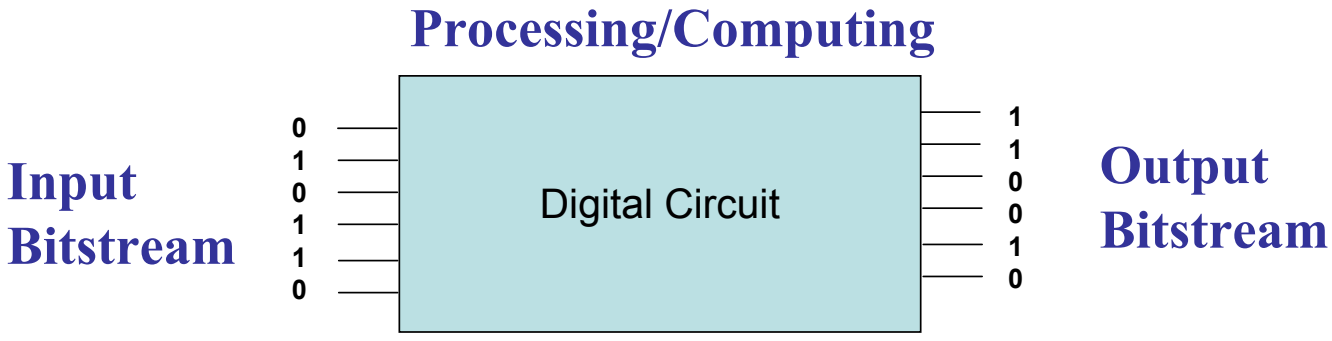
A Digital Circuit/System



數位電路都是由一連串的0或1的位元(bit)來表示輸入/輸出訊號, 所以電路內的運算處理過程也應以二進制0或1的方式進行。電路設計者需要決定那些0或1代表什麼資訊、如何解釋。

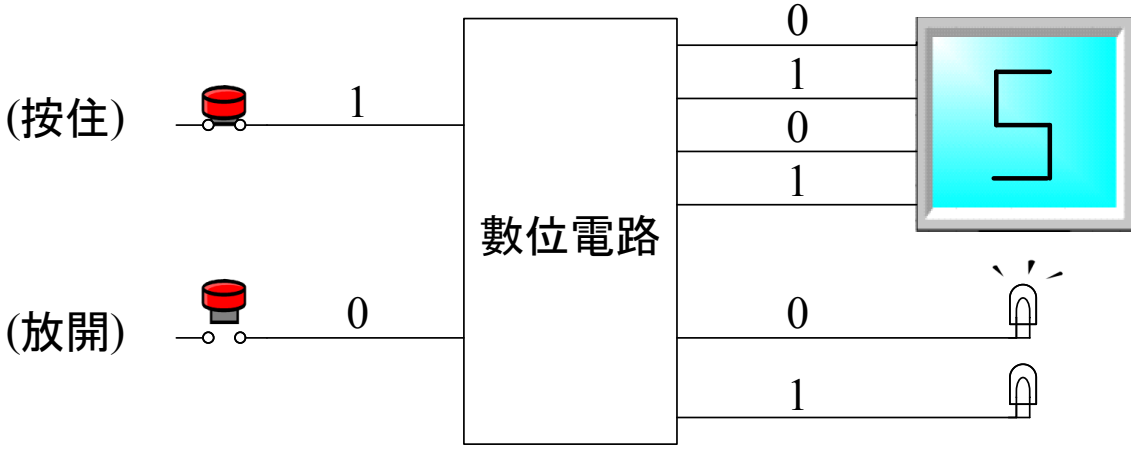
(1)如何透過輸入裝置將輸入訊號輸入系統中

(2)電路如何執行所需0與1的計算

(3)如何將結果展示於輸出裝置上

例如:按鍵被按住表示輸入1，按鍵被放開表示輸入0

輸出0101時，螢幕秀出數字5；
輸出1001時，螢幕秀出數字9。
或是輸出0表示某個LED燈要點亮，輸出1表示某個LED燈要熄滅。



Basic Elements of a Digital Circuit

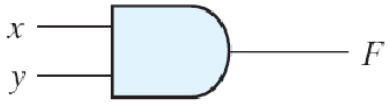
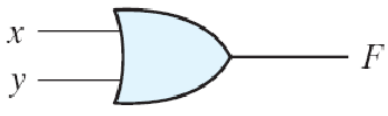
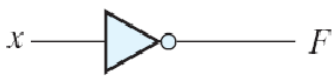
Name	Graphic symbol	Algebraic function	Truth table (真值表)
AND		$F = xy$	input: x, y / output: F 0 0 0 0 1 0 1 0 0 1 1 1
OR		$F = x + y$	x y F 0 0 0 0 1 1 1 0 1 1 1 1
Inverter		$F = x'$	x F 0 1 1 0
Buffer		$F = x$	x F 0 0 1 1

