Logic Gate

College of
Engineering & Technology

Al-Mustaqbal
University

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

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2024-2025

Numbering system
Number base conversion

The majority of this course material is based on text and presentations of :

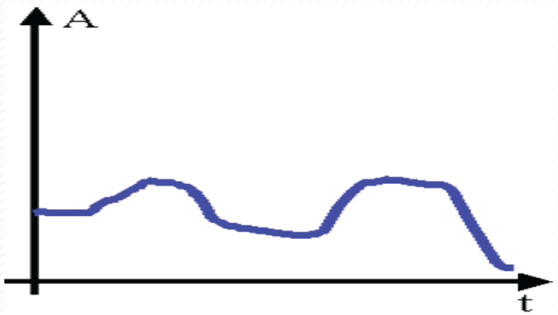
Outline

- **Glimpse from Electronics History**
- **The notion of “*Digital* ” in Electronics**
- **The notion of “*Logic*” in Electronics**
- **The notion of “Abstraction” in Electronics**
- **Pre-view at *Digital Logic* Gats in Electronics**
- **Numbering Systems**

تقييم (توزيع الدرجات) لمادة (Logic Gates) حسب مسار بولونيا

Module Evaluation تقييم المادة الدراسية					
		Time/Number	Weight (Marks)	Week Due	Relevant Learning Outcome
Formative assessment	Quizzes	2	10% (10)	5, 10	LO #1, 2, 10 and 11
	Assignments	2	10% (10)	2, 12	LO # 3, 4, 6 and 7
	Projects / Lab.	1	10% (10)	Continuous	All
	Report	1	10% (10)	13	LO # 5, 8 and 10
Summative assessment	Midterm Exam	2 hr	10% (10)	7	LO # 1-7
	Final Exam	2hr	50% (50)	16	All
Total assessment			100% (100 Marks)		

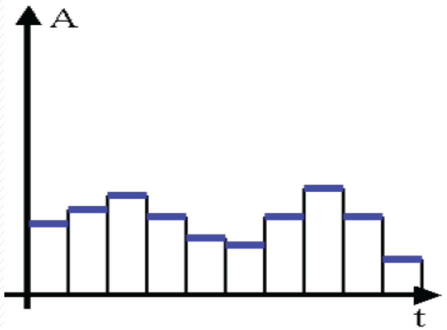
Analog signal is ***time-varying*** and generally bound to a range (e.g. +12V to -12V, if we are talking about **voltage signal**), but there is an infinite number of values within that continuous range.



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.



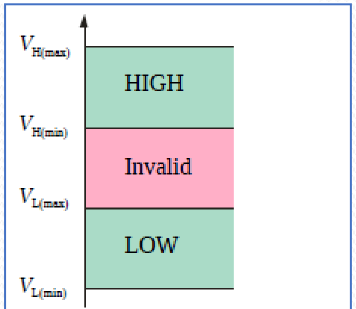
Digital signal – large time divisions

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).

