Fundamentals of Nanotransistors

Unit 1: Transistor Fundamentals

Lecture 1.8: Unit 1 Summary

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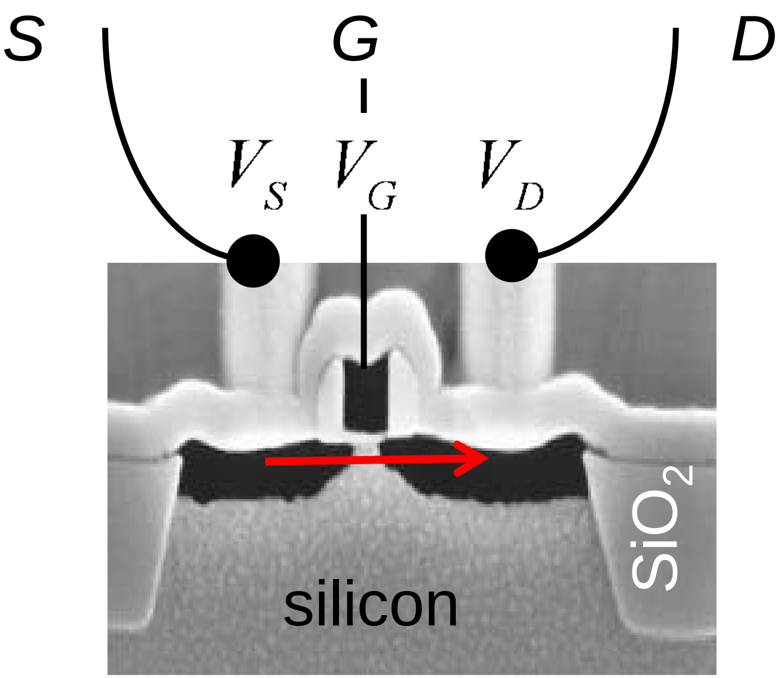
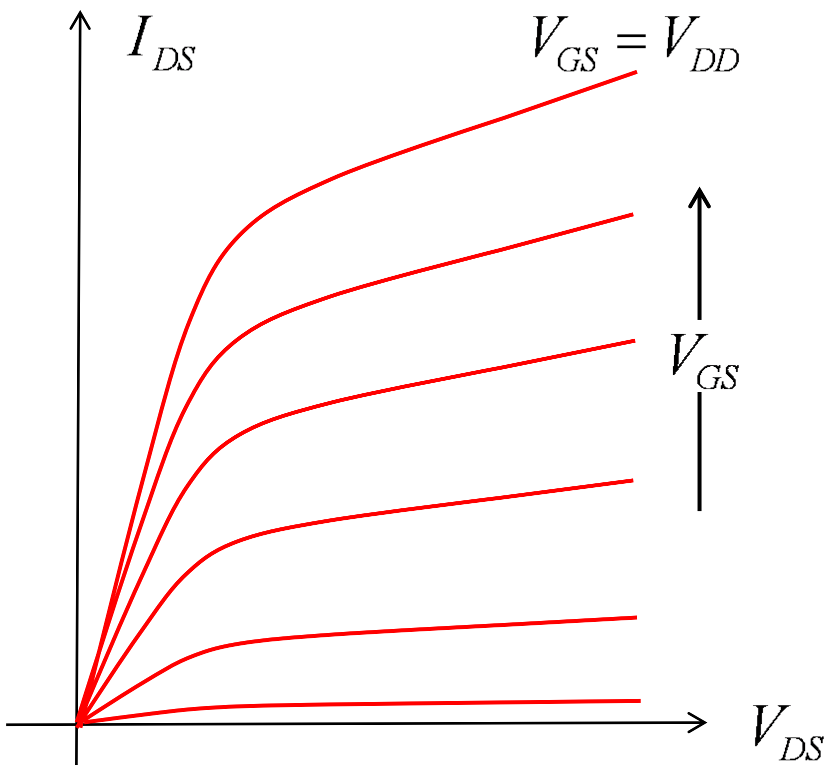
Outline: Unit 1

Lecture 1.1: Introduction
Lecture 1.2: The MOSFET as a Black Box
Lecture 1.3 MOSFET Device Metrics
Lecture 1.4 Transistors to Circuits
Lecture 1.5 Energy Band View of Transistors
Lecture 1.6 Traditional IV Theory
Lecture 1.7 The Virtual Source Model
Lecture 1.8 Unit 1 Summary

Lecture 1.1: Course objectives



(Source: Texas Instruments, ~ 2000)

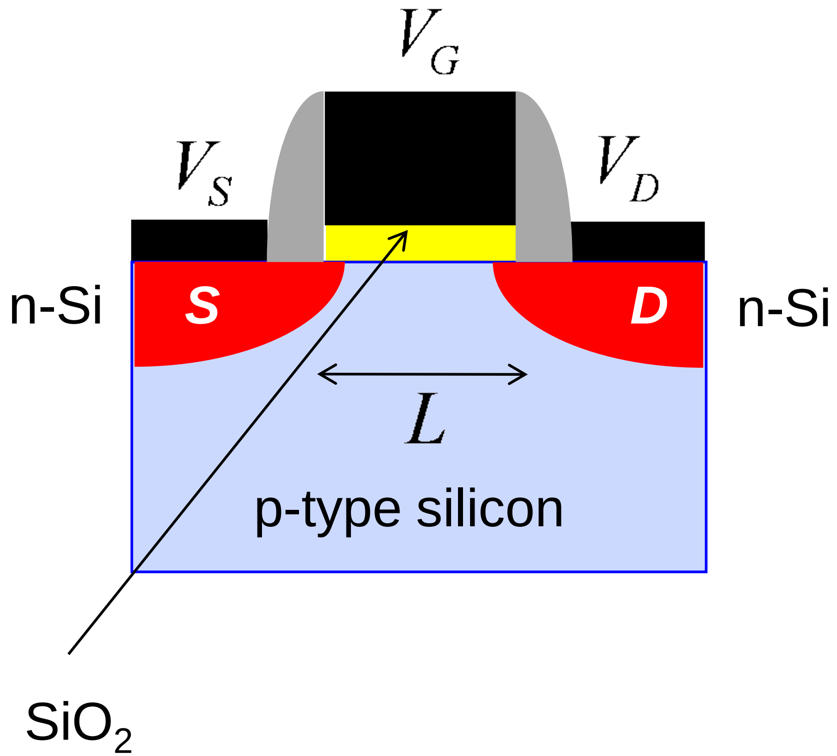


1) Understand the physical operation of nanoscale transistors.

