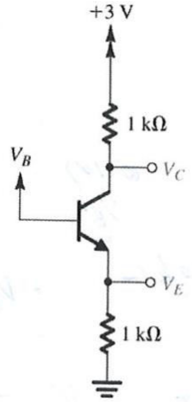
19EEE114 Electronic Circuits

Assignment #4 **SOLUTION** **Due on: 4th May 2022**

Q1. The Transistor in the circuit below has a very high β, Find V_E and V_C for V_B = +2.0V.



Solution:

$V_{BE} = V_B - V_E$

$V_E = V_B - V_{BE} = 2 - 0.7 = 1.3$ V

$I_E = V_E/R_E = 1.3$ mA

Transistor has high β, => $I_C \simeq I_E = 1.3$ mA

$V_C = V_{CC} - I_C R_C = 3 - 1.3 = 1.7$ V

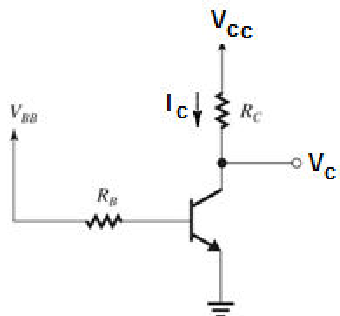
Q2. For the circuit below let V_{CC} = 10 V, R_C = 1kΩ, and R_B = 10 kΩ. The bipolar junction transistor has β = 50. Find the values of V_{BB} that results in the transistor operating

(a) in the active mode with V_C = 2 V;

(b) at the edge of saturation;

(c) deep in saturation with βforced = 10.

Assume $V_{BE} \approx 0.7$ V.



Solution:

(a) $I_C = (V_{CC} - V_C) / R_C$ = (10-2)/1 = 8 mA

$I_B = I_C/\beta$ = 0.16 mA

$V_{BB} = V_B + I_B R_B = 2.3$ V

$V_C > V_B$, therefore active mode

(b) at edge of saturation, V_{CE} = 0.3V

V_E = 0V => V_C = 0.3 V

I_C = 9.7 mA

I_B = 9.7 / 50 = 0.194 mA

V_{BB} = 2.64 V

(c) in deep saturation V_{CE} = 0.2 V

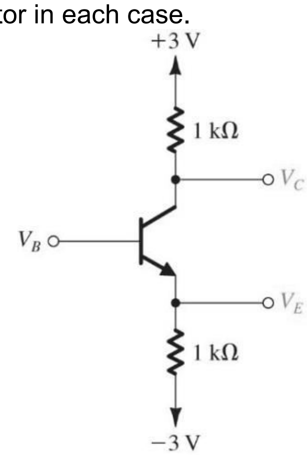
V_E = 0V => V_C = 0.2 V

I_C = 9.8 mA

$I_B = I_C/\beta_{forced}$ = 9.8 / 10 = 0.98 mA

V_{BB} = 10.5 V

Q3. Consider the operation of the circuit shown below for V_B at -1 V, 0 V, and +1 V. Assume that β is very high. What values of V_E and V_C result? What is the mode of operation of transistor in each case.



Solution:

(a) V_B = -1 V, V_E = -1 – 0.7 = -1.7 V

$I_C = I_E$ =(-1.7 – (-3))/1 = 1.3 mA

V_C = 3 – 1.3 = 1.7 V

$V_C > V_B$, therefore active region

(b) V_B = 0 V, V_E =– 0.7 V

$I_C = I_E$ =(-0.7 – (-3))/1 = 2.3 mA

V_C = 3 – 2.3 = 0.7 V

$V_C > V_B$, therefore active region

(c) V_B = 1 V, V_E = 1– 0.7 = 0.3V

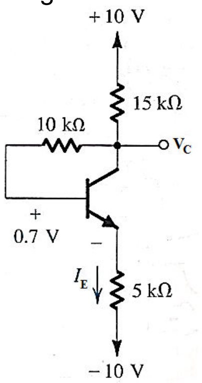
$I_C = I_E$ = 0.3 – (-3))/1 = 3.3 mA

V_C = 3 – 3.3 = - 0.7 V

$V_C < V_B$, therefore saturation region

Not in active mode, so $I_C \# I_E$, $V_C = V_E + V_{CE}$ = 0.5V

Q4. For the circuit shown below, assume that the transistor has very large β. Find the values of the labeled voltages and current.



