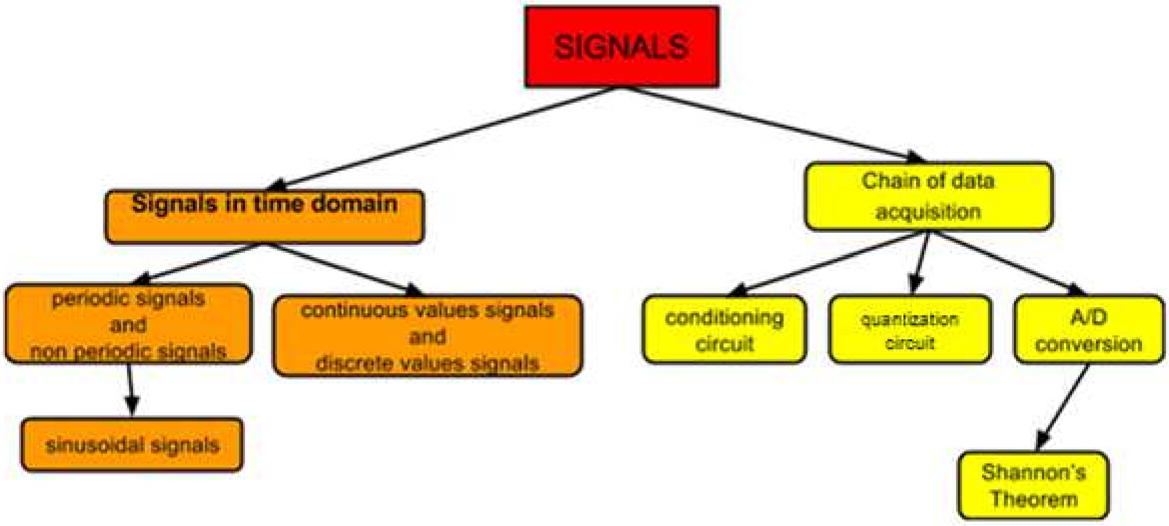
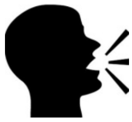
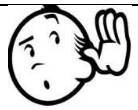
School: Technical Institute



Subject: Electronics

Module title:	Signals
Module planning:	UD1: Signal in time domain,
	UD2: Chain of data acquisition
Estimated time	15 hours
Class	5B, Electronics and Electrical Engineering
Pupils language level:	B1

Symbols used to identify the activities of the learning unit in the slides

Warm-up	Speaking	Writing
		
Reading	**Listening**	**Assessment**
		

UNIT 1

Unit 1 title:	Signals in time domain
Unit planning:	UDA 1.1: Signals classification
	UDA 1.2: Periodic signals
	UDA 1.3: Sinusoidal signals
	UDA 1.4: Analog and digital signal
Estimated time	7 hours

UNIT 1: Signals in time domain

Contents	Cognitive operations	Reading and listening Speaking and writing	Study skills Comprehension and revision strategies	Language: Structures and vocabulary
Concept of signal Signal classification Sinusoidal signals and their peculiarities The transition from the analog world to the digital world	Inferring the characteristics of a function from the graphs Identifying common and specific features of different signals Memorizing and and reproducing the function graphs Generalize from some periodic functions the general properties Calculating the parameters of a periodic function Calculating the parameters of a sinusoidal function Drawing the graph of a sinusoidal function using the given parameters Pointing out the inconsistencies and contradictions within a text.	Reading a simplified text. Understanding an oral definition about a known context (use of diagrams). Writing the required definition. Giving the required definition orally. Describing a graph orally. Watching a short video identifying the keywords. Watching a short video answering simple multiple choice questions.	Using inference and prediction strategies to anticipate the contents of a text with the help of graphics. Identifying key information and details of a drawing Using the dictionary to understand the meaning of technical terms Understanding written texts; answering multiple choice questions.	STRUCTURES: Present simple tense; passive forms, connectives and conjunctions. Question forms. GLOSSARY: Keywords of the lesson, synonyms and antonyms found (when possible) with or without the guidance of the teacher Learning how to paraphrase the new terms . Using compound words.

UNIT 2

Unit 2 title:	Chain of data acquisition
Unit planning:	UDA 2.1: Analog to digital conversion
	UDA 2.2: Shannon's Theorem
	UDA 1.3: Digital to analog conversion: diagrams of electronic circuits
Estimated time	7 hours

UNIT 2: Chain of data acquisition

Contents	Cognitive operations	Reading and listening Speaking and writing	Study skills Comprehension and revision strategies	Language: Structures and vocabulary
Comparison between analog and digital signals Block diagram of a data acquisition system Analog to digital conversion Shannon theorem Digital to analog conversion	Identifying the advantages and disadvantages of digital signals over analog signals Memorizing and reproducing the block diagram of a data acquisition system. Understanding the importance of the Sampling Frequency Calculating Sampling Frequency. Identifying the essential features of an A/D converter according to the situations in which it is used.	Reading a simplified text Understanding an oral definition about a known context (use of diagrams) Writing the required definition Giving the required definition orally Describing a graph orally. Watching a short video identifying the key words. Watching a short video answering simple multiple choice questions.	Using inference and prediction strategies to anticipate the contents of a text with the help of graphics. Identifying key information and details of a drawing Using the dictionary to understand the meaning of technical terms Understanding written texts; answering multiple choice questions.	STRUCTURES: Present simple tense. Impersonal forms, passive forms, connectives and conjunctions. GLOSSARY: Keywords of the lesson, synonyms and antonyms found (when possible) with or without the guidance of the teacher Learning how to paraphrase the new terms. Using compound words.

UDA 1.1 **SIGNALS CLASSIFICATION**

Study skills Comprehension and revision strategies	Using inference and prediction strategies to anticipate the contents of a text with the help of graphics.
	Identifying key information and details of a drawing
	Understanding written texts; answering multiple choice questions.
Language: Grammar and Vocabulary	GRAMMAR STRUCTURES: Use of present simple. Question forms. Connectives and conjunctions.
	GLOSSARY: Keywords, paraphrasing the new terms, using compound words.
Cognitive operations	Inferring the characteristics of a function from the graphs
	Identifying common and specific features of different signals
	Identifying the inconsistencies and contradictions within a text,.
Texts	Written by the teacher (see file 1)
Multimedia contents	https://www.youtube.com/watch?v=8kYPa1pEsoA file: Continuous-Time Signal to Discrete-Time Signal (minutes from 1 to 6)
Language Reference	http://www.wordreference.com/ http://dictionary.cambridge.org/
Expected time	3 hours

Part 1 – Warm-up	
POWER POINT PAGES 1,2,3,9,	
Brainstorming (expectancy: grammar activation), compare your ideas with the other students, justify your choices	
Part 2 – Speaking & Writing	
POWER POINT PAGES 3,4,5 Talk to your desk-mate and explain your choices. Write the definitions of the keywords using the dictionary.	
Part3 – Reading & Listening	
POWER POINT PAGES 6,7,8,10,11 Read the definitions, watch the video of the link	
Part 3 – Assessment	
POWER POINT PAGES 6,9,12,14 open-ended questions, multiple choice questions	