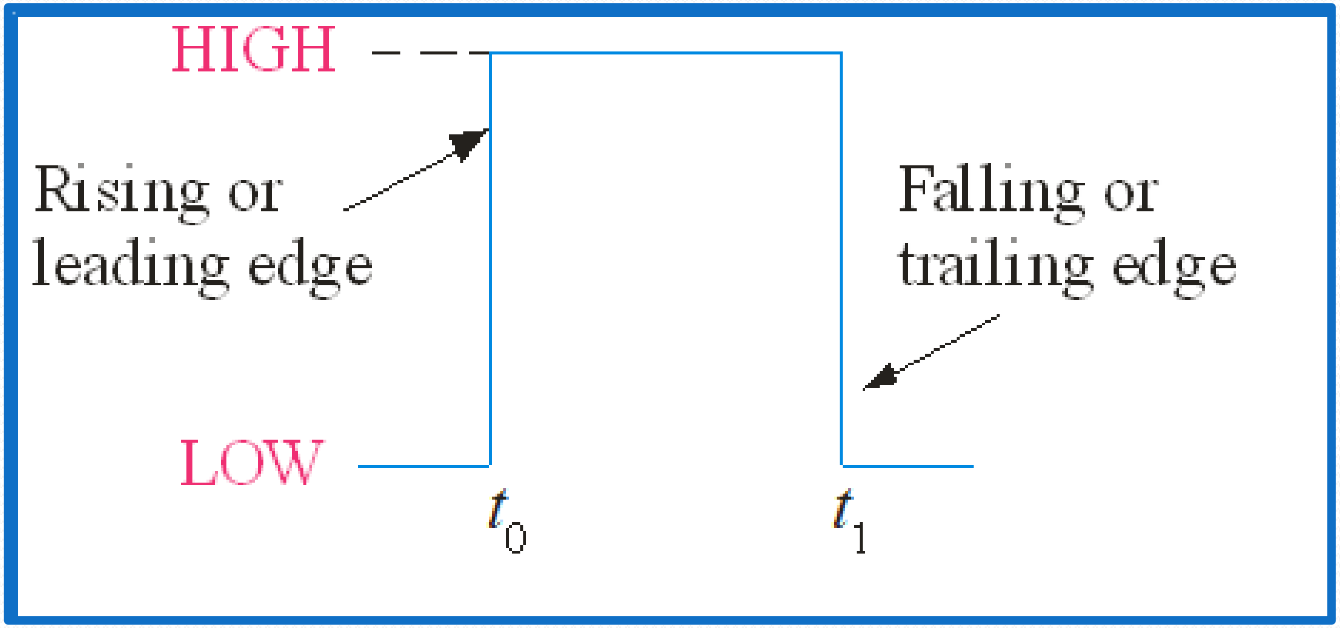
This is why we say "Logic" ..



Digital System functions only in the green zone

Digital Waveforms

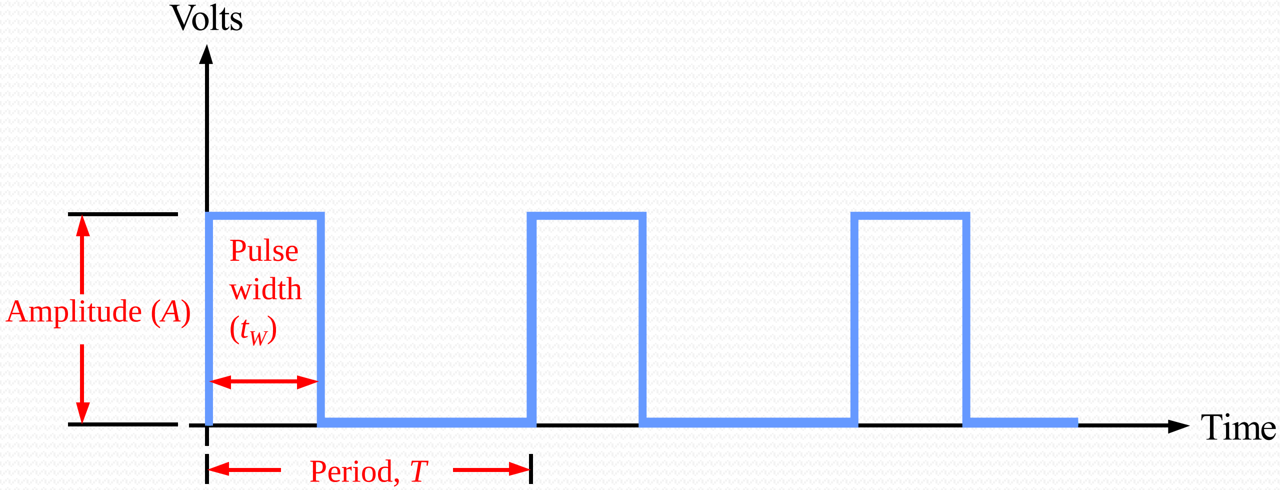
Digital waveforms change between the LOW and HIGH levels. A positive going pulse is one that goes from a normally LOW logic level to a HIGH level and then back again. Digital waveforms are made up of a series of pulses.



