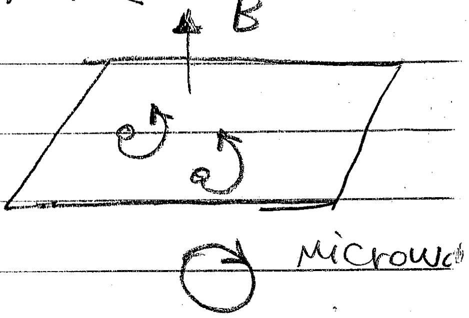
Q1 explain the effect of cyclotron from absorbed the M-energy. 5

Cyclotron resonance technique

Centripetal force = Lorentzian Force



$\frac{m_n v^2}{r} = q v B$

$v = qBr/m_n$

$f_{cr} = \frac{v}{2\pi r} = qB/2\pi m_n$

- f_{cr} is the cyclotron fr
- it's independent of v and r
- electrons strongly absorb M-w of that freq. by measuring f_{cr}, m_n can be found.

5

2- Drive an Exp. E_f is in the middle of E_g for in Si.

in intrinsic semiconductor $n = p$ and therefore

$E_c - E_f \simeq E_f - E_v$

E_f is nearly at the middle of E_g is called E_i

$E_i = E_f \simeq E_c - E_g/2$ (intrinsic Fermi level)

$$\ln n_i = \ln \sqrt{N_c N_v} - E_g/2kT \rightarrow ①$$

$n = n_i$ (intrinsic Condition)

$$E_i = E_c - kT \ln \frac{N_c}{n_i} \qquad n_i = N_c e^{-(E_c - E_i)/kT}$$

$$= E_c + kT \ln n_i - kT \ln N_c$$

$$= E_c - \frac{E_g}{2} - kT \ln \sqrt{\frac{N_v}{N_c}}$$

$$\boxed{E_i = E_c - E_g/2} \quad \text{if } N_c = N_v$$

$E_i \rightarrow$ intrinsic Fermi level.

$\boxed{5}$ Born atoms (P-type)

$\therefore N_a = 4 * 10^{6}\ cm^{-3}$

a) B is acceptor atom so its P-type where B is a group III element. $\boxed{1}$

) $P = N_a = 4 * 10^{6}\ cm^{-3}$

$n = n_i^2 / P = 10^{20} / 10^{16} = 2500\ cm^{-3}$ $\boxed{1}$

) The mobile carriers increases at high Temp. There's enough energy to free more electrons from Si/Si bonds and consequently # of intrinsic carriers increases. $\boxed{1}$

) $P = N_V\, e^{-(E_f - E_V)/kT}$ $\boxed{2}$

$E_f - E_V = kT \ln \frac{N_V(T)}{P(T)} = 0.34\ eV.$

AT 600k

$n_i = \sqrt{N_c(600k)\, N_V(600k)}$

$N_c = 2.8 * 10^{19} * \left[\frac{600}{300}\right]^{3/2} = 7.92 * 10^{19} / cm^3$

$N_V = 1.04 * 10^{19} * \left[\frac{600}{300}\right]^{3/2} = 2.94 * 10^{19} / cm^3$

$n_i = \sqrt{N_c N_V}\, e^{-E_g/2kT} = 1.16 * 10^{15} / cm^3$

$\therefore E_f - E_V = \underset{0.026}{kT} \ln \frac{7.92 * 10^{19}}{4.12 * 10^{16}} = 0.34\ eV.$

$P = N_a + n_i = 4 * 10^{16} + 1.16 * 10^{15}$

$= 4.12 * 10^{16}$ at 600k

$\boxed{4}$ $F(E_F + \Delta E) = 1 - F(E_F - \Delta E)$

$\boxed{5}$ $R.H.S = 1 - F(E_F - \Delta E)$

$$= 1 - \left[\frac{1}{1 + e^{(E_F - \Delta E - E_F)/kT}}\right]$$

$$= \frac{1 + e^{-\Delta E/kT} + 1}{1 + e^{-\Delta E/kT}} = \frac{e^{-\Delta E/kT}}{1 + e^{-\Delta E/kT}}$$

by divided $e^{\Delta E/kT}$

$$= \frac{1}{1 + e^{\Delta E/kT}} = \frac{1}{1 + e^{(E_F + \Delta E - E_F)/kT}}$$

$$= F(E_F + \Delta E) = L.H.S$$

$\boxed{\text{or}}$

$$F(E + \Delta E) = 1/[1 + e^{(E_F + \Delta E - E_F)/kT}]$$

$$= 1/1 + e^{\Delta E/kT} \longrightarrow ①$$

$$1 - F(E - \Delta E) = 1 - \frac{1}{1 + e^{(E_F - \Delta E - E_F)/kT}}$$

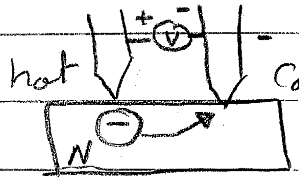
$$= \frac{e^{-\Delta E/kT}}{1 + e^{-\Delta E/kT}} * \frac{e^{\Delta E/kT}}{e^{\Delta E/kT}}$$

$$= \frac{1}{1 + e^{\Delta E/kT}} \longrightarrow ②$$

∴ From ① and ②

∴ $F(E + \Delta E) = 1 - F(E - \Delta E)$.

