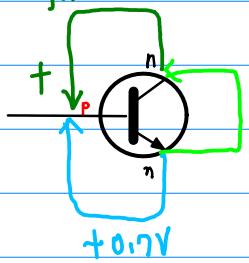
$V_{CE} = V_{CB} + V_{BE} = -V_{BC} + V_{BE} = -0.7 + 0.7 = 0$

Ⓐ–Ⓑ Saturation





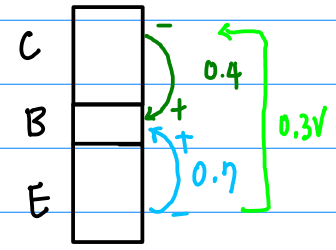
forward bias → ON diode

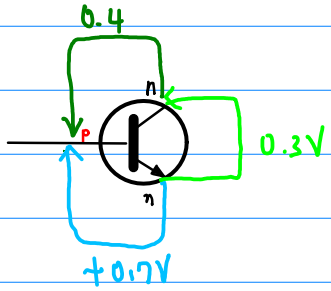


< 0.7V for saturation

+0.7V

forward bias → ON diode



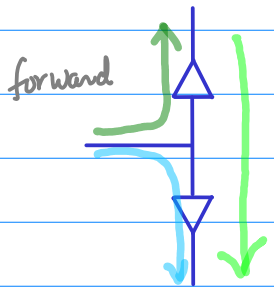


$V_{BC} = 0.4 = -V_{CB}$

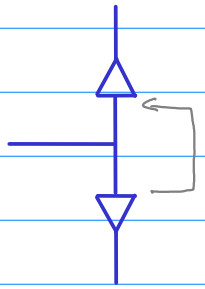
$V_{BE} = 0.7$

V_{CB} ↑

V_{BE} ↑ V_{CE}



net current



very small voltage (0.3V ≈ 0V)

