數位IC設計

Pei-Yin Chen, 陳培殷

資訊工程系 特聘教授 兼 計算機與網路中心主任

Syllabus (1/2)

- Time and Place
  - Tuesday : 9:10 ~ 12:00　　Rm.化工系 華立廳
- Contact Information
  - 資訊系 11F Rm:65B13 (06-2757575 EXT 62547)
  - E-mail: pychen@mail.ncku.edu.tw
- Office Hour
  - Monday: 8:00~12:00
- Assistants
  - 資訊系 10F 數位IC設計實驗室(65A01)
    博士生 陳宥融 lt2es.93039@gmail.com

Syllabus (2/2)

評分方式: 考試(40%~50%)

作業含Demo(60%~50%)

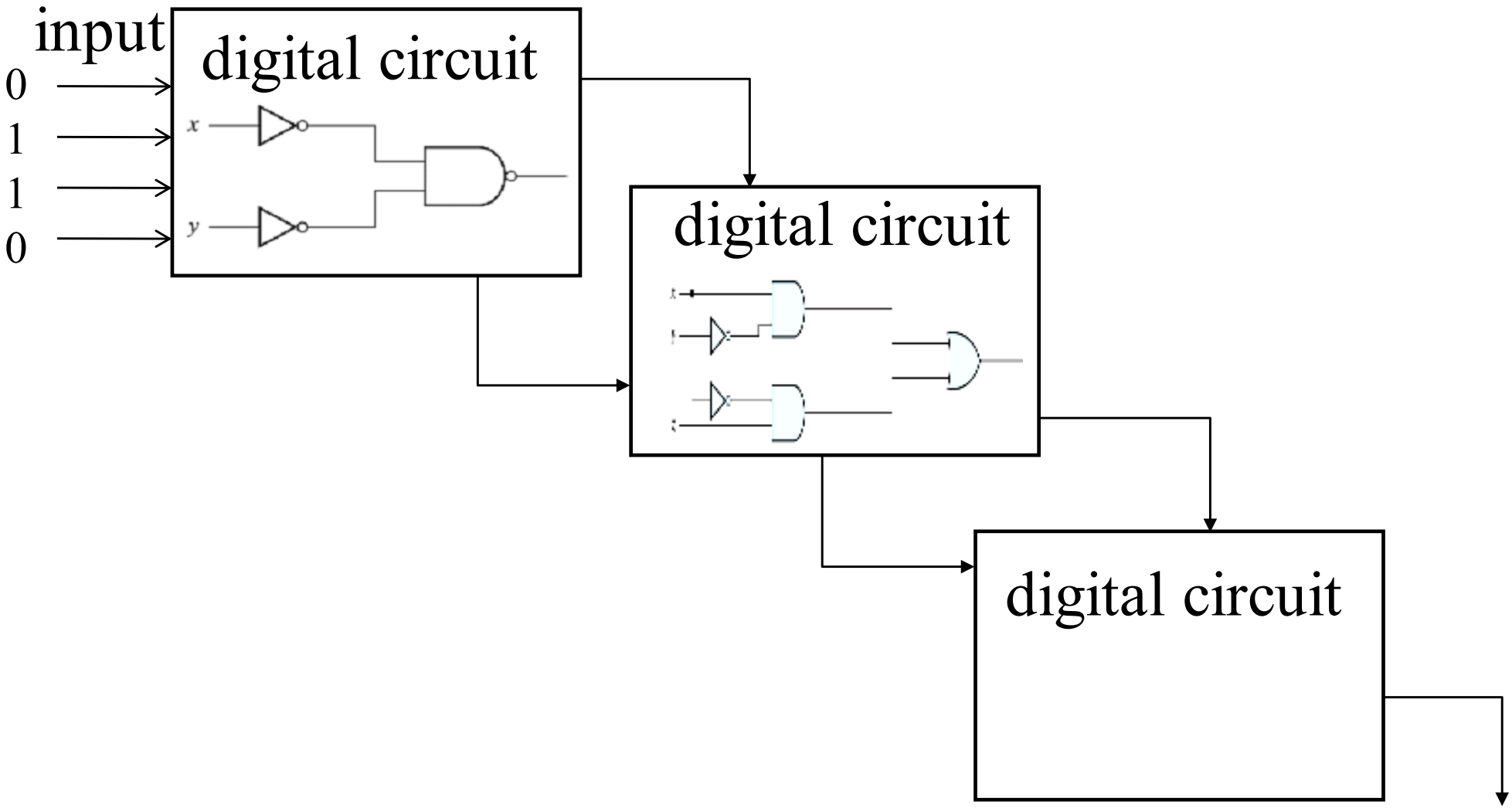
考試為Verilog實作設計，因修課人數較多，考試與作業皆以pass與fail評分，不會部分給分。