Figure 2.5 Digital logic gates (continued)

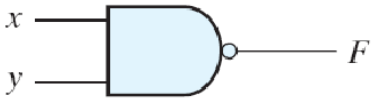
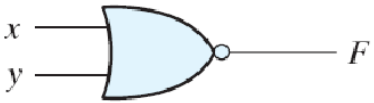
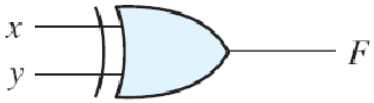
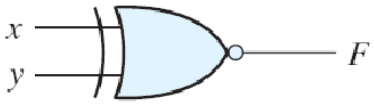
NAND		$F = (xy)'$	x y F 0 0 1 0 1 1 1 0 1 1 1 0
NOR		$F = (x + y)'$	x y F 0 0 1 0 1 0 1 0 0 1 1 0
Exclusive-OR (XOR)		$F = xy' + x'y$ $= x \oplus y$	x y F 0 0 0 0 1 1 1 0 1 1 1 0
Exclusive-NOR or equivalence		$F = xy + x'y'$ $= (x \oplus y)'$	x y F 0 0 1 0 1 0 1 0 0 1 1 1

Figure 2.5 Digital logic gates

A Simple Digital Circuit --- Adder (1/3)

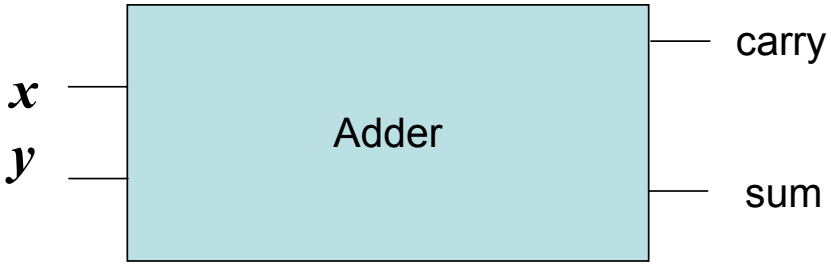
function of an one-bit adder

x	0	0	1	1
+ y	0	1	0	1
	0 0	0 1	0 1	1 0

carry

sum

Step 1



Step 2

Truth Table

x	y	carry	sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

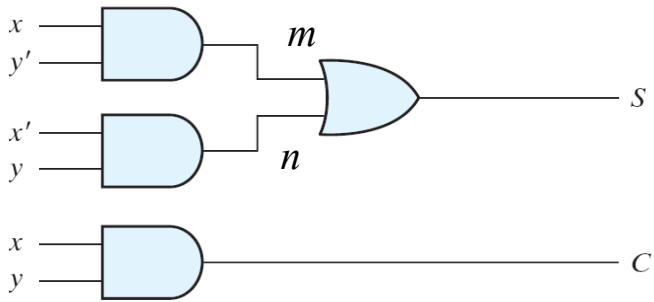
A Simple Digital Circuit --- Adder (2/3)

x	y	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Truth Table

The same

Step 3

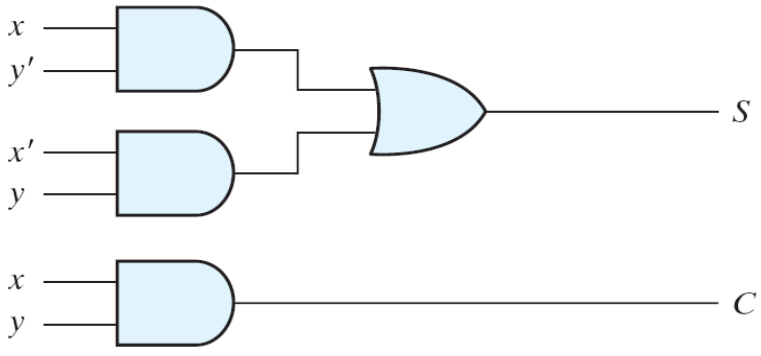


(a) $S = xy' + x'y$
$C = xy$

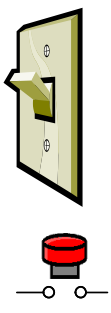
Why?

