EE3032 Introduction to VLSI Design

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Syllabus

Contents

- Introduction to CMOS Circuits
- MOS Transistor Theory
- Fabrication of CMOS Integrated Circuits
- Electrical Characteristics of CMOS Circuits
- Elements of Physical Design
- Combinational Circuit Design
- Sequential Circuit Design
Syllabus

☐ Reference Books

☐ Grading
  ■ Homework 35% (Overdue homework is not accepted!)
  ■ (Mid+Final) 65%
    - [Max(Mid, Final)\times60\%+Min(Mid, Final)\times40\%]
  ■ Attendance: reference for adjusting the grade of students if it is required.

☐ Prerequisite
  ■ Digital logic design

☐ Key dates
  ■ Midterm: 10:00-12:00, Wed., Nov. 7, E1-124
  ■ Final: 10:00-12:00, Wed., Jan. 16, E1-124
# Lecture Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1 (9/19, 9/20)</td>
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<td>Week 2 (9/26, 9/27)</td>
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<td>Week 3 (10/3, 10/4)</td>
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<tr>
<td>Week 4 (10/10, 10/11)</td>
<td>No class on 10/10</td>
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<td>Week 5 (10/17, 10/18)</td>
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<td>Week 6 (10/24, 10/25)</td>
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<td>Week 7 (10/31, 11/1)</td>
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<td>Week 8 (11/7, 11/8)</td>
<td>11/7: Midterm</td>
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<td>Week 9 (11/14, 11/15)</td>
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<td>Week 10 (11/21, 11/22)</td>
<td>No class (運動會)</td>
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<td>Week 11 (11/28, 11/29)</td>
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<td>Week 12 (12/5, 12/6)</td>
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<td>Week 13 (12/12, 12/13)</td>
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<td>Week 14 (12/19, 12/20)</td>
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<td>Week 15 (12/26, 12/27)</td>
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<td>Week 16 (1/2, 1/3)</td>
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<td>Week 17 (1/9, 1/10)</td>
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<tr>
<td>Week 18 (1/16)</td>
<td>1/16: Final Exam</td>
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</table>
Teaching Assistant & Lecture Slides

☐ Teaching assistants
  - 陳宇軒 (E1-417)
  - 楊其峻 (E1-417)
  - 楊維軒 (E1-417)
  - 陳宣豪 (E1-417)

☐ Course Website:
  http://www.ee.ncu.edu.tw/~jfli/
Integrated Circuit (IC) & System Board
CPU

Main Memory System

Central Processing Unit (CPU)
- Cache memory
- Operational Registers
  - Program Counter
- Arithmetic and Logic Unit
- Control Unit

Input/Output System

Instruction Sets

Address

Data/Instruction
System to Silicon Design

System Requirements

Algorithm

Hardware Architecture

Synthesis

System Integration

Fabricate and Test

Physical

Design For Test

\[ X[k] = \sum x[n]e^{j2\pi k/N} \]

\[ x[n] = \sum X[k]e^{j2\pi k/N} \]

[Source: MITRE]
Example of Digital Circuit

- **Binary counter**

<table>
<thead>
<tr>
<th>Present state</th>
<th>Next state</th>
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</thead>
<tbody>
<tr>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

\[ A = a'b + ab' \]
\[ B = a'b' + ab' \]

Source: Prof. V. D. Agrawal
Realization of Logic Gates

☐ An example of Inverter
  ▀ Inverter logic gate

☐ Realizing logic gates using switches

- PMOS
- NMOS
What is This Course all About?

- Scopes of very large-scale integration (VLSI) design
  - Digital circuits
  - Analog circuits
  - Mixed-signal circuits
  - Memory circuits

- This course will cover the following contents
  - CMOS devices and manufacturing technology; CMOS inverters and gates; propagation delay; noise margins; CMOS power dissipation; sequential circuits

- What will you learn?
  - Understanding, designing, and optimizing digital circuits with respect to different quality metrics: area, speed, and power dissipation
ENIAC - The First Electronic Computer (1946)

Source: J. Rabaey, 2004
The Transistor Revolution

First transistor (Bell Labs, 1948)

Source: J. Rabaey, 2004
Integrated Circuits

ECL 3-input Gate (bipolar logic), Motorola 1966

Source: J. Rabaey, 2004
Intel 4004 Microprocessor

1000 transistors, 1 MHz operation, 1971

Source: J. Rabaey, 2004
Intel Pentium (IV) microprocessor

Source: J. Rabaey, 2004
Itanium (JSSC, Jan. 2006)
Moore’s Law

In 1965, Gordon Moore noted that the number of transistors on a chip doubled every 18 to 24 months. He made a prediction that semiconductor technology will double its effectiveness every 18 months.

Source: J. Rabaey, 2004

Electronics, April 19, 1965.
What Does an IC Look Like Today?

SPARC SOC Processor (IEEE JSSC, 2011)

1. TSMC 40nm high performance process (11 Cu metals and four transistor types)
2. 16 cores
3. Die area=377mm²
4. 1 billion transistors and 2.5 million flip-flops
5. 1.65-2.0 GHz consuming 120W
6. 833 signals and 1284 power pins
7. Scan test, MBIST, Loop-back tests (SerDes)
What Does an IC Do?

Consumer Electronic Products

http://www.youtube.com/watch?v=B-RuuD2gR-c

Cloud Computing

Automotive

Biotechnology

Green Technology