PDS0101

Introduction to Digital Systems

Logic Gates

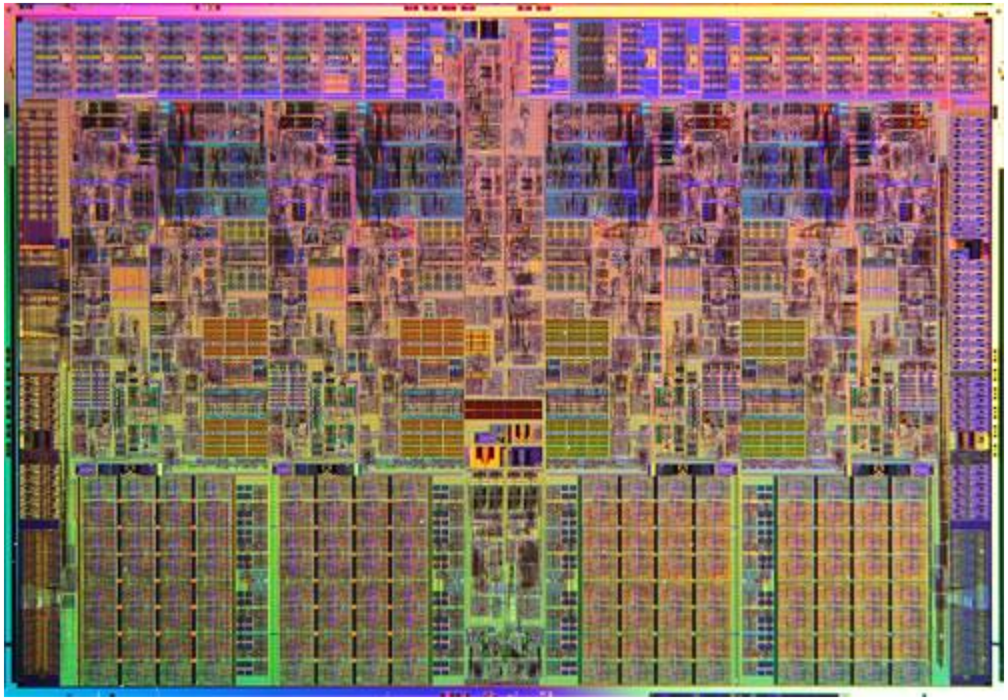
MULTIMEDIA UNIVERSITY

Lecture outcome

- By the end of today’s lecture you should know
  - Common logic gates used in digital systems
  - Symbols used to represent logic gates in circuits
  - The boolean algrebra equivalency of each gate
  - Basic differences with PLD and FLD components

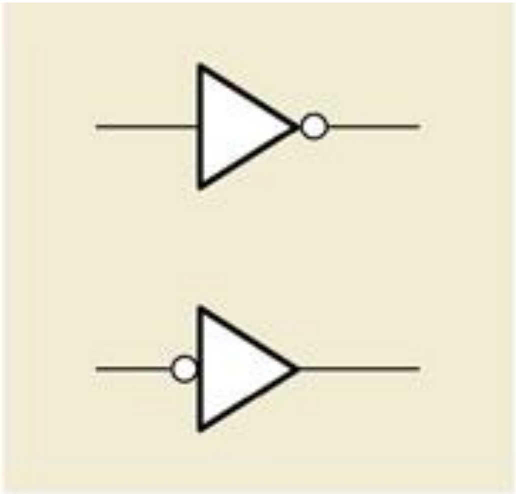
Logic Gates

- Logic gates are the building blocks of computers
- Most of the functions in a computer, with the exception of certain types of memory, are implemented with logic gates used on a very large scale
- For example, a microprocessor, which is the main part of the computer, is made of up of hundreds of thousands of logic gates

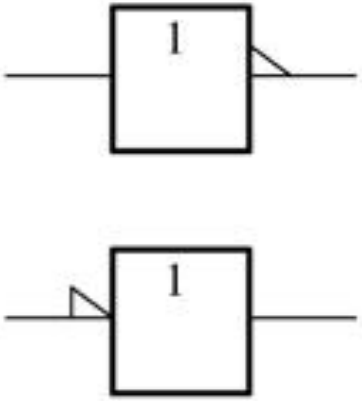


The Inverter

- The Inverter (NOT circuit) performs the operation called inversion or complementation.
- The inverter changes one logic level to the opposite level. In terms of bits, it changes a 1 to a 0 and a 0 to 1
- The symbol for a NOT circuit, which is more commonly called INVERTER:



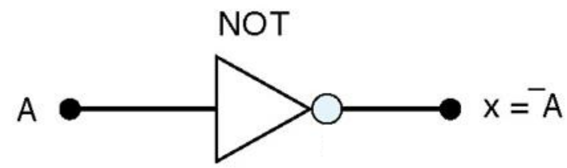
(a) Distinctive shape symbols with negation indicators



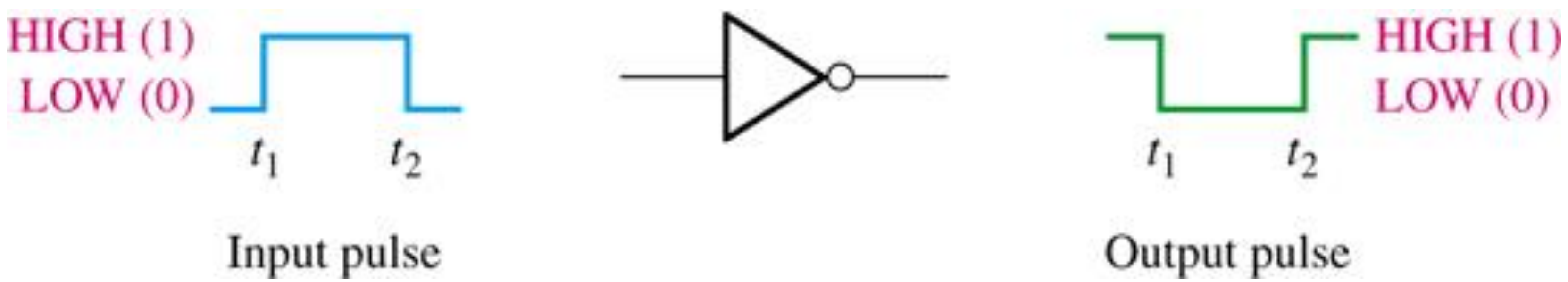
(b) Rectangular outline symbols with polarity indicators

The Inverter

- This circuit always has only a single input and its output logic level is always opposite to the logic level of this input



- When the input is LOW, the output is HIGH; when the input is HIGH, the output is LOW, thereby ,producing an inverted output pulse.

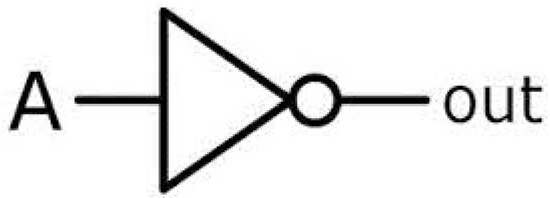


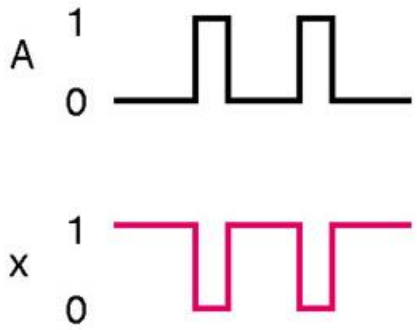
Inverter truth table

Input A	Output X = Ā
Low (0)	High (1)
High (1)	Low (0)

Boolean Equation Output = $\overline{\text{Input}}$

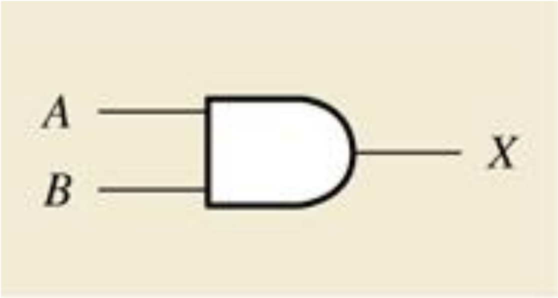
$X = \overline{A}$



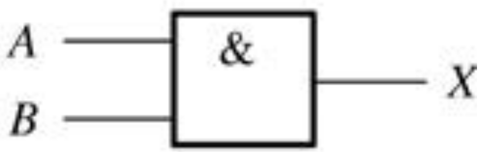


The AND gate

- The AND gate is one of the basic gates that can be combined to form any logic function
- An AND gate can have two or more inputs and performs what is known as logical multiplications
- The AND gate is a circuit that operates in such a way that its output is HIGH only when ALL its inputs are HIGH.
- For all other cases the AND gate output is LOW



(a) Distinctive shape



(b) Rectangular outline with the AND (&) qualifying symbol

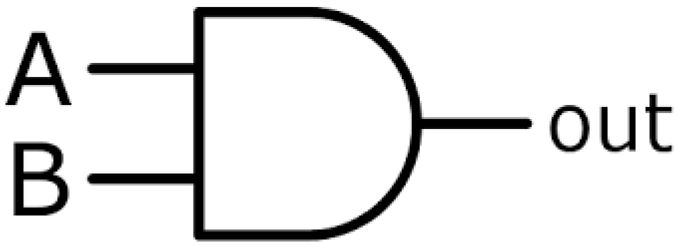
- The AND gate output is equal to the AND product of the logic inputs; that is x=AB

The AND gate

- All possible logic levels for a 2-input AND gate.

