

CS2100

COMPUTER ORGANISATION

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Lecture #14

Logic Circuits



NUS
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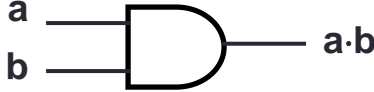



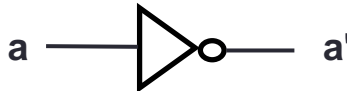

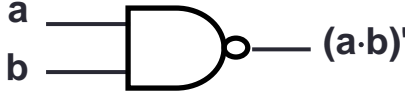





School of
Computing

Lecture #14: Logic Circuits

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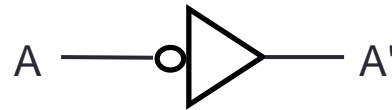
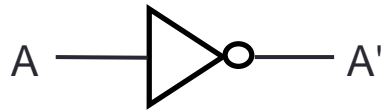
1. Logic Gates

Gate symbols

	Symbol set 1	Symbol set 2 (ANSI/IEEE Standard 91-1984)
AND		
OR		
NOT		
NAND		
NOR		
EXCLUSIVE OR		

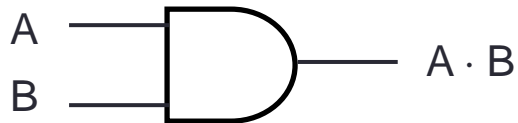
1.1 Inverter/AND/OR Gates

■ Inverter (NOT gate)



A	A'
0	1
1	0

■ AND gate



A	B	A · B
0	0	0
0	1	0
1	0	0
1	1	1

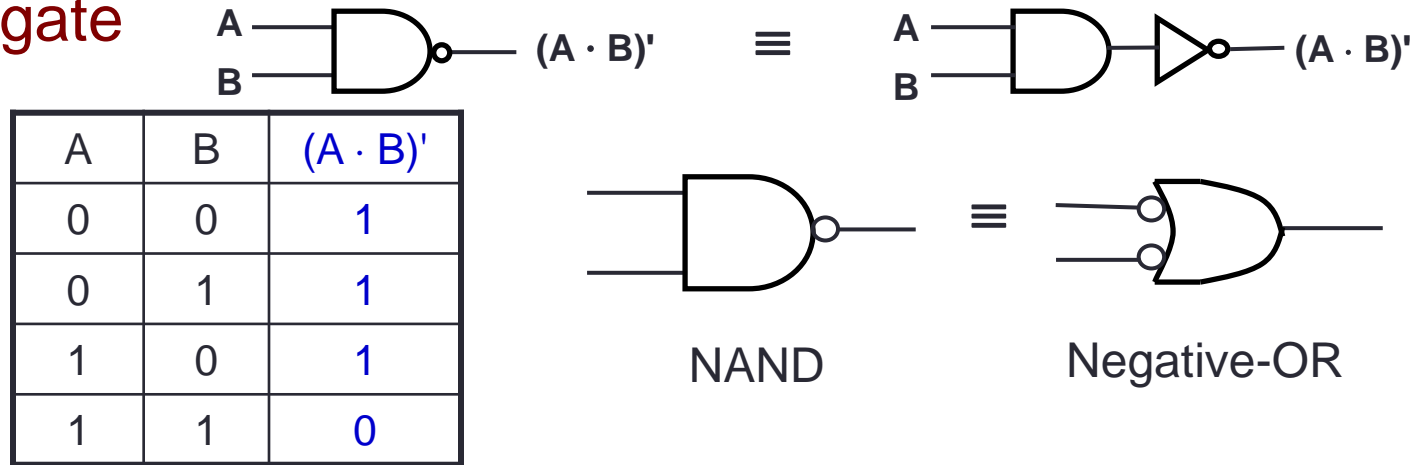
■ OR gate



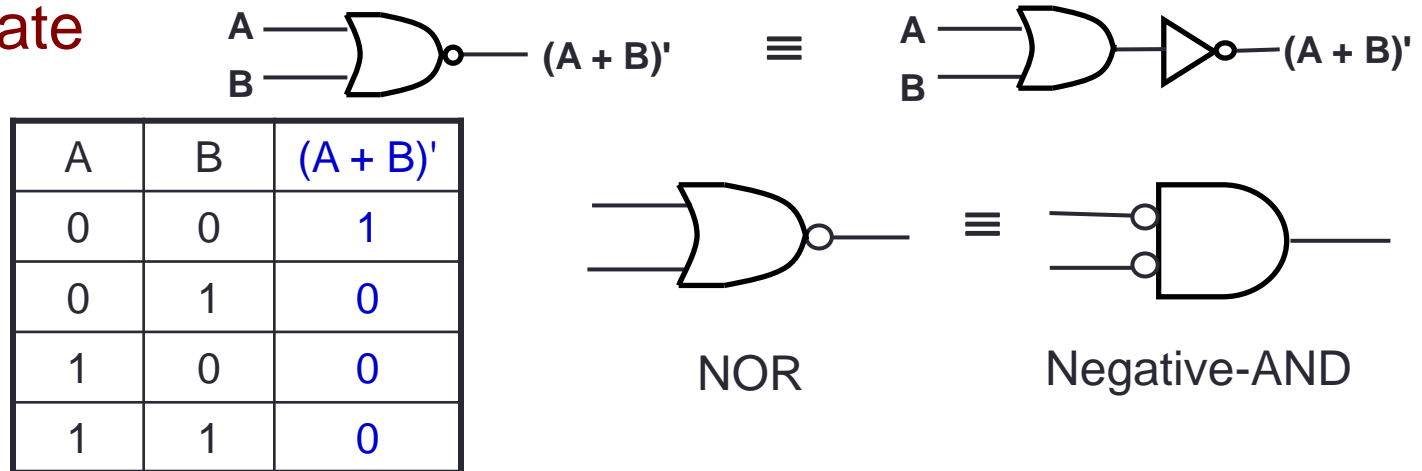
A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	1

