Logic Gate

College of
Engineering & Technology

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Level 1 , Semester 1
@ Department of prosthetic and orthotic Engineering

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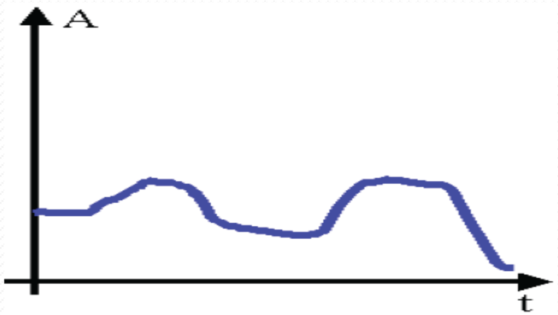
Arithmetic Operations & Boolean Algebra

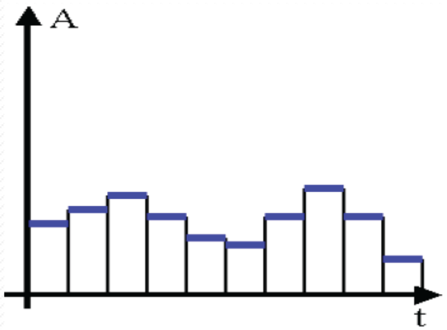
The majority of this course material is based on
Fundamentals of Electric Circuits – presentations.
Charles K. Alexander | Matthew n. o. Sadiku, 5TH edition © 2013 McGraw-Hill

Analog signal is ***time-varying*** and generally bound to a range (e.g. +12V to -12V, if we are talking about **voltage signal**), but there is an infinite number of values within that continuous range.



Analog signal – continuously varying

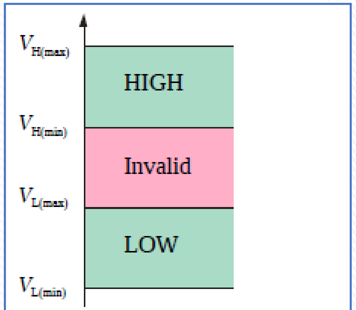
A digital signal is a signal that represents data as a sequence of ***discrete values***.
A **digital signal** can only take on one value from a finite set of possible values at a given time.



Digital signal – large time divisions

In *Digital Electronic Devices*, signals which can have just **two voltage values** (**two states**):
HIGH Voltage or LOW Voltage …
(true or false … 0 or 1).

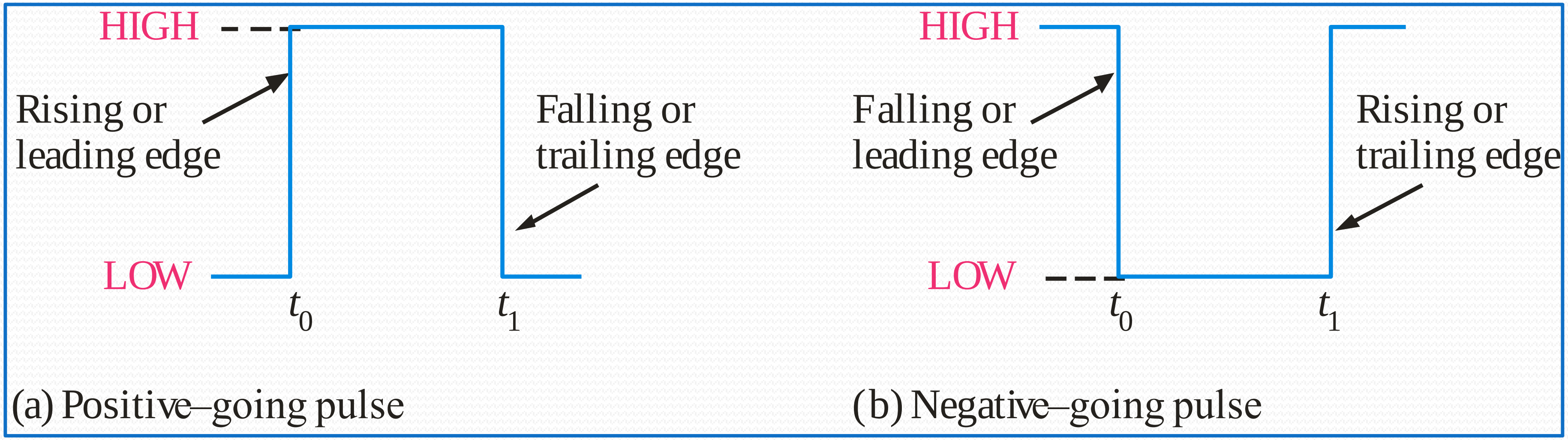
This is why we say "Logic" ..



