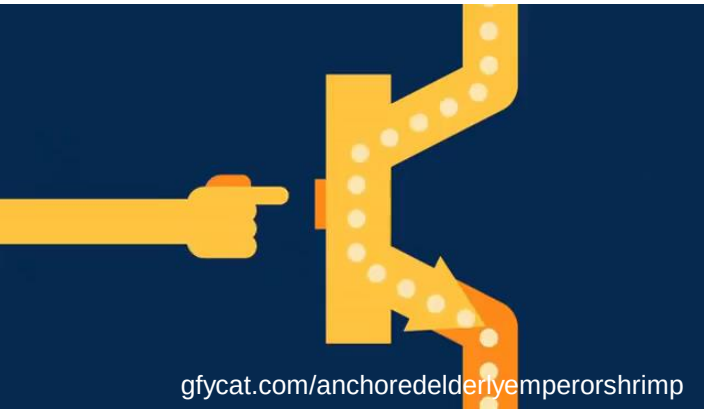
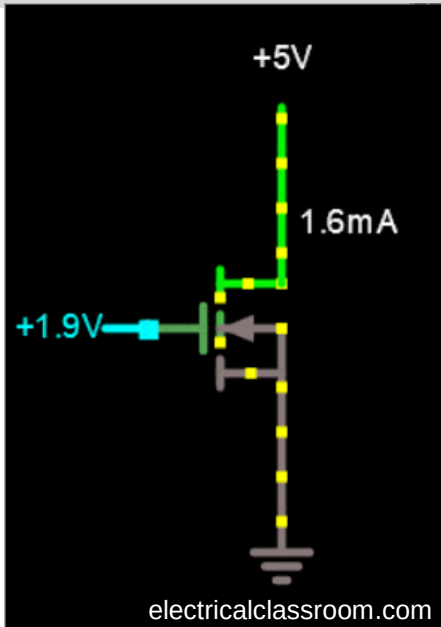
Introduction to Electronic Devices

EE302

Prof. Sangyoon Han

Fall 2023





Course info: general

- **Course number: EE302 (3 units)**
- **Lecture location: E7 236**
- **Lecture hours**
  - **Tue/Thu 4:00 – 5:15 PM**
- **Lecturer**
  - **Sangyoon Han, Robotics&Mechatronics Engineering**
  - **Email: s.han@dgist.ac.kr**
- **TA**
  - **Gyu Won Yang, ygw7692@dgist.ac.kr**
  - **Sang Ho Yu, sangho-yu@dgist.ac.kr**
- **Pre-requisite**
  - **Introduction to semiconductor physics (EE304)**

Course info: office hours

- **Office hours**
  - **Tue/Thu 5:15 – 5:45 PM**
  - **At E5, 308 (Prof. Han's office)**

Class schedule - tentative

- Week 1 : Semiconductor fundamentals 1
- Week 2 : Semiconductor fundamentals 2
- Week 3 : PN junction
- Week 4 : Metal-semiconductor contacts (Schottky diodes)
- Week 5 : Metal-oxide-semiconductor fundamentals 1
- Week 6 : Metal-oxide-semiconductor fundamentals 2
- Week 7 : MOSFETs: ideal
- Week 8 : Mid-term exam
- Week 9 : MOSFETs: electrostatics
- Week 10: MOSFETs: C-V characteristics
- Week 11: MOSFETs: nonideal
- Week 12: CMOS inverters
- Week 13: FinFET
- Week 14: Device applications 1
- Week 15: Device applications 2
- Week 16: Final exam

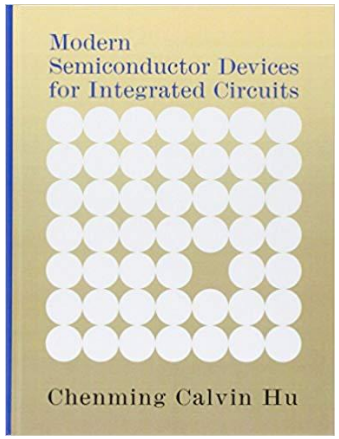
Grading

Criteria	Percentage (%)
Attendance	10
Homework	20
Midterm	30
Final exam	40

- **Attendance (10%):Up to two classes may be missed without a penalty. Beyond the two, there will be prorated penalty. Based on the DGIST rules, students must attend more than 75% of the entire classes in order not to fail (학칙 제48조).**

Textbooks

No.	Name	Authors	Publisher	Year
1	**Modern Semiconductor Devices for Integrated Circuits**	**Chenming Hu**	**Pearson**	**2009**
2	Semiconductor Device Fundamentals	Robert F. Pierret	Pearson Academic 퍼스트북	2018



Chenming Hu @ UC Berkeley

- **Available online**
  - **https://www.chu.berkeley.edu/modern-semiconductor-devices-for-integrated-circuits-chenming-calvin-hu-2010/**

Textbooks

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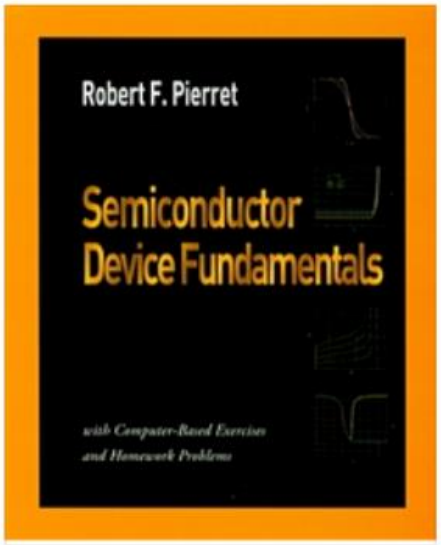


Robert F. Pierret @ Purdue University

- **Chapter 17, 18, 19 and more are available as PDF on the following webpage**
  - **http://www.firstbook.kr/bbs/board.php?bo_table=pds&wr_id=4**
- **Originally, it is 1997 version.**

Grading

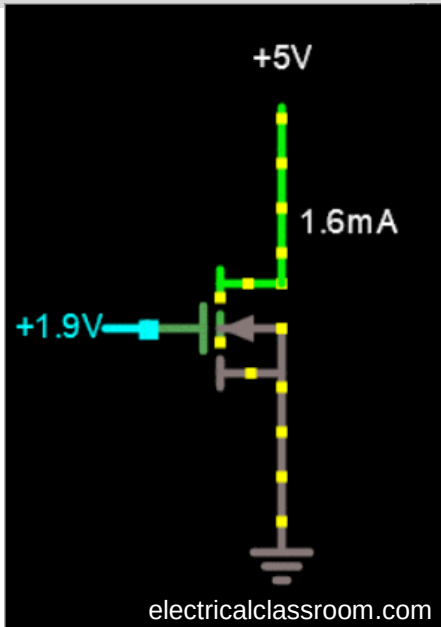
Criteria	Percentage (%)
Attendance	10
Homework	20
Midterm	30
Final exam	40

- **Midterm: During the midterm week (Oct 16–20) or One week after**
- **Final exam: During final week (Dec 11 – 15)**

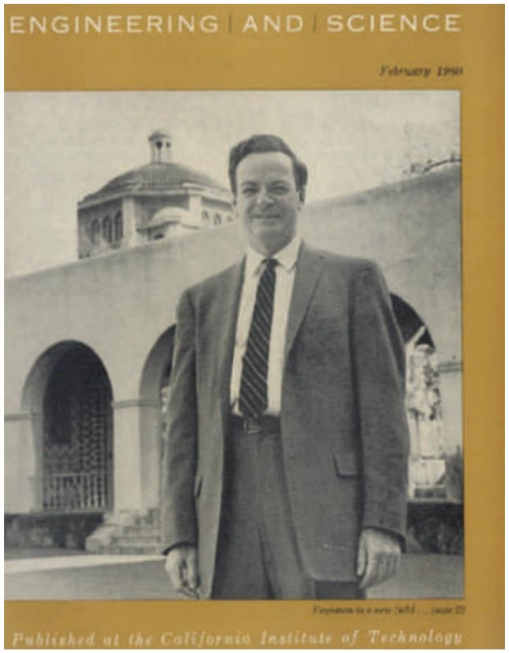
Today's lecture

- **Orientation to the potential students**
- **A lecture & Q&A session**

Introduction



There's plenty of room at the bottom!



ENGINEERING AND SCIENCE MAGAZINE / CALTECH

Feynman's 1959 lecture ventured far beyond physics.

"it turns out that all of the information that man has carefully accumulated in all the books in the world could be stored in ~10^{15} bits of information. For each bit I allow 100 atoms and conclude that it all could be stored in a cube of material that is one two-hundredth of an inch on a side (~.13mm)"

