Diode Capacitance

Transition and Diffusion Capacitance

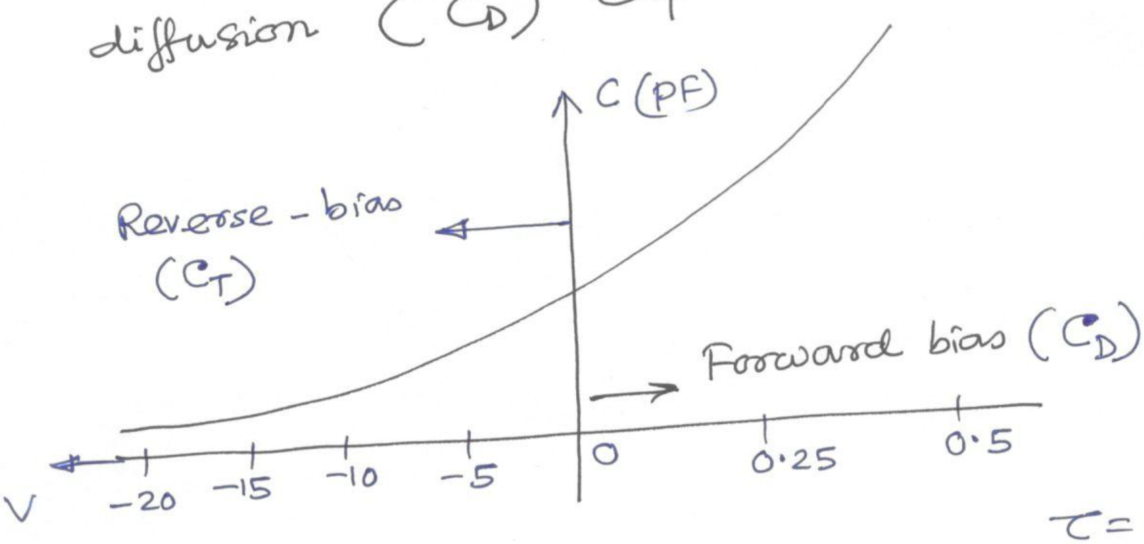
Electronic Devices are sensitive to high frequencies.

$X_C = \frac{1}{2\pi f C}$ is very large when f is small. (open ckt).

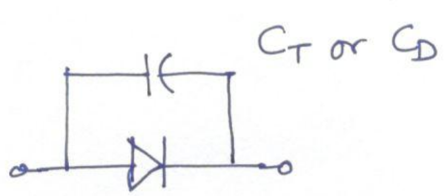
At high frequency, f is high X_C low

In p-n semiconductor diode, two capacitive effects are considered.

In reverse-bias region we have transition or depletion-region capacitance (C_T) while in forward-bias region we have diffusion (C_D) Capacitance.



$\tau = RC$



Capacitance of a parallel plate capacitor

$C = \frac{\epsilon A}{d}$, ϵ permittivity of dielectric

In the <u>reverse bias</u> region, there is a depletion region (free of carriers) which behaves essentially like an insulator / dielectric.

Depletion width (d) increases with increase in reverse bias, so transition Capacitance C_T reduces.

Capacitance (C_T) depends on applied reverse bias.

<u>In Fwd bias</u>: Capacitance effect directly dependent on the rate at which charge is injected into regions outside the depletion region.

Increased levels of ct $\longrightarrow$ increased levels of diffusion ~~ct~~. capacitance.

Increased ct. level reduces associated resistance, resulting time const <u>$\tau = RC$</u> does not become excessive. τ is imp in high speed application.

Capacitive Effects in P-N junction

Depletion or Junction Capacitance

When a PN jn is reverse bias with voltage V_R, charge stored on either side of Depletion region

$$Q_J = A\sqrt{2\epsilon_s q \frac{N_A N_D}{N_A + N_D}(V_0 + V_R)}$$

Thus for a PN junction

$$Q_J = \alpha\sqrt{V_0 + V_R}$$

$$\alpha = A\sqrt{2\epsilon_s q \frac{N_A N_D}{N_A + N_D}}$$

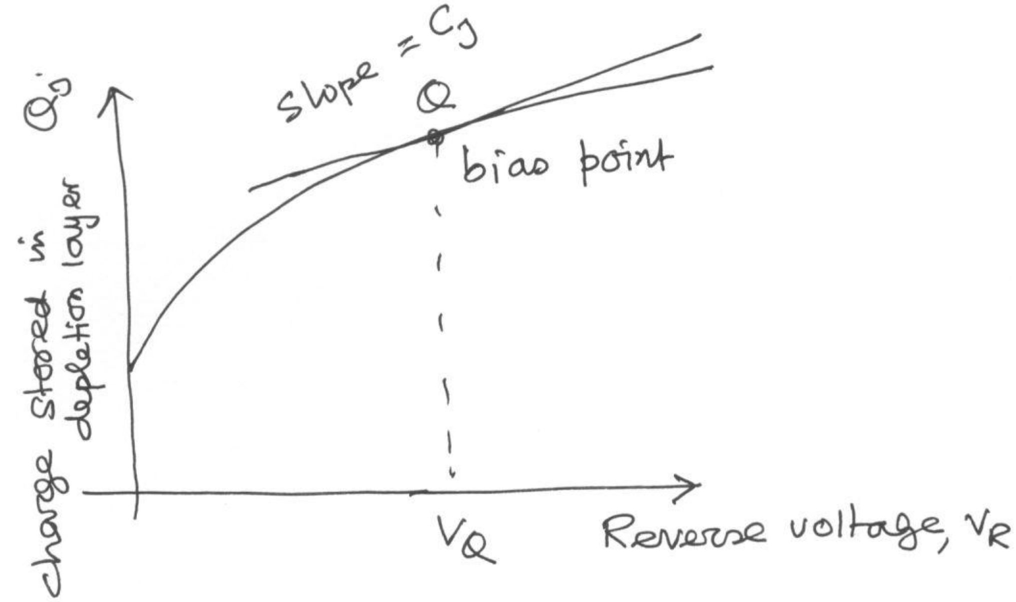
N_A : Acceptor Conc $\quad N_A \gg n_i$

N_D : Donor Conc.

ϵ_s : electrical permittivity

V_0 : barrier voltage

V_R : reverse voltage



$$C_J = \left.\frac{dQ_J}{dV_R}\right|_{V_R = V_Q}$$

$$= \frac{\alpha}{2\sqrt{V_R + V_0}}$$

at $V_R = 0$, $\quad C_{j0} = \dfrac{\alpha}{2\sqrt{V_0}}$

Hence $\quad C_J = \dfrac{C_{J0}}{\sqrt{1 + \dfrac{V_R}{V_0}}}$

Abrupt jn, or graded jn

$$C_J = \frac{C_{J0}}{\left(1 + \dfrac{V_R}{V_0}\right)^m}$$

m : const grading coefficient, values ranges from 1/3 to 1/2 depending on the manner in which concentration changes from the p side to n side.

Application: Varactor Diode [ref Shedra/Smith]