Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.012
Microelectronic Devices and Circuits
Spring 2007
Homework #6
Out: 04/13/2007 Due: 04/20/2007

Problem 1

An npn transistor with area A_E = 2.5 µm x 2.5 µm is biased in the forward active region, with the collector current I_C = 50 µA. The emitter, base and collector dimensions and doping are:
$N_{dE} = 10^{19}$ cm^{-3}, W_E = 0.3 µm, $N_{aB} = 10^{17}$ cm^{-3}, W_B = 0.25 µm, and $N_{dC} = 10^{16}$ cm^{-3}, W_C = 1.5 µm.

A) Draw a picture of the minority carrier concentration in the emitter and base (identify the minority carrier concentration at the base and emitter edges).
B) Find the base-emitter bias $V_{BE.}$
C) Find the base current $I_{B.}$
D) For the npn BJT biased as above, given that V_{An} = 25 V, find the transconductance g_m, the input resistance r_π, and the output resistance r_o.
E) For the npn BJT biased as above, given that the emitter-base depletion region width is x_{BE} = 0.05 µm, what is the minority electron charge storage in the base Q_{NB}(VBE) at this operating point?
F) What is C_π at this operating point?

Problem 2

In this problem we will consider an important development of the late 1980s, the SiGe alloy base BJT. This Hetero Bipolar Transistor (HBT) is usually fabricated as an npn BJT with a base made of SiGe to increase the intrinsic carrier concentration in the base and with Si collector and emitter. The emitter, base, and collector dimensions are:
$N_{dE} = 5\text{x}10^{19}$ cm^{-3}, W_E = 0.25 µm, $N_{aB} = 10^{18}$ cm^{-3}, W_B = 0.25 µm, and $N_{dC} = 10^{17}$ cm^{-3}, W_C = 1.5 µm. Note that at room temperature the intrinsic carrier concentration of SiGe is $n_{iSiGe} = 5\text{x}10^{10}$ cm^{-3}.

For this problem assume that the concentration of Ge is low. Therefore the mobility and the dielectric constant of the SiGe base film remain unchanged from that of Si.

A) Find α_F and the forward active current gain β_F for the npn SiGe HBT (SiGe Base Transistor) and npn BJT (Si Base) at room temperature.
B) What is the ratio between forward active current gains for the npn SiGe HBT and the corresponding npn BJT?
C) Determine the base doping of the npn BJT that will yield the same value of β_F as in the npn SiGe HBT.

Problem 3

A p^+np bipolar transistor has the geometry and doping profile described below. For all the following questions the BJT is operating in a common-emitter mode in the forward active region.

BJT Data:

$D_p = 5\ cm^2/s$; $D_n = 10\ cm^2/s$; $W_E = 500$ nm; $A = 25\ \mu m^2$; $N_{aE} = 10^{19}\ cm^{-3}$; $N_{dB} = 10^{17} cm^{-3}$; $N_{aC} = 10^{16} cm^{-3}$.

A) We want the current gain β_F to be 100, what should be the value for the base thickness W_B? Neglect depletion region widths.
B) What is the saturation current I_S for the emitter-base p-n diode?
C) What should be the EB voltage to obtain a collector current of $I_C = 100\ \mu A$?
D) What is the transconductance at $I_C = 100\ \mu A$?
E) What is the capacitance C_π at $I_C = 100\ \mu A$?
F) What is the imput resistance at $I_C = 100\ \mu A$?
G) What is the output resistance at $I_C = 100\ \mu A$ given an Early Voltage $V_A = 30V$?
H) In forward active regime find the frequency limit set by the base diffusion transit time?

Problem 4

The figure below shows six possible ways of connecting an npn bipolar transistor that may yield a diode-like behavior. Using the Ideal Non-Linear Hybrid-π Model, write the I-V characteristics of the two-terminal device in each configuration. Express your results as a function of I_S, β_F, and β_R.