Ajay Kumar Garg Engineering College, Ghaziabad
Department of ECE
MODEL SOLUTION ST2

Course: B.Tech
Session: 2016-17
Subject: EDC
Max.Marks: 50

Semester: III
Section: EC-1,EC-2,EC-3,EI
Sub.Code: REC-302
Time: 3 Hour

Section - A

1) An abrupt Si p-n junction has $N_a = 10^{18}\,cm^{-3}$ on one side and $N_d = 5\times10^{15}\,cm^{-3}$ on the other side. Calculate the Fermi level position in p & n regions when $KT = 0.0259$ ($n_i = 1.5\times10^{10}\,cm^{-3}$)

$$qV_0 = KT \ln \frac{N_a N_d}{n_i^2} =$$

$$= 0.0259 \ln\left(\frac{5\times10^{33}}{2.25\times10^{20}}\right)$$

$$= 0.79\ eV$$

2) What is fill factor of solar cell? what is its importance?

The ratio $\dfrac{I_m V_m}{I_{sc} V_{oc}}$ is called fill factor.

where $I_m V_m$ is the maximum power delivered.

I_{sc} is the short circuit current

V_{oc} is the open circuit Voltage.

Fill factor is the Figure of merit of solar cell so it is important to show efficiency.

Q3:- what is aspect ratio of MOSFET? on what factor it depends?

The ratio of width of channel to the length of ch is called the aspect ratio of MOSFET ie W/L ratio is aspect ratio.

It depends on the meanufacturing of MOSFET. Concentration of N_a acceptor and donor charge carriers.

Q4:- what is body effect in MOSFET?

when body and source are not short circuited incremental change in V_{SB} gives rise to increase in V_t that results in increase in i_D at constant V_{GS} ie Body Voltage controls i_D. Hence body / substrate acts as the another gate. This is called body effect. T

The body effect degrades the circuit performance.

Q5:- Define threshold Voltage in MOSFET

The excess of V_{GS} over the V_t is called overdrive Voltage. The over drive Voltage determines the charge in channel

$$V_{OV} = V_{GS} - V_t$$

where V_{GS} is Gate to source voltage

V_t is threshold Voltage

V_{OV} is over derive voltage

Threshold Voltage is the minimum voltage required to form Channel in MOSFET.

Section B

6) Draw V-I characteristics of illuminated Junction. Explain region of operation of diff. opto electronic devices.

For opto electronic P-n junction devices the current equation is

$$I = I_{th}\left(e^{qV/kT} - 1\right) - I_{op}.$$

where I_{th} is thermal ~~volto~~ current.

I_{op} is current generated due to optically generated carriers.

So V-I characteristic curve is lowered by amount proportional to I_{op} generation rate.

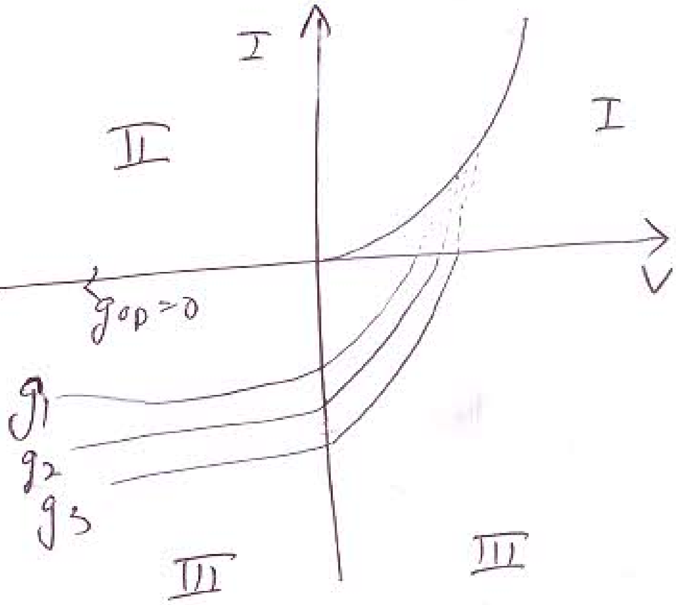


Figure:- V-I. charateristic of optoelectronic device

$g_1 < g_2 < g_3$ are the generation rate

Quadrent of operation:-

① The optoelectronic P-n Junction acts as normal Junction in Ist quadrent. But can be used as LED with special material.