Solution:

Equating the collector and emitter currents:

$$I_C = I_E$$

$$\frac{10 - V_C}{15} = \frac{(V_C - 0.7) - (-10)}{5} \rightarrow 10 - V_C = 3V_C + 27.9$$

$$4V_C = -17.9$$

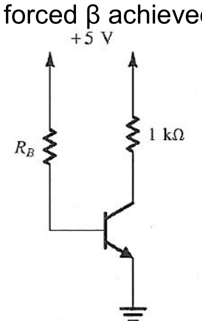
$$V_C = -4.475 \text{ V}.$$

$$I_C = \frac{10 - (-4.475)}{15} = 0.965 \text{ mA} = I_E$$

$I_C = I_E = 0.965$ mA

Q5. For the circuit shown, design a value for R_B so

that the transistor saturates with an overdrive factor of 10. The BJT is specified to have a minimum β of 20 and $V_{CEsat} = 0.2$ V. What is the value of forced β achieved?



Solution:

$$I_{C(sat)} = \frac{5 - 0.2}{1} = 4.8 \text{ mA}$$

$$I_{B(EOS)} = \frac{I_{C(sat)}}{\beta_{min}} = \frac{4.8}{20} = 0.24 \text{ mA}$$

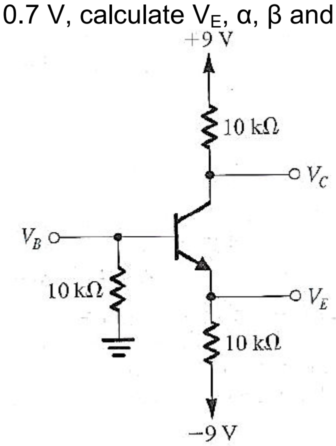
$$I_B = I_{B(EOS)} \times ODF = 2.4 \text{ mA}$$

$$I_B = \frac{5 - 0.7}{R_B} \rightarrow R_B = \frac{4.3}{2.4} = 1.792 \text{ k}\Omega$$

$$\beta_{forced} = \frac{I_{C(sat)}}{I_B} = \frac{4.8 \text{ mA}}{2.4 \text{ mA}} = 2;$$

$\beta_{forced} = 2$

Q6. For the circuit shown, $V_B = -1.5$ V. Assuming $V_{BE} = 0.7$ V, calculate V_E, α, β and V_C.



Solution:

$$I_B = \frac{0 - (-1.5)}{10} = 0.15 \text{ mA}$$

$$V_E = V_B - 0.7 = -1.5 - 0.7 = -2.2 \text{ V}$$

$$I_E = \frac{V_E - (-9)}{10} = \frac{-2.2 + 9}{10} = \frac{6.8}{10} = 0.68 \text{ mA}$$

$$I_C = I_E - I_B = 0.68 - 0.15 = 0.53 \text{ mA}$$

$$V_C = 9 - 0.53 \times 10 = 3.7 \text{ V}$$

$$V_{BC} = -1.5 - 3.7 = -5.2 \text{ V} \le 0.4 \text{ V}$$

which means the transistor is in the active mode.

$$\beta = \frac{I_C}{I_B} = \frac{0.53}{0.15} = 3.5333$$

$$\alpha = \frac{\beta}{\beta + 1} = \frac{3.5333}{4.5333} = 0.7794 = \frac{I_C}{I_E}$$

Q7. A transistor with β = 120 is biased to operate at a DC collector current of 1.2mA. Find the values of gm, rπ, and re.

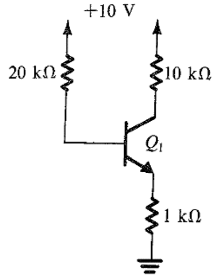
Solution:

$$g_m = \frac{I_C}{V_T} = \frac{1.2}{25} = 0.048\,\Omega^{-1}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{120}{0.048} = 2500\,\Omega$$

$$r_e = \frac{\alpha}{g_m} = \frac{\beta}{\beta+1}\frac{1}{g_m} = \frac{120}{121}\frac{1}{0.048} = 20.7\,\Omega$$

Q8. Find the collector voltage in the circuit shown below. Also, calculate forced β for the transistor. Assume the transistor is operating in saturation.



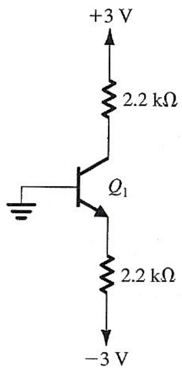
Solution:

$$\beta_{\text{forced}} = \frac{I_C}{I_B}$$

$$= \frac{\frac{V_{CC}-V_C}{R_C}}{\frac{V_{CC}-V_C-V_{BC}}{R_B}}$$

$$= \frac{\frac{10-1.46}{10}}{\frac{10-1.46-0.5}{20}} = 2.12$$

Q9. Consider the circuit shown below. Find the emitter, base and collector voltages and currents. Use β=50, but assume $|V_{BE}|$ = 0.8 V independent of current level.



