UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE 130/230A — Prof. Liu
Fall 2013

Homework Assignment #7

Due at the beginning of class on Thursday, 10/17/13

Problem 1: pn Junction – Non-Ideal Behavior

(a) Consider the impact of recombination-generation in the depletion region of a "one-sided" pn diode:

- **(i)** Under forward bias, $pn > n_i^2$ so that there is *net recombination* in the depletion region, which results in a *positive* diode current component $I_{R\text{-}G}$. How does $I_{R\text{-}G}$ depend on the dopant concentration on the lightly doped side of the junction, under forward bias? Explain briefly.
- **(ii)** Under *reverse* bias, $pn < n_i^2$ so that there is *net generation* in the depletion region which results in a *negative* diode current component $I_{R\text{-}G}$. How does $I_{R\text{-}G}$ depend on the dopant concentration on the lightly doped side of the junction, under reverse bias? Explain briefly.

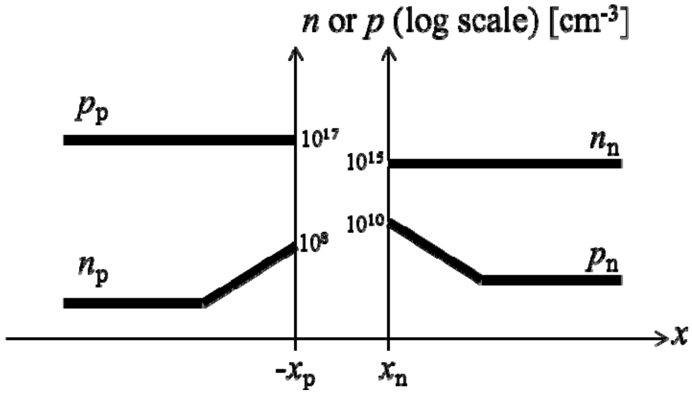
(b) Consider an ideal pn step-junction Si diode maintained at 300K with saturation current $I_0 = 10^{-15}$ A and series resistance $R_S = 1\ \Omega$. Estimate the forward current level for which for which the voltage across the depletion region (V_J) differs significantly (by 10%) from the applied voltage (V_A).
Hint: Since the diode is strongly forward biased in this case, use the approximation

$$I = I_0\exp\{qV_J/kT\} = I_0\exp\{(0.9)V_A/kT\}$$

Find the value of V_A such that $IR_S = 0.1V_A$, to within 10 mV, via iteration.
Then calculate $I = I_0\exp\{(0.9)V_A/kT\}$ for this value of V_A.

Problem 2: pn Junction Diode Charge Control Model

The carrier concentrations inside a pn step-junction Si diode with long quasi-neutral regions (much wider than their respective minority carrier diffusion lengths) and cross-sectional area $A = 100\ \mu\text{m}^2$ are plotted below. The minority-carrier lifetimes are $\tau_n = 10^{-6}$ s on the p side and $\tau_p = 10^{-6}$ s on the n side. $T = 300$K.



(a) What is the value of the applied voltage V_A?

(b) What are the excess minority carrier densities at the edges of the depletion region, *i.e.* $\Delta n_p(-x_p)$ and $\Delta p_n(x_n)$? Do low-level injection conditions prevail in the quasi-neutral regions of the diode? Explain.

(c) Calculate the minority carrier diffusion lengths L_n and L_p.

(d) Calculate the excess minority carrier charge stored (Q_P and Q_N) within the quasi-neutral regions.

(e) Calculate the diode current using the charge control model. Is it dominated by hole injection into the n side or by electron injection into the p side?

<u>Problem 3</u>: pn-Junction – Small Signal Model

For the diode in Problem 2:

(a) What is the diode conductance, G?

(b) What is the depletion capacitance, C_J ?

(c) What is the diffusion capacitance, C_D ?

(d) Qualitatively, how would your answers to parts (a), (b) and (c) change if V_A were to be increased?

<u>Problem 4</u>: pn Junction – Turn-off Transient Response

Explain how the storage delay time of a one-sided pn junction diode would be affected by the following changes:

(a) The dopant concentration on the lightly doped side is increased.

(b) The temperature is increased.

(c) The hole recombination lifetime on the n-type side is decreased.