The solutions to the minority-carrier diffusion equation, equations (3.106) and (3.107), can be used to evaluate the minority-carrier current densities, equations (3.110) and (3.111). These can then be substituted into equation (3.116), which, with some algebraic manipulation, yields

$$I = I_{\mathrm{SC}} - I_{o1}(\mathrm{e}^{qV/kT} - 1) - I_{o2}(\mathrm{e}^{qV/2kT} - 1) \tag{3.118}$$

where I_{SC} is the short-circuit current and is the sum of the contributions from each of the three regions: the n-type region ($I_{\mathrm{SC}N}$), the depletion region ($I_{\mathrm{SCD}} = AJ_{\mathrm{D}}$), and the p-type region ($I_{\mathrm{SC}P}$)

$$I_{\mathrm{SC}} = I_{\mathrm{SC}N} + I_{\mathrm{SCD}} + I_{\mathrm{SC}P} \tag{3.119}$$

where

$$I_{\mathrm{SC}N} = qAD_p \left[\frac{\Delta p'(-x_N)T_{p1} - S_{\mathrm{F,eff}}\Delta p'(-W_N) + D_p \left.\dfrac{\mathrm{d}\Delta p'}{\mathrm{d}x}\right|_{x=-W_N}}{L_p T_{p2}} - \left.\frac{\mathrm{d}\Delta p'}{\mathrm{d}x}\right|_{x=-x_N} \right] \tag{3.120}$$

with

$$T_{p1} = D_p/L_p \sinh[(W_N - x_N/L_p] + S_{\mathrm{F,eff}} \cosh[(W_N - x_N/L_p] \tag{3.121}$$

$$T_{p2} = D_p/L_p \cosh[(W_N - x_N)/L_p] + S_{\mathrm{F,eff}} \sinh[(W_N - x_N)/L_p] \tag{3.122}$$

and

$$I_{\mathrm{SC}P} = qAD_n \left[\frac{\Delta n'(x_P)T_{n1} - S_{\mathrm{BSF}}\Delta n'(W_P) + D_n \left.\dfrac{\mathrm{d}\Delta n'}{\mathrm{d}x}\right|_{x=W_P}}{L_n T_{n2}} + \left.\frac{\mathrm{d}\Delta n'}{\mathrm{d}x}\right|_{x=x_P} \right] \tag{3.123}$$

with

$$T_{n1} = D_n/L_n \sinh[(W_P - x_P)/L_n] + S_{\mathrm{BSF}} \cosh[(W_P - x_P)/L_n] \tag{3.124}$$

$$T_{n2} = D_n/L_n \cosh[(W_P - x_P)/L_n] + S_{\mathrm{BSF}} \sinh[(W_P - x_P)/L_n] \tag{3.125}$$

I_{o1} is the dark saturation current due to recombination in the quasi-neutral regions,

$$I_{o1} = I_{o1,p} + I_{o1,n} \tag{3.126}$$

with

$$I_{o1,p} = qA\frac{n_{\mathrm{i}}^2}{N_{\mathrm{D}}}\frac{D_p}{L_p}\left\{\frac{D_p/L_p \sinh[(W_N - x_N)/L_p] + S_{\mathrm{F,eff}} \cosh[(W_N - x_N/L_p]}{D_p/L_p \cosh[(W_N - x_N)/L_p] + S_{\mathrm{F,eff}} \sinh[(W_N - x_N)/L_p]}\right\} \tag{3.127}$$