Digital System functions only in the green zone

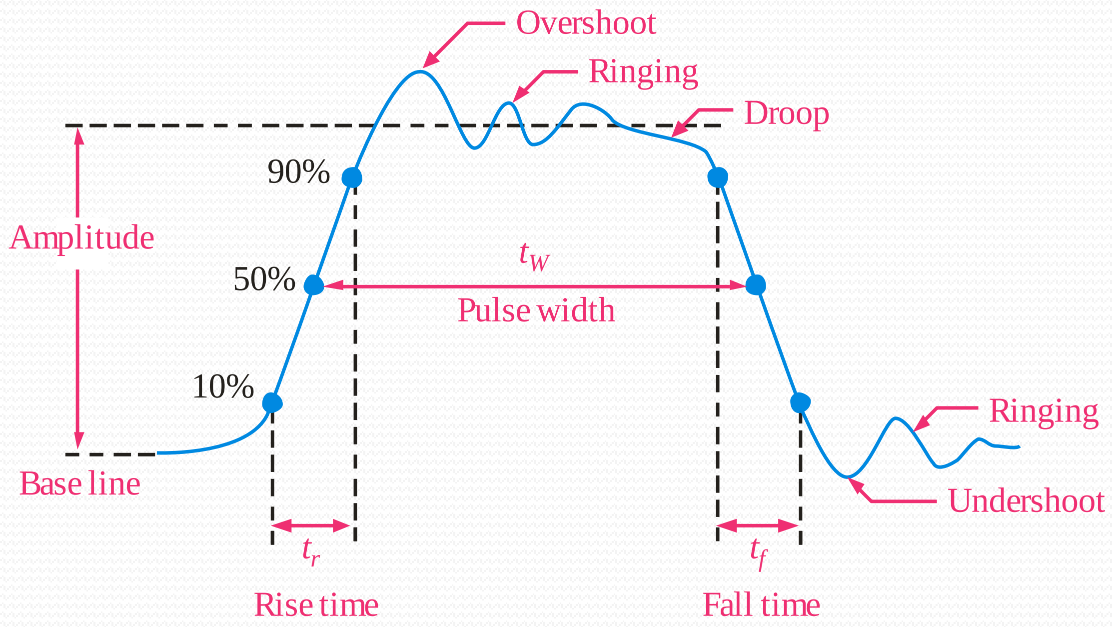
Digital Waveforms

Digital waveforms change between the LOW and HIGH levels. A positive going pulse is one that goes from a normally LOW logic level to a HIGH level and then back again. Digital waveforms are made up of a series of pulses.



Pulse Definitions

Actual pulses are not ideal but are described by the rise time, fall time, amplitude, and other characteristics.



Periodic Pulse Waveforms

Periodic pulse waveforms are composed of pulses that repeats in a fixed interval called the **period (T)**. The **frequency** is the rate it repeats and is measured in hertz.

$$f = \frac{1}{T} \qquad T = \frac{1}{f}$$

The **clock** is a basic timing signal that is an example of a periodic wave.

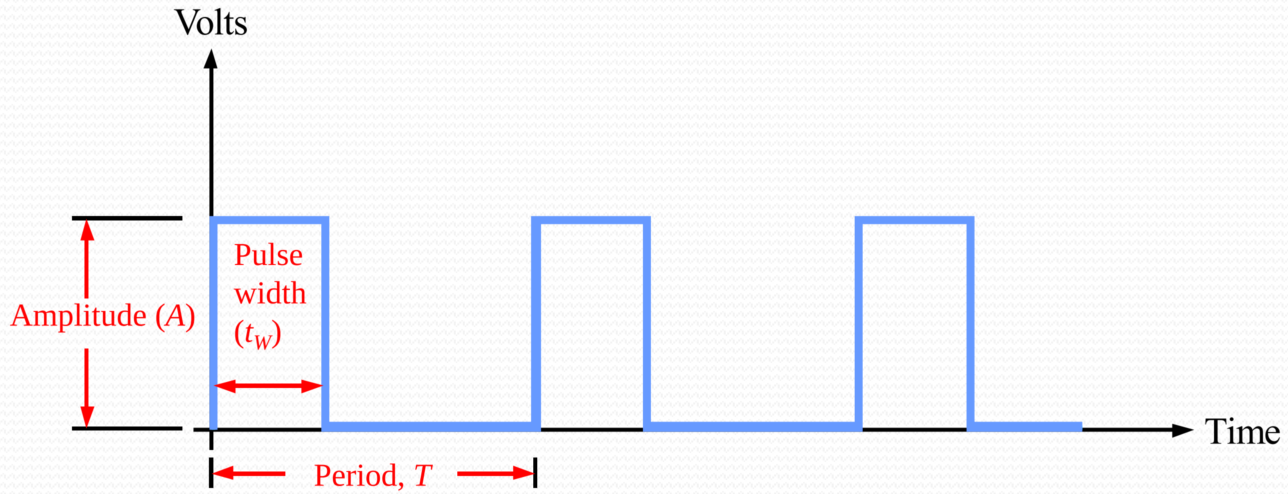
Example What is the period of a repetitive wave if f = 3.2 GHz?

