Appendix B

E in the Depletion Region – Its Role or Lack thereof

We know that the $\vec{E}$ field in the depletion region of a *pn* junction is very large ($\sim$ a volt per micron!), and that it will change significantly if a bias is applied; the question is "does the (bias-caused) change of $\vec{E}$ cause anything significant?".

The answer is no. Basically.... What I mean by this is that it does not affect the leading order perturbation calculation.

That this is the case can be deduced from our solution, the ideal diode equation.

$$I = I_0 \left[\exp(e\beta V_A) - 1 \right]$$

I_0 is given in Eq. 16.10, and is independent of V_A. As we discussed (LNs 15,16), the first term is the exponential enhancement ($V_A > 0$) or suppression ($V_A < 0$) of the net diffusion (due to the Boltzmann factor $\exp(-\beta\epsilon_i)$ associated with the energy level at ϵ_i). The second term, -1, subtracts out the net drift term, which is *identical* with the equilibrium value in this lowest order perturbation solution!

How can this be? How is the net drift term be independent of E, or equivalently, independent of V_A? We do have the sense that when the electric field is small, then the drift term will be somewhat smaller. And when the electric field is large (reverse bias), then the drift term will be somewhat larger. While this is true, the effect is not caught in the leading order calculation. The staring point of the leading order calculation is to take $J_p = J_n = 0$ within the depletion region. This means that whatever the value of the electric field is, the drift current due to it is completely compensated by the diffusion current. So, whatever mild effect of the variation of $\vec{E}$ might appeal to us, it is not being captured in the leading order calculation.