Systems and Circuits

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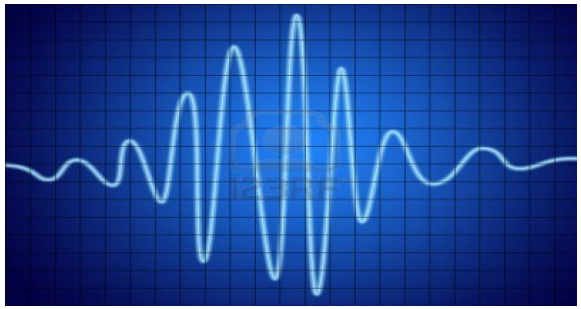
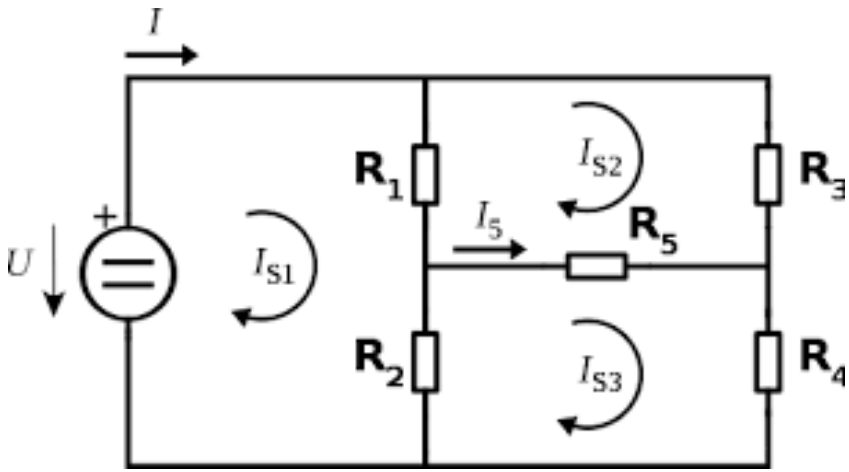
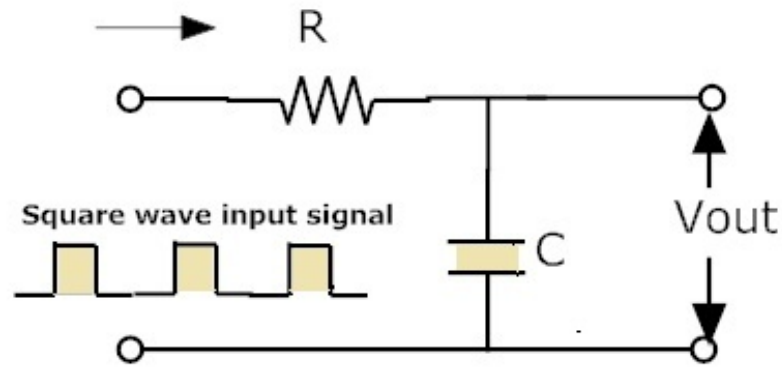
Systems and Circuits → Introduction to Electrical Engineering

- Introduce the basic concepts of signals and systems.



- Introduce the basic concepts of electric circuit analysis.

