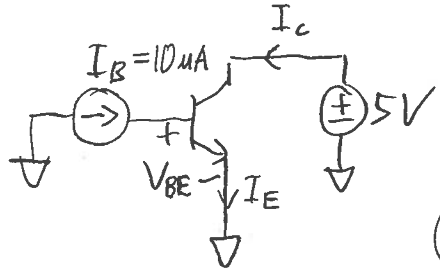
EECS 311 - fall 2008 - HW#5 sol'ns

P5.1



BE $I_s = 10^{-17}$ $\quad V_{CE} > V_{BE} = V_{BE,on}$ For. Act.

ignore V_A

$$I_c = I_B\beta_F \approx I_s e^{V_{BE}/V_T}$$

$$I_E = I_B + I_c = (1+\beta_F) I_B$$

$$I_B = I_s e^{V_{BE}/V_T}$$

$$\frac{V_{BE}}{V_T} = \ln\left(\frac{I_B}{I_s}\right) \Rightarrow V_{BE} = V_T \ln\left(\frac{I_B}{I_s}\right) \approx 0.718\ V$$

V_T: 0.026 @ room T

P5.2

a) $\alpha_F = \dfrac{I_c}{I_E} = \dfrac{\beta_F I_B}{(1+\beta_F) I_B} = \dfrac{\beta_F}{1+\beta_F}$

b) $\alpha_F = \dfrac{\beta_F}{1+\beta_F} \Rightarrow \beta_F = \dfrac{\alpha_F}{1-\alpha_F}$

$$\frac{I_B}{I_E} = \frac{1}{1+\beta_F} = \frac{1}{1+\frac{\alpha_F}{1-\alpha_F}} = 1-\alpha_F$$

c) 5% tolerance:

$\alpha_F > 0.95$

$\beta_F > \dfrac{\alpha_F}{1-\alpha_F}$

$> \dfrac{0.95}{1-0.95}$

> 19

1% tolerance:

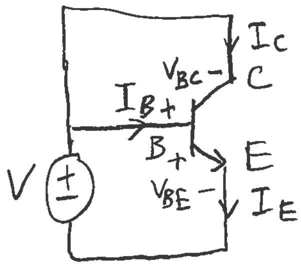
$\alpha_F > 0.99$

$\beta_F > \dfrac{0.99}{1-0.99}$

> 99

P5.3

a)



b) $V = 0.640\,V$ find I_S, β_F, β_R ($\alpha_R = 0.5$)

$I_C = 275\,\mu A$

$I_B = 4\,\mu A$

$V_{BE} > 0$

$V_{BC} = 0$ (not on)

$V_{CE} = V_{BE}$

$\left.\begin{matrix} \\ \\ \end{matrix}\right\}$ for. act. $I_C = I_S e^{V_{BE}/V_T}$

$275 \times 10^{-6} = I_S e^{0.64/0.026}$

$I_S \approx 5.61 \times 10^{-15} A$

$$\beta_F = \frac{I_C}{I_B} \approx 68.75\ A/A$$

$$\beta_R = \frac{\alpha_R}{1-\alpha_R} = \frac{0.5}{1-0.5} = 1$$

P5.4

$I_B + I_C = I_E = 10^{-4}$

$I_B(1+\beta_F) = 10^{-4}$

$$I_B = \frac{1}{10^4(1+199)} = 0.5\,\mu A$$

$I_C = \beta_F I_B = 99.5\,\mu A$

$$\beta_F = \frac{\alpha_F}{1-\alpha_F} = \frac{0.995}{1-0.995} = 199$$

BJT is diode connected

↳ for. act. mode

P5.5 npn, for. act., $I_B = 3\mu A$, $V_{CE} = 5V \rightarrow I_C = 240\mu A$

$V_{CE} = 10V \rightarrow I_C = 265\mu A$

(5.72 J&B) find β_{FO} & V_A

$$\beta_F = \beta_{FO}\left(1 + \frac{V_{CE}}{V_A}\right) = \frac{I_C}{I_B}$$

① $\frac{240}{3} = \beta_{FO}\left(1 + \frac{5}{V_A}\right)$

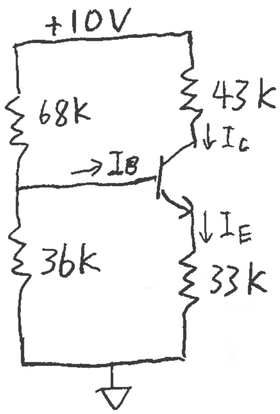
② $\frac{265}{3} = \beta_{FO}\left(1 + \frac{10}{V_A}\right)$