Solution $T = \dfrac{1}{f} = \dfrac{1}{3.2\,\text{GHz}} =$ 313 ps

Pulse Definitions

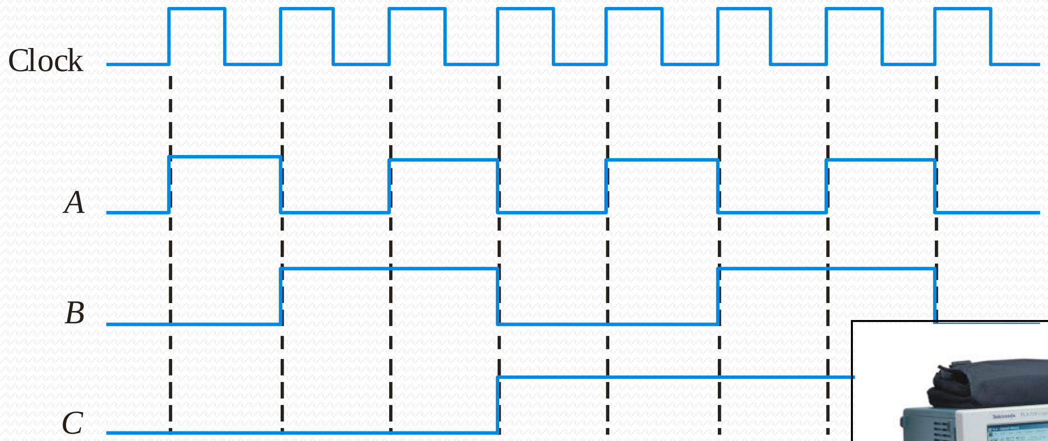
In addition to ***frequency*** and ***period***, repetitive pulse waveforms are described by the ***amplitude*** (***A***), ***pulse width*** (t_W) and ***duty cycle***.

Duty cycle is the ratio of t_W to T.

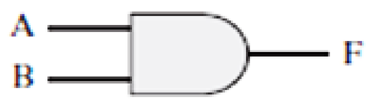
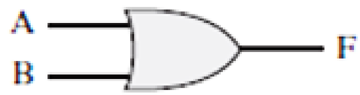
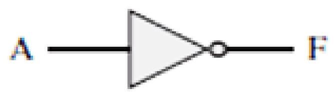
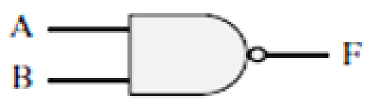
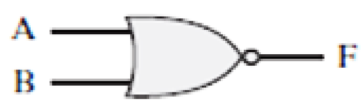
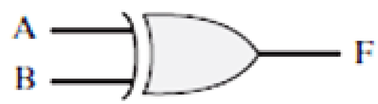


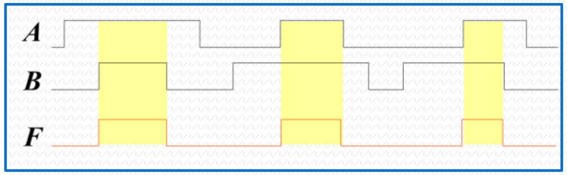
Timing Diagrams

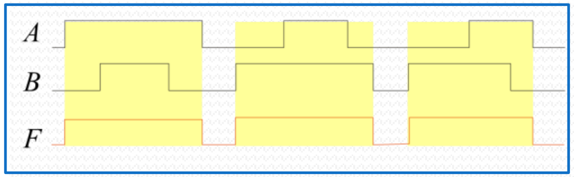
A timing diagram is used to show the relationship between two or more digital waveforms,

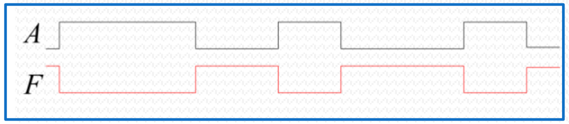


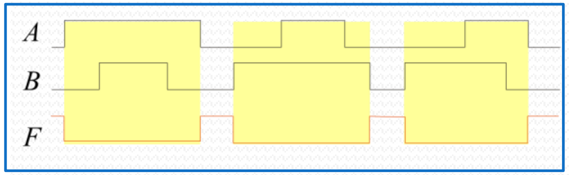
A diagram like this can be observed directly on a logic analyzer.