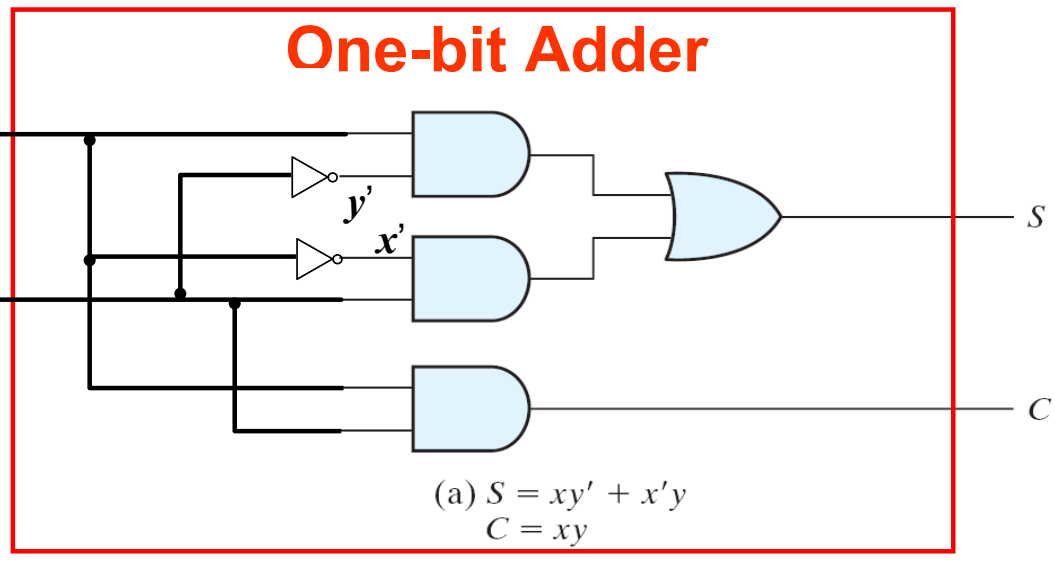
x	y	x'	y'	m	n	C	S
0	0	1	1	0	0	0	0
0	1	1	0	0	1	0	1

A Simple Digital Circuit --- Adder (3/3)



(a) $S = xy' + x'y$
$C = xy$





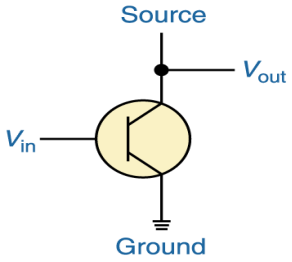
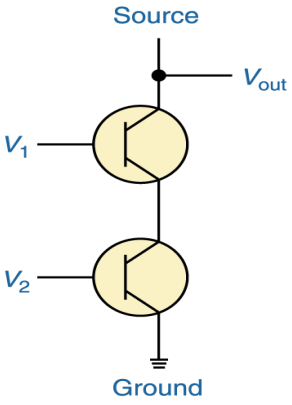
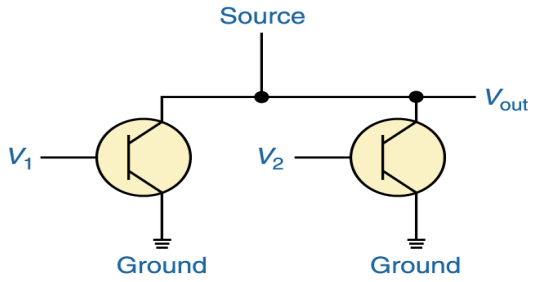
(a) $S = xy' + x'y$
$C = xy$

Constructing Gates

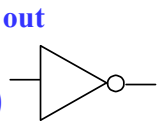
How to implement the digital circuit?

How to realize those different gates?

