Switching Circuits & Logic Design

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Course Info

- Instructor
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- Course webpage
  - http://cc.ee.ntu.edu.tw/~jhjiang/instruction/courses/fall13-ld/ld.html
  - http://access.ee.ntu.edu.tw/course/logic_design_103/index.html

Textbook

- C. H. Roth, Jr. *Fundamentals of Logic Design*, 7th edition, Cengage Learning, 2013.

Schedule

- 9/12 §1 Introduction, Number Systems and Conversion
- 9/13 §2 Boolean Algebra, §3 Boolean Algebra (Continued)
- 9/19,20 -- (Mid-Autumn Festival)
- **9/26** §4 Applications of Boolean Algebra
- **9/27** §5 Karnaugh Maps
- 10/3,10/4 -- (Prof. Jiang out of country)
- 10/10 -- (National Day)
- **10/11** §5 Karnaugh Maps, §7 Multi-Level Gate Circuits
- 10/17 Quiz 1 (§1~§4)
- **10/18** §7 Multi-Level Gate Circuits
- **10/24** §8 Combinational Circuit Design
- 10/25 §9 Multiplexers, Decoders, and PLDs
- 11/1 Verilog: Combinational Circuits
- 11/7 --
- 11/8 Midterm Exam

Dates in boldface indicate additional makeup lectures
(Thu 13:20-14:10; Fri 17:30-18:20, except for 9/27 17:30-19:20)

Schedule (cont'd)

- **11/14** §11 Latches and Flip-Flops
- 11/15 -- (NTU Anniversary)
- 11/21,22 -- (Prof. Jiang out of country)
- **11/28** §11 Latches and Flip-Flops, §12 Registers and Counters
- **11/29** §12 Registers and Counters, §13 Analysis of Clocked Sequential Circuits
- 12/5 §13 Analysis of Clocked Sequential Circuits
- 12/6 §14 Derivation of State Graphs and Tables
- 12/12 Quiz 2 (§11~§13)
- 12/13,19 §15 Reduction of State Tables (§15.1~2)
- 12/20,26 §16 Sequential Circuit Design (§16.1~4)
- 12/27,1/2 §18 Ckts for Arithmetic Operations (§18.1~2)
- 1/3 Supplementary Materials
- 1/9 --
- 1/10 Final Exam

Dates in boldface indicate additional makeup lectures
(Thu 13:20-14:10; Fri 17:30-18:20, except for 9/27 17:30-19:20)

Grading

- Raw score
  - Homework 18%
  - Quiz 1 4%
  - Midterm 35%
  - Quiz 2 6%
  - Final 35%
  - Participation 2%
- Final letter grade
  - Grade on a curve based on the raw scores
  - A+: within top 8% among the total student body of four classes

Policies

- Homework assignments due before lecture
  - 14:10-14:20 on Thursday or 15:20-15:30 on Friday
    - Late homework penalty: -33% per day
  - Plagiarism strongly prohibited
    - No borrowing
    - Discussions are strongly encouraged, but solutions need to be written down independently

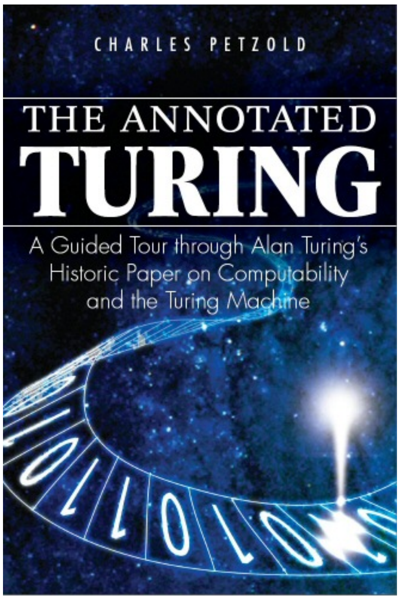
§0 Introduction

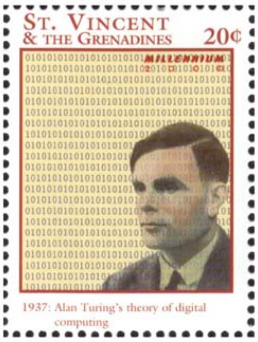
Good Old Days of Computation

Babbage's difference engine (1822)
powered by cranking a handle

Good Old Days of Computation

Computability and the Turing machine
Alan Turing
Cambridge, UK (1937)





Book cover: Wiley (2008)