1.2 NAND/NOR Gates

■ NAND gate



■ NOR gate



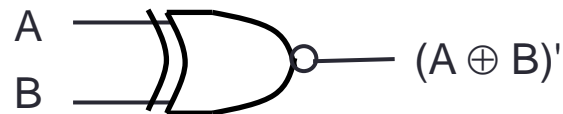
1.3 XOR/XNOR Gates

■ XOR gate



A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

■ XNOR gate

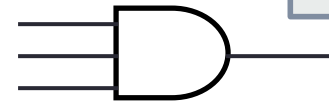


A	B	$(A \oplus B)'$
0	0	1
0	1	0
1	0	0
1	1	1

XNOR can be represented by \odot
(Example: $A \odot B$)

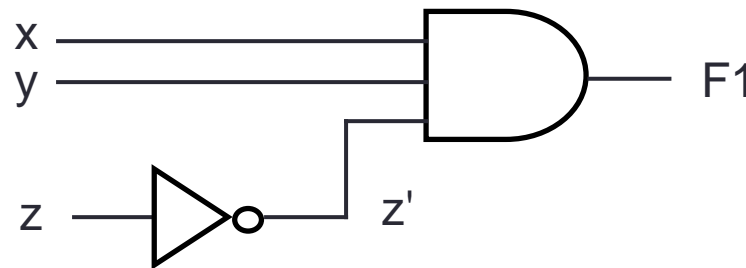
2. Logic Circuits (1/2)

- **Fan-in**: the number of inputs of a gate.
- Gates may have fan-in more than 2.
 - Example: a 3-input AND gate



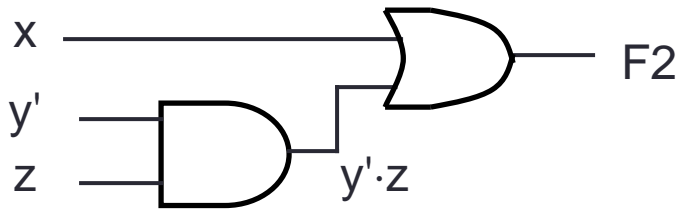
Every input must be connected in a working circuit!

- Given a Boolean expression, we may implement it as a logic circuit.
- Example: $F1 = x \cdot y \cdot z'$ (note the use of a 3-input AND gate)

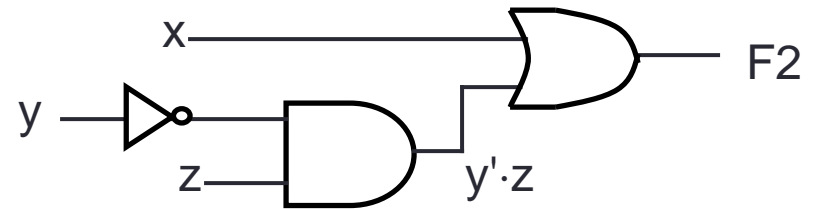


2. Logic Circuits (2/2)

- Example: $F2 = x + y' \cdot z$

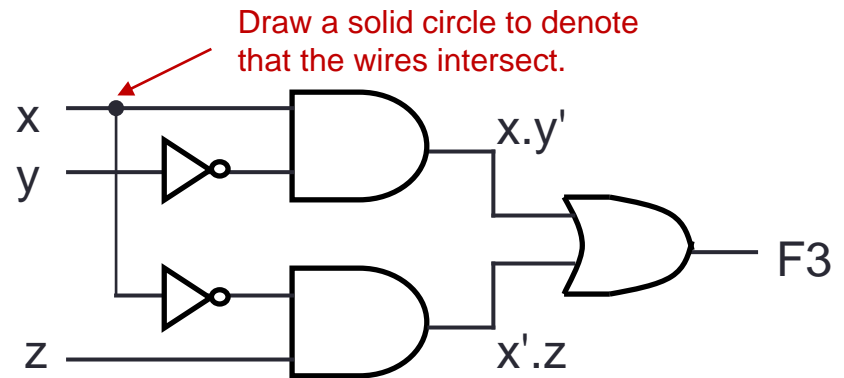
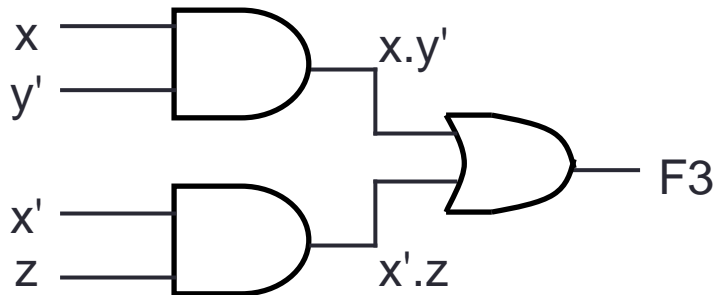


