1. Introductory Concepts

Objectives

- Distinguish between analog and digital representation.
- Name the advantages, disadvantages, and major differences between Analog and Digital systems.
- Understand the need for analog-to-digital converters (ADCs) and digital-to-analog converters (DACs).
- Understand why the binary numbering system & not the decimal system is used in Digital Electronics.
- Identify typical digital signals.
- Cite several different IC fabrication technologies.
- Identify timing diagrams.
- State the difference between serial and parallel transmission.

Introduction

When you first hear the word ***DIGITAL*** you think of:

- digital calculators
- digital watches
- digital computer

Nowadays Digital circuits are being used in almost all electronic products ranging from:-

- CD players
- video games
- video cassette players
- televisions
- radios
- microwave ovens
- automobile control systems
  - electronic fuel injection
  - ABS (Antilock Braking System)
  - cruise control
  - adaptive suspension
- test equipment
  - Multimeters
  - oscilloscopes
  - signal generators

  etc.

Numerical Representations

In Science & Technology, real world quantities are measured, monitored, recorded and processed.

There are basically 2 ways of representing the numerical values of quantities.

- ***Analog Representation -***
  One quantity is represented by another which is directly proportional to the first.

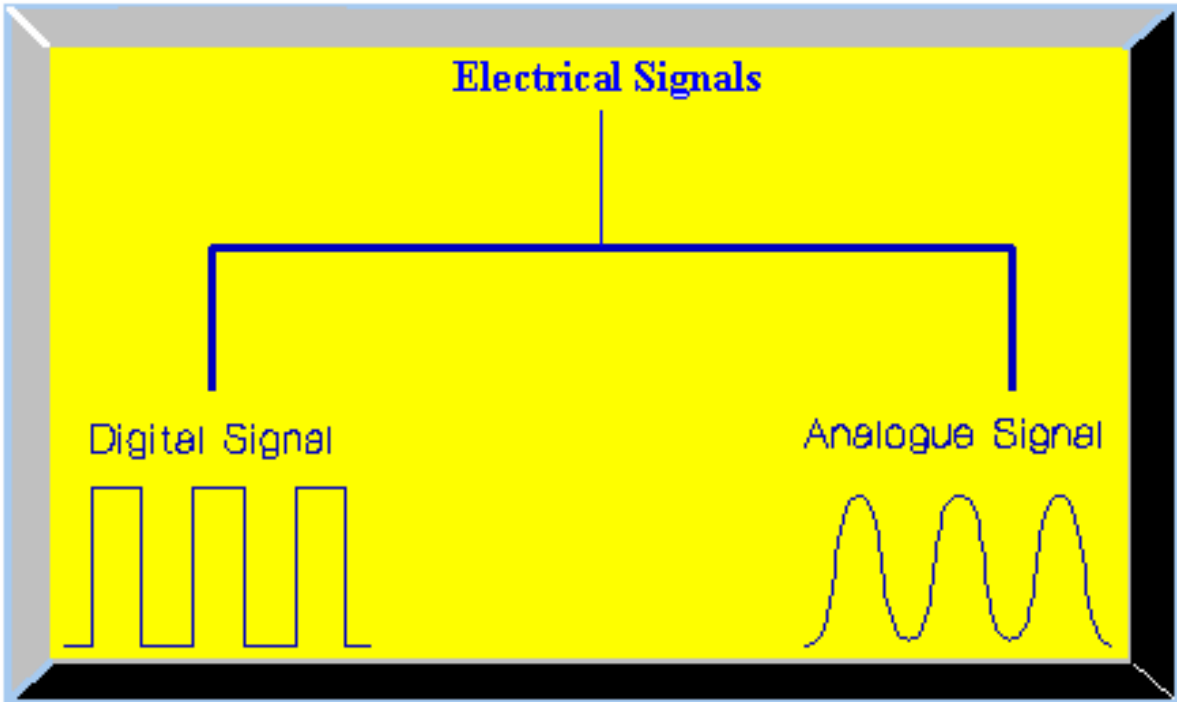
  Analogue quantities can vary over a continuous range of values.