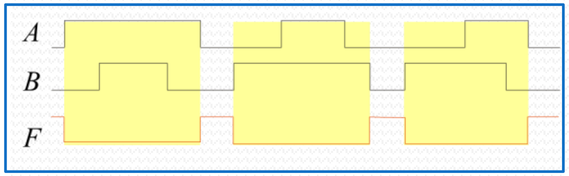
Name	Graphical Symbol	Algebraic Function	Truth Table
AND		$F = A \bullet B$ or $F = AB$	A B | F 0 0 | 0 0 1 | 0 1 0 | 0 1 1 | 1
OR		$F = A + B$	A B | F 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 1
NOT		$F = \overline{A}$ or $F = A'$	A | F 0 | 1 1 | 0
NAND		$F = \overline{AB}$	A B | F 0 0 | 1 0 1 | 1 1 0 | 1 1 1 | 0
NOR		$F = \overline{A + B}$	A B | F 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 0
XOR		$F = A \oplus B$	A B | F 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 0

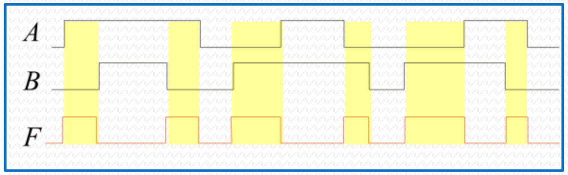












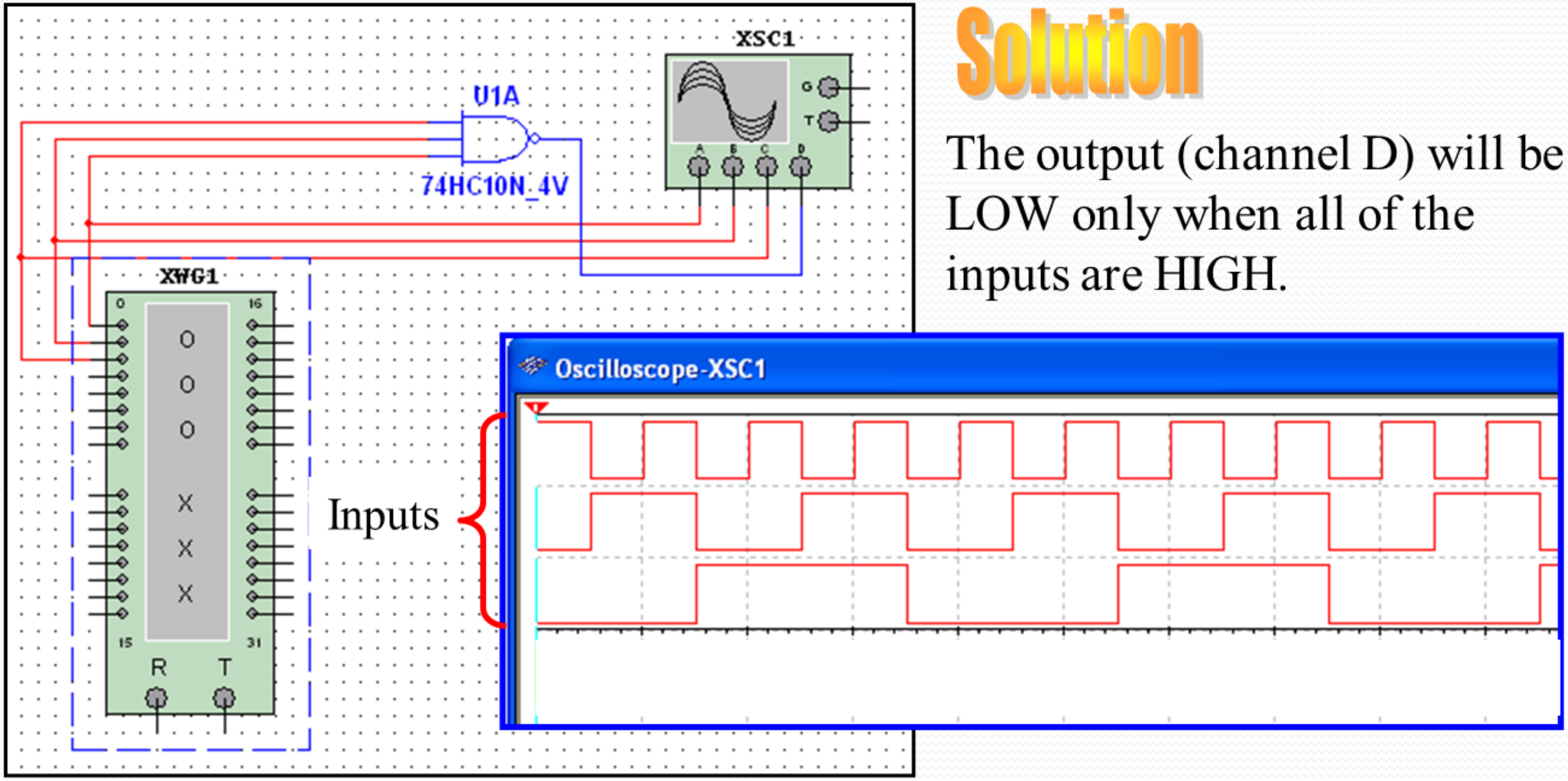
Basic Logic Gated

F : Output Waveforms

The NAND Gate

Example

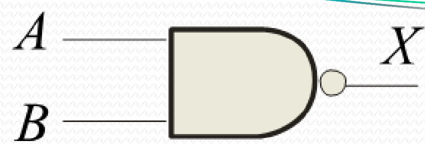
