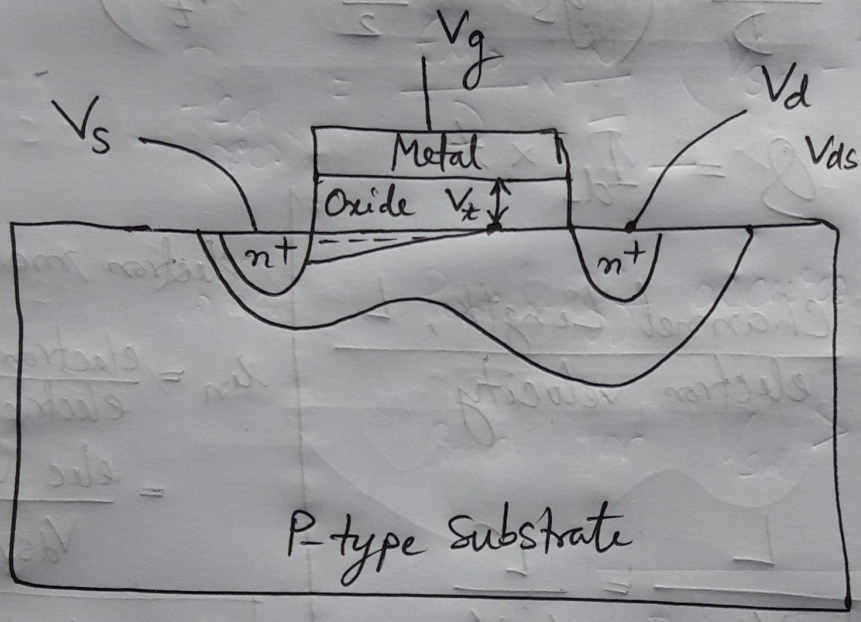
(b) P-16

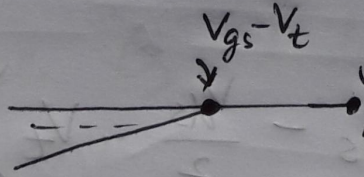
Saturation region

In this region, $V_{ds} \geq V_{gs} - V_t$



The drain voltage when $V_{ds} = V_{gs} - V_t$ the end of inversion channel resides at drain.

* As the drain increases, the end point of the inversion Channel moves away from the drain (as shown in the figure)

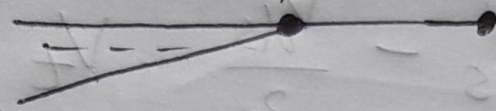


Difference
$= V_{ds} - (V_{gs} - V_t)$
$= V_{ds} - V_{gs} + V_t$

drain terminal $= V_{ds}$

$= V_{ds} - (V_{gs} - V_t)$

$= V_{ds} - V_{gs} + V_t$



drain terminal $= V_{ds}$

Excessive voltage of $(V_{ds} - V_{gs} + V_t)$ causes a high electric field across this very short distance and electrons (from inversion channel) are quickly swept across this area to drain terminal

When $V_{ds} = V_{gs} - V_t$

NMOS is in sat^n

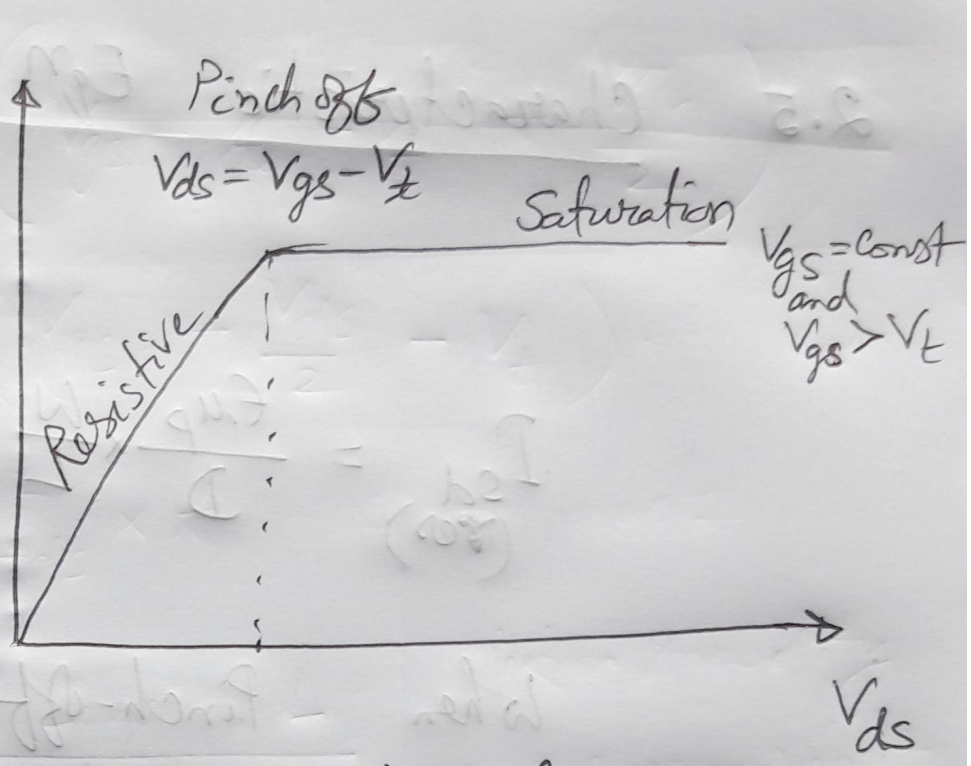


Fig: I_{ds} vs V_{ds} for NMOS

So we get,

$$I_{ds} = \frac{\epsilon \mu_n}{D} \times \frac{W}{L} \times \left[(V_{gs} - V_t) \times (V_{gs} - V_t) - \frac{(V_{gs} - V_t)^2}{2} \right]$$

$$\therefore \boxed{I_{ds(sat)} = \frac{\epsilon \mu_n}{D} \times \frac{W}{L} \times \frac{(V_{gs} - V_t)^2}{2}}$$

Standard values, we will use

$$\frac{\epsilon \mu_n}{D} = 30\ \mu A/V^2 \quad \text{[Enhancement NMOS]}$$

$$= 25\ \mu A/V^2 \quad \text{[Depletion NMOS]}$$

$$\boxed{\frac{\epsilon \mu_p}{D} \Rightarrow 15\ \mu A/V^2} \quad \text{PMOS}$$

2.5 Characteristic Eqn of PMOS

$$I_{sd(res)} = \frac{\epsilon \mu_p}{D} \times \frac{W}{L} \left[\left(V_{sg} - V_t \right) V_{sd} - \frac{V_{sd}^2}{2} \right]$$

When Pinch-off occurs at $V_{sd} = V_{sg} - V_t$

and for $V_{sd} > V_{sg} - V_t$, it is in Satⁿ region

and $$\boxed{I_{sd(sat)} = \frac{\epsilon \mu_p}{D} \frac{W}{L} \times \frac{\left(V_{sg} - V_t \right)^2}{2}}$$