$\beta_{FO} = \frac{215}{3} \approx 71.7\ A/A$

$V_A = 43\ V$

P5.6 $\beta_R = 1$, $\beta_F = 50$, $V_{BE} = 0.7V$

(5.82 J&B) a)



$$\frac{10 - V_B}{68000} - \frac{V_B}{36000} = I_B$$

$$V_E = I_E(33000) = (1+\beta_F) I_B\, 33000 = 51(33000) I_B$$

$$V_B - V_E = 0.7$$

$$10 - V_C = 43000\, I_C = 43000(50) I_B$$

→ 4 eq. 4 unknown:

$I_B \approx 1.618\ \mu A$ ⇒ $I_C = \beta_F I_B \approx 80.9\mu A$

for. act. ✓

$V_B \approx 3.4234\ V$

$V_E \approx 2.7234\ V$

$V_C \approx 6.5208\ V$

$V_{CE} \approx 3.797\ V$

b) $$\frac{5(10 - V_B)}{68000} - \frac{5V_B}{36000} = I_B$$

$$V_E = 51\left(\frac{33000}{5}\right) I_B$$

$$V_B - V_E = 0.7$$

$$10 - V_C = \frac{43000}{5}(50) I_B$$

$I_B \approx 8.091\ \mu A$ ⇒ $I_C \approx 404.6\ \mu A$

$V_B \approx 3.4234\ V$

$V_E \approx 2.7234 V$

$V_C \approx 6.5208 V$

$V_{CE} \approx 3.797\ V$

for. act. mode ✓

(over)

c) $V_{EB} = 0.7$

$$\frac{10 - V_B}{36000} - \frac{V_B}{68000} = -I_B$$

$$10 - V_E = 33000(51) I_B$$

$$V_c = 43000(50) I_B$$

$I_B \approx 1.618\ \mu A \Rightarrow I_c \approx 80.9\ \mu A$

$V_B \approx 6.5766\ V$

$V_E \approx 7.2766\ V$

$V_c \approx 3.4792\ V$

$V_{EC} \approx 3.797\ V$

for. act. mode ✓

d) $V_{EB} = 0.7$

$$\frac{5(10 - V_B)}{36000} - \frac{5 V_B}{68000} = -I_B$$

$$10 - V_E = \frac{33000}{5}(51) I_B$$

$$V_c = \frac{43000}{5}(50) I_B$$

$I_B \approx 8.091\ \mu A \Rightarrow I_c \approx 404.6\ \mu A$

$V_B \approx 6.5766\ V$

$V_E \approx 7.2766\ V$

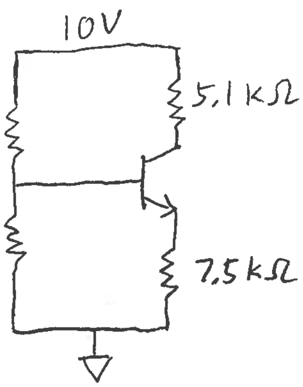
$V_c \approx 3.4792\ V$

$V_{EC} \approx 3.797\ V$

for. act. mode

P5.7

(5.85 J&B)



$V_{BE,on} = 0.7V$

$\beta_F = 100$

same approach as before...

$I_B \approx 3.554\ \mu A \Rightarrow I_c \approx 355.4\ \mu A$

$V_B \approx 3.392\ V$

$V_E \approx 2.692\ V$

$V_c \approx 8.188\ V$

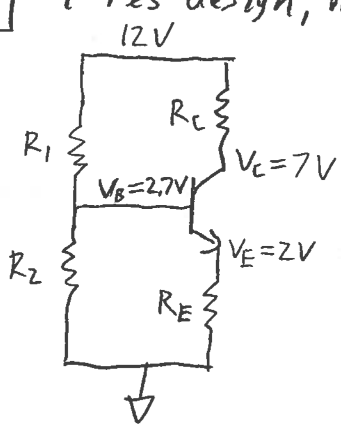
$V_{CE} \approx 5.496\ V$

for. act. mode ✓

P5.8 4-res design, npn, $I_c = 1mA$, $V_{CE} = 5V$, $V_E = 2V \rightarrow V_{cc} = 12V$

(5.87 J&B)

$\beta_F = 100$, $V_{BE,on} = 0.7$



$$R_c = \frac{12-7}{10^{-3}} = 5k\Omega$$

$$R_E = \frac{2}{I_B + I_c} = \frac{2}{10^{-3}(1+\frac{1}{100})} \approx 1.980\ k\Omega$$

$$I_B = \frac{I_c}{\beta_F} = 10\ \mu A = \frac{12-2.7}{R_1} - \frac{2.7}{R_2} \Rightarrow R_1 = \frac{9.3\times10^5 R_2}{R_2 + 2.7\times10^5}$$

pick $R_2 = 50\ k\Omega$

$R_1 \approx 145.3\ k\Omega$

these values ensure I_B doesn't suck all the current from the V_B bias network