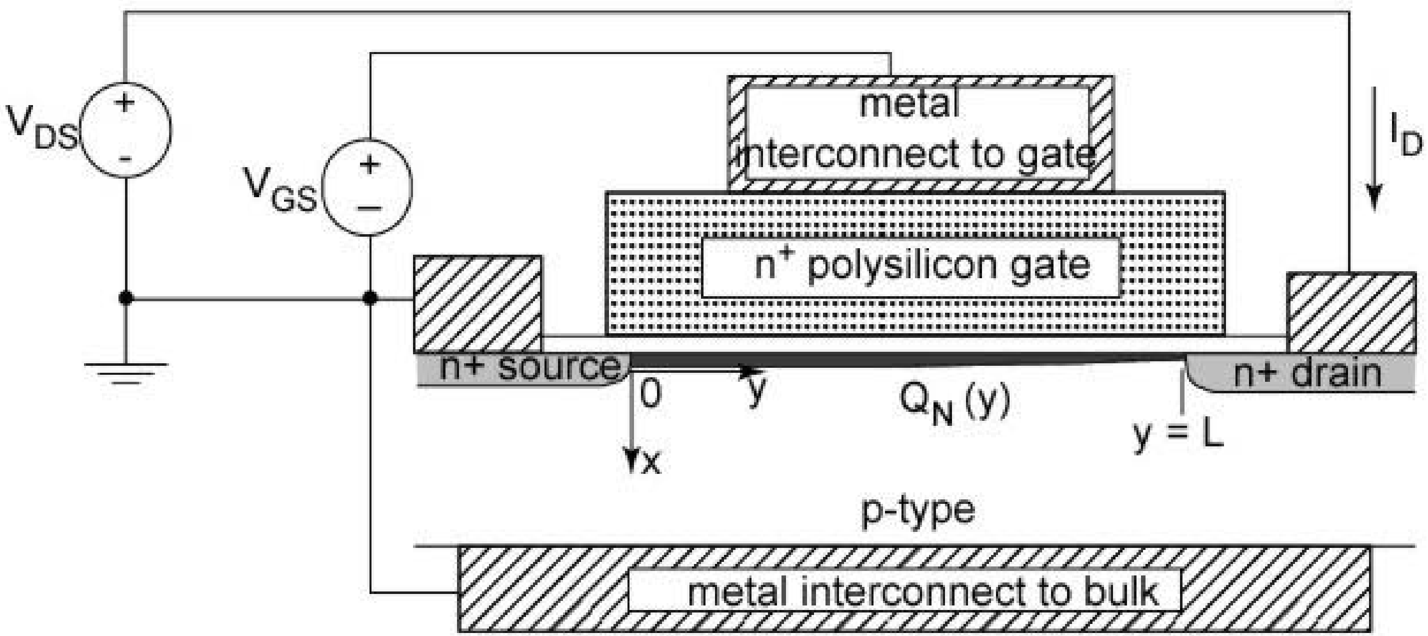
Lecture 14

- Last time:
  - MOS field effect transistor (MOSFET) current-voltage characteristics
- Today : quantitative models for $I_D(V_{GS},V_{DS})$ for :
  - Square-law MOSFET model
  - Linear MOSFET model

Finding $I_D = f(V_{GS}, V_{DS})$

- Approximate inversion charge $Q_N(y)$: drain is higher than the source → less charge at drain end of channel



Inversion Charge

$$Q_N(y) \approx Q_N(y=0) + Q_N(y=L)$$

$$Q_N(y=0) = -C_{ox}(V_{GS} - V_{Tn})$$

$$Q_N(y=L) = -C_{ox}(V_{GD} - V_{Tn})$$

$$V_{GD} = V_{GS} - V_{DS}$$

Average inversion charge:

Drift Velocity and Drain Current

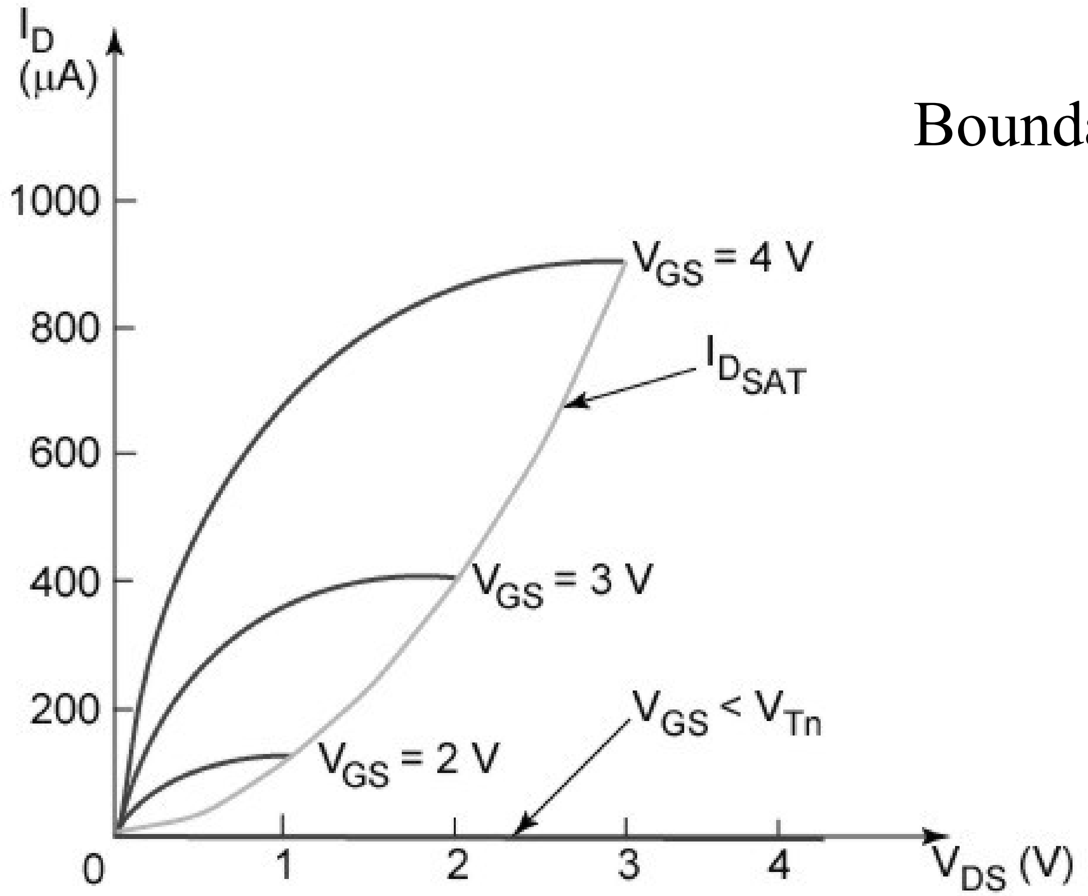
"Long-channel" assumption: use mobility to find v

