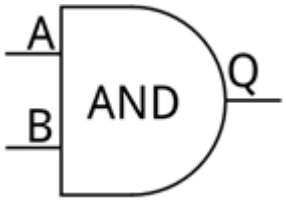
Logic Gates

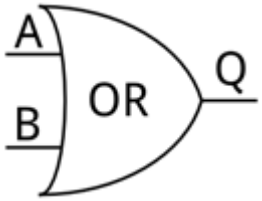
Shinwoong Kim

Binary Logic

- **Binary logic**
  - ✓ Binary logic consists of binary variables and a set of logical operations
- **Two values as the variables**
  - ✓ True and false, yes or no, etc.
  - ✓ In terms of binary bits, '0' and '1' → e.g., 0V and 5V
- **Logical operation**
  - ✓ Three basic logical operation: AND, OR, NOT



Q is '1' when A='1' and B='1'
Otherwise, Q is '0'



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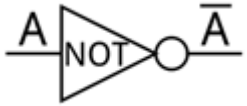
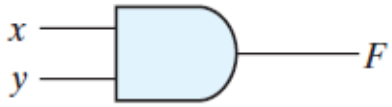
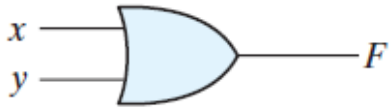
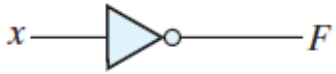
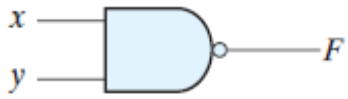
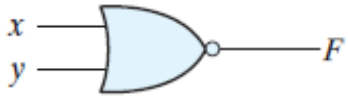
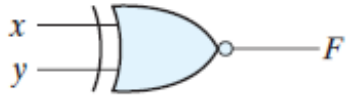


Complement operation
So, output is not A

Basic Logic Gates

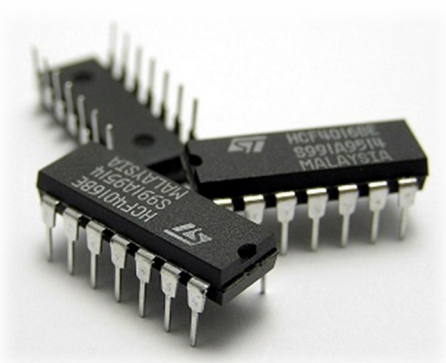
Name	Graphic symbol	Algebraic function	Truth table
AND		$F = x \cdot y$	x y | F 0 0 | 0 0 1 | 0 1 0 | 0 1 1 | 1
OR		$F = x + y$	x y | F 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 1
Inverter		$F = x'$	x | F 0 | 1 1 | 0
Buffer		$F = x$	x | F 0 | 0 1 | 1

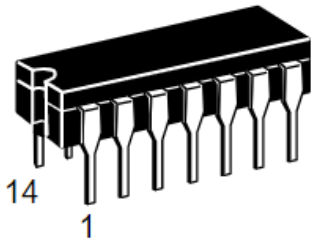
Basic Logic Gates

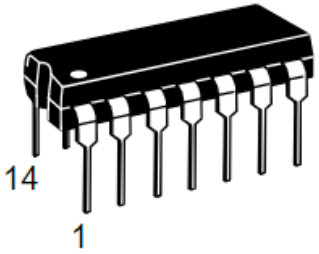
Name	Graphic symbol	Algebraic function	Truth table
NAND		$F = (xy)'$	x y | F 0 0 | 1 0 1 | 1 1 0 | 1 1 1 | 0
NOR		$F = (x + y)'$	x y | F 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 0
Exclusive-OR (XOR)		$F = xy' + x'y$ $= x \oplus y$	x y | F 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 0
Exclusive-NOR or equivalence		$F = xy + x'y'$ $= (x \oplus y)'$	x y | F 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 1

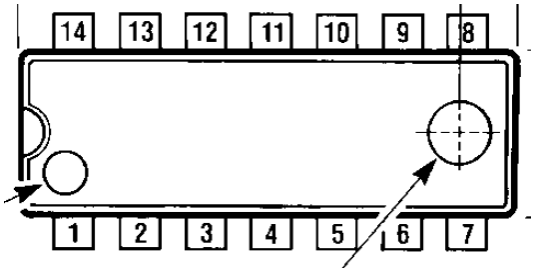
Integrated Circuit

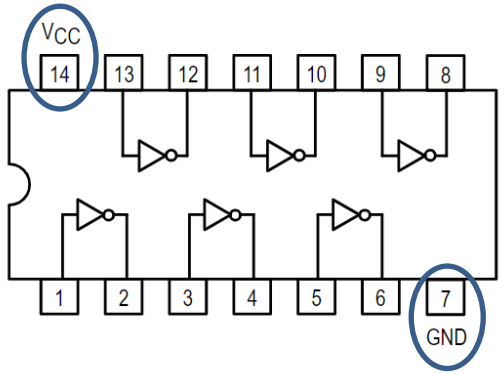
- **IC**
  - ✓ is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material, usually silicon
  - ✓ For example, **Inverter (7404)** gates
    - Power (VCC), Ground (GND), input pins, output pins











Integrated Circuit

- **Datasheet**
  - ✓ 각 칩에 대해서 자세한 설명을 해 놓은 자료
  - ✓ 제품명만 검색해도 많은 datasheet가 검색 됨

FAIRCHILD SEMICONDUCTOR™

August 1986
Revised March 2000

DM74LS04
Hex Inverting Gates

DM74LS04 Hex Inverting Gates

General Description

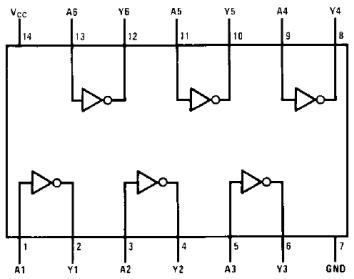
This device contains six independent gates each of which performs the logic INVERT function.