AND gate truth table

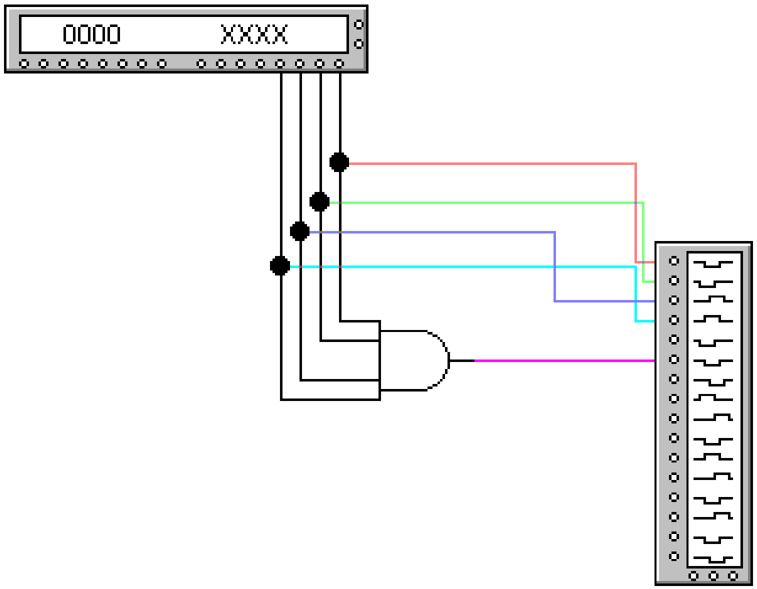
Input A	Input B	Output (AB)
Low (0)	Low (0)	Low (0)
Low (0)	High (1)	Low (0)
High (1)	Low (0)	Low (0)
High (1)	High (1)	High (1)

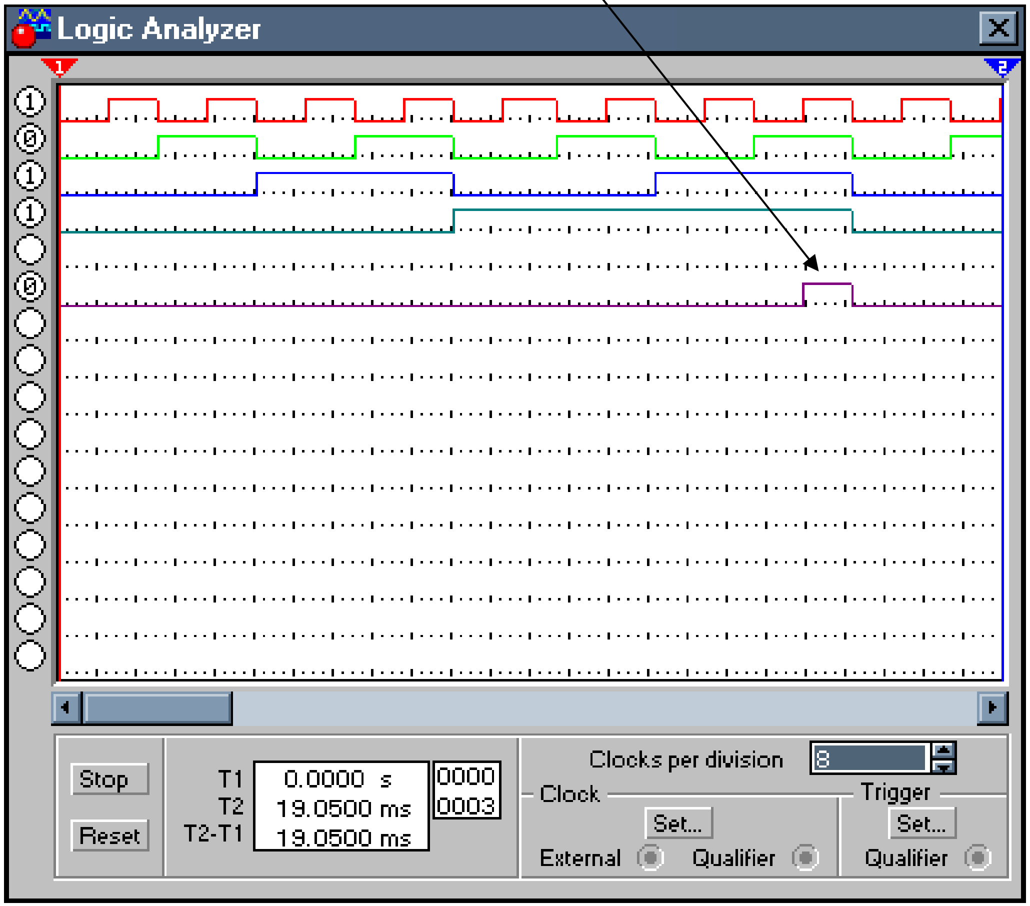


Boolean Equation X = AB

AND Timing diagram

All inputs must be high for the output to be high





Problem solving

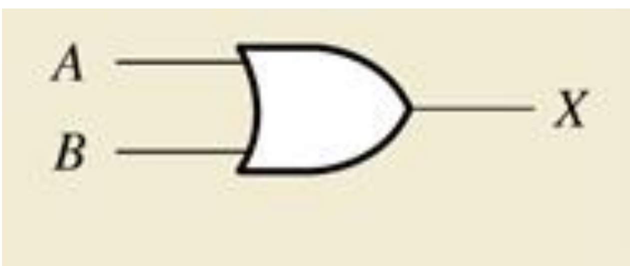
1. Develop the truth table for a 3-input AND gate.
2. Determine the total number of possible input combinations for a 4-input AND gate.
3. What is the only input combination that will produce a HIGH at the output of the five-input AND gate?

Summary of the AND operation

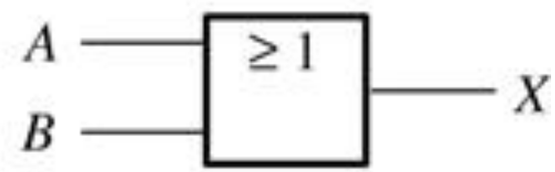
- The AND operation is performed the same as ordinary multiplication of 1s and 0s.
- An AND gate is a logic circuit that performs the AND operation on the circuit's inputs.
- An AND gate output will be 1 only for the case when all inputs are 1; for all other cases the output will be 0.
- The expression x=AB is read as “ x equal A AND B”.

The OR gate

- It can have any number of inputs greater than one.
- An OR gate produces a HIGH on the output when any of the inputs is HIGH.
- The output is LOW only when ALL inputs are LOW.
- Therefore OR gate determines when one or more inputs are HIGH and produces a HIGH on its output to indicate this condition.