  Example - Car speedometer
  Other thermostat
  Examples - audio microphone
  TV signal

- ***Digital Representations*** -
  The digital quantities are represented by symbol called digits.
  Digital quantities have discrete steps or values.

  Example - Digital watch
  Other resistor substitution box
  Examples - grains of sand on a beach
  status of a Light bulb

Similarly, in electronics, Signals are basically either **Digital** or **Analog**:



As can be seen from the waveforms:

A digital signal has amplitude values that varies in discrete steps.

An analog signal has amplitude values that varies continuously with time.

Analog & Digital Quantities

Q1. State whether the following Quantities are Analog or Digital.

		Select Answer
(a)	The Letters A to Z in the English Alphabet	❑ Analog ❑ Digital
(b)	Temperature in a microwave oven.	❑ Analog ❑ Digital
(c)	Electrical energy consumed by a computer.	❑ Analog ❑ Digital
(d)	Loose change in a pocket or wallet.	❑ Analog ❑ Digital
(e)	Number of fishes caught at sea everyday.	❑ Analog ❑ Digital
(f)	Electric signals generated by a microphone.	❑ Analog ❑ Digital
(g)	Sounds emitted by a loudspeaker.	❑ Analog ❑ Digital

Advantages of Digital Techniques

There is an increasing trend towards the use of digital techniques because of the many advantages that can be derived.

These include:

- Digital systems are easier to design *
- Information storage is easy
- Accuracy and precision are greater *
- Circuit stability over temperature and time
- Operation can be easily programmed
- Digital circuits are less affected by electrical noise *
- More digital circuitry can be fabricated on IC chips *

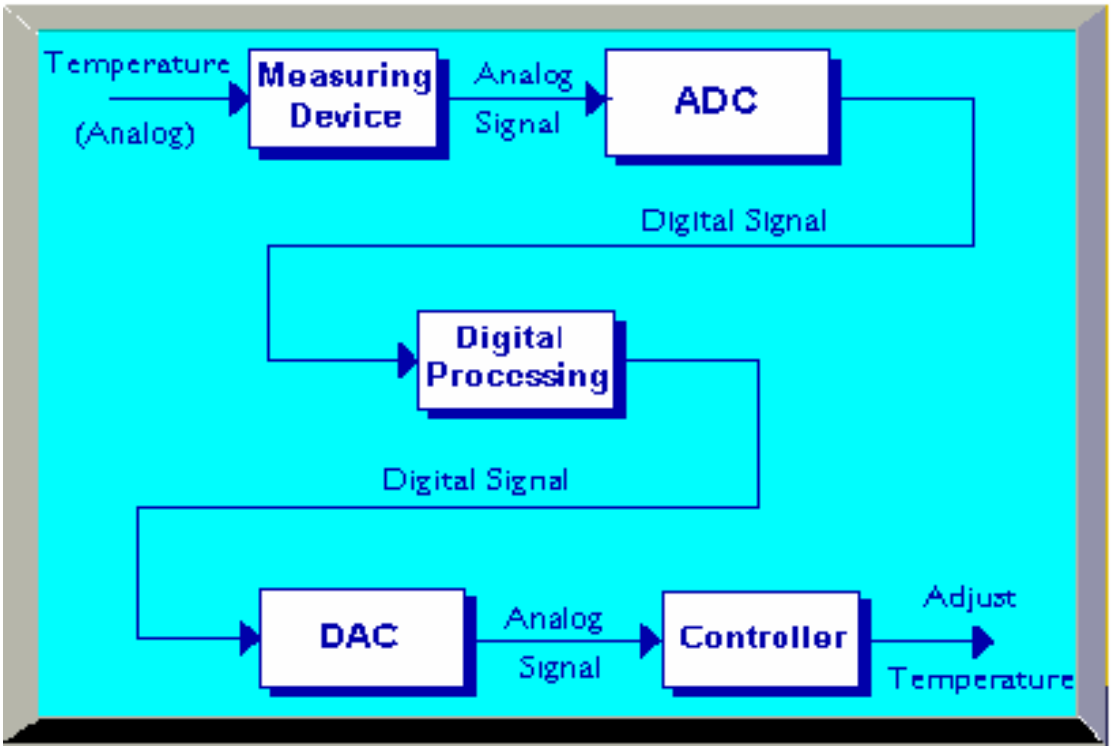
Generally, many of the advantages are due to the fact that in digital circuits the exact values of signal voltages are not important, only the level (H or L) they fall into is important.

