EE-210

Sol^{n} to HA # 4

1 $V_E = -1V \Rightarrow I_E = \frac{V_E - (-5)}{4K} = 1\,mA$, $V_{BE} = 0.7V \Rightarrow V_B = V_E + V_{BE} = -1 + 0.7 =$ $0.3V \Rightarrow I_B = \frac{0 - (-0.3)}{60K} = 5\,\mu A$, $I_C = I_E - I_B = 1mA - 5\mu A = 0.995\,mA$, $V_C = +5 - I_C \times 3K = 5 - 0.995 \times 3 = 2.015\,V \Rightarrow V_{CE} = V_C - V_E = 2.015 - (-1) = 3.015\,V$, $\beta = \frac{I_C}{I_B} = \frac{0.995\,mA}{5\,\mu A} = 199$ $\alpha = \frac{\beta}{\beta+1} = \frac{199}{199+1} = 0.995 = \frac{I_C}{I_E}$.

Power drawn from $\pm 5V$ supplies $P_{drawn} = +5V \times I_C + |-5V| \times I_E$

$\Rightarrow P_{drawn} = 5 \times 0.995 + 5 \times 1 = 9.975\,mW$

Power dissipated in the transistor, $P_Q = V_{CE} \times I_C = 3.015 \times 0.995 = 3\,mW$

" " " 60K resistor, $P_{60K} = I_B^2 \times 60K = (5\mu A)^2 \times 60K = 1.5\,\mu W$

" " " 3K " , $P_{3K} = I_C^2 \times 3K = (0.995\,mA)^2 \times 3K = 2.97\,mW$

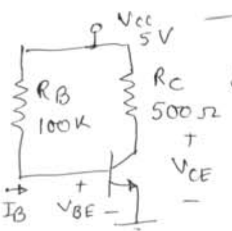
" " " 4K " , $P_{4K} = I_E^2 \times 4K = (1mA)^2 \times 4K = 4\,mW$

$\Rightarrow$ Total power dissipated, $P_{dissipated} = P_Q + P_{60K} + P_{3K} + P_{4K} = 9.97\,mW$

$\Rightarrow$ Total power drawn = total power dissipated $\Rightarrow$ Conserved quantity.

Due to the principle of conservation of total energy.

2



Nominal $\beta = 100 \Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{5 - 0.7}{100K} = 43\,\mu A$.

Note that this current is independent of β.

$I_C = \beta I_B = 4.3\,mA$ (nominal), $V_{CE} = V_{CC} - I_C R_C = 2.85V$ (nominal)

$\beta = 50$: $I_C = 2.15\,mA \Rightarrow$ % change $= -50\%$ (same as β)

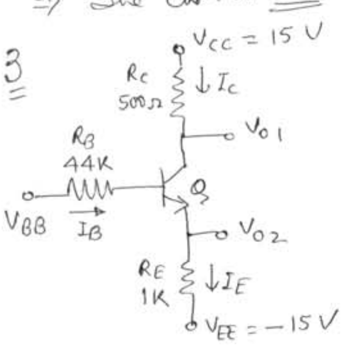
$V_{CE} = 3.925V \Rightarrow$ % change $= +37.72\%$

$\beta = 150$: $I_C = 6.45\,mA \Rightarrow$ % change $= +50\%$, $V_{CE} = 1.775V \Rightarrow$ % change $= -37.72\%$

Thus, there is a large change in I_C & V_{CE} with respect to β variation

$\Rightarrow$ The ckt. is not robust at all.

3



a) i) $V_{BB} = 0$: Writing KVL in the BE loop of Q: Also, $I_E = (\beta+1) I_B$

$I_B R_B + V_{BE} + I_E R_E + V_{EE} = 0$

$\Rightarrow I_B = \frac{-V_{BE} - V_{EE}}{R_B + (\beta+1) R_E} = \frac{-0.7 + 15}{44K + 101 \times 1K} = 98.62\,\mu A$

$I_C = \beta I_B = 9.86\,mA$ & $I_E = (\beta+1) I_B = 9.96\,mA$

$V_{O1} = V_{CC} - I_C R_C = 15 - 9.86 \times 0.5 = 10.07V$

$V_{O2} = V_{EE} + I_E R_E = -15 + 9.96 \times 1 = -5.04V$

Note: $V_{CE} = V_C - V_E = 15.11\,V \Rightarrow$ forward active

ii) With $V_{o1} = 0$, $V_{CE} = \underline{5.04\,V}$ ⇒ Thus, the transistor would remain in the forward active mode. ∴ I_C would remain independent of R_C, & for $V_{o1} = 0$, $I_C R_C$ must equal V_{CC}, which gives $R_C = \frac{V_{CC}}{I_C} = \frac{15\,V}{9.86\,mA} = \underline{1.52\,K}$.