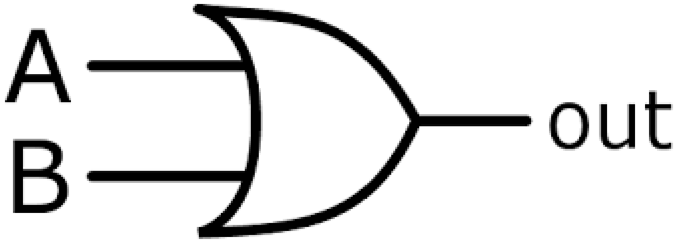
(a) Distinctive shape



(b) Rectangular outline with the OR (≥ 1) qualifying symbol

OR gate truth table

Input A	Input B	Output X = A+B
Low (0)	Low (0)	Low (0)
Low (0)	High (1)	High (1)
High (1)	Low (0)	High (1)
High (1)	High (1)	High (1)



Boolean Equation X = A+B

Boolean addition is the same as the OR function

0 + 0 = 0

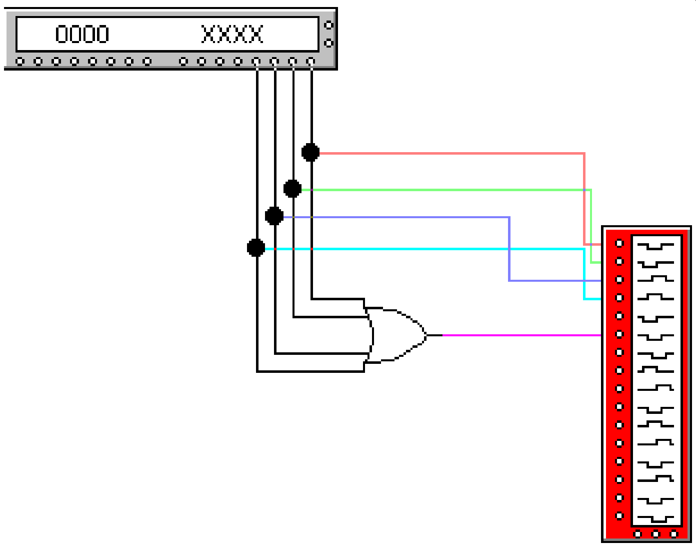
0 + 1 = 1

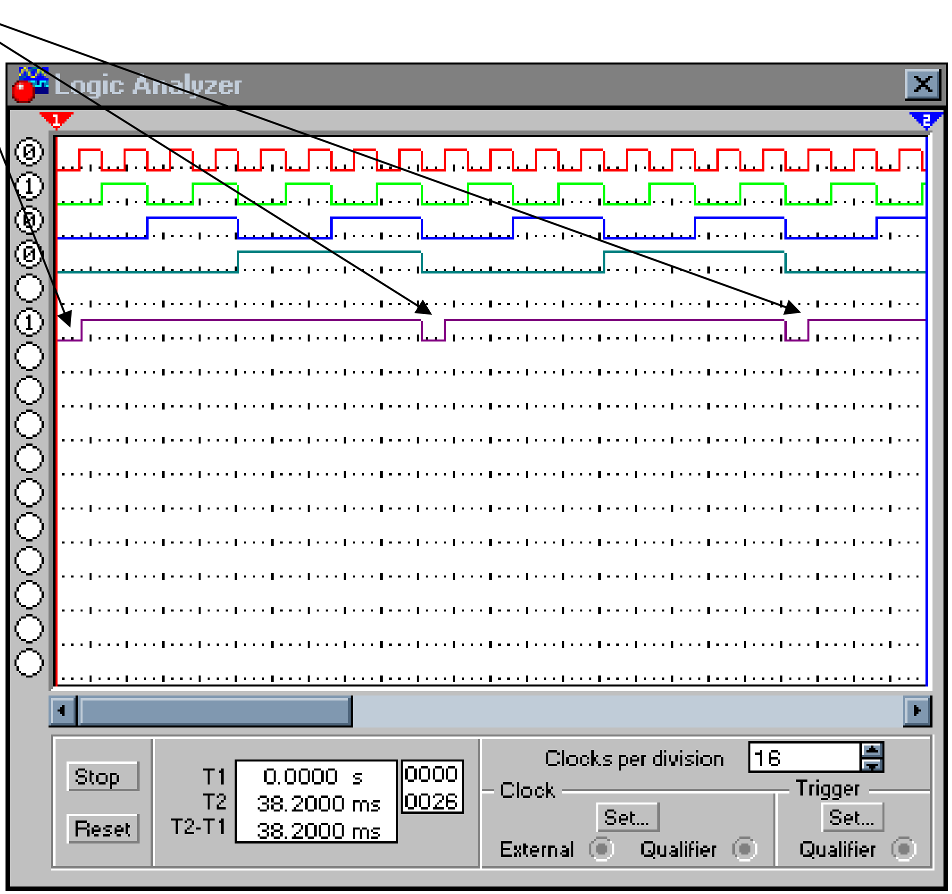
1 + 0 = 1

1 + 1 = 1

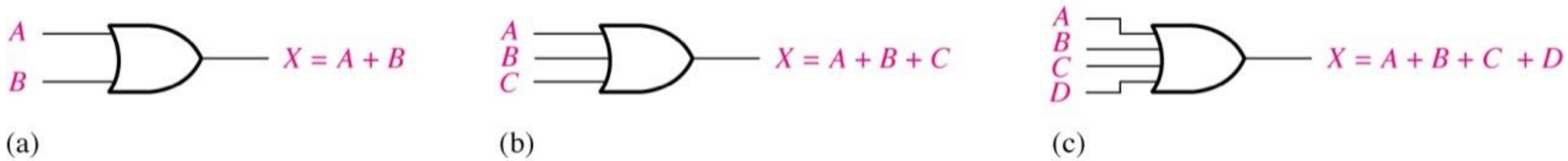
OR Timing diagram

All must be low for the output to be low





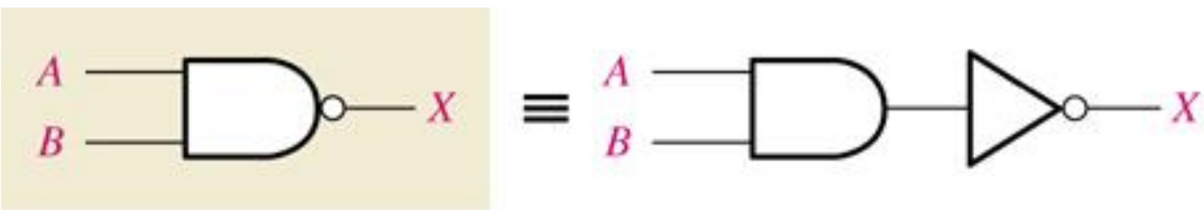
- The operation of a 2-input OR gate can be expressed as follows:
  - if one input variable is A, if the another input variable is B, then output variable is X = A + B
- Figure shows boolean expressions for OR gates with two, three, and four inputs



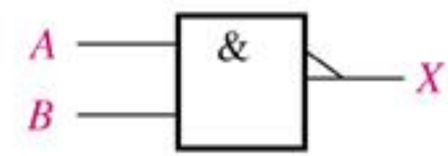
The NAND gate

- The NAND operates like an AND gate followed by an INVERTER

$$X = \overline{AB}$$



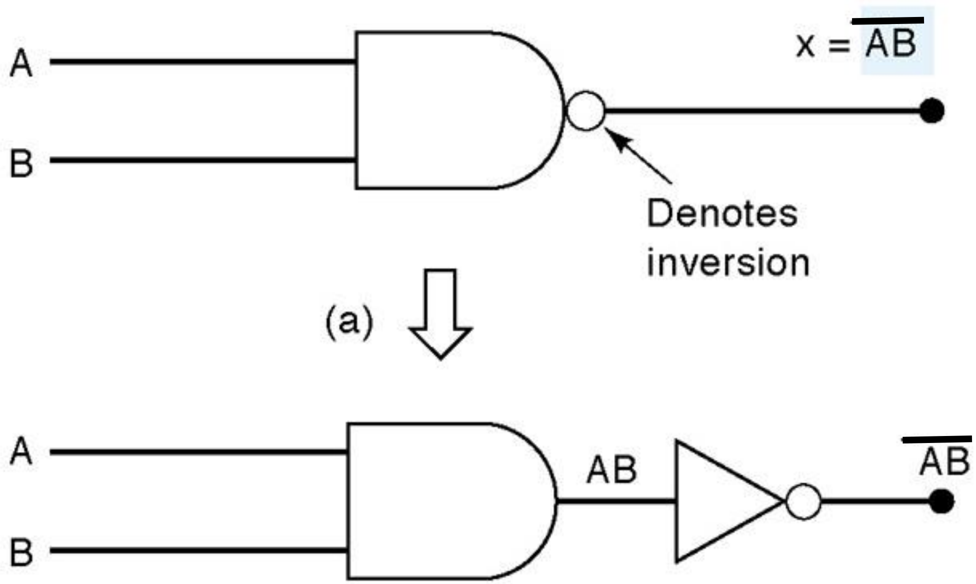
(a) Distinctive shape, 2-input NAND gate and its NOT/AND equivalent



(b) Rectangular outline, 2-input NAND gate with polarity indicator

The NAND gate

- The symbol for a 2 input NAND gate is shown in fig; It is same as the AND gate symbol except for the small circle on its output



(b)

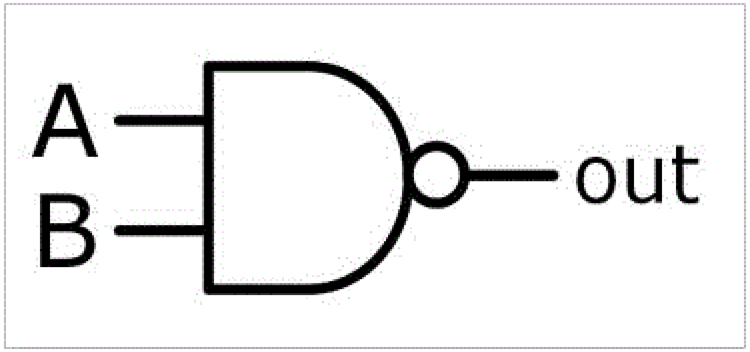
		AND	NAND
A	B	AB	$\overline{AB}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

(c)

- Once again this small circle in front denotes the inversion operation.