UDA 1.2 **PERIODIC SIGNALS**

Study skills **Comprehension and revision strategies**	Using inference and prediction strategies to anticipate the contents of a text with the help of graphics.
	Identifying key information and details of a drawing
	Understanding written texts; answering multiple choice questions.
	Using the dictionary to understand the meaning of technical terms
Language: **Grammar and vocabulary**	GRAMMAR STRUCTURES: Use of the present simple. Question forms. Connectives and conjunctions. Use of impersonal forms, passive forms.
	GLOSSARY: Keywords, ability to paraphrase the new terms, use of compound words.
Cognitive operations	Inferring the characteristics of a function from the graphs
	Identifying common and specific features of different signals
	Memorizing and reproducing the function graphs
	Generalizing from some periodic functions the general properties
	Calculating the parameters of a periodic function (mean value)
Language Reference	http://www.wordreference.com/ http://dictionary.cambridge.org/
Expected time	1 hour

This short lesson is the introduction to sinusoidal functions.
Some exercises are used to fix the general concepts.
The meaning of the mean value is explained.

Part 1 – Warm-up	
POWER POINT PAGES 2,	
Brainstorming (expectancy: grammar activation),	
Par2 – Reading & Listening	
POWER POINT PAGES 3,5 Read the definitions, watch the linked video	
Part 3 – Assessments	
POWER POINT PAGES 4, 6, Closed-ended questions. Solving activities	

UDA 1.3 **SINUSOIDAL SIGNALS**

Study skills **Comprehension and revision strategies**	Using inference and prediction strategies to anticipate the contents of a text with the help of graphics.
	Identifying key information and details of a drawing
	Understanding written texts; answering multiple choice questions.
	Using the dictionary to understand the meaning of technical terms
Language: **Grammar and vocabulary**	GRAMMAR STRUCTURES: Use of the present simple. Question forms. Connectives and conjunctions. Use of impersonal forms, passive forms.
	GLOSSARY: Keywords, ability to paraphrase the new terms. Use of compound words.
Cognitive operations	Understanding the video
	Think logically for analogy to find the right answers
	Inferring the characteristics of a function from the graphs
	Memorizing and reproducing the sin function graphs
	Calculating the parameters of a sinusoidal function
Multimedia contents	https://www.youtube.com/watch?v=dHUM_ZgZ9Hg file: Interpreting Sinusoidal Functions
Link and animations	http://www.barrascarpetta.org/01_ele/m_2/m2_u2.htm http://www.wolframalpha.com/
Language Reference	http://www.wordreference.com/ http://dictionary.cambridge.org/
Expected time	2 hours

This is one of the most difficult lessons of the module.
After watching the video, we suggest 4 questions (slide 2). The pupils can answer the questions only after understanding the video. The video is also used to introduce the second kind of exercises (slide 3). This part has a high cognitive content and a low linguistic content. Using a simulator (a mathematical software), pupils have to understand the property of a sinusoidal function.

Part 1 – Warm-up	
POWER POINT PAGES 2,3,	
The questions require the understanding of very common examples and some tips can be found in the video. The cognitive operations are very high. At the same time the pupils have to understand the video (language), working by analogy.	
Part 3 – Speaking & Writing	
POWER POINT PAGES 7 Pair-work: the pupils have to describe the graphs.	
Part3 – Reading & Listening	
POWER POINT PAGES 2,4,5 Reading the definitions, watching the linked video	
Part 3 – Assessment	
POWER POINT PAGES 2,3,6,8 Understanding the most important points of a video. Problem solving activity..	

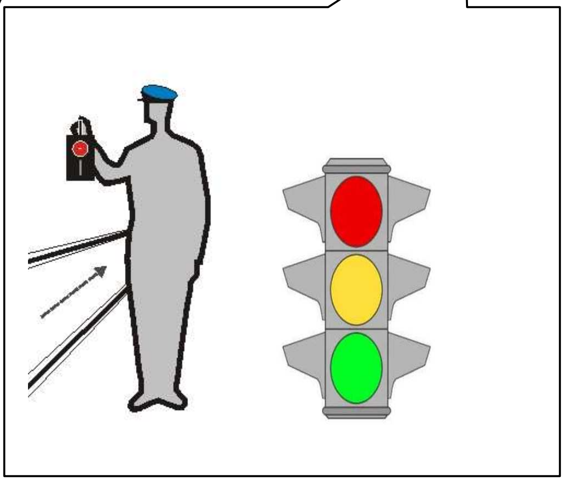
UDA 1.2 **ANALOG AND DIGITAL SIGNAL**

Study skills **Comprehension and revision strategies**	Using inference and prediction strategies to anticipate the contents of a text with the help of graphics.
	Identifying key information and details of a drawing
	Understanding written texts; answering multiple choice questions.
	Using the dictionary to understand the meaning of technical terms
Language: **Grammar and vocabulary**	GRAMMAR STRUCTURES: Use of the present simple. Question forms. Connectives and conjunctions. Use of impersonal forms, passive forms.
	GLOSSARY: Keywords, ability to paraphrase the new terms. Use of compound words.
Cognitive operations	Inferring the characteristics of a function from the graphs
	Identifying common and specific features of different signals
	Memorizing and reproducing the function graphs
	Generalizing from some periodic functions the general properties
	Calculating the parameters of a periodic function
Multimedia contents	https://www.youtube.com/watch?v=XCu6L4kQF3k File: Physics - Waves - Analogue and Digital Signals https://www.youtube.com/watch?v=ubEijRkLweo File: Digital Electronics- 1) Digital versus Analog signals
link	https://learn.sparkfun.com/tutorials/analog-vs-digital
Language References	http://www.wordreference.com/ http://dictionary.cambridge.org/
Expected time	2 hours

Signals

1.1 Introduction: what is a signal?

A signal is something that is used to carry **information**. Smoke for example! Or messages with light.

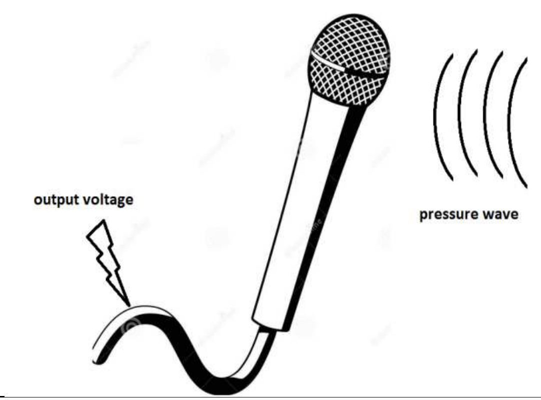
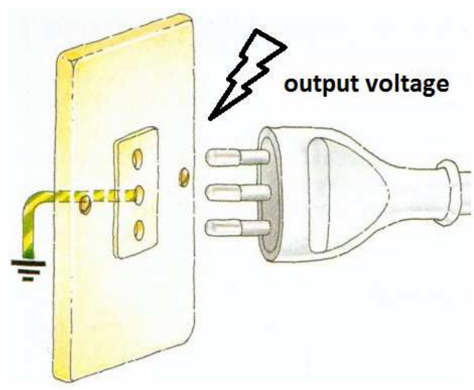


In electronics, a signal is an electrical quantity such as current, voltage, or electromagnetic waves, that can be varied in order to convey information.

