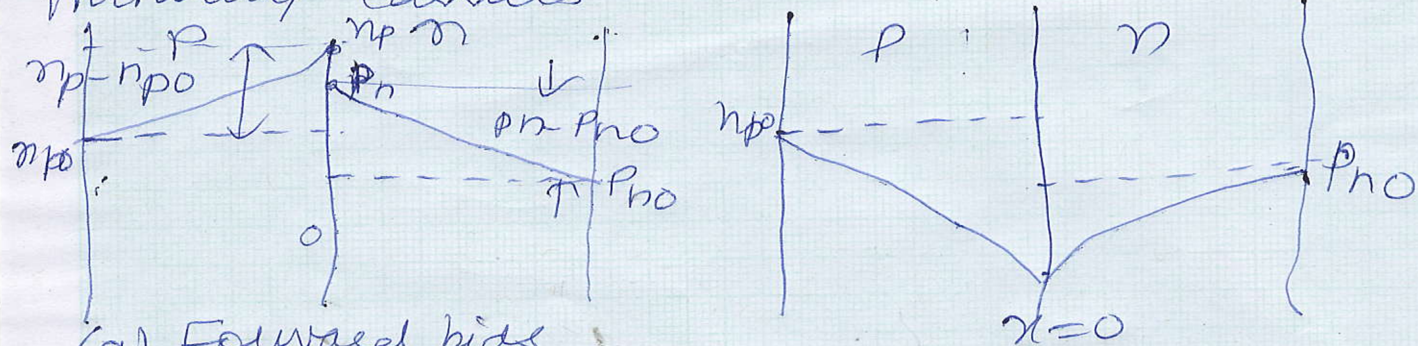
Switching characteristics of diode

When diode is switched from forward bias to the reverse biased state or vice versa, it takes finite time to attain a steady state.

This time consists of a transient and an interval of time before the diode attains a steady state. The behaviour of the diode during this time is called switching characteristics of diode

Forward biased junction:
Large number of electrons diffuse from n side to p side and large number of holes diffuse from p side to n side. On each side there is a large no. of minority carriers



