# Section 22
# PN Diode Large Signal Response

## 22.3 Steady-State expression from Charge Control

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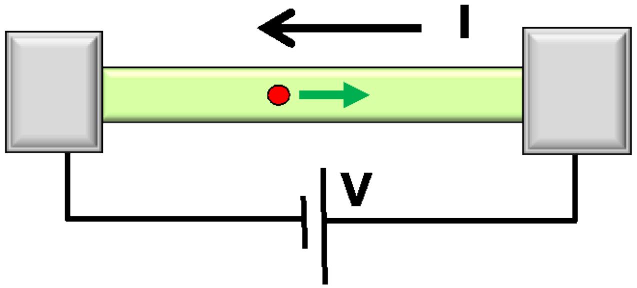
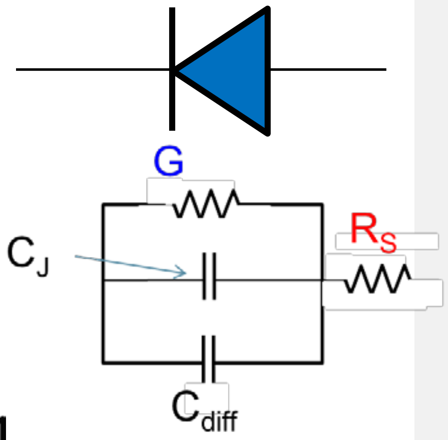
# PN Diode Large Signal Response




$$I = G \times V$$
$$= q \times n \times v \times A$$

charge density velocity area

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- 22.2 Turn-off and Turn-on characteristics
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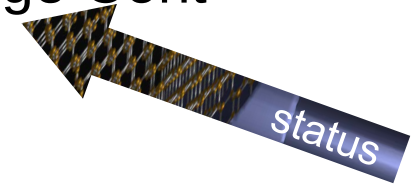
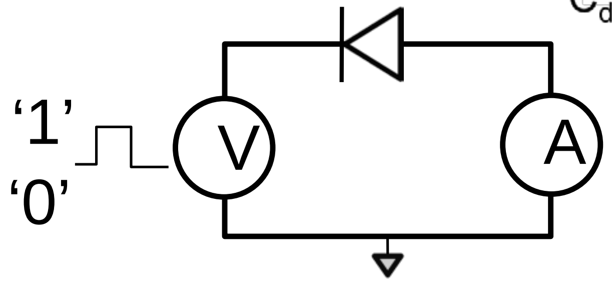


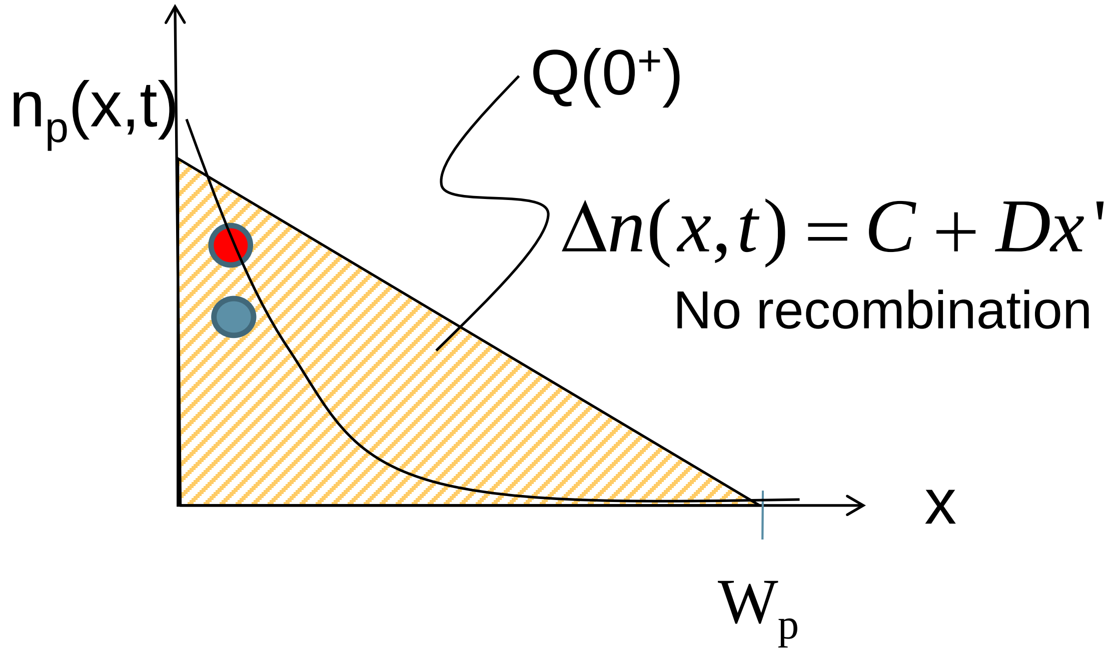

$$Q(t) = Q(t \to \infty)\left(1 - e^{-\frac{t}{\tau_n}}\right) = I_F \tau_n \left(1 - e^{-\frac{t}{\tau_n}}\right)$$