*If complemented literals
are available*



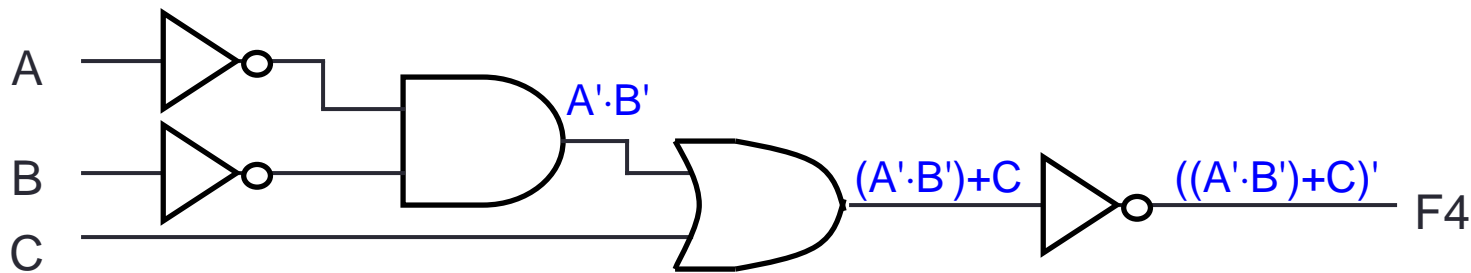
*If complemented literals
are not available*

- Example: $F3 = x \cdot y' + x' \cdot z$



2.1 Analysing Logic Circuits

- Given a logic circuit, we can analyse it to obtain the logic expression.
- Example: Given the logic circuit below, what is the Boolean expression of F4?



$$F4 = ((A' \cdot B') + C)' = (A + B) \cdot C'$$

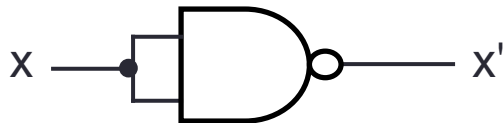
- DLD page79 Quick Review Questions Questions 4-1 to 4-4.

3. Universal Gates

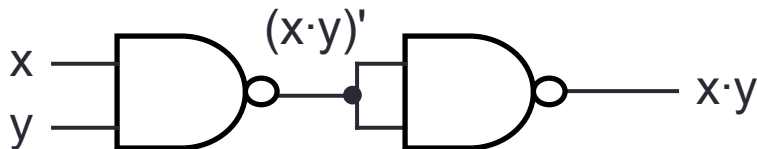
- AND/OR/NOT gates are sufficient for building any Boolean function.
- We call the set {AND, OR, NOT} a **complete set of logic**.
- However, other gates are also used:
 - Usefulness (eg: XOR gate for parity bit generation)
 - Economical
 - Self-sufficient (eg: NAND/NOR gates)

3.1 Universal Gates: NAND Gate

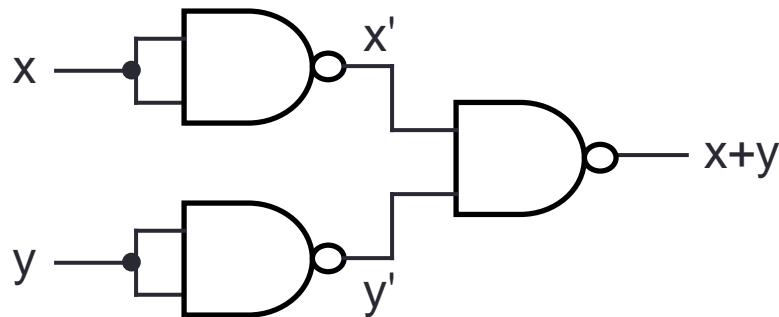
- **{NAND}** is a complete set of logic.
- Proof: Implement NOT/AND/OR using only NAND gates.



$$(x \cdot x)' = x' \quad (\text{idempotency})$$



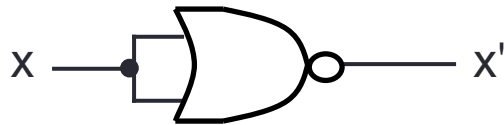
$$\begin{aligned} ((x \cdot y)' \cdot (x \cdot y)')' &= ((x \cdot y)')' && (\text{idempotency}) \\ &= x \cdot y && (\text{involution}) \end{aligned}$$