Ordering Code:

Order Number	Package Number	Package Description
DM74LS04M	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150 Narrow
DM74LS04SJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
DM74LS04N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



Function Table

$Y = \overline{A}$

Input	Output
A	Y
L	H
H	L

H = HIGH Logic Level
L = LOW Logic Level

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			−0.4	mA
I_{OL}	LOW Level Output Current			8	mA
T_A	Free Air Operating Temperature	0		70	°C

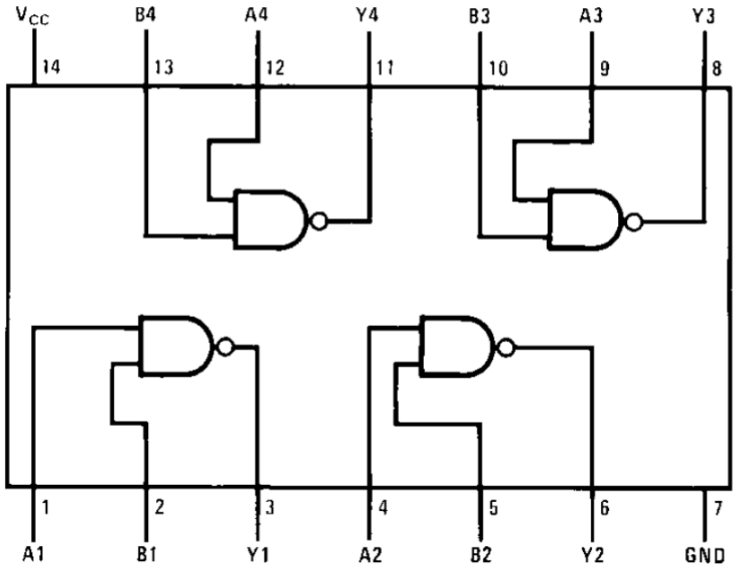
Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

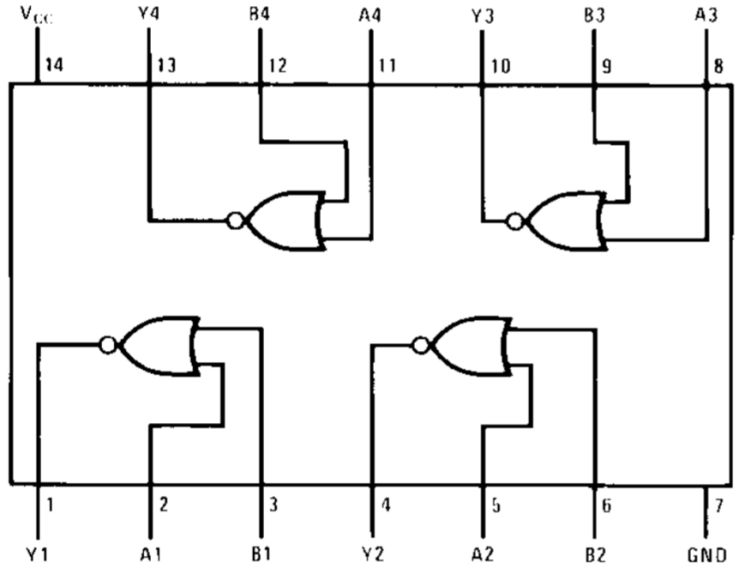
Symbol	Parameter	Conditions	Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA			−1.5	V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IL} = Max	2.7	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IH} = Min		0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V			0.1	mA
I_{IH}	HIGH Level Input Current	V_{CC} = Max, V_I = 2.7V			20	µA
I_{IL}	LOW Level Input Current	V_{CC} = Max, V_I = 0.4V			−0.36	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	−20		−100	mA
I_{CCH}	Supply Current with Outputs HIGH	V_{CC} = Max		1.2	2.4	mA
I_{CCL}	Supply Current with Outputs LOW	V_{CC} = Max		3.6	6.6	mA