$$\frac{\partial Q}{\partial t} = i_{diff} - \frac{Q}{\tau_n}$$

$$t_{rr} = t_r + t_f \approx \begin{cases} \dfrac{W_p^2}{2D_n}\left(\dfrac{I_R}{I_F}\right)^{-2} & (W_p \ll L_n) \\ \dfrac{\tau_p}{2}\left(\dfrac{I_R}{I_F}\right)^{-2} & (W_p \gg L_n) \end{cases}$$

# Minority Carrier Recombination or Diffusion

Electrons get scattered to the other side, the average time is…



Electrons get scattered to the other side, the average time is…

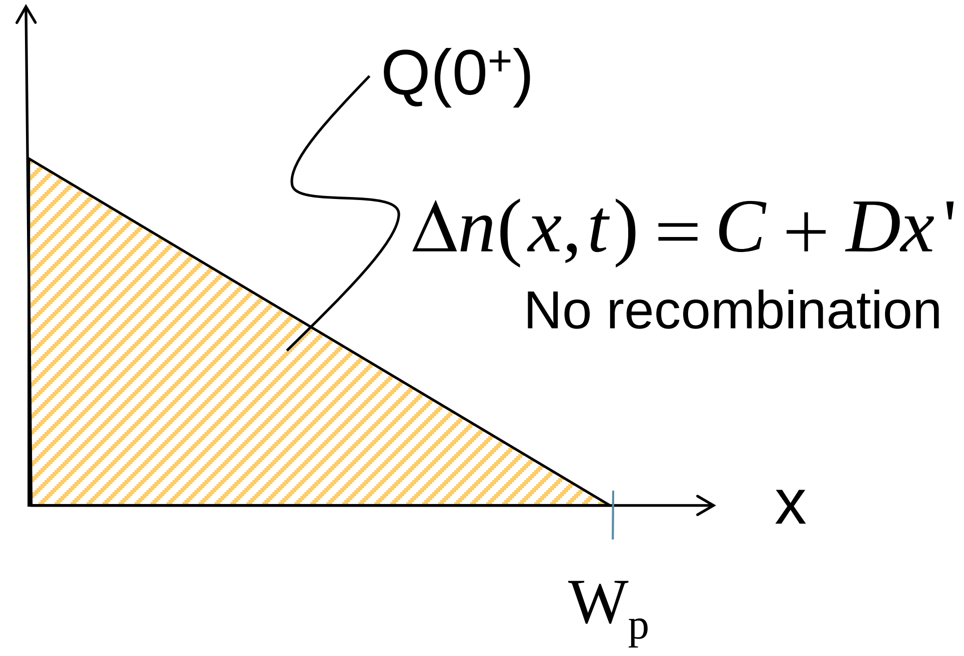
$$\frac{\partial Q}{\partial t} = i_{diff} - \frac{Q}{\tau_n}$$

$$\frac{Q(0^+) - Q(t=\infty)}{\tau_{diff}} = i_{diff}$$

$$\tau_{diff} = \frac{Q(0^+)}{i_{diff}} = \frac{q\left[\frac{\Delta n_p(0)}{2}\right]W_p}{qD_n\frac{\Delta n_p(0)}{W_p}} = \frac{W_p^2}{2D_n} \sim \frac{1}{2} \times \frac{W_p}{(D_n/W_p)}$$