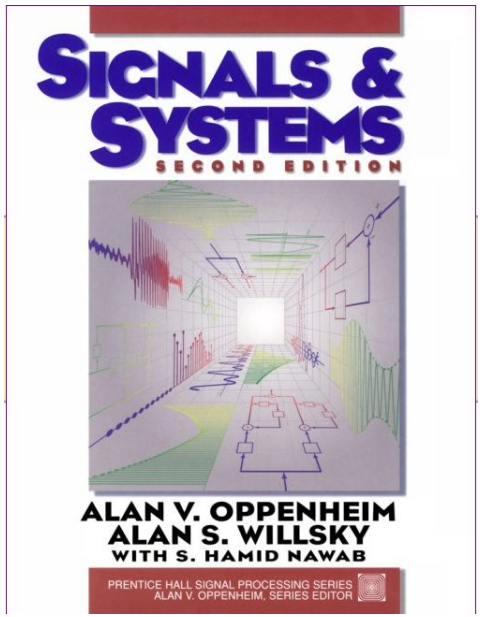


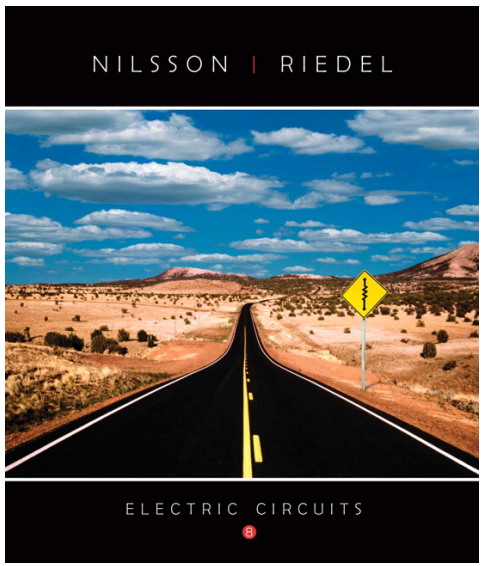


Course materials

1.- Basic books: (I really encourage you to follow them!)

- Signals and systems. Alan V. Oppenheim.
- Electric circuits 6th ed. James William Nilsson.





2.- Slides that I will use in class

- Aula Global.
- Please report mistakes you find (typos, errors in formulas, etc...). Thank you very much!!

3.- Online material

- Large amount of resources at your disposal. Just an example...
  - M.I.T. Open courseware $\Rightarrow$ Signal and Systems.
    http://ocw.mit.edu/resources/res-6-007-signals-and-systems-spring-2011/index.htm
  - M.I.T. Open courseware $\Rightarrow$ Circuits and Electronics.
    http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-002-circuits-and-electronics-spring-2007/index.htm

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Signal Processing

- The concepts of signal and systems arise in an extremely wide variety of fields.
  - Communications
  - Aeronautics
  - Circuit design
  - Acoustics
  - Biomedical engineering
  - Energy generation
  - Speech Processing
  - Machine Learning
  - Computer Vision
  - ...

Signal processing is a cornerstone of any engineering branch. You will apply the concepts and tools acquired in this course for the next four years.

The physical world: representation by means of signals and systems

- Signals: Functions that represent variations in physical magnitudes.
- Information is contained in the variation with respect some independent variables.