A Multisim circuit is shown. XWG1 is a word generator set in the count up mode. A four-channel oscilloscope monitors the inputs and output. What output signal do you expect to see?



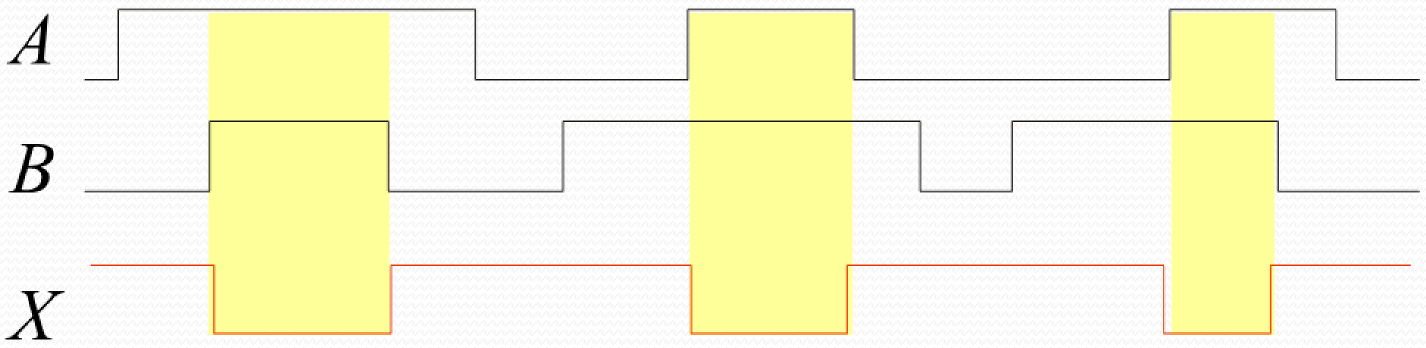
Solution

The output (channel D) will be LOW only when all of the inputs are HIGH.

The NAND Gate

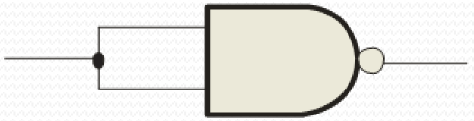


Example waveforms:

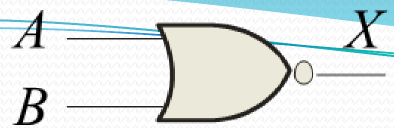


The NAND gate is particularly useful because it is a "universal" gate – all other basic gates can be constructed from NAND gates.

Question How would you connect a 2-input NAND gate to form a basic inverter?



The NOR Gate

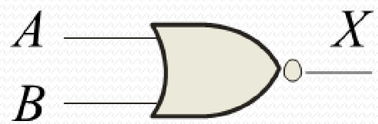


The **NOR gate** produces a LOW output if any input is HIGH; if all inputs are HIGH, the output is LOW. For a 2-input gate, the truth table is