NAND gate truth table

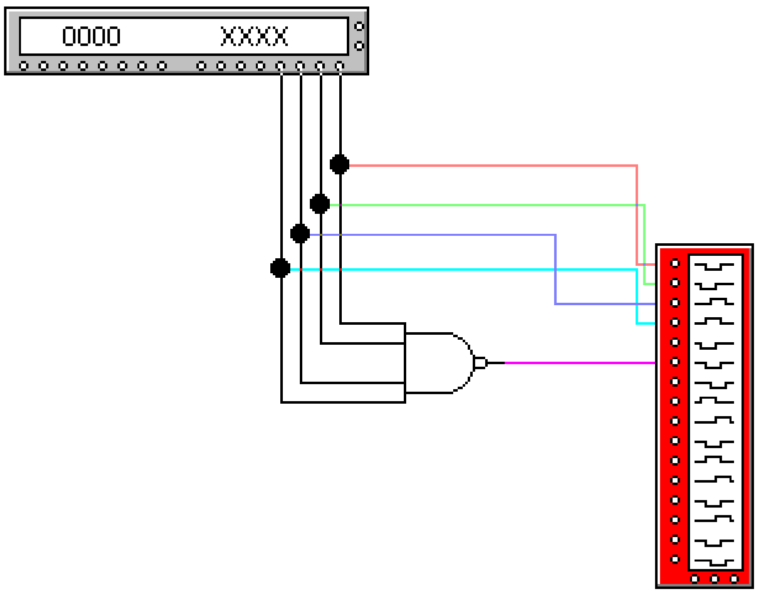
Input A	Input B	Output ($\overline{AB}$)
Low (0)	Low (0)	High (1)
Low (0)	High (1)	High (1)
High (1)	Low (0)	High (1)
High (1)	High (1)	Low (0)

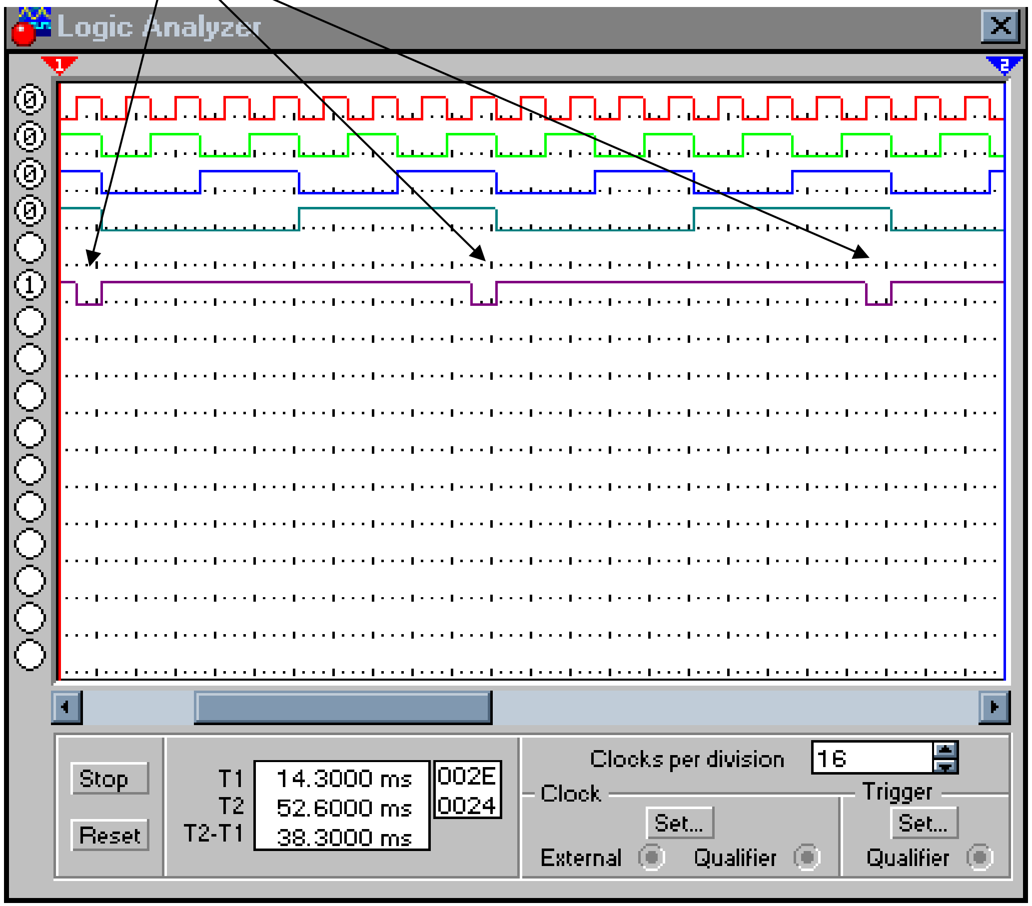


Boolean Equation X = $\overline{AB}$

NAND Timing diagram

All inputs must be high for the output to be low

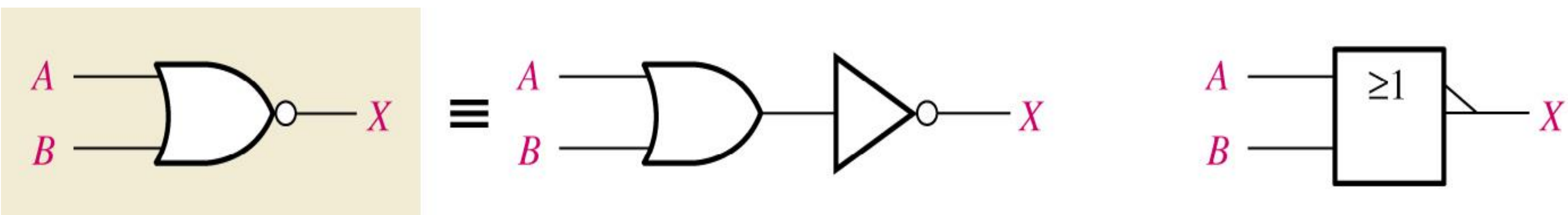




The NOR gate

- The NOR operates like an OR gate followed by an INVERTER.