② In 3rd quadrent V is -ve & I is also negative. The total power is VI which depends on gop so the devices can be used as optical / photodetector.

③ In 4th quadrent I is -ve & power = -VI -ve sign shows the power is develued from the device to outer Circuit eg in Solarcell.

Q7:- Derive equation of contact potential in terms of N_a & N_d for a p-n junction at equilibrium.

net current that flow across the junction at equilibrium is zero

i.e $J_p(\text{drift}) + J_p(\text{diffusion}) = 0$

i.e $\left(q \mu_p p(x) \mathcal{E}(x)\right) + \left(-D_p q \dfrac{dp(x)}{dx}\right) = 0$

$\Rightarrow q\left[\mu_p p(x) \mathcal{E}(x) - D_p q \dfrac{dp(x)}{dx}\right] = 0$

$\Rightarrow \dfrac{\mu_p}{D_p} \mathcal{E}_x = \dfrac{1}{p(x)} \dfrac{dp(x)}{dx}$

using Einstein Relation $\dfrac{\mu_p}{D_p} = \dfrac{q}{KT}$

& By defination of electric field $\mathcal{E}(x) = -\dfrac{dv(x)}{dx}$

So $\dfrac{-q}{KT} \cdot \dfrac{dv(x)}{dx} = \dfrac{1}{p(x)} \dfrac{dp(x)}{dx}$

Integrating on both sides,

$$\frac{-q}{KT} \int_{V_p}^{V_n} dv(x) = \int_{P_p}^{P_n} \frac{1}{p(x)} \, dp(x)$$

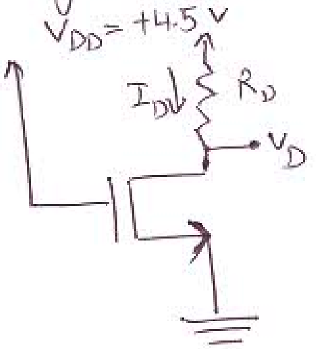
$$\frac{-q}{KT}(V_n - V_p) = \ln(P_n) - \ln(P_p) = \ln\left(\frac{P_n}{P_p}\right)$$

$\Rightarrow V_0 = \dfrac{KT}{q} \ln\left(\dfrac{P_p}{P_n}\right)$ (where $V_0 = V_n - V_p$ is contact potential)

as $P_p = N_a$ & $P_n = n_i^2 / N_d$

$$\Rightarrow V_0 = \frac{KT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

Q8:- Design The circuit given below to establish a drain Voltage of 0.2V. Calculate the effective resistance between drain and source at this operating point. Assume $V_t = 1V$ and $K_n = 1 mA/V^2$. Neglect channel modulation effect.



for the given circuit $V_D < V_{GS}$ So operation of MOSFET in triode region

$$V_G - V_D = (4.5 - 0.2)\,V = 4.3\,V$$

In triode region drain current

$$I_D = k'_n W/L \left[(V_{GS} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

$$k'_n \frac{W}{L} = 1 mA/V^2$$

$V_{GS} = 4.5$ $\quad V_{DS} = 0.2$

$V_t = 1$

$$I_D = 1 \left[(4.5 - 1) \times 0.2 - \frac{1}{2} (0.2)^2 \right]$$

$$= 3.5 \times 0.2 - 0.02$$

$$= 0.68 mA$$

Required value of $R_D = \dfrac{V_{DD} - V_D}{I_D} = \dfrac{4.5 - 0.2}{0.68} = 6.32 k\Omega$

$R_D = 6.32 k\Omega$ //

Q9. With the help of Voltage transfer curve Explain region of Operation of MOSFET to work as amplifier as switch.