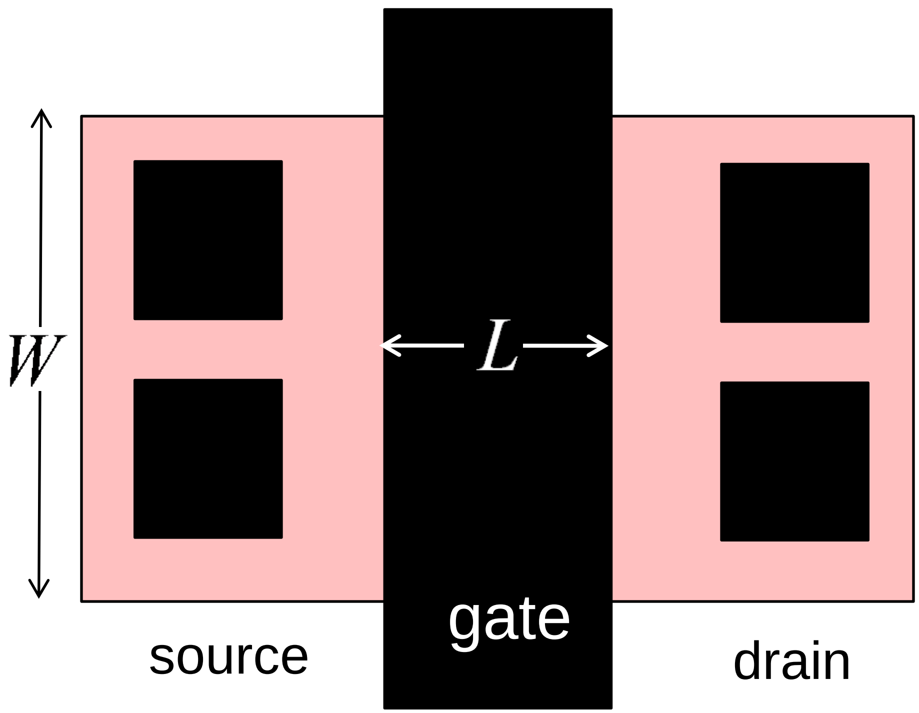
2) Relate that physical understanding to the *IV* characteristics.