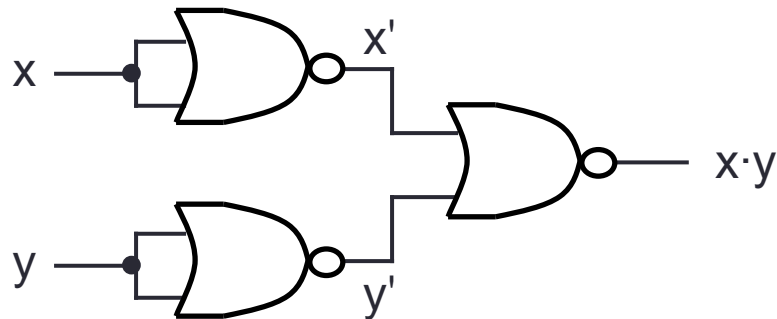
$$\begin{aligned} ((x \cdot x)' \cdot (y \cdot y)')' &= (x' \cdot y')' && (\text{idempotency}) \\ &= (x')' + (y')' && (\text{DeMorgan}) \\ &= x + y && (\text{involution}) \end{aligned}$$

3.2 Universal Gates: NOR Gate

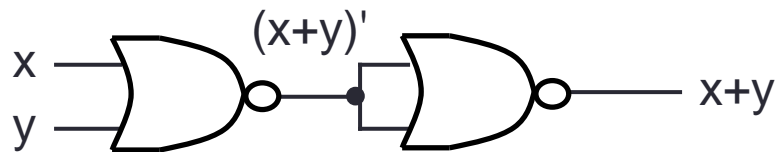
- {NOR} is a complete set of logic.
- Proof: Implement NOT/AND/OR using only NOR gates.



$$(x+x)' = x' \quad (\text{idempotency})$$



$$\begin{aligned} ((x+x)' + (y+y'))' &= (x' + y')' && (\text{idempotency}) \\ &= (x')' \cdot (y')' && (\text{DeMorgan}) \\ &= x \cdot y && (\text{involution}) \end{aligned}$$

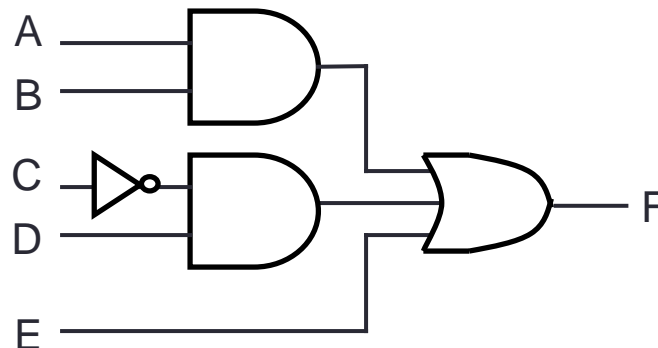


$$\begin{aligned} ((x+y)' + (x+y))' &= ((x+y))' && (\text{idempotency}) \\ &= x+y && (\text{involution}) \end{aligned}$$

- DLD page79 Quick Review Questions Questions 4-6 to 4-8.