What is an electrical signal?

Do you know other kinds of signals?

Which of these waves is a signal?

The output voltage of a microphone	The voltage in a plug of the electrical network
	

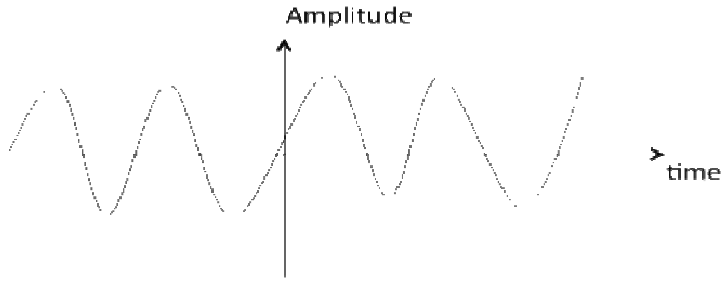
Be careful: In most practical cases, a signal is varying in time or similarly, it is a function of time. This is why we often use the word "function" as a synonym of "signal".

1.2 Classification of Signals

Signals can be classified in various ways depending on the values they can take, the way they change over time or if they are predictable or not.

1.3 Continuous Time and Discrete Time Signals

A signal is said to be **continuous** when it is defined for all instants of time.
Continuous-time signal is a quantity defined at each instant of time: at each moment its value can be known.

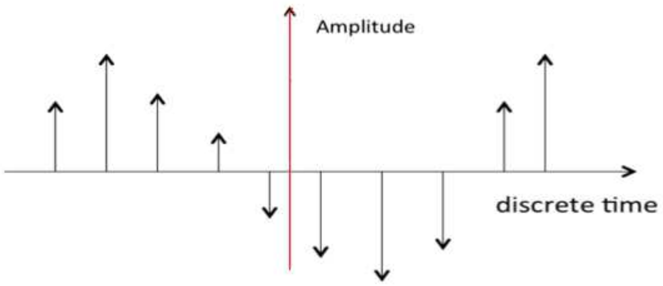


What is a continuous time signal?

What is a discrete time signal?

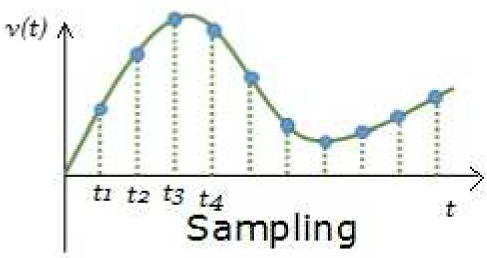
How can you obtain a discrete time signal by a continuous time signal?

A signal is said to be **discrete** when it is defined at only discrete instants of time.
In a **Discrete-time signal** its value can change only in fixed instants of time.



A discrete signal or discrete-time signal is a time series consisting of a sequence of quantities. In other words, it is a time series that is a function over a domain of integers.

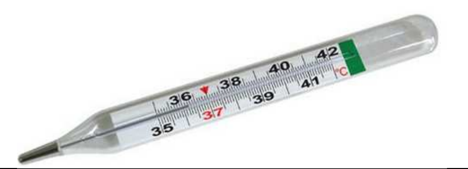
Unlike a continuous-time signal, a discrete-time signal is not a function of a continuous argument; however, it may have been obtained by sampling from a continuous-time signal, and then each value in the sequence is called a **sample**. When a discrete-time signal obtained by sampling a sequence corresponds to uniformly spaced times, it has an associated **sampling rate**; the sampling rate is not apparent in the data sequence, and so needs to be associated as a characteristic unit of the system (the clock of the system).



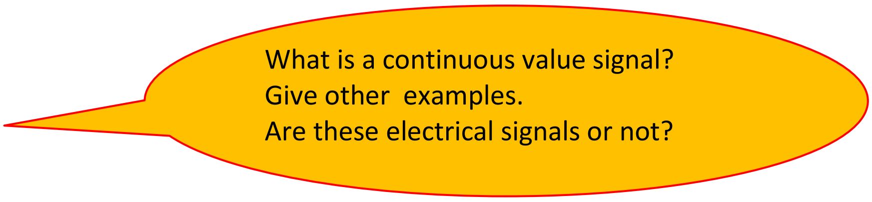
1.4 Continuous Values and Discrete value Signals

A continuous value signal is a signal for which the amplitude can assume an infinite number of values in a fixed range. For example, the mercury level in a thermometer is a continuous signal because the mercury can fill the entire column of the thermometer.

In electronics, the output voltage of a microphone is a continuous value signal because the voltage follows the variations of the voice that are continuous variations.

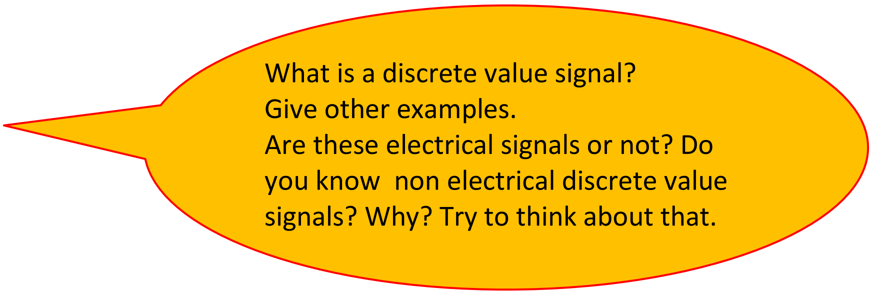


The mercury level in a thermometer is a continuous signal



A discrete value signal is signal for which the amplitude can assume only a finite number of values, in other words, its value takes on only values from a discrete set (a countable set that can be mapped one-to-one to a subset of integers). For example, the music recorded in an mp3 device is a discrete value signal because it is a sequence of binary numbers.

the music recorded in an mp3 device is a sequence of binary numbers



We usually named <u>DIGITAL SIGNALS</u>: signals discrete in values and in time and <u>ANALOG SIGNALS</u>: signals ??? Questa frase è incompleta

EXERCISE

An Analog Signal is continuous in both ____ and _____.

- A Frequency, Power
- B Time, Amplitude
- C Modulation, waveform
- D Segments, packets

Analog Signals is usually a measure of __________

- A Base
- B Physical phenomena
- C thicknet
- D BUS

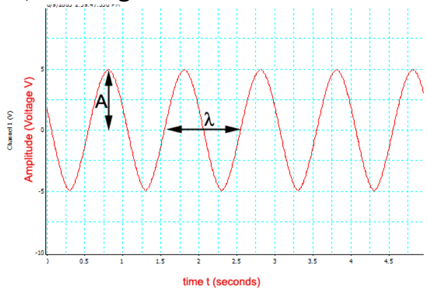
_______ is both discrete and quantized.