上課1~15週(期末考)，3週非同步線上(於第1週看完)。

參考書目：

1. 教育部P&L聯盟課程講義–FPGA系統設計實務
2. HDL chip design (Douglas J. Smith), Doone Publications
3. Principles of digital design (Daniel D. Gajski), Prentice Hall
4. Modeling, synthesis, and rapid prototyping with the Verilog HDL (Michael. D. Ciletti), Prentice Hall
5. 數位IC設計--Verilog,(陳培殷),滄海書局

Digital System

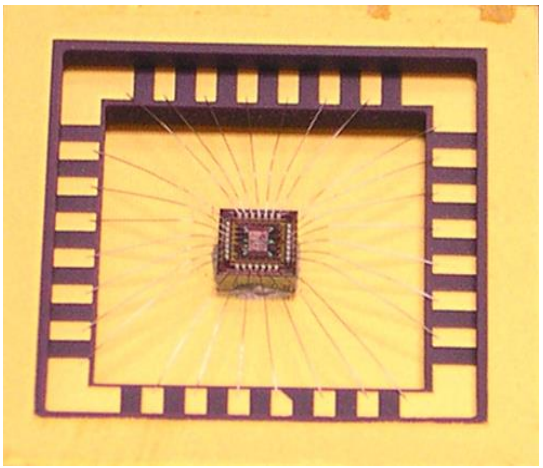


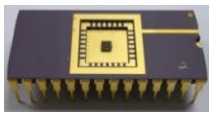
digital circuit === IC (integrated circuit)

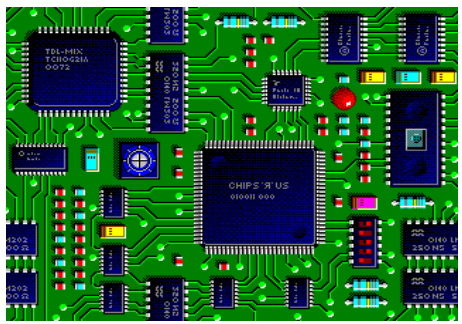
semiconductor

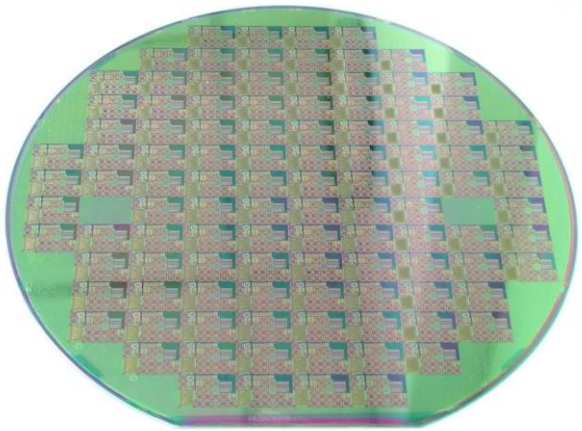
Chip/Circuit Everywhere!