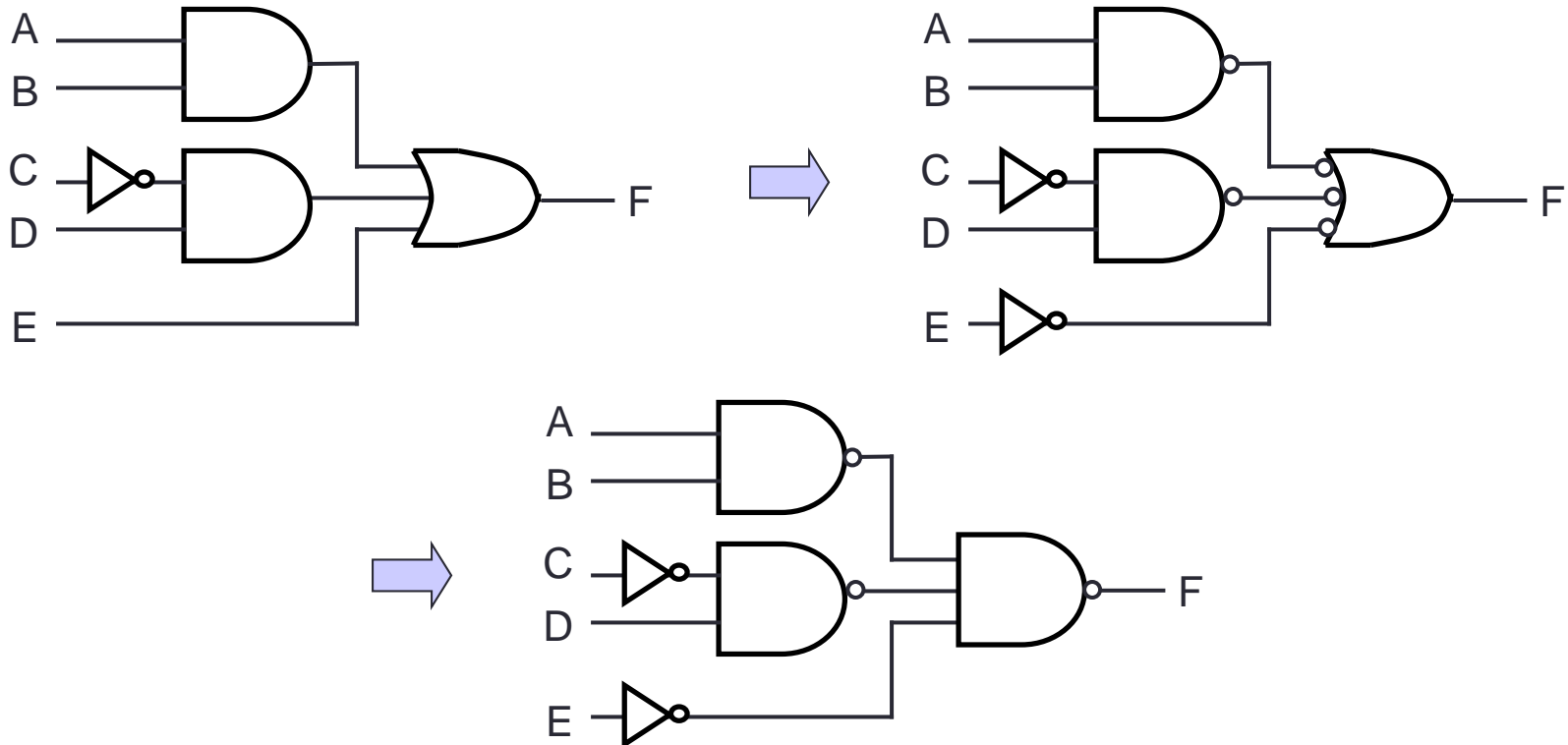
3.3 SOP and NAND Circuits (1/2)

- An SOP expression can be easily implemented using
 - 2-level AND-OR circuit
 - 2-level NAND circuit
- Example: $F = A \cdot B + C' \cdot D + E$
 - Using 2-level AND-OR circuit



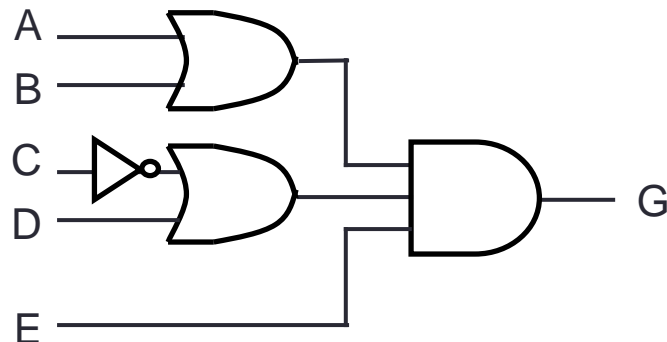
3.3 SOP and NAND Circuits (2/2)

