Continous Assessment - 6

BJT

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1. $\tau_P = 10\tau_n$ $\quad W_B = 0.1 \cdot L_P$

$$\frac{L_p^n}{L_n^p} = \frac{\sqrt{D_p^n \cdot \tau_p}}{\sqrt{D_n^p \cdot \tau_n}} = \sqrt{2}$$

$$\alpha = \beta \cdot \gamma = \frac{1}{\cosh\left(\frac{W_B}{L_P}\right) + \frac{L_p^n\, n_n\, \mu_n^p}{L_n^p\, p_p\, \mu_p^n} \sinh\left(\frac{W_B}{L_P}\right)} = 0.988$$

$$\beta = \frac{\alpha}{1-\alpha} = 82$$

2. a) $$I_C = \frac{q \cdot A \cdot D_p \cdot p_n}{W} = \frac{q \cdot A \cdot D_p \cdot n_i^2}{N_A W_B} \cdot e^{\frac{qV_{BE}}{KT}}$$

$$I_C' = \frac{I_C}{10 \times 0.5} = \frac{I_C}{5}$$

b) $$I_E \propto \frac{n_i^2}{N_E \cdot W_E} \cdot e^{\frac{q \cdot V_{BE}}{KT}}$$

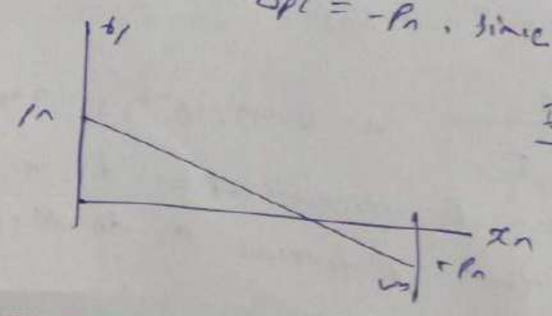
$$\gamma = \frac{I_{Ep}}{I_{Ep} + I_{En}} = \frac{1}{1 + \frac{N_B \cdot W_B}{100 \cdot N_B \cdot 0.1 \cdot W_B}} = \frac{1}{1+0.1} = 0.91$$

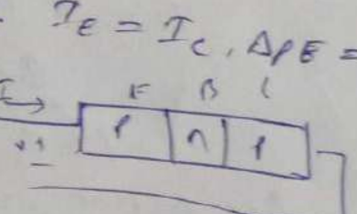
c) Base carrier profile for long diode exponentially decays to 0;
If $N_E = 100 \cdot N_B$, $L_n = L_p = L$ $\quad B = 0$

$$I_{Ep} \propto \frac{n_i^2}{N_B \cdot L} \cdot e^{\frac{q \cdot V_{BE}}{KT}} \text{ and } I_{En} \propto \frac{n_i^2}{N_E \cdot L} \cdot e^{\frac{q \cdot V_{BE}}{KT}}$$

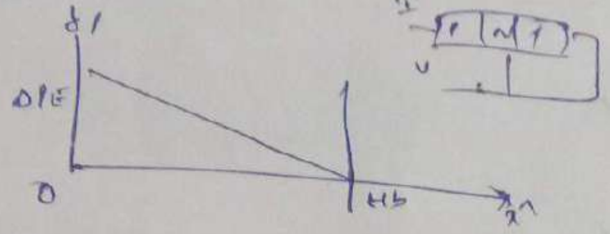
$$\gamma = \frac{I_{Ep}}{I_{Ep} + I_{En}} = \frac{1}{1 + \frac{N_B}{N_E}} = \frac{1}{1 + \frac{N_B}{100 \cdot N_B}} = \frac{1}{1+0.01} = 0.99$$

3) a) $I_E = I_C$, $I_B = 0$. since V is large & the collector is strongly reverse biased. $\Delta p_C = -p_n$. Since $I_E = I_C$, $\Delta p_E = -\Delta p_C = p_n$

