Practice Problem Set #1

Transistor Biasing Basic

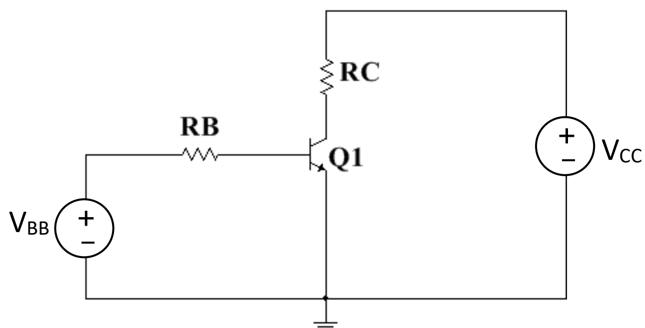
ENEL469: Analog Electronics

1. For a BJT, we know that $I_E = I_C + I_B$, $\beta = I_C/I_B$, and $\alpha = I_C/I_E$. Using these three equations, show that

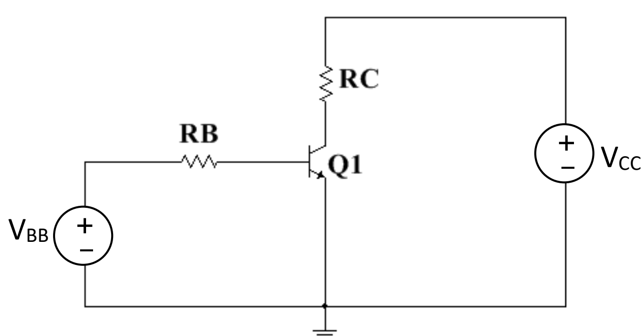
   $\alpha = \beta/(\beta + 1)$ and $\beta = \alpha/(1 - \alpha)$

   Note: these equations will be frequently used for problem solving in this course

2. Consider the following BJT circuit where two separate sources are used for simplicity.
   Given, $\beta = 80$, $V_{BE(on)} = 0.7V$, $V_{BB} = 1.5V$, $V_{CC} = 8V$, $R_B = 80k$, and $R_C = 5k$.
   Determine α, I_B, I_C, and V_{CE}.



3. Consider the following BJT circuit where two separate sources are used for simplicity.
   Given, $\alpha = 0.9836$, $V_{BE(on)} = 0.7V$, $V_{BB} = 5.2V$, $V_{CC} = 3V$, $R_B = 90k$, and $R_C = 0.5k$.
   Determine I_B, I_C, and V_{CE}.



Additional thoughts

- In this example, V_{CC} is less than V_{BB}. Is the transistor properly biased?

1. For a BJT, we know that $I_E = I_C + I_B$, $\beta = I_C/I_B$, and $\alpha = I_C/I_E$. Using these three equations, show that

   $\alpha = \beta/(\beta + 1)$ and $\beta = \alpha/(1 - \alpha)$

   Note: these equations will be frequently used for problem solving in this course

$I_E = I_C + I_B \rightarrow I_B = I_E - I_C$

÷ all by I_B

$\frac{I_E}{I_B} = \frac{I_C}{I_B} + 1$

$\boxed{I_E = I_B(\beta + 1)}$

$\frac{I_E}{I_B} = \beta + 1$

$\alpha = \frac{I_C}{I_E}$

÷ by I_B

$\alpha = \frac{I_C/I_B}{I_E/I_B}$

$\boxed{\alpha = \frac{\beta}{\beta+1}}$

$\beta = \frac{I_C}{I_B}$

$= \frac{I_C}{I_E - I_C}$

÷ by I_E

$= \frac{I_C/I_E}{I_E/I_E - I_C/I_E}$

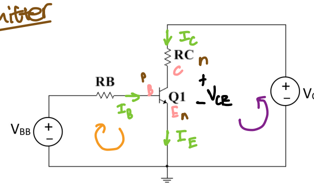
$\boxed{\beta = \frac{\alpha}{1-\alpha}}$

---

2. Consider the following BJT circuit where two separate sources are used for simplicity.
   Given, $\beta = 80$, $V_{BE(on)} = 0.7V$, $V_{BB} = 1.5V$, $V_{CC} = 8V$, $R_B = 80k$, and $R_C = 5k$.
   Determine α, I_B, I_C, and V_{CE}.

npn

common-emitter



$\alpha = \frac{\beta}{\beta+1} = \frac{80}{80+1} = 0.987654321$

why - and not + ?

