4.3.6. The abrupt p-i-n junction

For a p-i-n junction the above expressions take the following modified form:

$$f_n + f_p + f_u = f_i - V_a \tag{4.3.36}$$

$$f_n = \frac{qN_d x_n^2}{2e_s}, f_p = \frac{qN_a x_p^2}{2e_s} \text{ and } f_u = \frac{qN_a x_p d}{e_s} \tag{4.3.37}$$

$$qN_a x_p = qN_d x_n \tag{4.3.38}$$

Where f_u is the potential across the middle undoped region of the diode, which has a thickness d. Equations (4.3.36) through (4.3.38) can be solved for x_n yielding:

$$x_n = \frac{\sqrt{d^2 + \frac{2e_s}{q}\frac{(N_a + N_d)}{N_a N_d}(f_i - V_a)} - d}{1 + \frac{N_d}{N_a}} \tag{4.3.39}$$

From x_n and x_p, all other parameters of the p-i-n junction can be obtained. The total depletion layer width, x_d, is obtained from:

$$x_n = \sqrt{d^2 + \frac{2e_s}{q}\frac{(N_a + N_d)}{N_a N_d}(f_i - V_a)} - d \tag{4.3.40}$$

The potential throughout the structure is given by:

$$f(x) = -\frac{qN_d}{2e_s}(x + x_n)^2 \qquad -x_n < x < 0 \tag{4.3.41}$$

$$f(x) = -f_n - \frac{qN_d x_n}{e_s} x \qquad 0 < x < d \tag{4.3.42}$$

$$f(x) = -(f_i - V_a) + \frac{qN_a}{2e_s}(x - d - x_p)^2 \qquad d < x < d + x_p \tag{4.3.43}$$

where the potential at $x = -x_n$ was assumed to be zero.

4.3.6.1. Capacitance of the p-i-n junction

The capacitance of a p-i-n diode can be obtained from the series connection of the capacitances of each region, simply by adding both depletion layer widths and the width of the undoped region:

$$C_j = \frac{e_s}{x_n + x_p + d} = \frac{e_s}{x_d} \tag{4.3.44}$$