Design and Analysis of VLSI Subsystems
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Lecture - 08
Short channel current model analysis

The saturation current in short channel is,

$$I_{ds,sat} = C_{ox} W \frac{V_{gt}^2}{V_c + V_{gt}} V_{sat}$$

(8.1)

If $V_{gs} - V_t \ll V_c$, enters into drain to source voltage in saturation region due to pinch-off effect.

Then,

$$I_{ds,sat} = C_{ox} W \frac{(V_{gs} - V_t)^2}{V_c} V_{sat}$$

(8.2)

The above current expression is a function of square of $(V_{gs} - V_t)^2$. Hence its defined as a square law.

If $V_{gs} - V_t \gg V_c$, enters into drain to source voltage in saturation region due to velocity saturation.

Then,

$$I_{ds,sat} = C_{ox} W (V_{gs} - V_t) V_{sat}$$

(8.2)

The above current expression is a function of linear of $(V_{gs} - V_t)$. Hence its defined as a linear law. Thus, the current is directly proportional to $(V_{gs} - V_t)$.

From figure 8.1 consider the two profiles, one is the velocity profile with respect to V_{ds} and the other is the current profile with respect to V_{ds}. Where $V_{ds} = E_{ds}xL$ in velocity profile. The value of critical voltage V_c is 1.01 volts for the NMOS transistor.

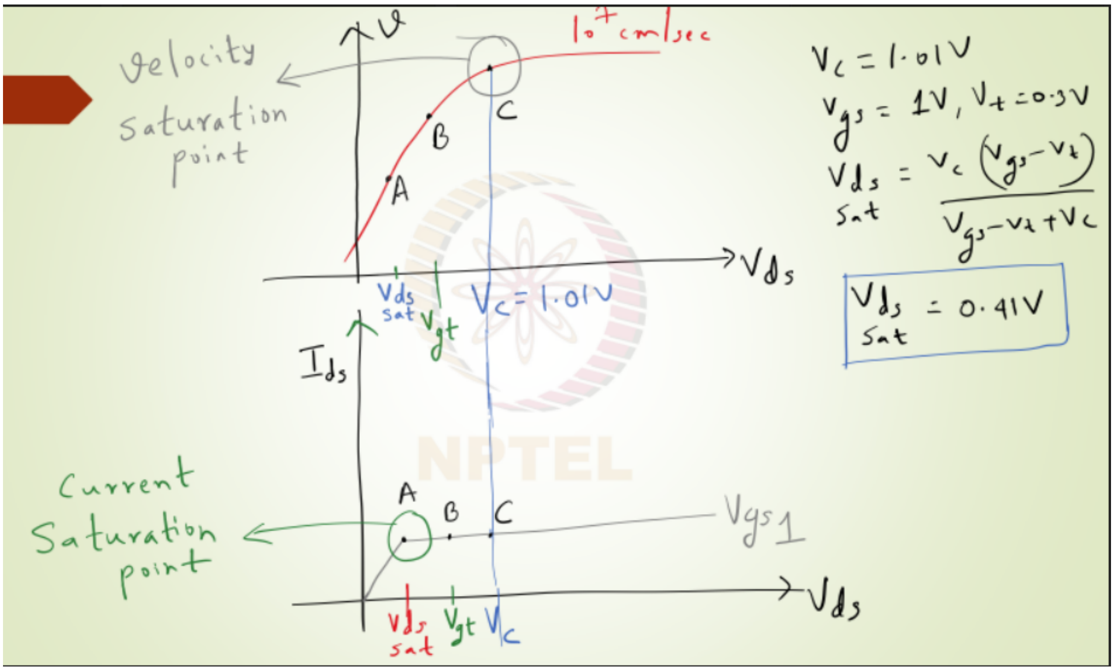

Figure 8.1: Velocity and Current Profile.

As discussed earlier, the effective mobility of the NMOS transistor is around $97cm^2/v - sec$ and channel length is 50nm for 1 volt of V_{gs}.

For 65nm technology node, the value of V_t is 0.3 volt and V_{gs} is 1 volt, the channel is pinched off in nmos transistor when $V_{ds} = V_{gs} - V_t = 0.7\ volt$t The 0.7 volts represent the point B in the velocity profile.

Consider the velocity saturation at point C is $10^7 cm/sec$. Two points B and C is achieved, the point B in the velocity profile will always lie on the linear profile, for the velocity. Point C is where the velocity saturation starts and point B is where it is still behind the saturation point.

As V_c is 1.01 volts, $V_{gs} - V_t$ is 0.7 volts, then

$$V_{ds,sat} = \frac{V_c(V_{gs}-V_t)}{V_{gs}-V_t+V_c} = 0.41V$$

This 0.41 volt lies on point A in the velocity profile on x-axis.

Similarly, the current profile is drawn for point A. The velocity saturates at point C and also current saturates at point C. As velocity reaches saturation, the current also reaches the saturation. In velocity profile at point B, velocity increases linearly but in current profile, it remains constant. In velocity profile, the saturation point reaches at c whereas in current profile the saturation reaches at point A.

According to the short channel model for the NMOS transistor, the saturation current is attained much earlier than the V_c and also the pinch-off region which is $V_{gs} - V_t$ is attained at point A and not at point B or C.

The empirical reason is the current flowing from the source to the drain side, will have a multiple effect. The first reason is, if the point A is actually very close to point B or rather 0.41 is closer to 0.7 volts, then the channel at the drain side starts decreasing. Another reason is, it has an effect of the critical voltage where the velocity at the point A is away from C. But it is closer to C in terms of the other points which are below A. There is a kind of tendency of the velocity is ceases to increase as the electric field increases then lateral voltage also increases. Thereby the point A is the dual effect of the velocity saturation as well as the pinch-off effect, such that the current will start attaining the saturation value.