Junction Temperature Effects

Reverse saturation current I_o - has minority carriers

when temp ↑, incr. no of e^- break away from their atoms

I_o - known for a gn temp T_1, it can be calc. for another temp. level T_2,

$$I_{o(T_2)} \approx I_{o(T_1)} \left(2^{(T_2 - T_1)/10}\right)$$

I_o doubles for each 10°C rise in temp.

* -tion current & voltage,

$I_D = I_0 [e^{V_D/\eta V_T} - 1]$

i. $V_T = kT/q$.

$V_T = 26mV$

$k = 1.38 \times 10^{-23}$

$T \rightarrow$ abs temp.

$q = 1.6 \times 10^{-19}$.

when $T = 300 K$ ($27°C$)

$V_T = 26mV$

- reverse biased jn,

current always = to the

reverse saturation current

-nction voltage

$V_D = (\eta V_T) \ln(I_D/I_0)$ - eqn not completely accurate

Static Char:-

Boltzmann Diode Eqn.

$e = 1.6 \times 10^{-19}$

$$I = I_0 (e^{eV/\eta kT} - 1) \text{ ampere}$$

$\cancel{1.88}$

$I_0 \to$ Diode reverse saturation I

$V \to$ voltage across jn - +ive for FB & -ive for RB

$k \to$ Boltzman const $= 1.38 \times 10^{-23}\ J/{}^\circ K$

$T \to$ crystal temp in $^\circ K$

$\eta = 1$ - for Ge
$= 2$ - for Si

$V_T \to$ volt eqrt of temp.

$\therefore$ diode eqn becomes

$$I = I_0 (e^{eV/kT} - 1) \quad \text{- for Ge}$$

$$I = I_0 (e^{eV/2kT} - 1) \quad \text{for Si}$$

Now $e/k = 11,600$, put $T/11,600 = V_T$, eqn bec.

$$I = I_0 (e^{11,600 V/\eta T} - 1) = I_0 (e^{V/\eta V_T} - 1) \text{ ampere.}$$

At room temp of $(273 + 20) = 293^\circ K$, $V_T = \frac{293}{11,600}$
$= 0.025V$
$= 25 mV$

$\frac{1}{25} mV = 40$

subs η,

$$I = I_0 (e^{40V} - 1) \quad \text{- for Ge}$$

$$\simeq I_0 e^{40V} \quad \text{- if } V > 1 \text{ volt}$$

$\frac{1.00}{25}$

$$I = I_0 (e^{20V} - 1) \quad \text{- for Si}$$

$$\simeq I_0 e^{20V} \quad \text{. if } V > 1 \text{ volt}$$

η - gen recomb factor

Diode eqn $I = \cancel{I_0 (e^{V_F/\eta V_t} - 1)}$ ~~- forward bias~~

$= \cancel{I_0 (e^{-V_R/\eta V_t} - 1)}$ ~~- reverse bias~~

$$= I_0 (e^{V_F/\eta V_T} - 1) \text{ - FB}$$

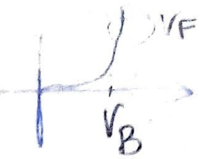
$$= I_0 (e^{-V_R/\eta V_T} - 1) \text{ - RB}$$

Parameters: 76

1. resistance B. r_B

Sum of R value of P & N type sc of diode

$r_B = r_p + r_N$ - very small.



$r_B = (V_F - V_B) / I_F$ → resistance offered by diode well above barrier voltage ie when current is large. This r → offered in forward direction

2. Jn resistance (r_j)

$V_T = \frac{293}{11,600} = 25mV$.

$r_j = 25mV / I_F$ mA - for Ge $\frac{V_T}{I_F}$ it is a variable resistance

$= 50 mV / I_F$ mA - for Si

3. Dynamic or ac resistance

r_{ac} or $r_d = r_B + r_j$ (small neg, → large neg)

for large values of forward current r_j is negligible

∴ $\boxed{r_{ac} = r_B}$ For small values of I_F, r_B is negligible compared to r_j ∴ $\boxed{r_{ac} = r_j}$

4. Forward voltage drop :- $= \frac{\text{Power dissipated}}{\text{forward dc current}}$

5. Reverse Saturation current I_0 :-

6. " Breakdown voltage V_{BR}

7. " dc resistance $R_R = \frac{\text{reverse voltage}}{\text{" current}}$

...tion resistance.

is incremental / dynamic resistance.