$V_{BB} - I_B R_B - V_{BE(on)} = 0$

$V_{BB} = I_B R_B + V_{BE(on)}$

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

$= \frac{1.5 - 0.7}{80{,}000} = 10 \times 10^{-6}$

$= 10\ \mu A$

using $\beta = \frac{I_C}{I_B}$

$I_C = \beta I_B$

$= 0.8\ mA$

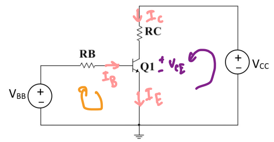
$V_{CC} - I_C R_C - V_{CE} = 0$

$V_{CE} = V_{CC} - I_C R_C$

$= 8 - (0.8 \times 10^{-3} \times 5000)$

$= 4V$

3. Consider the following BJT circuit where two separate sources are used for simplicity.
Given, $\alpha = 0.9836$, $V_{BE(on)} = 0.7V$, $V_{BB} = 5.2V$, $V_{CC} = 3V$, $R_B = 90k$, and $R_C = 0.5k$.
Determine I_B, I_C, and V_{CE}.



Additional thoughts

- In this example, V_{CC} is less than V_{BB}. Is the transistor properly biased?

$$\beta = \frac{\alpha}{1-\alpha} = 59.97560976$$

$$\beta = \frac{I_c}{I_B}$$

yes it's 'properly' biased since BE is fwd biased while CB is rev biased

$$V_{BB} - I_B R_B - V_{BE(on)} = 0$$

$$I_B = \frac{V_{BB} - V_{BE(on)}}{R_B} = \frac{5.2 - 0.7}{90{,}000} = 50\,\mu A$$

using $I_c = \beta I_B$

$$= 59.97560975 \times 50\,\mu A$$

$$\approx 3\ mA$$

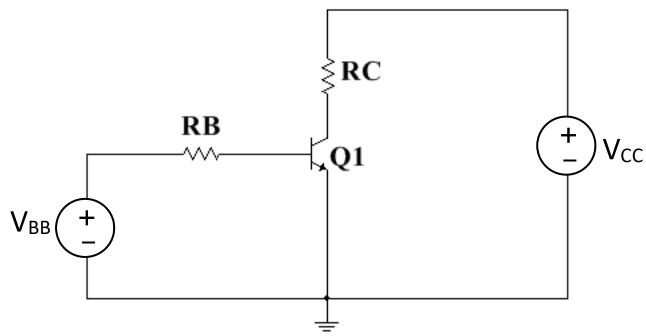
$$V_{CC} - I_C R_C - V_{CE} = 0$$

$$V_{CE} = V_{CC} - I_C R_C$$

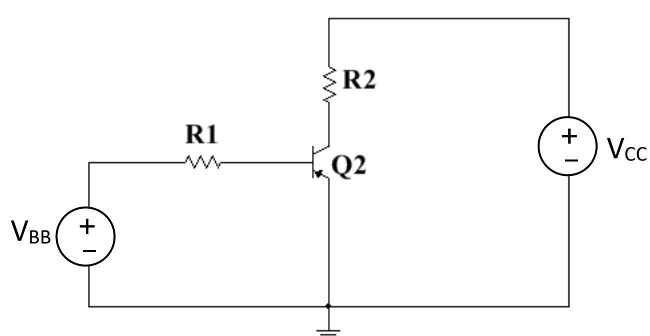
$$= 3 - (3\times10^{-3} \cdot 0.5k)$$

$$= 1.5\ V$$

4. Consider the following BJT circuit where two separate sources are used for simplicity. Design a BJT biasing circuit for which I_C should be set to 6mA. The collector-base junction is reverse biased by 7.8V. Also, given that β = 150, $V_{BE(on)}$ = 0.7V, V_{BB} = 2.3V, and R_C = 1.5k. (Hint: determine R_B and V_{CC})



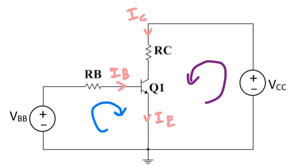
5. Consider the following BJT circuit where two separate sources are used for simplicity.
   Given, β = 100, $V_{BE(on)}$ = 0.7V, V_{BB} = 3.5V, V_{CC} = 10V, R_B = 50k, and R_C = 3k. Determine I_B, I_C, and V_{CE}.