P2] Distiguish between n & P types by using Hot Point Probe Can determine sampling doping type.



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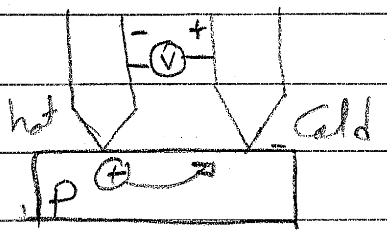
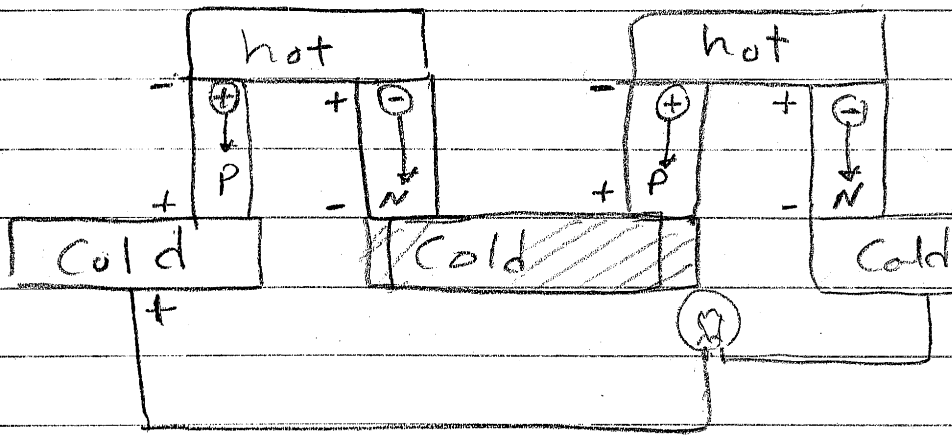


5

Thermoelectric Generator
from heat to electricity
and Cooler ((from electricity
to refrigeration))

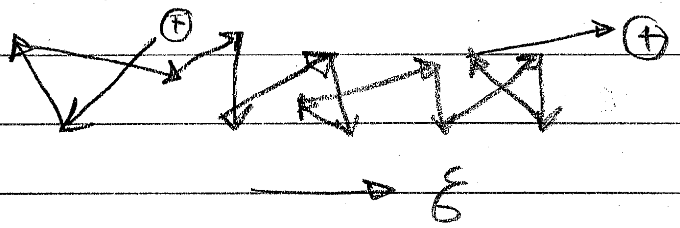
3

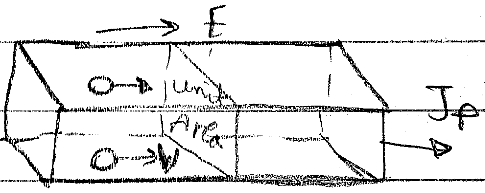


with explain

5

2-2] Drift crt → is The crt which introduced by Drift the Motion caused by E.F.





$J_{p\,drift} = qpv = qp\mu_p E$ $\quad J_p = qpv$

J_{n} " $= -qnv = qn\mu_n E$ $\quad$ A/cm² $\quad$ C/cm²-sec

$J_{drift} = J_{nd} + J_{pd} = \sigma E = (qn\mu_n + qp\mu_p)E$

$\sigma \to$ Conductivity (1/ohm-cm)

$\sigma = qn\mu_n + qp\mu_p$

$\boxed{2\text{-}3}$ charge neutrality: $\boxed{2.5}$

charge neutrality is satisfied at equilibrium ($P' = n' = 0$

⇒ when a non zero n' is present, an equal p' may be assumed to be present to maintain charge equality and vice versa.

⇒ if charge neutrality is not satisfied, the net charge will attract or repel the (majority) carriers through the drift cnt until neutrality is restored $\boxed{n' = p'}$.

n' & p' → excess carrier concent.

$n = n_0 + n'$

$P = P_0 + P'$

$\boxed{2\text{-}5}$

Rate of Recombination: $\frac{dn'}{dt} = -\frac{n'}{\tau}$ (($s^{-1}\ cm^{-3}$))

$n' = p'$ & $\frac{dn'}{dt} = \frac{-n'}{\tau} = \frac{-p'}{\tau} = \frac{dp'}{dt}$

where $n' = p'$ in

where recombination is a nature way of restoring equilibrium ($n' = p' = $ zero))

τ ranges from 1ns to 1ms in Si and depend on the density of metal impurities such as Au & Pt.

There's 2 type

① direct recombi.