$r_j = dV/dI$ or $g_j = dI/dV$.

$I = I_0(e^{V/\eta V_T} - 1) = I_0 e^{V/\eta V_T} - I_0$.

$g_j = \frac{dI}{dV} = \frac{I_0 e^{V/\eta V_T}}{\eta V_T} = \frac{I + I_0}{\eta V_T}$ $\qquad \frac{V}{\eta V_T}$ - in potential

Reverse bias

RB ↑ - g_j ↓

r_j ↑

⇓

R_R

when RB >> few tenths of a V, i.e. when $|V/\eta V_T| >> 1$, then g_j is small so that r_j is very large. That high value is reps by R_R.

Forward bias :-

Again FB > few tenths of a V, $I >> I_0$, hence $g_j = I/\eta V_T$

I ↑

$r_j = \eta V_T / I$.

At room temp of 293°K, $V_T = T/11,600 = 293/11,600$

$= 25 mV$.

Also $\eta = 1$ for Ge & 2 for Si.

$r_j = 25 mV / I\ mA$ - for Ge

$= 50 mV / I\ mA$ - for Si

Under ↑ reverse voltage ; 2 mech. resp for break down,

1. Zener Breakdown :- – Occurs in jn, being heavily doped have narrow dep layers. BD V sets up a very strong electr field (10^8 V/m) across this narrow layer. This field - strong enough to break or rupture the covalent bonds generating e⁻ hole pairs. Even a small further ↑ in rev V. is capable producing large no. of I carriers

- jn has very low resistance in BD region

Avalanche BD:- occurs in jn. lightly doped jn. have wide dep layers, where electric field not strong enough to produce Zener BD but minority carriers (accelerated by this field) collide with si atoms in dep region.

On collision with valence e⁻, covalent bonds broken & e⁻ hole pairs generated. These newly gen. charge carriers accelerated by electric field, resulting in more collisions ∴ more production of charge carriers.

This leads to avalanche (or flood) of charge carriers ∴ to a very low reverse resistance

Junction Capacitance -

cap effects - exhibited by PN jn - in FB & RB bias

a) Transition Cap C_T or space charge cap C_{pn} or C_T

PN jn $\boxed{RB}$ dep reg - like insulator or dielectric material - for making a capac

P & N region - sides - have low R. act as plate

$C = \epsilon A / d$, width $\approx 40 pF$

↑ RB →
↓ RB →

Thickness of dep layer - dep on amt of R bias

incremental capacitance.

C_T - ctrlred by applied bias

⇒ used in varicap/varactor

$$C_T = \frac{K}{(V_K + V_R)^n}$$

V_K - knee V ; V_R - applied rev V

K - const dep on sc materials

$n = \frac{1}{2}$ - for alloy jn &

$= \frac{1}{3}$ - for diffused jn

of RB pn jn - used in
- voltage variance cap
AFC - automatic freq ctrl - in FM tuner,
self balance bridge ckts,
I special type of Al - parametric Al &
electronic tuners in TV

Diffusion / storage Cap C_D :- → Rate of change of injected charge with applied V - $C_D = \frac{dQ}{dV}$ >> C_T

$\propto I$ If minority carriers stored
when jn FB. dQ → change in no. of charge in V dV aplied
outside dep reg. where time delay in moving charges
Diff cap - to acount for
across jn by diffusion process
- Varies directly with mag. of forward I. I_F.
if applied V reversed suddenly I_F ceases suddenly but leave
lot of maj carriers in dep region
↳ must get out of region, bec. wider in RB.

suddenly FB be RB, Rev I ↑ then ↓ to satur
I I_0 - Like dischage I of cap. ∴ keeps diff
no of charge caries left in dep layer - $\propto$ FI,
$C_D \propto I_F$.
10-1000 PF.
Value = 0.02 µF. = 5000 times C_T,
require rapid swith F to RB.
If C_D - large, switching slow. $C_D = \frac{\tau I}{\eta V_T}$ ↳ diode I
↳ generation or recombfactor
effect of C_D - recovery time / carrier storage
τ - mean life time of charge carriers
Q yields a diode I flow of charge