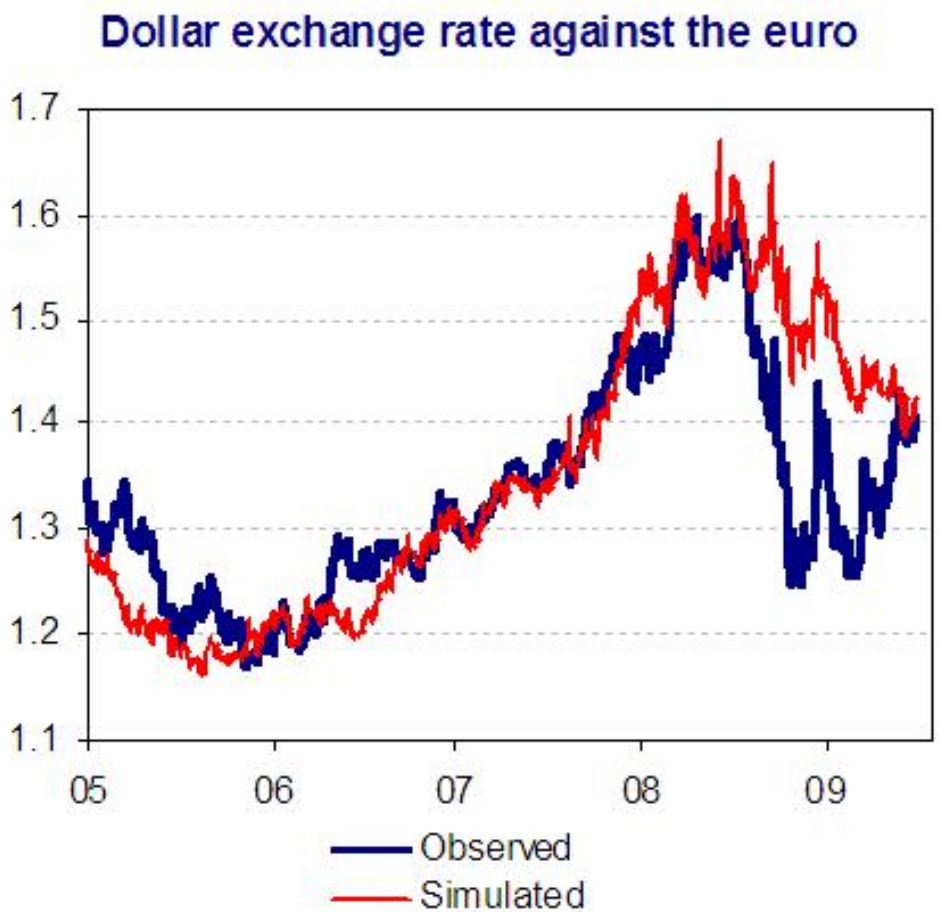
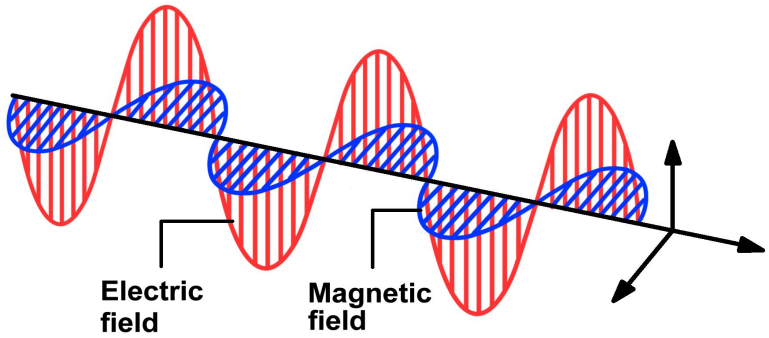
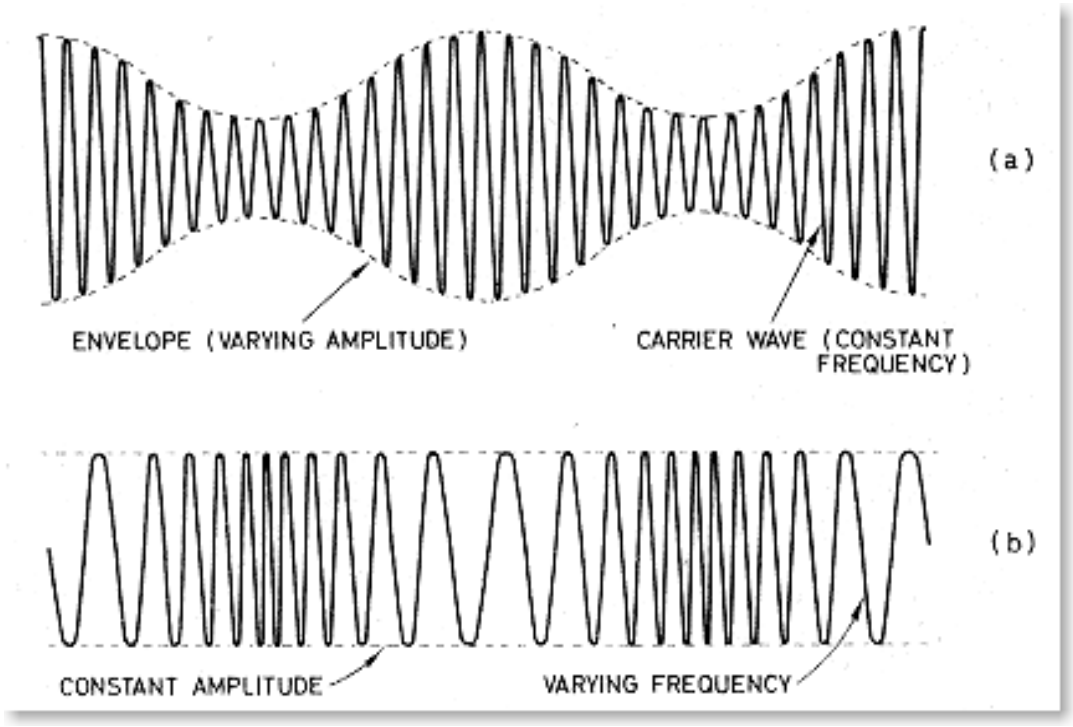


Figure: Source
http://voxeu.org/article/euro-dollar-exchange-rate-during-crisis.