Integrated Circuit

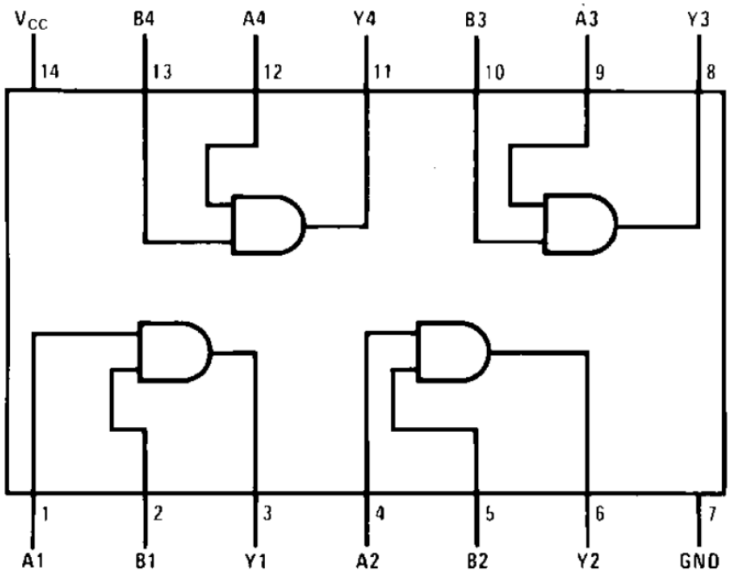
7400



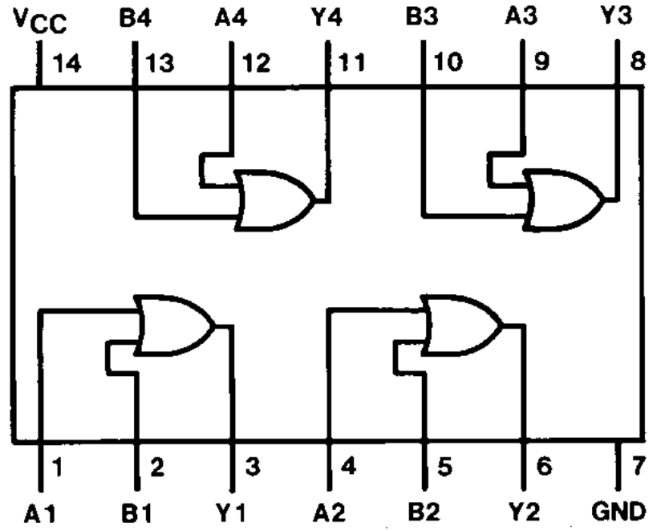
7402



7408

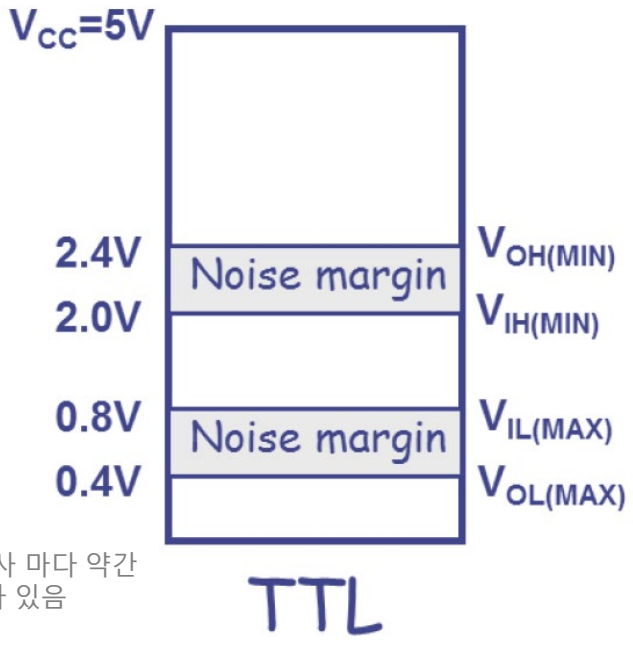


7432

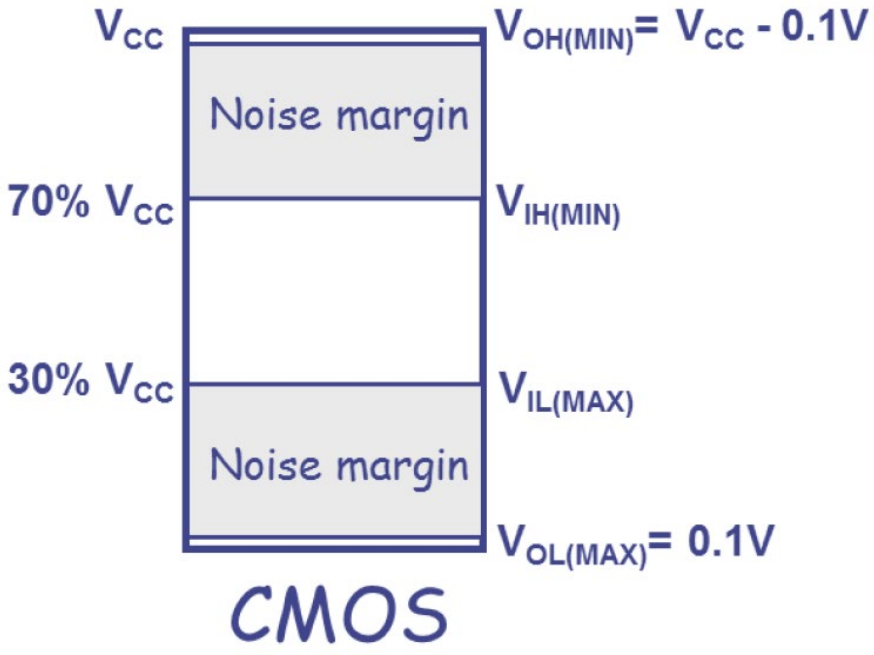


Integrated Circuit

- **IC type**
  - ✓ TTL(transistor-transistor logic)
    - 74LS00, 74LS02 … (low power shorttky TTL)
  - ✓ CMOS (Complementary metal-oxide semiconductor)
    - 74HC00, 74HC02 … (high speed CMOS)

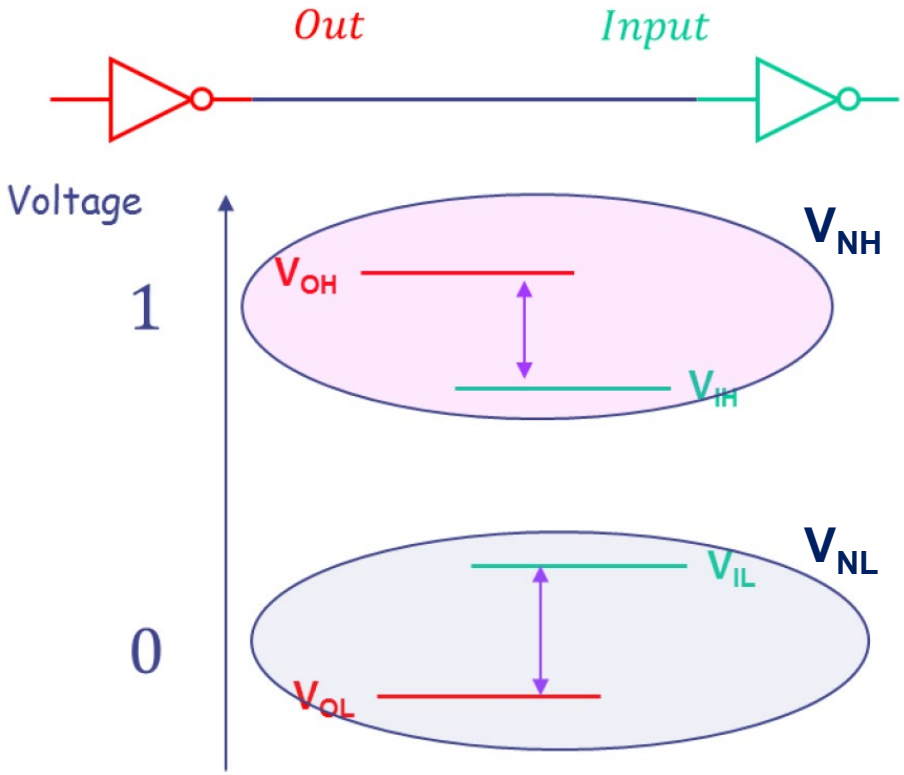


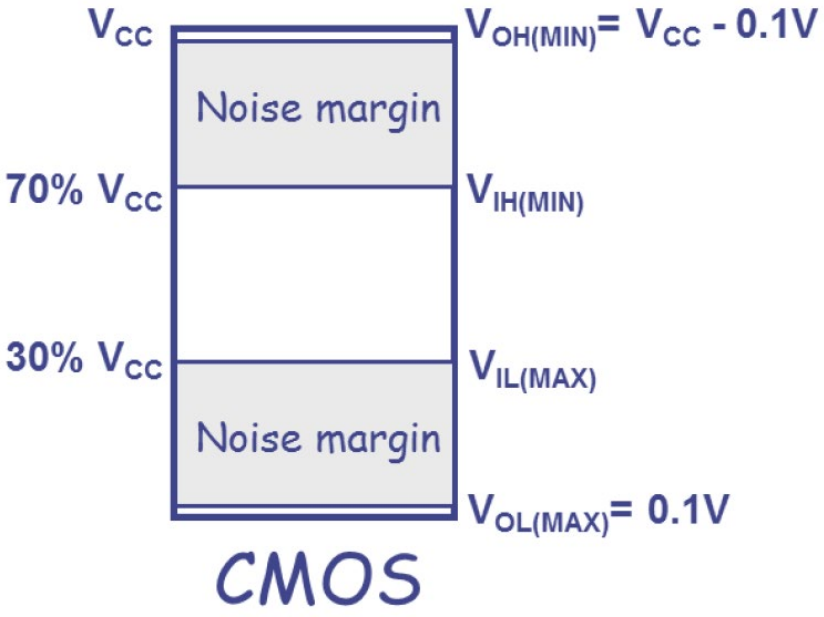
*제조사 마다 약간 차이가 있음



Characteristic: Noise margin

- **Noise margin**
  - $V_{NH} = V_{OH(min)} - V_{IH(min)}$
  - $V_{NL} = V_{IL(max)} - V_{OL(max)}$