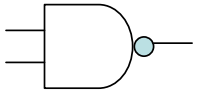
➔ **Semiconductor Technology**

NOT gate	NAND gate	NOR gate
		

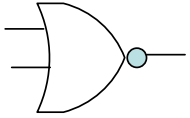
V_{in}	V_{out}
0	1
1	0



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

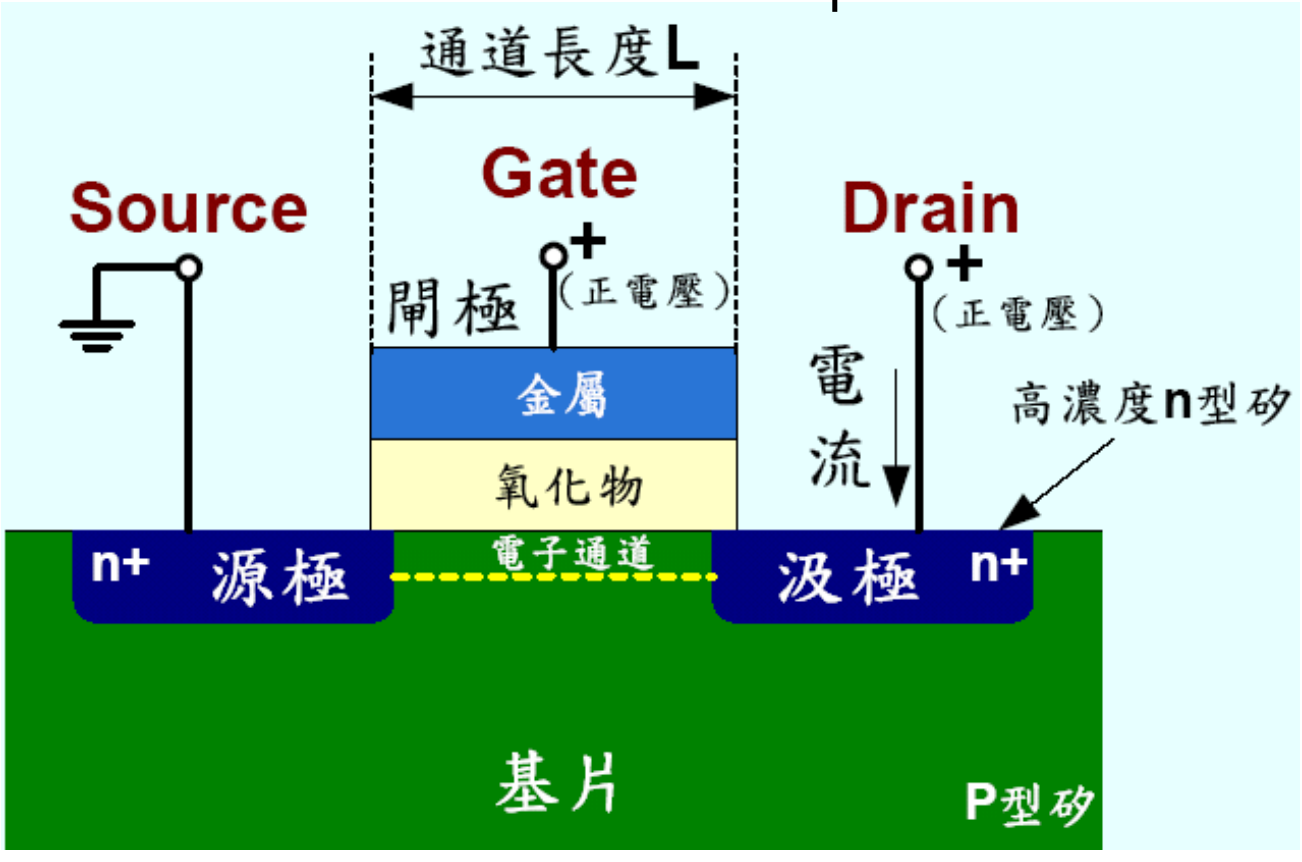


V_1	V_2	V_{out}
0	0	1
0	1	0

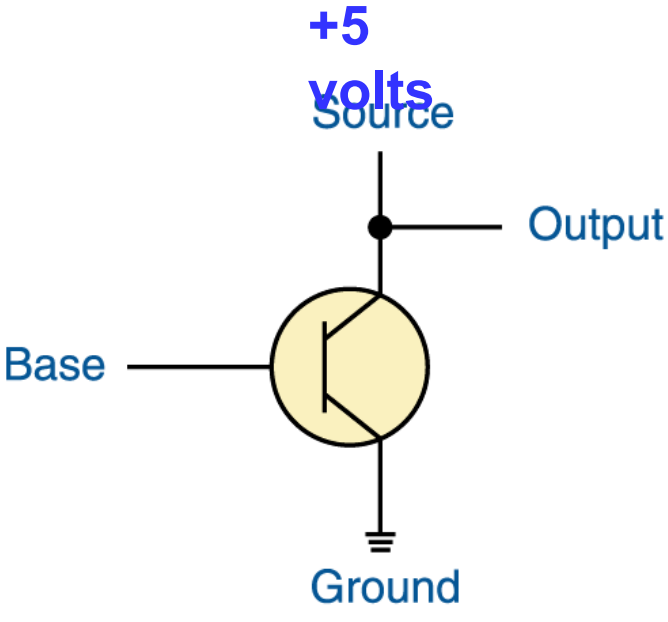


MOS電晶體示意圖 (semiconductor)

Transistor



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)

Circuits

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

  A combination of interacting transistors

- **Circuit**

  A combination of interacting gates designed to accomplish a specific logical function ➔ Integrated Circuit (IC)

- **System**

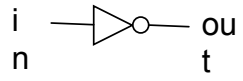
  A combination of some circuits ? ? ?