$$v(y) = -\mu_n E(y) \approx -\mu_n(-\Delta V / \Delta y) = \mu_n V_{DS} / L$$

Substituting:

$$I_D = -W v Q_N \approx$$

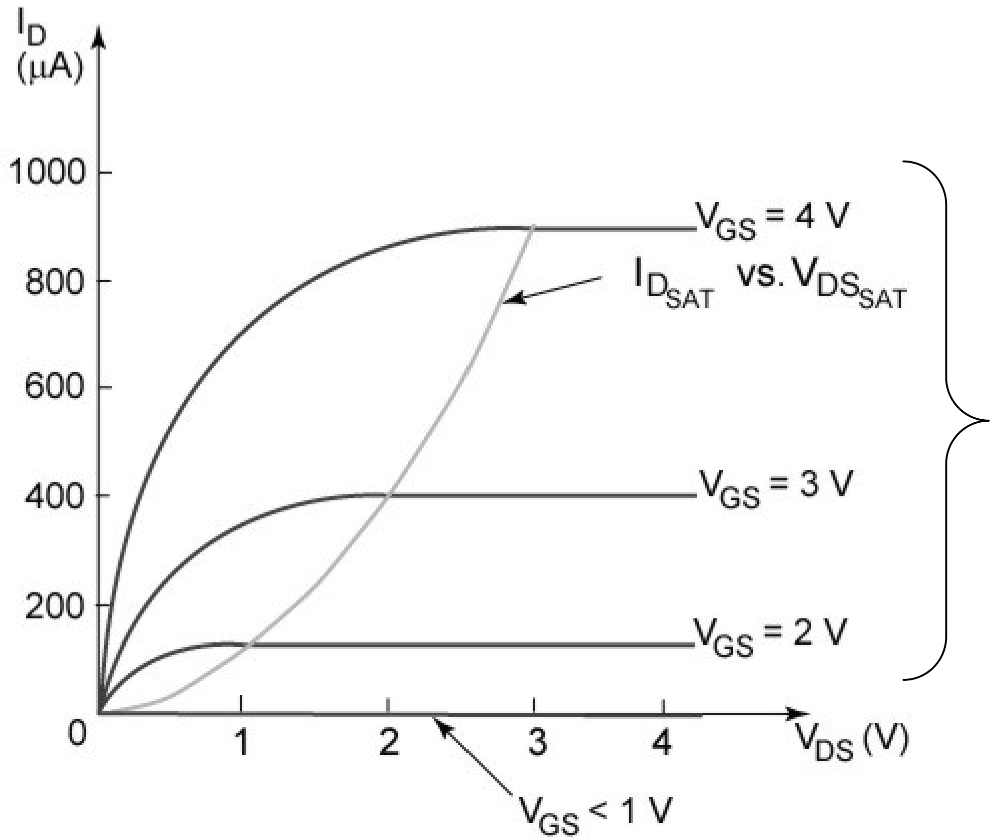
Square-Law Characteristics



Boundary: what is $I_{D,SAT}$?

The Saturation Region

When $V_{DS} > V_{GS} - V_{Tn}$, there isn't any inversion charge at the drain … according to our simplistic model



Why do curves flatten out?

Square-Law Current in Saturation

Current stays at maximum (where $V_{DS} = V_{GS} - V_{Tn} = V_{DS,SAT}$)

$I_D =$

Measurement: I_D increases slightly with increasing V_{DS}
model with linear "fudge factor"

$I_{D,SAT} =$

Linear MOSFET Model

Channel (inversion) charge: neglect reduction at drain

Velocity saturation defines $V_{DS,SAT} = E_{sat} L$ = constant

↖ $- v_{sat} / \mu_n$

Drain current:

$$I_{D,SAT} = -WvQ_N = -W(v_{sat})[-C_{ox}(V_{GS} - V_{Tn})],$$

$|E_{sat}|$ = 10^4 V/cm, L = 0.12 μm → $V_{DS,SAT}$ = 0.12 V!

Linear MOSFET in Saturation

$$I_{D,SAT} = v_{sat} W C_{ox} (V_{GS} - V_{Tn})(1 + \lambda_n V_{DS})$$

Implication of weaker dependence on V_{GS}: