EI-27003: Electronics Devices and Circuits Lecture - 11

Subject Incharge: Mr. Rajesh Khatri
Associate Professor

LECTURE - 11

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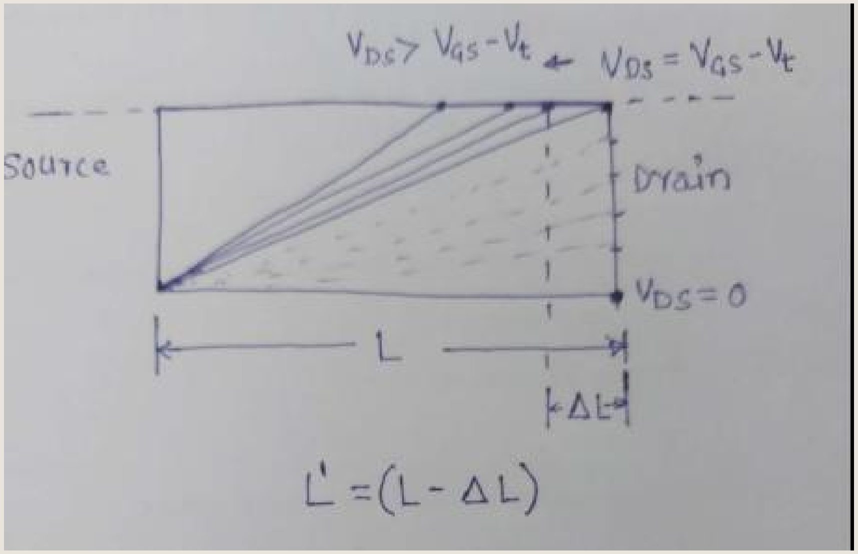
Drain Current I_D with channel length Modulation

- In NMOS we have seen that if V_{DS} is increased beyond $(V_{GS}-V_t)$, the channel decreases from L to (L- ΔL).



- At $V_{DS}=(V_{GS}-V_t)$, we have saturation eq

$$I_D = \frac{1}{2}K_n(W/L)(V_{GS}-V_t)^2 \text{ ----(1)}$$

- So replace L by (L- ΔL) in above equation (1)

$$I_D = \frac{1}{2}K_n[W/(L-\Delta L)](V_{GS}-V_t)^2 \text{ ----(2)}$$

$$I_D = \frac{1}{2}\frac{W}{L}\frac{1}{1-(\Delta L/L)}(V_{GS}-V_t)^2 \text{ ----(3)}$$

- Assume that $\Delta L \ll L$

$$I_D = \frac{1}{2}\frac{W}{L}\left(1+\frac{\Delta L}{L}\right)(V_{GS}-V_t)^2 \text{ ---(4)}$$

Drain Current I_D with channel length Modulation

- We know that ΔL is proportional to VDS

$$\Delta L \propto V_{DS} \quad \text{or} \quad \Delta L=\lambda' V_{DS}$$

Where λ' is process technology parameter with dimensions of μm/V

Thus eq.(4) becomes: $I_D = \frac{1}{2}\frac{W}{L}(1 + \frac{\lambda'}{L}V_{DS})(V_{GS}-V_t)^2$ ----(5)

Usually, $\frac{\lambda'}{L}$ is denoted by λ is another process technology parameter also called as channel length modulation parameter with dimensions V^{-1}

Hence eq(5) becomes: $I_D = \frac{1}{2}\frac{W}{L}(1 + \lambda V_{DS})(V_{GS}-V_t)^2$ ----(6)

for $V_{DS} >> (V_{GS}-V_t)$ deep saturation

I_D –V_{DS} characteristics with Channel length modulation effect

- Fig shows I_D-V_{DS} characteristics with channel length modulation effect.
- From this fig we can observe that when straight line I_D-V_{DS} characteristics are extrapolated they intercept the V_{DS}-axis at point V_{DS}= -V_A.

Early Voltage

- From eq.(6): I_D=0 at V_{DS}= -1/ λ
- It follows that V_A= 1/ λ.
- Thus V_A is a process-technology parameter with dimensions of V.
- V_A is proportional to channel length L

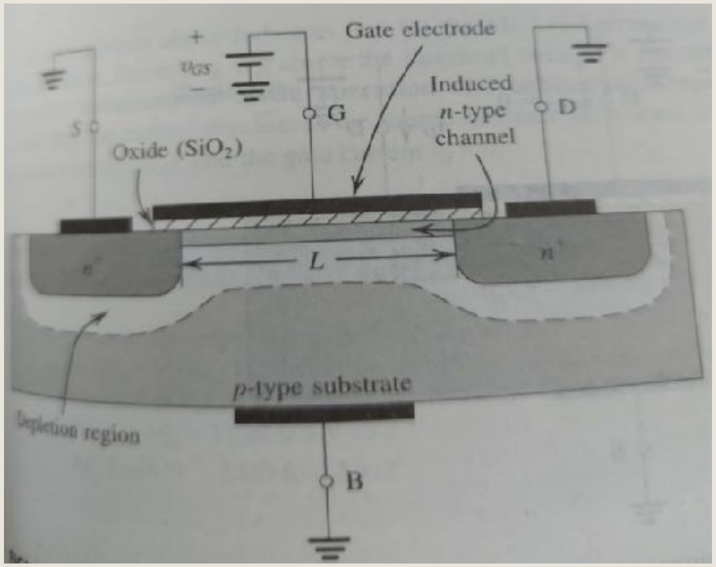
$$V_A \propto L \quad \text{or } V_A = V_A'L$$

- V_A' is another process-technology parameter with dimensions of V/µm.

- But the Voltage V_A is usually referred to as the Early voltage (J. M. Early)

Body Effect (Role of Body Terminal)

- We know that the Body(Substrate) of NMOS is connected to GND(most –ve terminal) and that of PMOS is connected to VDD (most +ve terminal).
- This is done to make diode formed between induced channel and body, reverse bias. i.e. body becomes inactive.



- Now if some +ve or –ve voltage is applied between source and body(V_{SB}), then it will have some effect on device operation.
- Let us consider NMOS and let its substrate is made –ve relative to source.

Body Effect

- The reverse bias voltage will widen the depletion region. This in turn reduces the channel depth. So Vgs has to be increased to increase ID.
- Thus it can be concluded that, increasing the reverse substrate bias voltage VSB results in an increase in Vt. This is given by :

$$V_t = V_{t0} + \gamma[\sqrt{2\Phi_f + V_{SB}} - \sqrt{2\Phi_f}] \quad \text{----(A)}$$

- Where V_{t0} is the threshold voltage for $V_{SB}=0$; Φ_f is a physical parameter with $2\Phi_f$ typically 0.6V; γ is a fabrication-process parameter given by:

$$\gamma = \frac{\sqrt{2qN_A\varepsilon_s}}{Cox}$$

- Where q is charge of electron; N_A is doping concentration of p-type substrate; ε_s is permittivity of silicon
- The parameter γ is also known as Body effect parameter and has dimensions of $\sqrt{V}$
- Equation (A) indicates that an incremental change in VSB gives rise to an incremental change in Vt which in turn results in an incremental change in ID even though VGS might have been kept constant

Body Effect

- Equation (A) indicates that an incremental change in VSB gives rise to an incremental change in Vt which in turn results in an incremental change in ID even though VGS might have been kept constant

- It follows that the body voltage controls drain current ID, thus body acts as another gate for MOSFET, a phenomenon known as Body Effect.

- Body/substrate is sometimes also called as Back Gate of MOSFET.

Its time for Quiz

https://forms.gle/UB7fsWHeq1zNUNMM9