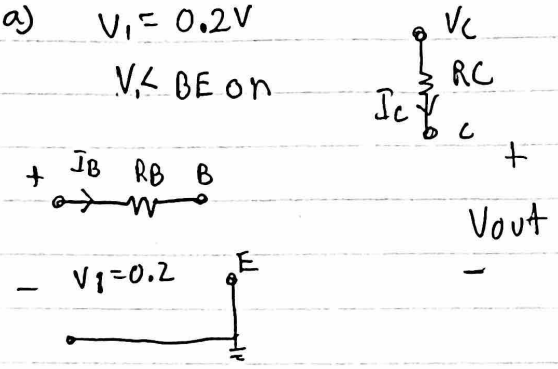
But Hw1 Digital Elec

1

a) $V_1 = 0.2V$

$V_1 < V_{BE\,on}$

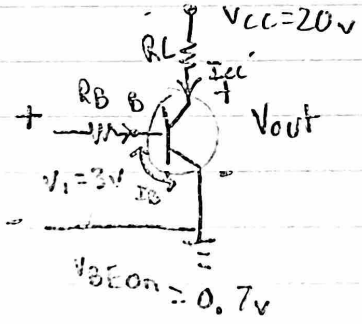


$I_B = 0A$ $\quad I_C = \beta_F I_B = 100 \times 0 \Rightarrow I_C = 0A$

$V_{out} = V_{cc} - I_C R_C = 20 - (0 \cdot 500) = 20 \Rightarrow V_{out} = 20V$

b) $V_1 = 3V$

$V_1 > V_{BE\,on}$



$V_1 = I_B R_B + V_{BE\,on}$

$I_B = \frac{V_1 - V_{BE\,on}}{R_B} = \frac{3 - 0.7}{1K} = 2.3\,mA \Rightarrow I_B$

$I_C = \beta_F I_B \Rightarrow 100 \times 2.3m \Rightarrow I_C = 0.23A$

$V_{out} = V_{cc} = I_C R_C = 20 - (0.23 \times 500) \Rightarrow 20 - 115 \Rightarrow V_{out} = -95V$

$V_{out} = V_{cesat} = 0.2V$

$V_{out} = V_{cc} - I_C R_C$

$0.2 = 20 - I_C \times 500$

$I_C = 99mA$ $\quad I_{C(sat)} = 99mA$

(c) $V_1 = 8\,V$

$V_1 > V_{BE\,on}$

$$I_B = \frac{V_1 - V_{BE\,on}}{R_B} = \frac{8 - 0.7}{1K} = 7.3\,mA$$

$$I_C = \beta_E I_B = 100 \times 7.3m = 0.73A$$

$I_C > I_{C(sat)}$

So, $V_{out} = V_{Cesat} = 0.2V$

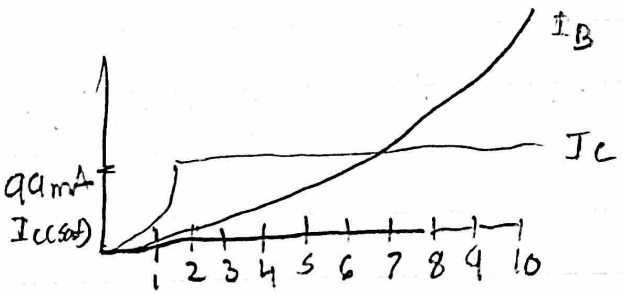
$I_C = I_{C(sat)} = 99\,mA$

(e) $I_{C(sat)} = 99\,mA$

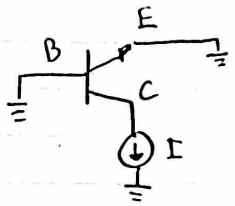
$$\beta_F = \frac{I_{C(sat)}}{I_B} \qquad I_B = \frac{I_{C(sat)}}{\beta} = \frac{99m}{100} = 990\,\mu A$$

$$I_B = \frac{V_1 - V_{BE\,on}}{R_B} \Rightarrow 990\mu = \frac{V_1 - 0.7}{1K} = 1.69V = V_1$$

At $V_1 = 1.69\,V$ transistor enters Saturation



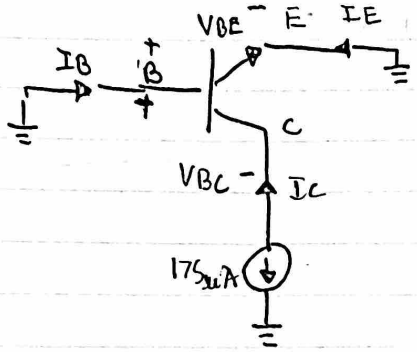
2 a)