- **In year 1959, in Feynman's lecture….**
- **He said 100 atoms/bit!**

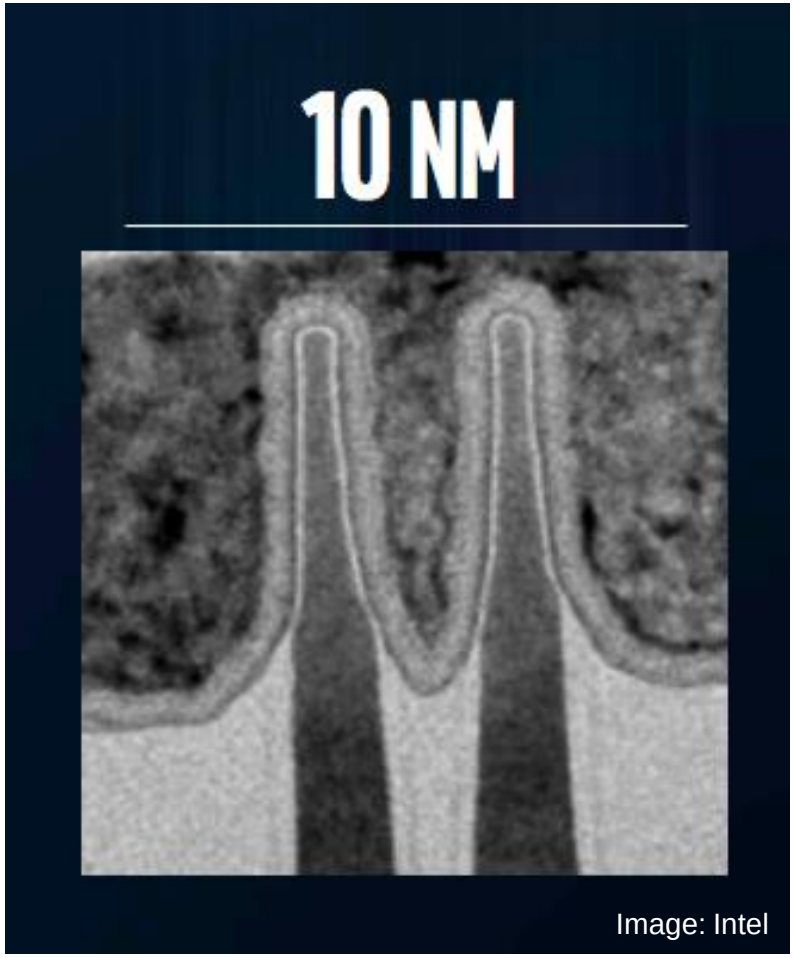
In year 1959

동대문 부근

한국 최초의 패션쇼

In 2020s

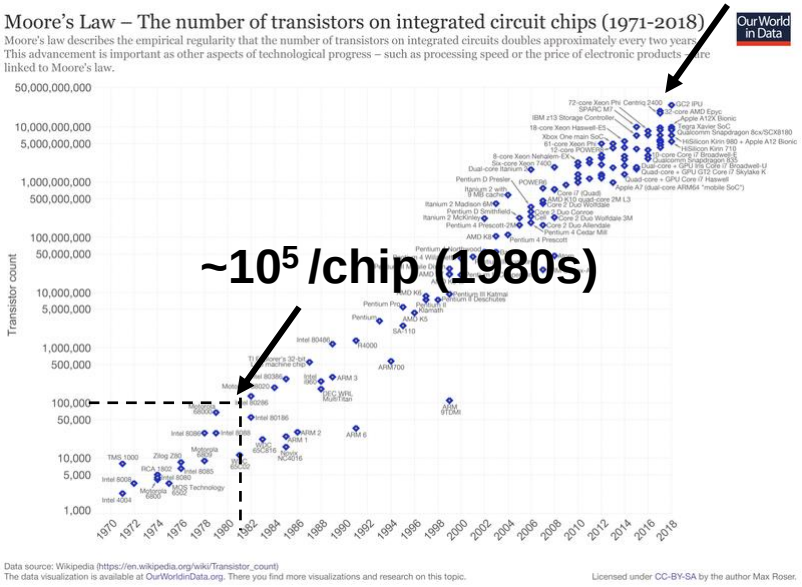
Transistor…



In 2020s

Moore's law

~10^{10} /chip



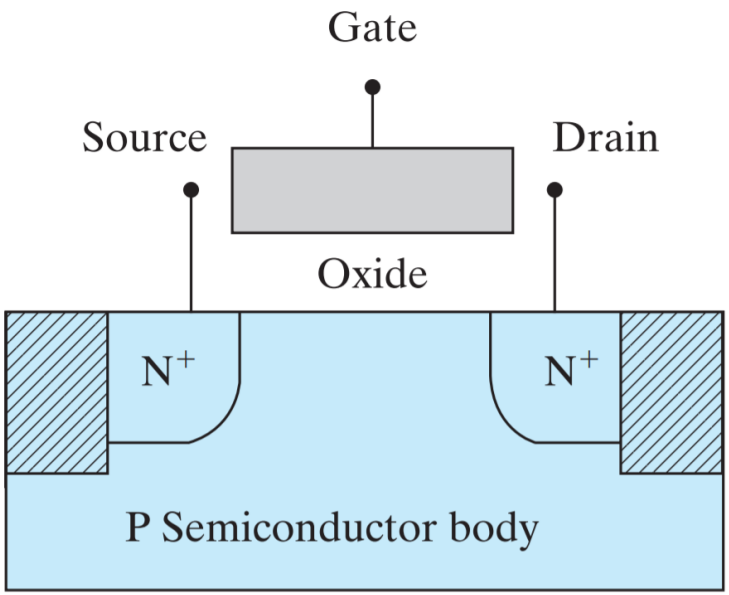
~10^{5} /chip (1980s)

ourworldindata.org

- **$(5nm)^3 \approx 10^3$ atoms (Si)**
- **Feynman said: 100 atoms/bit! (62 years ago)**

What you will learn in this class

Transistor (CMOS)



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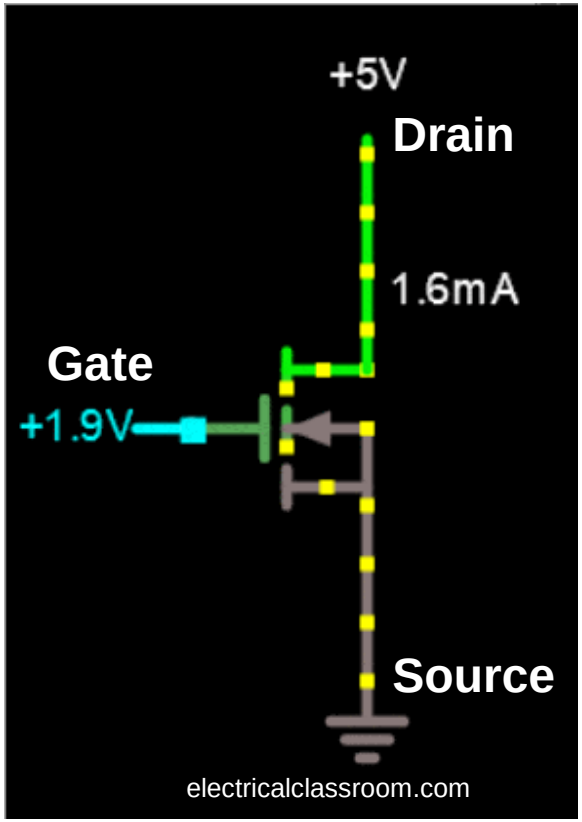

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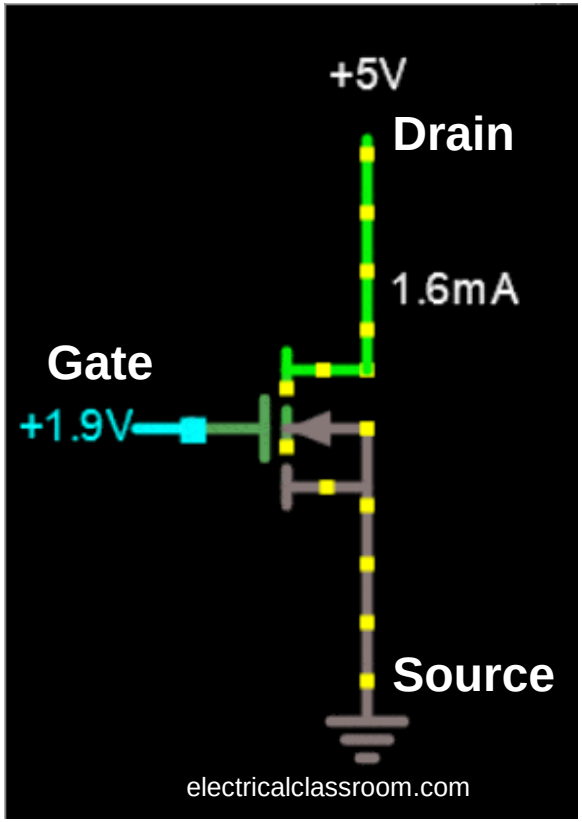

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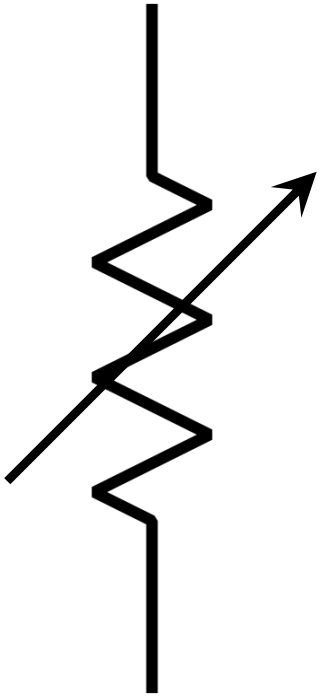
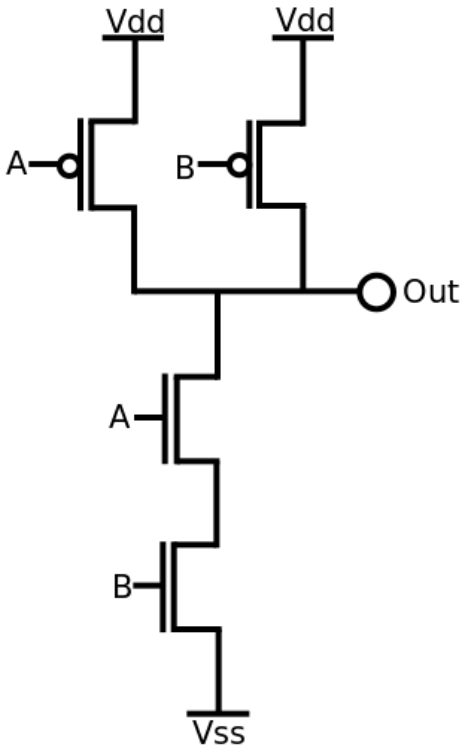
Variable resistor



Resistance is controlled electrically!