Characteristic: Noise margin

- **Issue**

CMOS --> TTL

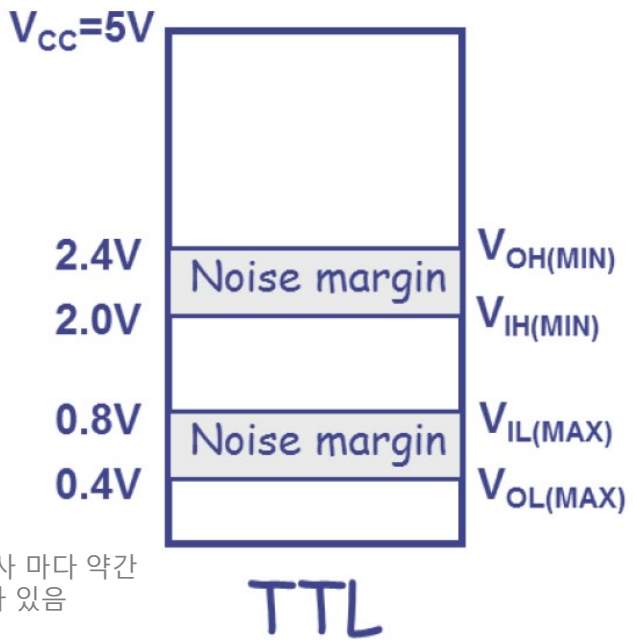
Sending Low (**0.1V -> 0.8V**)

Sending High (**4.9V -> 2.0V**)

TTL --> CMOS

Sending Low (**0.4V -> 1.5V**) Pass

Sending High (**2.4V -> 3.5V**) No Pass!



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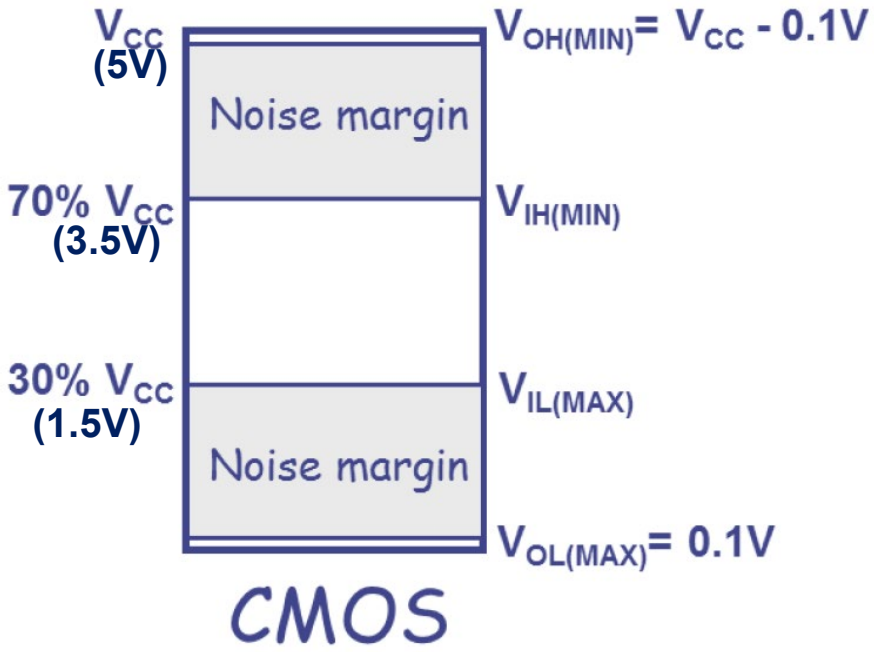

Characteristic: Noise margin

- e.g., Datasheet (74LS04)

Recommended Operating Conditions

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V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IH} = Min		0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V			0.1	mA
I_{IH}	HIGH Level Input Current	V_{CC} = Max, V_I = 2.7V			20	µA
I_{IL}	LOW Level Input Current	V_{CC} = Max, V_I = 0.4V			−0.36	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	−20		−100	mA
I_{CCH}	Supply Current with Outputs HIGH	V_{CC} = Max		1.2	2.4	mA
I_{CCL}	Supply Current with Outputs LOW	V_{CC} = Max		3.6	6.6	mA

Characteristic: Noise margin

- **e.g., Datasheet (74HC04)**

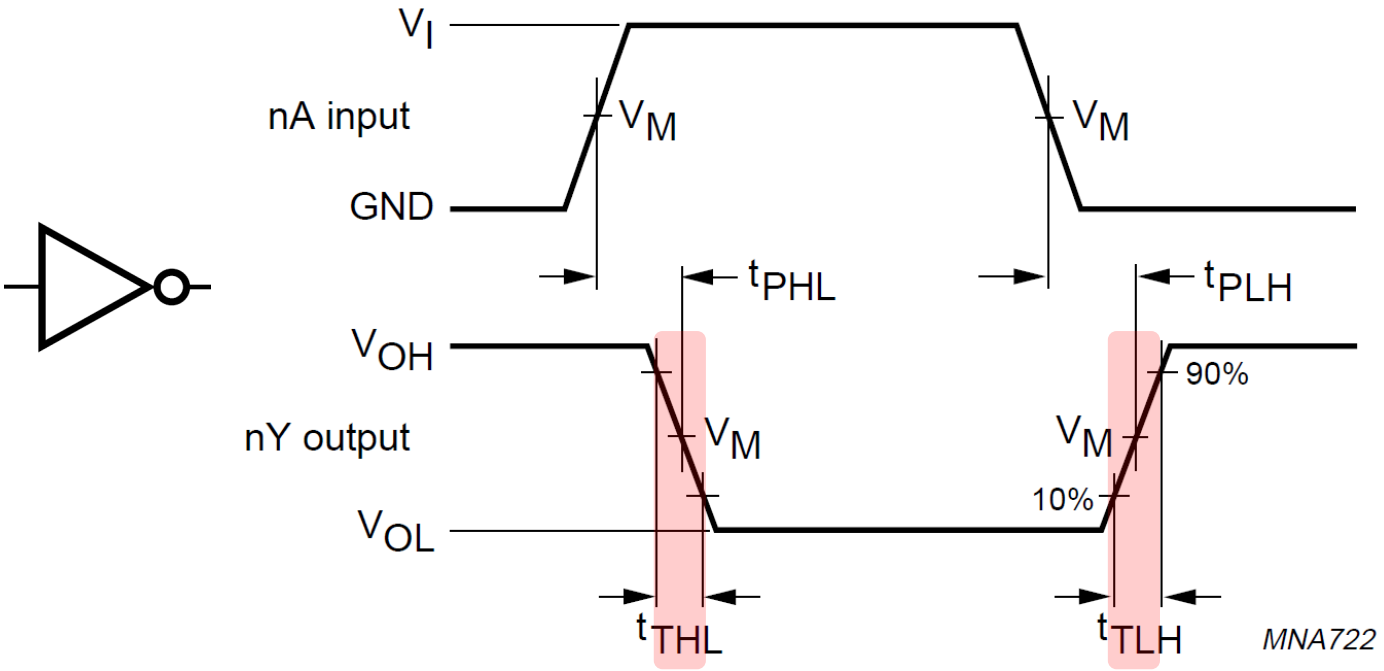
Type 74HC04

At recommended operating conditions; voltages are referenced to GND (ground = 0 V).