- A Digital Signal
- B Analog signal
- C Modulated signal
- D Synchronized Signal

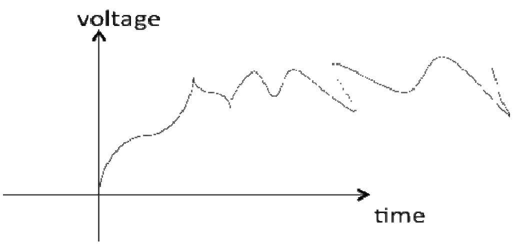
https://www.youtube.com/watch?v=8kYPa1pEsoA

1.5 Deterministic and Non-deterministic Signals

A signal is said to be deterministic if there is no uncertainty with respect to its value at any instant of time. Or, the signals which can be defined exactly by a mathematical formula are known as deterministic signals.



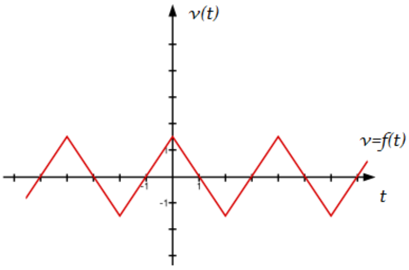
A signal is said to be non-deterministic or **aleatory** if there is uncertainty with respect to its value at some instant of time. Non-deterministic signals are random in nature hence they are called random signals. Random signals cannot be described by a mathematical equation. They are modelled in probabilistic terms.

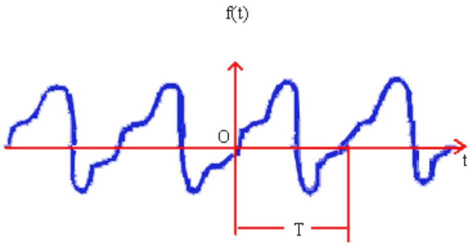


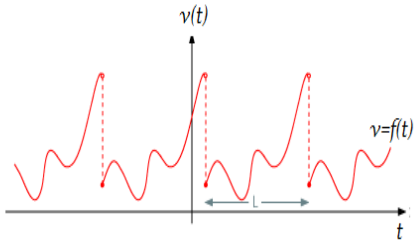
The definition of "deterministic signal" is in contrast with the given general definition of signal.
Do you understand why?
In other words, is a deterministic-signal a signal according to the previous definition?

2.1 Periodic and aperiodic signals

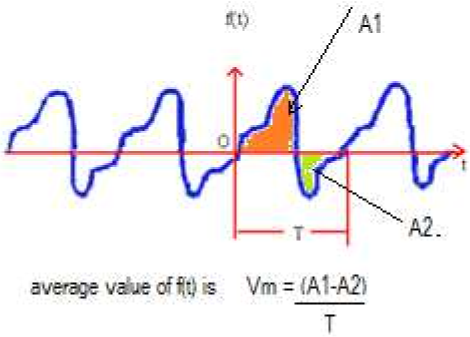
A **periodic signal** is a wave that repeats equal to itself at fixed intervals of time
A periodic signal is characterized by the **PERIOD** (**T**, the interval of time after which the wave repeat itself), the **FREQUENCY** (**f,** the number of time the signal repeats in a second. Frequency is linked to the period by the relation: T=1/f) and the **MEAN VALUE**.







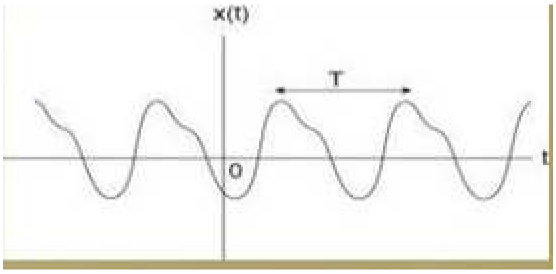
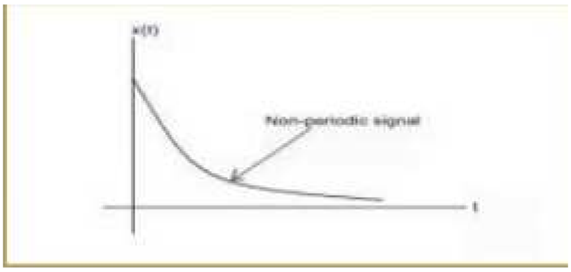
To define the average value of a periodic function you should know the mathematical concept of the integral but you can understand the meaning of mean value by using the pictures 1 and 2.
The mean value is the difference between the area above the x-axis (A1) and the area below (A2) divided by the period.



An **aperiodic signal** is a non periodic signal.

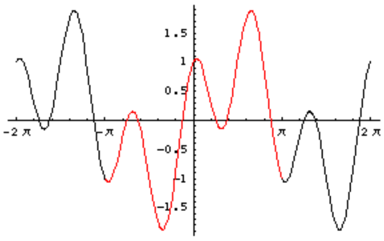
Exercises

1) Tick the box "periodic signal" or "aperiodic signal " corresponding to the definition

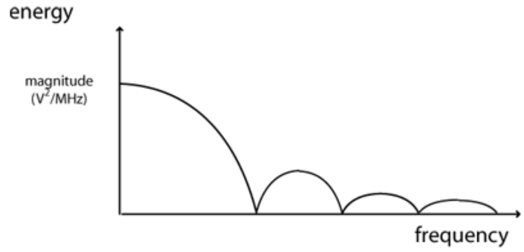
	Periodic Signal	Aperiodic Signal
A signal which repeats itself after a specific interval of time		
Their value cannot be determined with certainty at any given point of time		
Example: sine, cosine etc		
They cannot be represented by any mathematical equation		
A signal which does not repeat itself after a specific interval of time		
They can be represented by mathematical equation		
Their value can be determined at any point of time		
They are deterministic signals		
Example: sound signal from radio, all types of noise signals		
They are random signals		
		
		

Which of the functions shown in the following picture represent periodic signals?