$$X=\overline{A+B}$$

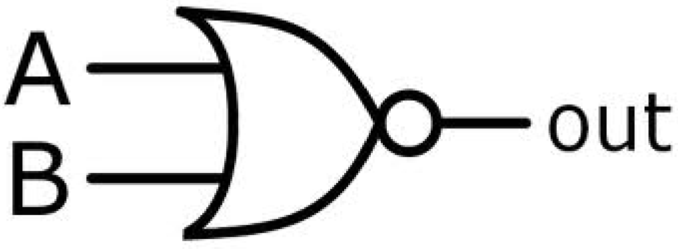


(a) Distinctive shape, 2-input NOR gate and its NOT/OR equivalent

(b) Rectangular outline, 2-input NOR gate with polarity indicator

NOR gate truth table

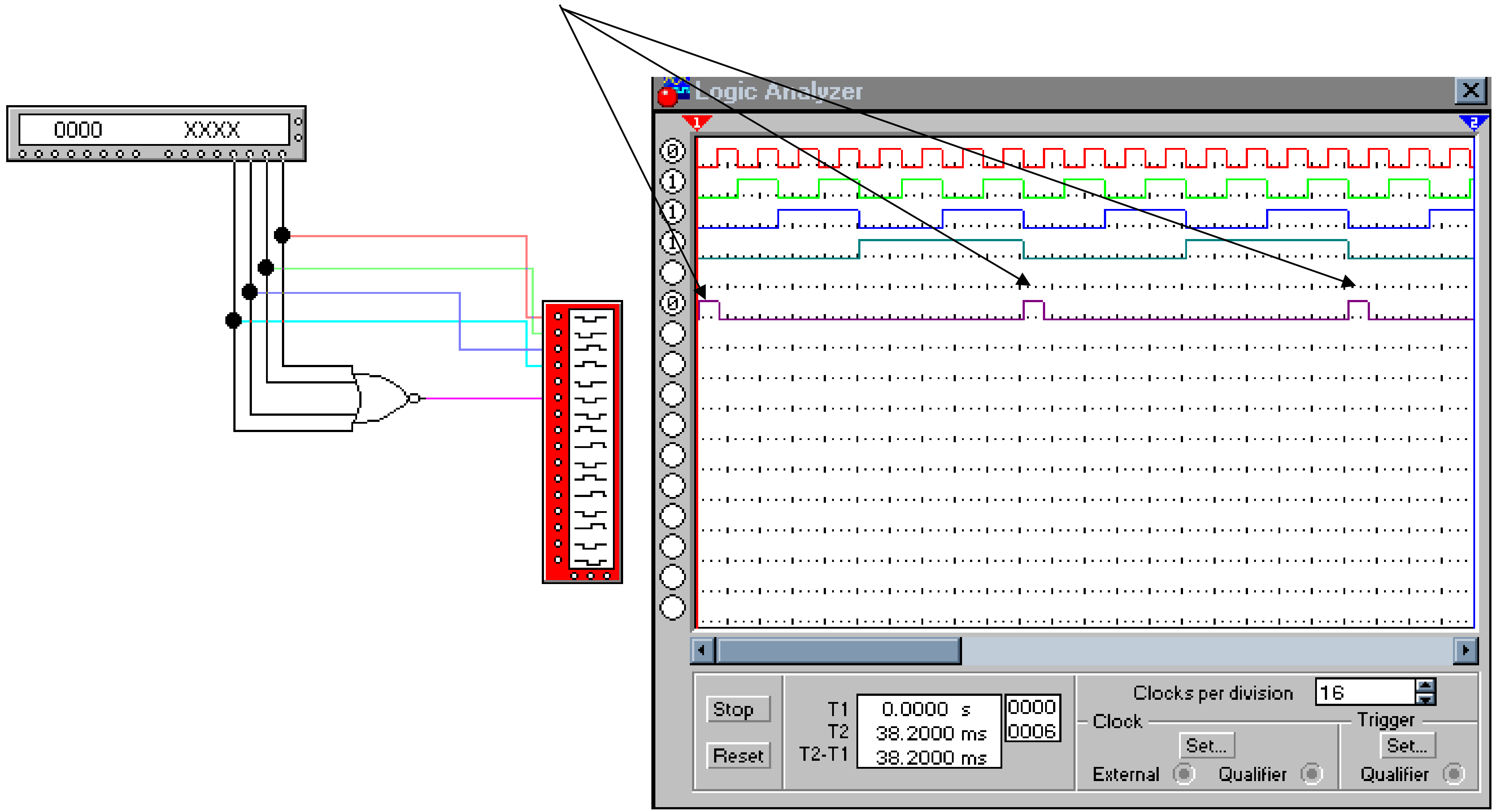
Input A	Input B	Output $(\overline{A+B})$
Low (0)	Low (0)	High (1)
Low (0)	High (1)	Low (0)
High (1)	Low (0)	Low (0)
High (1)	High (1)	Low (0)



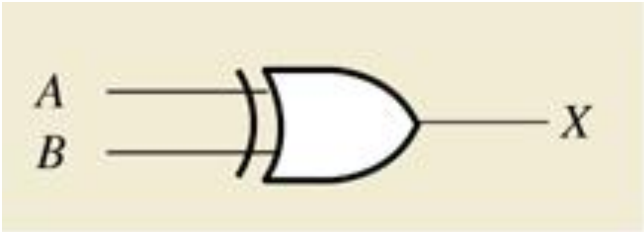
Boolean Equation X = $\overline{A+B}$

NOR Timing diagram

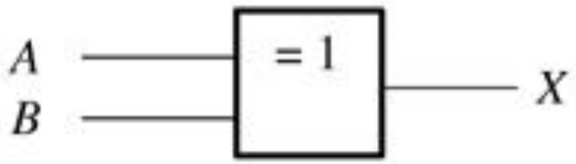
All inputs must be low for the output to be high



The Exclusive -OR gate



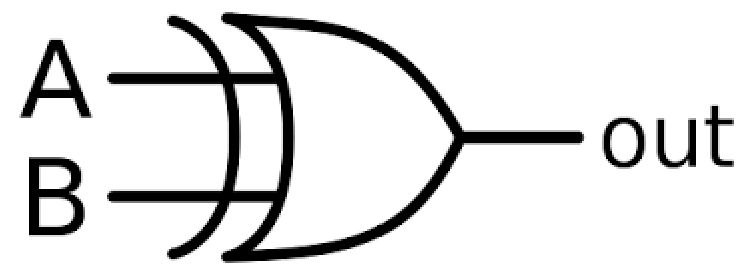
(a) Distinctive shape



(b) Rectangular outline with the XOR qualifying symbol (= 1)

Exclusive-OR gate truth table

Input A	Input B	Output (A ⊕ B)
Low (0)	Low (0)	Low (0)
Low (0)	High (1)	High (1)
High (1)	Low (0)	High (1)
High (1)	High (1)	Low (0)

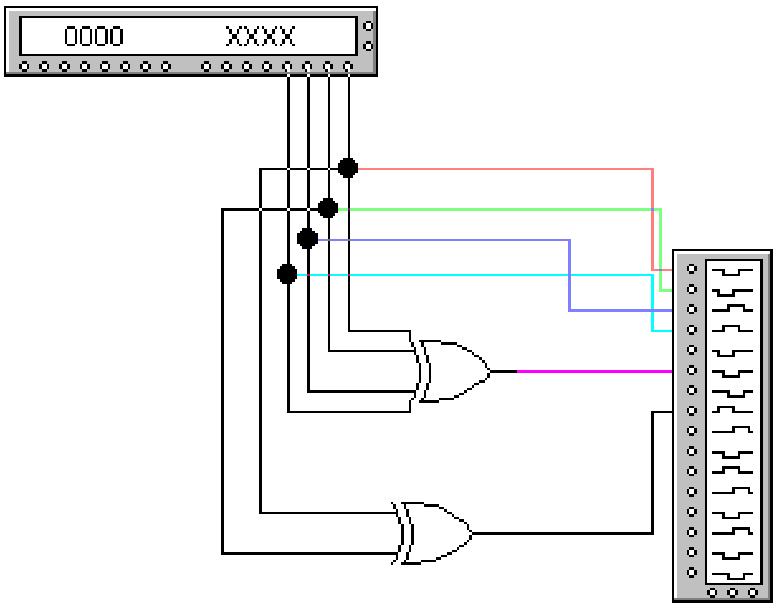


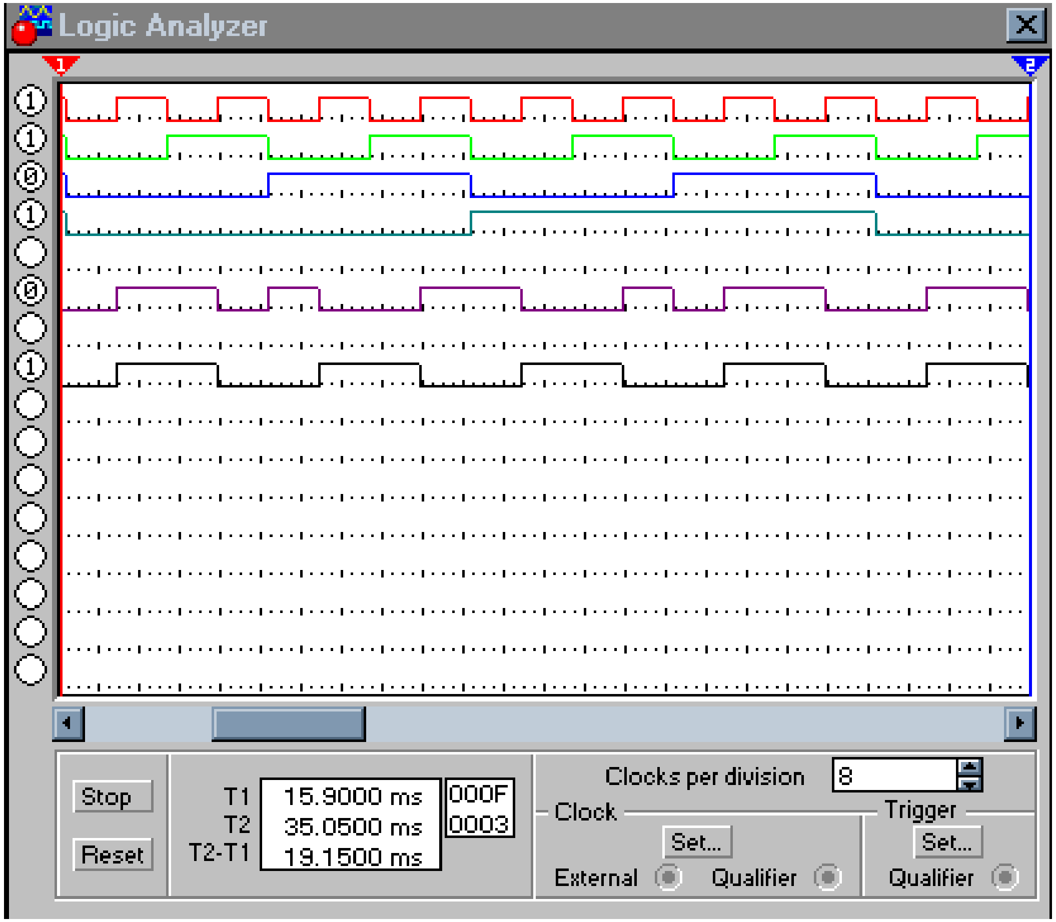
Boolean Equation $X = \overline{A}B + A\overline{B} = A \oplus B$