Side and top views of a MOSFET

Metal **O**xide **S**emiconductor **F**ield **E**ffect **T**ransistor



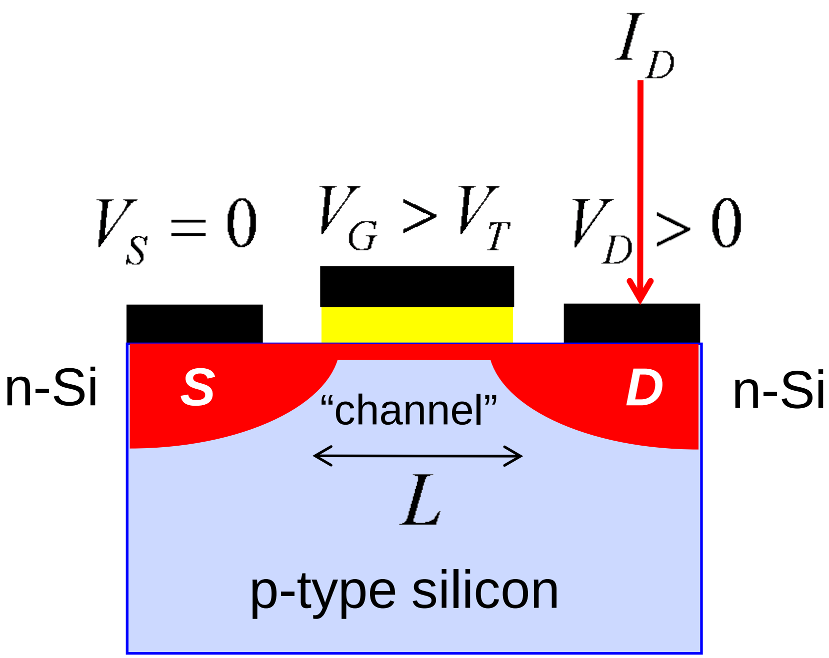
side view



top view

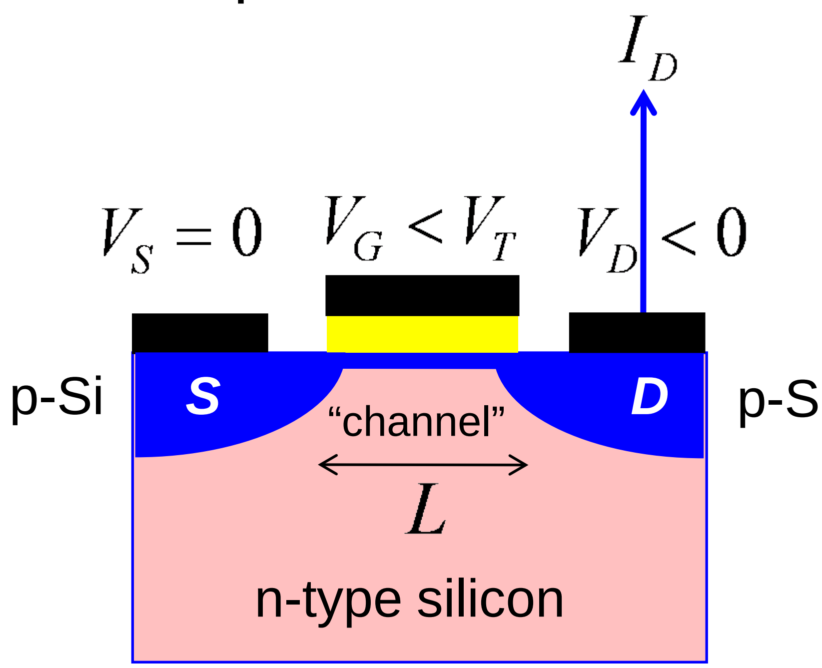
CMOS

n-MOSFET



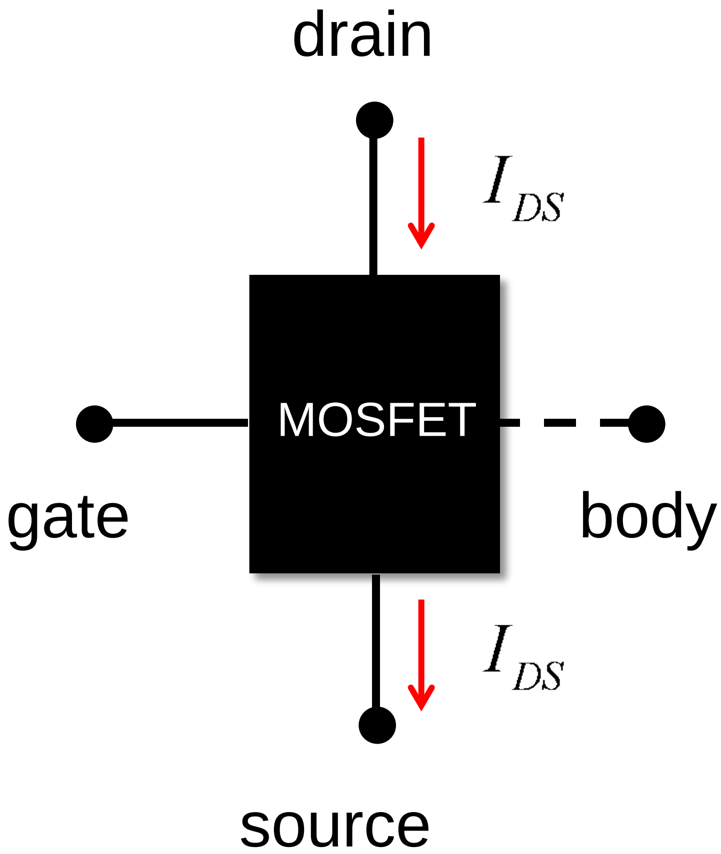