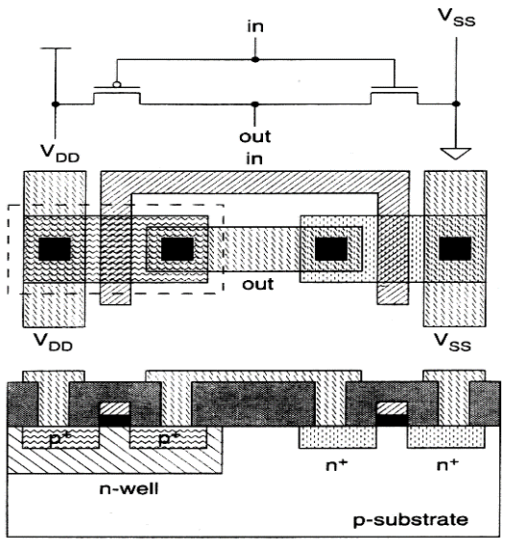
Applications

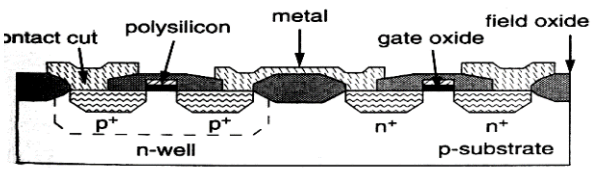












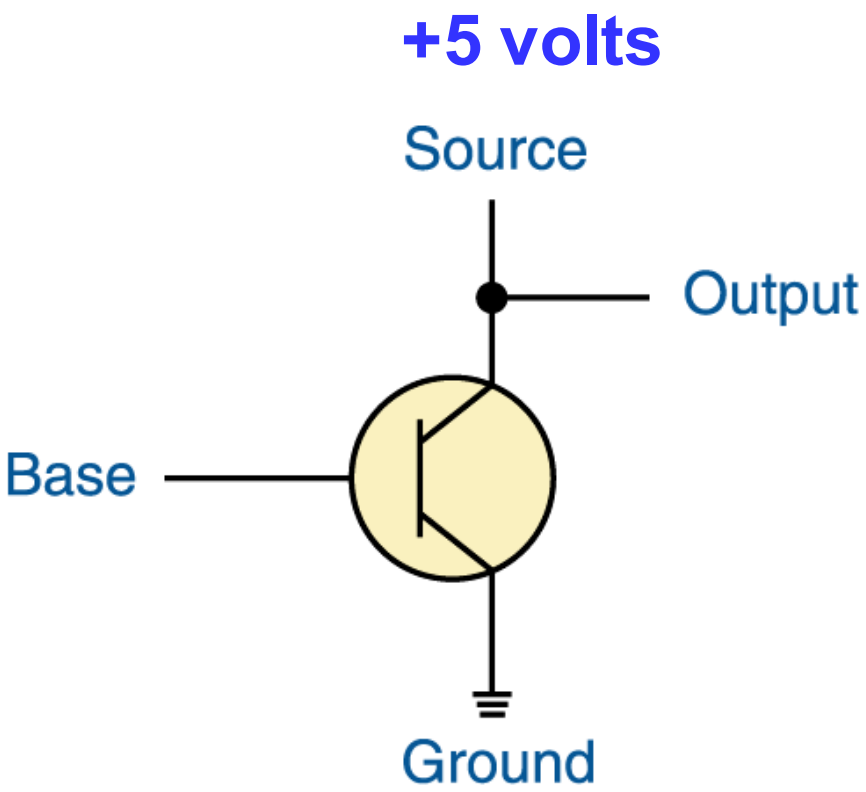
Circuits

- **Transistor**
- **Gate (1 gate ~= 2~14 transistors)**

  A combination of interacting transistors
- **Circuit**

  A combination of interacting gates designed to accomplish a specific logical function
- **IC (Integrated Circuit)**
- **System➔ PCB (printed circuit board)**
- **SoC (system on a chip) ➔ How many gates in a chip?**