Pulse Definitions

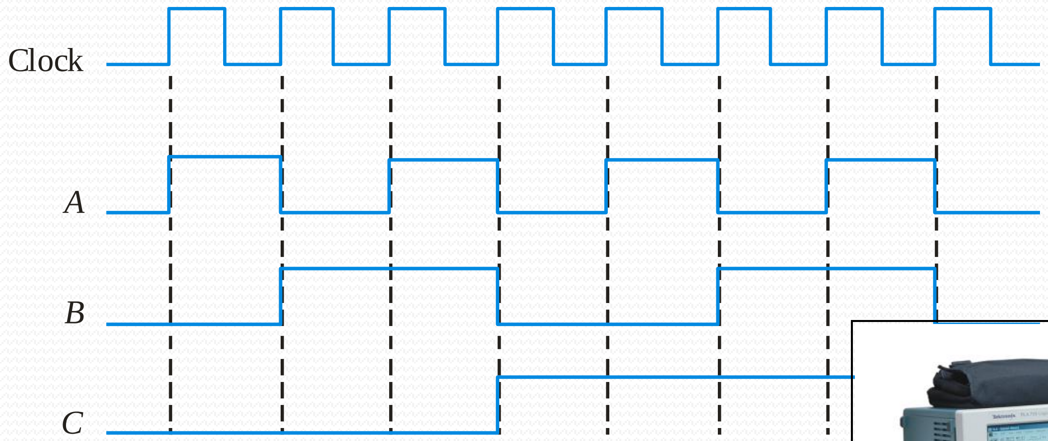
In addition to ***frequency*** and ***period***, repetitive pulse waveforms are described by the ***amplitude*** (***A***), ***pulse width*** (t_W) and ***duty cycle***.

Duty cycle is the ratio of t_W to T.

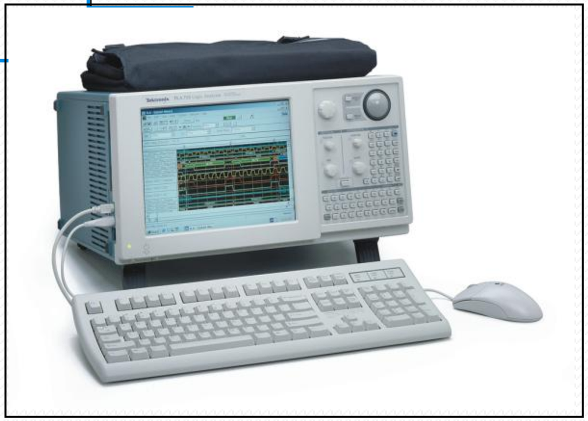


Timing Diagrams

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.



Periodic Pulse Waveforms

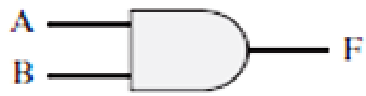
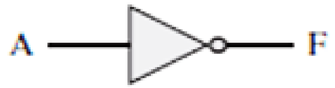
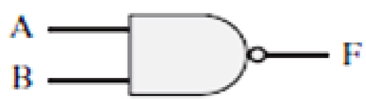
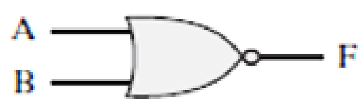
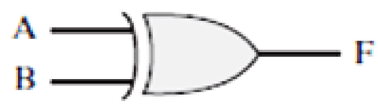
Periodic pulse waveforms are composed of pulses that repeats in a fixed interval called the **period (T)**. The **frequency** is the rate it repeats and is measured in hertz.

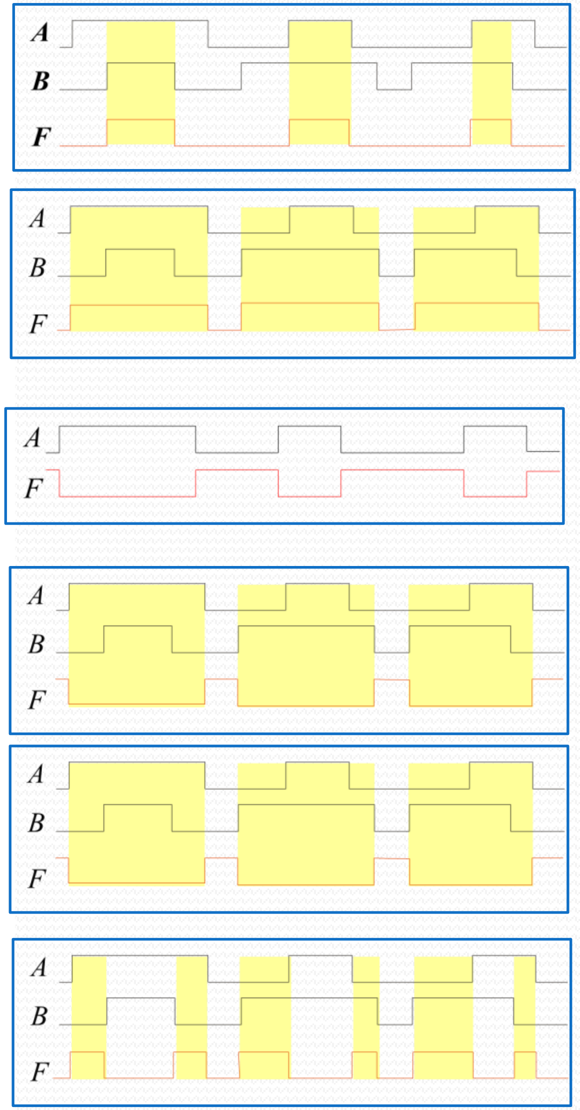
$$f = \frac{1}{T} \qquad T = \frac{1}{f}$$