② indirect ,,

4] $\boxed{a}$ $\rho = \frac{1}{\sigma}$ $\boxed{1}$

$= \frac{1}{q N_d \mu_n} = 1/1\text{-}6\times10^{-19}\times10^{16}\times1250 = 0.5\ \Omega.\text{cm}$

b] $N_a = N_d = 10^{16}\ \text{cm}^{-3}$, $N_a - N_d = 0$ $\boxed{1\text{-}5}$

$\rho = 1/\sigma = 1/\{n_i q\ (\mu_n + \mu_p)\}$

$= 1/\{1\text{-}6\times10^{-19}\times10^{10}\times(1400+470)\}$

$= 334224\text{-}6\ \Omega.\text{cm}.$

] $\rho = \frac{1}{\sigma} = \frac{1}{q n_i (\mu_n + \mu_p)} = 334224\text{-}6\ \Omega.\text{Cm}$ $\boxed{2\text{-}5}$

we Can note That the results of Part b & c are equal, Then we Can Conclude That the Conductivity is equal to The intrinsic sample at the same Temp.
or The resistivity of any Compensated sample

3] built in Potential. $\boxed{5}$

$n = N_d = N_c e^{-qA/kT}$ (n- region)

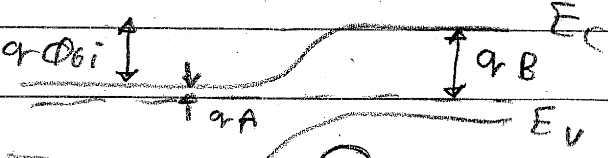
$A = kT/q \ln N_c/N_d$ ②

$n = \frac{n_i^2}{N_a} = N_c e^{-qB/kT}$ (P- region)

$B = kT/q \ln \frac{N_c N_a}{n_i^2}$

$\Phi_{bi} = B - A = \frac{kT}{q}\left[\ln \frac{N_c N_a}{n_i^2} - \ln \frac{N_c}{N_d}\right]$

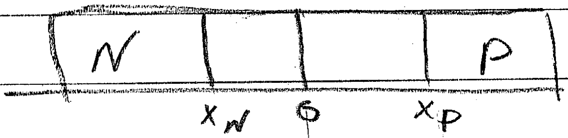
$$\boxed{\Phi_{bi} = \frac{kT}{q} \ln \frac{N_d N_a}{n_i^2}}$$



①

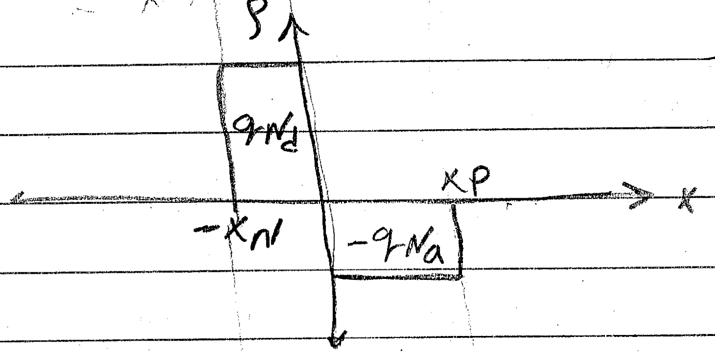
* Depletion layer Model (Field & Potential in D-L)

②



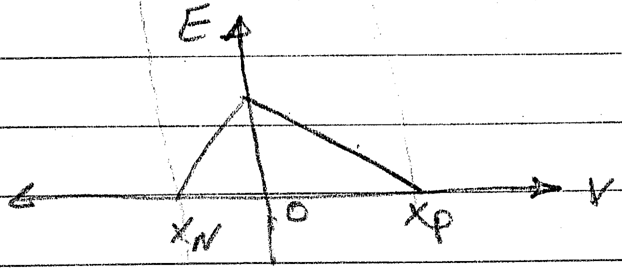
$\rho = -qN_a$

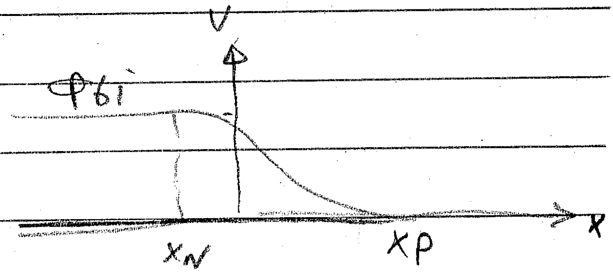
$$\frac{dE}{dx} = \frac{-qN_a}{\varepsilon_s}$$



$\rho = qN_d$

$$E(x) = \frac{qN_d}{\varepsilon_s}(x - x_N)$$





$$V(x) = \frac{qN_a}{2\varepsilon_s}(x_p - x)^2 \qquad (P\text{-side})$$

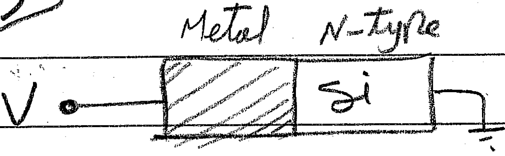
$$V(x) = D - \frac{qN_d}{2\varepsilon_s}(x - x_n)^2 \qquad (N\text{-side})$$