  ➔ PCB (printed circuit board)

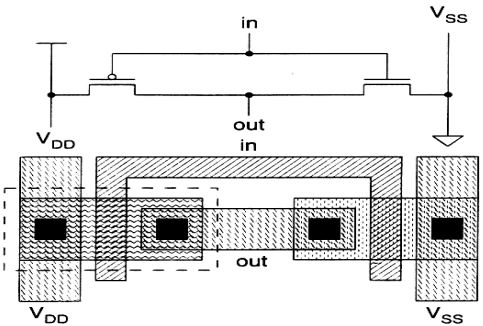
IC Design
(with CMOS semiconductor technology)

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

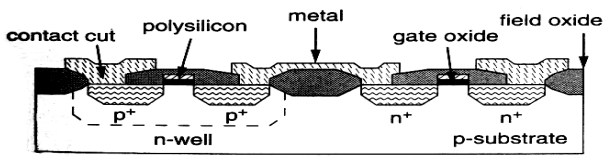
CMOS Inverter



done by chip designer



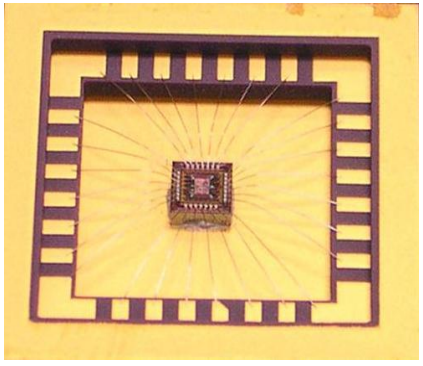
maskin g

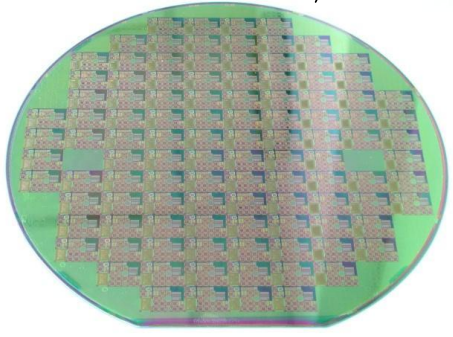


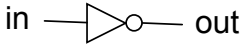
done by TSMC, UMC

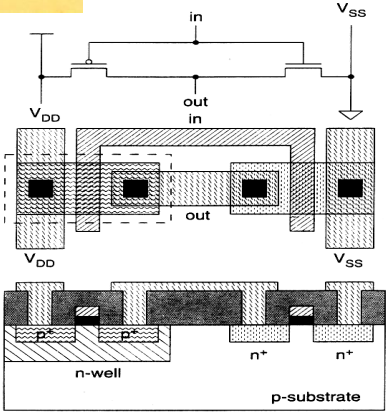
Packing, Testing

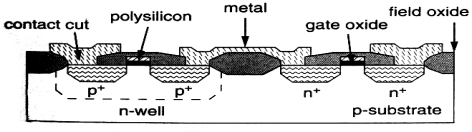
Chip/Circuit Everywhere!