- Example: $F = A \cdot B + C' \cdot D + E$
 - Using 2-level NAND circuit



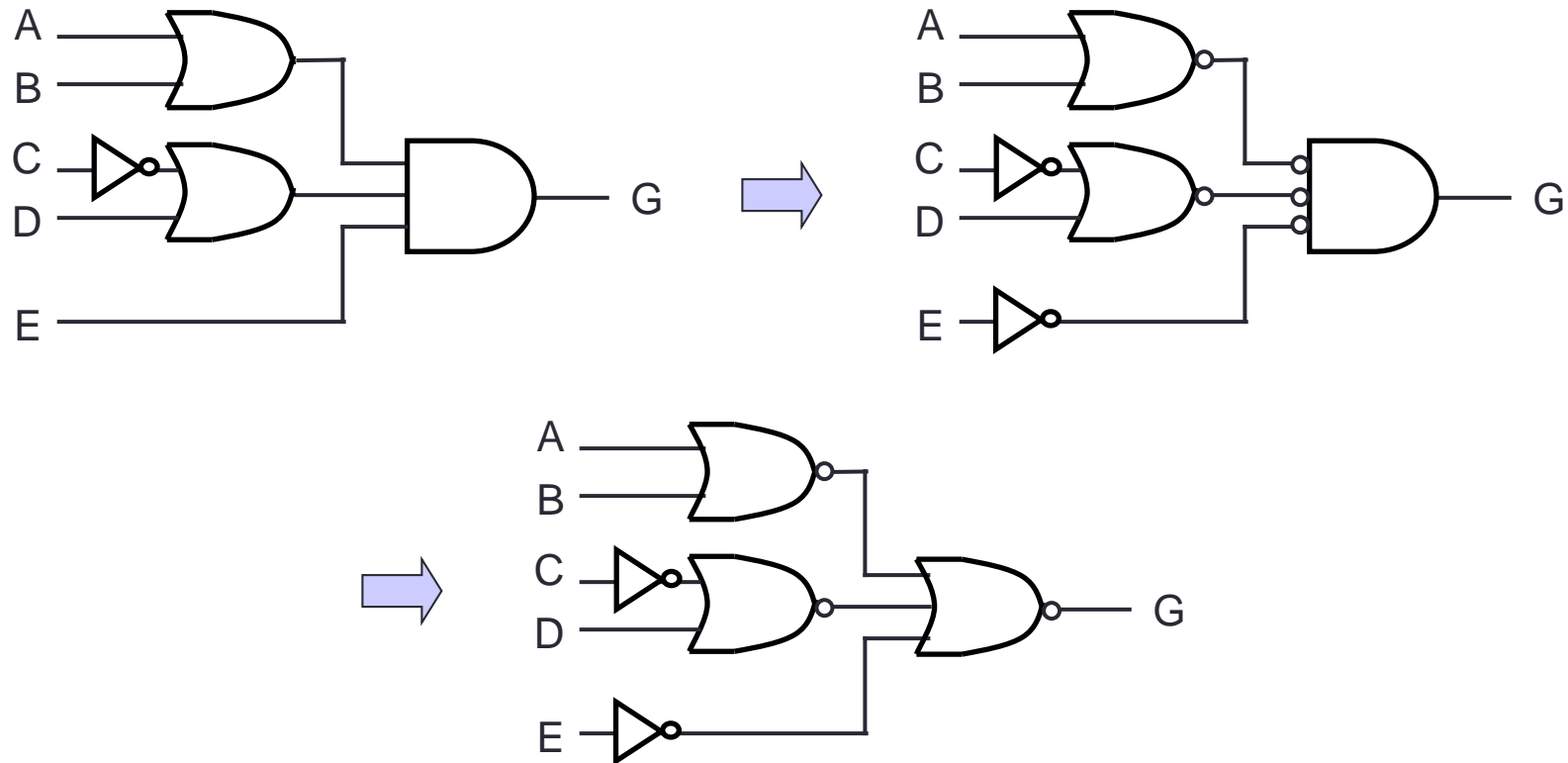
3.4 POS and NOR Circuits (1/2)

- A POS expression can be easily implemented using
 - 2-level OR-AND circuit
 - 2-level NOR circuit
- Example: $G = (A+B) \cdot (C'+D) \cdot E$
 - Using 2-level OR-AND circuit



3.4 POS and NOR Circuits (2/2)

- Example: $G = (A+B) \cdot (C'+D) \cdot E$
 - Using 2-level NOR circuit

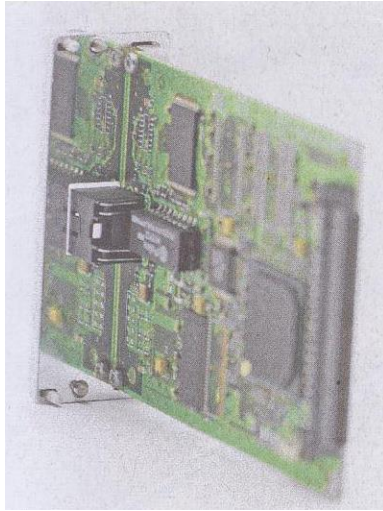


Reading

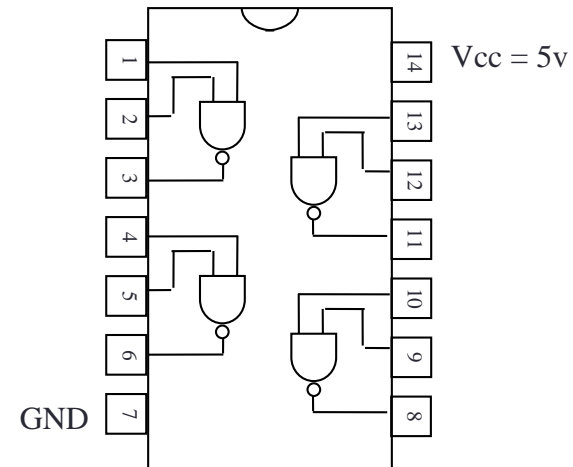
- **Propagation Delay**
 - Read up DLD section 4.5, pg 75 – 77.
- **Integrated Circuit Logic Families**
 - Read up DLD section 4.6, pg 77 – 78.