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 $T = \frac{1}{f} = \frac{1}{3.2\ \text{GHz}} =$ 313 ps

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

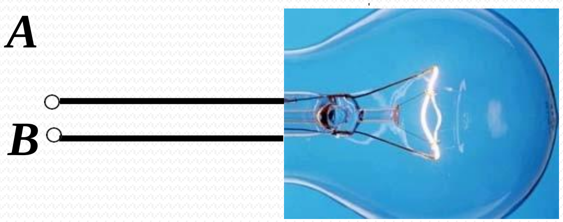


Basic Logic Gated

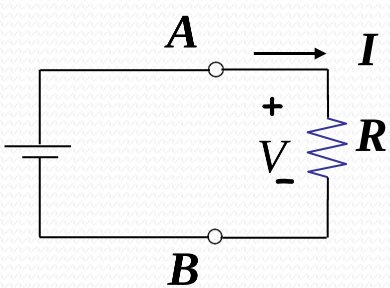
F : Output Waveforms

Abstraction in Electronics

The Easy Way…



Replace the bulb with a *discrete resistor* to calculating the current.



and $I = \frac{V}{R}$

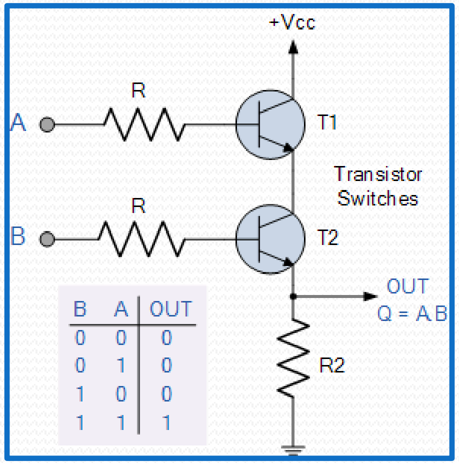
R represents the only property of interest

في علم الإلكترونيك، التجريد (**Abstraction**) هي عملية تجريد التفاصيل غير الضرورية للتركيز على المعلومات الأساسية التي تساعد على فهم وتطوير النظام. حيث يستخدم هذا المفهوم لتحويل النظريات العلمية والقوانين الطبيعية (مثل معادلات ماكسويل) إلى تصميمات عملية للأجهزة والمنظومات.

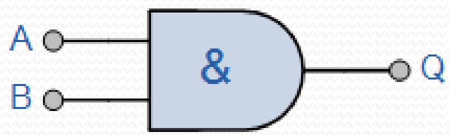
على سبيل المثال، يتم تحويل معادلات ماكسويل العلمية إلى مفاهيم أكثر تجريدًا مثل مفهوم الكهرباء والمغناطيسية وموجات الراديو. ثم يتم تحويل هذه المفاهيم إلى مخططات تصميم الدوائر الإلكترونية والمكونات المستخدمة فيها.

ويستخدم الـ **Abstraction** في تصميم الأجهزة والمنظومات الكبيرة مثل المركبات الفضائية وأجهزة الرنين المغناطيسي في المستشفيات.