Example of signals: electromagnetic wave





AM signal

FM signal

Example of signals: digital image

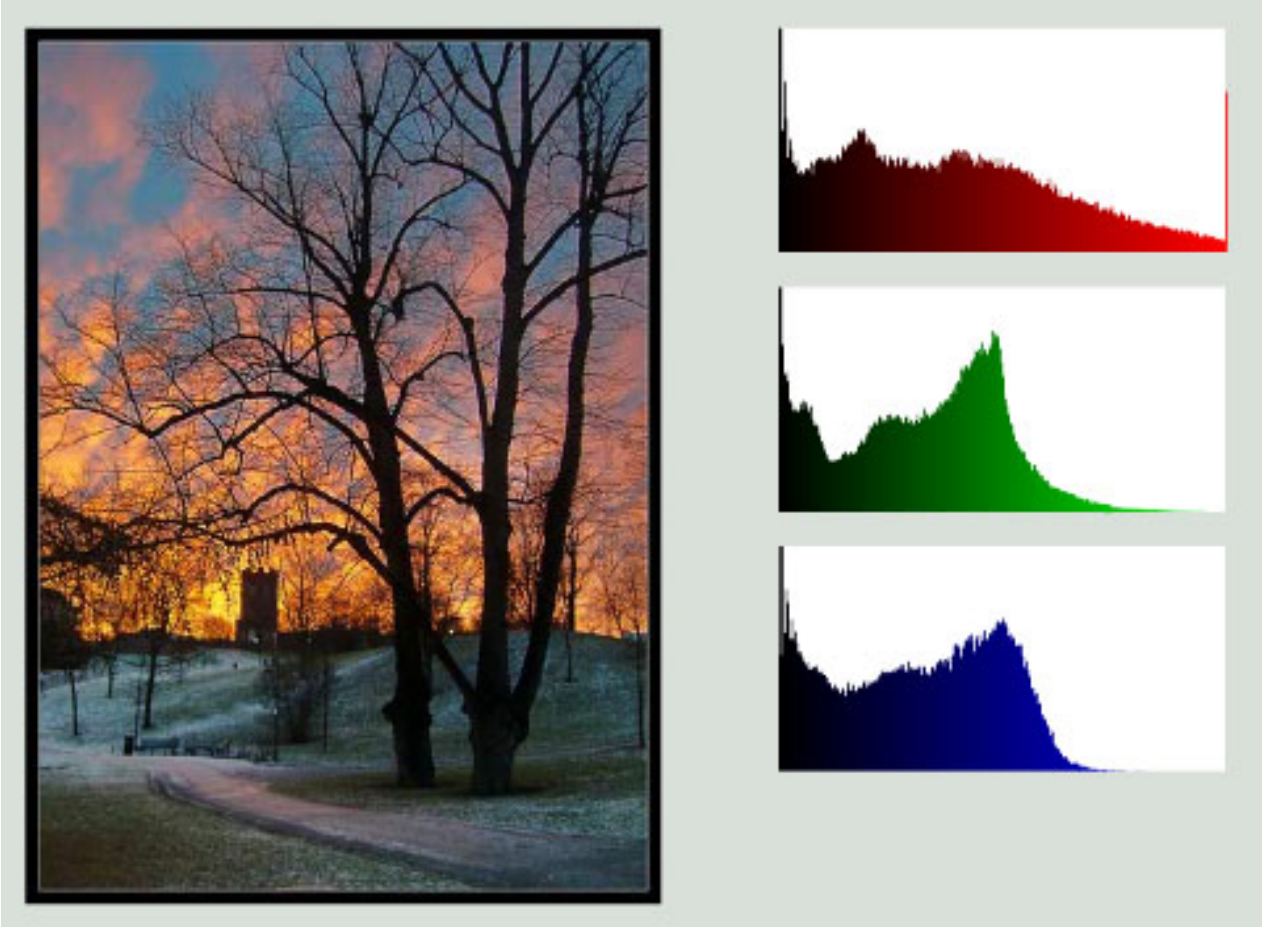
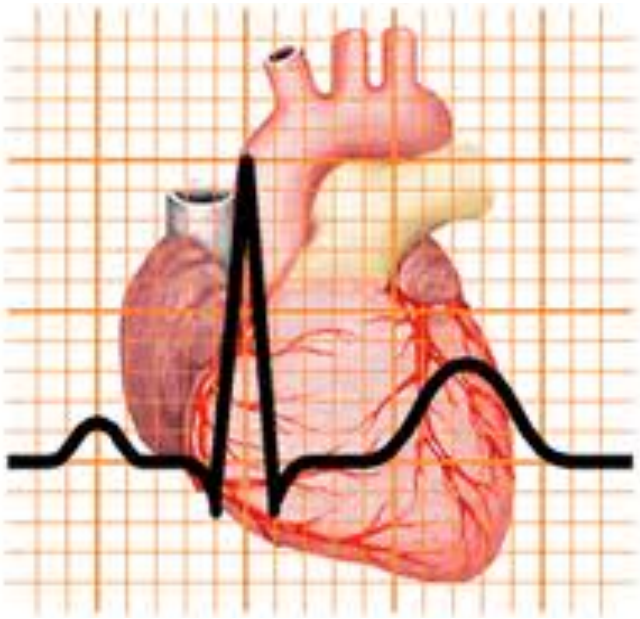
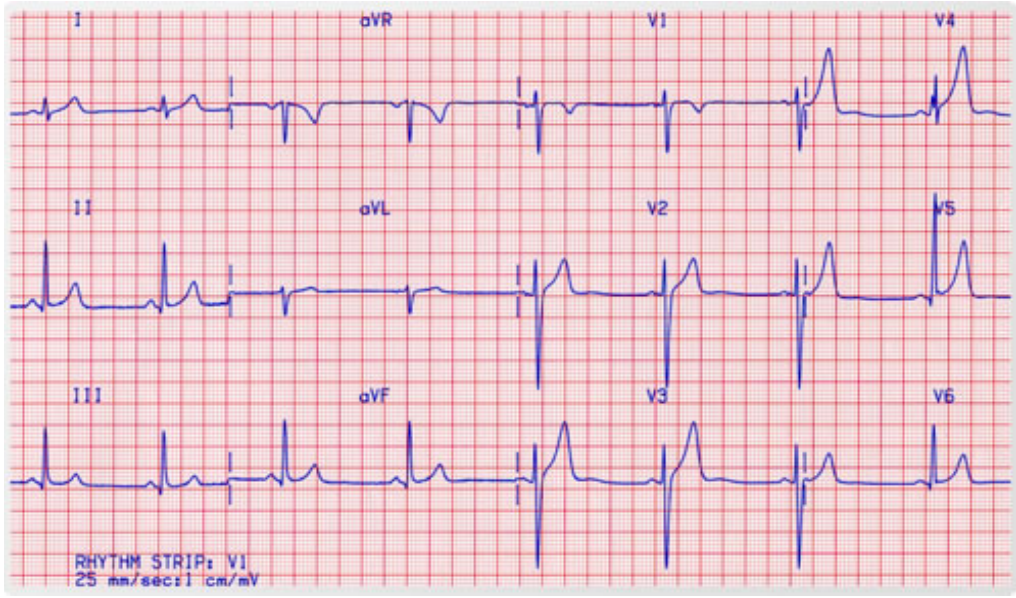