4. Integrated Circuit (IC) Chip

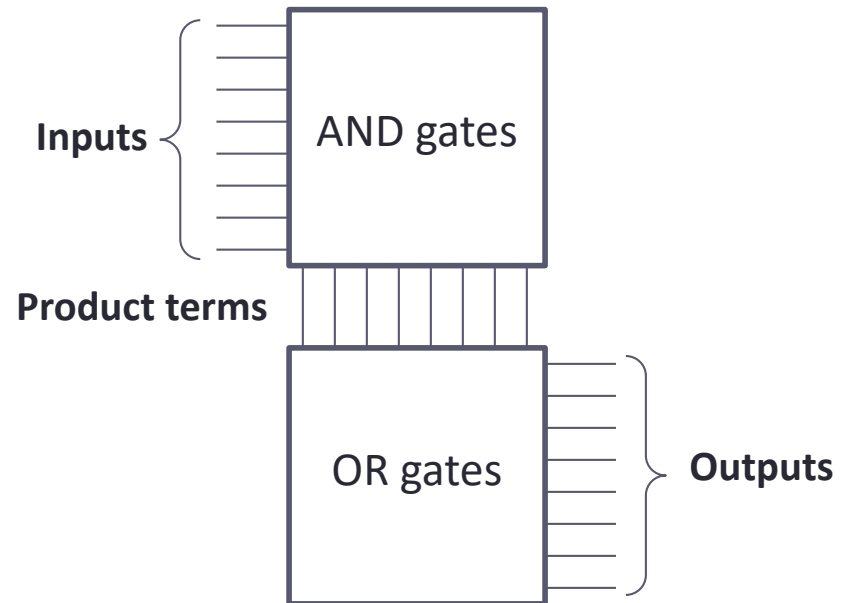


- Example of a **74LS00** chip: Quad NAND gates.



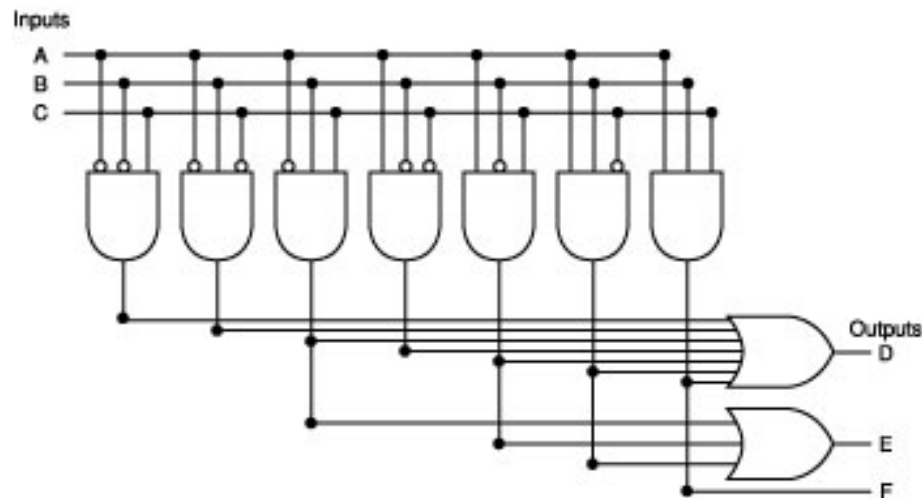
5. Programming Logic Array (PLA) (1/3)

- A programmable integrated circuit – implements sum-of-products circuits (allow multiple outputs).
- **2 stages**
 - AND gates = product terms
 - OR gates = outputs
- Connections between inputs and the planes can be 'burned'.



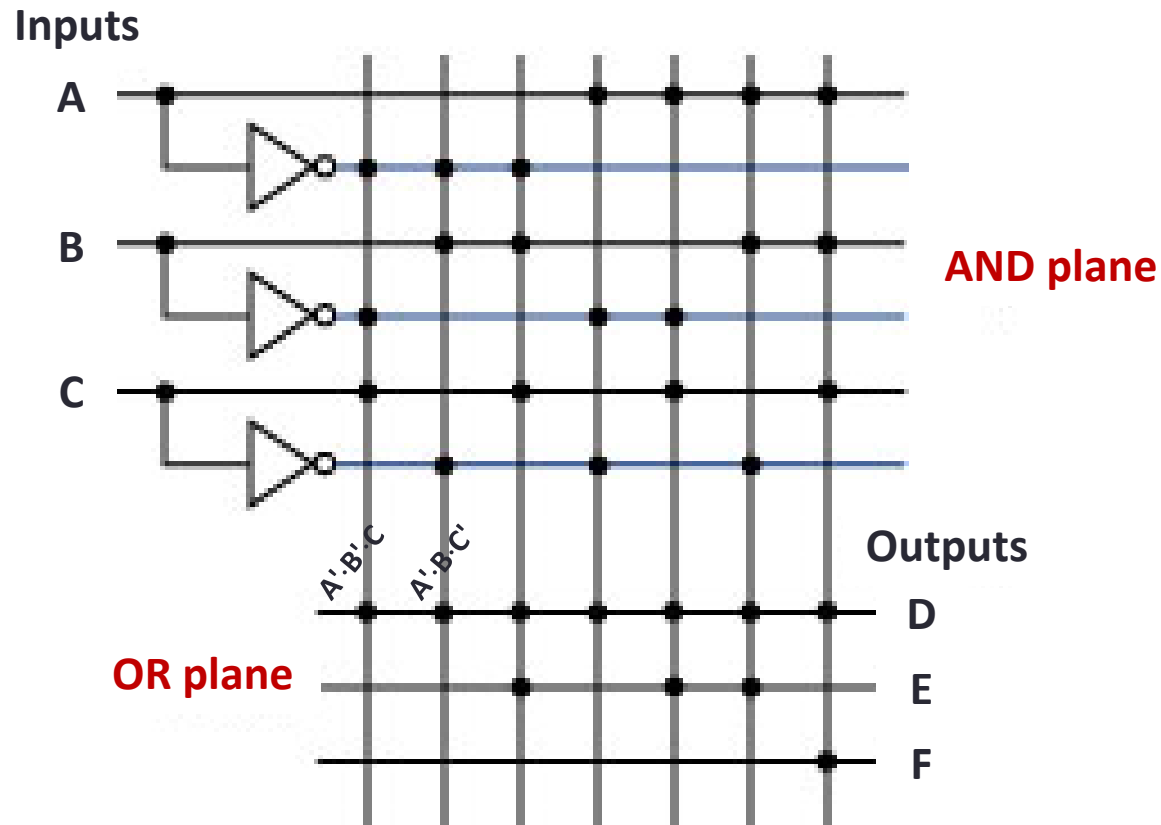
5. PLA Example (2/3)