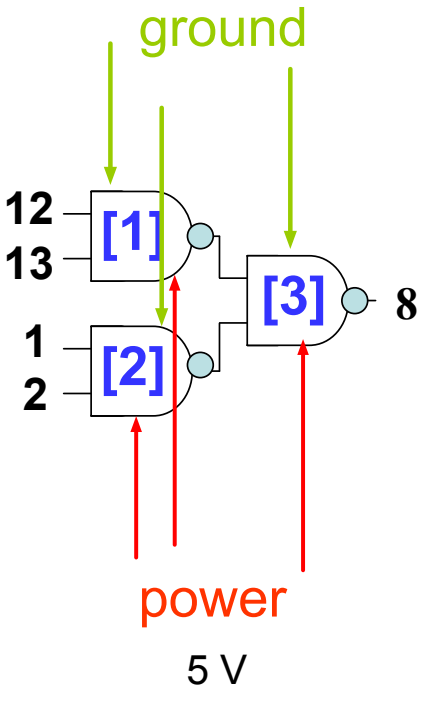


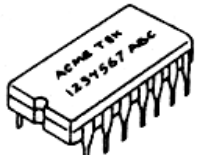


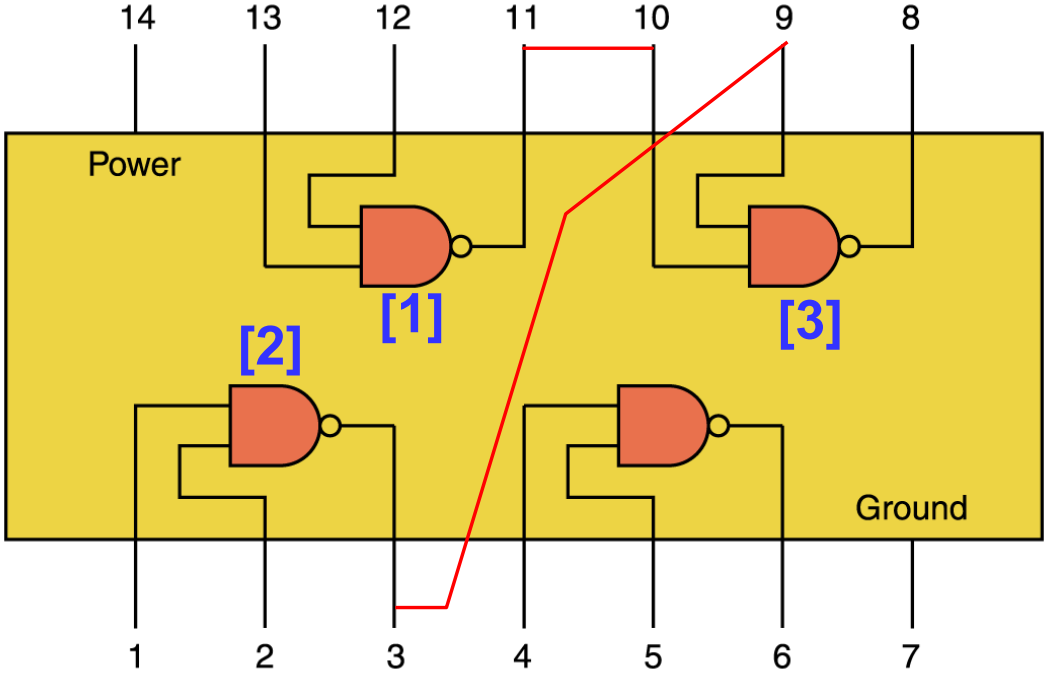




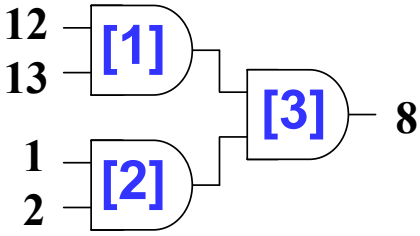
Integrated Circuits

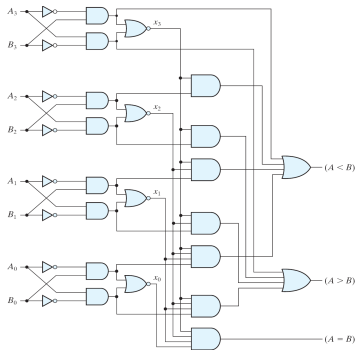


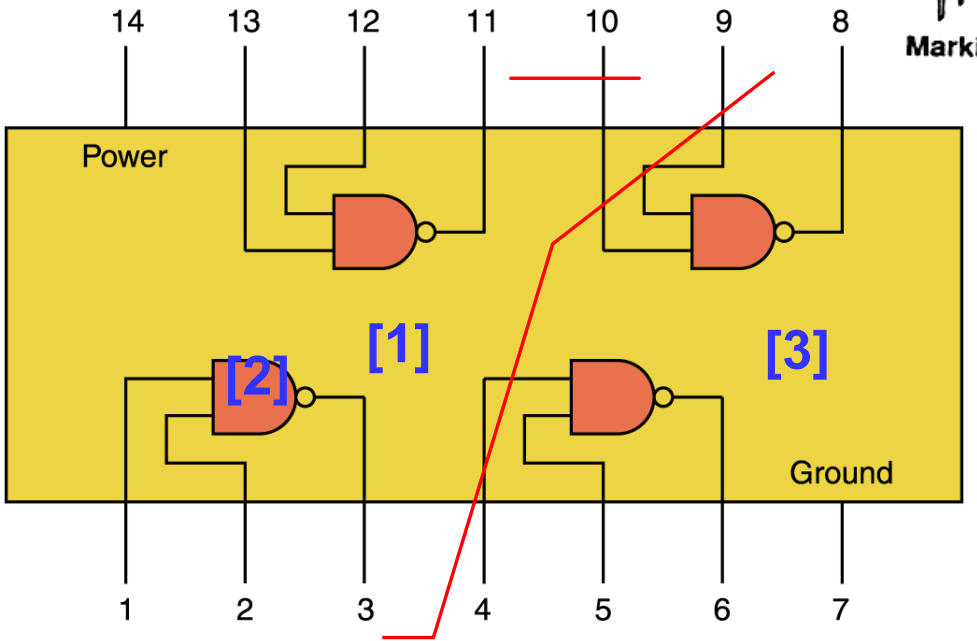


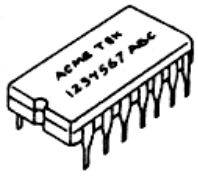