Good Old Days of Computation

- ENIAC (1946)
  - First general purpose (Turing-complete) electronic computer
  - Vacuum-tube based implementation

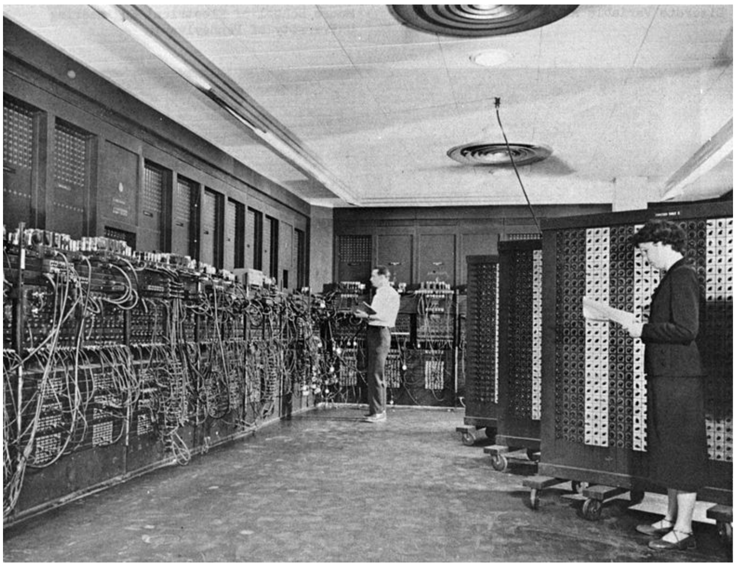


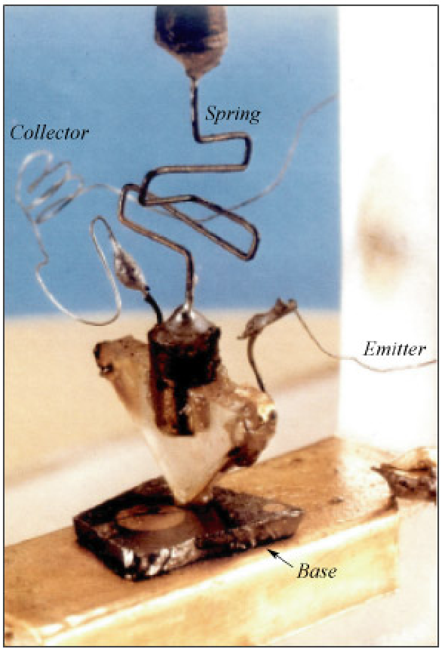
Photo: US Army, Roth audio

Good Old Days of Computation

The first point contact transistor

William Schockley, John Bardeen, and Walter Brattain

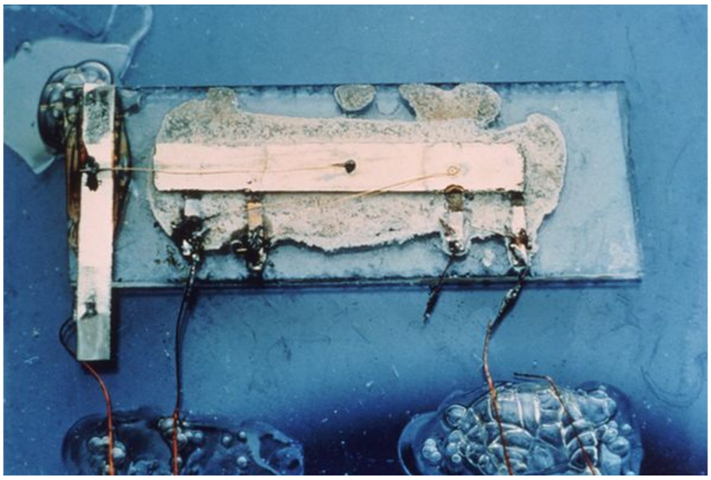
Bell Laboratories, Murray Hill, New Jersey (1947)



Photos: Lucent Technologies

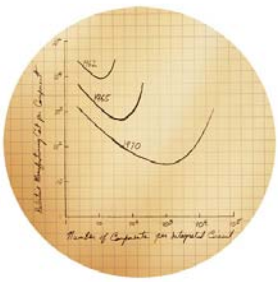
Good Old Days of Computation

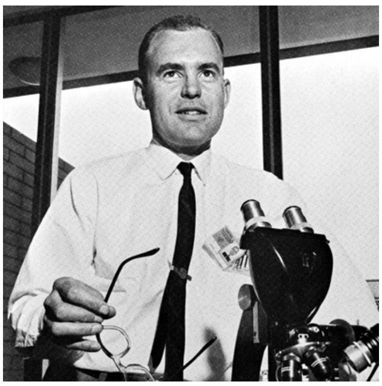
The first integrated circuit
Jack Kilby
Texas Instruments, Texas (1958)