acts as closed switch C E

↓

most of V_{CC} will be on external R_C or R_E

$V \uparrow \Rightarrow I \uparrow \rightarrow I_C, I_E$ large

$\frac{V}{R} = I$

⊕ ⊖

$I_E = I_B + I_C$ difference

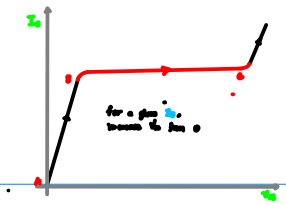
⊖ ⊕

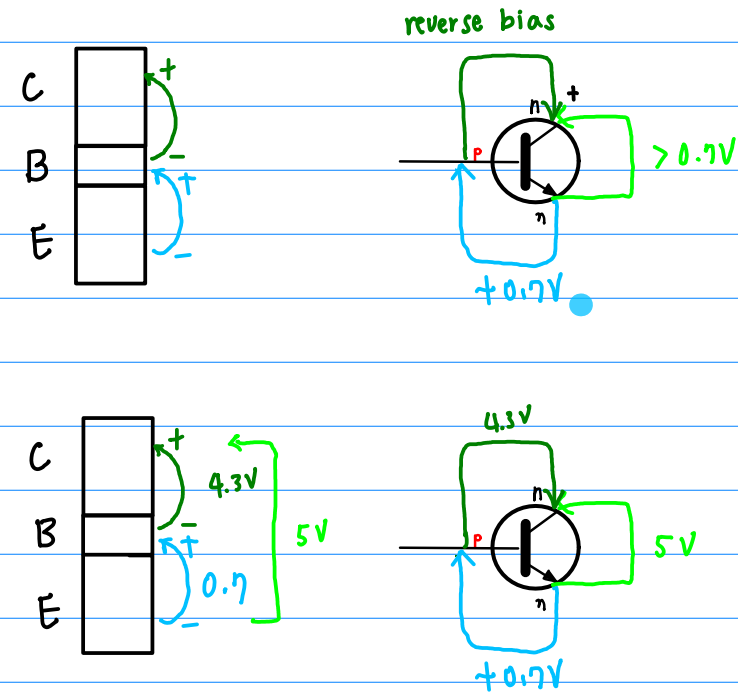
$I_E - I_C = I_B$

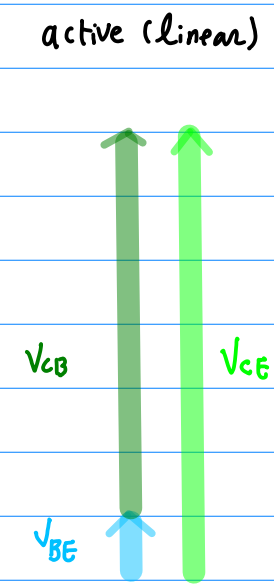
comparatively large I_B

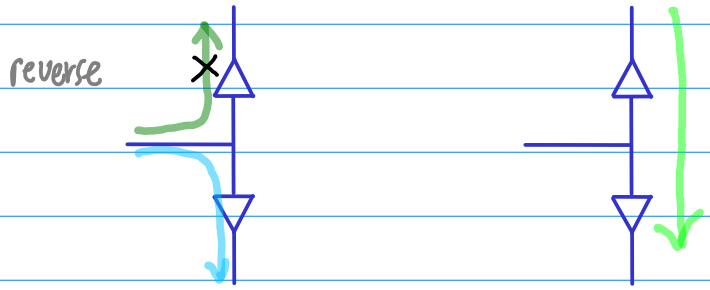
difference current I_E small

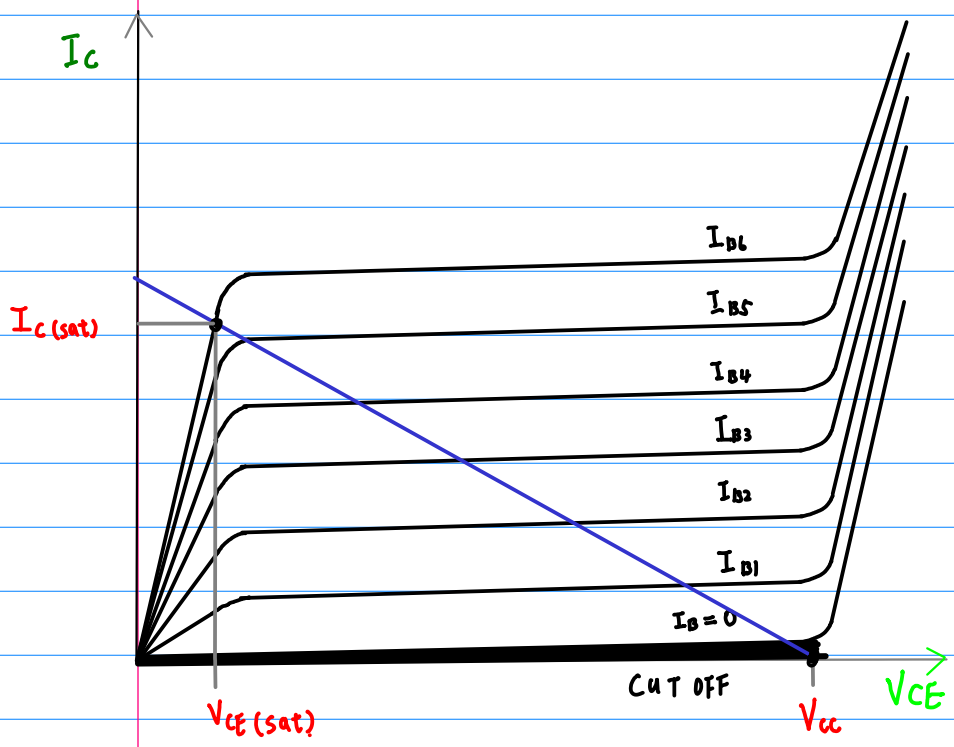
B – C Active (Linear)