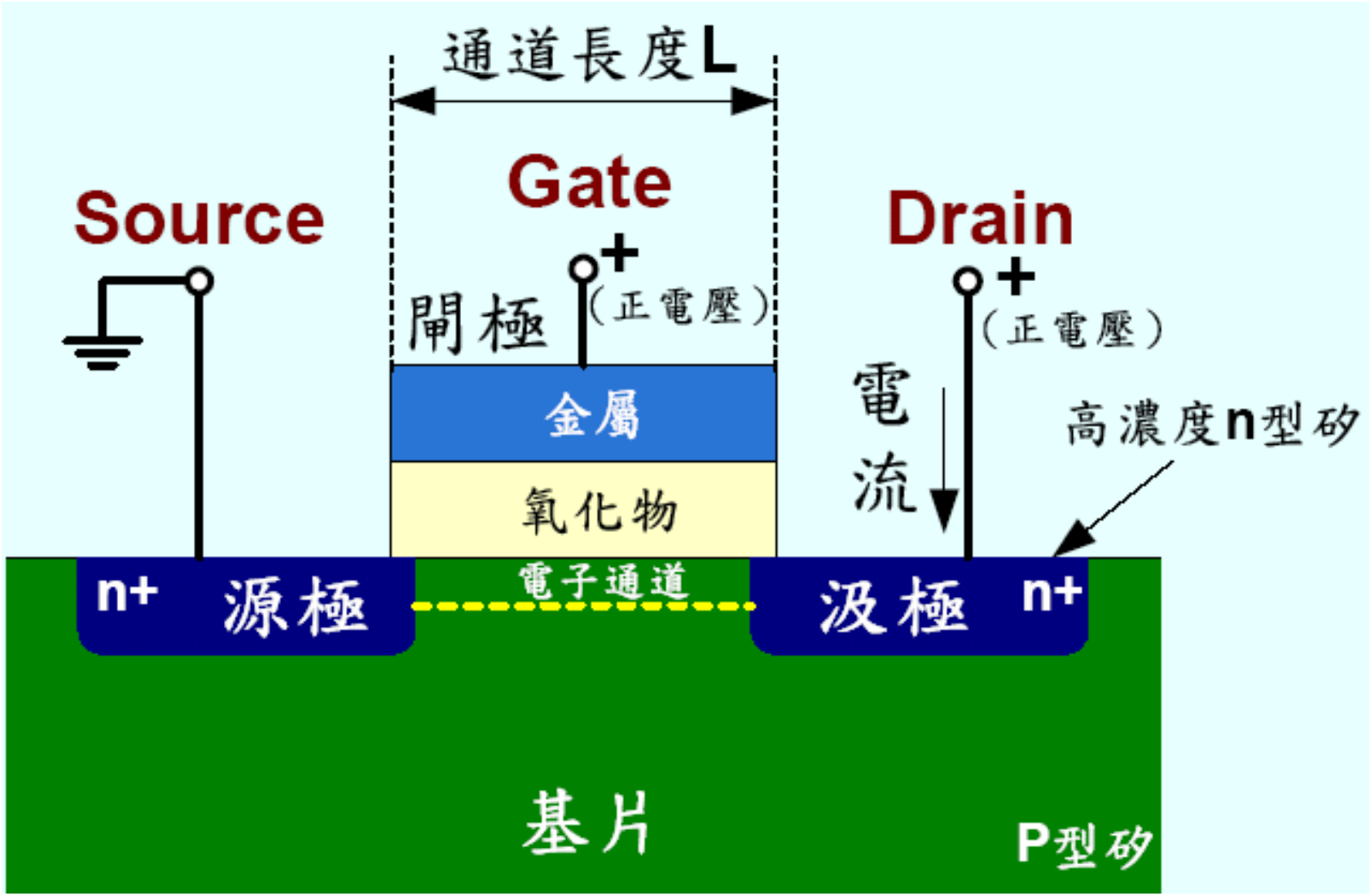
Transistor(電晶體)



- A transistor has three terminals
  - A source (feed with 5 volts)
  - A base
  - An emitter, typically connected to a ground wire
- If the base signal is high (close to +5 volts), the source signal is grounded and the output signal is low (0). If the base signal is low (close to 0 volts), the source signal stays high and the output signal is high (1)

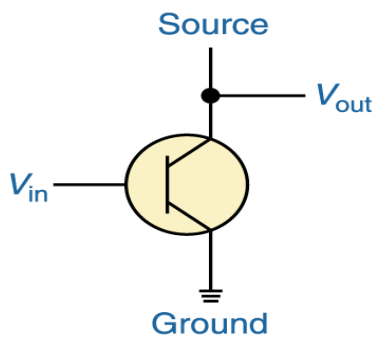
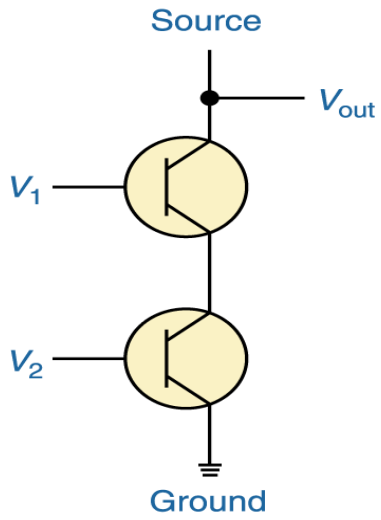
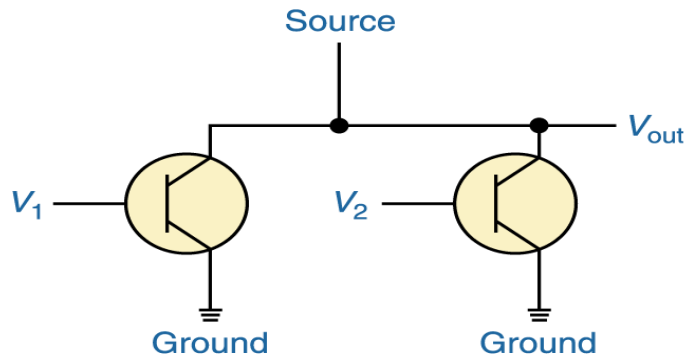
N-channel MOS Transistor

Transistor (電晶體)– Semiconductor(半導體)



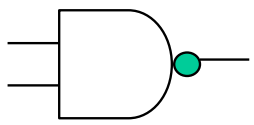
Constructing Gates (semiconductor)

