BIPOLAR JUNCTION TRANSISTOR - BJT

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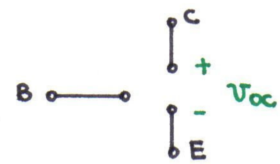
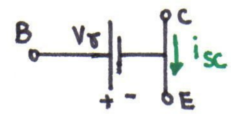
ECE 205 - SP09

(1) Compute

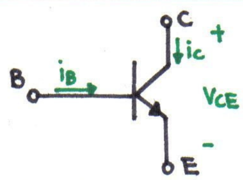
(a) the OPEN-CIRCUIT VOLTAGE V_{oc}



(b) the SHORT-CIRCUIT CURRENT i_{sc}



(2) You start ASSUMING that the BJT is operating in ACTIVE MODE so you use the following model to solve the circuit



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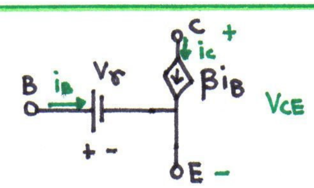
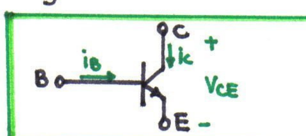


$$i_c = \beta i_B$$
$$V_{BE} = V_\gamma$$

Solve the circuit and determine V_{CE} and i_c

(3) (a) IF $0 < V_{CE} < V_{oc}$, $0 < i_c < i_{sc}$ then the BJT is indeed operating in **ACTIVE MODE** and thus the analysis carried in step (2) is correct (= you are done)

(b) IF $V_{CE} > V_{oc}$ or $i_c < 0$ then the BJT is operating in **CUTOFF MODE** which means that the analysis carried in step (2) is NOT CORRECT so you have to solve the circuit again using the following model



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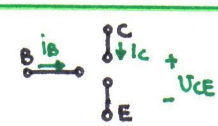
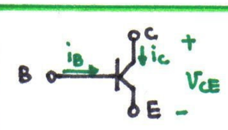


$$V_{CE} = V_{oc}$$
$$i_B = i_c = 0$$

(c) IF $V_{CE} < 0$ or $i_c > i_{sc}$ then the BJT is operating in **SATURATION MODE** which means that the analysis carried in step (2) is NOT CORRECT so you have to solve the circuit again using the following model



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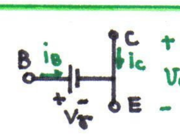
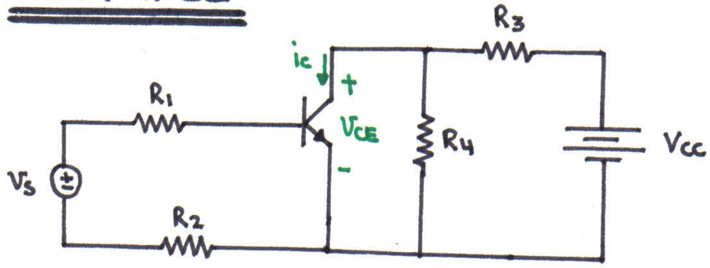