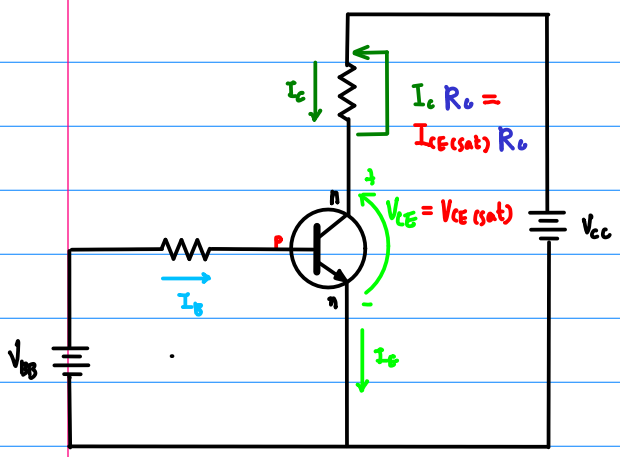


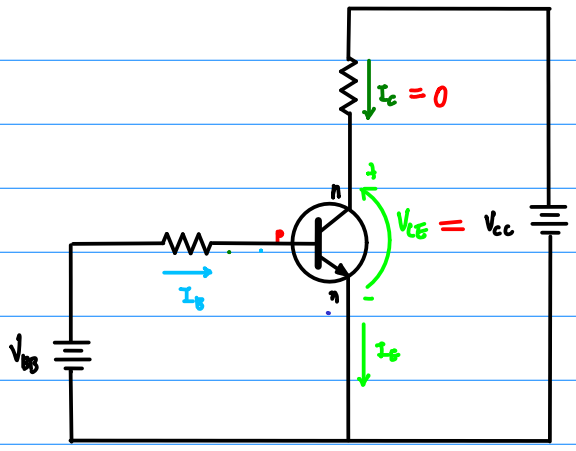


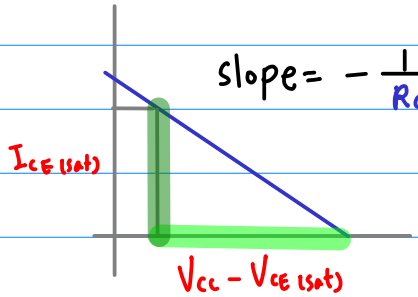


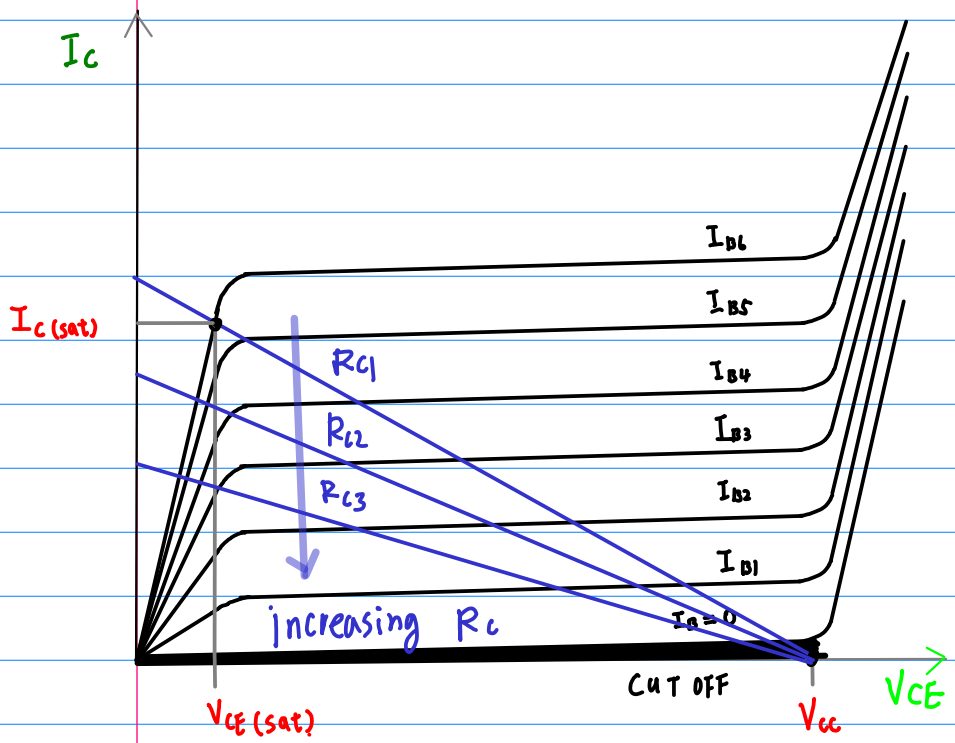


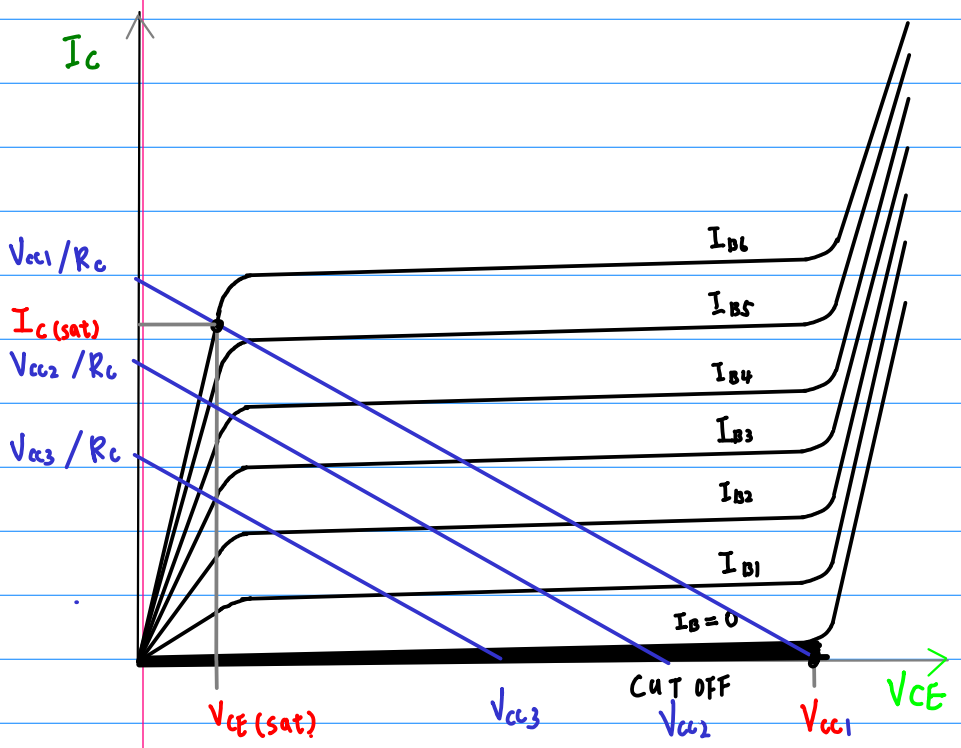