n/b: the output is shown High if and only if the total numbers of the input “High” is in odd number

Exclusive-OR Timing diagram

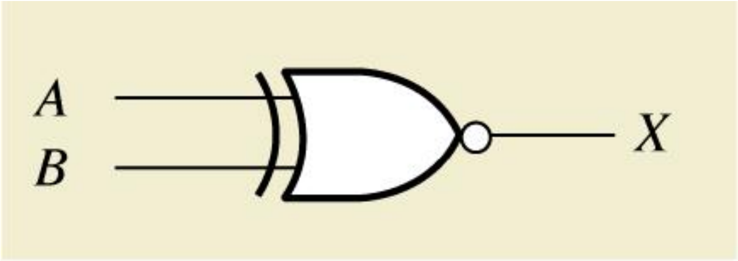
The 2 input exclusive–OR is less busy



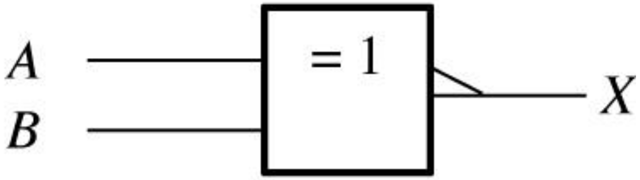


The Exclusive-NOR gate

- The output to the XNOR gate is high when both inputs A and B are high and when neither A nor B is high



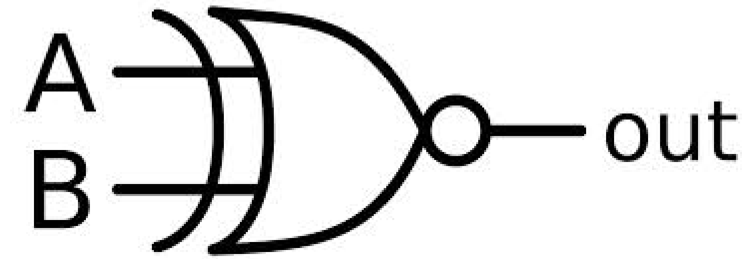
(a) Distinctive shape



(b) Rectangular outline

Exclusive-NOR gate truth table

Input A	Input B	Output (A ⊕ B)
Low (0)	Low (0)	High (1)
Low (0)	High (1)	Low (0)
High (1)	Low (0)	Low (0)
High (1)	High (1)	High (1)

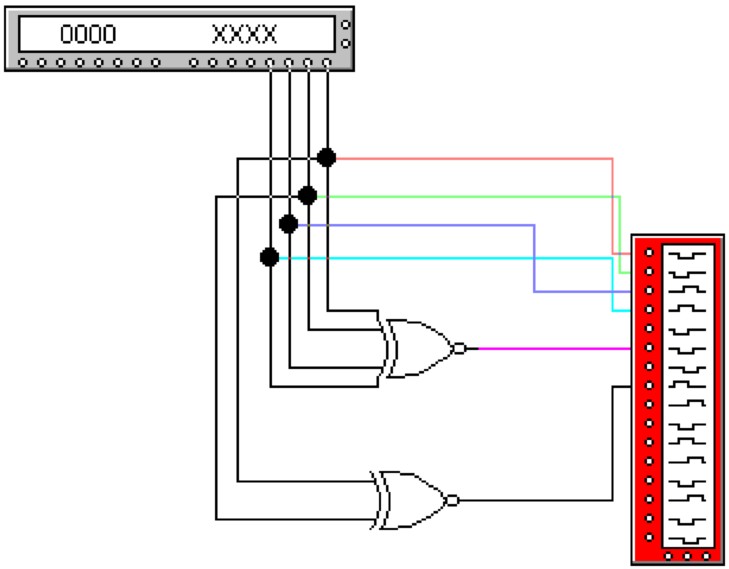


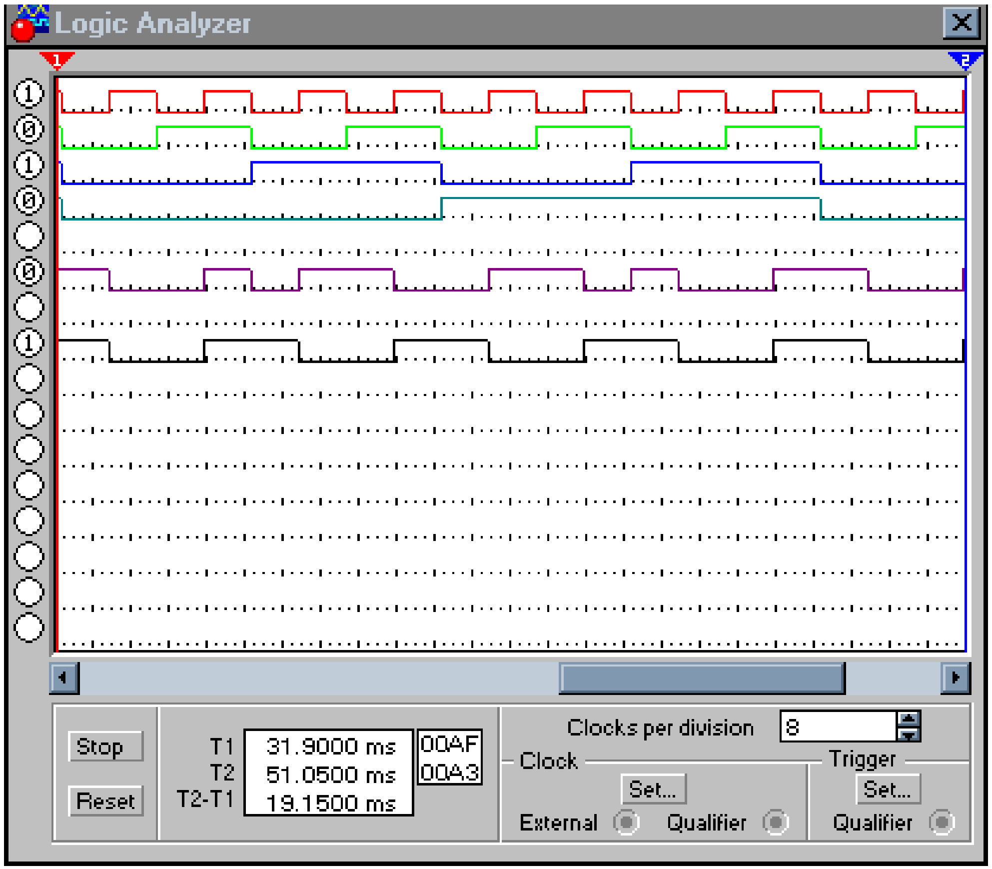
Boolean Equation $X = \overline{\bar{A}B+A\bar{B}}$