Logic device (NAND gate)



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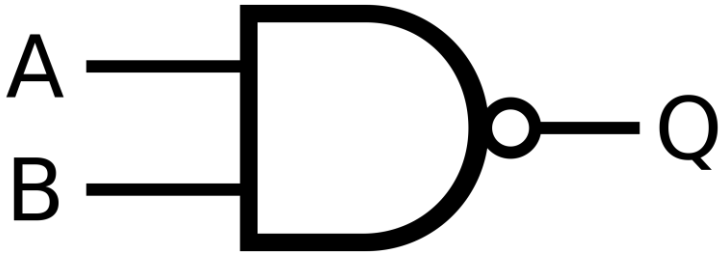
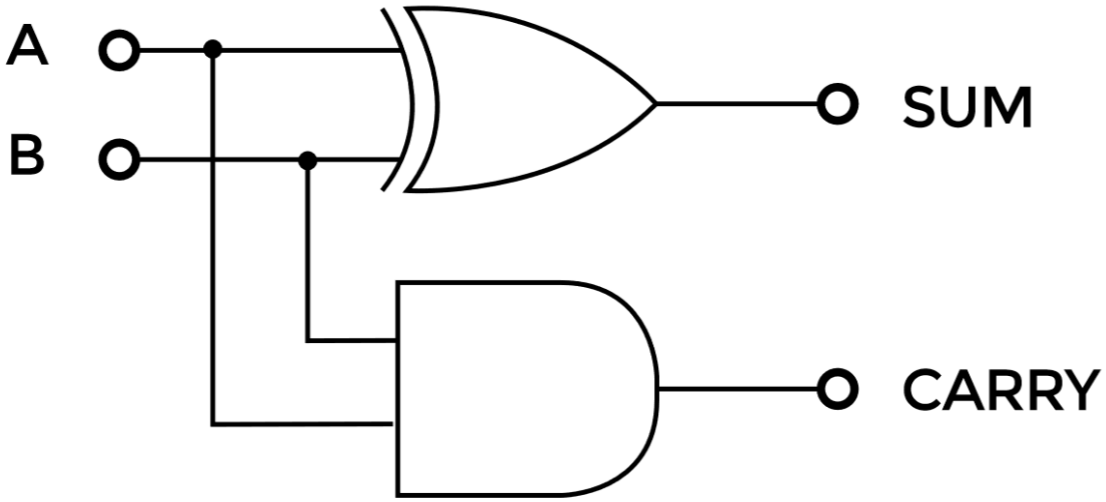


Input		Output
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

en.wikipedia.org/wiki/NAND_gate

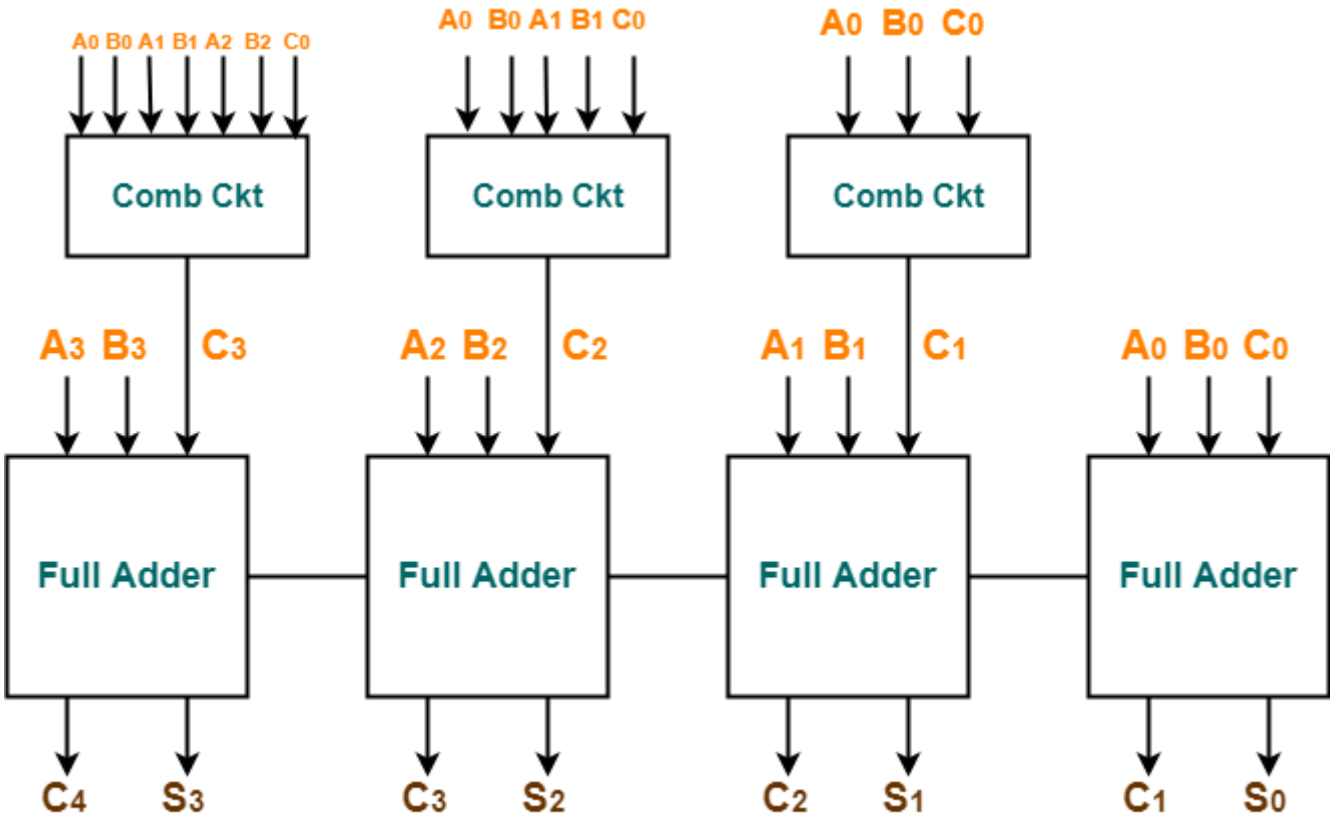
Adder (2진수)



A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

projects.raspberrypi.org/

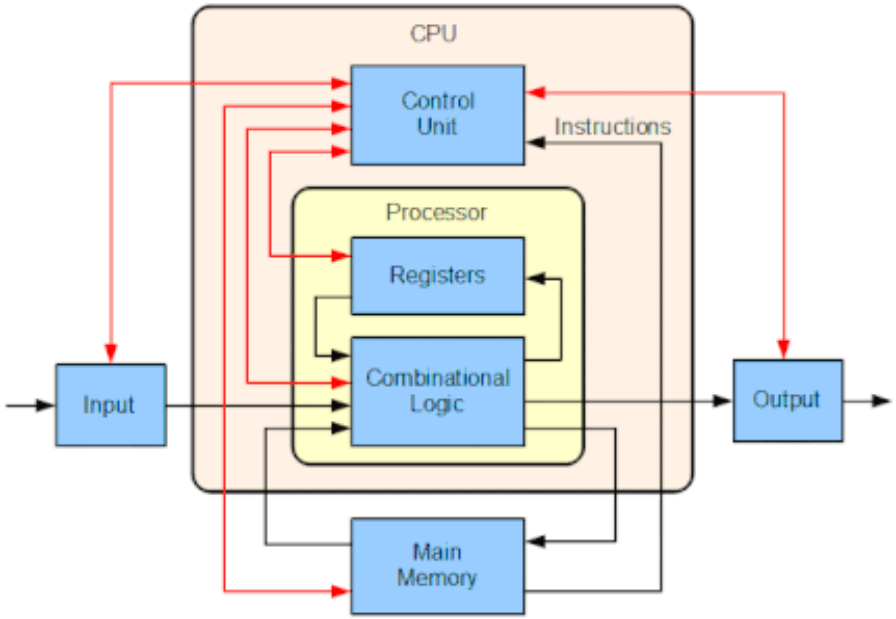
More complex adder (진짜 덧셈 같은…)



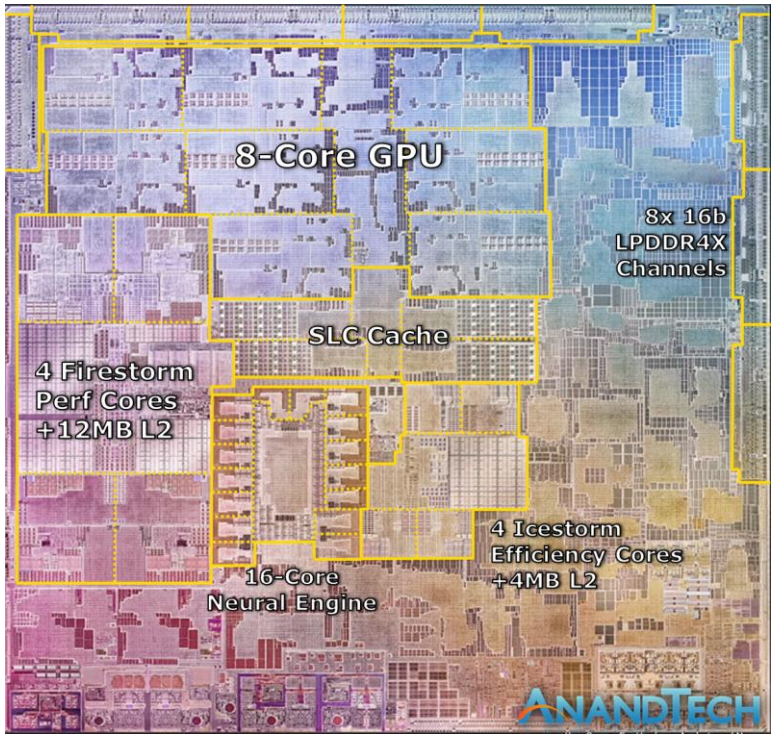
Carry Look Ahead Adder Logic Diagram

gatevidyalay.com

CPU



M1 processor (Apple)