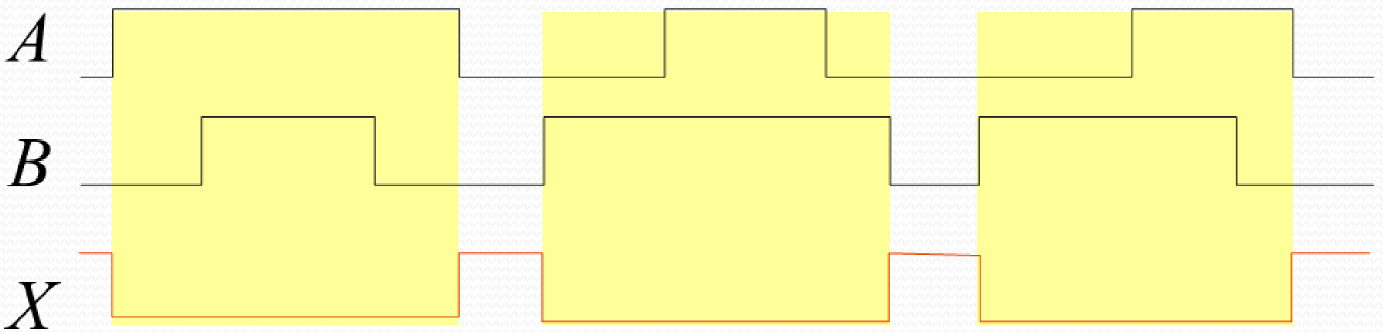
Inputs		Output
A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

The **NOR** operation is shown with a plus sign (+) between the variables and an overbar covering them. Thus, the NOR operation is written as $X = \overline{A + B}$.

The NOR Gate

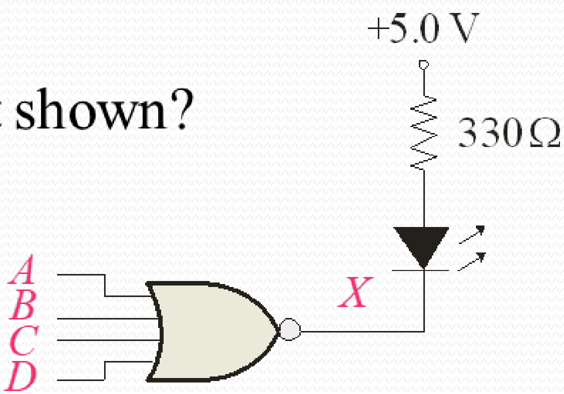


Example waveforms:



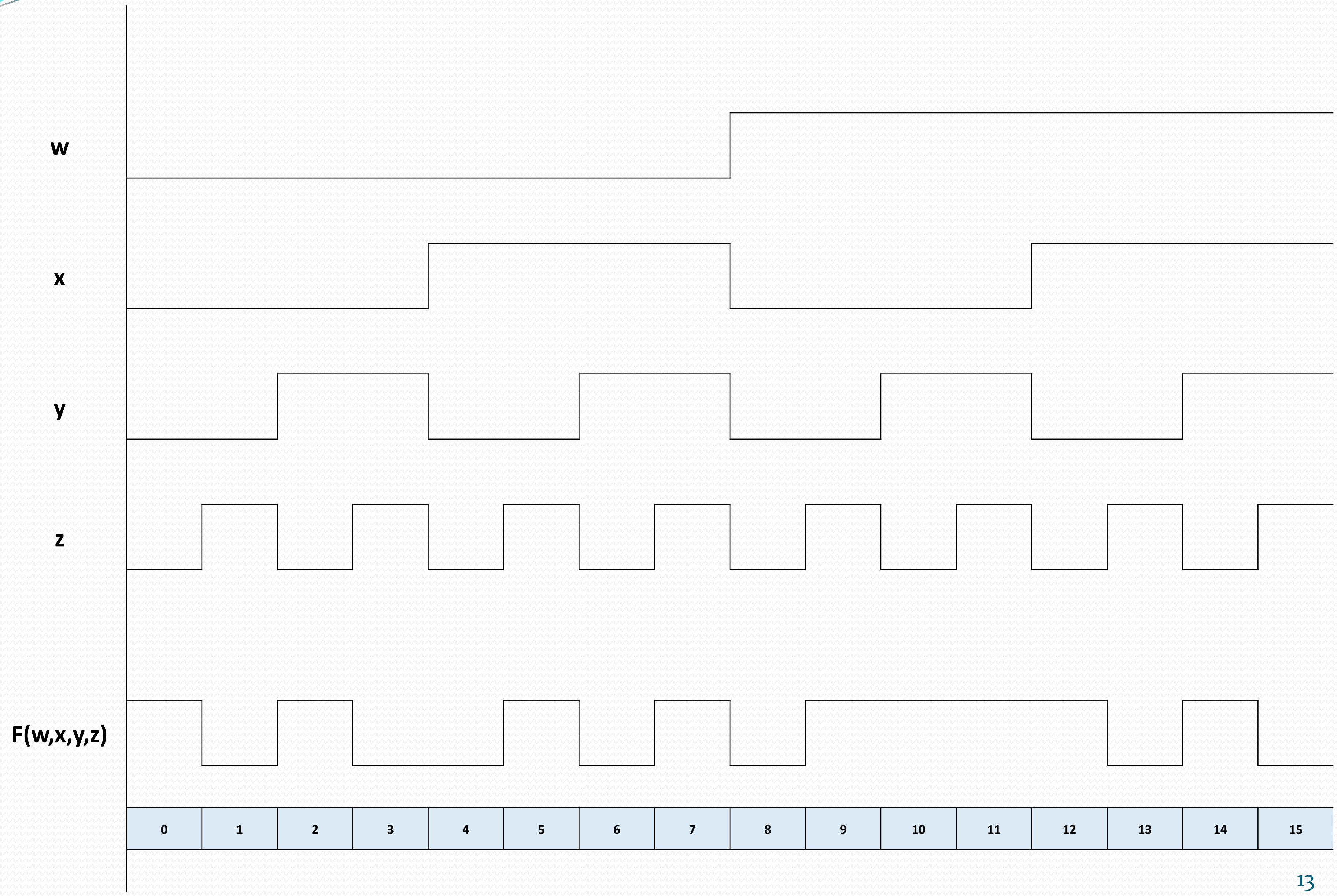
The NOR operation will produce a LOW if any input is HIGH.

