Design & Simulate 4 Ex1.6

ECE2204 CRN:82929

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Problem 4.6.a.1:

Design

Consider a silicon pn junction at $T = 300K$ with a donor doping concentration of $N_d = 10^{14}cm^{-3}$, and at $V_R = 3V$ the junction capacitance is $C_j = 0.245pF$. Assume that the Boltzmann constant is $k = 86 \times 10^{-6}eV/K$, the electron charge is $e = 1.6 \times 10^{-19}C$, $n_i = 2.3 \times 10^{10}cm^{-3}$ and $C_{j0} = 0.7pF$. Assume $\mathbb{e}$ is the exponential. Find the acceptor doping concentration N_a.

$$V_{bi} = \frac{kT}{e}\ln(\frac{N_a N_d}{n_i^2}) \implies N_a = \frac{n_i^2}{N_d}\mathbb{e}^{(\frac{e \times V_{bi}}{kT})} \tag{1}$$

$$C_j = C_{j0}(1 + \frac{V_R}{V_{bi}})^{-1/2} \implies V_{bi} = \frac{V_R}{(\frac{C_j}{C_{j0}})^{-2} - 1} \tag{2}$$

$$V_{bi} = \frac{3V}{(\frac{0.245pF}{0.7pF})^{-2} - 1} = 0.42V \tag{3}$$

$$N_a = \frac{(2.3 \times 10^{10}cm^{-3})^2}{10^{14}cm^{-3}}\mathbb{e}^{(\frac{1.6 \times 10^{-19}C \times 0.42V}{300K \times 86 \times 10^{-6}eV/K})} = 6.078 \times 10^{13}cm^{-3} \tag{4}$$

The acceptor doping concentration is $N_a = 6.078 \times 10^{13}cm^{-3}$.

Validation

I was not able to get LTSpice to generate a validation simulation with N_a as my dependent value. As a result there is no validation simulation.

Note to grader: If you know how to get LTSpice to simulate with N_a as the dependent variable and V_R as the driving independent variable, I would be very appreciative if you could leave me a comment as as to how. Despite being generally decent with LTSpice I could not make it work this time around.

Problem 4.6.b.1:

Derived from 1.23 by changing values.

Design

The zero-biased junction capacitance of a silicon pn junction is $C_{j0} = 0.5pF$. The doping concentrations are $N_a = 1.2 \times 10^{16} cm^{-3}$ and $N_d = 5 \times 10^{15} cm^{-3}$. Assume $n_i = 1.5 \times 10^{10} cm^{-3}$. Determine the junction capacitance at $V_R = 2V$.

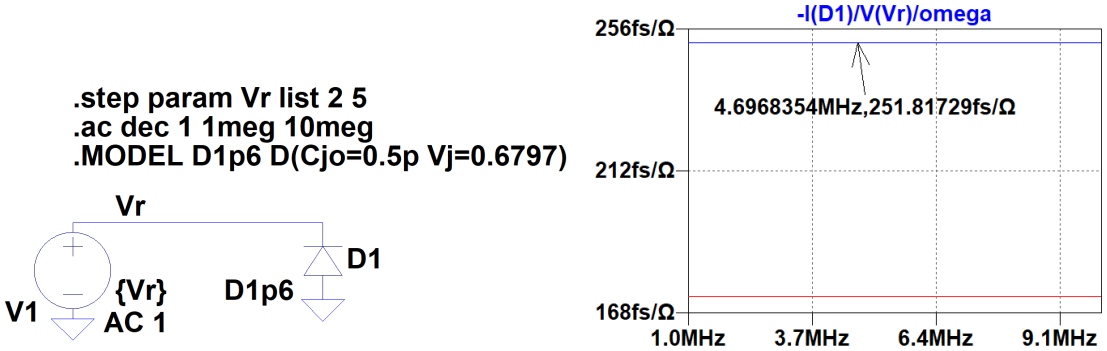
$$V_{bi} = \frac{300K \times 86 \times 10^{-6} eV/K}{1.6 \times 10^{-19} C} \ln\left(\frac{1.2 \times 10^{16} cm^{-3} \times 5 \times 10^{15} cm^{-3}}{(1.5 \times 10^{10} cm^{-3})^2}\right) = 0.6797V \quad (5)$$

$$C_j = 0.5pF\left(1 + \frac{2V}{0.6797V}\right)^{-1/2} = 0.252pF \quad (6)$$

The junction capacitance at $V_R = 2V$ is $C_j = 0.252pF$

Validation

LTSpice Implementation (accurate with $< 1\%$ deviation from design result)



$$Err = \frac{|252 - 251.8|}{252} = 0.00079 = 0.079\%$$

This assignment demonstrates an understanding of basic pn junction theory, the equations, and derivations necessary to solve for parameters essential to the function of pn junctions.

I have neither given nor received unauthorized assistance on this assignment.