side view

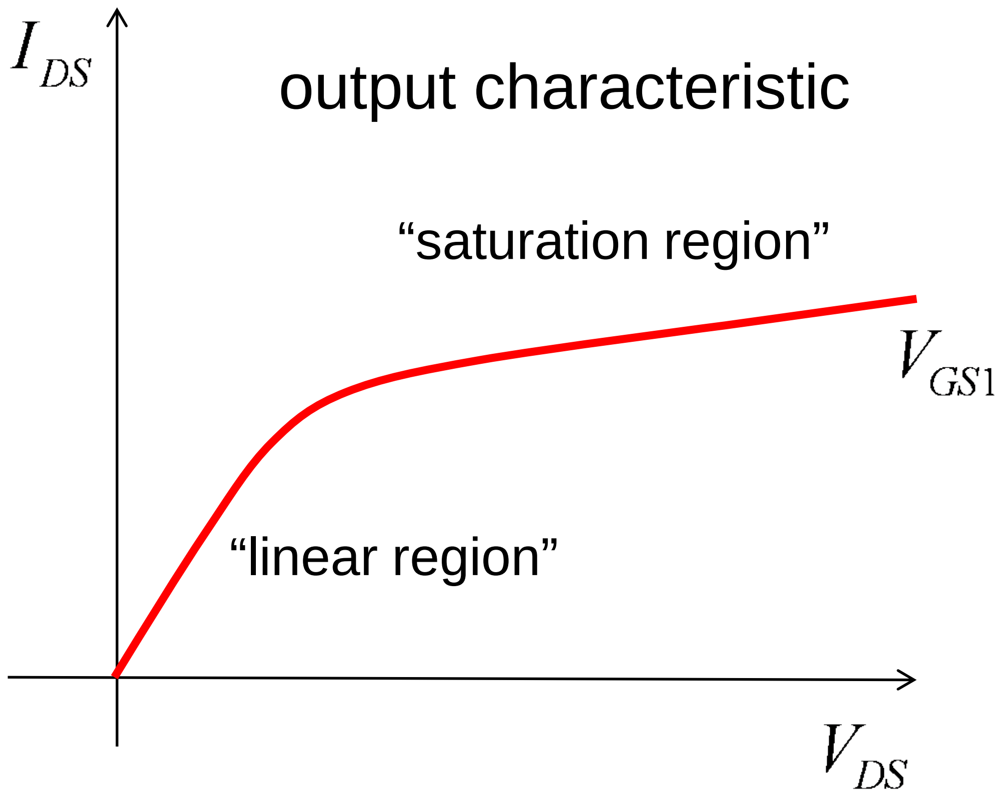
p-MOSFET



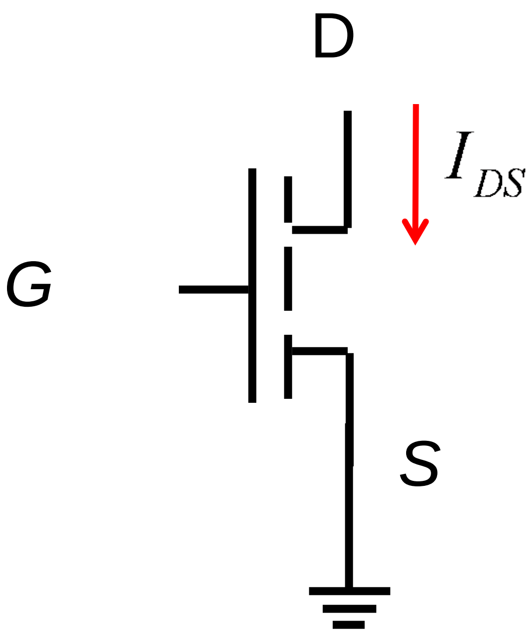
side view

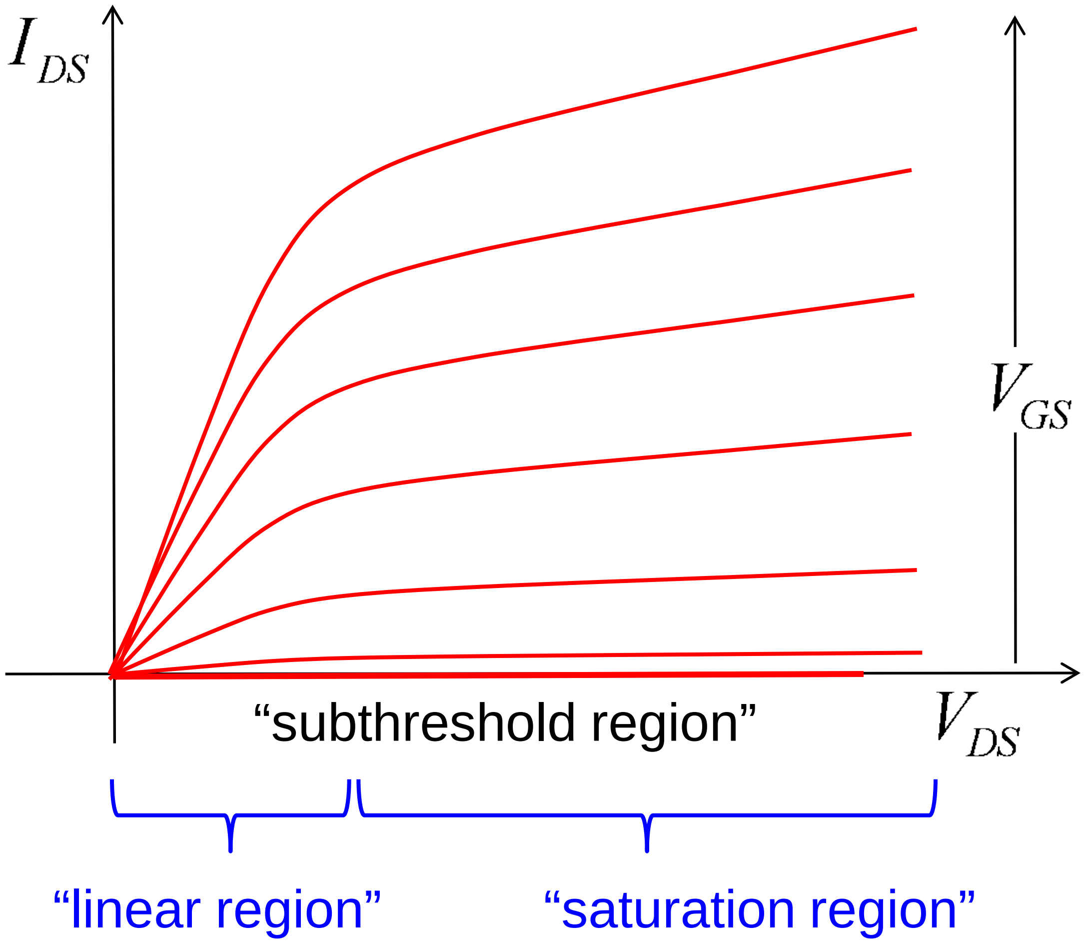
Lecture 1.2: MOSFET as black box





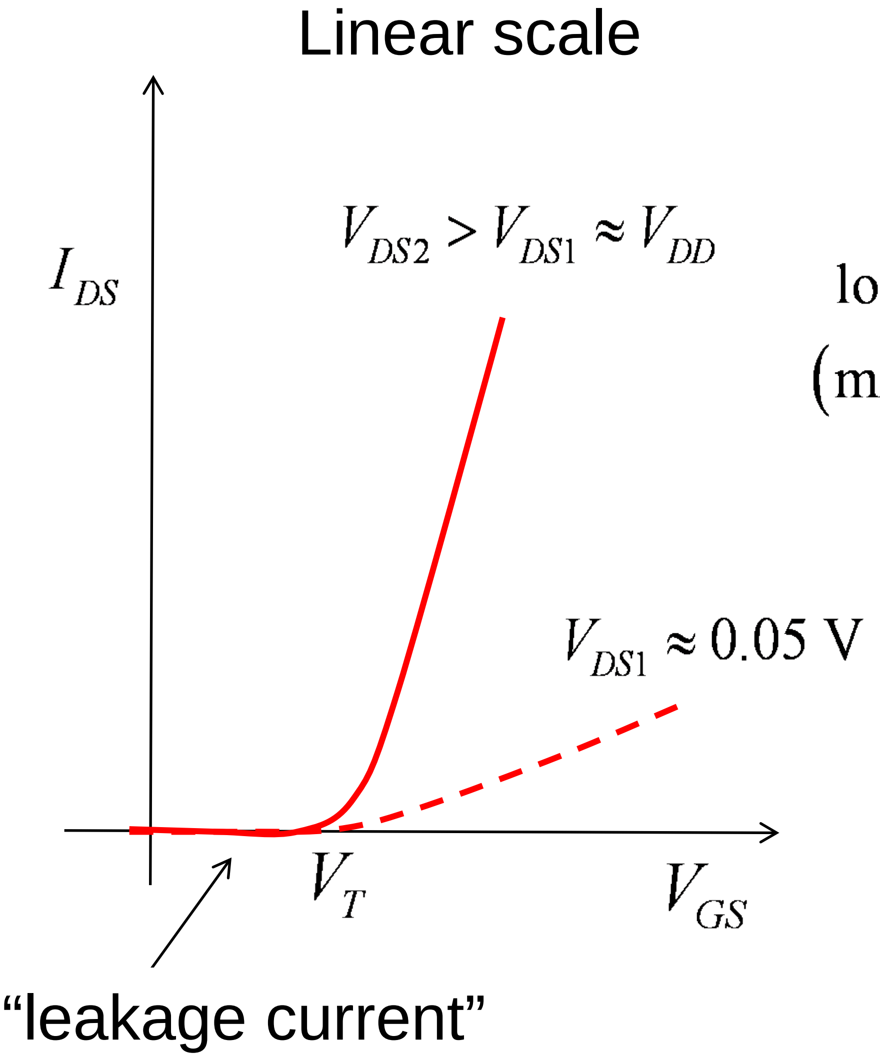