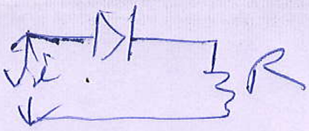
(a) Forward bias

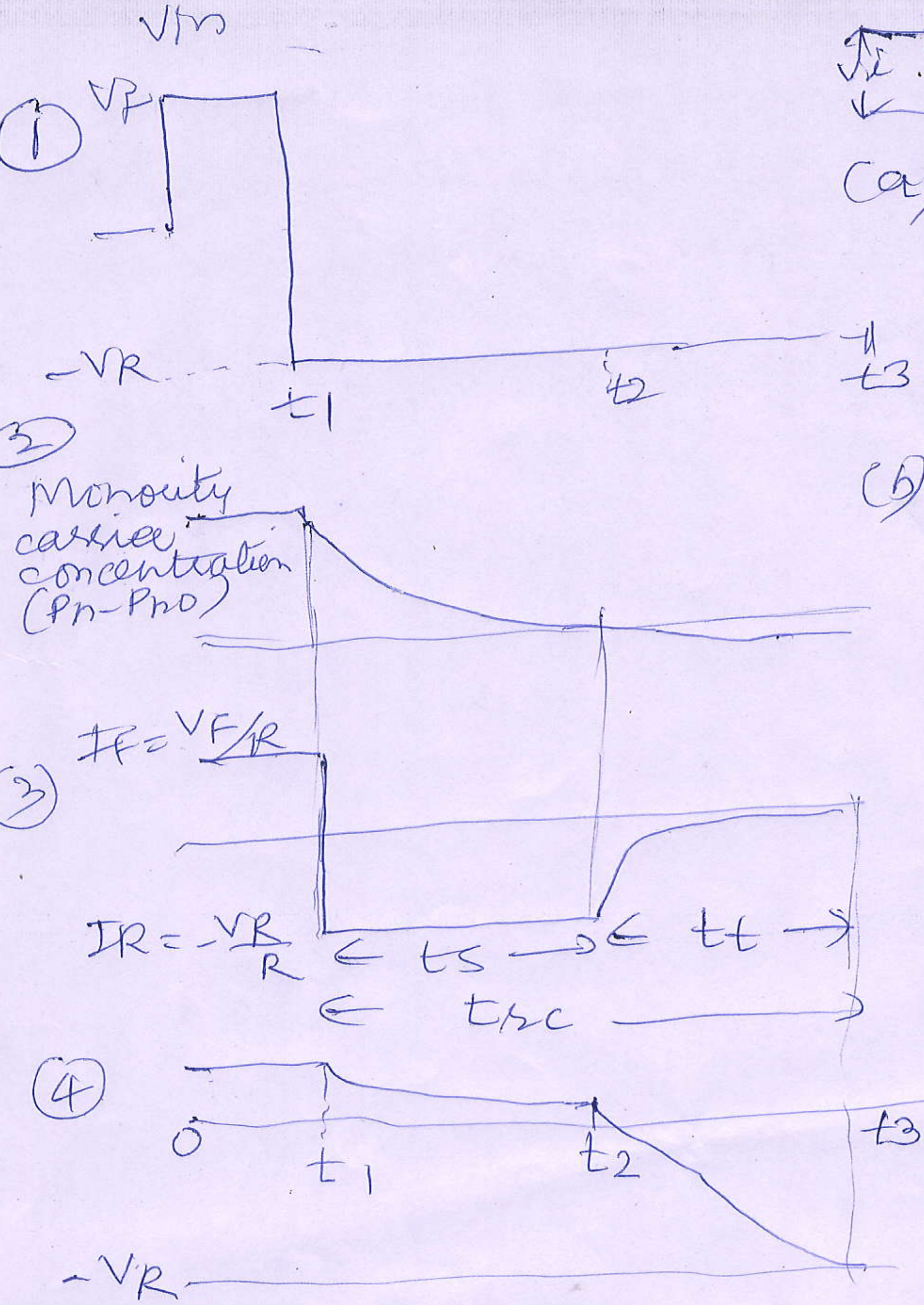
(b) Reverse bias

Fig: Distribution of minority carrier distribution

When diode is switched from forward to reverse bias, $p_n - p_{no}$ & $n_p - n_{po}$ reduces to zero. Till that time diode continues to conduct.

(8)





(a) Input voltage

(b) Minority carrier concentration

(c) Diode current

Diode voltage

(1) Input voltage:
Till time t_1, the forward voltage applied is V_F, and the diode is forward biased. Resistance 'R' is large enough such that drop across diode, is very small compared to drop across 'R'.

$I_F \simeq \frac{V_F}{R}$ neglecting forward resistance of diode

(2) Minority carrier concentration
At time 't_1', the applied voltage is suddenly reversed and '$-V_R$ is applied to the circuit.

Diode does not switch immediately. The no. of minority carriers take time to reduce from $P_n - P_{no}$ to zero at the junction. Due to this at t_1 current just reverses and remains at that reversed value $-I_R$ till the minority carrier concentration reduces to zero.

The current is given by $-I_R = -\frac{V_R}{R}$. This continues to flow till time t_2.

$t_s = t_1$ to t_2 = storage time as minority charge carriers remain stored and decrease slowly to zero.

(3) From t_2 onwards the diode voltage starts to reverse and the diode current starts decreasing.

At $t = t_3$, the diode state completely get reversed and attains steady state in reverse biased condition.

$t_t = t_2$ to t_3 = time required by the diode current to reduce to its reverse saturation value is called transition interval or transition time.

$t_{rr} = t_s + t_t$ = reverse recovery time

It ranges from a few n secs to usec. Specially manufactured diodes can have t_{rr} = few p secs.

t_{rr} limits the max. operating freq of the diode.