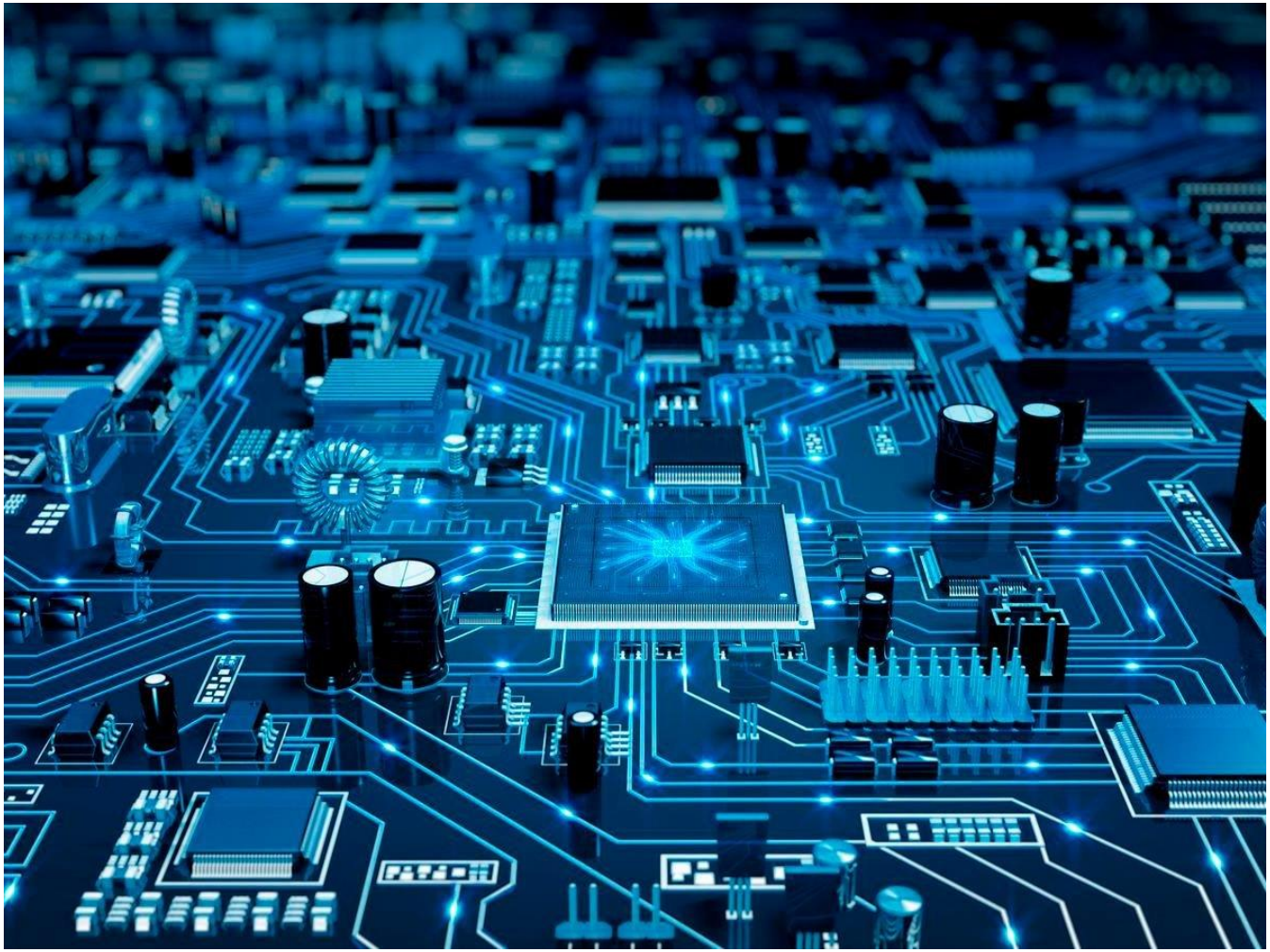


- **~40 billion transistors in CPU today**

www.anandtech.com/show/16252/mac-mini-apple-m1-tested

en.wikipedia.org/wiki/Computer_architecture

Computer! (Finally…)

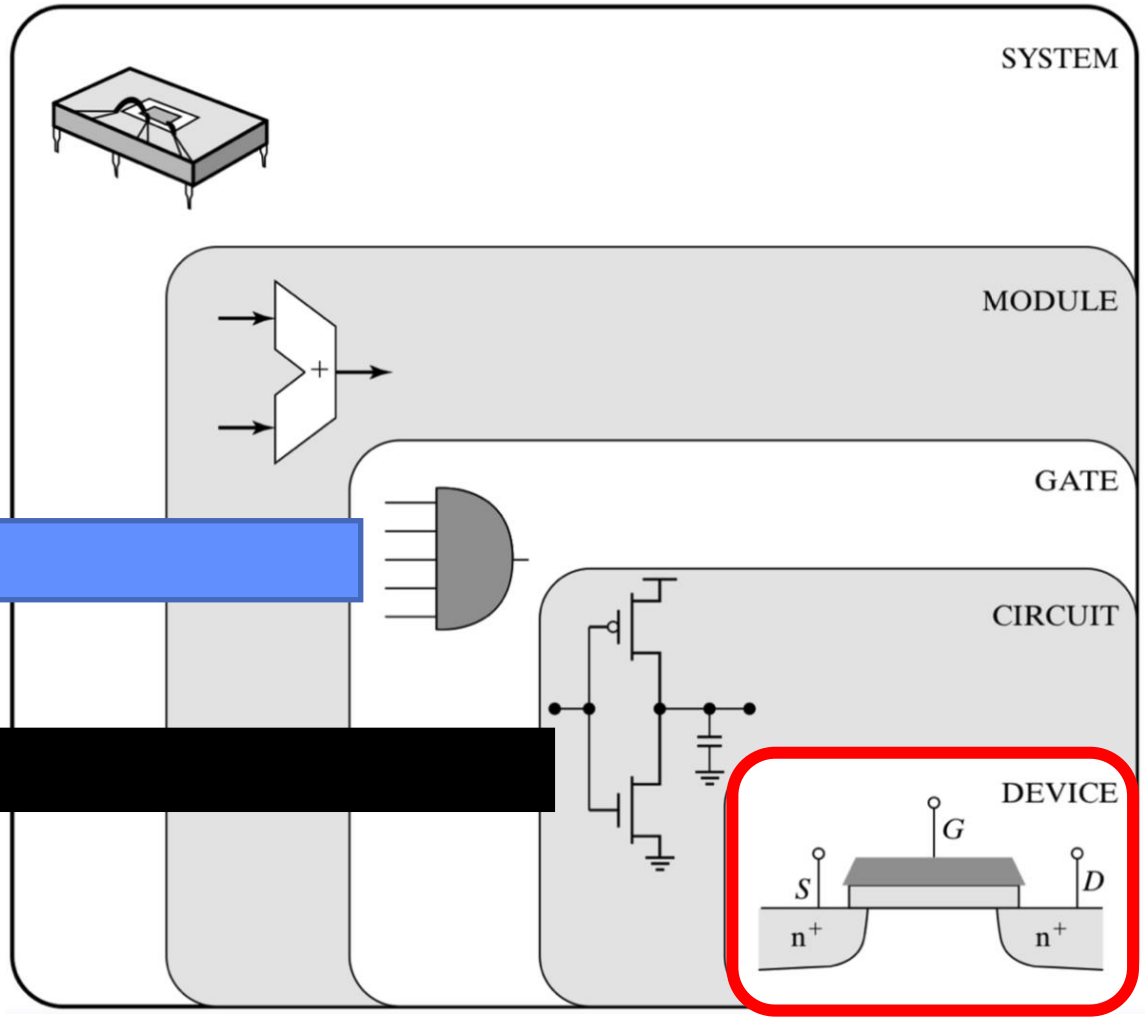


https://www.techadvisor.com/how-to/pc-components/computer-specs-3512328/

Hierarchy of electronics

From EECS 141 lecture Prof. Rabaey @ UC Berkeley

From SE393 Prof. Kang @DGIST



- 디지털 논리회로
- 디지털 집적회로

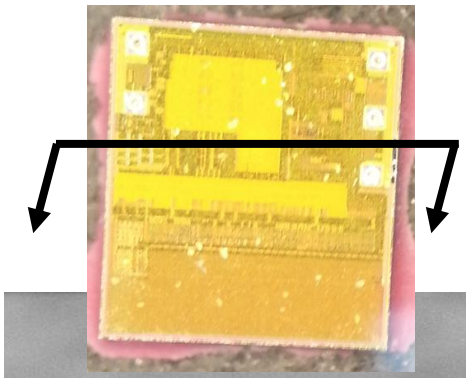
- 전자회로와계측법
- 전자회로 이론
- 집적회로의 기초

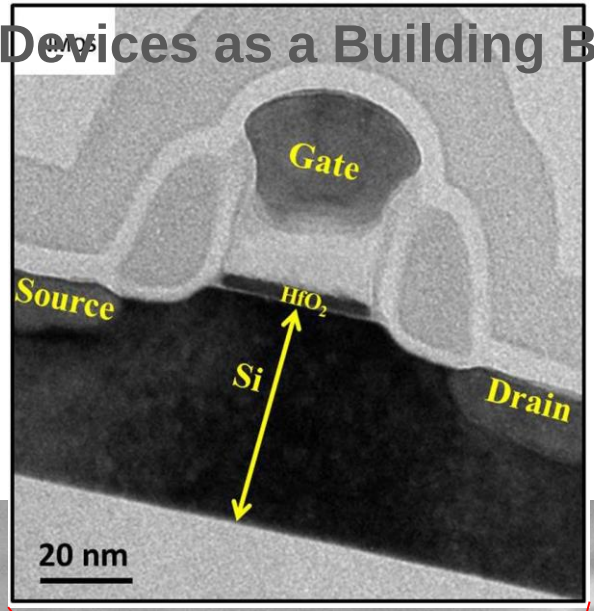
- 전자소자 (Electronic Devices)
- 반도체 소자 (Semiconductor Devices)