Output characteristics

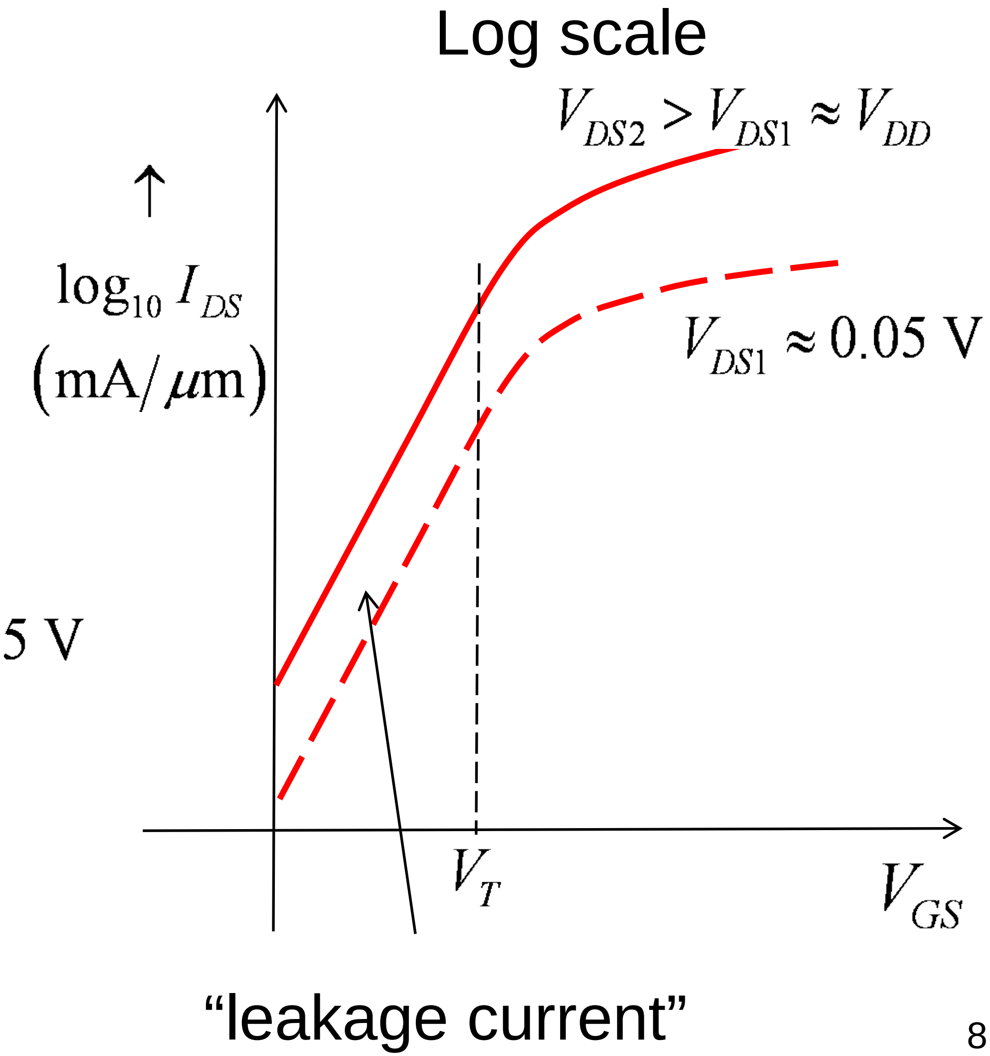




n-channel enhancement mode MOSFET

Transfer characteristics

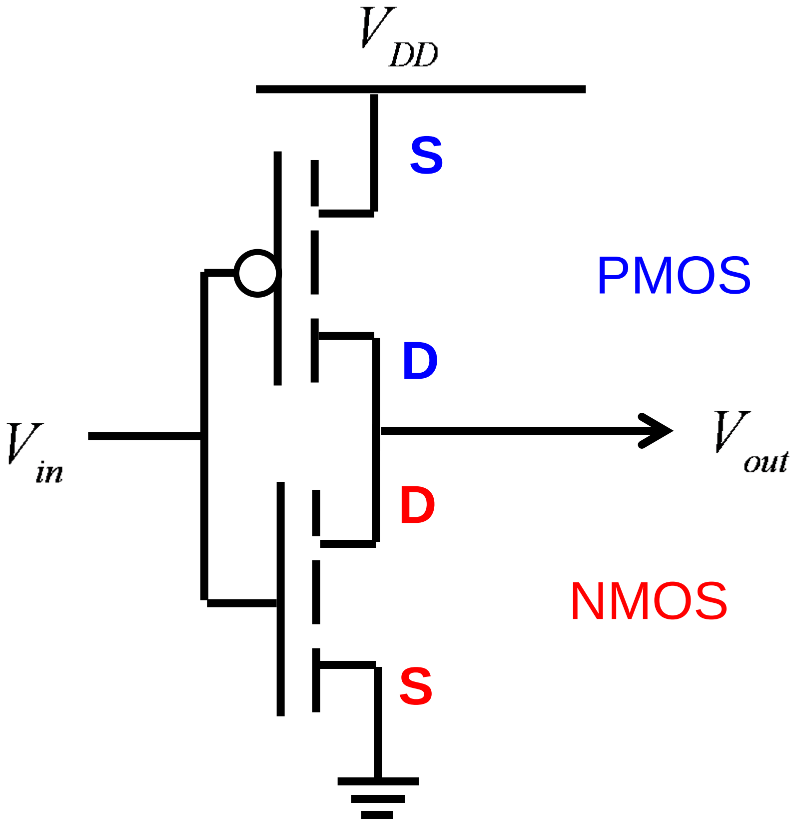




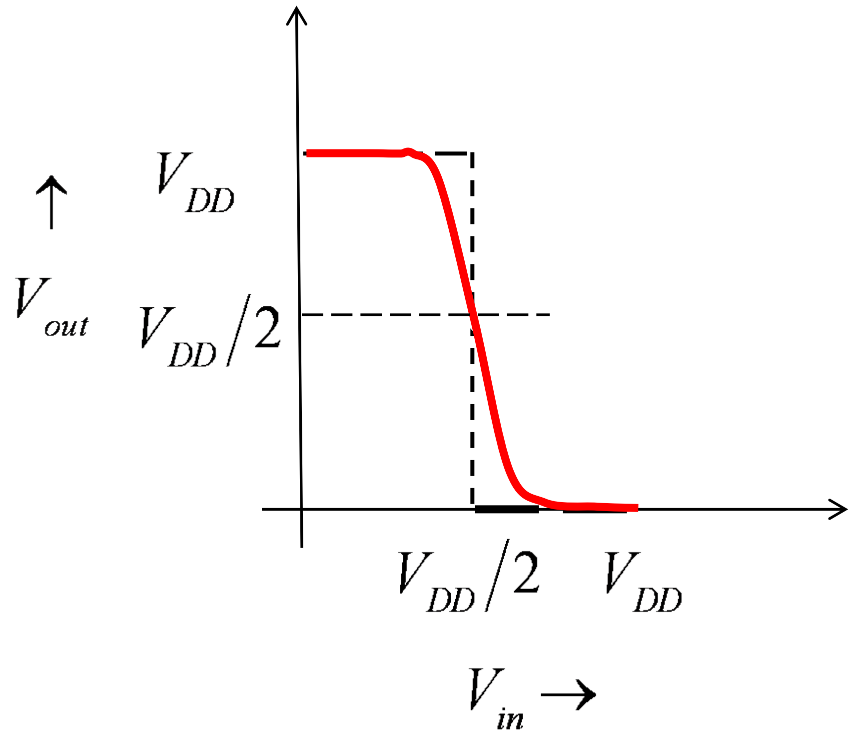
Lecture 1.3: Device parameters and metrics