Solution:

Assuming the transistor is in active mode:

$$V_E = -0.8 \;\rightarrow\; I_E = \frac{-0.8-(-3)}{2.2} = \frac{2.2}{2.2} = 1\text{ mA}$$

$$I_B = \frac{I_E}{\beta+1} = \frac{1}{51} = 19.61\times10^{-3}\text{ mA}$$

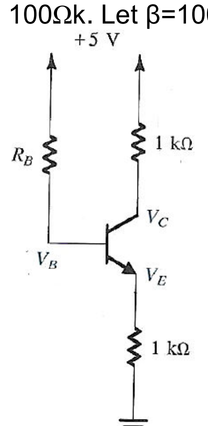
$$I_C = \beta I_B = 50\times33.78\times10^{-3} = 0.980\text{ mA}$$

$$V_B = 0$$

$$V_C = 3-2.2\times0.980 = 0.844\text{ V.}$$

$V_{BC} = 0-(0.844) = -0.844 \;\le\; 0.4 \;\rightarrow$ the CBJ is *reverse*-biased $\rightarrow$ the transistor is in active mode as assumed!

Q10. For the circuit shown below, find V_B, V_E and V_C for R_B = 100Ωk. Let β=100.



Solution:

$$R_B = 100\text{ k}\Omega$$

Assuming the transistor is in active mode:

$$(\beta+1)I_B = I_E$$

$$101\times\frac{5-(0.7+V_E)}{100} = \frac{V_E}{1} \;\rightarrow\; 4.3 - V_E = \frac{100}{101}V_E$$

$$\rightarrow V_E = 2.16\text{ V} \;\rightarrow\; I_E = \frac{2.16}{1} = 2.16\text{ mA}$$

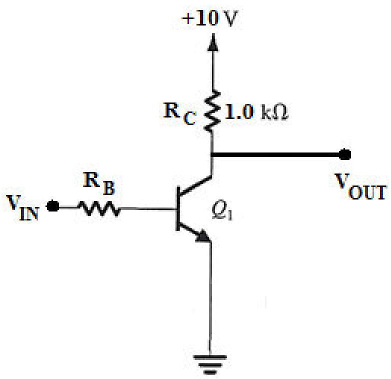
$$V_B = V_E + 0.7 = 2.16+0.7 = 2.86\text{ V}$$

$$V_C = 5-1\times I_C = 5-(\frac{100}{101})\times I_E = 2.86\text{ V}$$

$$V_{BC} = V_B - V_C = 0 \;\le\; 0.4\text{ V}$$

the BJT is in active mode as assumed.

Q11. (a) For the transistor circuit shown, what is V_{CE} when V_{IN} = 0 V?
(b) What minimum value of I_B is required to saturate this transistor if β_{DC} is 200? Neglect $V_{CE(sat)}$.
(c) Calculate the maximum value of R_B when V_{IN} = 5 V.



Solution:

(a) When $V_{IN} = 0V$,

the transistor is in cutoff

$$V_{CE} = V_{CC} = 10V = V_{CE(cutoff)}$$

(b) Since $V_{CE(sat)}$ is neglected

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{10V}{1.0K\Omega} = 10mA$$

$$I_{B(\min)} = \frac{I_{C(sat)}}{\beta_{DC}} = \frac{10mA}{200} = 50\mu A$$

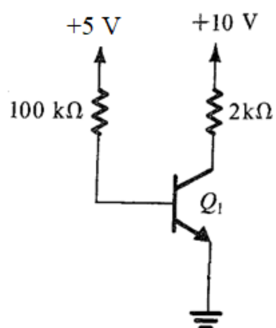
(c) When the transistor is on.

$$V_{BE} \cong 0.7V$$

$$V_{R_B} = V_{IN} - V_{BE} = 5 - 0.7V = 4.3V$$

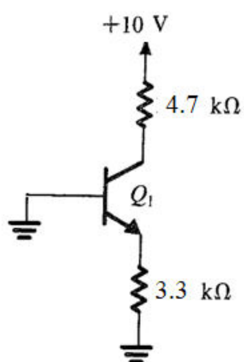
$$R_{B(\max)} = \frac{V_{RB}}{I_{B(\min)}} = \frac{4.3}{50\mu A} = 86K\Omega$$

Q12. Determine the voltage at all nodes and current through the branches. Assume β=100.



Refer lecture notes

Q13. Determine the voltage at all nodes and current through the branches. Assume β=100.



Refer lecture notes