$I_S = 4 \times 10^{-16} A$ $\quad \beta_F = 100$ $\quad \beta_R = 0.25$

b) Transistor is npn type

c)



d) $I = 175\mu A$ $\quad I_C = -I \Rightarrow -175\mu A$

$V_{BE} = 0V$ $\quad I_C = I_S\left[e^{\left(\frac{V_{BE}}{V_T}\right)} - e^{\left(\frac{V_{BC}}{V_T}\right)}\right] - \frac{I_S}{\beta_R}\left[e^{\left(\frac{V_{BC}}{V_T}\right)} - 1\right]$

- $V_{BE} = 0$

So $\Rightarrow$ $I_C = -I_S\left(1 + \frac{1}{\beta_R}\right)\left[e^{\left(\frac{V_{BC}}{V_T}\right)} - 1\right]$

$$I_B = -\left[\frac{I_C}{(\beta_R + 1)}\right]$$

$I_E = -\beta_R I_B$

$I_C = -175\mu A$ $\Rightarrow$ $I_B = -\left(\frac{-175\mu A}{(0.25+1)}\right) = \underline{140\mu A}$

emitter current $\Rightarrow$ $I_E = -\beta_R I_B \Rightarrow -0.25 \times 140\mu A \Rightarrow \underline{-35\mu A = I_E}$

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2 continued

$$V_{BC} = V_T \ln\left[\left(\frac{-B_R}{(B_R+1)} \times \left(\frac{I_C}{I_S}\right)\right)+1\right]$$

$V_T = 0.025\,V$

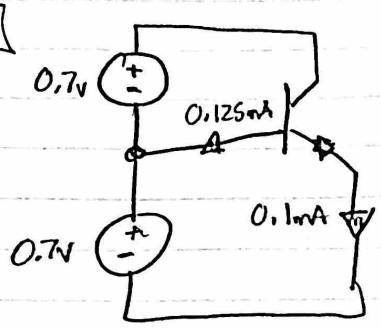
$$\text{So, } V_{BC} = 0.025\,V \ln\left[\left(-\frac{0.25}{(0.25+1)}\right) \times \left(\frac{-175\,\mu A}{4\times10^{-16}\,A}\right)\right)+1\Big]$$

$$= 0.025\,V \ln\left[(0.2 \times 43.75)+1\right] \Rightarrow \underline{V_{BC} = 0.057\,V}$$

So,

$I_E = -35\,\mu A$
$I_C = -175\,\mu A$
$I_S = 140\,\mu A$
$V_{BC} = 0.057\,V$
$V_{BE} = 0\,V$

3



$$I_B = \frac{I_S}{\beta_R}\left[e^{\left(\frac{V_{CB}}{V_T}\right)} - 1\right] \qquad V_{CB} = 0.7V \quad V_T = 0.025V \checkmark$$

$$I_E = -I_S\left[e^{\left(\frac{V_{CB}}{V_T}\right)} - 1\right]$$

$$\Rightarrow \frac{I_E}{I_B} = \left(\frac{-I_S\left[e^{\left(\frac{V_{CB}}{V_T}\right)} - 1\right]}{\left[\frac{I_S}{\beta_R}\left[e^{\left(\frac{V_{CB}}{V_T}\right)} - 1\right]\right]}\right) = -\beta_R$$

$$\beta_R = \frac{-I_E}{I_S} \qquad I_E = -0.1mA \qquad I_B = 0.125mA$$

Sub $-0.1mA$ for I_E & 0.125 for I_B

$$\beta_R = -\left(\frac{-0.1mA}{0.125mA}\right) \Rightarrow \underline{\beta_R = 0.8}$$

$$I_E = -I_S\left[e^{\left(\frac{V_{CB}}{V_T}\right)} - 1\right] \Rightarrow I_S = \frac{-I_E}{\left[e^{\left(\frac{V_{CB}}{V_T}\right)} - 1\right]}$$