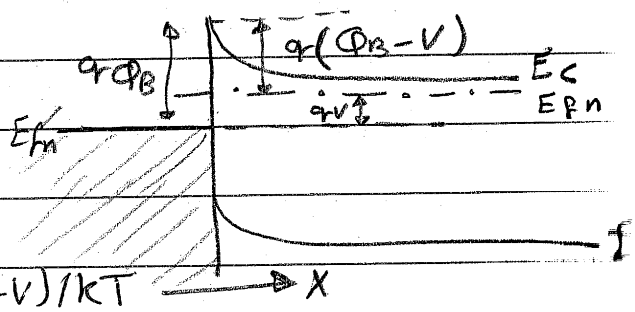
or

$$= \phi_{bi} - \frac{qN_d}{2\varepsilon_s}(x - x_N)^2$$

$\boxed{5}$

$\boxed{3-2}$





$$n = N_c e^{-q(\phi_B - V)/kT}$$

$$= 2\left[\frac{2\pi m_n kT}{h^2}\right]^{3/2} e^{-q(\phi_B - V)/kT}$$

$$V_{th} = \sqrt{3kT/m_n} \quad \& \quad V_{thx} = \sqrt{2kT/\pi m_n}$$

$$J_{S \to M} = -\frac{1}{2} q n V_{thx}$$

$$= \frac{4\pi q m_n k^2}{h^3} T^2 e^{-q\phi_B/kT} e^{qV/kT}$$

$J_{S\to M} = J_0 e^{qV/kT}$ & $J_0 \approx 100 e^{-q\phi_B/kT}$ A/cm^2

3/ 1- SCR cnt :- ②

under the forward bias, SCR cnt is an extra cnt with a slope 120 mV/decade.

$n \approx P \approx n_i e^{qV/2kT}$

net recomb (gene) rate : $\frac{n_i}{\tau_{dep}}(e^{qV/2kT}-1)$

$I = I_0(e^{qV/kT}-1) + A\frac{qn_iW_{dep}}{\tau_{dep}}(e^{qV/2kT}-1)$

SCR I

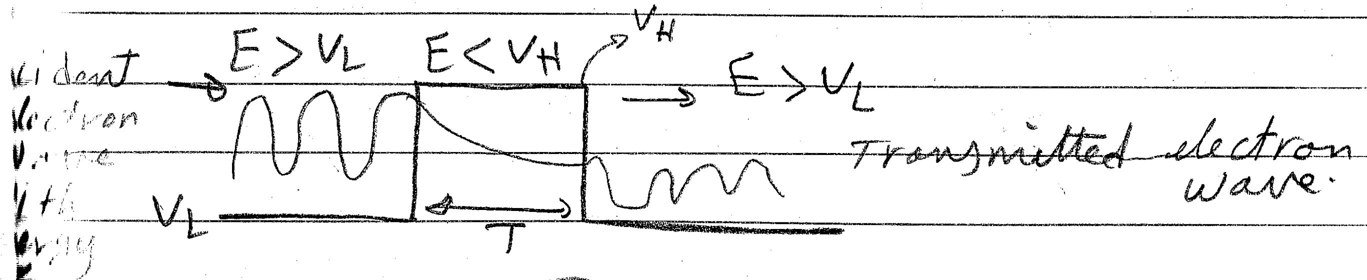
$I_{leakage} = I_0 + A\, qn_iW_{dep}/\tau_{dep}$

2- Fermi level Pining (1.5)

a high density of energy states in the band gap at the metal semiconductor interface pins E_f to narrow range and ϕ_{Bn} is (0.4 to 0.9 V)

3- Quantum Mechanical Tunneling (1.5)

$P \approx \exp(-2T\sqrt{\frac{8\pi^2 m}{h^2}(V_H-E)})$ Tunneling Probability



⑧

$\boxed{3\text{-}4}$ $N_d = 10^{16}\,cm^{-3}$ & $N_a = 5\times10^{15}\,cm^{-3}$, at $T = 300k$

a) built in vge ①

$$\Phi_{bi} = \frac{kT}{q}\ln\frac{N_aN_d}{n_i^2} = 0.026\ln\frac{10^{16} * 5*10^{15}}{10^{20}}$$

$$\boxed{\Phi_{bi} = 0.7V}$$

(b) $$W_{dep} = \sqrt{\frac{2\varepsilon_s\Phi_{bi}}{q}\left[\frac{1}{N_a}+\frac{1}{N_d}\right]}$$ ②

$$= \sqrt{\frac{2*(12*8.85*10^{-14})*0.7}{1.6*10^{-19}} * \frac{1}{N}}$$

$$\frac{1}{N} = \left[\frac{1}{N_a}+\frac{1}{N_d}\right] = \left[\frac{1}{5*10^{15}}+\frac{1}{10^{16}}\right]$$

$w_{dep} = 5.28*10^{-5}\ Cm$

$w_{dep} = 0.53\ \mu m$

$\therefore W_{dep} = X_n + X_p = 0.53\,\mu m$

$N_a|X_p| = N_d|X_n|$

$$\frac{X_p}{X_n} = \frac{N_d}{N_a} = \frac{10^{16}}{5\times10^{15}} = 2$$

$\therefore X_p = 2X_n$

$3X_n = 0.53\,\mu m$

$$\boxed{\begin{aligned} X_n &= 0.18\,\mu m \\ X_p &= 0.35\,\mu m \end{aligned}}$$

(c) E_{max} at $x = $ zero ②

$$E(x) = \frac{qN_a}{\varepsilon_s}(X_p - x)$$

$$E(x) = \frac{1.6*10^{-19}*5*10^{15}}{12*8.85*10^{-14}} * 3.5*10^{-5}\ Cm$$

$E(0)_{max} = 26.365\ kV/Cm.$

① as in q in $\boxed{3-1}$ وتم بتعليم نسب الأبعاد

(Q4-1)

applications of schottky diodes: $\boxed{4}$

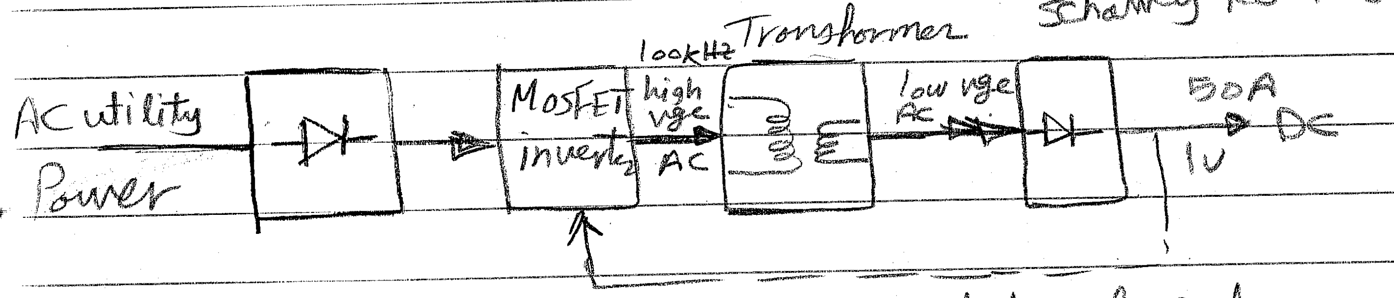
① rectifier in low vge.

② high cnt application

because I_o of a schottky diode is 10^3 to 10^8 times larger than a PN jun diode depending on ϕ_B

larger I_o means smaller forward drop V.

$\boxed{1-2}$ switching Power supply. $\boxed{4}$



F.B. to modulate the pulse width to keep Vout = 1V.

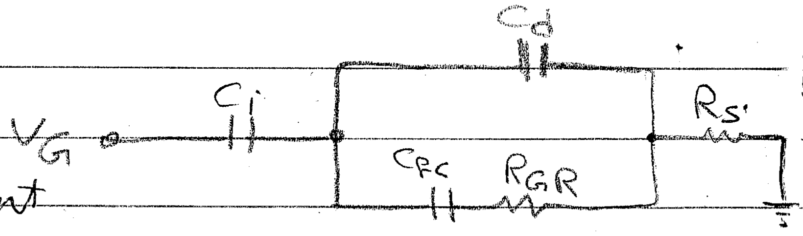
$\boxed{4-3}$ $\boxed{4}$

$$n = \frac{1}{q \rho \mu_n} = 1/[1.6 \times 10^{-19} \times 1 \times 3900] = 1.6 \times 10^{15}\ cm^{-3}$$

$$N_C = 1.98 \times 10^{15} \times T^{3/2} = 1.98 \times 10^{15} \times (293)^{3/2}$$
$$= 9.93 \times 10^{18}\ cm^{-3}$$

$$\phi_{Bn} = \phi_{Au} - \chi_{Ge} = 5.1 - 4 = 1.1\ eV$$

$$\phi_{bi} = \phi_{Bn} - (E_c - E_f) = \phi_{Bn} - \frac{kT}{q} \ln \frac{N_c}{n}$$
$$= 1.1 - 0.025 \times \ln \frac{9.93 \times 10^{18}}{1.6 \times 10^{15}}$$
$$= 0.87\ eV$$



Eq. Cir of Mos Cap.

$\boxed{4-4}$

is clearly freq.-dependent
Can neglect the effects of R_{GR} & R_s

$C_s = C_d + C_{fc}$

C_d → depletion layer capacitance

$C_d = \varsigma \varepsilon_s / d$ & $d_d = \sqrt{\frac{2 \varepsilon_s \psi_s}{q N_a}}$

$C_{dT} = \varsigma \varepsilon_s / d_{dT}$ ((min of C_d))

$C_{fc} = C_s - C_d$

↳ free carrier capacitance

R_{GR} → delay caused by Generation / recombination mechanisms in build up and removal of inversion charge response to change in bias vge.

$C_i = \varsigma \varepsilon_i / d_i$

$C_{Mos} = \frac{C_i C_s}{C_i + C_s}$

$C_s = \varsigma | dQ_s / d\psi_s |$

$C_{s0} = \varsigma \varepsilon_s / L_{Dp}$ (ψ_s = zero)

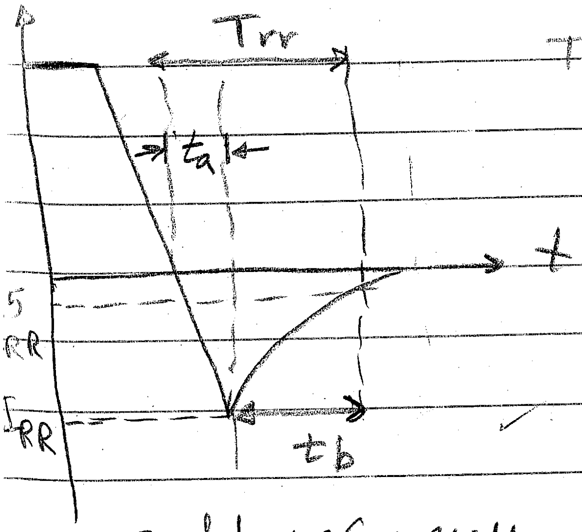
$C^0_{mos} = \frac{C_s C_i}{C_s + C_i}$

in strong inversion $C_s \gg C_i$

$C^0_{mos} \approx C_i$ (low freq.)