SYMBOL	PARAMETER	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT
		OTHER	V_{CC} (V)				
T_{amb} = 25 °C							
V_{IH}	HIGH-level input voltage		2.0	1.5	1.2	–	V
			4.5	3.15	2.4	–	V
			6.0	4.2	3.2	–	V
V_{IL}	LOW-level input voltage		2.0	–	0.8	0.5	V
			4.5	–	2.1	1.35	V
			6.0	–	2.8	1.8	V
V_{OH}	HIGH-level output voltage	V_I = V_{IH} or V_{IL}					
		I_O = –20 µA	2.0	1.9	2.0	–	V
		I_O = –20 µA	4.5	4.4	4.5	–	V
		I_O = –4.0 mA	4.5	3.98	4.32	–	V
		I_O = –20 µA	6.0	5.9	6.0	–	V
		I_O = –5.2 mA	6.0	5.48	5.81	–	V
V_{OL}	LOW-level output voltage	V_I = V_{IH} or V_{IL}					
		I_O = 20 µA	2.0	–	0	0.1	V
		I_O = 20 µA	4.5	–	0	0.1	V
		I_O = 4.0 mA	4.5	–	0.15	0.26	V
		I_O = 20 µA	6.0	–	0	0.1	V
		I_O = 5.2 mA	6.0	–	0.16	0.26	V
I_I	Input leakage current	V_I = V_{CC} or GND	6.0		0.1	±0.1	µA

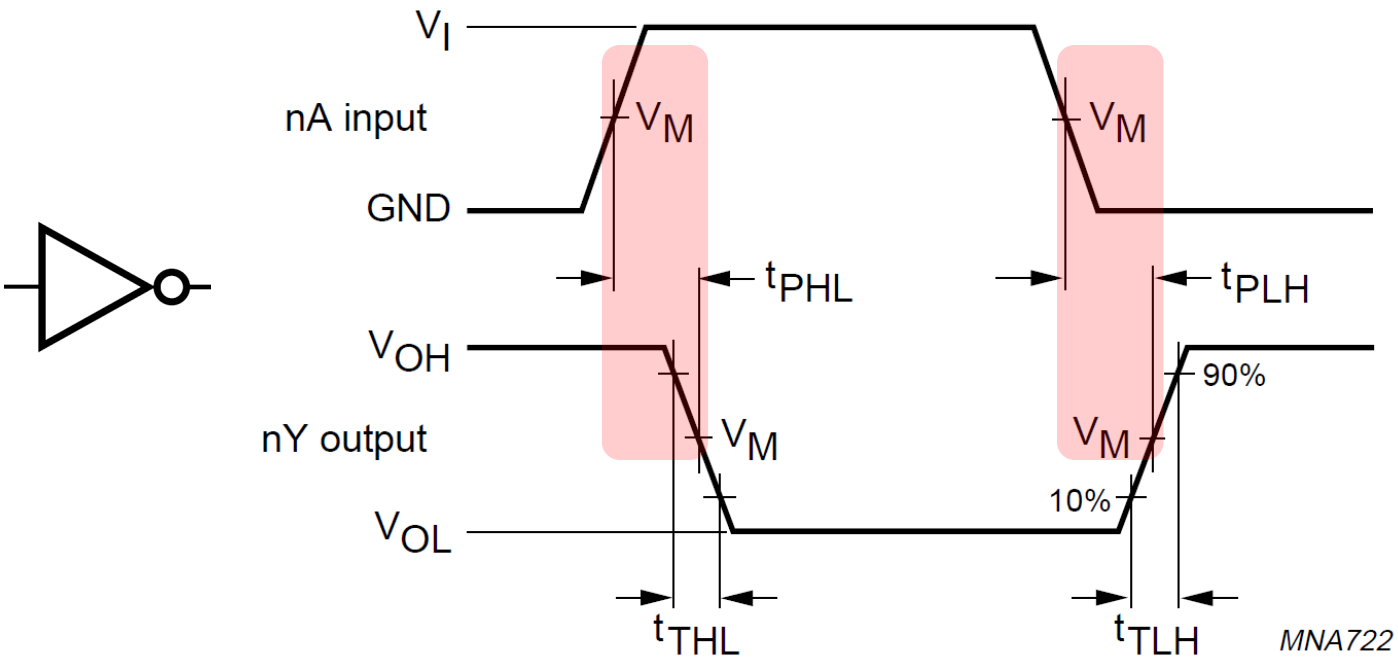
Characteristic: Delay

- **Transition time**
  - ✓ Transition High-to-Low (t_{THL})
    - 출력이 high 90% → low 10%가 될 때까지의 시간
  - ✓ Transition Low-to-High (t_{TLH})
    - 출력이 low 10% → high 90%가 될 때까지의 시간



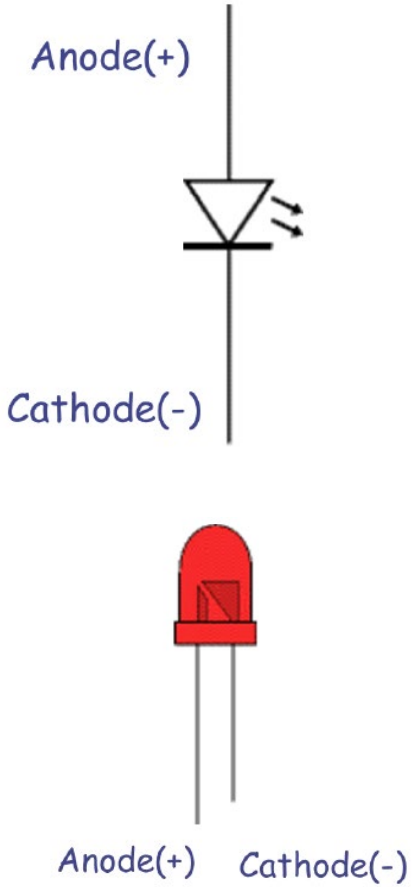
Characteristic: Delay

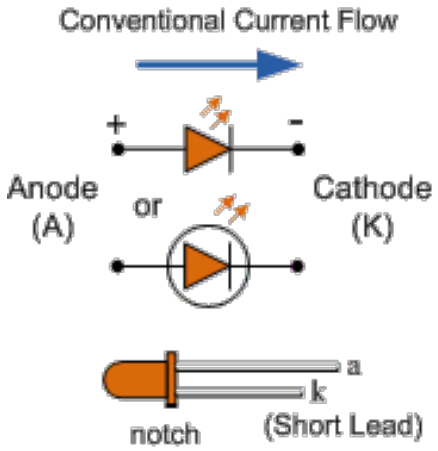
- **Propagation time**
  - ✓ Propagation High-to-Low (t_{PHL})
    - 출력이 High → Low가 될 때, 입력 신호와의 시간 차이
      (50% 지점 간의 차이)
  - ✓ Propagation Low-to-High (t_{PLH})
    - 출력이 Low → High가 될 때, 입력 신호와의 시간 차이
      (50% 지점 간의 차이)