Inputs			Outputs		
<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>
0	0	0	0	0	0
0	0	1	1	0	0
0	1	0	1	0	0
0	1	1	1	1	0
1	0	0	1	0	0
1	0	1	1	1	0
1	1	0	1	1	0
1	1	1	1	0	1



5. PLA Example (3/3)

- Simplified representation of previous PLA.

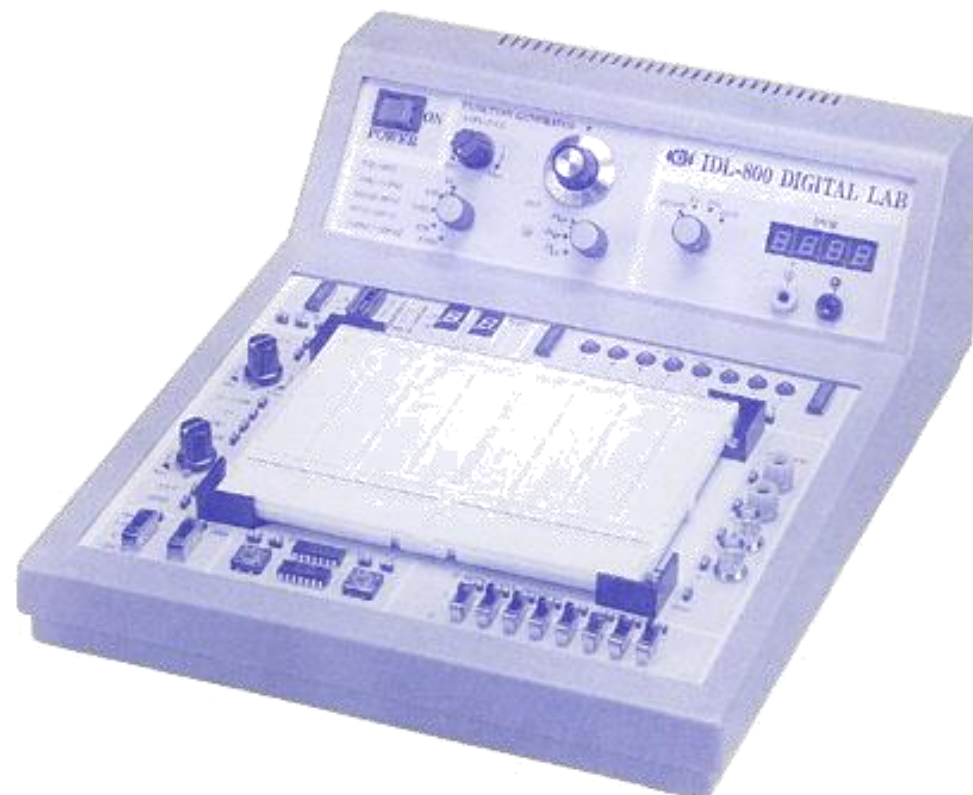


6. Read Only Memory (ROM)

- Similar to PLA
 - Set of inputs (called addresses)
 - Set of outputs
 - Programmable mapping between inputs and outputs
- Fully decoded: able to implement any mapping.
- In contrast, PLAs may not be able to implement a given mapping due to not having enough minterms.

Lab Assignments (1/2)

- For the next few labs, you will implement simple circuits using the Logic Trainer



Lab Assignments (2/2)



- Lab sheets will be given out in lectures.
- Remember to read the **Logic Lab Guidelines** before you come for your first lab session.
- Please read the lab sheet and **fill up as much as you can** before the lab, or you may not have enough time to complete your lab experiment.
- Aim to finish your experiment as quickly as possible. Vacate the room 10 minutes before the hour. If not, just submit your lab report.

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