- It turns out that, because the way a transistor works, the easiest gates to create are the NOT, NAND, and NOR gates

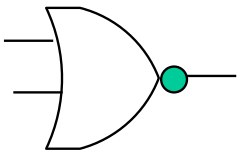
NOT gate	NAND gate	NOR gate
		

V_{in}	V_{out}
0	1
1	0

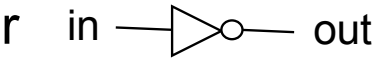
V_1	V_2	V_{out}
0	0	1
0	1	1
1	0	1
1	1	0



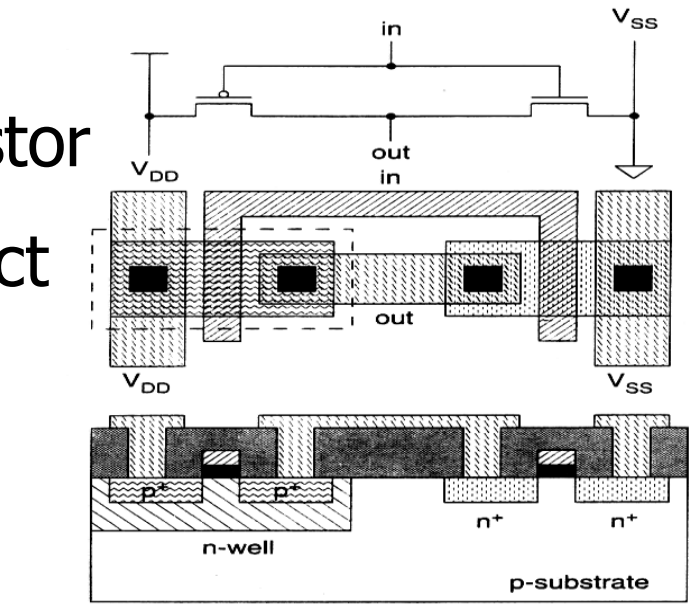
V_1	V_2	V_{out}
0	0	1
0	1	0
1	0	0
1	1	0



IC Design (with CMOS)

CMOS Inverter 

One npn transistor and one pnp transistor are used to construct one inverter.