Disadvantages of Digital Techniques.

There are nevertheless some *disadvantages* of using Digital Techniques.

- The real world is mainly analog *
- Some circuits are still built cheaper in analog.
- Some types of circuits can't be built using digital techniques *
- The need for ADCs and DACs.

Processing real world analog quantities using digital techniques require the use of ADCs and DACs:



Questions on Digital & Analog Techniques

Q1. Why does the application of Digital Techniques leads to greater noise immunity?

(a) Electrical noise does not exists in digital circuits.
(b) The absence of Inductors in digital circuits leads to less electrical noise.
(c) Precise voltage values are not important in digital circuits.
(d) Digital ICs used have built-in noise reduction filters.

Select Answer:

Q2. Which one of the following statements pertaining to Digital Technology is TRUE?

(a) Digital ICs are harder to fabricate as compared to Analog ICs.
(b) Storage of data is more difficult when digital techniques are employed.
(c) ADCs and DACs are a definite requirement when processing real world quantities.
(d) Not all circuits can be built using digital techniques.

Select Answer:

Digital Numbering Systems

Numbering systems are used in everyday computation as well as in digital systems.

The most common numbering systems used in digital systems are:

Binary	Binary or base2 uses only 2 digits or symbols, which are: 0 and 1. Eg 110110.
Octal	Octal uses only 8 symbols or digits. These are: 0 1 2 3 4 5 6 7. Eg 3672.
Decimal	The most common numbering system. Digits are: 0 1 2 3 4 5 6 7 8 9. Eg 23569.
Hexa-decimal	Commonly known as Hex, this system uses 16 digits. They are: 0 to 9 and A B C D E F. Eg 1FACE.

With digital systems, the binary format is the most useful and appropriate numbering system.

Decimal System

The **Decimal** system is the one that we use in our everyday transactions.

It uses 10 numerals or symbols and like all other numbering systems, is a positional-value system.

E.g. each digit of the decimal number 6183.25 would have weights as illustrated:

Positional Values or Weights *

10^3	10^2	10^1	10^0		10^{-1}	10^{-2}
6	1	8	3	.	2	5
|				|		|
MSD				Point		LSD

Multiplying each digit by its weights and summing up the products would yield the number,

$6 \times 10^3 + 1 \times 10^2 + 8 \times 10^1 + 3 \times 10^0 + 2 \times 10^{-1} + 5 \times 10^{-2} = 6183.25$

In other words, 6183.25 =
6 thousands + 1 hundred + 8 tens + 3 units + 2 tenths + 5 hundreths.

Binary Number System

In **Binary** system there are only two symbols or digit values : 0 *and* 1 *

The positional values of a binary number are in powers of 2 such as: 2^3 , 2^2 , 2^1 , 2^0

A *Binary Digit* is often called a *bit* *

With N places or digits there are 2^N different numbers &
Largest number (*in decimal*) = $2^N - 1$

E.g. A binary number with 8 places will have:
(a) $2^8 = 256_{10}$ different values
(b) $2^8 - 1 = 255_{10}$ is max value
(c) Number range from
0 to 11111111_2

E.g. a binary number such as 1101011_2

weights	2^6		2^5		2^4		2^3		2^2		2^1		2^0	
binary	1		1		0		1		0		1		1	
decimal	64	+	32	+	0	+	8	+	0	+	2	+	1	$=107_{10}$

Counting in Binary

The sequence begins with all bits at 0.

With each successive count, the unit (2^0) position toggles.

When the unit changes from 1 to 0, the twos (2^1) toggles.

When the twos changes from 1 to 0, the fours (2^2) toggles.