$V_{CB} = 0.7V \quad V_T = 0.025V$

$I_E = -0.1mA$

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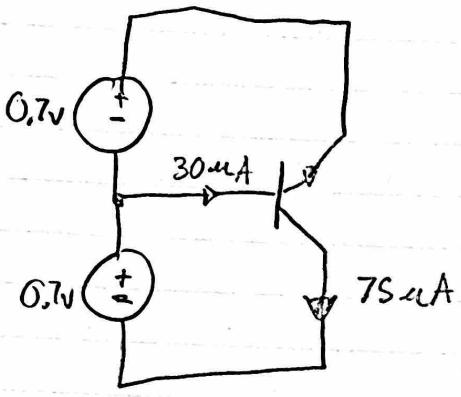
3 continued

$$I_S = -\frac{(-0.1\times10^{-3}A)}{\left[\left(e^{\left(\frac{0.7V}{0.025}\right)}-1\right)\right]} \Rightarrow \boxed{6.9\times10^{-17}\,A = I_S}$$

4



$$I_B = \frac{I_S}{B_R}\left[e^{\left(\frac{V_{BC}}{V_T}\right)}-1\right] \qquad V_{BC}=0.7V \qquad V_T=0.025V$$

$$I_C = -I_S\left(1+\frac{1}{B_R}\right)\left(e^{\left(\frac{V_{BC}}{V_T}\right)}-1\right]$$

$$\Rightarrow \frac{I_C}{I_B} = \frac{-I_S\left(1+\frac{1}{B_R}\right)\left[e^{\left(\frac{V_{BC}}{V_T}\right)}-1\right]}{\left[\frac{I_S}{B_R}\left[e^{\left(\frac{V_{BC}}{V_T}\right)}-1\right]\right]} = -(B_R-1$$

$$\Rightarrow B_R = -\left(\frac{I_C}{I_B}\right)-1 \qquad I_C=-75\,uA \qquad I_B=30uA$$

$$B_R = -\left(\frac{-75\,uA}{30\,uA}\right)-1 \Rightarrow 2.5-1 \Rightarrow \underline{B_R = 1.5}$$

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4 continued

$I_E = I_B + I_C \Rightarrow 30\mu A + (-75\mu A) = \underline{-45\mu A}$

$I_E = -I_S\left[e^{\left(\frac{V_{BC}}{V_T}\right)} - 1\right] \Rightarrow I_S = \dfrac{-I_E}{\left[e^{\left(\frac{V_{BC}}{V_T}\right)} - 1\right]}$

$I_E = -45\mu A$

$V_{BC} = 0.7V$

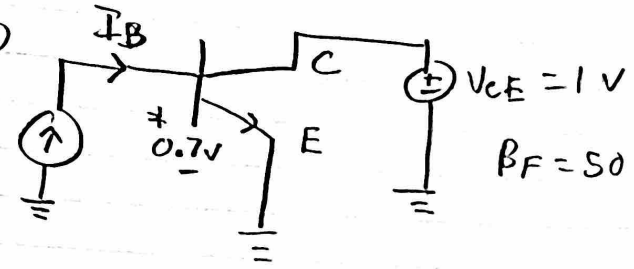
$V_T = 0.025V$

So, $I_S = -\dfrac{(-45\times10^{-6}A)}{\left[\left(e^{\left(\frac{0.7V}{0.025V}\right)} - 1\right)\right]} = 3.10\times10^{-17}A$

$B_R = 1.5$

$I_S = 3.10\times10^{-17}A$

5 ①



$V_{BE} = 0.7V$

$V_E = 0V$

So, $V_B = 0.7V$ $V_C = 1V$

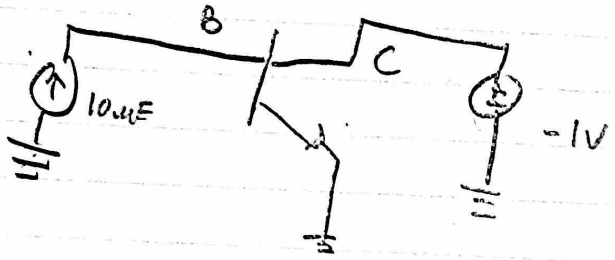
$V_C > V_B$ — So BJT will be on

$I_C = \beta I_b = (50)(10 \times 10^{-6}) \Rightarrow 500 \times 10^{-6}$

$I_C = 500\mu A$ or $0.5mA$

$I_E = (\beta + 1) I_B = 0.51mA$

②



$(V_C = -1V) < (V_B = 0.7V)$ So BJT off

• but $\beta_R = 4 \Rightarrow I_C = \beta_R I_B$ $I_E = (\beta_R + 1) I_B$

So $I_C = \underline{40\mu A}$

$I_E = (4+1)(10\mu) = \underline{50\mu A = I_E}$