Additional thoughts

- Have you noticed anything strange in biasing?
- What type of biasing the emitter-base junction has?
- What type of biasing the base-collector junction has?

4. Consider the following BJT circuit where two separate sources are used for simplicity. Design a BJT biasing circuit for which I_C should be set to 6mA. The collector-base junction is reverse biased by 7.8V. Also, given that $\beta = 150$, $V_{BE(on)} = 0.7V$, $V_{BB} = 2.3V$, and $R_C = 1.5k$. (Hint: determine R_B and V_{CC})



$$\beta = 150 = \frac{I_c}{I_B}$$

$$I_B = \frac{I_c}{150} = \frac{6\times10^{-3}}{150}$$

$$= 40\mu A$$

$$V_{cc} - I_c R_c - V_{CE} = 0$$

$$V_{cc} = (6\times10^{-3} \cdot 1.5\times10^{3}) + 8.5V$$

$$= 9 + 8.5$$

$$\boxed{= 17.5}$$

$$\boxed{V_B = 0.7}$$

$$V_c = 0.7 + 7.8 = \boxed{8.5V}$$

since $\boxed{V_E = 0}$ $\boxed{V_{CE} = 8.5V}$

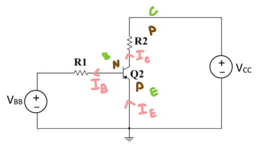
$$V_{BB} - I_B R_B - V_{BE(on)} = 0$$

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

$$= \frac{2.3 - 0.7}{40\times10^{-6}} = \boxed{40\text{ K}}$$

---

5. Consider the following BJT circuit where two separate sources are used for simplicity.
Given, $\beta = 100$, $V_{BE(on)} = 0.7V$, $V_{BB} = 3.5V$, $V_{CC} = 10V$, $R_B = 50k$, and $R_C = 3k$. Determine I_B, I_C, and V_{CE}.



Additional thoughts
- Have you noticed anything strange in biasing?
- What type of biasing the emitter-base junction has?
- What type of biasing the base-collector junction has?

* idk *

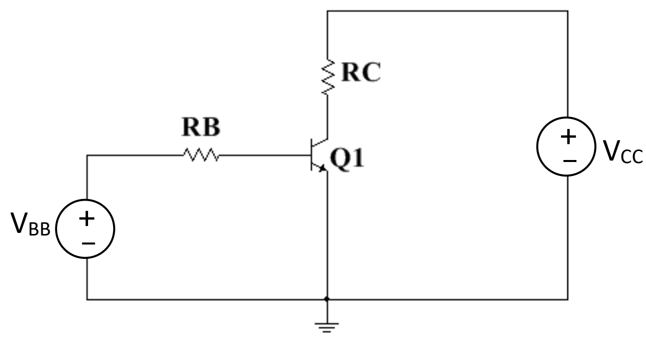
BE junction is reverse biased
therefore $I_B = 0$

$$\therefore \beta = \frac{I_c}{I_B} \Rightarrow I_c = \beta I_B$$
$$= 0$$

$$V_{CE} = V_{cc} = 10V$$

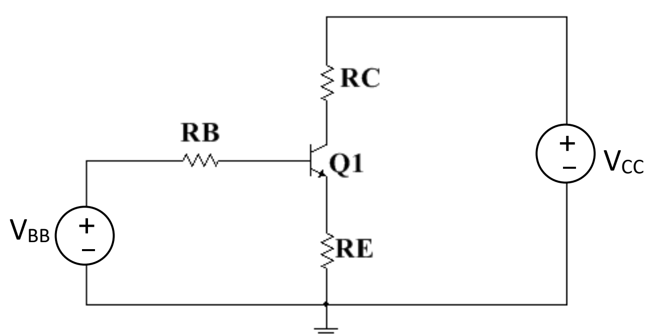
cuz no voltage drop across R2

6. Consider the following BJT circuit where two separate sources are used for simplicity.
Given, $\beta = 100$, $V_{BE(on)} = 0.7V$, $V_{BB} = 2.3V$, $V_{CC} = 10V$, $R_B = 20k$, and $R_C = 2k$. Determine I_B, I_C, and V_{CE}.