Similarly, when the fours changes from 1 to 0, the eights (2^3) toggles.

This same process continues for any higher order bit positions.

$2^3 = 8$	$2^2 = 4$	$2^1 = 2$	$2^0 = 1$		Decimal
0	0	0	0	:	0
0	0	0	1	:	1
0	0	1	0	:	2
0	0	1	1	:	3
0	1	0	0	:	4
0	1	0	1	:	5
0	1	1	0	:	6
0	1	1	1	:	7
1	0	0	0	:	8

Representing Binary Quantities

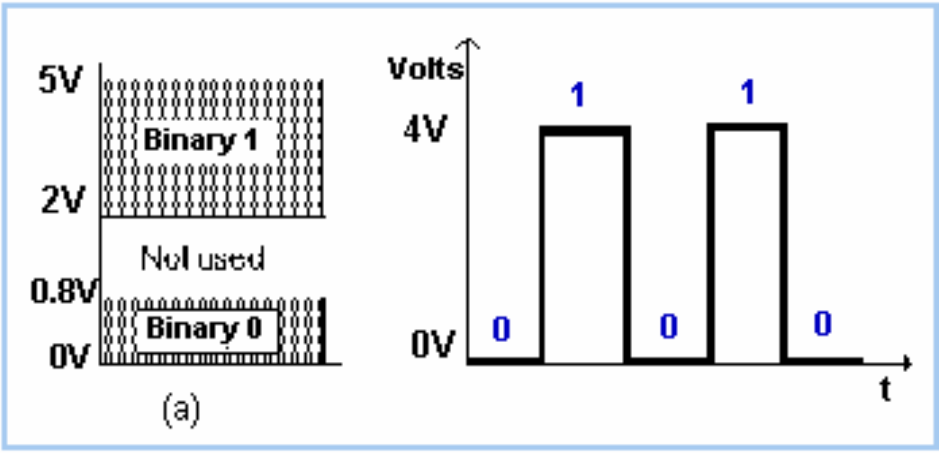
Binary information can be represented by any device that has only two operating states.

switch	open	»	closed
transistor	on	»	off
diode	Conducting	»	Non-conducting
relay	energized	»	de-energized
thermostat	open	»	closed

In electronic systems binary information is represented by voltage (or currents), E.g.

- Binary 0 or Logic L is represented by 0 volts
- Binary 1 or Logic H is represented by 5 volts

In digital systems the exact voltage is *not* important.
It is important *only* to know if a voltage is greater than or less than a defined value(s).



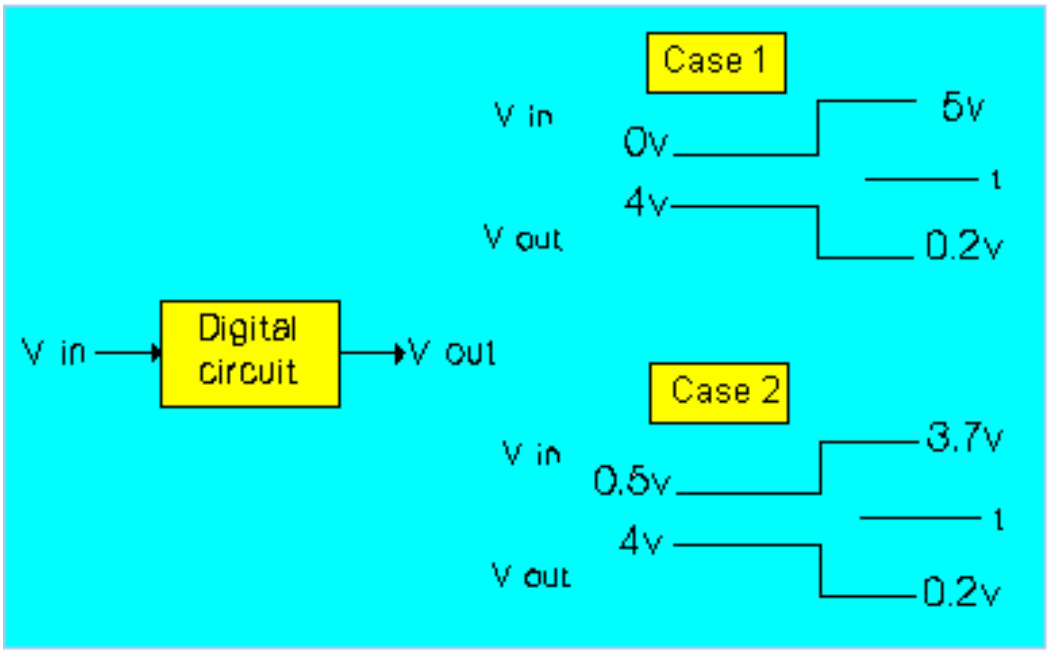
For a voltage of 3.6V, what is the logic level?