$$V_{CC} - V_{CE(sat)} = I_{CE(sat)} R_C$$





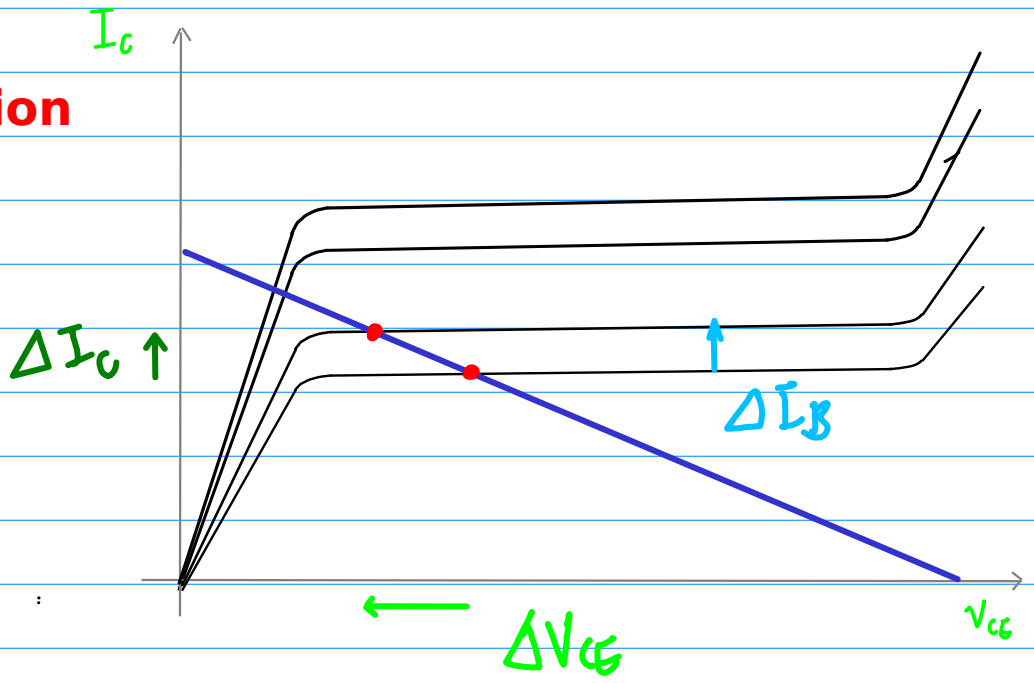



I_C
$I_{C(sat)}$
I_{B6}
I_{B5}
I_{B4}
I_{B3}
I_{B2}
I_{B1}
$I_B = 0$
R_{C1}
R_{C2}
R_{C3}
increasing R_C
CUT OFF
$V_{CE(sat)}$
V_{CC}
V_{CE}