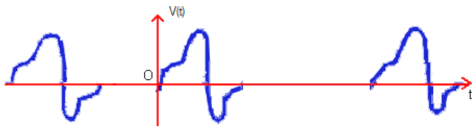
Periodic Aperiodic



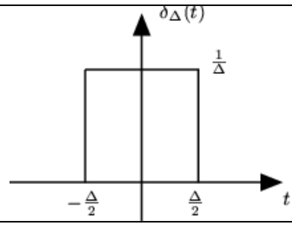
Periodic Aperiodic



Periodic Aperiodic

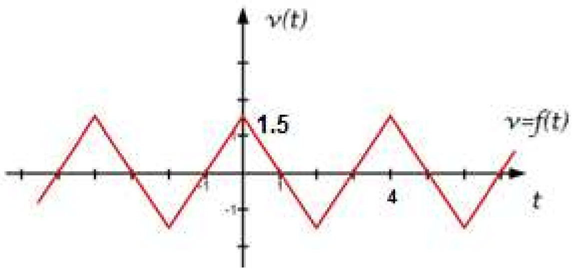


Periodic Aperiodic

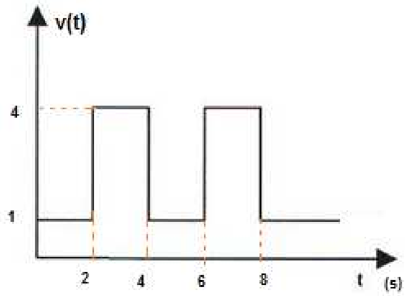


Calculate the mean value of the periodic functions in the picture below:

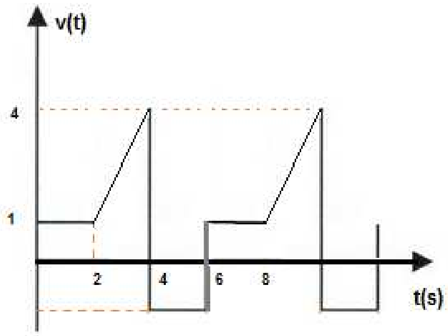
Mean value= ?



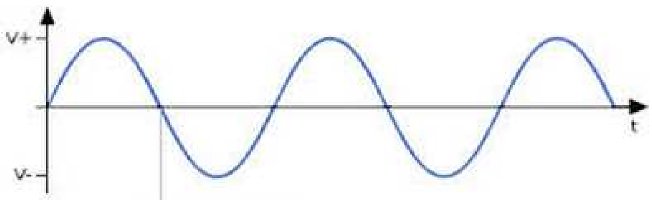
Mean value= ?



Mean value= ?



Mean value= ?



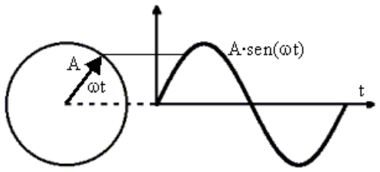
3.1 Sinusoidal signals

https://www.youtube.com/watch?v=dHUM_ZgZ9Hg

A very important kind of periodic signal is the sinusoidal function or simply SIN(x).

You have already met the sinusoidal function in Maths but in electronics this is a function of time and not of a generic variable x.

The sinusoidal function can be thought as the projection along the y axis of a vector of length A , rotating with constant angle speed ω .

	http://www.barrascarpetta.org/01_ele/m_2/m2_u2.htm

The sinusoidal function is characterized by 3 parameters: Amplitude, frequency and phase.

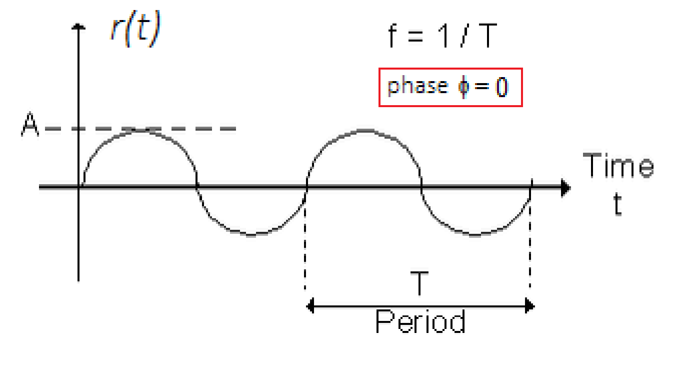
The **amplitude i**s the maximum value reached by the function and is equal to the module of the minimum value.

The **frequenc**y is the number of time the function repeats in a second (but in the graph below you see the period, that is the inverse of the frequency).

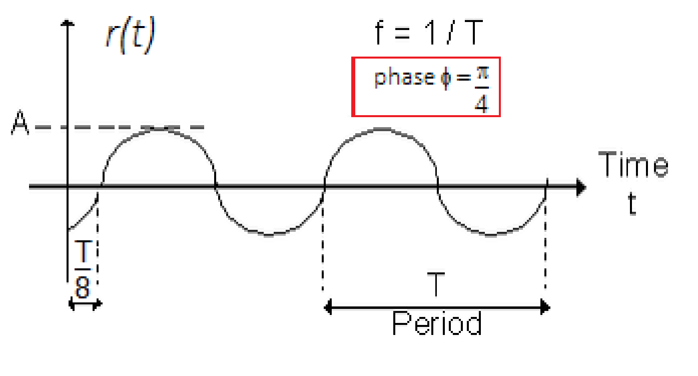
The **phase** is linked to the shifting of the wave along the x-axis.

In the picture below, you can find different examples of sinusoidal functions. Pay attention to the meaning of amplitude, frequency and phase. Try to understand the connection between phase and time-shift.

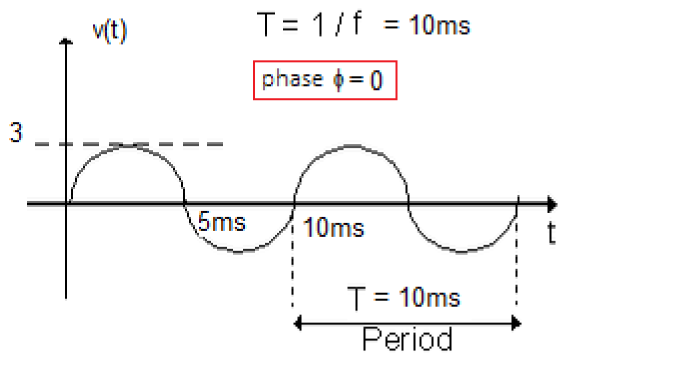
$r(t) = A\,sen(2\pi\,f\,t)$



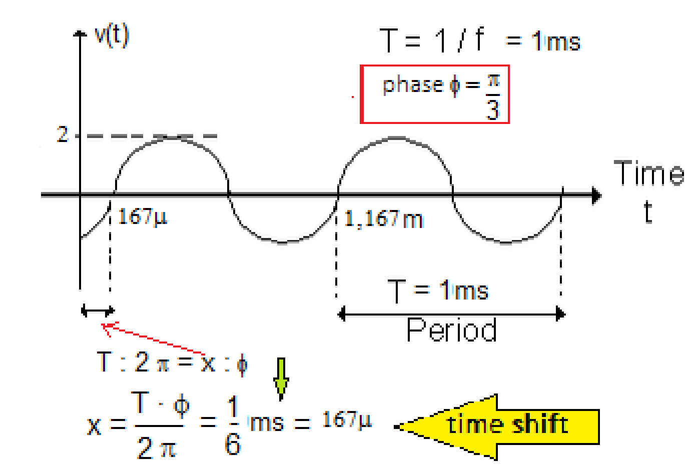
$r(t) = A\,sen(2\pi\,f\,t + \pi/4\,)$



$v(t) = 3\,sen(2\pi 100\,t)$



$v(t) = 2\,sen(2\pi\,1000\,t + \pi/3\,)$



Exercises

Draw the following sinusoidal functions, specifying in the graph: the period, time of shift due to the phase, and amplitude:

$$v_1(t) = 4\,sen\left(2\pi\,20\,t + \frac{\pi}{2}\right)$$

$$v_2(t) = -2\,sen\left(2\pi\,2000\,t + \frac{\pi}{3}\right)$$

$$v_3(t) = sen(2\pi\,1000\,t) + 3$$

Homework

Try to explain the meaning of the different terms in the glossary

Glossary

Signal		mean value	
Wave		Sinusoidal	
Function		Discrete in values	
Phase		Continuous in values	
Frequency		Deterministic	
Amplitude		Random	
Discrete		Probability	
Continuous		sampling	

Analog vs. Digital

[https://learn.sparkfun.com/tutorials/analog-vs-digital]

Introduction

We live in an analog world. There are an infinite amount of colors to paint an object (even if the difference is indiscernible to our eye), there are an infinite number of tones we can hear, and there are an infinite number of smells we can smell. The common theme among all of these analog signals is their **infinite** possibilities.