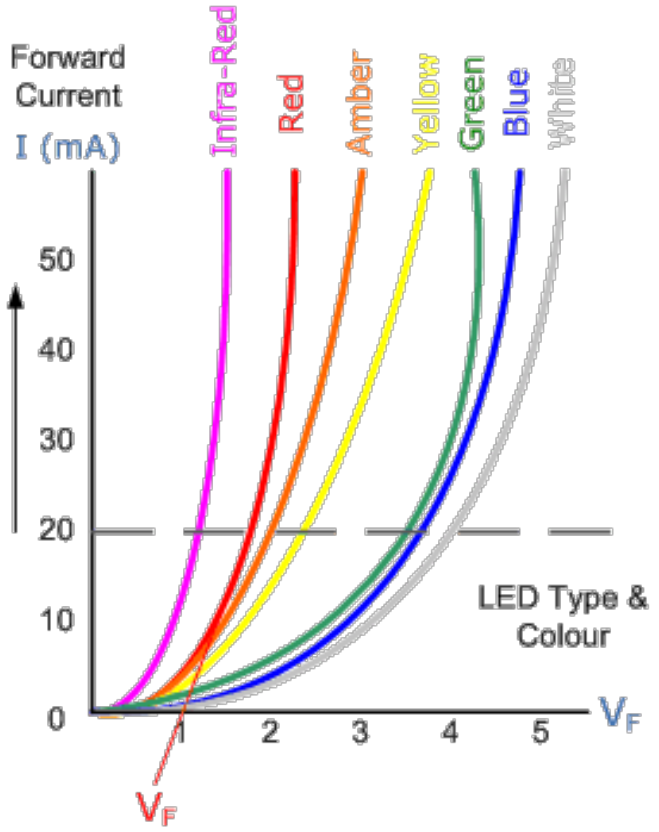


Light-Emitting Diode (LED)

- 동작
  - ✓ Anode(+) 전압 > Cathode(-) 전압인 경우, 즉 순방향으로 전압을 가했을 경우, 전류가 흐르며 발광(發光)함, 밝기는 전류에 비례함



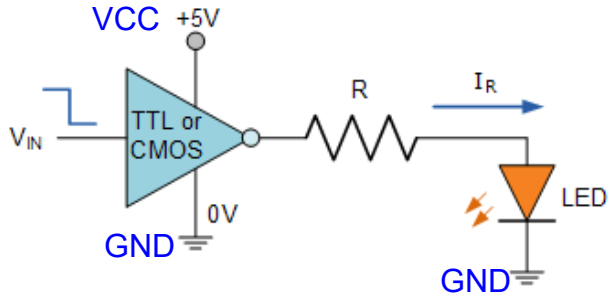




*https://www.electronics-tutorials.ws/diode/diode_8.html

Light-Emitting Diode (LED)

- **회로 구성**
  - ✓ 전류 제한을 위해 저항과 함께 사용
    - LED는 일반적으로 V_F=2V에서 20mA 정도 소모
  - ✓ 로직 출력이 'High(5V)'일 때 LED가 켜지도록 하는 경우

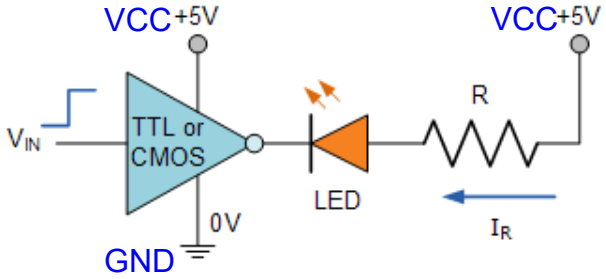


LED is "ON" when the output is HIGH (current source)

*필요한 저항 값 계산

$$R = \frac{5V-2V}{20mA} = 150\Omega$$

  - ✓ 로직 출력이 'Low(0V)'일 때 LED가 켜지도록 하는 경우

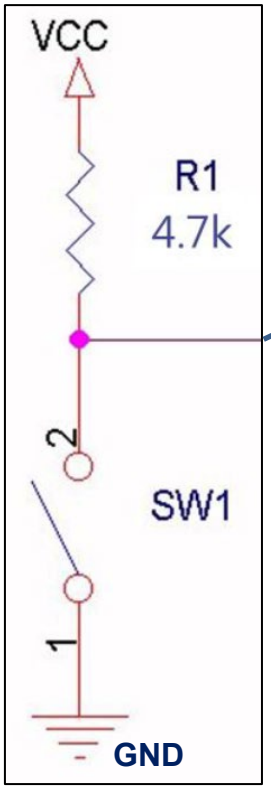


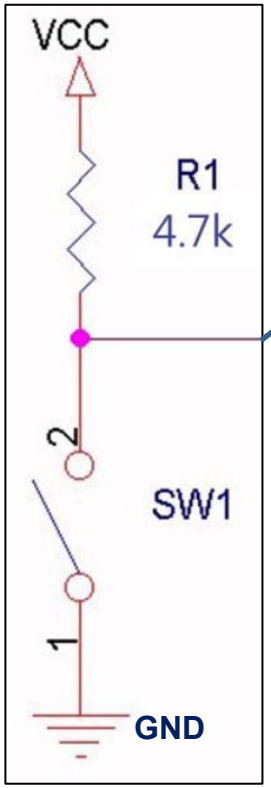
LED is "ON" when the output is LOW (current sink)

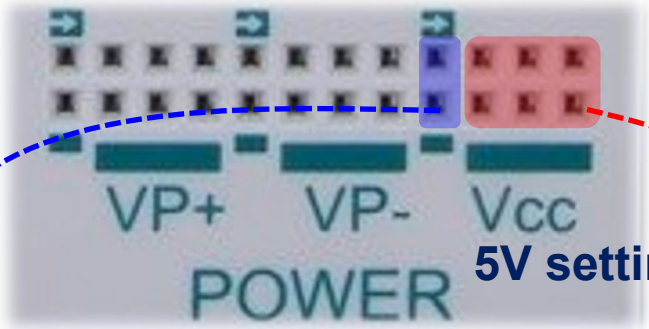
*https://www.electronics-tutorials.ws/diode/diode_8.html