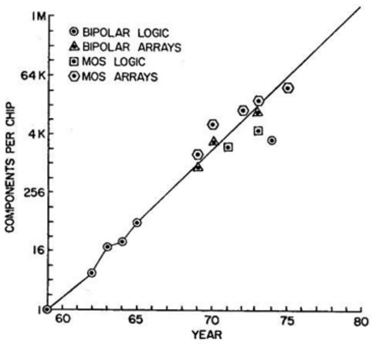
Photos: Texas Instructments

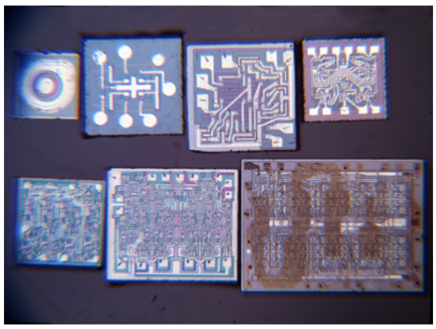
Roadmap of VLSI Design

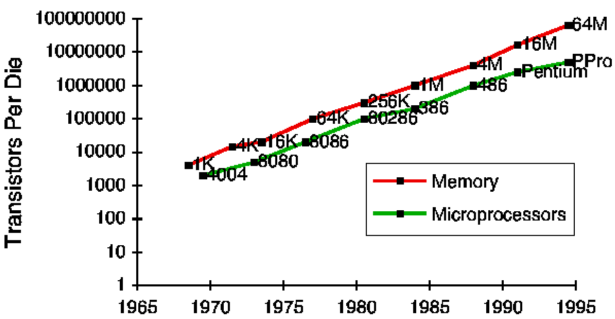




Gordon Moore at Fairchild (1962)