- 전자소자 개론
- 반도체 공정 개론
- 재료공학 개론
- 디스플레이공학 개론 등

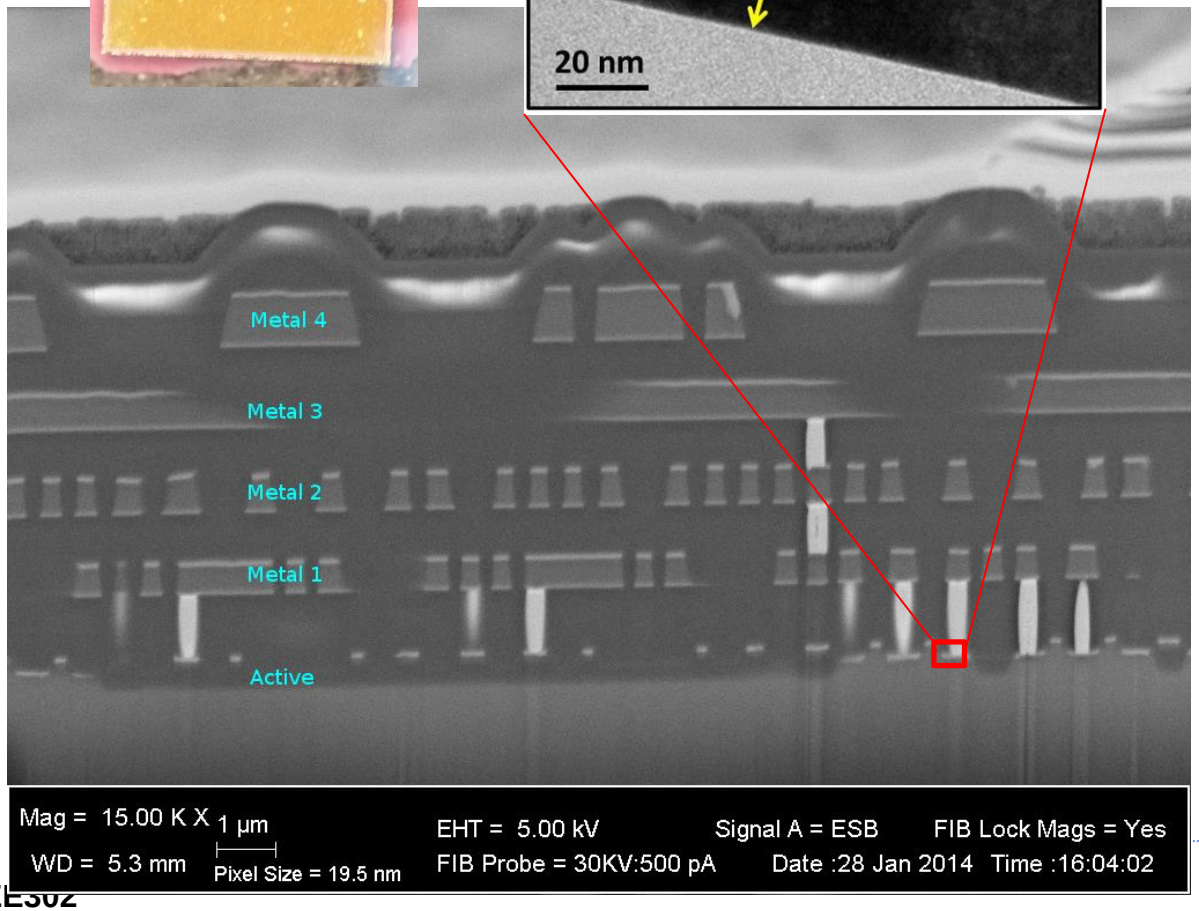
Electronic Devices as a Building Block for Microelectronics

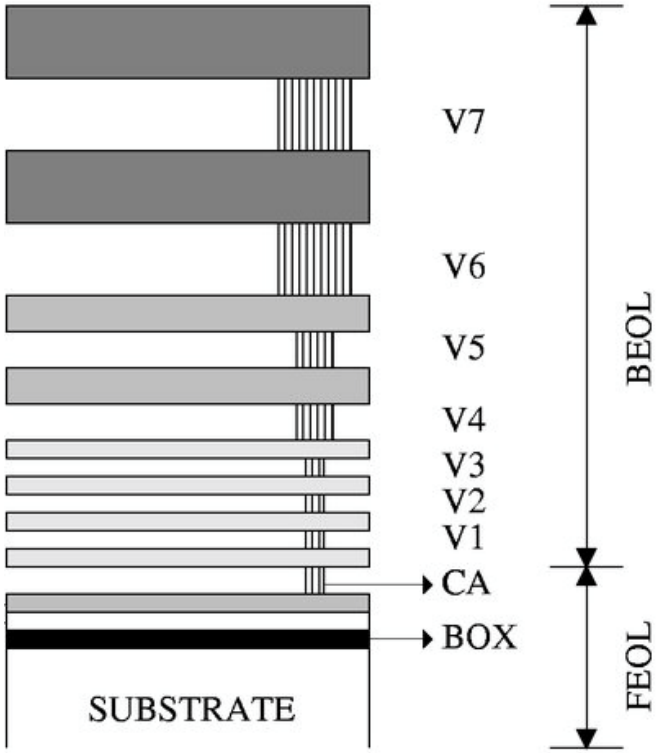
From SE393 Prof. Kang @DGIST



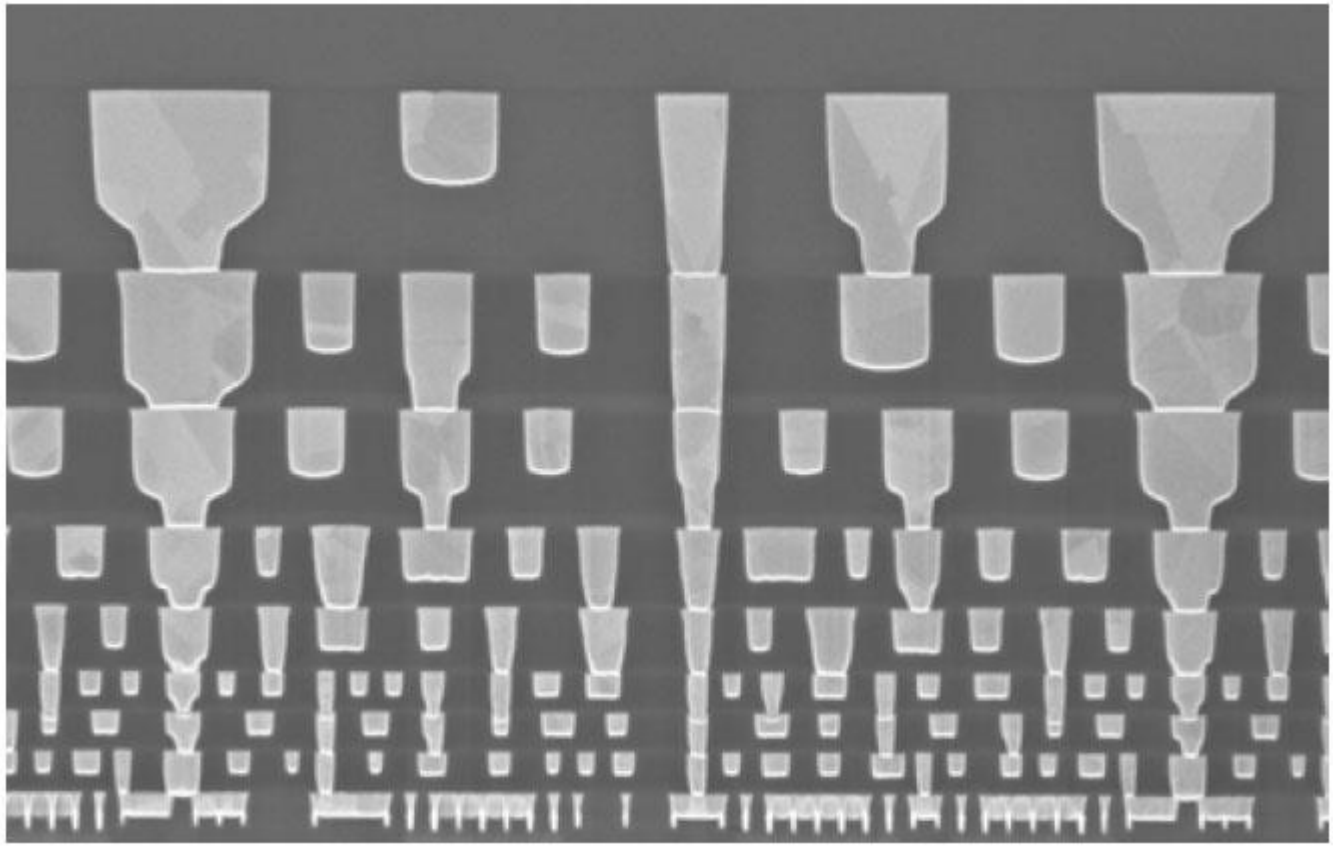


Transistors
Diodes etc.





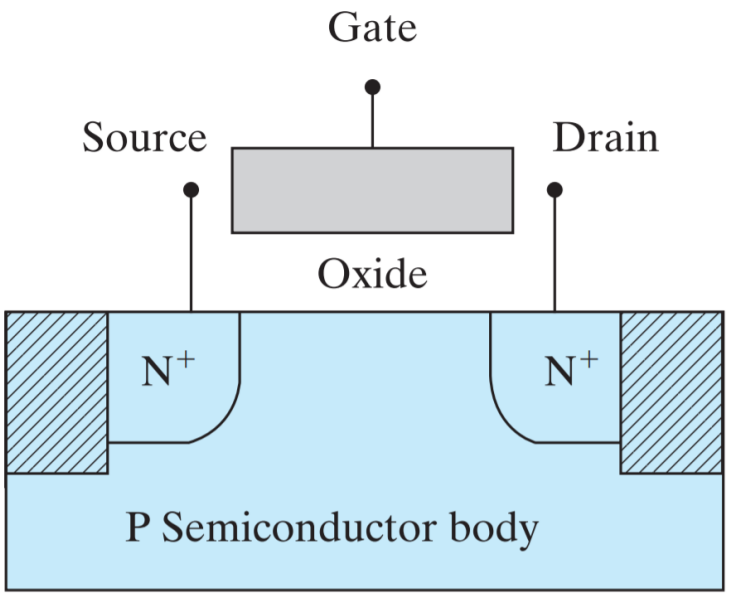
Chip cross section (SEM)



- **Just bunch of transistors and metal wires**

What you will learn in this class

Transistor (CMOS)



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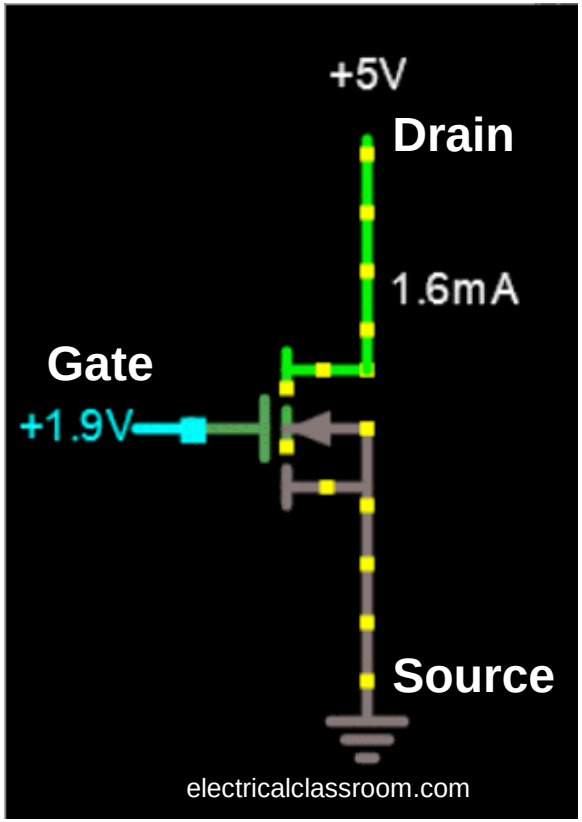


What is semiconductor?