1. on-current: I_{ON}
2. off-current: I_{OFF}
3. subthreshold swing, *SS*
4. drain induced barrier lowering: DIBL
5. threshold voltage: V_T (lin) and V_T (sat)
6. Drain to source resistance: R_{DS}
7. drain saturation voltage: V_{DSAT}
8. output resistance: r_o
9. *transconductance:* g_m

Lecture 1.4: CMOS inverter



Real transfer characteristic



Circuit performance

1) Switching energy: $E_S = \frac{1}{2} C_{sw} V_{DD}^2$

2) Dynamic power: $P_D = \alpha f C_{sw} V_{DD}^2$

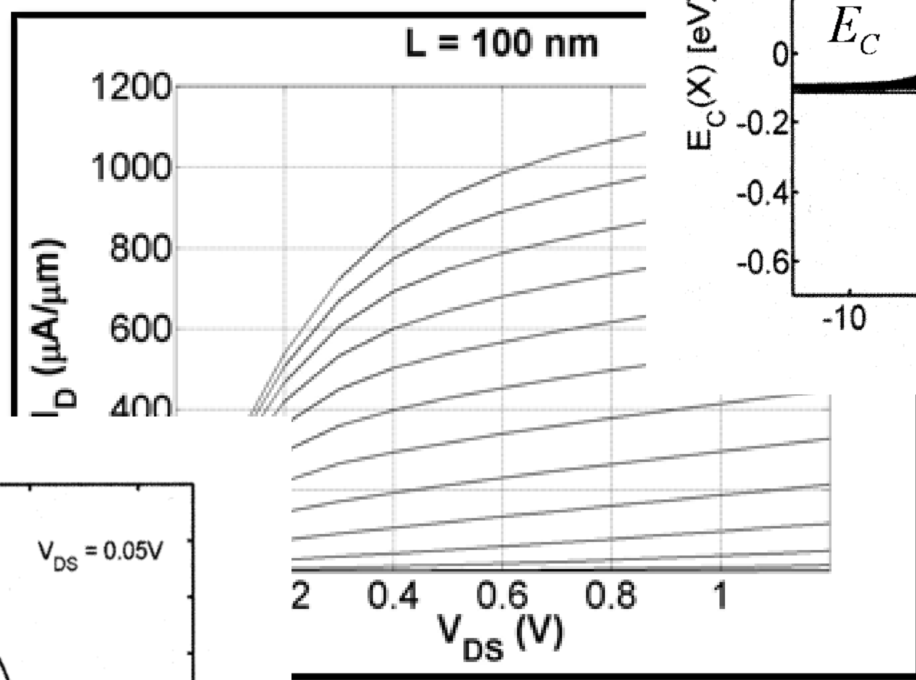
3) Standby power: $P_{SB} = I_{OFF} V_{DD}$

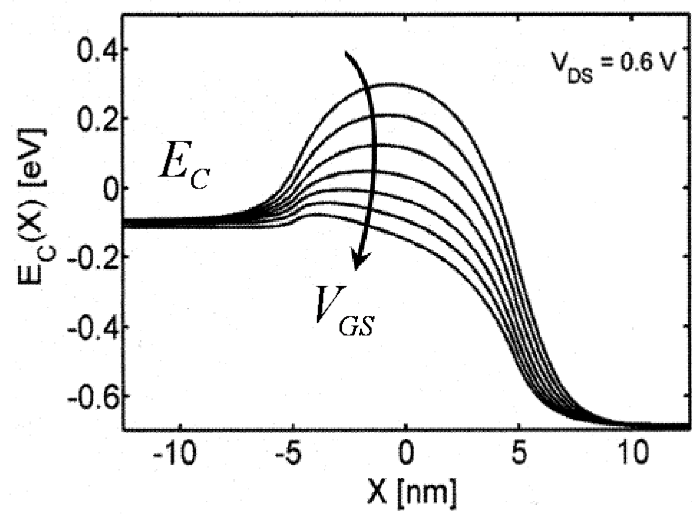
4) Switching delay: $\tau = \frac{C_{sw} V_{DD}}{2 I_{ON}}$