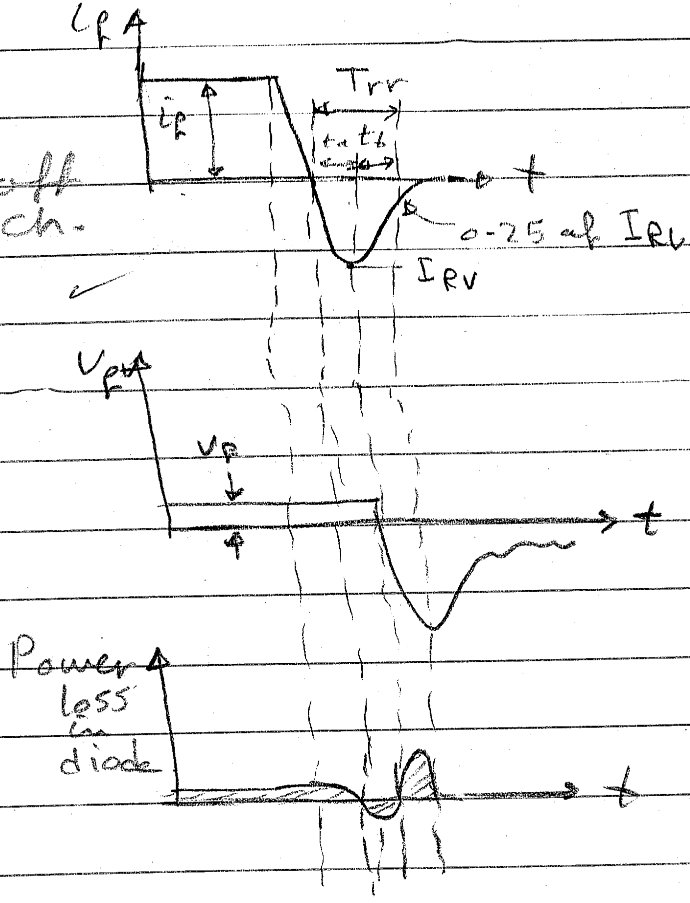
at high freq $C^\infty_{mos} = \frac{C_{dT} C_i}{C_{dT} + C_i}$

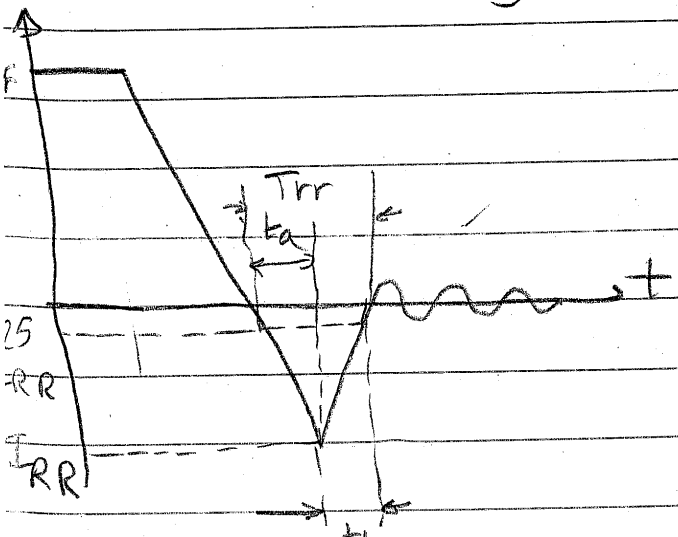
R5-1



Soft recovery

Turn off c/ch.





Abrupt recovery

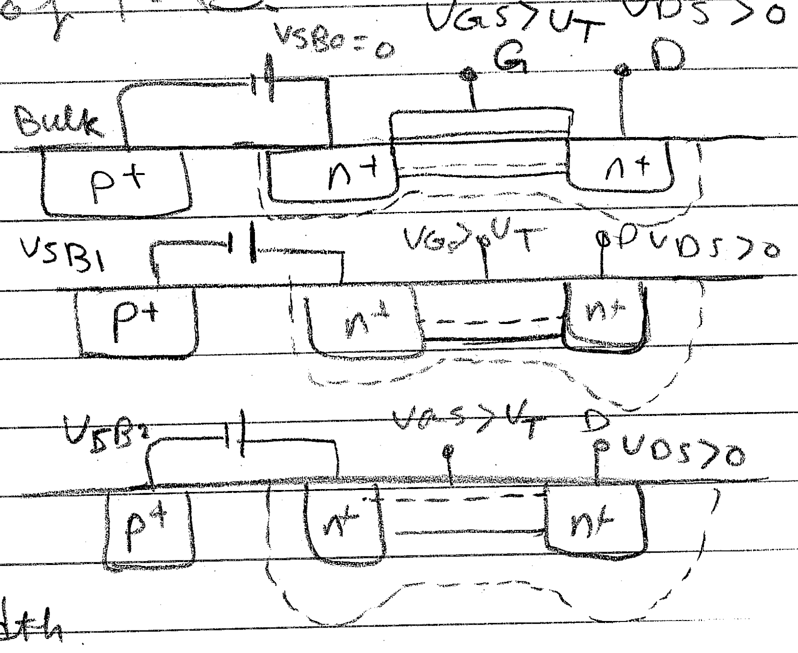
R-R c/ch of P-D.