$$V_{CE} = 0$$
$$i_c = i_{sc}$$
$$V_{BE} = V_\gamma$$

EXAMPLE



$V_{CC} = 20\,V$

$R_1 = R_2 = 25\,k\Omega$

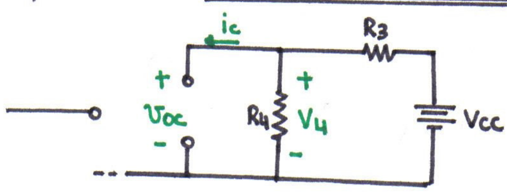
$R_3 = R_4 = 2\,k\Omega$

$\beta = 100$

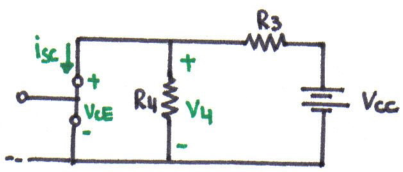
$V_\gamma = 0.7\,V$

Find i_C and V_{CE} for (a) $V_S = 3V$
(b) $V_S = 8V$

(1) Compute the OPEN-CIRCUIT VOLTAGE and SHORT-CIRCUIT CURRENT

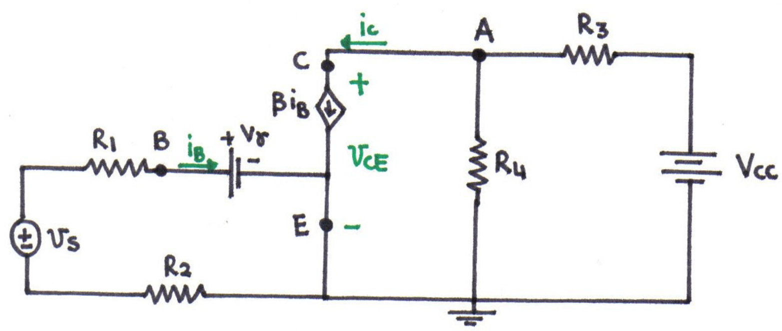


$i_C = 0 \Rightarrow \boxed{V_{OC}} = V_4 = \frac{R_4}{R_3+R_4} V_{CC} = \boxed{10V}$



$V_{CE} = 0 \Rightarrow V_4 = 0 \Rightarrow \boxed{i_{SC}} = \frac{V_{CC}}{R_3} = \boxed{10\,mA}$

(2) ASSUME that the BJT is operating in ACTIVE MODE and solve the circuit



$i_C = \beta i_B$

$V_{BE} = V_\gamma$

KVL @ LOOP 1 $\quad R_1 i_B + V_\gamma + R_2 i_B = V_S \Rightarrow i_B = \frac{V_S - V_\gamma}{R_1+R_2} = \frac{V_S - 0.7}{50K}$

$$\boxed{i_C} = \beta i_B = \beta \frac{V_S - V_\gamma}{R_1+R_2} = \boxed{100 \frac{V_S - 0.7}{50K}} \qquad (*)$$

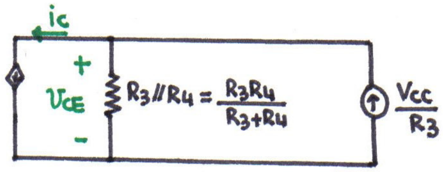
KCL @ NODE A $\quad \frac{V_A - V_{CC}}{R_3} + \frac{V_A}{R_4} + i_C = 0$

$(R_3+R_4) V_A = R_4 V_{CC} - i_C (R_3 R_4)$

since $V_{CE} = V_A$

$$\boxed{V_{CE} = \frac{R_4}{R_3+R_4} V_{CC} - \frac{R_3 R_4}{R_3+R_4} i_C} \qquad (**)$$

NOTE: you can obtain (**) applying a source transformation instead of the KCL @ node A



$$V_{CE} = \frac{R_3 R_4}{R_3+R_4}\left(\frac{V_{CC}}{R_3} - i_C\right)$$

$$V_{CE} = \left(\frac{2K}{4K}\right) V_{CC} - \left(\frac{4\cdot 10^6}{4\cdot 10^3}\right)\left(100\ \frac{V_S-0.7}{50K}\right) = \frac{V_{CC}}{2} - 2\,(V_S-0.7)$$

$$i_C = 2\,(V_S-0.7)\cdot 10^{-3}$$
$$V_{CE} = 10 - 2\,(V_S-0.7)$$

(3) (a) $V_S = 3V$

$i_C = 2\cdot(3-0.7)\cdot 10^{-3} = 4.6\ mA < 10\ mA = i_{SC}$

$V_{CE} = 10 - 2(3-0.7) = 5.4\ V < 10\ V = V_{OC}$

since $\begin{cases} i_C < i_{SC} \\ V_{CE} < V_{OC} \end{cases}$ ⇨ the BJT is indeed operating in active mode, thus

$i_C = 4.6\ mA$
$V_{CE} = 5.4\ V$

(b) $V_S = 8V$

$i_C = 2\cdot(8-0.7)\cdot 10^{-3} = 14.6\ mA > 10\ mA = i_{SC}$

since $i_C > i_{SC}$ then the BJT is not operating in active mode but in SATURATION MODE, thus

$i_C = i_{SC} = 10\ mA$
$V_{CE} = 0\ V$

NOTE: if you have to compute only i_C and V_{CE} you are done.
if you are required to find other quantities (for instance the potential difference across R_3) then you have to solve the circuit again using the BJT model for saturation mode