$= AB + \bar{A}\bar{B}$

$= \overline{A \oplus B}$

Exclusive-NOR Timing diagram





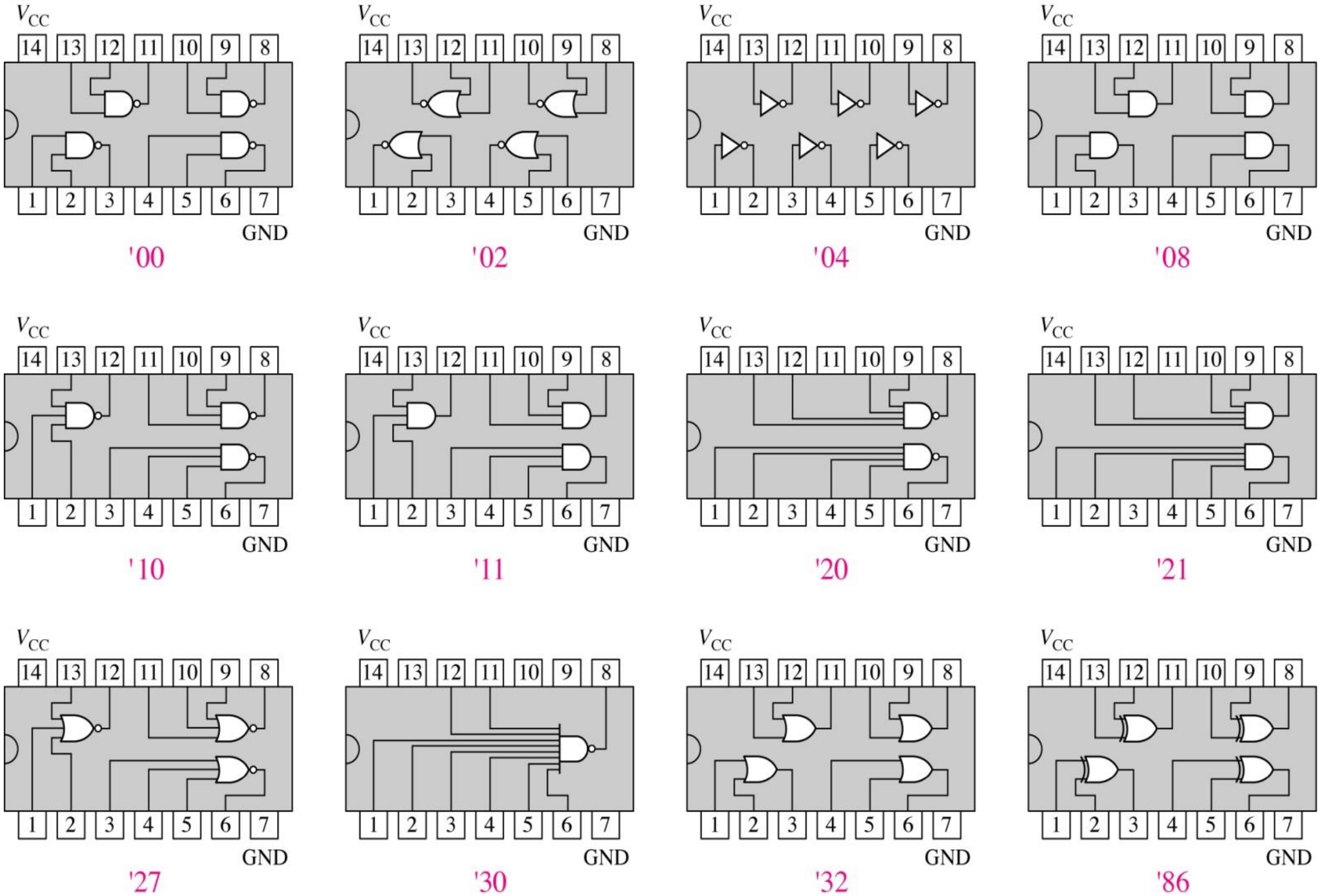
Logic devices

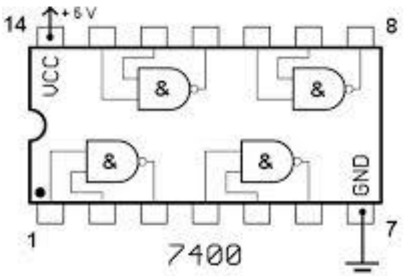
- Logic devices can be classified into two broad categories
- Fixed Function Logic Devices
  - Fixed logic devices are permanent, the specific logic function is contained in the IC package when it is purchased and it can never be changes “hard-wired”

- Programmable Logic Devices (PLD)
  - One in which the logic function is programmed by the user and can be programmed many times
  - PLDs can be changed at any time to perform different functions.

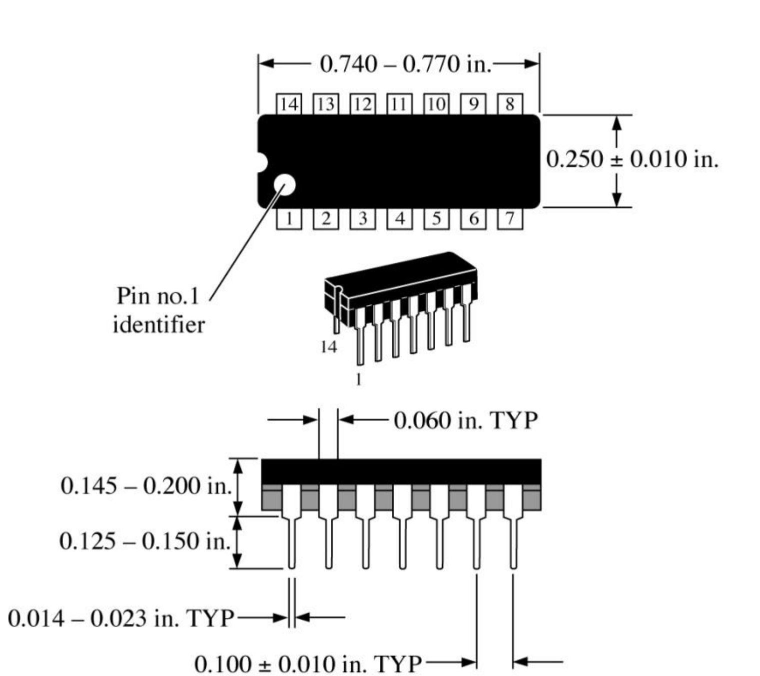
Fixed function logic

- Pin configuration diagrams for some common fixed-function IC gate configurations.