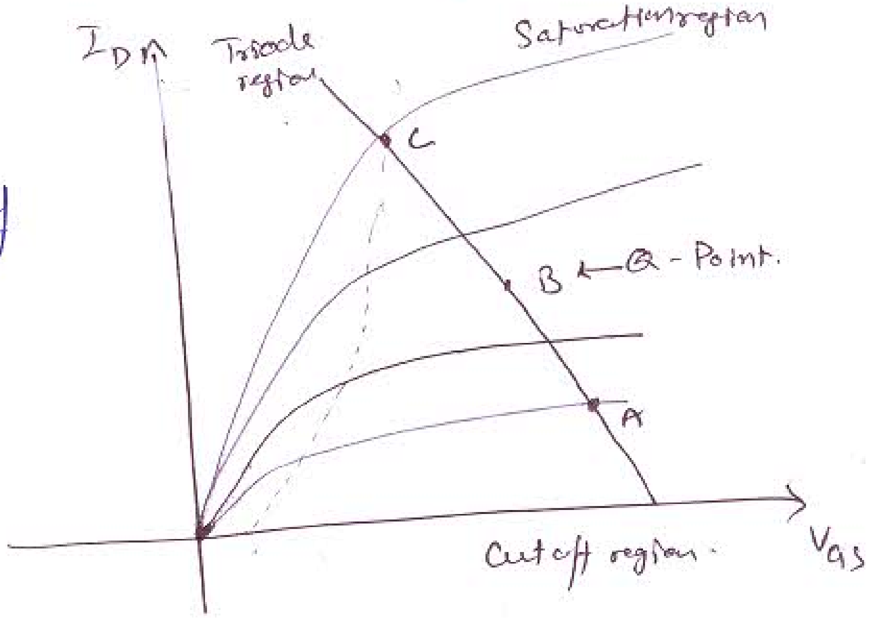


Figure V-I curve of MOSFET

~~Transfer~~

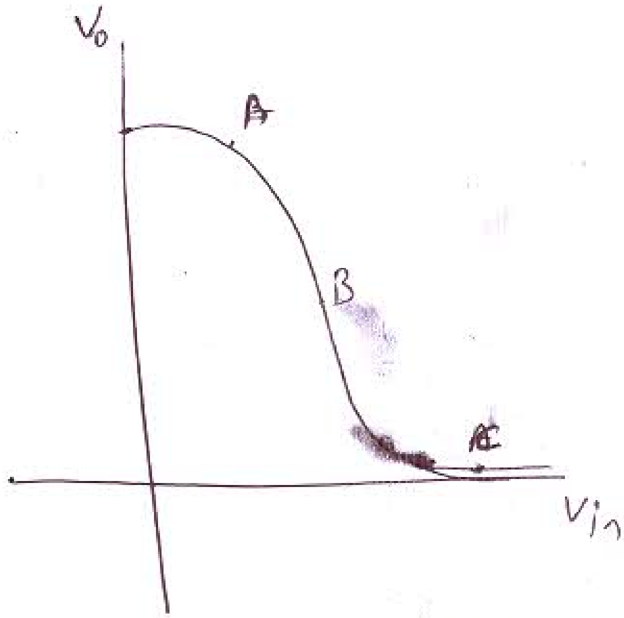


Figure :- Voltage Transfer curve of MOSFET.

In the V-I curve. The line A B C is the load line
The transfer curve is graph between V_o & Vin.
The point B is called the Q point or operating point.

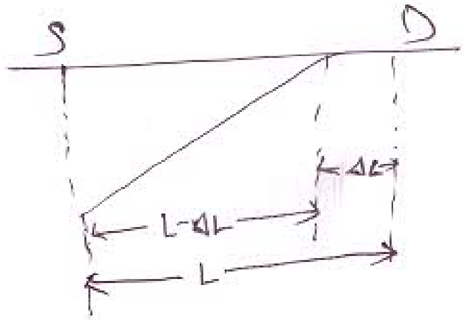
MOSFET as Amplifier :- MOSFET works as Amplifier, it should operate in the linear region around Q point. So that signal should not chopped off.