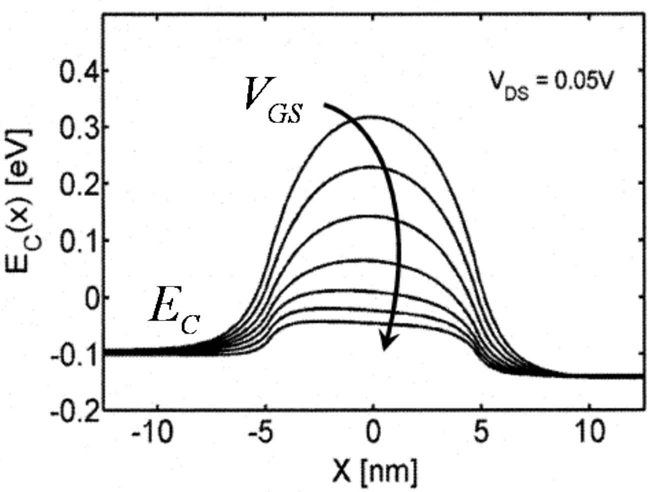
5) Noise margins: $|A_v| = g_m r_0 > 1$

Lecture 1.5: Energy band view

2007 N-MOSFET

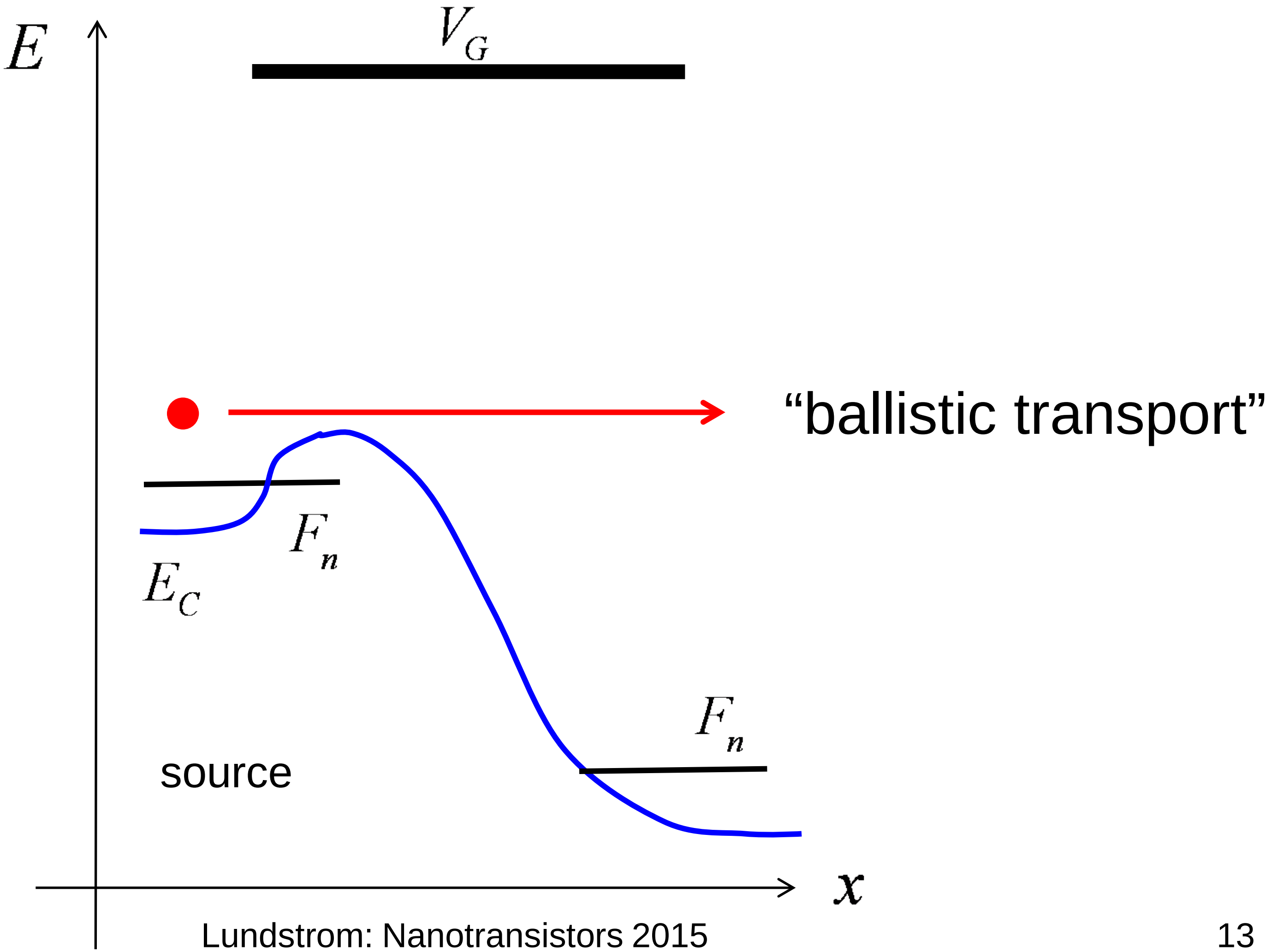




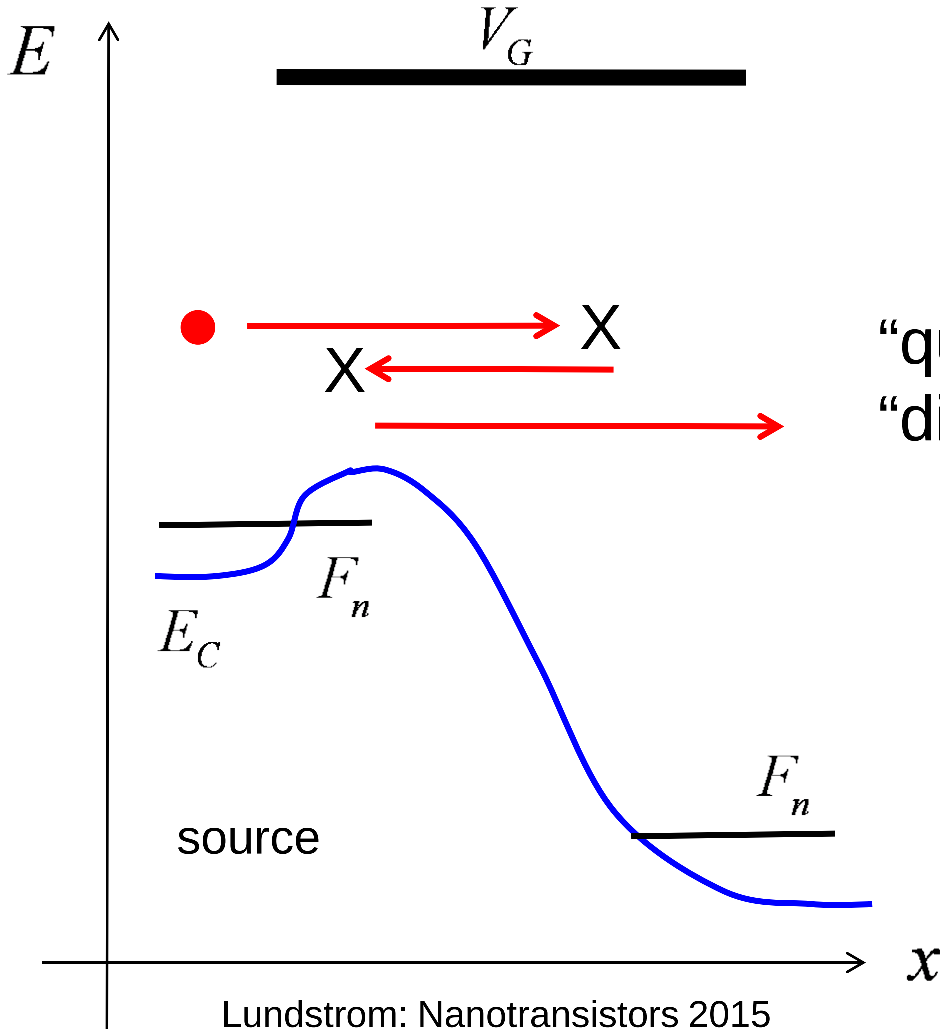


tesy, Shuji Ikeda, ATDF, Dec. 2007)