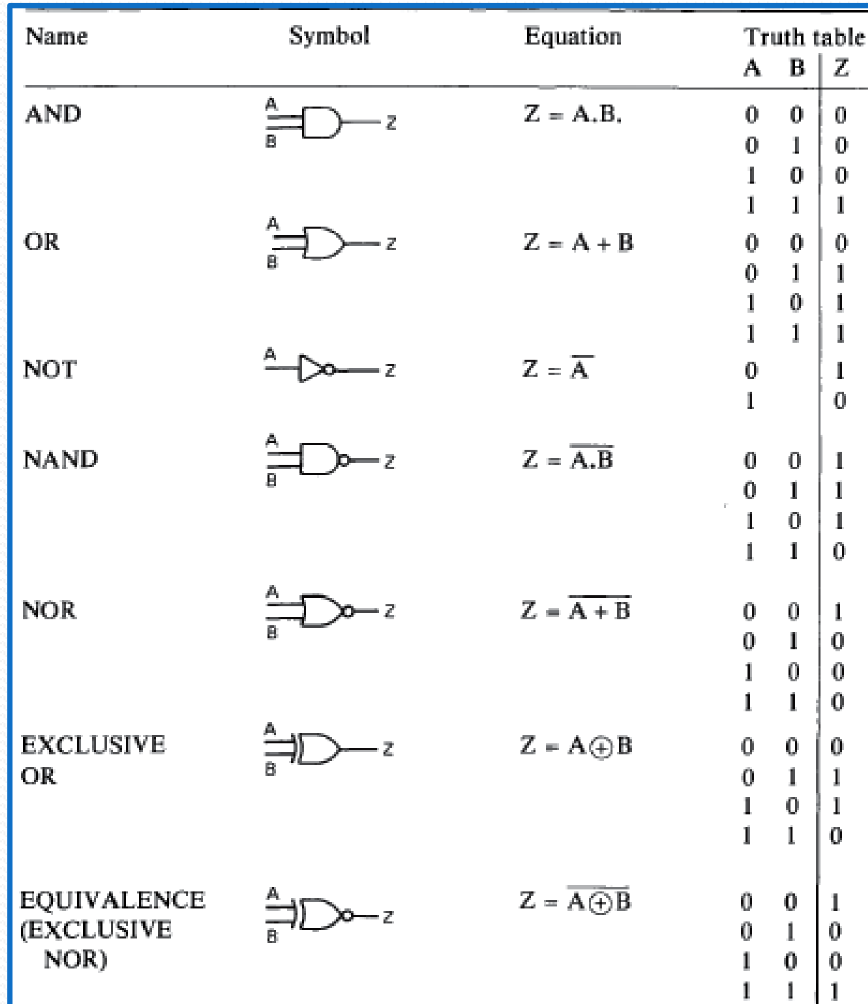
Abstraction in Electronics



AND circuit
Abstraction



AND Logic
Abstraction



Name	Equation	A	B	Z
AND	$Z = A.B.$	0	0	0
		0	1	0
		1	0	0
		1	1	1
OR	$Z = A + B$	0	0	0
		0	1	1
		1	0	1
		1	1	1
NOT	$Z = \overline{A}$	0		1
		1		0
NAND	$Z = \overline{A.B}$	0	0	1
		0	1	1
		1	0	1
		1	1	0
NOR	$Z = \overline{A + B}$	0	0	1
		0	1	0
		1	0	0
		1	1	0
EXCLUSIVE OR	$Z = A \oplus B$	0	0	0
		0	1	1
		1	0	1
		1	1	0
EQUIVALENCE (EXCLUSIVE NOR)	$Z = \overline{A \oplus B}$	0	0	1
		0	1	0
		1	0	0
		1	1	1