$T = 10 t_{rr}$

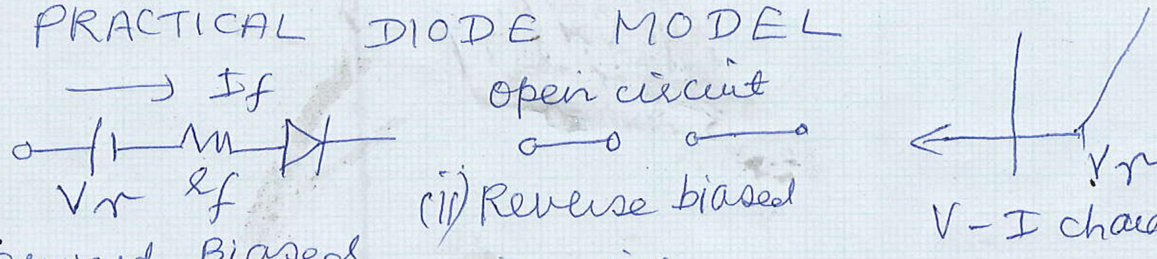
i.e. $f_{max} = \frac{1}{T} = \frac{1}{10 t_{rr}}$

Forward recovery time : is the time difference between the 10% point of the diode voltage and the time when this voltage reaches and remains with 10% of its final value. t_{fr} does not cause serious problem.

CIRCUIT MODELS OF A DIODE

The diode is required to be replaced by the equivalent circuit in many practical electronic circuits for the analyses purpose. Such an equivalent circuit of a diode is called circuit model.

(1) PRACTICAL DIODE MODEL

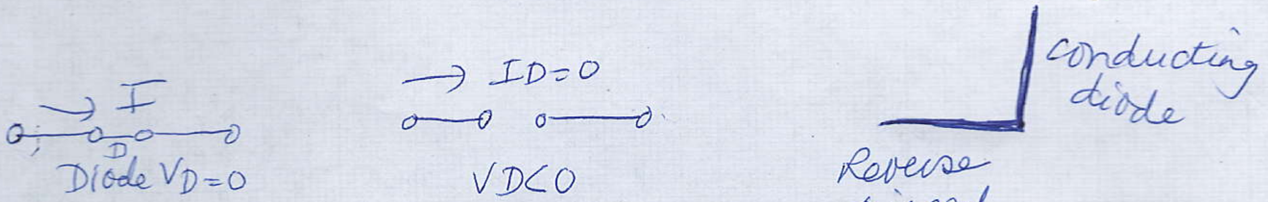


(i) Forward Biased (ii) Reverse biased V-I characteristics

i) Forward biased condition : A battery equal to cut-in voltage V_r and the forward resistance in series with the ideal diode.

(ii) Reverse biased condition: I_o is very small & neglected, diode is open circuited

(2) IDEAL DIODE MODEL

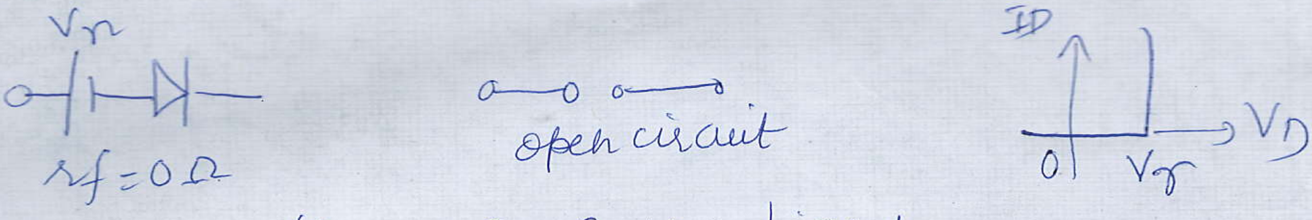


(i) Forward biased (ii) Reverse biased V-I characteristics

(i) Forward biased: Ideal diode starts conducting instantaneously when applied voltage V_D just greater than ~~V_γ~~ zero and the drop across the conducting diode is zero. ∴ conducting diode is replaced by short circuit.

(ii) Reverse bias condition: $V_D < 0$, open circuited

(3) PIECEWISE LINEAR MODEL OF DIODE



(i) Forward biased (ii) Reverse biased

(i) Forward biased:
$r_f = 0$. R_f is neglected & diode is assumed to conduct instantaneously when applied forward bias voltage V_D is equal to cut-in voltage V_γ. The current increases instantaneously giving straight line.

(ii) Reverse biased:
When $V_D < 0$, the diode does not conduct at all. Diode is open circuited

Applications of p-n diode

1. Rectifiers in power supplies
2. Clipper circuits used for wave shaping
3. Clamper circuits used as d.c restorer in T.V. receivers.
4. Voltage multipliers.
5. As a switch in digital circuits.