ECSE-2210 Microelectronics Technology
Homework 7 – Solution

Reading List: Chapter 10, Chapter 11 (pages 389 - 403)

1. Consider an npn transistor with doping concentration and dimensions shown below.

   Answer the following questions.

a. If $V_{BC} = 0$, and $I_C = 1$ mA, what is value of V_{BE}?

   $I_C = (qAD_B n_{B0}/W_B) \times \exp(qV_{BE}/kT)$
   $D_B = \mu_{nB} \times kT/q = 25.9\ \text{cm}^2/\text{s}$
   $n_{B0} = 10^{20}\ \text{cm}^{-6}/(10^{16}\ \text{cm}^{-3}) = 10^4\ \text{cm}^{-3}$

   $V_{BE} = 0.398$ V

b. With the transistor biased as in (a), what is the component of the base current due to recombination in the base region?

   $I_{BR} = (qAW_B)/(2\tau_B)\ n_{B0}\exp(qV_{BE}/kT) = 7.54 \times 10^{-6}$ A

c. With the transistor biased as in (a), what is the component of base current due to injection of holes into the emitter region?

   $I_{BE} = [(qAD_E)/L_E] \times\ p_{E0} \exp(qV_{BE}/kT)$
   $D_E = 75\ \text{cm}^2/\text{Vs} \times 0.0259\ \text{V} = 1.94\ \text{cm}^2/\text{s}$
   $p_{E0} = 10^{20}\ \text{cm}^{-6}/(5 \times 10^{18}\ \text{cm}^{-3)} = 20\ \text{cm}^{-3}$
   $L_E = (1.94\ \text{cm}^2/\text{s} \times 10^{-9}\ \text{s})^{1/2} = 4.4 \times 10^{-5}$ cm

   $I_{BE} = 0.664\ \mu\text{A}$

d. What is the value of the emitter injection efficiency, γ?

   $I_{EN} = I_C + I_{BR} = 10^{-3}\ \text{A} + 7.54 \times 10^{-6}$ A
   $I_{EP} = I_{BE} = 0.664 \times 10^{-6}$ A
   injection efficiency $\gamma = I_{EN} / (I_{EN} + I_{EP}) = 0.9993$

e. What is the value of the base transport factor, α_T?

   Base transport factor $= I_C / (I_C + I_{BR}) = 10^{-3}/(10^{-3} + 7.54 \times 10^{-6}) = 0.9925$

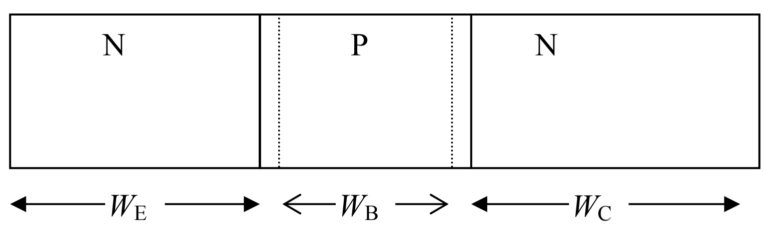
f. What is the value of the common emitter current gain, β_{dc}?

$\beta_{dc} = I_C/I_B = 10^{-3}/(7.54 \times 10^{-6} + 0.664 \times 10^{-6}) = 121$

g. If V_{BE} is held constant at the value found in (a), and the collector-to-base voltage is increased so as to reduce the width of the neutral base region, W_B, to 10^{-4} cm, (i.e., half the original value) what is the common emitter current gain, β_{dc} now? Note that this is called "base width modulation" (also called "Early effect") which is common in narrow base-width transistors.

When the base width is reduced, I_{BR} will be reduced. New $I_{BR} = 0.5 \times 7.54 \times 10^{-6}$ A
I_C will be increased to 2 mA.
So, new $\beta_{dc} = 2 \times 10^{-3}/(0.664 \times 10^{-6} + 0.5 \times 7.54 \times 10^{-6}) = 451$

Area A = 1 cm^2



	Emitter	Base	Collector
Doping conc. (cm^{-3})	5×10^{18}	10^{16}	5×10^{18}
W (µm)	10	2	10
Lifetimes (s)	10^{-9}	10^{-7}	10^{-9}
Elect. mobility (cm^2/Vs)	120	1000	120
Hole mobility (cm^2/Vs)	75	300	75