-3

V_{BS0} = zero

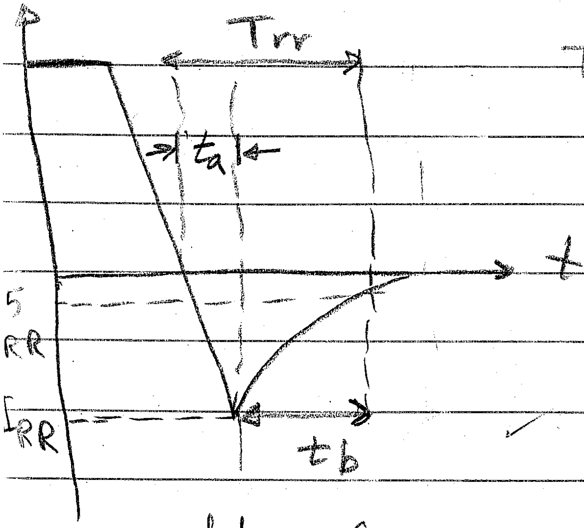
$V_{BS1} > 0V$

$V_{BS2} > V_{BS1}$



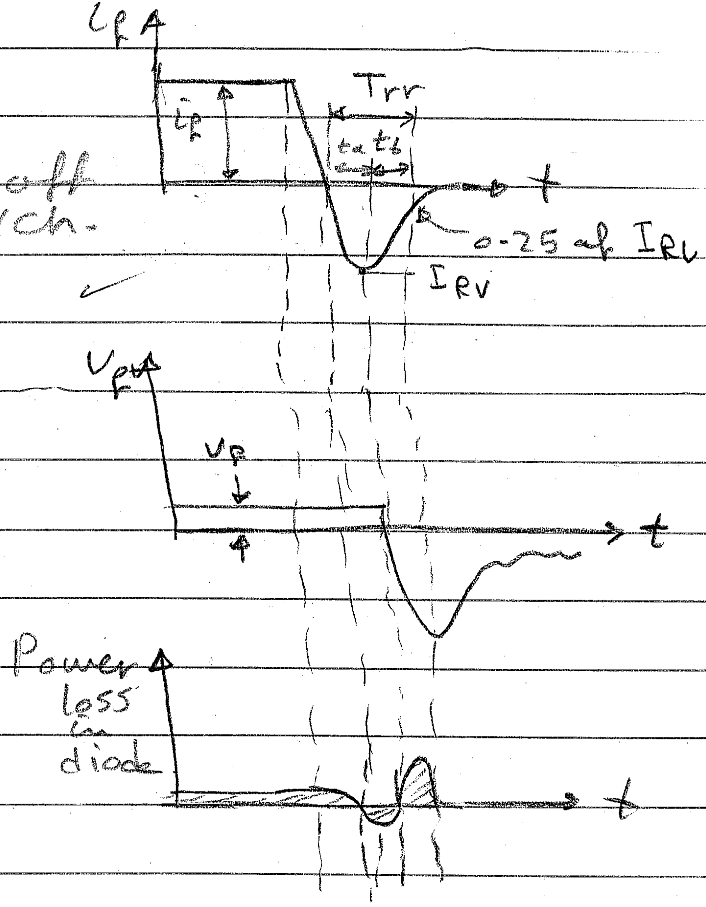
effect on The ch-width by varying VT

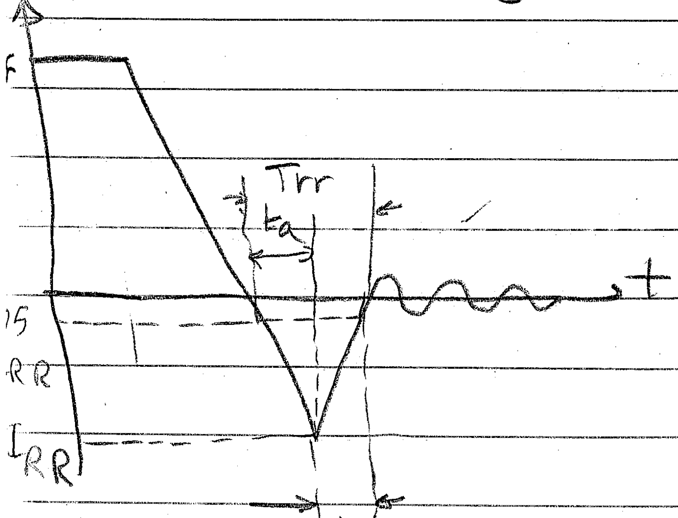
25-1



Soft recovery

Turn off c/ch.