이게 반도체?

- "반도체" 하면 뭐가 떠오르세요?

Definition from a dictionary

semiconductor noun

Save Word

semi·con·duc·tor | \ ˌse-mē-kən-ˈdək-tər, ˌse-ˌmī-, -mi- \

Definition of *semiconductor*

: any of a class of solids (such as germanium or silicon) whose electrical conductivity is between that of a conductor and that of an insulator in being nearly as great as that of a metal at high temperatures and nearly absent at low temperatures

Merriam-Webster

More practical definition

Si wafer (& ingot)

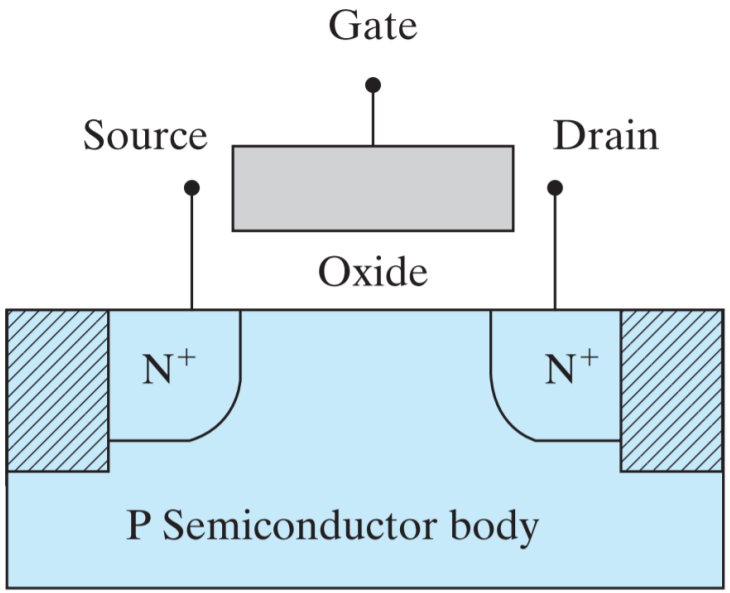
Semiconductor (반도체)

- **1. 물질이다 (극단적으로 pure 한)**
- **2. 전기전도도가 외부 자극 (주로 전기 자극)에 의해 변하는**

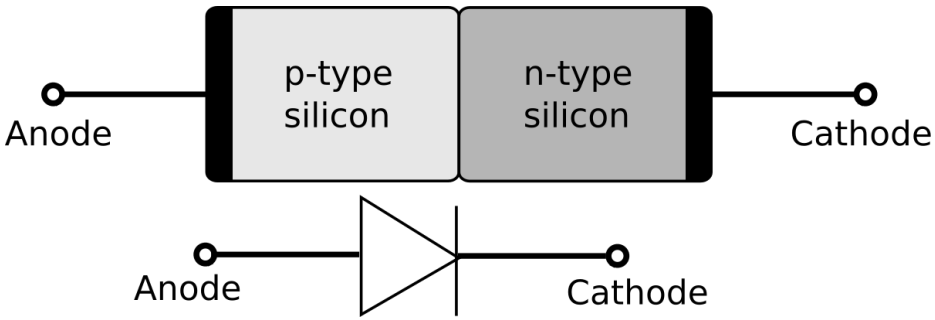
https://www.tel.com/museum/magazine/material/150430_report04_03/02.html

What is device? (그럼 소자란 무엇이냐?)

Transistor (CMOS)



Diode (PN junction)



- **Introduction to electronic *devices* (EE302)**
- **위 두가지가 우리가 다룰 (거의) 모든 소자!**

https://en.wikipedia.org/wiki/P%E2%80%93n_junction

What is device? (그럼 소자란 무엇이냐?)

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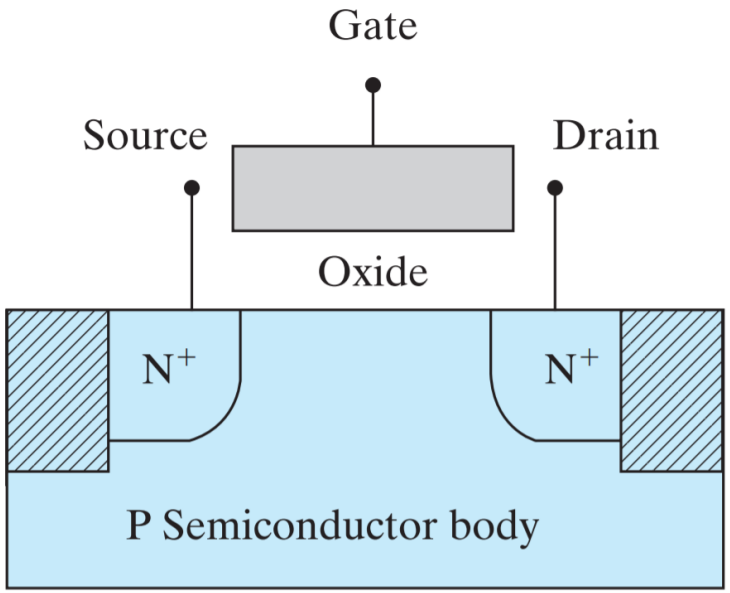

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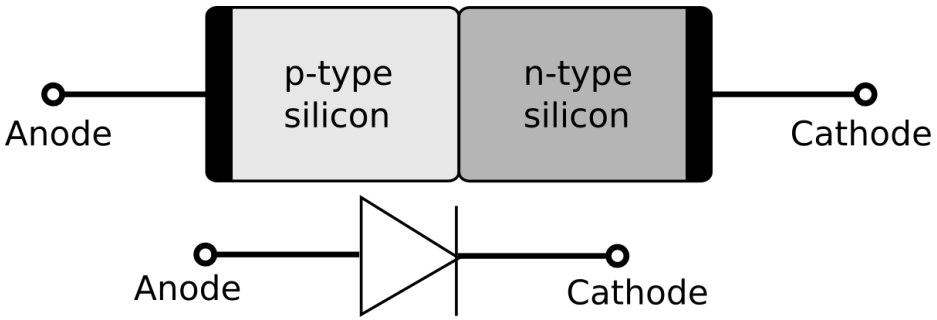

- **Combinations of materials (semiconductor, insulator, conductor, etc.)**

https://en.wikipedia.org/wiki/P%E2%80%93n_junction

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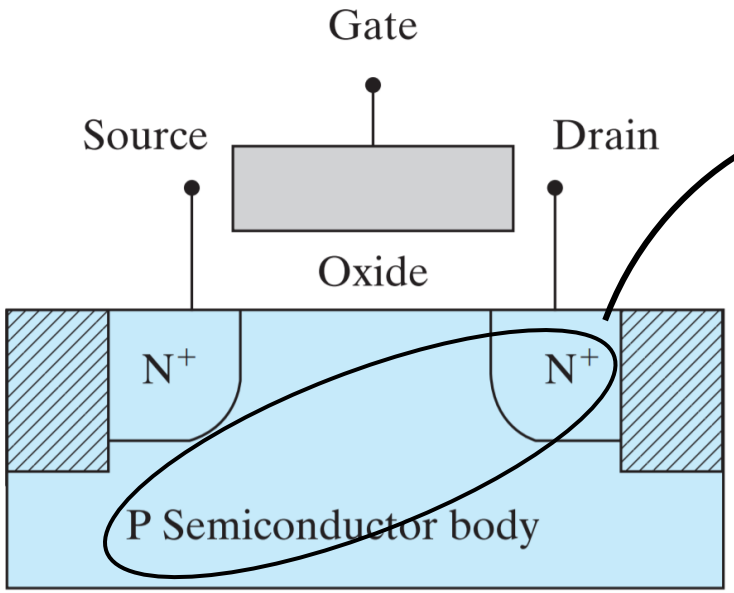

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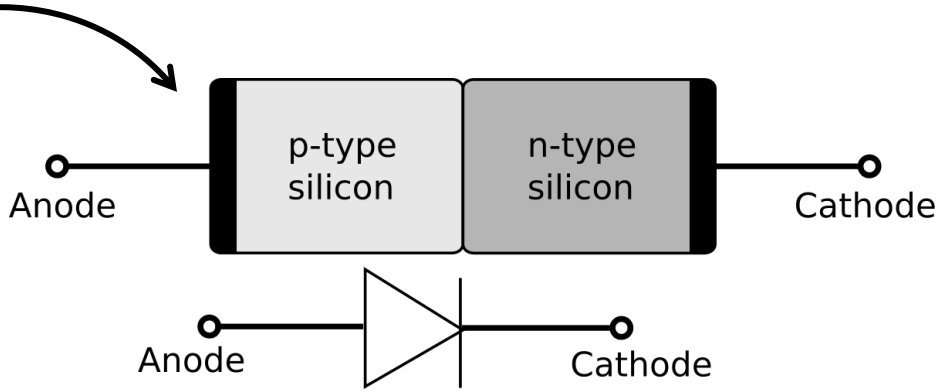