Integrated Circuits







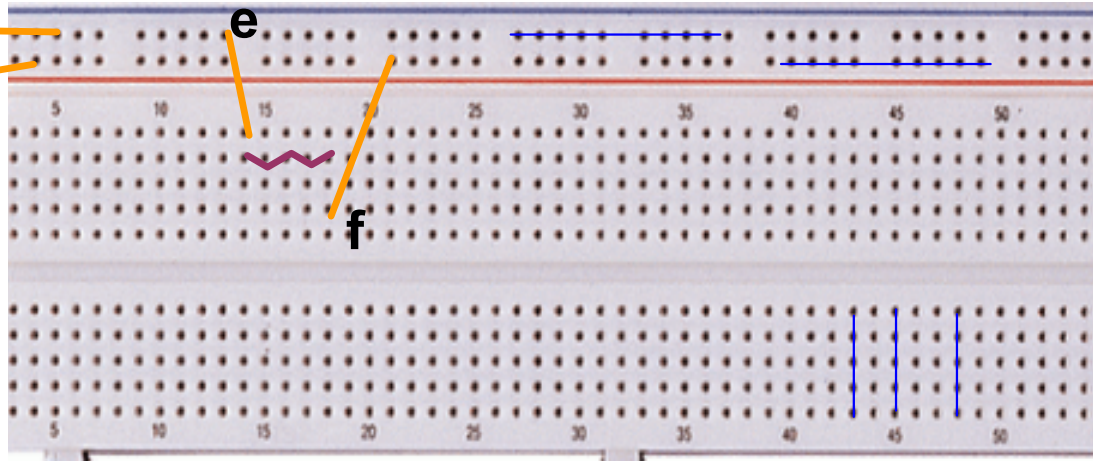


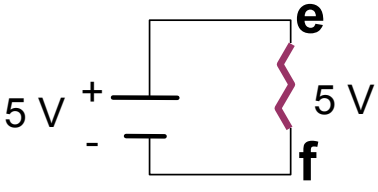
- Multiple chips (gates) combined to a circuit to solve a specific problem(解決特定問題)

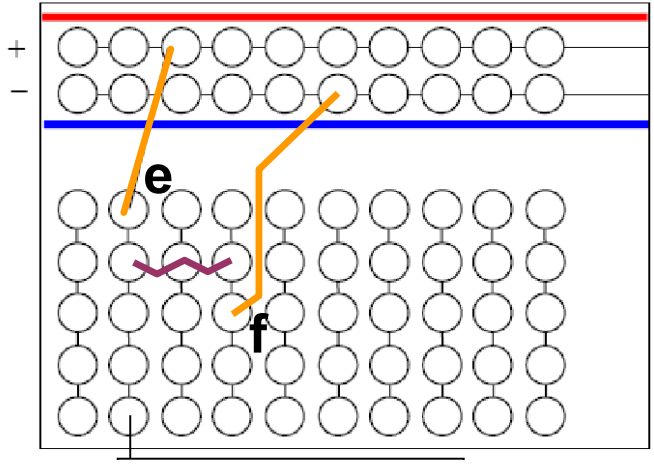
2. A dedicated chip (ASIC, application specific integrated circuit

?