b) i) At onset of saturation: $V_{BE} = 0.7\,V$ & $V_{CE} = 0.7\,V$ (with $V_{BC} = 0$)
At this point, β & α would retain their nominal midband values.
Writing KVL at the output ckt:

$$V_{CC} - V_{CE} - V_{EE} = I_C R_C + I_E R_E \quad \& \quad I_E = \frac{I_C}{\alpha} \Rightarrow V_{CC} - V_{CE} - V_{EE} = I_C\left(R_C + \frac{R_E}{\alpha}\right)$$

with $\beta = 100$ $\quad \alpha = \frac{\beta}{\beta+1} = \frac{100}{101} = \underline{0.99}$

$$\Rightarrow I_C = \frac{15 - 0.7 + 15}{500 + 1000/0.99} = \underline{19.4\,mA} \Rightarrow I_B = \frac{I_C}{\beta} = \underline{194\,\mu A} \ \& \ I_E = \frac{I_C}{\alpha} = \underline{19.6\,mA}$$

$$\therefore V_{BB} = I_B R_B + V_{BE} + I_E R_E + V_{EE} = 194\,\mu A \times 44K + 0.7 + 19.6\,mA \times 1K - 15 = \underline{13.84\,V}.$$

ii) $\beta_{sat} = 10 \Rightarrow Q$ in hard saturation with $V_{BE} = 0.8\,V$ & $V_{CE} = 0.1\,V$, also $\alpha = \frac{10}{11} = \underline{0.909}$

For this case, $I_C = \frac{15 - 0.1 + 15}{500 + 1000/0.909} = \underline{18.7\,mA}$

which gives $I_E = \frac{I_C}{\alpha} = \underline{20.56\,mA}$ & $I_B = \frac{I_E}{\beta+1} = \underline{1.87\,mA}$

$\therefore V_{BB} = 1.87\,mA \times 44K + 0.8 + 20.56\,mA \times 1K - 15 = \underline{88.64\,V}$ (Very large!)

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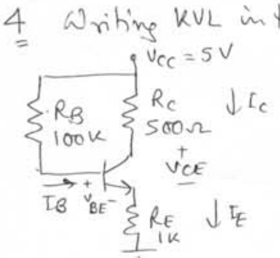
4 Writing KVL in the BE loop: $V_{CC} = I_B R_B + V_{BE} + I_E R_E$ with $I_E = (\beta+1) I_B$



$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} = \underline{21.4\,\mu A}\ (\beta = 100, \text{nominal}),\ \underline{28.48\,\mu A}\ (\beta = 50),$$
and $\underline{17.13\,\mu A}$ ($\beta = 150$)

$\Rightarrow I_C = \beta I_B = 2.14\,mA$ ($\beta = 100$), $1.424\,mA$ ($\beta = 50$), & $2.57\,mA$ ($\beta = 150$)

% change in $I_C = \underline{-33.46\%}$ ($\beta = 50$), & $+\underline{20.09\%}$ ($\beta = 150$)

$I_E = I_C + I_B = 2.16\,mA$ ($\beta = 100$), $1.45\,mA$ ($\beta = 50$), & $2.59\,mA$ ($\beta = 150$)

$\therefore V_{CE} = V_{CC} - I_C R_C - I_E R_E = \underline{1.77\,V}$ ($\beta = 100$), $\underline{2.84\,V}$ ($\beta = 50$), & $\underline{1.125\,V}$ ($\beta = 150$)

% change in $V_{CE} = \underline{+60.45\%}$ ($\beta = 50$), & $\underline{-36.44\%}$ ($\beta = 150$)

⇒ % change in I_C decreased, but that of V_{CE} increased a bit. (as compared to Prob. 2)

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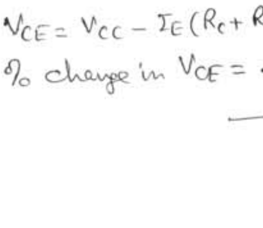

Note: Current thru $R_C = I_C + I_B = I_E$ ⇒ KVL ⇒ $V_{CC} = I_E R_C + I_B R_B + V_{BE} + I_E R_E$

$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1)(R_C + R_E)} = \underline{17.1\,\mu A}\ (\beta = 100, \text{nominal}),\ \underline{24.36\,\mu A}\ (\beta = 50),$$
& $\underline{13.17\,\mu A}$ ($\beta = 150$)

$\Rightarrow I_C = \beta I_B = \underline{1.71\,mA}$ ($\beta = 100$), $\underline{1.218\,mA}$ ($\beta = 50$), $\underline{1.976\,mA}$ ($\beta = 150$)

% change in $I_C = \underline{-28.77\%}$ ($\beta = 50$), & $+\underline{15.56\%}$ ($\beta = 150$)

$I_E = I_C + I_B = 1.727\,mA$ ($\beta = 100$), $1.242\,mA$ ($\beta = 50$), & $1.989\,mA$ ($\beta = 150$)

$V_{CE} = V_{CC} - I_E(R_C + R_E) = \underline{2.41\,V}$ ($\beta = 100$), $\underline{3.137\,V}$ ($\beta = 50$), & $\underline{2.017\,V}$ ($\beta = 150$).

% change in $V_{CE} = +\underline{30.17\%}$ ($\beta = 50$), & $-\underline{16.31\%}$ ($\beta = 150$). Performance improved, but not that much!

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