Abrupt recovery

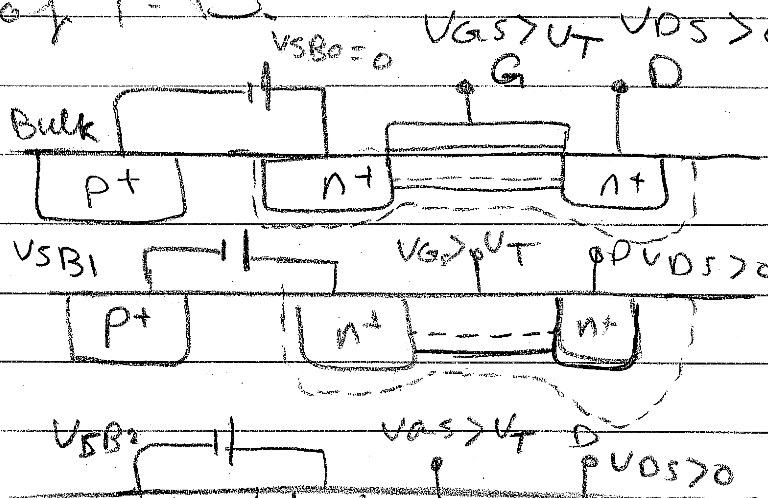
R.R c/ch of P.D.

3]

V_{BS0} = zero

$V_{BS1} > 0V$

$V_{BS2} > V_{BS1}$

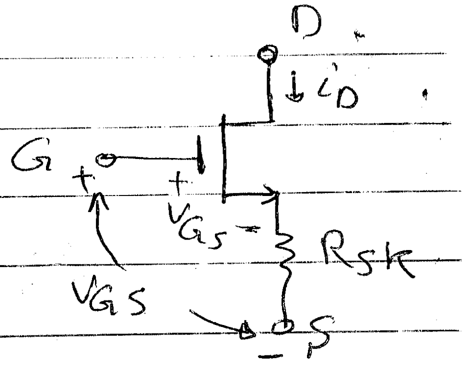


Effect on The ch-width by varying VT

⑫

$\boxed{5\text{-}2}$ let u maw that

$$i_D = \frac{k'W}{2L}\left(V_{GS}' - V_T\right)^2$$



$$V_{GS} = V_{GS}' + i_D R_{SK}$$

or $V_{GS}' = V_{GS} - i_D R_{XS}$

subs. V_{GS}' into i_D.

$$i_D = \frac{k'W}{2L}\left(V_{GS} - i_D R_{SX} - V_T\right)^2$$

So $i_D = \dfrac{k'}{2\left[1 + k'\frac{W}{L}R_{SX}\left(V_{GS} - V_T\right)\right]}\dfrac{W}{L}\left(V_{GS} - V_T\right)^2$

Comparing

$$\theta = k'\frac{W}{L}R_{SX}$$

$$R_{SK} = \frac{\theta L}{k'W} = \frac{1}{E_C k'W}$$

$\boxed{5\text{-}4}$ $V_T = V_{FB} + 2\Phi_F + \sqrt{4\varepsilon_s q N_a \Phi_F} / C_{ox}$

$$V_{FB} = \Phi_{MS} = \Phi_M - \chi - \frac{E_g}{2q} - V_t \ln\frac{N_a}{n_i}$$

$$= 4.1 - 4.05 - 0.56 - 0.026 \times \ln\frac{10^{17}}{10^{10}}$$

$$= -0.93\,V$$

$$\therefore V_T = -0.93 + 2 \times 0.42 + \sqrt{\frac{4 \times 11.9 \times 8.85 \times 10^{-14}}{3.9 \times 8.85 \times 10^{-14}}}$$

$$\sqrt{\times 10^{17} \times 0.42}$$

$$= -0.09\,V.$$

$\boxed{5-5}$

$$N_C = 8.63\times10^{13}\times T^{3/2} = 8.63\times10^{13}\times 300^{3/2} = 4.48\times10^{17}$$

$$\Phi_{bi} = \Phi_{Bn} - \frac{KT}{q}\ln\frac{N_C}{N_d}$$

$$= \phi_{Au} - X_{GaAs} - \frac{KT}{q}\ln\frac{n_i}{N_d}$$

$$= 5.1 - 4.07 - 0.026\ln\frac{10^{17}\times4.48}{10^{16}}$$

$$= 0.93\ \text{eV}.$$

$$V = \Phi_{bi} - \frac{qN_d}{2\varepsilon}(x-x_n)^2$$

$$x-x_n = \sqrt{\frac{2\varepsilon(\Phi_{bi}-V)}{qN_d}} = \begin{cases} V=0 & x-x_n = 3.64\ \mu m \\ V=3V & = 3\ \mu m \\ V=-100 & = 37.95\ \mu m \end{cases}$$

$$E = \frac{qN_d}{\varepsilon}(x-x_n) = \begin{cases} 3.64\ \mu m & E = 5.1\times10^{4}\ V/cm \\ 3\ \mu m & E = 4.2\times10^{4}\ V/cm \\ 37.95\ \mu m & E = 53.7\times10^{4}\ V/cm \end{cases}$$