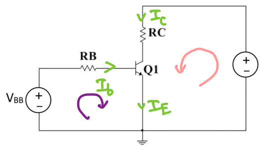


Additional thoughts
- Have you noticed anything that does not make sense?
- Apply KVL at the output (i.e., R_C, V_{CE}, and V_{CC}) circuit. Have you noticed now?

7. Consider the following BJT circuit where two separate sources are used for simplicity. Given, $\beta = 80$, $V_{BE(on)} = 0.7V$, $V_{BB} = 1.5V$, $V_{CC} = 6V$, $R_E = 500\Omega$, $R_B = 80k$, and $R_C = 5k$. Determine I_B, I_C, and V_{CE}.



6. Consider the following BJT circuit where two separate sources are used for simplicity.
Given, $\beta = 100$, $V_{BE(on)} = 0.7V$, $V_{BB} = 2.3V$, $V_{CC} = 10V$, $R_B = 20k$, and $R_C = 2k$.
Determine I_B, I_C, and V_{CE}.



Additional thoughts

- Have you noticed anything that does not make sense?
- Apply KVL at the output (i.e., R_C, V_{CE}, and V_{CC}) circuit. Have you noticed now?

$V_{BB} - I_b R_B - V_{BE(on)} = 0$

$$I_b = \frac{V_{BB} - V_{BE(on)}}{R_B} = \frac{2.3 - 0.7}{20{,}000} = 80\mu A$$

$$\beta = \frac{I_C}{I_B}$$

$$I_C = \beta I_B = 100 \times 80\mu A = 8mA$$

$V_{CC} - I_C R_C - V_{CE} = 0$

$$V_{CE} = V_{CC} - I_C R_C = 10 - (8\times10^{-3} \cdot 2000) = 10 - 16 = -6$$

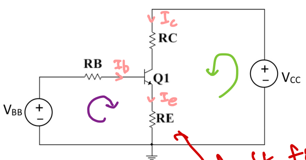
not possible, the transistor will be saturated

$$\boxed{\begin{aligned} &V_{CE} \approx V_{CE(sat)} \approx 0.3V \\ &I_C R_C = V_{CC} - V_{CE(sat)} \text{ and so on} \end{aligned}}$$

what does this mean?

---

7. Consider the following BJT circuit where two separate sources are used for simplicity. Given, $\beta = 80$, $V_{BE(on)} = 0.7V$, $V_{BB} = 1.5V$, $V_{CC} = 6V$, $R_E = 500\Omega$, $R_B = 80k$, and $R_C = 5k$. Determine I_B, I_C, and V_{CE}.



don't forget I_e and R_e

$V_{BB} - I_b R_B - V_{BE(on)} = 0$

$$I_b = \frac{V_{BB} - V_{BE(on)}}{R_B} = \frac{1.5 - 0.7}{80{,}000} = 10\mu A$$

$$\beta = \frac{I_C}{I_B}$$

$$I_C = \beta I_B = 80 \times 10 \times 10^{-6} = 0.8 mA$$

$$I_e = I_b + I_c = 810\mu A$$

$V_{CC} - I_C R_C - V_{CE} - I_e R_E = 0$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E = 6 - (0.8\times10^{-3} \cdot 5000) - (810\times10^{-6} \cdot 500) =$$

$V_{BB} - I_b R_B - V_{BE(on)} - I_e R_E = 0$

$V_{BB} = I_b R_B + V_{BE(on)} + I_E R_E$

$V_{BB} = I_b R_B + V_{BE(on)} + i_B(\beta+1) R_E$

$$I_b = V_{BB} - V_{BE(on)} - i_B(\beta+1) R_E$$

recall

$i_E = i_B(\beta+1)$

$$V_{BB} = I_B R_B + V_{BE} + I_E R_E = I_B R_B + V_{BE} + (I_B + \beta I_B) R_E = I_B R_B + V_{BE} + I_B(\beta+1) R_E$$

wrong rearranging

$$\therefore I_B = \frac{V_{BB} - V_{BE}}{R_B + (\beta+1) R_E} = 6.6\mu A$$

$\therefore I_C = \beta I_B = 0.53 mA$; $I_E = I_B + I_C = 0.5346 mA$

$V_{CE} = V_{CC} - I_C R_C - I_E R_E = 3.083V$