MOSFET as switch :- To work MOSFET as switch the MOSFET should be operated at point A or at, B ie in triode region or in cut off region.

Q10 :- What is Channel Modulation effect in MOSFET? Derive the expression of drain current in saturation region considering this effect.

In practice increasing V_{DS} beyond $V_{DS\,sat}$. the pinch off point moves slightly away from drain toward source. The voltage across ch. remains constant at $V_{GS} - V_t = V_{D\,sat}$. and additional voltage applied to drain appears as voltage drop. across narrow depletion region between the end of the ch. and drain region. This voltage accelerate the electrons that races the drain end of ch and sweeps them across depletion region. with widening of depletion layer the ~~width~~. channel length reduces. This effect is called channel modulation effect.

drain current :-



at saturation The drain current

$$i_D = \frac{1}{2} k_n' \frac{W}{L} (V_{OV})^2$$

when channel modulation effect is considered.

$$i_D = \frac{1}{2} k_m' \frac{W}{L+\Delta L} (V_{GS} - V_t)^2$$

$$= \frac{1}{2} k_n' \frac{W}{L} \left(1 + \frac{\Delta L}{L}\right) (V_{OV})^2$$

assuming $\frac{\Delta L}{L} << 1$ also $\Delta L \propto V_{DS}$

$\Delta L = \lambda' V_{DS}$ where λ is constant of proportionality

$$\text{So } i_D = \frac{1}{2} k_n' \frac{W}{L} \left(1 + \frac{\lambda'}{L} V_{DS}\right) V_{OV}^2$$

Let $\frac{\lambda'}{L} = \lambda$

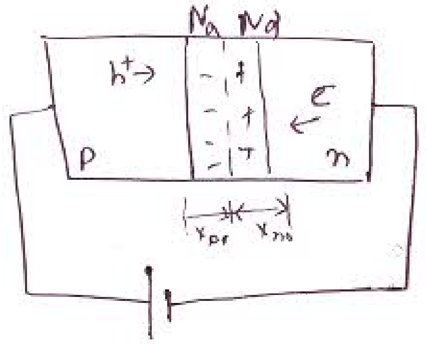
So $I_D = \frac{1}{2} k'_n \frac{W}{L} (V_{OV})^2 (1+\lambda V_{DS})$

The factor $(1+\lambda V_{DS})$ is representing channel mod. effect.

Section C

11 Derive the equation for space charge region in both sides of p-n junction at equilibrium. Also draw the variation of charge density and electric field across the junction.

Space charge region is the depletion layer of p-n junction that can be shown as.



The space charge region W is $x_{po} + x_{no}$

By the poissons equation

$$E = \int \frac{\rho}{\epsilon}$$

whe ρ is charge density
ϵ is permitivity.

For P region

$$\mathcal{E}_p = \frac{q N_a x_{po}}{\epsilon}$$

&

For n region

$$\mathcal{E}_n = \frac{q N_a x_{no}}{\epsilon}$$

If A be the area of crossection then at equilibrium

$$N_a x_{po} q A = N_d x_{no} q A$$

$$\Rightarrow \frac{x_{po}}{x_{no}} = \frac{N_d}{N_a}$$

Also from defination of electric field.

$$\mathcal{E} = \frac{-dv}{dx}$$

$$\Rightarrow \mathcal{E}\, dx = -dv$$

integrating both sides.

$$\int_{0}^{v_0} dv = -\mathcal{E} \int_{x_{po}}^{x_{no}} dx$$

$$\Rightarrow \quad V_0 = \frac{1}{2}\, \mathcal{E}(x_{po} + x_{no})$$

$$\Rightarrow V_0 = \cancel{\tfrac{1}{2}}\; \frac{1}{2}\, \mathcal{E} W$$

||ly for holes

$$V_0 = \frac{1}{2}\, \frac{q N_a x_{po}}{\epsilon} \cdot W$$ using equation of $\mathcal{E}$.