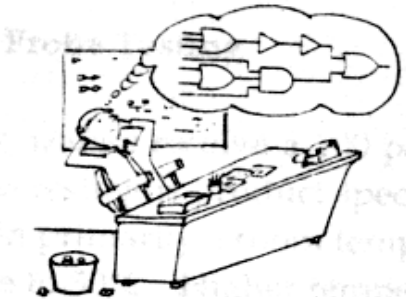
done by chip designer

masking

done by TSMC, UMC

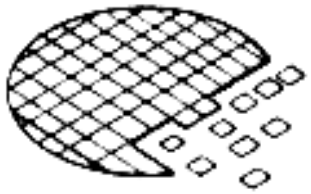
Packing, Testing

IC Industry in Taiwan

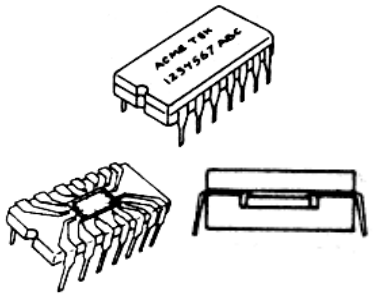


邏輯設計

光罩設計



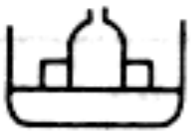
晶粒測試及切割



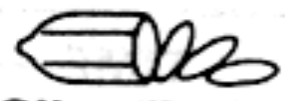
封　裝

成品測試

設計 → 光罩 → 製造 → 封裝 → 測試



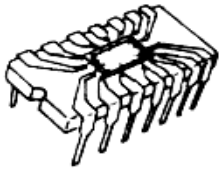
長晶



晶圓切割

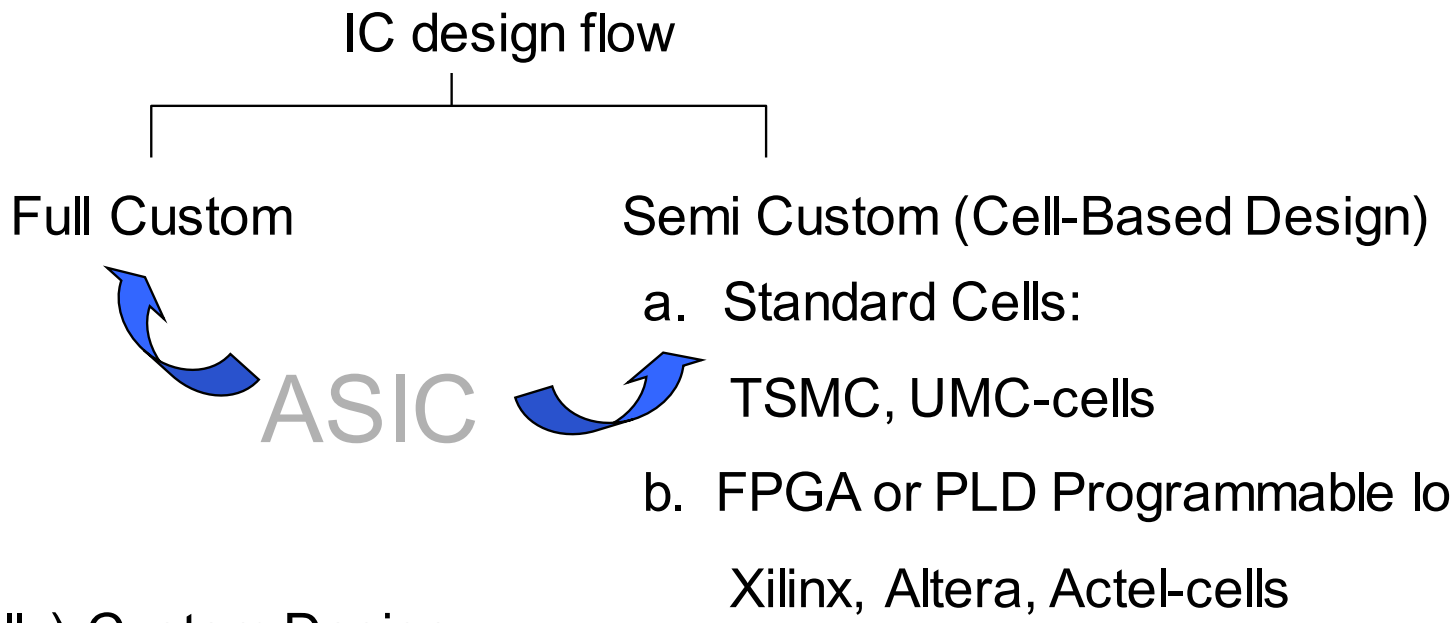
晶圓

化學品



導線架

IC Design flow



Full (Fully) Custom Design:

a. For analog circuits and digital circuits requiring custom optimization
b. Gates, transistors and layout are designed and optimized by the engineer

Semi Custom Design:

a. For larger digital circuits
b. Real gates, transistors and layout are synthesized and optimized by related software tools
c. Realization with hardware description language (HDL) such as VHDL and Verilog