I_C
V_{CC1}/R_C
$I_{C(sat)}$
V_{CC2}/R_C
V_{CC3}/R_C
I_{B6}
I_{B5}
I_{B4}
I_{B3}
I_{B2}
I_{B1}
$I_B = 0$
CUT OFF
$V_{CE(sat)}$
V_{CC3}
V_{CC2}
V_{CC1}
V_{CE}

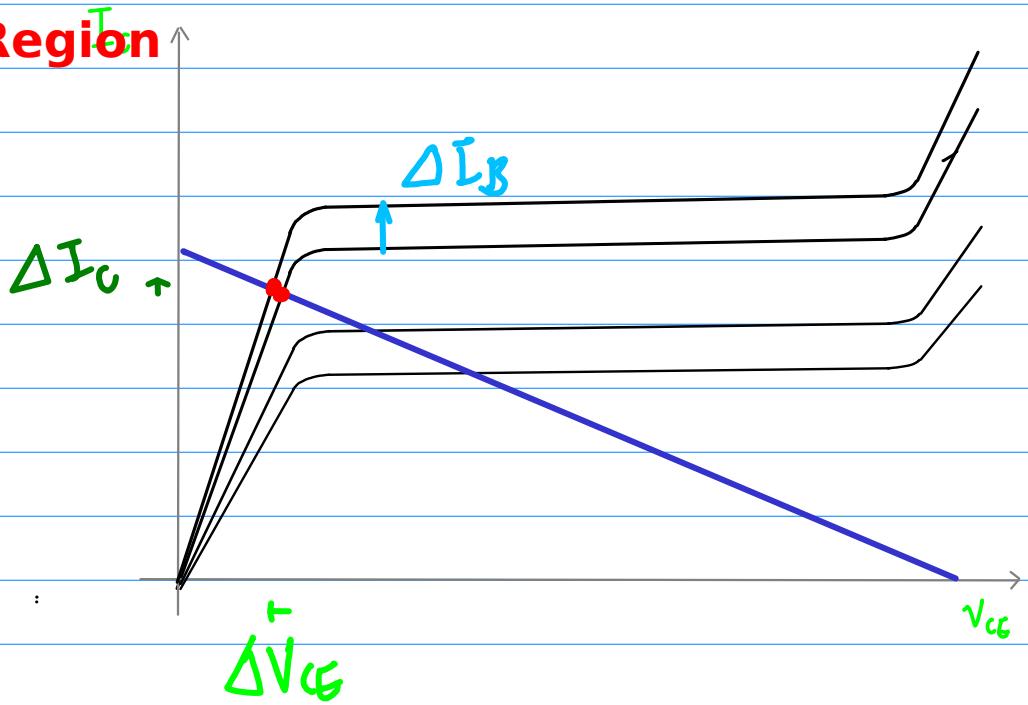
Why Saturation

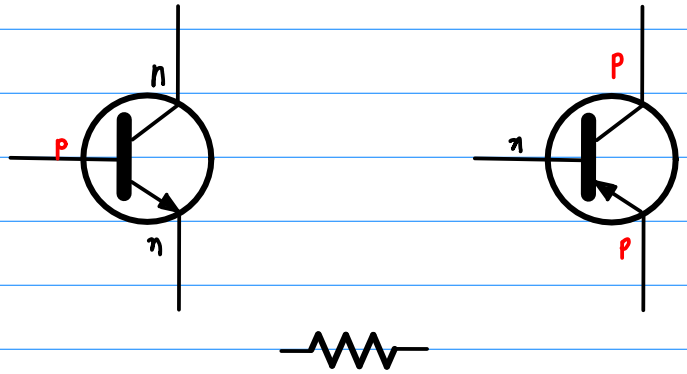
Active Region



Saturation Region

very small change
no visible change
Saturated

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