Digital signals and objects deal in the ***realm*** of the **discrete** or **finite**, meaning there is a limited set of values they can be. That could mean just two total possible values, 255, 4,294,967,296, or anything as long as it's not ∞ (infinity).

Real-world objects can display data, gather inputs by either analog or digital means. (From left to right):

Clocks, ***multimeters*** *, and joysticks can all take either form (analog above, digital below).*

Working with electronics means ***dealing with*** both analog and digital signals, inputs and outputs. Our electronics projects have to interact with the real, analog world in some way, but most of our microprocessors, computers, and logic units are purely digital components. These two types of signals are like different electronic languages; some electronics components are bi-lingual, others can only understand and speak one of the two.

Realm	Field, sector
Multimeter	Instrument used to measure voltage, current and resistance
To deal with	Treat, work with, have to do with

Pros and cons

Over the last 50 years digital signals have replaced analog signals in most of circuits and devices. Digital signals have, indeed, a lot of **advantages**:

1. digital signals have a higher immunity to noise. The noise is a signal which superimposes to the useful signal usually during the transmission. When the signal is analog it is impossible to distinguish the useful signal from the noise, but in a digital signal, characterized by 2 levels, it is possible to rebuild the original signal if we can recognize which level is transmitted.
2. the quantity of memory occupied by a digital signal can be reduced by using compression techniques.
3. information transmitted with a digital signal can ensure privacy: this is obtained by using cryptography techniques.
4. digital information is elaborated by digital circuits. These devices can be easily updated by changing software. No change of device is required.
5. Checking and correction techniques are developed for digital signals
6. When a signal is converted into digital data it can be elaborated independently of the nature of the original data (video, music, text...) therefore digital information can be transferred or stored using the same circuits for all kind of signals.

On the other hand digital signals have some **disadvantages:**

1. digital communication has to use specific synchronization sequences for determining synchronization.
2. digital communications require a common language which should be possessed by both sender and receiver.
3. to represent a continuously variable analog value in a digital form it is necessary to sample and simplify the signal. This operation, called quantization, implies an error that can be reduced but not eliminated.

Exercise

1. Fill in the blanks with the correct word. Use each listed word once only.

   engineering, order, should, current, transferred, data, RF, air, talking, wires, convey, signal,

   Before going too much further, we SHOULD talk a bit about what a SIGNAL actually is, electronic signals specifically. The signals we're TALKING about are time-varying "quantities" which CONVEY some sort of information. In electrical ENGINEERING the quantity that's time-varying is usually voltage (if not that, then usually CURRENT).

   Signals are passed between devices in ORDER to send and receive information, which might be VIDEO , audio, or some sort of encoded data. Usually the signals are transmitted through WIRES , but they could also pass through the AIR via radio frequency (RF) waves. Audio signals, for example might be TRANSFERRED between your computer's audio card and speakers, while DATA signals might be passed through the air between a tablet and a WiFi router.

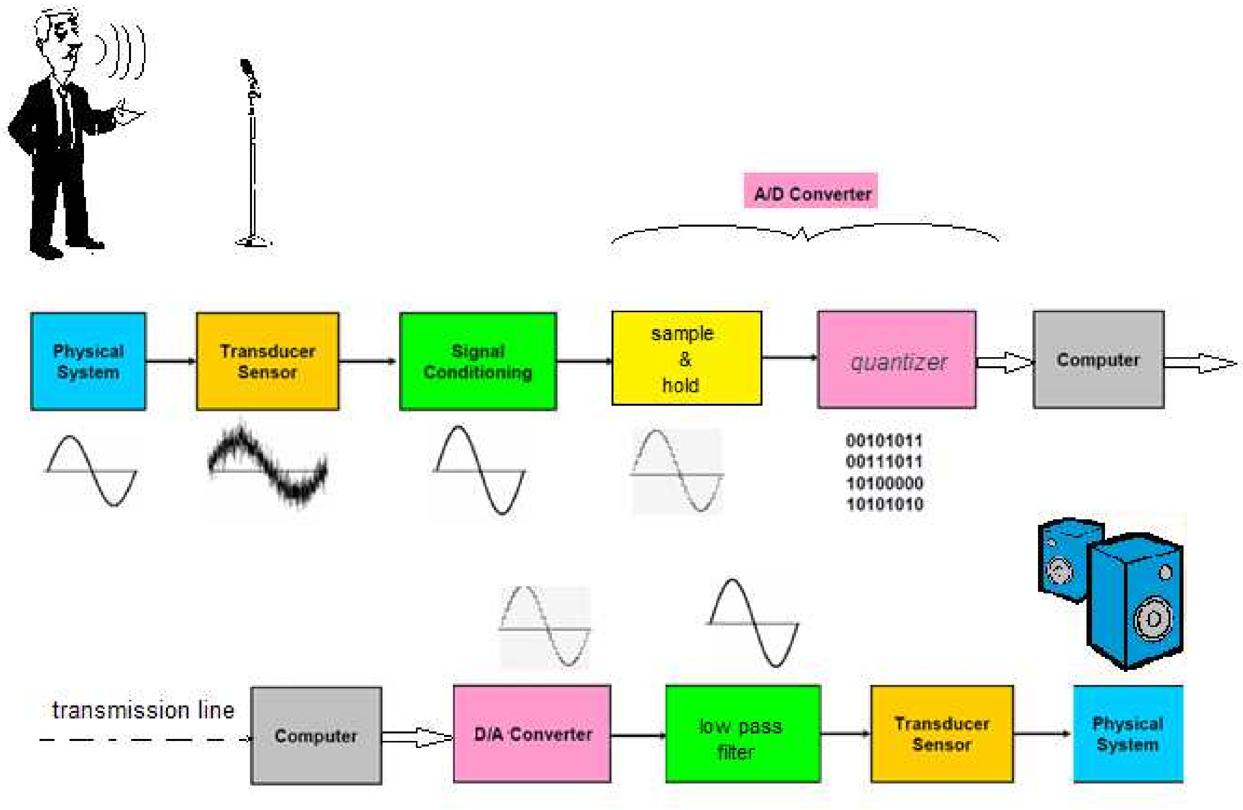
2. Watch and listen to the video twice.

   https://www.youtube.com/watch?v=XCu6L4kQF3k

   Try to reply to the following questions:

   i) Which kind of signal is the human voice?
   ii) Which kind of signal is transmitted by a mobile phone ?
   iii) When an analog signal is transmitted over a long transmission line what does it happen?
   iv) Which are the benefits of digital signals?