AND Logics examples

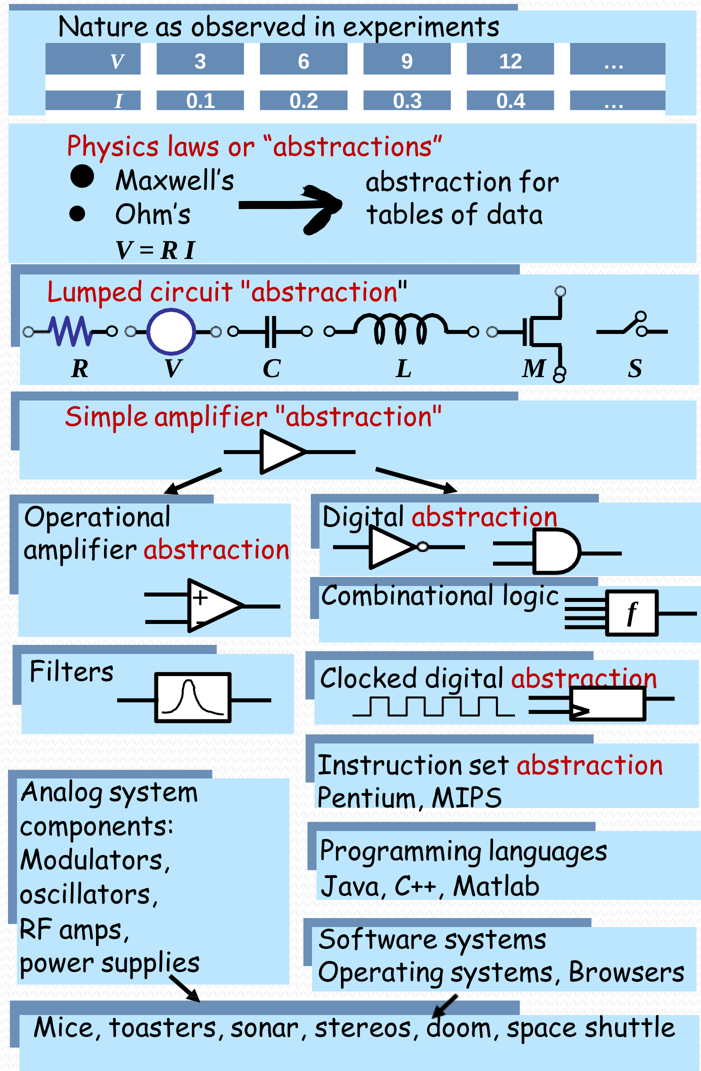
VHDL (programming Language)

```
entity AND_Gate1 is
    port(A,B:in
    bit:Q:out bit);
end entity AND_Gate1
```

Programming Language Abstraction

Abstraction in Electronics

Engineering
is
a purposeful use
of Science



الهندسة
هي
الأستخدام الهادف
للعلوم

For the rest of semester, we will work only in the

Digital (Logic) Level

Numbering Syatems

Decimal Numbers

The position of each digit in a weighted number system is assigned a weight based on the **base** or **radix** of the system.

The radix of **decimal numbers** is ten, because only ten symbols (0 through 9) are used to represent any number.

The column weights of **decimal numbers** are powers of ten that increase from right to left beginning with $10^0 = 1$:

…10^5 10^4 10^3 10^2 10^1 10^0.

For fractional decimal numbers, the column weights are negative powers of ten that decrease from left to right:

10^2 10^1 10^0. 10^{-1} 10^{-2} 10^{-3} 10^{-4} …

Decimal Numbers

Decimal numbers values can be expressed as the sum of the products of each **digit** times the **column weight** for that digit. Thus, the number 9240 can be expressed as

$$(9 \times 10^3) + (2 \times 10^2) + (4 \times 10^1) + (0 \times 10^0)$$

or

$$9 \times 1{,}000 + 2 \times 100 + 4 \times 10 + 0 \times 1$$

Example **Express the number 480.52 as the sum of values of each digit.**

Solution

480.52 = $(4 \times 10^2) + (8 \times 10^1) + (0 \times 10^0) + (5 \times 10^{-1}) + (2 \times 10^{-2})$

Binary Numbers

For **digital systems**, the **binary number** system is used. Binary has a radix of two and uses the digits 0 and 1 to represent quantities.

The column weights of binary numbers are powers of two that increase from right to left beginning with $2^0 = 1$:

$$\ldots 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0.$$

For fractional binary numbers, the column weights are negative powers of two that decrease from left to right:

$$2^2\ 2^1\ 2^0.\ 2^{-1}\ 2^{-2}\ 2^{-3}\ 2^{-4}\ \ldots$$

Binary Numbers

A binary counting sequence for numbers from zero to fifteen is shown.

Notice the pattern of zeros and ones in each column.

Digital counters frequently have this same pattern of digits:

Decimal Number	Binary Number
0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1
10	1 0 1 0
11	1 0 1 1
12	1 1 0 0
13	1 1 0 1
14	1 1 1 0
15	1 1 1 1

Binary Conversions

The **decimal equivalent** of a **binary number** can be determined by adding the column values of all of the bits that are 1 and discarding all of the bits that are 0.