Digital Circuits

Digital Circuits are designed to receive and produce output voltages that fall within prescribed H and L voltage ranges.

What this means is that as long as the input voltages fall within the specified voltage range for H and L of the circuit, the output response will be the same

Consider:



*

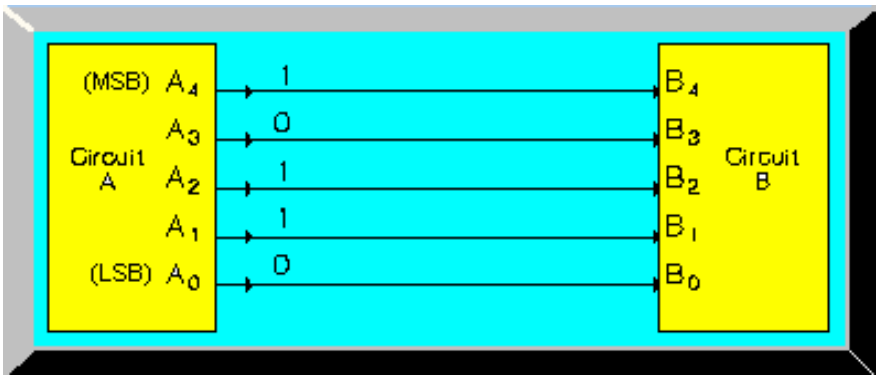
The output waveform of the digital circuit is the same in both cases because although the input waveforms differ in voltage values, they are at the same logic levels

Parallel And Serial Transmission

In Digital Systems, there are basically 2 methods to transfer data:

- **Parallel transmission**

Parallel data transfer is used to transfer data over short distances.



Parallel transmission uses one line per bit with one common signal ground, and all bits are transmitted simultaneously.

It is therefore fast when compared to Serial transmission.

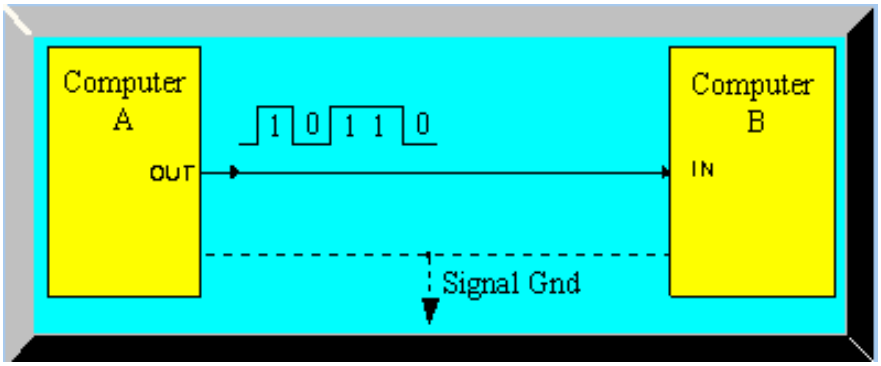
But it is prone to errors when used over long distances.

It is also more costly as more conductors are required.

• Serial transmission

Data is transmitted one bit at a time.

Serial data transfer used to transfer data over long distances.



Serial transmission uses only one pair of signal line, and the individual bits are transmitted one at a time.

It is more economical in terms of conductors (wires) required.

More importantly, it is less prone to errors when used over long distance.