Acquisition data scheme



Analog-to-Digital Conversion

[http://nutaq.com/en/blog/analog-digital-%E2%80%93-part-2-conversion-process]

A physical system, as the human body for example, always produce an analog signal (the human voice is a pressure wave, no sound can be produced in the vacuum) .
This signal is converted in an analog electrical signal by a sensor or transducer.
The signal conditioning circuit filters the output of the transducer with a low pass filter to neatly define the maximum frequency of the signal. Moreover this circuit adapts the signal to the downstream circuits (it can be necessary to reduce or increase the amplitude, or to sum an offset).

> Physical system

> Sensor

> Purpose of the conditioning circuit.
> Introduction to the signal maximum frequency's concept.
> Bounding of the signal maximum frequency by a low pass filter.

After that, the signal is sampled by a sample and hold device (sometime this circuit is integrated in the A/D converter). The sample&hold procedure consists of taking an instantaneous snapshot of the ADC's (analog to digital converters) input voltage and freezing it for the duration of the conversion. The S/H briefly opens its aperture window to capture the input voltage on the rising edge of the clock signal, and then closes it to hold its output at the newly acquired level. As shown in the

> What a sample&hold is.
> How it runs.
> Which the purpose of the S&H is.

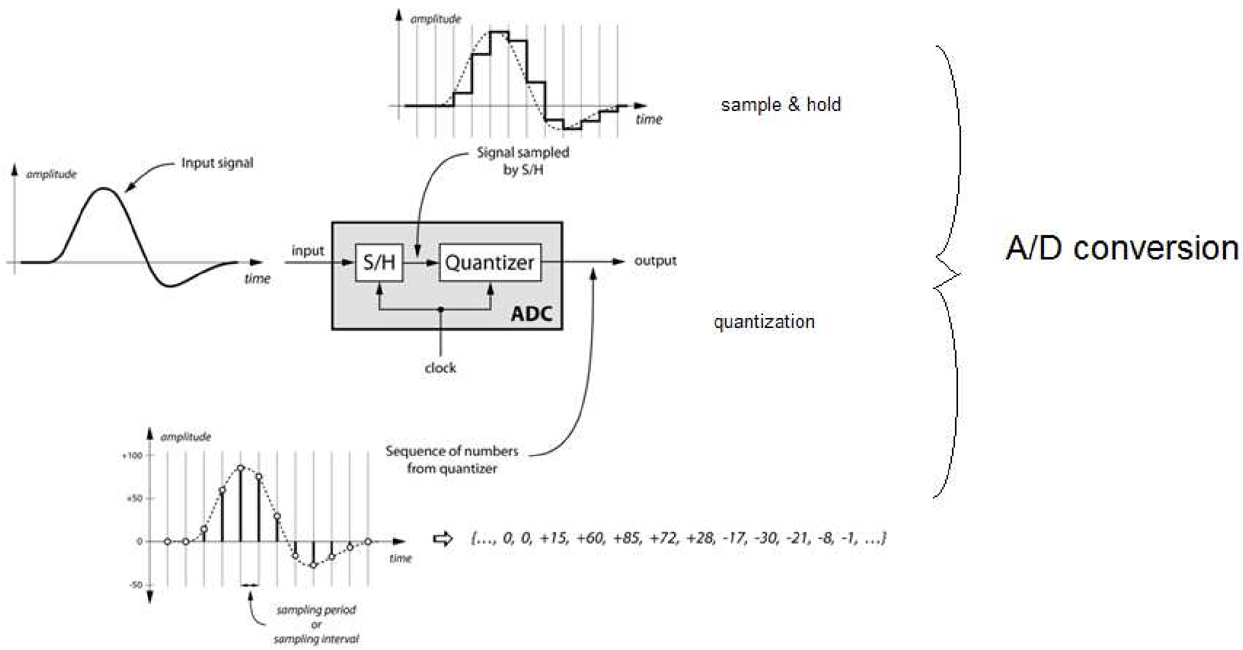
The second step assigns a numerical value to the voltage level present at the output of the S/H.
This process, known as quantization, searches for the nearest value corresponding to the amplitude of the S/H signal out of a fixed number of possible values covering its complete amplitude range. The quantizer can't search over an infinite number of possibilities and must restrict itself to a limited set of potential values. The size of this set corresponds to the range of the quantizer and is always a power of 2 (or 2N, such as 256, 512, 1024, and so on).
Once the closest discrete value has been identified by the quantizer, it is assigned a numerical value and encoded as a binary number. Since the value is necessarily contained in the complete set of 2N potential values, only N bits are required to represent all the binary encoded numbers that can be generated by the quantizer. For this reason, ADCs are often

> Quantization process
>
> Input signal and output signal of a quantizer
>
> Meaning of "ADC resolution"
>
> Meaning of "quantization step"

referred to as N-bit ADCs, where N represents the number of bits used by the ADC to encode its digitized values. By convention, N-bit is also used to denote the resolution of the ADC, since the quantization step (the distance between discrete quantization levels) is equal to 1/2N.

By its fundamental nature, the quantization and encoding process cannot be completely accurate and can only provide an approximation of the real values of the ADC's analog input. The higher the resolution of the quantizer, the closer this approximation will be to the actual value of the signal. Nevertheless, the conversion process will always introduce systematic quantization errors, which will fall within half the quantization step size (smaller than half a negative step if it rounds off to the nearest value, or smaller than half a positive step if it truncates to the nearest value). Because this error is normally distributed randomly from one digitized sample to the next, it's usually referred to as quantization noise.

Quantization noise



There are multiple constraints that limit the resolution of an ADC, but most of these constraints are related to the time required by the quantizer to determine the closest match for the signal at the output of the S/H. Scanning a larger set of potential values obviously requires more time, so a variety of techniques have been developed (and continue to be developed) to accelerate this process. The description of each of these techniques is beyond the scope of this discussion, but the final selection of one technique over the other is usually the result of an elaborate compromise between resolution, sampling rate, cost, and power consumption.

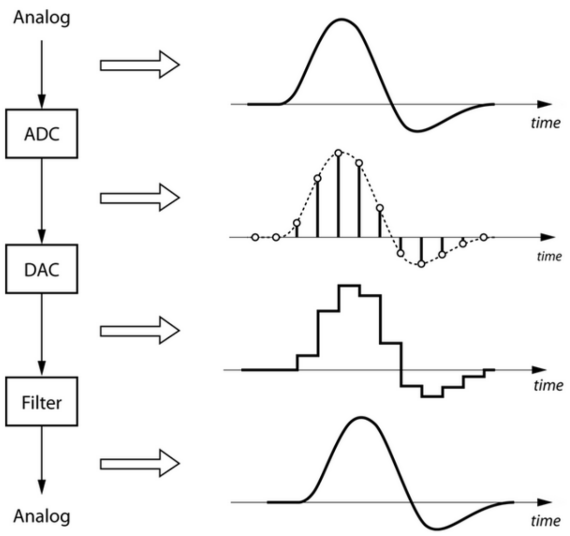
Shannon's theorem

After all, what comes out of an ADC is just a sequence of numbers representing a real and continuous signal at discrete moments in time. How can you get more from less? Well, in this case, you do.