Example When is the LED is ON for the circuit shown?



Solution The LED will be on when any of the four inputs are HIGH.

<u>Exercise</u>:- using the following Timing Diagram, obtain the Truth Table and write the final expression of the function (F(w,x,y,z) = ∑(. , . , . ,))

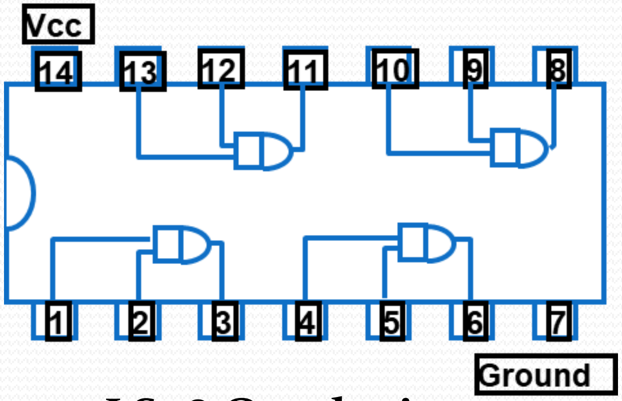


Combinational Logic circuits

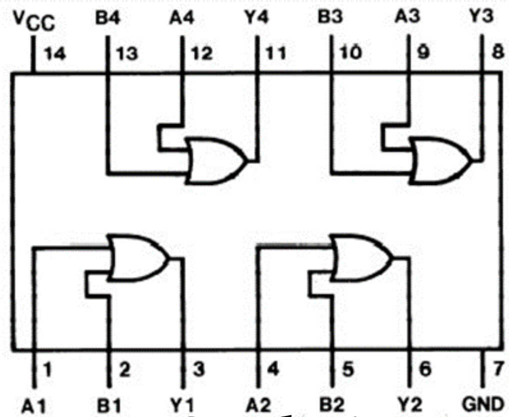
The AND, OR, NAND, NOR and NOT are the basic building blocks of digital systems.

The art of digital system design is to link these building blocks together in the most effective manner to construct what is called ***Combinational Logic circuits*** .

These are called ***combinational circuits*** because the ***output of a circuit at any given moment depends on the combination of input signals present***.

