EE539: ANALOG INTEGRATED CIRCUIT DESIGN.

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$\mathbf{V_{DS}} \uparrow \Longrightarrow \mathbf{I} \uparrow$ $\quad \Rightarrow \overrightarrow{E}$ feild increases $\Rightarrow$Charge moves faster; I increases;

$\mathbf{V_{GS}} \uparrow \Longrightarrow \mathbf{I} \uparrow$ $\quad$ because channel charges increases $\Rightarrow$ R decreases.

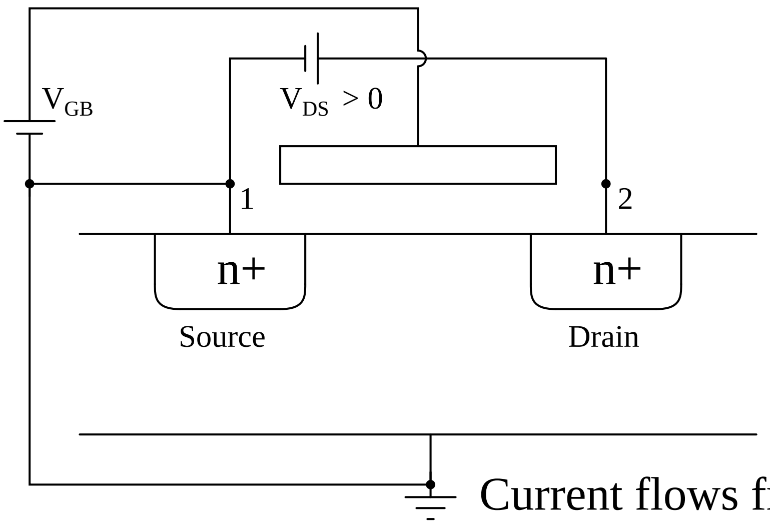
$$I = (\frac{Q_{tot}}{L_0})v \Longrightarrow -(V_{GS} - V_T - V_x)C_{ox}W = (\frac{Q_{tot}}{L})v$$

$$I = C_{ox}W(V_{GS} - V_T - V_x)\mu_n \frac{dV(x)}{dx}$$

$$\int_0^L I_D dx = \int_0^{V_{DS}} (V_{GS} - V_T - V_x) dv$$

$$I_D = \mu_n C_{ox}(\frac{W}{L})((V_{GS} - V_T)V_{DS} - \frac{{V_{DS}}^2}{2}) \qquad V_{DS} < V_{GS} - V_T$$

$$I_{DS} = \mu_n C_{ox}(\frac{W}{2L})(V_{GS} - V_T)^2 \qquad (V_{DS} > V_{GS} - V_T)$$

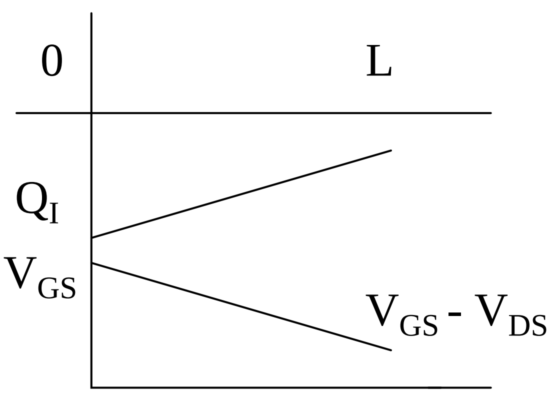


$V_{21} > 0$ — 2 . Drain, 1 . Source

$V_{21} < 0$ — 2 . Source, 1 . Drain

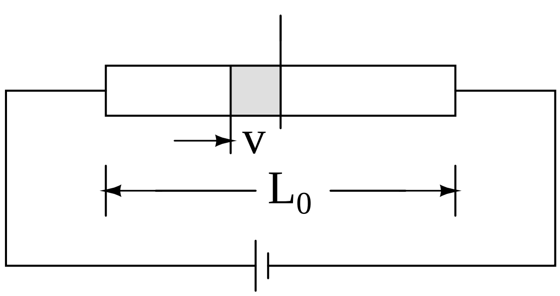
Current flows from drain to source (N-Mos)

(All voltages referred to Source.)