The detailed explanation for this might be quite laborious and revolves around what is known as the Nyquist-Shannon sampling theorem.

In simple terms, Shannon's theorem states that a continuous band-limited signal (or function) can be completely defined or reconstructed from an infinite sequence of samples if the sampling frequency is greater than the double of the signal maximum frequency.

In other words, if we digitize a signal using an ADC with an infinite precision (not limited to N bits), and we then convert the signal back to an analog format using a DAC (digital-to-analog converter), also having an infinite precision, we will get an exact copy of the original signal. Nothing will have been lost. This process is shown in the following picture.



Digital-to- Analog Conversion

The D/A conversion process is essentially the reciprocal of the A/D process. Digital words (binary numbers) are applied to the input of the D/A to create from a reference voltage an analog output signal that represents the digital word.

Properly regenerating the analog signal requires the use of an output analog *reconstruction filter* to smooth out the discrete steps present at the output of the DAC.

Exercise: Tick the correct answer

- Shannon's theorem:

a) Indicates the constraint on the minimum sampling frequency to maintain the information of a signal.
b) Indicates the constraint on the minimum number of bits necessary to encode a signal
c) Indicates the constraint on the minimum number of levels necessary to quantize a signal without losing too much information
d) None of the above

- An analog signal:

a) Cannot be stored.
b) Can drive an actuator.
c) Cannot be measured.
d) Is never obtained by the conversion from a digital signal.

- A merit of digital signals compared to analog signals is :

a) The high-fidelity which the analog signals guarantee.
b) The simplicity of the digital codes commonly used
c) The low sensibility of digital signals to electronic noise
d) The low attenuation of the digital signals after the transmission through a transmission channel.

- A digital signal:

a) Is always obtained by the conversion of an analog signal.
b) Has 3 significant voltage value levels.
c) Cannot be amplified.
d) Can be processed

- The quantize operation is:

a) A reversible operation.
b) A reversible operation only when there are no aliasing effects.
c) A reversible operation only when variable length codes are used.
d) Not reversible.

Solutions

1a, 2b, 3c, 4d,5d

EXERCISE: fill the empty space in the text

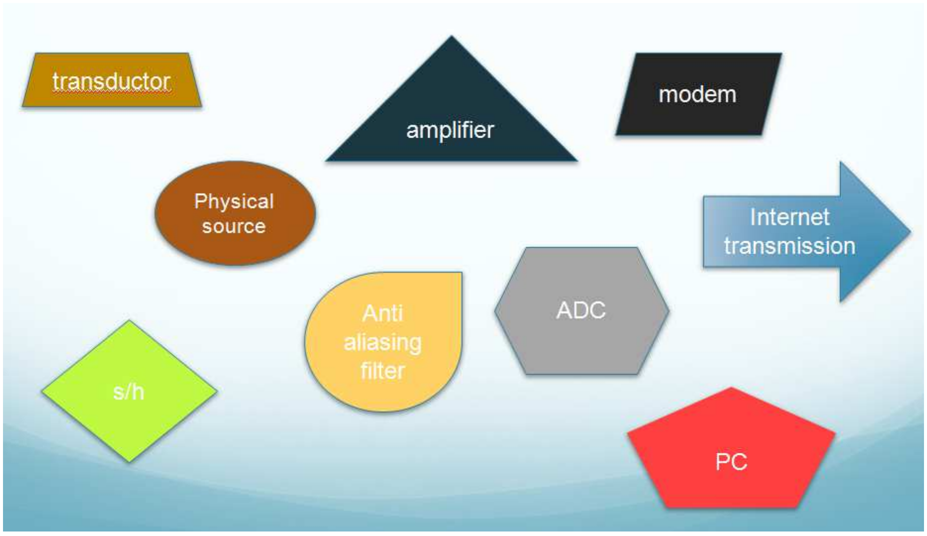
https://en.wikipedia.org/wiki/Digital_Revolution

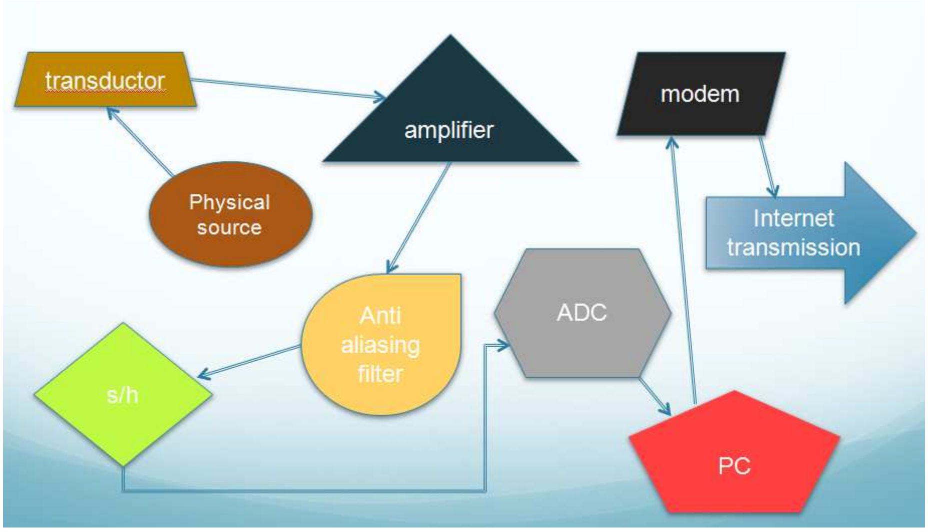
Each word can be used only once.

CONVERSION – RADICALLY- DIGITAL – IMPACT - PERFOMANCES - TECHNOLOGY – PIONEER - DAY- REVOLUTION – FROM- PROGRESS- SHANNON – COMMUNICATION – EXAMPLE – FEASIBLE -

The Digital Revolution, also called the Third Industrial Revolution, is the change from analog and mechanical technology to digital technology which began anywhere from the late 1950s to the present day. This revolution has been made possible by the progress of transistors technology, with continuous increasing performances, and by the theoretical studies on the information lossless conversion from analog to digital signals. One of the pioneer of these studies has been Claude Shannon, that published the famous article “Electrical communication in presence of noise”. The economic impact of the digital revolution has been large. Without the world wide web, for example, globalization and outsourcing would not be nearly as feasible as they are today. The digital revolution radically changed the way individuals and companies interact.

EXERCISE: connect the blocks in the right order




transductor
amplifier
modem
Physical source
Internet transmission
Anti aliasing filter
ADC
s/h
PC