Example **Convert the binary number 100101.01 to decimal.**

Solution Start by writing the column weights; then add the weights that correspond to each 1 in the number.

2^5 2^4 2^3 2^2 2^1 2^0. 2^{-1} 2^{-2}

32 16 8 4 2 1 . ½ ¼

1 0 0 1 0 1. 0 1

32 +4 +1 +¼ = 37¼

Binary Conversions

You can convert a decimal whole number to binary by reversing the procedure. Write the decimal weight of each column and place 1's in the columns that sum to the decimal number.

Example Convert the decimal number 49 to binary.

Solution The column weights double in each position to the right. Write down column weights until the last number is larger than the one you want to convert.

2^6	2^5	2^4	2^3	2^2	2^1	2^0.
64	32	16	8	4	2	1.
0	1	1	0	0	0	1.

Octal Numbers

Octal uses eight characters the numbers 0 through 7 to represent numbers. There is no 8 or 9 character in octal.

Binary number can easily be converted to octal **by grouping bits 3 at a time** and writing the equivalent octal character for each group.

Decimal	Octal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	10	1000
9	11	1001
10	12	1010
11	13	1011
12	14	1100
13	15	1101
14	16	1110
15	17	1111

Example

Express $1\ 001\ 011\ 000\ 001\ 110_2$ in octal:

Solution

Group the binary number by 3-bits starting from the right. Thus, $\mathbf{113016_8}$

Octal Numbers

Octal is also a weighted number system. The column weights are powers of 8, which increase from right to left.

Column weights { 8^3 8^2 8^1 8^0 .
512 64 8 1 .

Example Express **3702_8** in decimal.

Solution Start by writing the column weights:

512 64 8 1

3 7 0 2_8

3 (512) + **7** (64) + **0** (8) +**2** (1) = 1986_{10}

Decimal	Octal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	10	1000
9	11	1001
10	12	1010
11	13	1011
12	14	1100
13	15	1101
14	16	1110
15	17	1111

Hexadecimal Numbers

Hexadecimal uses sixteen characters to represent numbers: the numbers **0** through **9** and the alphabetic characters **A** through **F**.

Large binary number can easily be converted to hexadecimal **by grouping bits 4 at a time** and writing the equivalent hexadecimal character.

Example

Express $1001\ 0110\ 0000\ 1110_2$ in hexadecimal:

Solution

Group the binary number by 4-bits starting from the right. Thus, **960E**

Decimal	Hexadecimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Hexadecimal Numbers

Hexadecimal is a weighted number system. The column weights are powers of 16, which increase from right to left.

Column weights $\begin{cases} 16^3 & 16^2 & 16^1 & 16^0 \\ 4096 & 256 & 16 & 1 \end{cases}$.

Decimal	Hexadecimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Example Express $\mathbf{1A2F}_{16}$ in decimal.

Solution Start by writing the column weights:

4096 256 16 1

1 A 2 $\mathbf{F}_{16}$

$\mathbf{1}(4096) + \mathbf{10}(256) + \mathbf{2}(16) + \mathbf{15}(1) = 6703_{10}$

BCD

Binary coded decimal (BCD) is a weighted code that is commonly used in digital systems when it is **necessary to show decimal numbers such as in clock displays.**

The table illustrates the difference between straight binary and BCD.

BCD represents **each decimal digit with a 4-bit code**. Notice that the codes 1010 through 1111 are not used in BCD.

Decimal	Binary	BCD
0	0000	0000
1	0001	0001
2	0010	0010
3	0011	0011
4	0100	0100
5	0101	0101
6	0110	0110
7	0111	0111
8	1000	1000
9	1001	1001
10	1010	00010000
11	1011	00010001
12	1100	00010010
13	1101	00010011
14	1110	00010100
15	1111	00010101

BCD

You can think of BCD in terms of column weights in groups of four bits. For an 8-bit BCD number, the column weights are: 80 40 20 10 8 4 2 1.

Question: What are the column weights for the BCD number 1000 0011 0101 1001?

Answer:

8000 4000 2000 1000 800 400 200 100 80 40 20 10 8 4 2 1

Note that you could add the column weights where there is a 1 to obtain the decimal number. For this case:

$$8000 + 200 + 100 + 40 + 10 + 8 + 1 = 8359_{10}$$

BCD

A lab experiment in which BCD is converted to decimal is shown.