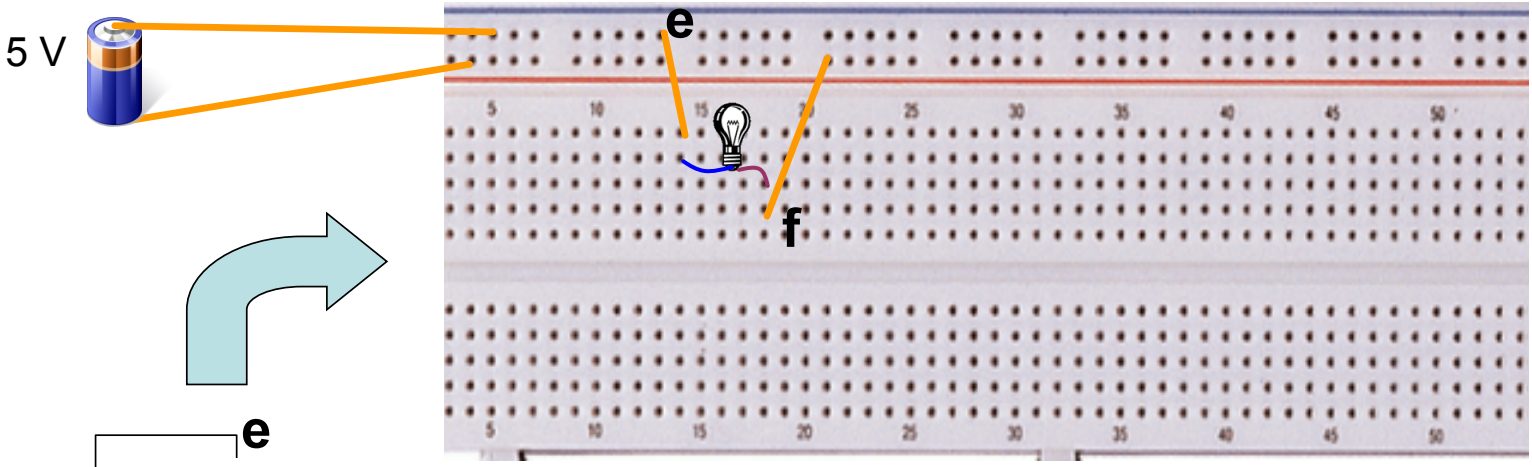
5 V

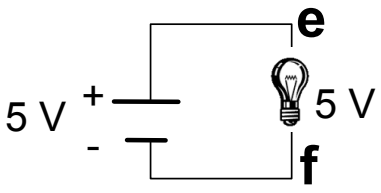


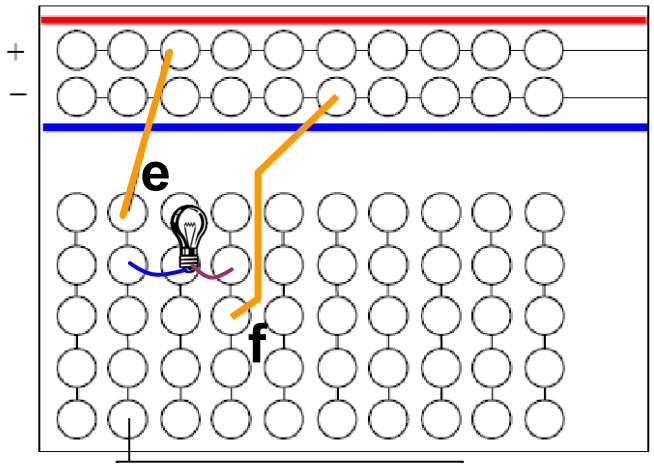




Two ways







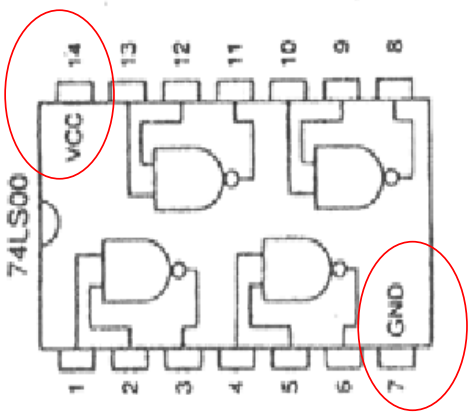
VCC

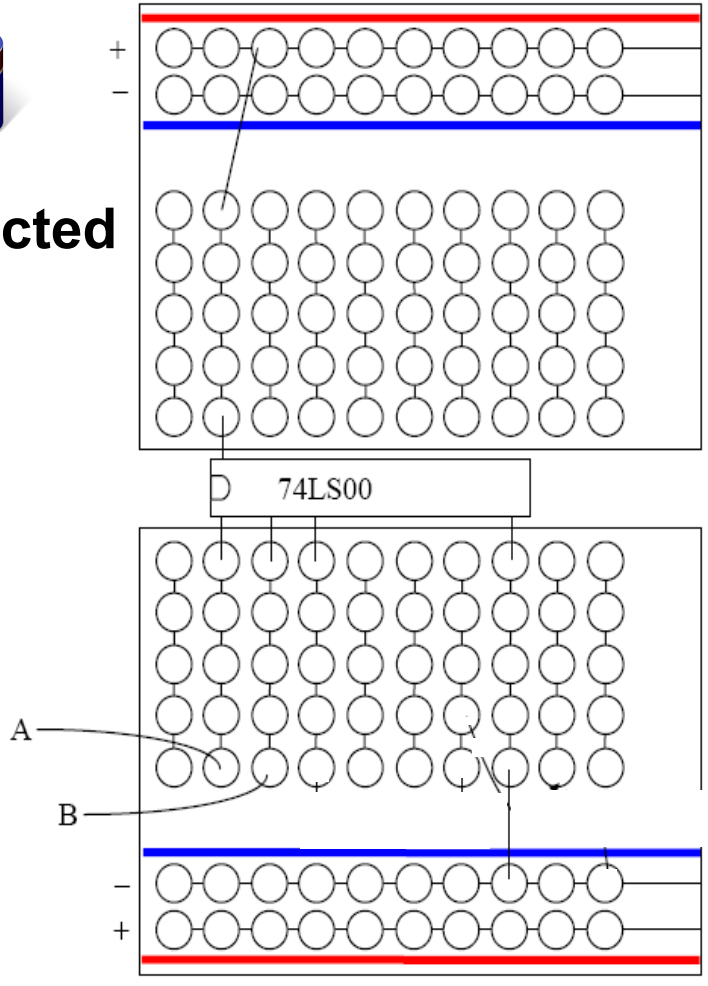
GND

Two ways

Solderless Breadboard

- **Example**
  - **VCC & GND must be connected**





Check the data sheet !!!!!

Different ICs might require different voltages (5V, 3.3V, 1.8V, …..)

Specification (datasheet) of ICs