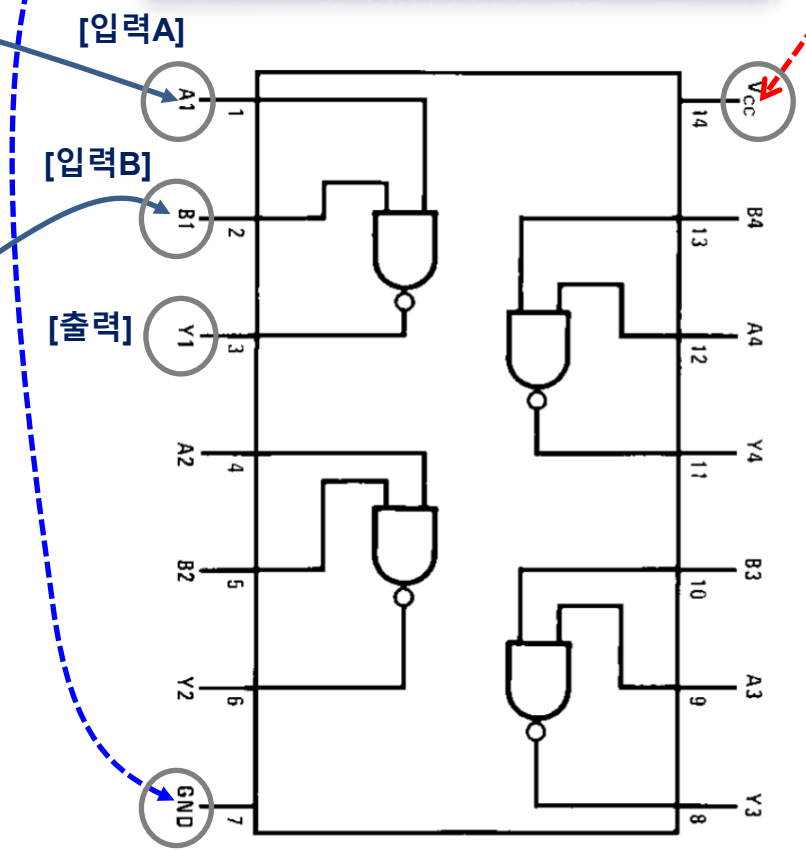
실험 1

- 기본 로직 동작 검증 (74LS00 NAND)









***Pull-up 저항을 이용한 입력 스위치**

OFF: VCC 연결 (logic high)
ON: GND 연결 됨 (logic low)

실험 1

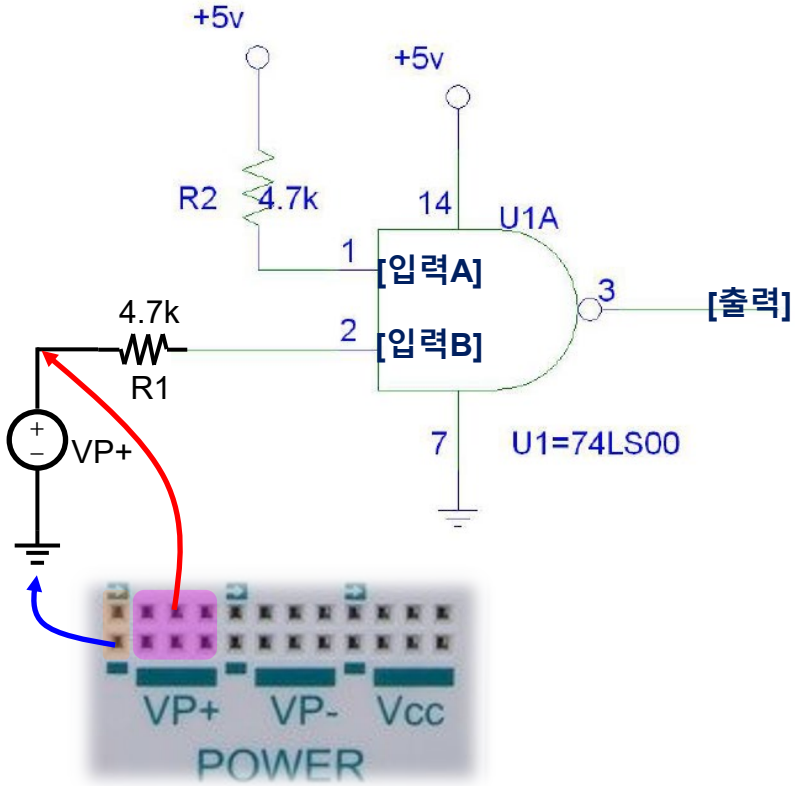
- **기본 로직 동작 검증 (74LS00 NAND)**
  - ✓ DMM을 이용하여 출력 전압을 측정하고 → 출력 논리를 판별

74LS00 (NAND)

입력 논리		예상 출력 논리	측정된 출력 전압	측정된 전압으로부터 얻은 논리
A	B	0 or 1?	? V	0 or 1?
0	0			
0	1			
1	0			
1	1			

실험 2

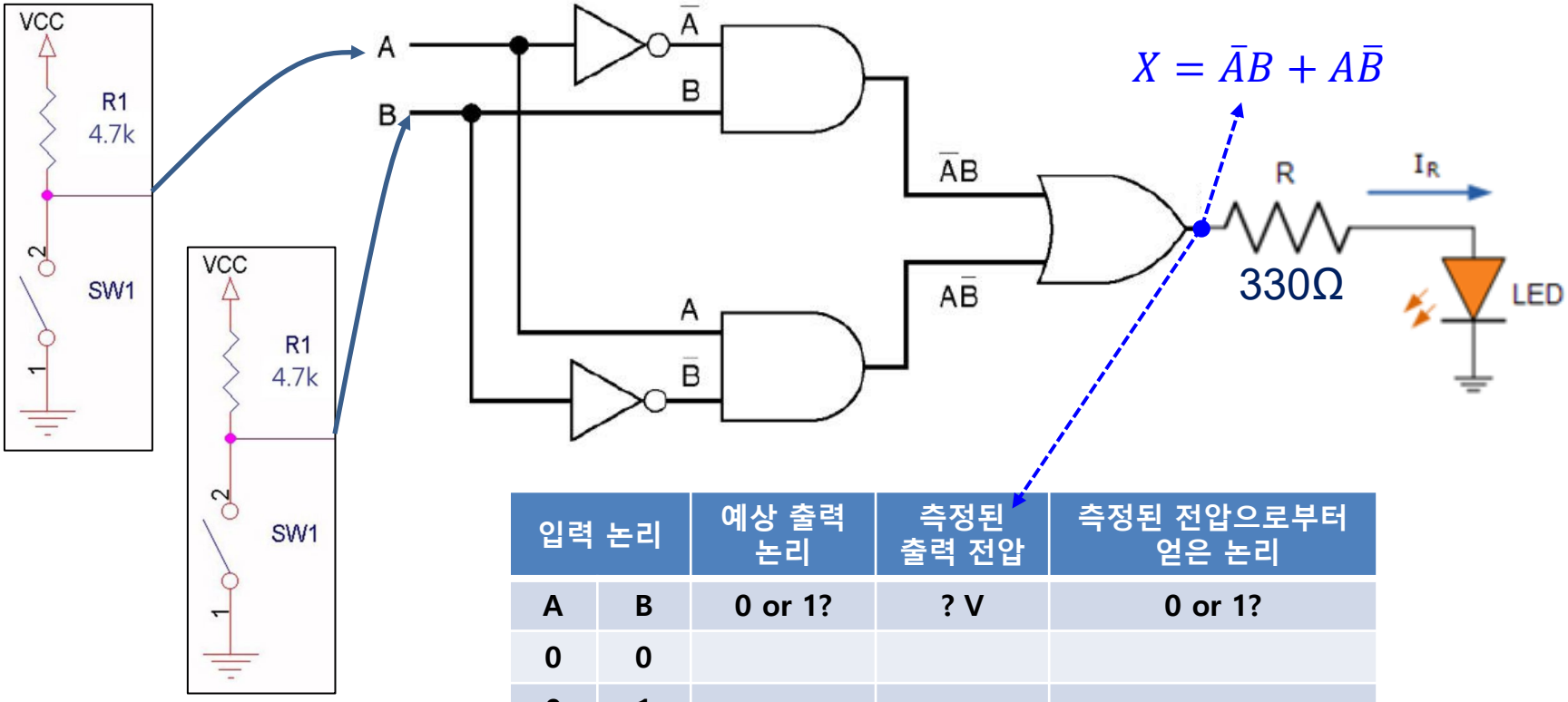
- **인가하는 전압 범위에 따른 특성 파악**
  - ✓ '실험1'에 이어서 진행, 입력 스위치 부분만 변경하면 됨
  - ✓ 입력 A (1번 핀) : 4.7kΩ을 이용하여 논리 high (VCC 5V)에 고정
  - ✓ 입력 B (2번 핀) : VP+ power에 연결하여 다양한 전압을 인가
  - ✓ [참고] Datasheet 기준, 74LS00의 $V_{IL(max)}$=0.8V, $V_{IH(min)}$=2.0V