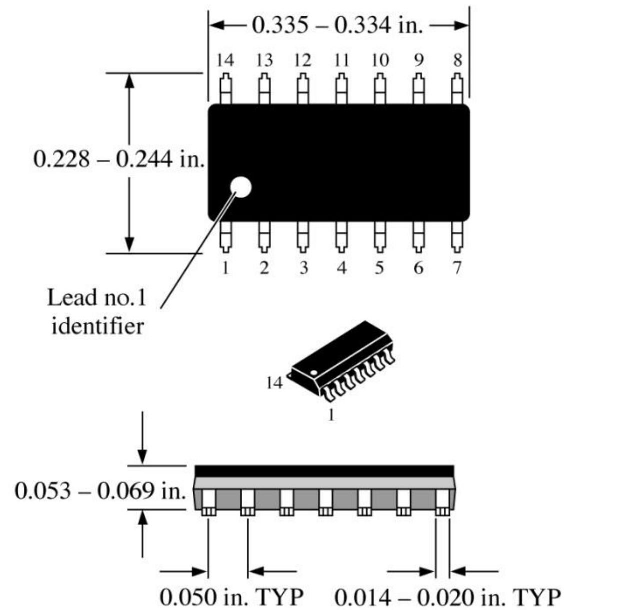




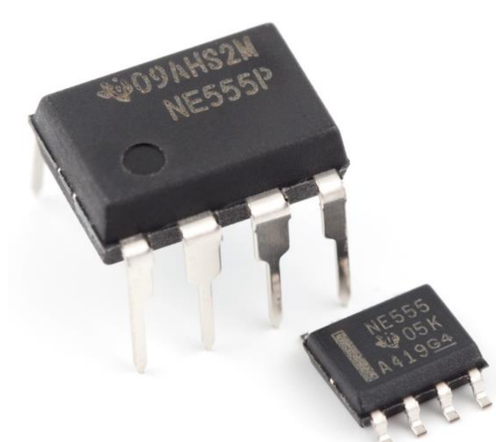
DIP and SOIC packages

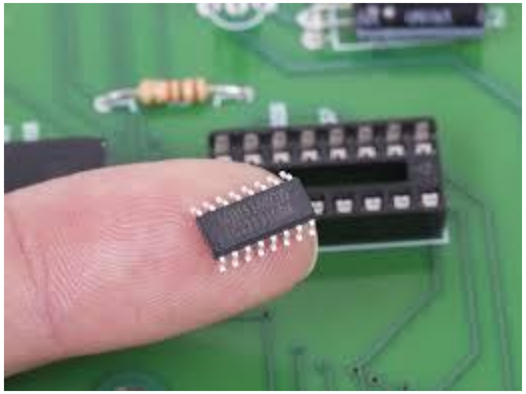


(a) 14-pin dual in-line package (DIP) for feedthrough mounting



(b) 14-pin small outline package (SOIC) for surface mounting



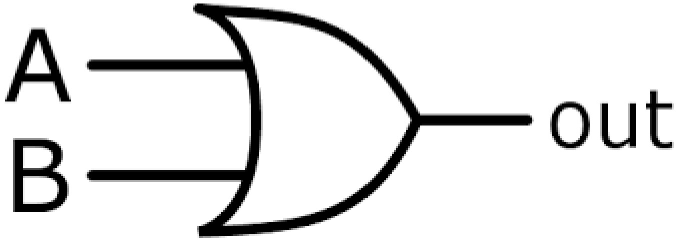


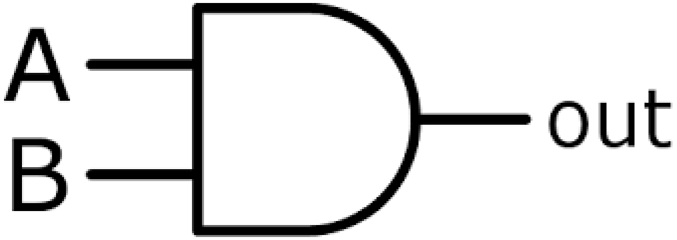
Programmable Logic Devices (PLD)

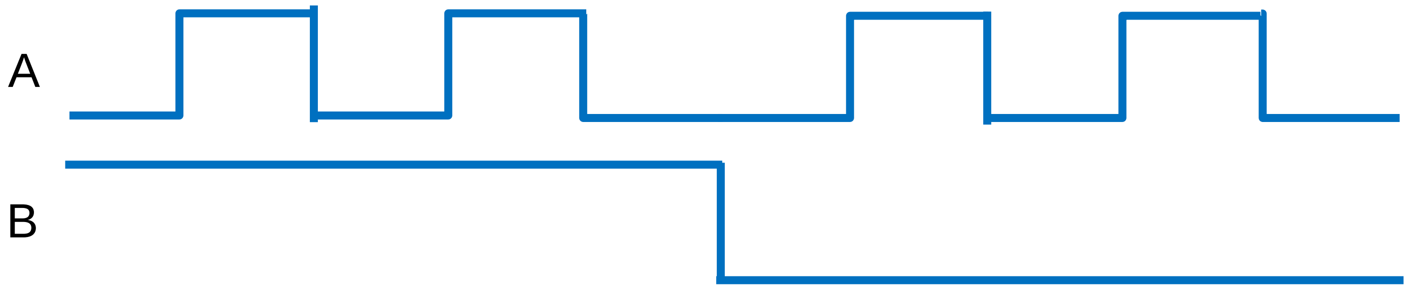
- The Another category of logic devices is one in which the logic function is programmed by the user and , in some cases , can be reprogrammed many times. These devices are called Programmable Logic Devices (PLD)
- Advantages of PLDs over Fixed function logic devices
- Many more logic circuits can be "stuffed" into a much smaller area with PLD
- Logic designs can be changed without rewiring or replacing components
- PLD design can be implemented faster than one using fixed function ICs once the required programming language is mastered

Problems

- Given that the following two-input gates are used, complete the timing diagram to show the output from both gates based on the input levels shown

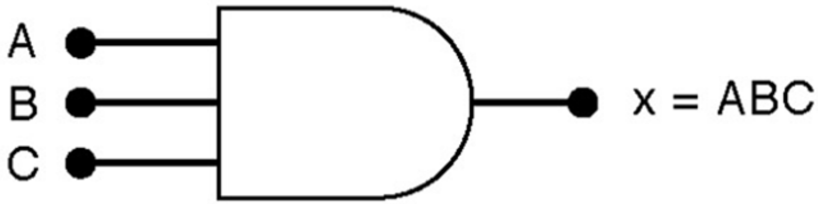


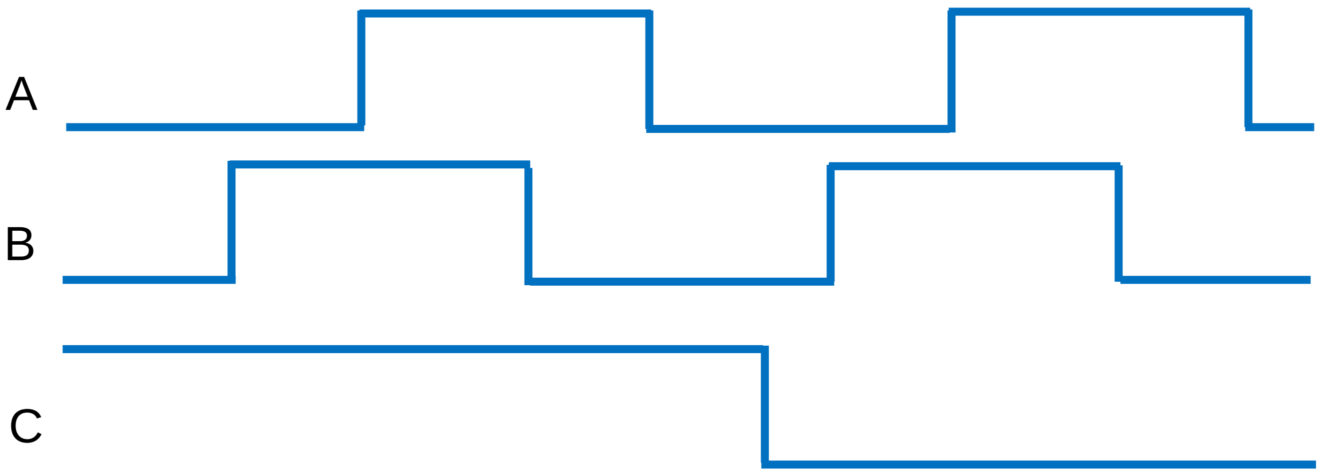




Problems

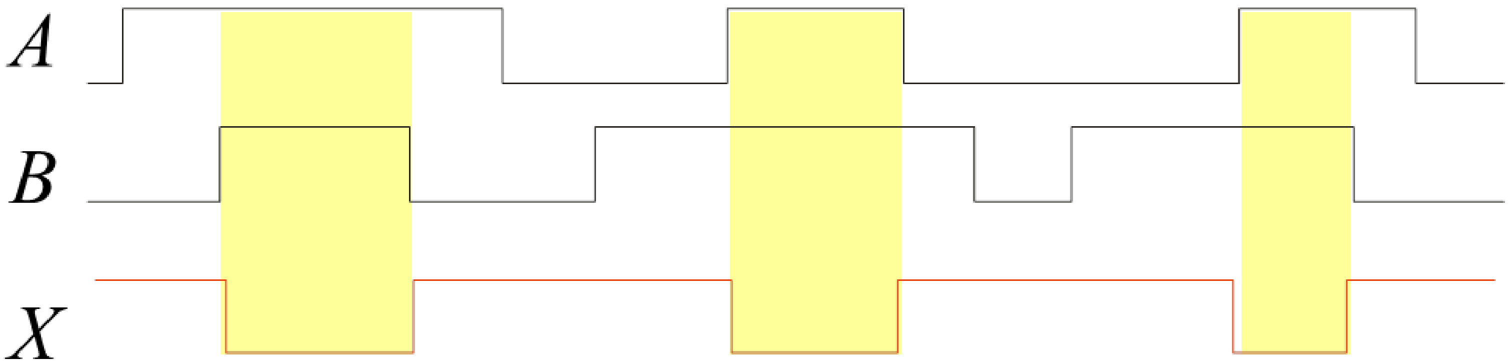
- Given that the following three-input gate is used, complete the timing diagram to show the output x from the gate based on the input levels shown





Problems

- A 2-input gate produces the following timing diagram where X represents the output. What type of gate is being used?



Summary

- Logic gates covered today

Inverter	A logic circuit that inverts or complements its inputs.
AND gate	A logic gate that produces a HIGH output only when all of its inputs are HIGH
OR gate	A logic gate that produces a HIGH output when one or more inputs are HIGH
NAND gate	A logic gate that produces a LOW output only when all of its inputs are HIGH
NOR gate	A logic gate that produces a LOW output when one or more inputs are HIGH
Exclusive-OR gate	A logic gate that produces a HIGH output only when its two inputs are at opposite levels
Exclusive-NOR gate	A logic gate that produces a LOW output only when its two inputs are at opposite levels