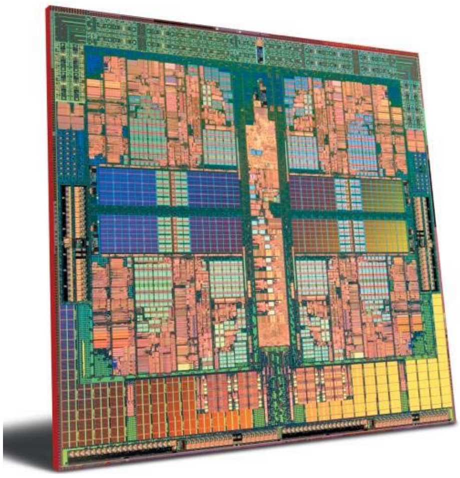




Photos: Intel

VLSI Design Nowadays

MPUs with billions of transistors



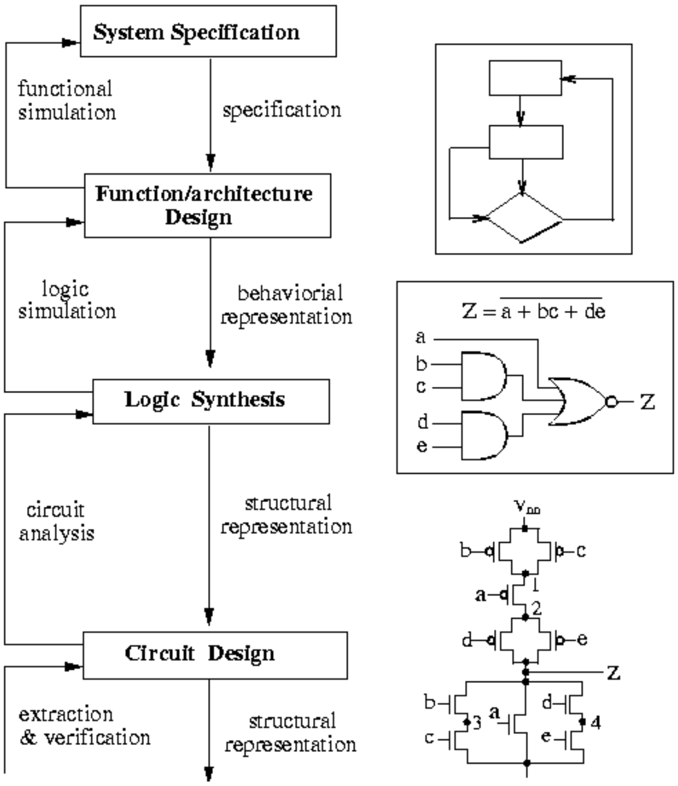
Systems with powerful capabilities

Photo: AMD; Apple

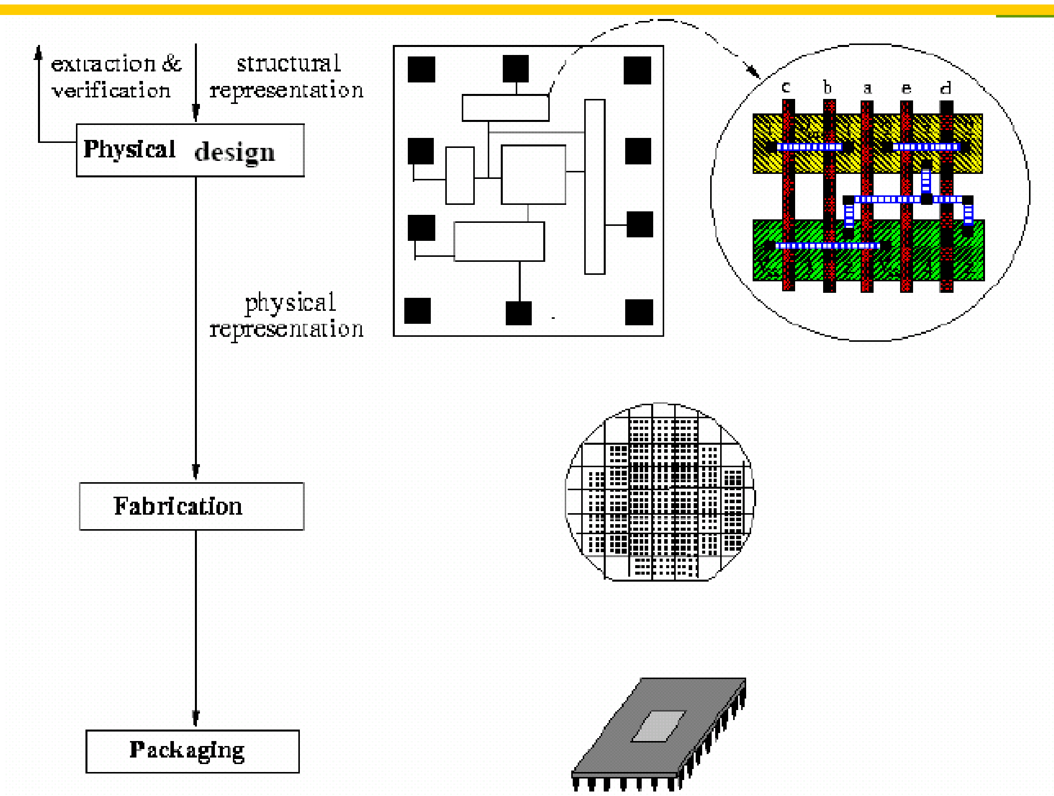
Cope with Complex Designs

- Proper design abstraction
  - E.g., treating digital circuits as switches
- Module-based design
- Design reuse
- Design automation
  - Computer-Aided Design (CAD) tools

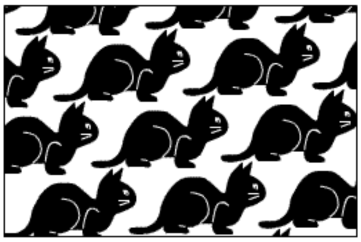
How to Build Digital Electronic Systems?



How to Build Digital Electronic Systems?