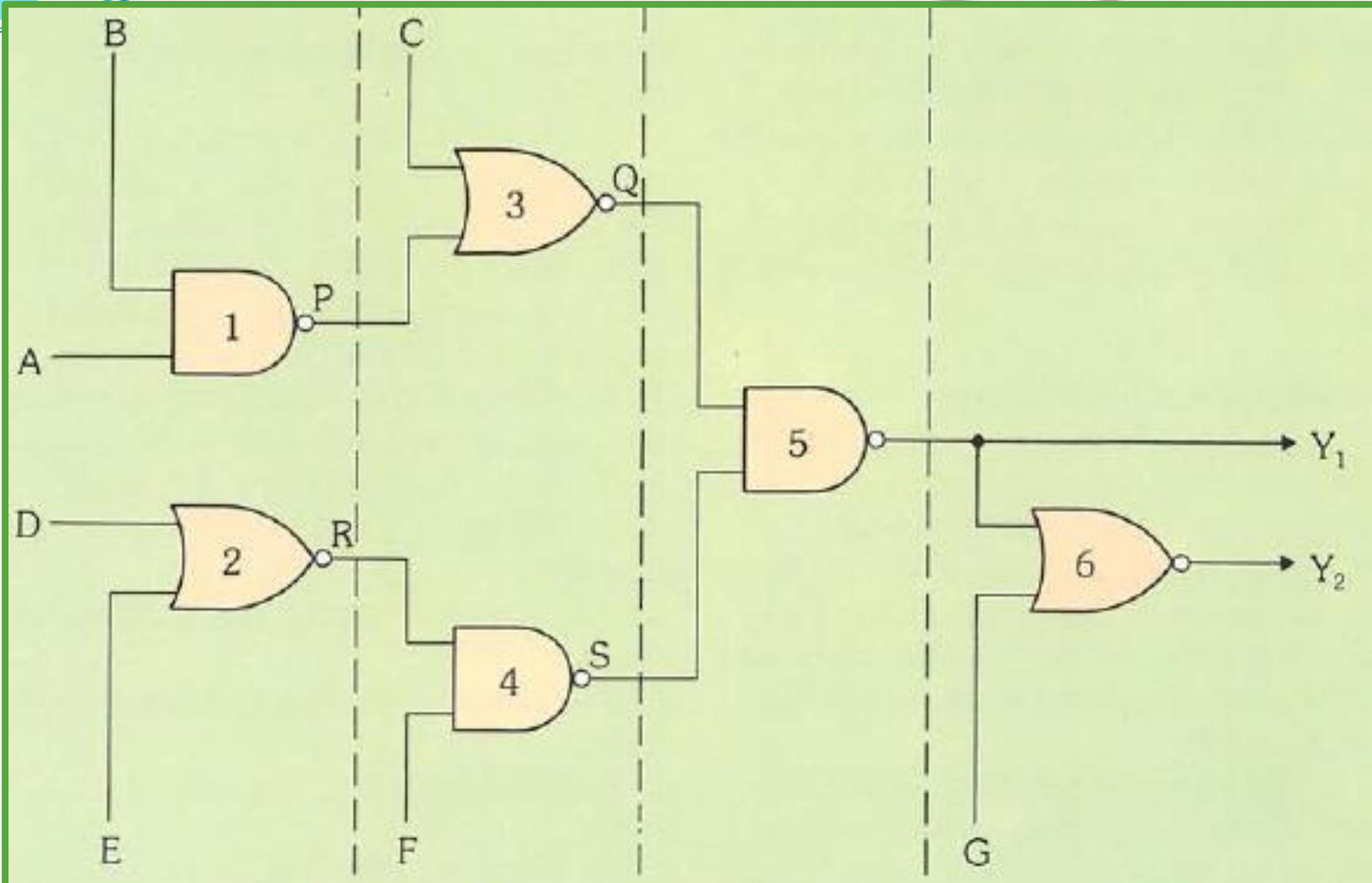


74LS08 Quad 2-input AND Gate IC Package



74LS08 Quad 2-input OR Gate IC Package

combinational circuits



How many inputs (i/p) and how many outputs (o/p) in the above circuit ?

Algebraic Function

Boolean Function Representation

The use of switching devices like transistors give rise to use a special mathematics case called the ***Boolean algebra.***

The principles of logic were developed by ***George Boole*** (1815-1884) who, along with ***Augustus De Morgan***, formulated a basic set of rules that govern the relationship between the ***true - false statements*** of logic. Boole's work laid the foundation to what later became known as ***Boolean Algebra***.

Nearly one hundred years later, ***Claude Shannon,*** an American postgraduate at Massachusetts Institute of Technology, realized that Boole's work was relevant in particular to the analysis of ***switching circuits in telephone exchanges*** and, more generally, formed a mathematical basis for the electronic processing of binary information.

Rules of Boolean Algebra

1. $A + 0 = A$
2. $A + 1 = 1$
3. $A \cdot 0 = 0$
4. $A \cdot 1 = \mathrm{A}$
5. $A + A = A$
6. $A + \overline{A} = 1$
7. $A \cdot A = A$
8. $A \cdot \overline{A} = 0$
9. $\overline{\overline{A}} = A$
10. $A + AB = A$
11. $A + \overline{A}B = A + B$
12. $(A + B)(A + C) = A + BC$

DeMorgan's Theorem

DeMorgan's 1st Theorem

The complement of a product of variables is equal to the sum of the complemented variables.

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

Homework (team/group work)

using Boolean algebra Rules,

1. *prove :*

$$A\,B + B\,C + \overline{A}\,C = A\,B + A\,\overline{C}$$

2. *Show that the function:*

$$F = A\,\overline{B}\,\overline{C} + A\,B\,\overline{C} + A\,\overline{B}\,C + A\,B\,C$$

equals 1 when A equals 1.