2.1 Drift in Depletion Region

We want to study in more detail how the charge carriers (electrons, holes) drift though the depletion region by taking into account the *varying* electrical field.

1. For the field we use the expression

$$E(x) = \frac{2V_{\text{depl}}(D-x)}{D^2} + \frac{V_{\text{over}}}{D},$$

where V_{depl} is the depletion voltage, V_{over} an additional overvoltage and D is the detector thickness. (The junction is at $x = 0$.)

2. Check that $E(x)$ integrates up to $V_{\text{depl}} + V_{\text{over}}$.

3. Plot $E(x)$.

4. The position of a drifting charge obviously depends on time. We want to calculate this $x(t)$. Start with the drift equation $v(t) = \mu \cdot E(x(t))$ and use $x(t)$ to express $v(t)$. Solve the resulting differential equation. You may want to used a mathematical software package for this.

5. Fix the integration constant by the initial condition $x(0) = 0$. If you can, plot the particle position vs. time. You may also include the solution for the naive assumption of a constant field $E_{flat}(x) = (V_{\text{depl}} + V_{\text{over}})/D$.

6. What is the general expression for the time required to reach the backside at $x = D$?

7. What is the drift time for a depletion voltage of 100 V and an overvoltage of 50 V in a $D = 300\,\mu$m thick sensor?

8. If you can, plot the drift time as a function of over-voltage. Plot also the result for the naive assumption $E_{flat}(x)$.

2.2 Numerical Calculation of Field and Depletion Area in Diode

Use the document on the Web Site ('Additional Documents') about the general solution of field/potential in doped structures to write a program which implements this method. Graphics output is not really necessary. A listing of numerical values (mainly $\Phi(x)$) is sufficient.

1. Check that constant doping leads to $E(x)$ as used in previous exercise.

2. Check that the structure behaves as expected when you double the doping or halve the thickness.

3. What happens if the bulk doping changes from n-type to p-type? (This can happen due to irradiation of the sensor.)

4. You could also implement an Avalanche Photo Diodes (APD) with a thin p^{++} (backside) surface layer, 200 μm p^- bulk, some microns p^+ and a thin n^{++} surface layer.