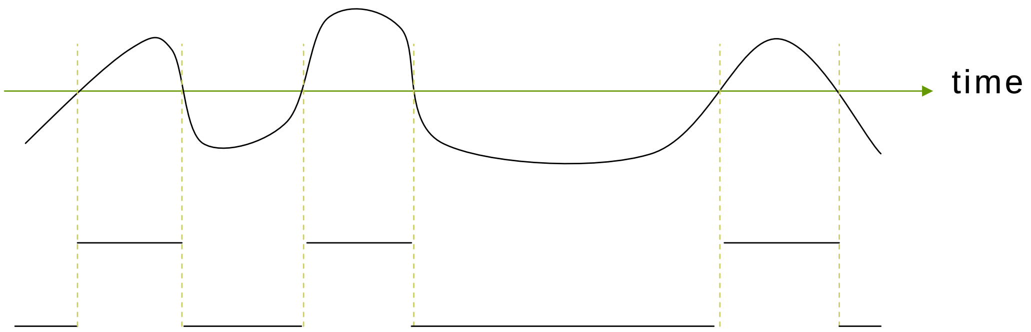
The World of **0** and **1**



People to Know

- George Boole
  - Logic + algebra → Boolean algebra
- Claude E. Shannon
  - Boolean algebra ↔ switching circuits

Digital vs. Analog



Digital vs. Analog

- Digital
  - Discrete in value
  - More artificial

  - Immune to noise
  - Easy error correction
  - Easy precision control
  - Easy design automation

  - Slow computation
- Analog
  - Continuous value
  - Closer to physical world

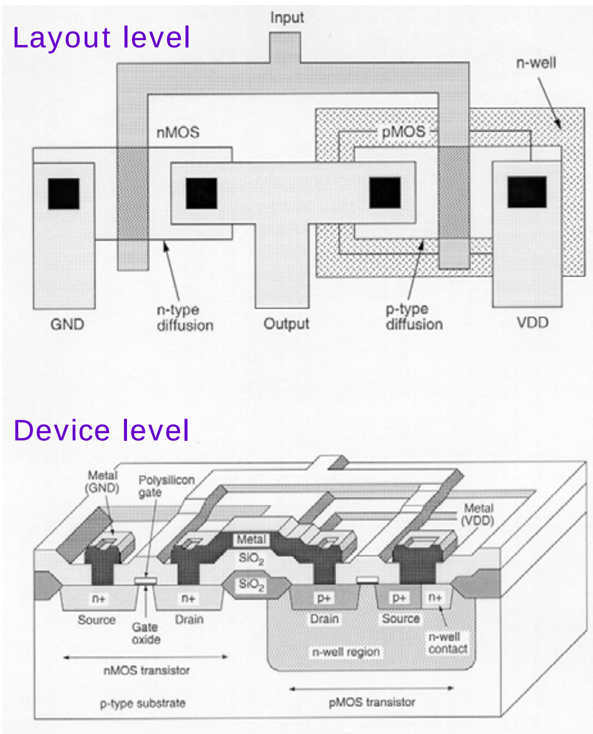
  - Vulnerable to noise
  - Hard error correction
  - Hard precision control
  - Hard design automation

  - Fast computation

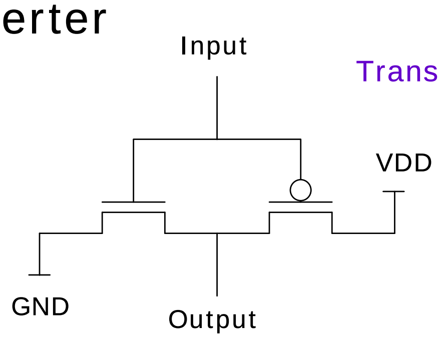
Binary vs. Multi-Valued

- A digital system can be binary or multi-valued
  - Binary:
    Signals with 2 values, e.g., {on, off}, {0,1},...
  - Multi-valued:
    Signals with > 2 values, e.g., {red, green, yellow}, {0,1,2,3}, ...
  - Binary systems are still the most popular design choice
    - Simple and fast operations
    - Higher noise immunity

Digital Circuits and Boolean Algebra

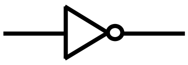


Inverter



Transistor level

Gate level

Input  Output

Input	Output
0	1
1	0

Reference: http://lsmwww.epfl.ch/Education/former/2002-2003/VLSIDesign/ch02/ch02.html

Switching Circuits and Logic Design

- This course is about digital circuit design at the gate level
  - Signals that we encounter are of {0,1} Boolean values
  - We will apply Boolean algebra to logic design
- Other applications
  - Biological network analysis and design
    - Gene regulatory networks can be abstracted as Boolean circuits
  - Non-conventional computation systems
    - E.g., quantum circuit design

Do You Know?

- What does "bit" stand for?
  - Binary Digit
- Who coined the term?
  - John Tukey (best known for his FFT algorithm)
- Who popularized the term?
  - Claude Shannon (in his famous paper entitled "A Mathematical Theory of Communication")