From above $x_{po} = \frac{N_d\, x_{no}}{N_a}$

Put in $x_{po} + x_{no} = W$

$$W = x_{po}\left[1 + \frac{N_a}{N_d}\right]$$

$$x_{po} \Rightarrow W\left[\frac{N_d}{N_a + N_d}\right]$$

Put the Value in V_0 expression

$$V_0 = \frac{1}{2}\, q\, \frac{N_a W}{\epsilon} \cdot W\left[\frac{N_d}{N_a + N_d}\right]$$

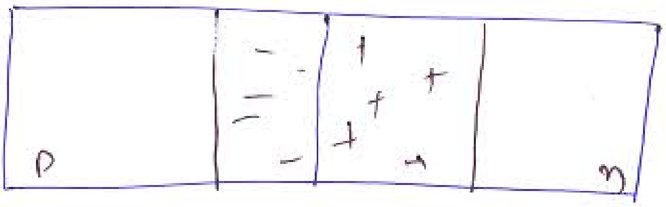
$$W^2 = \frac{2 \epsilon V_0}{q}\left[\frac{N_a N_d}{N_a + N_d}\right]$$

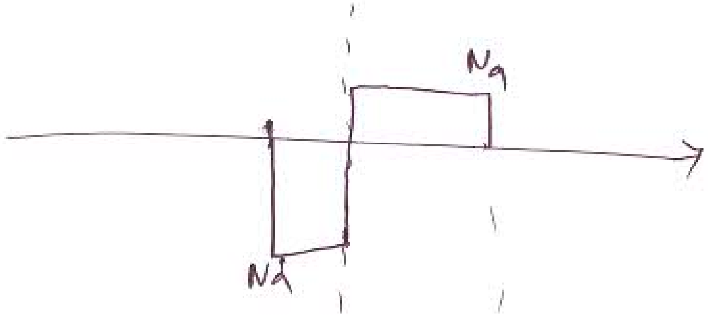
$$W = \sqrt{\frac{2 \epsilon V_0}{q}\left[\frac{1}{N_a} + \frac{1}{N_d}\right]}$$

This is space charge density.

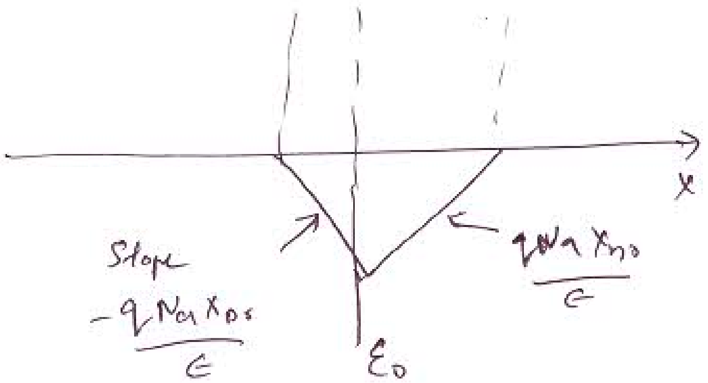
On p side $x_{po} = \sqrt{\frac{2\epsilon V_0}{q}\left[\frac{1}{N_a}+\frac{1}{N_a}\right]}\cdot\frac{N_a}{N_a+N_a}$

& $x_{no} = \sqrt{\frac{2\epsilon V_0}{q}\left[\frac{1}{N_a}+\frac{1}{N_a}\right]}\cdot\frac{N_d}{N_a+N_d}$





Variation of charge carriers



Varion of electric field

Q12:- Draw the structure of MOSFET to explain its working. Derive the expression of Drain current of for small V_{DS}.