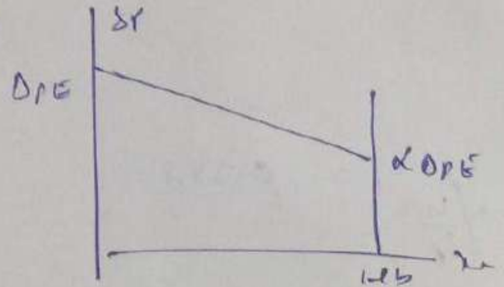




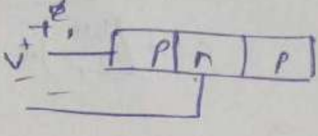
b) $v_{CB} = 0$, thus $\Delta p_C = 0$. Notice that the is the narrow-base diode distribution



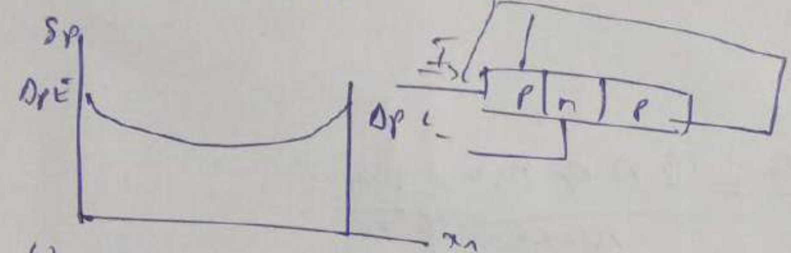
c)



since $I_C = 0$, $\Delta p_C = \alpha \Delta p_E$



d)



d) $V_{EB} = V_{CB} = V$ Thus $\Delta p_C = \Delta p_E$

connection (b) gives best diode. since stored charge is least and current is good. (a) not good diode since current is small (c) and (d) are not good.

4) current transfer ratio $= B = \dfrac{I_C}{I_{Ep}} = \dfrac{9.8\,mA}{10\,mA} = 0.980$

emitter efficiency

$= \gamma = \dfrac{I_{Ep}}{I_{Ep} + I_{En}} = 0.9901$

current gain $= \alpha = B \cdot \gamma = 0.97$

common gain $= \beta = \dfrac{\alpha}{1-\alpha} = 32.7$

$I_{CBO} = 1\,\mu A$

$\tau_t = 5 \cdot 10^{-9}\,s = 5\,ns$

$\tau_p = \dfrac{Q_b}{(1-B)\,I_{Ep}} = 2.45 \cdot 10^{-8}\,s = 24.5\,ns$

I_{Cp} decrease then B decrease and as do α, β

I_{Ep} decrease then B decrease as do α, β.

5) total delay time for parameter given as

$\tau_d = 100ps + \frac{10^{-4}}{10^{7}} s \cdot 10^{12} \frac{ps}{s} + 80ps + 10\Omega \cdot 0.1pF = 141ps$

$f_T = \frac{1}{2\pi\tau_d} = 1.1 GHz$

6) $\Delta n_E = n_p \cdot e^{\frac{qV_{BE}}{kT}} = N_a^B \rightarrow V_{BE} = \frac{kT}{q} \cdot \ln\frac{N_a^B}{n_p} = 0.795V$

$\frac{N_E}{N_B} = 100$, high level injection.

~~until~~ until emitter junction is baised to nearly 0.7 V,

. contact potential $V_0 = 0.81V$. this is very high bias.

7)

a) $V_{biBE} = 0.55 + \frac{kT}{q} \ln\frac{N_B}{n_i} = 0.878V$

→ buit-in potential at base-emitter junction can be given

→ collector - base junction given by,

$V_{biBC} = \frac{kT}{q}\left[\ln\frac{N_B}{n_i} + \ln\frac{N_C}{n_i}\right]$

$= 0.0257V\left[\ln\frac{10^{16}}{1.5\times10^{10}} + \ln\frac{10^{16}}{1.5\times10^{10}}\right] = 0.696V$

$W_{EB} = \sqrt{\frac{2\epsilon_B}{qN_B}(V_{biBE} - V_{EB})}$

Since $N_E \gg N_B$ and B-E junction is forward

$W_{EB} = \sqrt{\frac{2 \cdot 11 \times 8.8 \times 85 \times 10^{-14}}{1.6\times10^{-19} \cdot 8C \times 10^{-16}}}$