입력 전압 [입력 B]	예상 출력 논리	측정된 출력 전압	측정된 전압으로부터 얻은 논리
[V]	0 or 1?	? V	0 or 1?
0			
0.4			
0.8			
1.2			
1.6			
2.0			
3.0			
4.0			
5.0			

실험 3

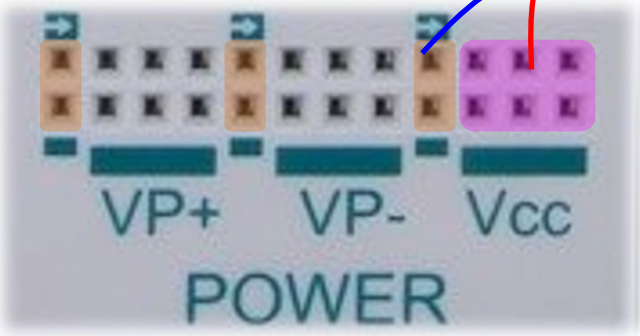
- **XOR 회로 설계**
  - Inverter(74LS04) + AND(74LS08) + OR(74LS32) 사용
  - LED 사용하여 출력 로직 판별 (출력이 'High'일 때 LED ON)

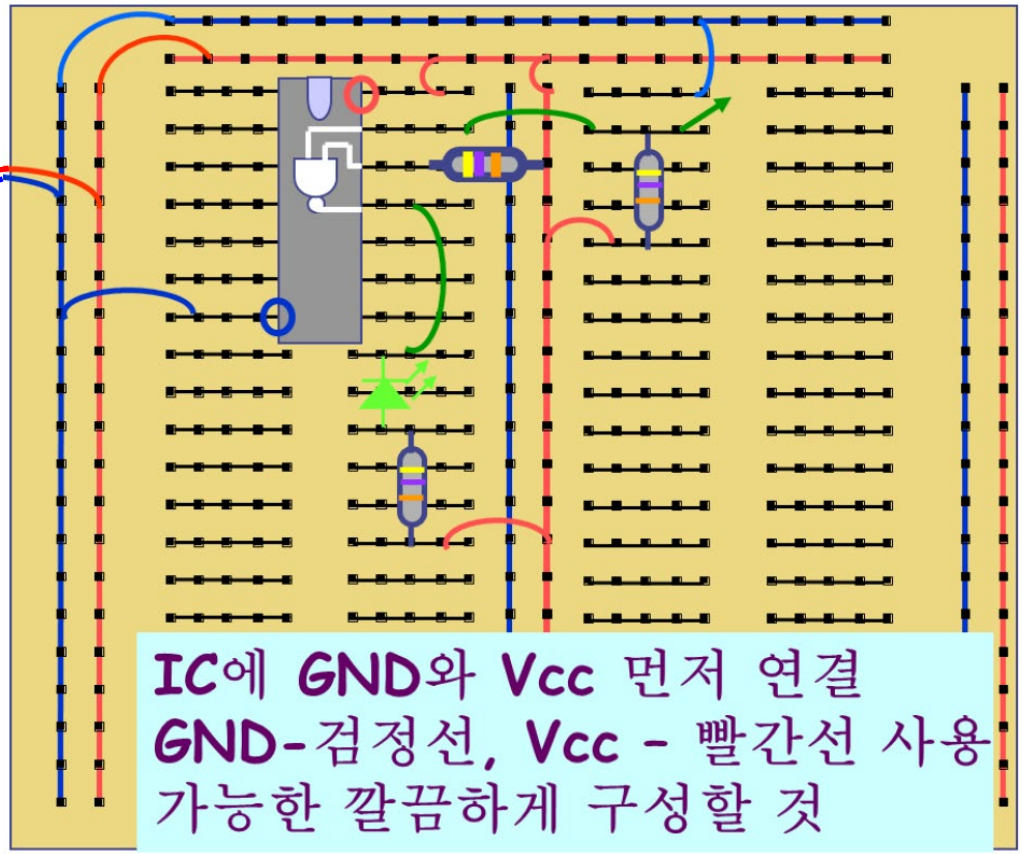


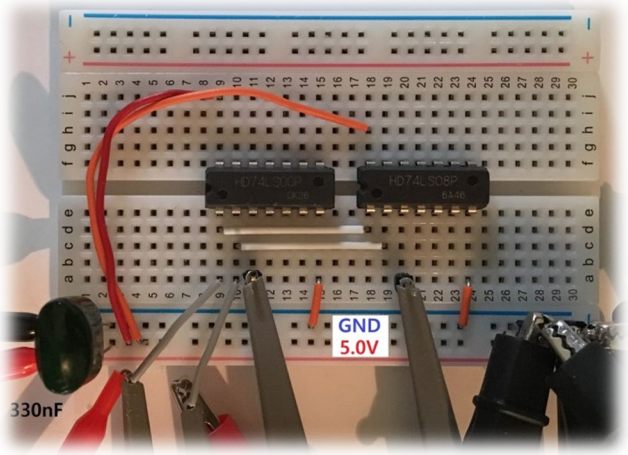
입력 논리		예상 출력 논리	측정된 출력 전압	측정된 전압으로부터 얻은 논리
A	B	0 or 1?	? V	0 or 1?
0	0			
0	1			
1	0			
1	1			

보드 구성 예

- **보드 구성**
  - ✓ 전원은 Vcc 사용 (5V)







*https://m.blog.naver.com/PostView.naver?isHttpsRedirect=true&blogId=specialist0&logNo=221247815110