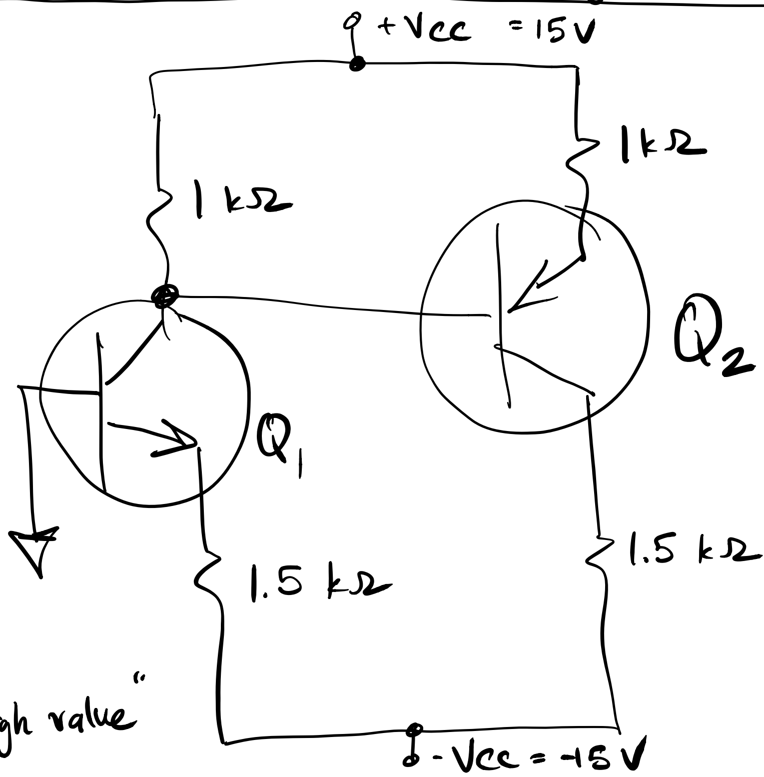
Direct-Coupled Active Region Circuits

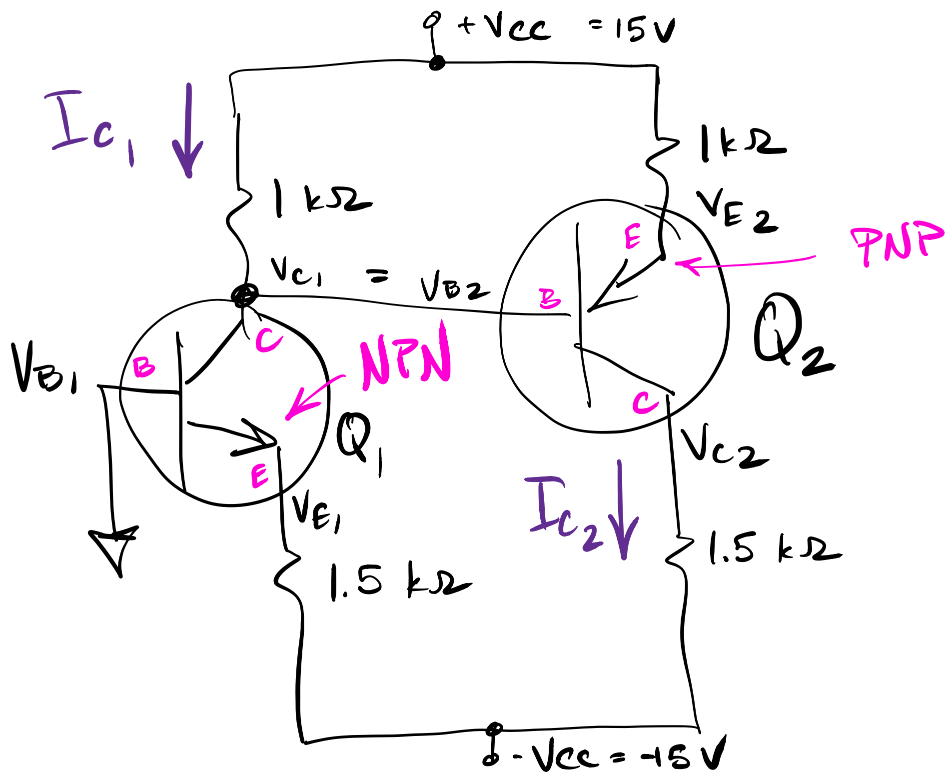
.. determine

V_{B1}	V_{B2}
V_{E1}	V_{E2}
V_{C1}	V_{C2}
V_{CE1}	V_{CE2}
I_{C1}	I_{C2}
I_{E1}	I_{E2}

.. assuming
β is a "high value"



.. the key: Q_1's collector voltage, V_{C1}, is also Q_2's base voltage, V_{B2} due to <u>direct coupling</u>.