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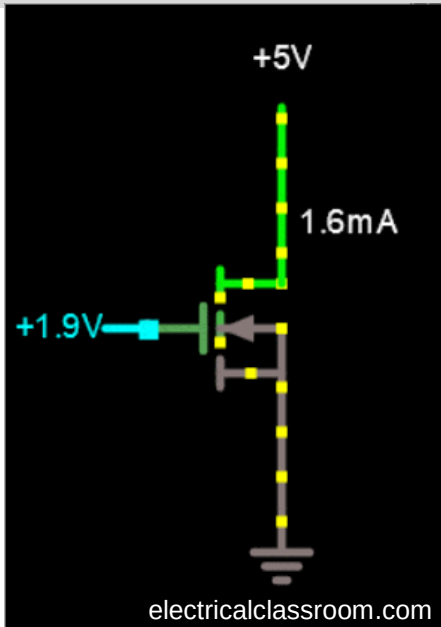
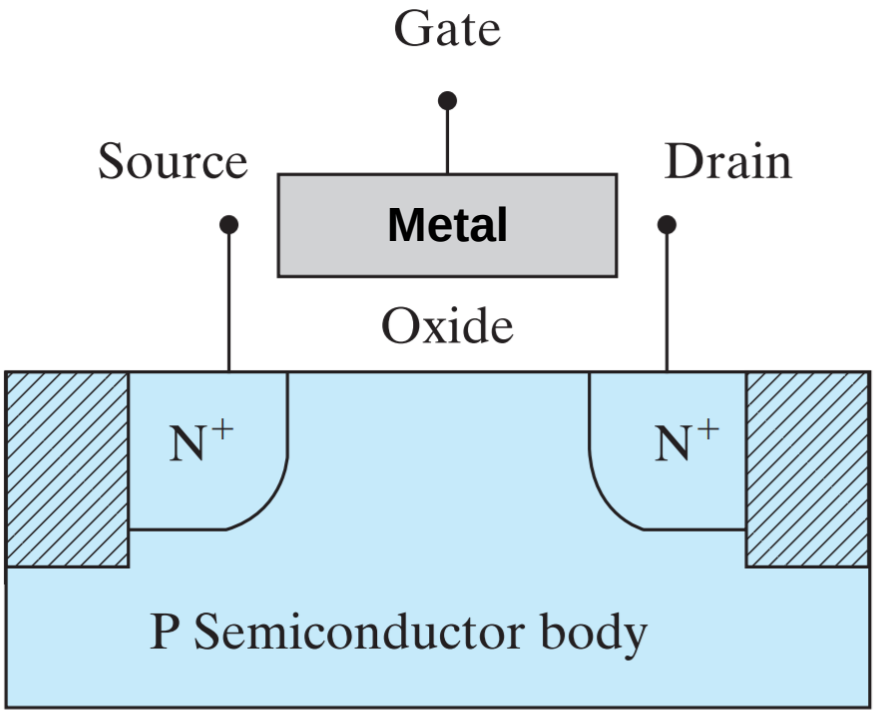
https://en.wikipedia.org/wiki/P%E2%80%93n_junction

Course overview



Week1~2: basic properties of materials



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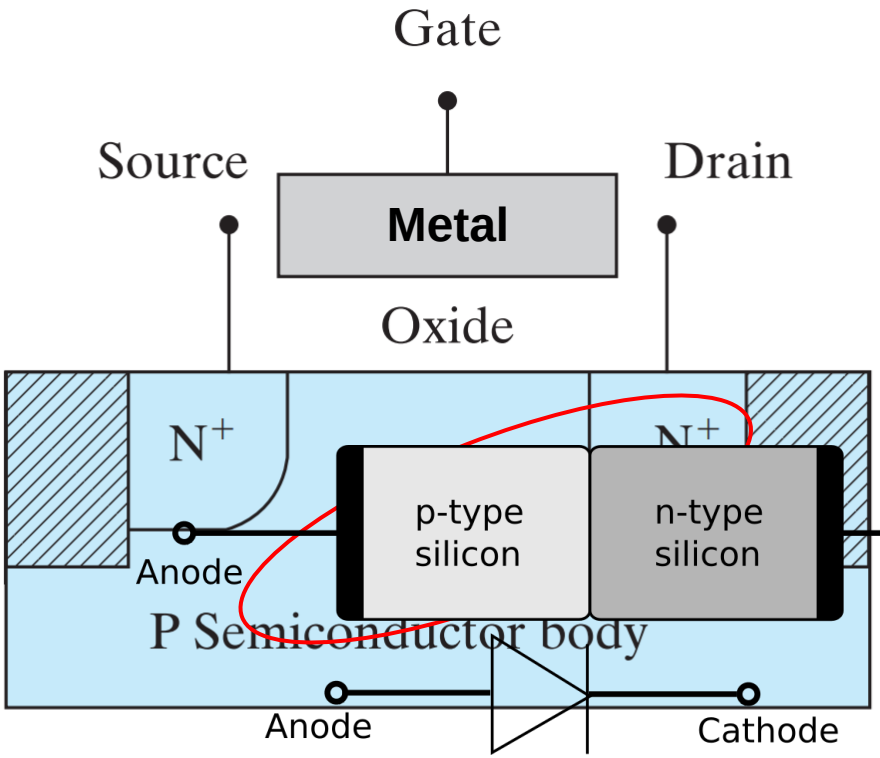
Week 13: FinFET
Week 14: Device applications 1
Week 15: Device applications 2
Week 16: Final exam

- **Semiconductor (Si): p-type, n-type**
- **insulator (SiO_2)**
- **metal (conductor)**

Week3: PN junction



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Week 15: Device applications 2
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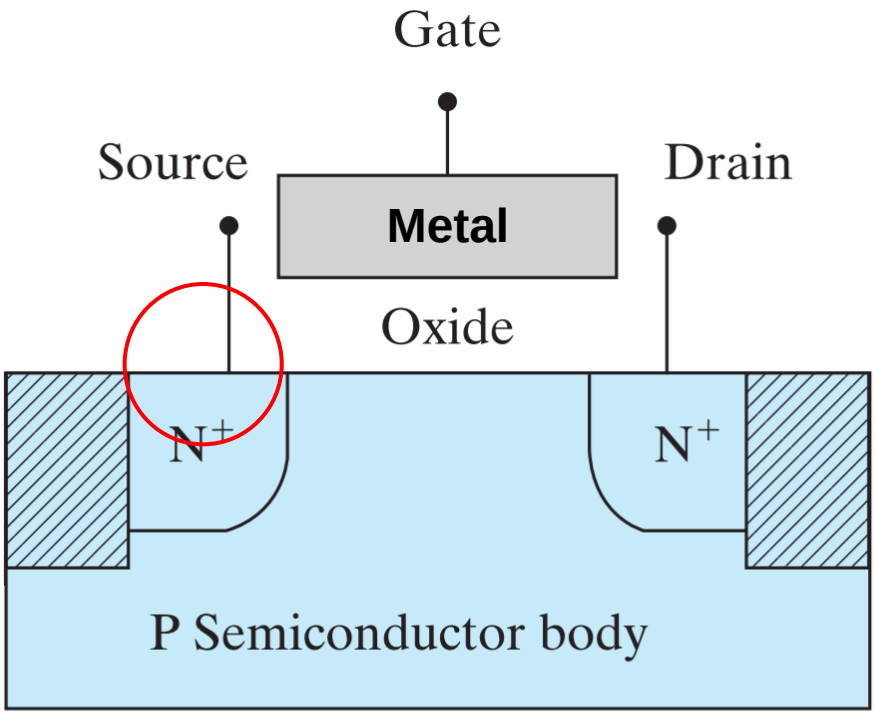
- **PN junction: p-type Si + n-type Si**

Week4: Metal-semiconductor contacts (Schottky diodes)



Week 1 : Semiconductor fundamentals 1

Week 2 : Semiconductor fundamentals 2

Week 3 : PN junction

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Week 6 : Metal-oxide-semiconductor fundamentals 2

Week 7 : MOSFETs: ideal

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Week 12: CMOS inverters

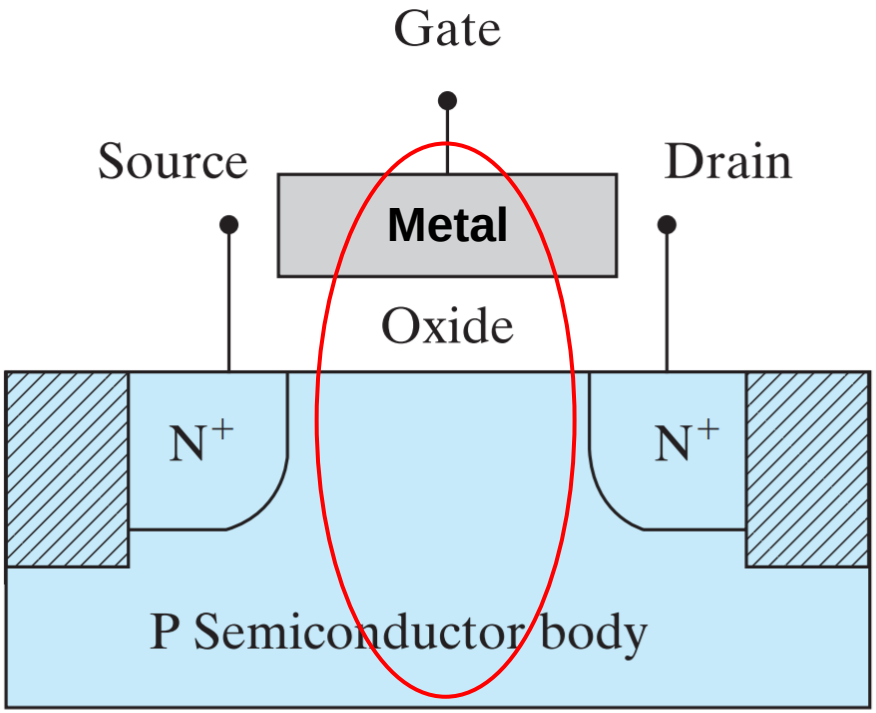
Week 13: FinFET

Week 14: Device applications 1

Week 15: Device applications 2

Week 16: Final exam

Week5-6: Metal-oxide-semiconductor



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Week 12: CMOS inverters

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Week 14: Device applications 1