Only half of them goes to the right

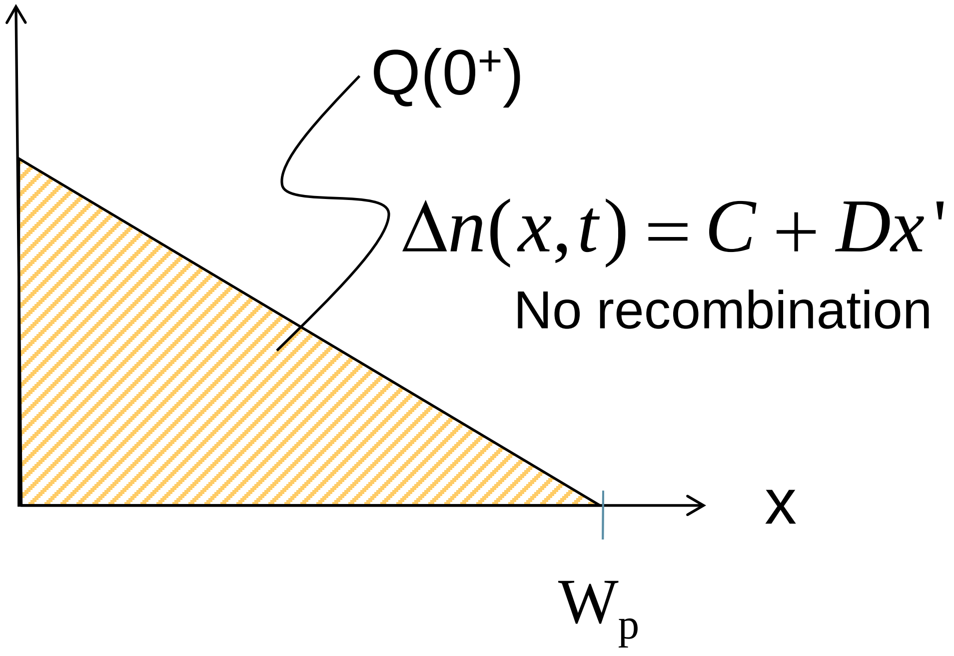
Diffusion velocity



$$\frac{\partial Q}{\partial t} = i_{diff} - \frac{Q}{\tau_n}$$

$$\tau_n \rightarrow \tau_{diff}$$

$$i_{diff} = \frac{Q}{\tau_{diff}}$$




$$i_{diff} = \frac{Q}{\tau_{diff}} = \frac{q \times \frac{1}{2}\frac{n_i^2}{N_A}\left(e^{qV_A\beta} - 1\right) \times W_p}{\frac{W_p^2}{2D_n}} = q\frac{D_n}{W_p}\frac{n_i^2}{N_A}\left(e^{qV_A\beta} - 1\right)$$

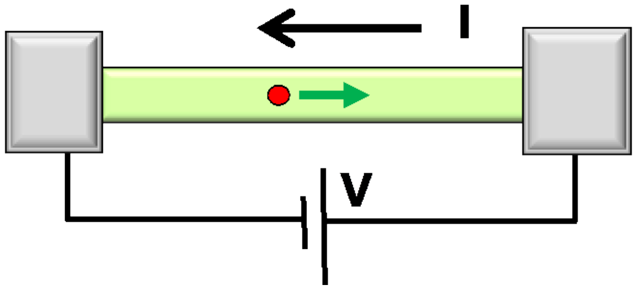
Exact Expression!

# Large Signal pn-diode
# Conclusion

Large signal response of devices of great importance for digital applications.

Analytical solution of partial differential equation often difficult (if not impossible),
=> approximate methods like Charge-control approximation often help simplify the solution and still provide a great deal of insight into the dynamics of switching operation.

Be careful in using the boundary condition which is often dictated by external circuit conditions.

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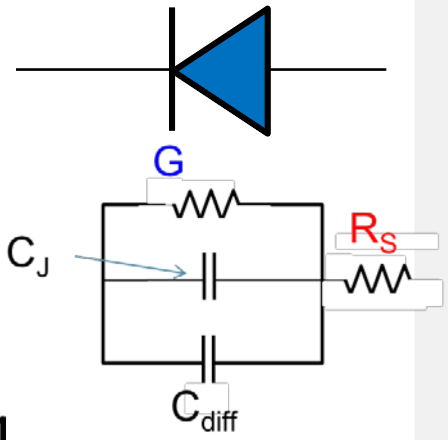


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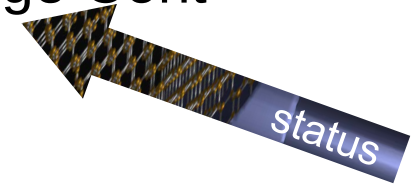


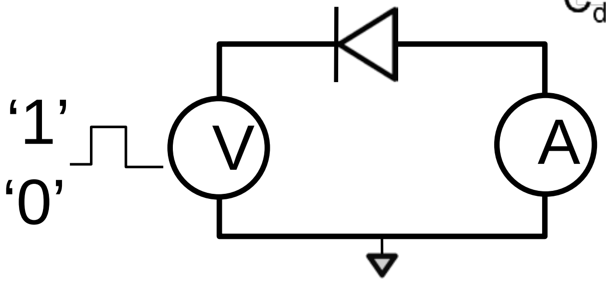


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