∴ no need to even label I_{B_1}, I_{B_2}, I_{E_1}, I_{E_2} because "high-β" assumption means:

$$I_{B_1} = 0 \quad , \quad I_{B_2} = 0$$

$$I_{C_1} = I_{E_1} \quad , \quad I_{C_2} = I_{E_2}$$

∴ let's start with Q_1 at the base terminal.

$V_{B_1} = 0$ ← because it's grounded

∴ in the active region, $\underline{V_{BE_1} = 0.7V}$ [Si]

$$\therefore \quad V_{BE_1} = V_{B_1} - V_{E_1}$$

$$\Rightarrow V_{E_1} = \underset{0}{\cancel{V_{B_1}}} - 0.7$$

$$\underline{V_{E_1} = -0.7V}$$

$$I_{E_1} = \frac{V_{E_1} - (-V_{cc})}{R_{E_1}} = \frac{-0.7 - (-15)}{1.5k}$$

$$\underline{I_{E_1} = 9.53\ mA}$$

because β is "high," $\underline{I_{C_1} = 9.53\ mA}$

$$V_{C_1} = V_{CC} - \underbrace{I_{C_1} R_{C_1}}_{\text{drop across collector resistor}}$$

$$= 15 - 9.53m \cdot 1k$$

$$V_{C_1} = 5.47\ V$$

$$V_{CE_1} = V_{C_1} - V_{E_1} = 5.47 - (-0.7)$$

$$V_{CE_1} = 6.17\ V$$ ⇐ verifies active region! $(> 0.2V)$

Q_1 is done!

∴ due to direct-coupling, $V_{B2} = V_{C_1} = 5.47V$

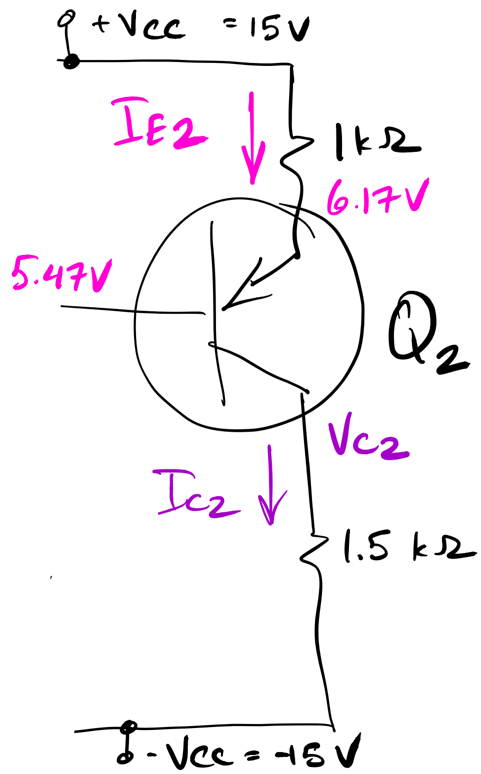
∴ for PNP in active region: $V_{BE_2} = -0.7V$