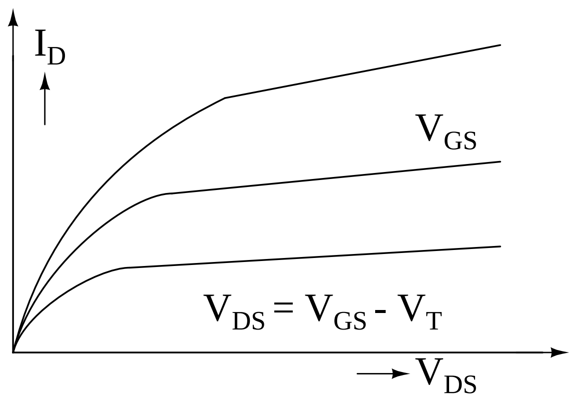


Gate to channel voltage is smaller at Drain than at Source.

V(x) - Channel potential w.r.t Source



$$\frac{Q_{tot}}{L_0} v$$



$$I_D = \mu_n C_{ox} (\frac{W}{L})((V_{GS} - V_T)V_{DS} - \frac{{V_{DS}}^2}{2}) \qquad 0 \leq V_{DS} \leq V_{GS} - V_T$$

$$I_{DS} = \mu_n C_{ox} (\frac{W}{2L})(V_{GS} - V_T)^2 \qquad V_{DS} \geq V_{GS} - V_T$$

$$I_{DS} = 0 \qquad V_{GS} < V_T$$

$\mathbf{V_{GS} - V_T}$ - Overdrive Voltage (bias after you turn it on)

- **Square law Device :** (Large W,L few μm)
  Square law model valid for large Devices.
  applications : Can be used in multipliers.

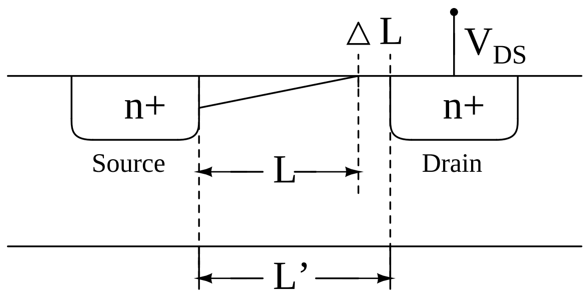
- $\mathbf{I_D \propto W}$: reasonably accurate.
  Current Density remains the same but I increases.

- $\mathbf{I_D \propto 1/L}$: not exact;
  Not quiet exact for short channels; for long channel FETs true.

- In triode regoin for very small V_{DS}

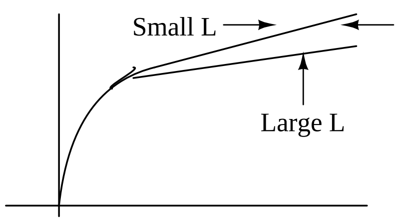
$$I_D \approx \mu_n C_{ox} (\frac{W}{L})(V_{GS} - V_T)V_{DS} \qquad V_{DS} << V_{GS} - V_T$$

$\Rightarrow$ conductor or resistor; value can be varied by varying the bias.



Region over which charge is present diminishes as we increase V_{DS}

For long channel devices L-L’ is small compared to L;



due to decrease in effective Length

Electronically Variable Resistor :

$$\mu_n C_{ox}(W/2L)(V_{GS}-V_T)^2 \frac{L}{L'(V_{DS})}$$

$$\frac{L}{L'(V_{DS})} = \frac{L}{L-\Delta L(V_{DS})} = \frac{1}{1-\frac{\Delta L(V_{DS})}{L}} \approx 1 + \frac{\Delta L(V_{DS})}{L}$$

A given change in length has smaller effect for longer channel

$$\frac{\Delta L}{L} = 1 + K_{eq}\frac{V_{DS}}{L} = 1 + \lambda V_{DS}$$

$$\mu_n C_{ox}(W/2L)(V_{GS}-V_T)^2(1+\lambda V_{DS})$$

Discontinuity in Graph.