for $V_{EB} = 0.2V$ $W_{EB} = 3.02 \times 10^{-5} cm$

$V_{EB} = 0.6V$ $W_{EB} = 1.97 \cdot 10^{-5} cm$

$$W_{CB} = \sqrt{\frac{2\epsilon_s}{q} \frac{N_C + N_B}{N_C N_B} \phi_?}$$

$N_B = N_C$

$W_{EB} = 0.426 \times 10^{-4} cm$

W = metallurgical base width = 1.5 microns

$$W_B = W - W_{EB} - \frac{N_C}{N_B + N_C} \times W_{CB}$$

$V_{EB} = 0.2V$

$$W_B = 1.5 - 0.302 - \frac{0.426}{2} = 0.98 \text{ micron}$$

$V_{EB} = 0.6V$

W_B = 1.09 microns,

b) $D_n = D_p = 10 \frac{cm^2}{s}$

$\tau_n = \tau_p = \tau_0 = 10^{-7} s$

$L_n = \sqrt{D_n \tau_n} = 10^{-3} cm$

$L_p = 10 \mu m$

$$B = \frac{1}{\cosh\left(\frac{W_B}{L_p}\right)} \approx 1 - \frac{1}{2} \times \left(\frac{W_B}{L_p}\right)^2$$

For $V_{EB} = 0.2V \rightarrow B = 1 - \frac{1}{2} \times \left(\frac{0.98 \mu m}{10 \mu m}\right)^2 = 0.995$

$V_{EB} = 0.6V \rightarrow B = 1 - \frac{1}{2}\left(\frac{1.07 \mu m}{10 \mu m}\right)^2 = 0.994$

calculated I_{Ep} and I_{En} as function of V_{EB}.

$$I_{Ep} = A \cdot q \cdot \frac{D_p n_i^2}{N_B W_B} \times e^{\frac{qV_{EB}}{KT}}$$

$$I_{En} = A \cdot q \cdot \frac{D_n \cdot n_i^2}{N_E W_E} \cdot e^{\frac{qV_{EB}}{KT}}$$ (hole current)

$I_{Ep} = 8.251 \times 10^{-12} A$

$I_{En} = 2.709 \times 10^{-15} A$

$\therefore$ At $V_{EB} = 0.6V$

$I_{Ep} = 3.8 \times 10^{-5} A$

$I_{En} = 1.38 \times 10^{-8} A$

$$\gamma = \frac{I_{Ep}}{I_{Ep} + I_{En}}$$

$V_{EB} = 0.2V$, $\gamma = 0.9997$

$V_{EB} = 0.6V$, $\gamma = 0.9996$.

c)

$\alpha = \beta \gamma$

$V_{EB} = 0.2V \rightarrow \alpha = 0.995 \times 0.9997 = 0.9947$

$V_{EB} = 0.6V \rightarrow \alpha = 0.994 \times 0.9996 = 0.9936$

To calculate beta,

$\beta = \frac{\alpha}{1-\alpha}$

$V_{EB} = 0.2 \rightarrow \beta = 187.7$

$V_{EB} = 0.6 \rightarrow \beta = 155.3$

calculate currents I_E, I_B and I_C for $V_{EB} = 0.2$ and $0.6V$

$I_E = I_{Ep} + I_{En}$

For $V_{EB} = 0.2V \rightarrow I_E = 8.251 \cdot 10^{-12} A + 2.709 \times 10^{-16} A$
$= 8.25pA$

$V_{EB} = 0.6V \rightarrow I_E = 3.8 \times 10^{-5} A = 38 \mu A$

collector and base current can be determined.

$$I_C = \beta \times A \times q \times \frac{D_p \times n_i^2}{N_B \times w_b} \times e^{\frac{q \times V_{EB}}{kT}}$$

$I_B = I_E - I_C$

$V_{EB} = 0.2V \rightarrow \alpha = 0.9947$, $I_E = 8.254pA$

$I_C = 8.21pA$

$I_B = 0.044pA$

$V_{EB} = 0.6V \rightarrow \alpha = 0.9936A$

$I_C = 37.8\mu A$

$I_B = 0.2\mu A$

$V_{EB} = 0.2V$, Gummel $= 10^{16} \frac{1}{cm^3} \times 1.09 \times 10^{-5} cm = 1.09 \times 10^{11} \frac{1}{cm^2}$

$V_{EB} = 0.6V$, Gummel $= 10^{16} \frac{1}{cm^3} \times 0.985 \times 10^{-4} cm = 9.85 \times 10^{11} \frac{1}{cm^2}$