$$V_{BE_2} = V_{B_2} - V_{E_2}$$

$$\Longrightarrow V_{E2} = V_{B2} - (-0.7) = 5.47 + 0.7$$

$$V_{E2} = 6.17\,V$$

I_{E2}



$$I_{E2} = \frac{V_{CC} - V_{E2}}{R_{E2}}$$

$$= \frac{15 - 6.17}{1k}$$

$$I_{E2} = 8.83\ mA$$

$$\text{high-}\beta \Rightarrow I_{C2} = I_{E2} = 8.83\ mA$$

$$V_{C2} - {-V_{CC}} = I_{C2} \cdot R_{C2}$$

$$V_{C2} = -V_{CC} + I_{C2}R_{C2} = -15 + 8.83 \cdot 1.5$$

$$V_{C2} = -1.76\,V$$

$$V_{CE_2} = V_{C_2} - V_{E_2} = -1.76 - 6.17$$

$$\underline{V_{CE_2} = -7.93\ V}$$

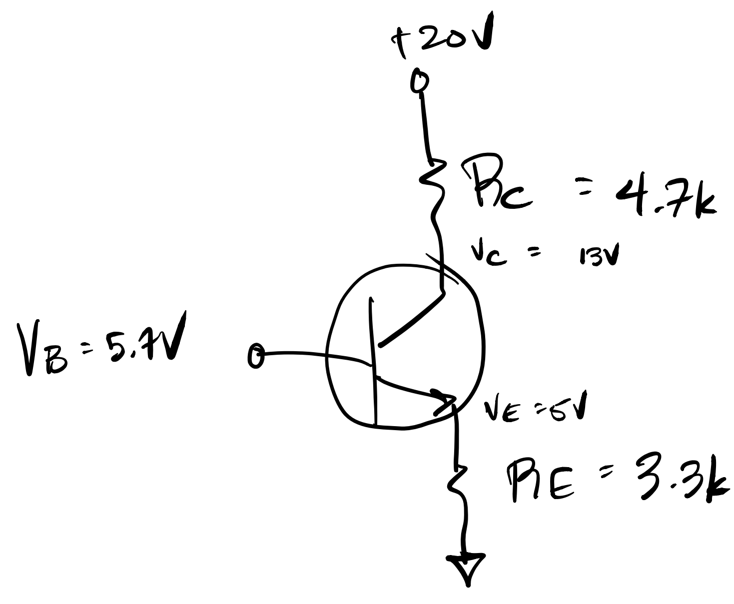
yep, negative!

∴ yep, active region; $|V_{CE}| > 0.2V$

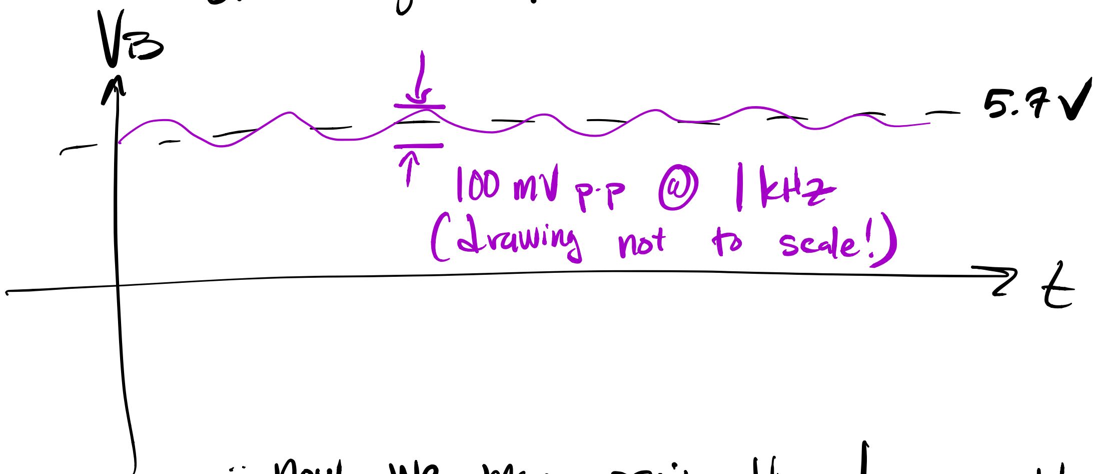
∴ why is the active region so important?

∴ permits linear amplification of small signals!

∴ back to simple NPN circuit:



∴ What if, instead of holding V_B steady at 5.7V, we wiggle it around 5.7V with some small signal?



∴ now we may split the base voltage into DC and AC components:

DC : $\underbrace{V_B}_{\text{capitalized!}} = 5.7V$

AC : $\underbrace{v_b}_{\text{lower case!}} = 100\ mV_{p\text{-}p}$ @ 1 kHz

small-signal component

- here's how linear amplification works.
  - "wiggling" V_B causes V_{BE} to wiggle
    - now we have a small-signal v_{be}!
  - wiggling V_{BE} causes I_C to wiggle
    - creates a small-signal i_c!
  - this causes the drop across R_C to wiggle

→ this causes V_C to wiggle

- creates a small-signal v_c, which, if we do everything right, is an amplified version of our original wiggle!!!!