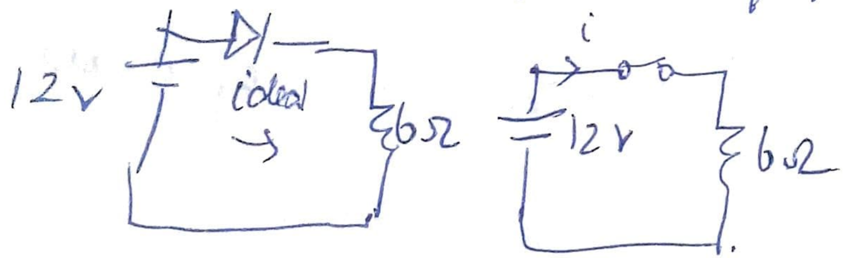
$I = \frac{Q}{\tau} = I_0 (e^{V/\eta V_T} - 1) \simeq I_0 e^{V/\eta V_T}$

$C_D = \frac{dQ}{dV} = \frac{\tau I_0}{\eta V_T} e^{V/\eta V_T} \simeq \frac{\tau I}{\eta V_T}$

$Q = I\tau = \tau I_0 e^{V/\eta V_T}$

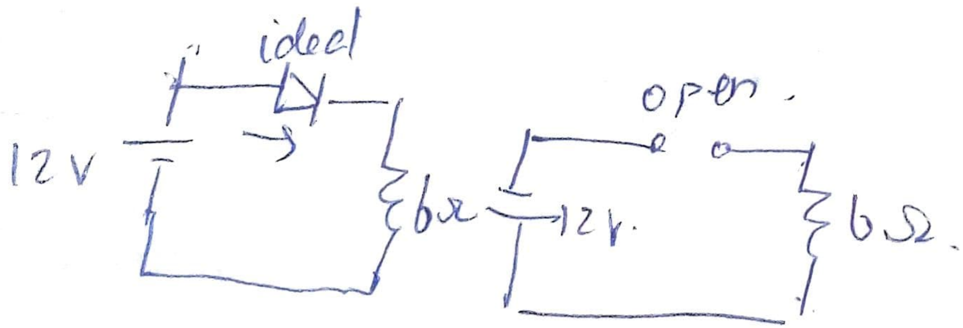
Prob

7). Calc ckt I & power dissipated in a) ideal diode. b) 6 Ω resistor of ckt. of fig 9.



- diode ideal & FB

∴ it can be replaced by s.hort (closed switch).



ckt I by ohms law

$I = 12/6 = 2A$.

a) Since there is no v drop across diode, power consumed by it is 0.

There is no power when either V or current is 0

In forward dir, there is I but no v drop.

ower dissipated by ideal diode is 0.

In rev. dir, there is V but no current.

∴ power dissipated by diode is again zero.

Ideal diode never dissipates any power.

b) power consumed ~~dissumed~~ by 6Ω resistor $= 2^2 \times 6 = 24W$.

The Ideal Diode:-

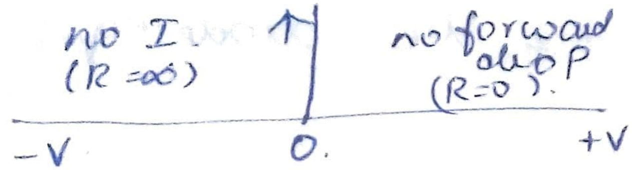
- no such. , simply.

2 term dev. which.

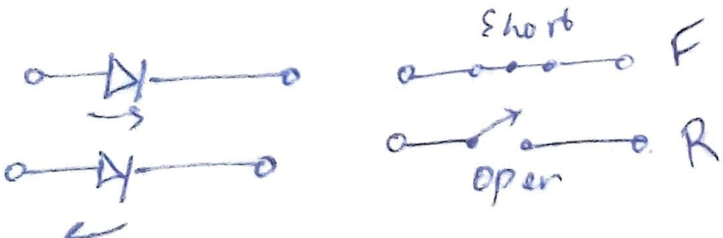
a) conducts with 0 resistance when FB &

b) appears as an infinite resistance when RB.

- Such device - acts as Short ckt in F direction & as open ckt in rev dir.



In F dir, no V drop. though I is there since a short has 0 resistance.



There is no rev. I bec. rev. resistance is ∞

Ideal diode - $\boxed{\text{bistable switch}}$ - 2 stable state: ON/o

closed in F dir & open in R dir.

Prob

1) ~~Calc ckt I & power dissip~~