Goal of Course

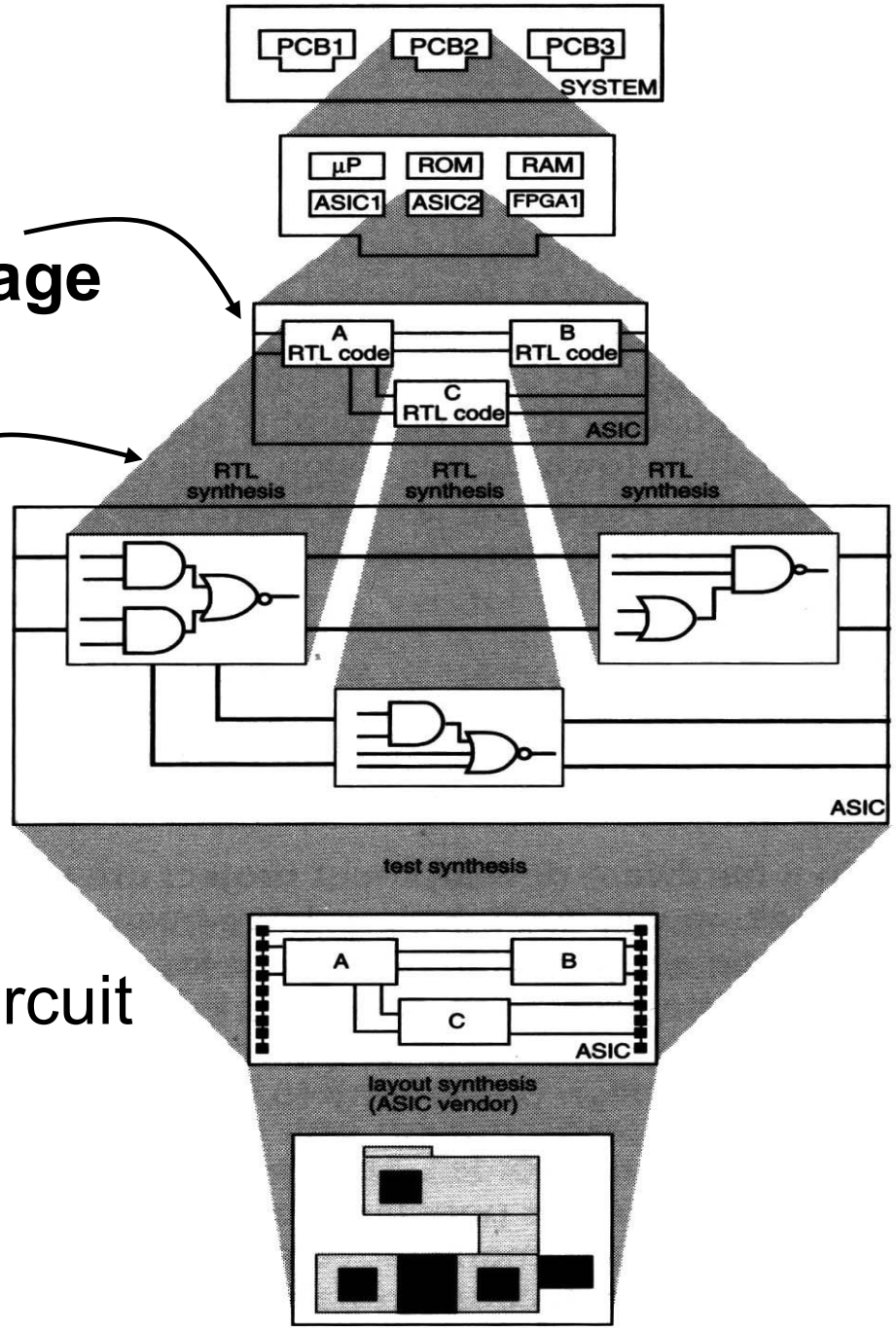
- Digital IC Design
- Cell-Based Design
- Verilog
- PC-based simulation

Hierarchical Components in PCB

1. **Describe the circuits with Hardware Description Language (HDL硬體描述語言)**

2. **Synthesis (合成) the circuits**

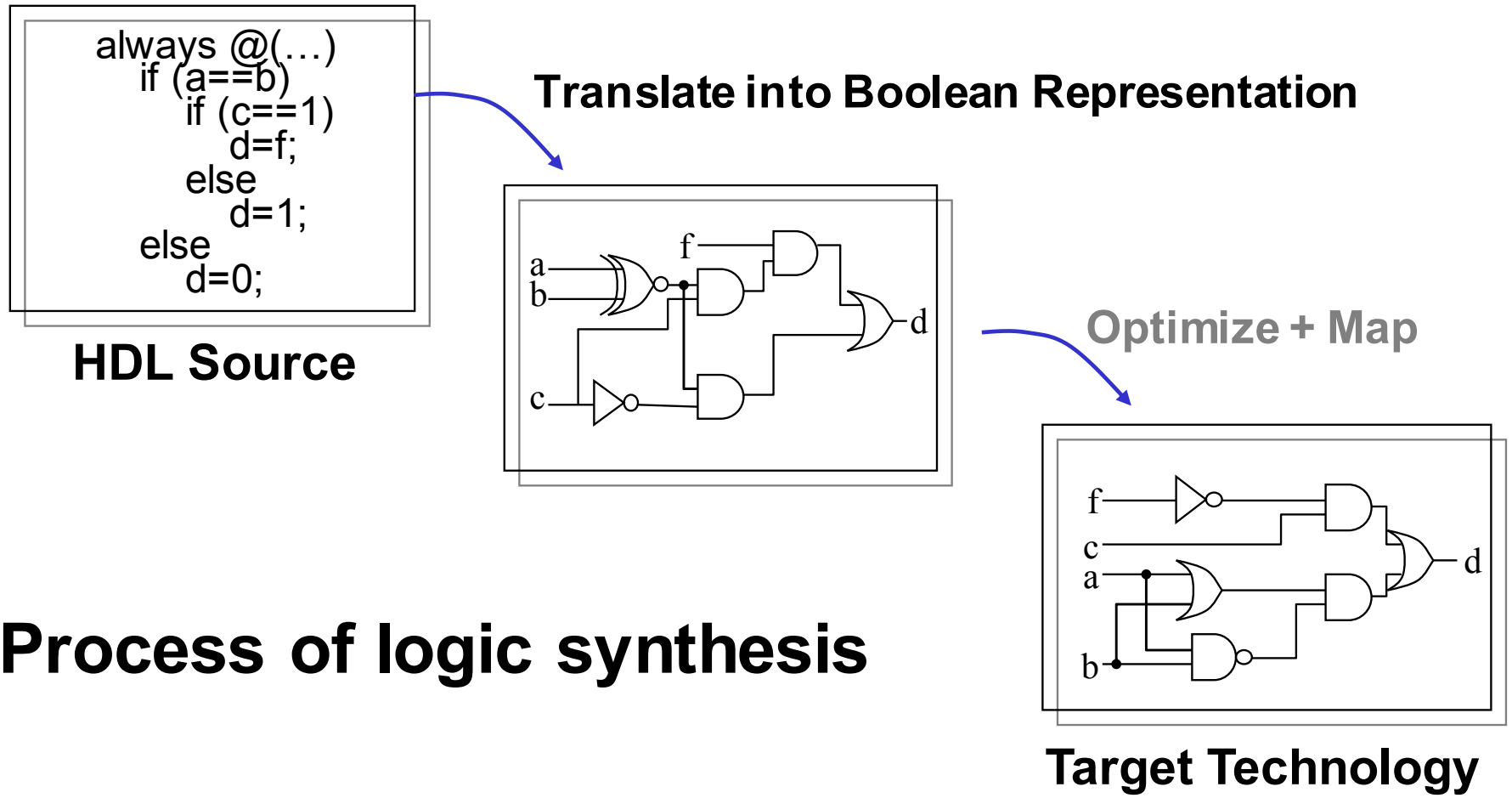
….