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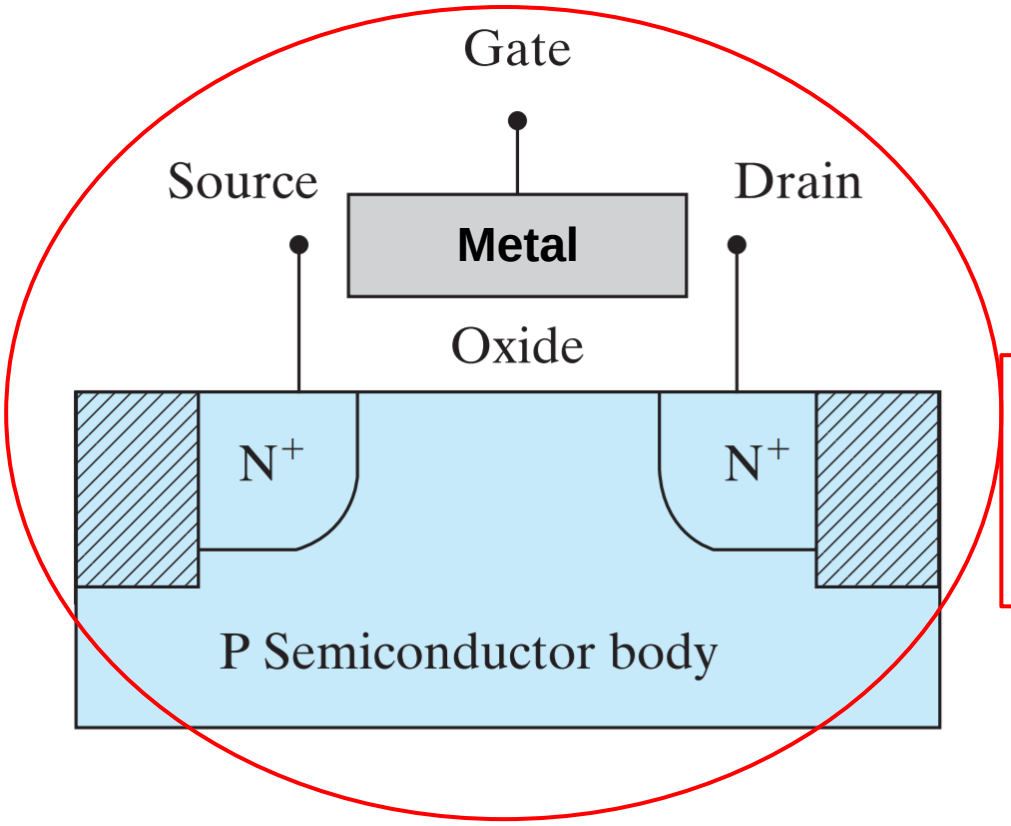
Week 16: Final exam

Week7-11: MOSFET: ideal & non-ideal



Week 1 : Semiconductor fundamentals 1

Week 2 : Semiconductor fundamentals 2

Week 3 : PN junction

Week 4 : Metal-semiconductor contacts (Schottky diodes)

Week 5 : Metal-oxide-semiconductor fundamentals 1

Week 6 : Metal-oxide-semiconductor fundamentals 2

Week 7 : MOSFETs: ideal

Week 8 : Mid-term exam

Week 9 : MOSFETs: electrostatics

Week 10: MOSFETs: C-V characteristics

Week 11: MOSFETs: nonideal

Week 12: CMOS inverters

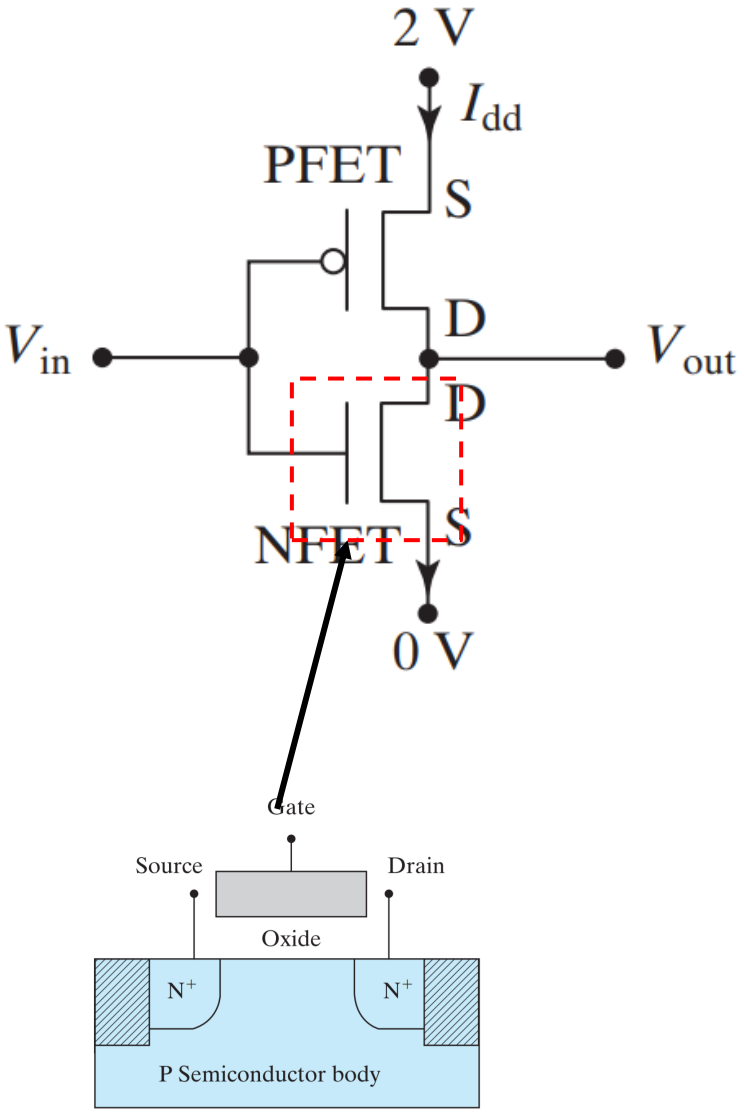
Week 13: FinFET

Week 14: Device applications 1

Week 15: Device applications 2

Week 16: Final exam

Week12: CMOS inverters



Week 1 : Semiconductor fundamentals 1

Week 2 : Semiconductor fundamentals 2

Week 3 : PN junction

Week 4 : Metal-semiconductor contacts (Schottky diodes)

Week 5 : Metal-oxide-semiconductor fundamentals 1

Week 6 : Metal-oxide-semiconductor fundamentals 2

Week 7 : MOSFETs: ideal

Week 8 : Mid-term exam

Week 9 : MOSFETs: electrostatics

Week 10: MOSFETs: C-V characteristics

Week 11: MOSFETs: nonideal

Week 12: CMOS inverters

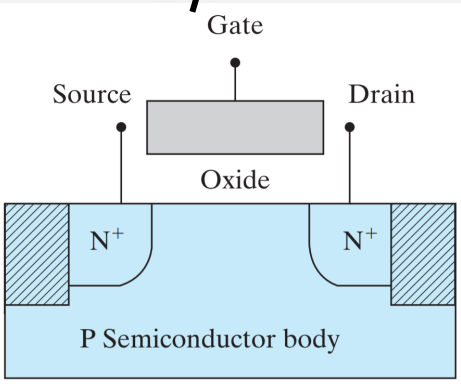
Week 13: FinFET

Week 14: Device applications 1

Week 15: Device applications 2

Week 16: Final exam

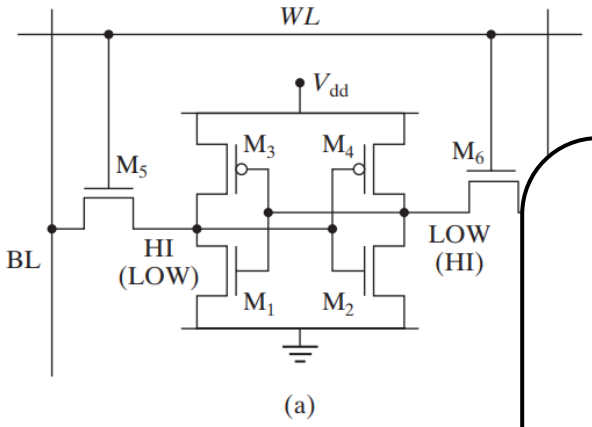
Week13: FinFET (geometrical evolution)



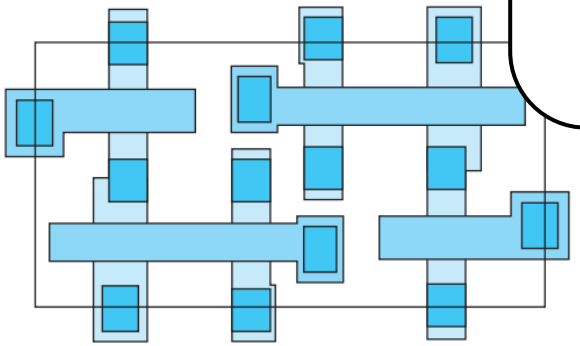
- **Week 13: FinFET**
- **Week 14: Device applications 1**
- **Week 15: Device applications 2**
- **Week 16: Final exam**

Week14,15: Device applications

SRAM



(a)

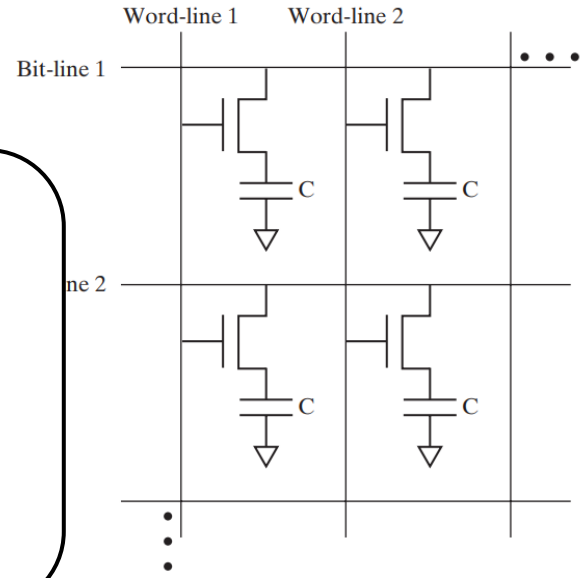


(b)

Or

TBD

DRAM



Week 13: FinFET

Week 14: Device applications 1

Week 15: Device applications 2

Week 16: Final exam

Q & A