Importance of transport



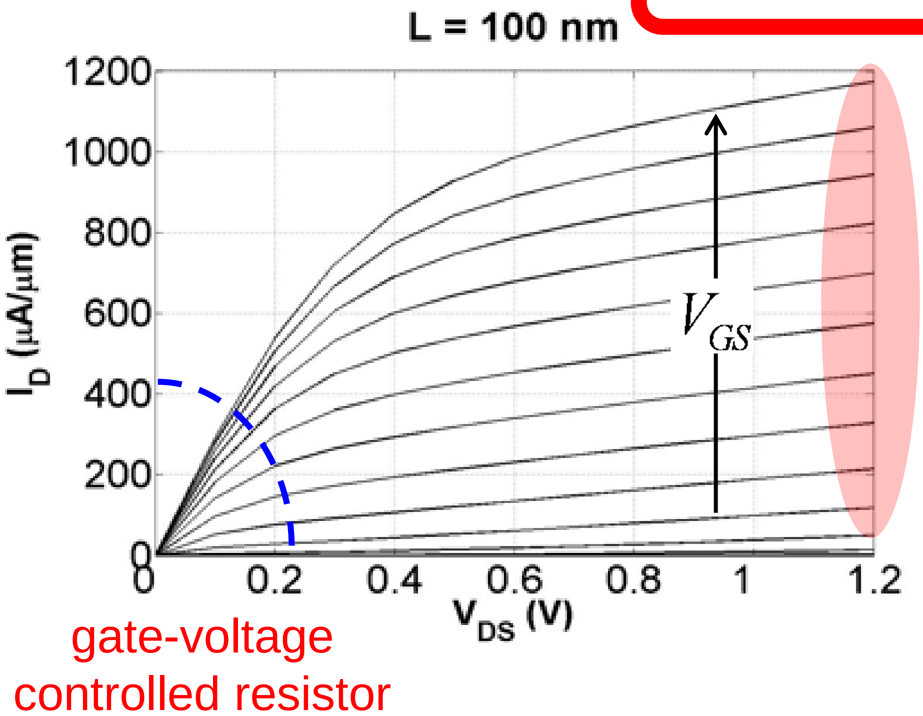
Importance of transport



"quasi-ballistic"
"diffusive:

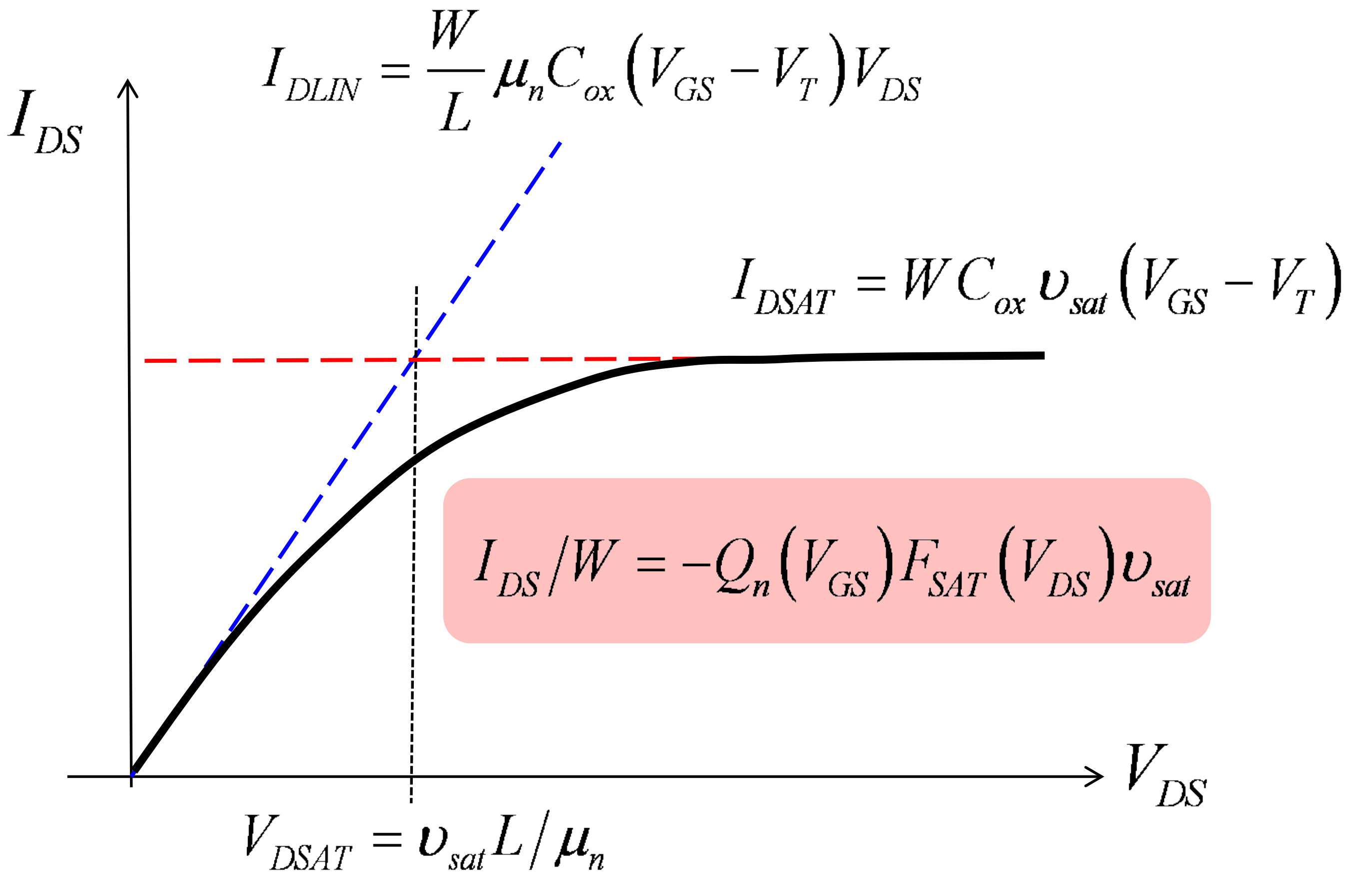
Lecture 1.6: MOSFET IV

$$I_D = W C_{ox} \upsilon_{sat} \left(V_{GS} - V_T\right)$$



$$I_D = \frac{W}{L} \mu_n C_{ox} \left(V_{GS} - V_T\right) V_{DS}$$

Lecture 1.7: Level 0 VS model



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Unit 2: MOS Electrostatics