application specific integrated circuit (ASIC晶片)

Synthesis

- *Synthesis = Translation+Optimization+Mapping*



Process of logic synthesis

2020 Top 10 Fabless IC Suppliers

https://www.telecomlead.com/wp-content/uploads/2020/08/Top-10-IC-design-companies-2020.png

Table: 2Q20 Revenue Ranking of Top 10 IC Design Companies (Unit: Million USD)

Rank	Company	2Q20 Revenue	2Q19 Revenue	YoY Change
1	Broadcom	3,976(E)	4,265	-6.8%
2	Qualcomm	3,807	3,567	6.7%
3	Nvidia	3,461	2,352	47.1%
4	MediaTek	2,259	1,977	14.2%
5	AMD	1,932	1,531	26.2%
6	Xilinx	727	850	-14.5%
7	Marvell	716	659	8.7%
8	Novatek	622	527	18.1%
9	Realtek	579	488	18.8%
10	Dialog	302	336	-10.1%

聯發科 ★

聯詠 ★

瑞昱 ★

Notes:

1. This table shows only the top 10 IC design companies with publicly disclosed earnings
2. NVIDIA's revenue excludes its OEM/IP businesses
3. Qualcomm's revenue includes its QCT business only and not QTL; Broadcom's revenue includes its semiconductor business only
4. 2Q20 USD/TWD = 1:29.93; 2Q19 USD/TWD = 1:31.14
5. Dialog's 2Q19 revenue does not include the $300 million payment it received from Apple

Source: TrendForce, Aug. 2020

2020台灣IC設計公司營收

三千兩百億

排名	公司	千元
1	聯發科	322,145,988
2	聯詠	79,955,521
3	瑞昱	77,759,469
	群聯 [*]	48,496,522
	擎亞 [*]	26,889,818
4	奇景光電	26,214,000
	新唐 [*]	20,668,056
5	慧榮	15,507,030
6	譜瑞	15,278,350
7	晶豪	15,268,091
8	義隆	15,099,690
9	瑞鼎	14,425,152
10	矽力	13,936,157
11	矽創	13,804,562
12	敦泰	13,800,348
13	創意	13,569,441
14	天鈺	10,884,838
15	原相	8,148,017
16	致新	7,407,799
17	祥碩	6,987,470
18	威盛	6,502,741
19	神盾	6,224,427
20	盛群	5,614,539
21	智原	5,498,295
22	凌陽	6,439,865
23	茂達	5,389,874

Outline

- **Chapter 1**: Introduction
- **Chapter 2**: Semi Custom Design Flow
- **Chapter 3**: RTL Coding-Part I
- **Chapter 4**: RTL Coding-Part II
- **Chapter 5**: Digital System Design
- **Chapter 6**: Control Unit
- **Chapter 7**: Datapath
- **Chapter 8**: Case Study
- **Chapter 9**: System on a Chip
- **Chapter 10**: Low-Power Design