Figure: RGB level per pixel.

Example of signals: Electrocardiogram (ECG) signal





Electrical activity of the heart over a period of time: The ECG device detects and amplifies the tiny electrical changes on the skin that are caused when the heart muscle depolarizes during each heartbeat.

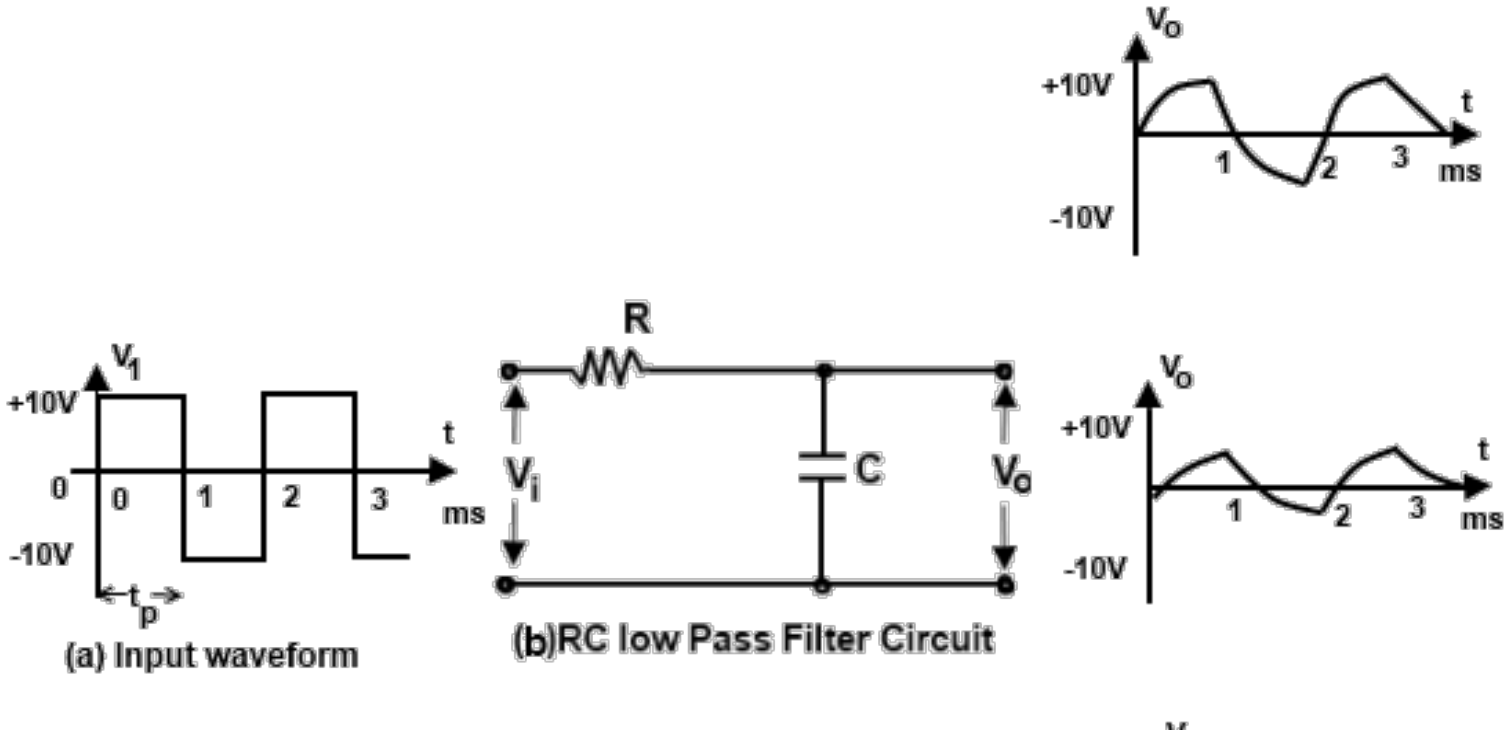
Systems

- Physical device that performs an operation on a signal.
- Any process that transforms one signal into another.
- Systems can model the behavior of a chemical process, a hydraulic system, an electric circuit, a communication channel, ...

Signal Processing

Area of systems engineering, electrical engineering and applied mathematics that deals with the analysis of the properties of signals and the design of systems that attain an specific purpose.

System examples: electric circuits



In this course, we will apply what we have learnt about signal and systems to analyze elementary electric circuits.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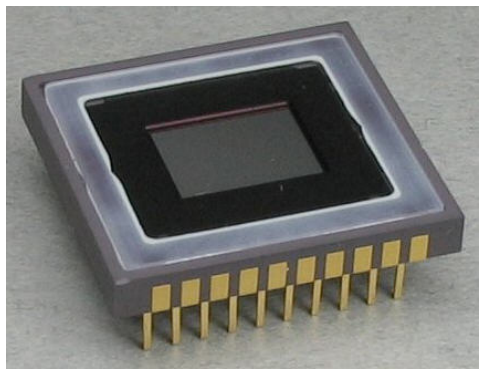
WordPress

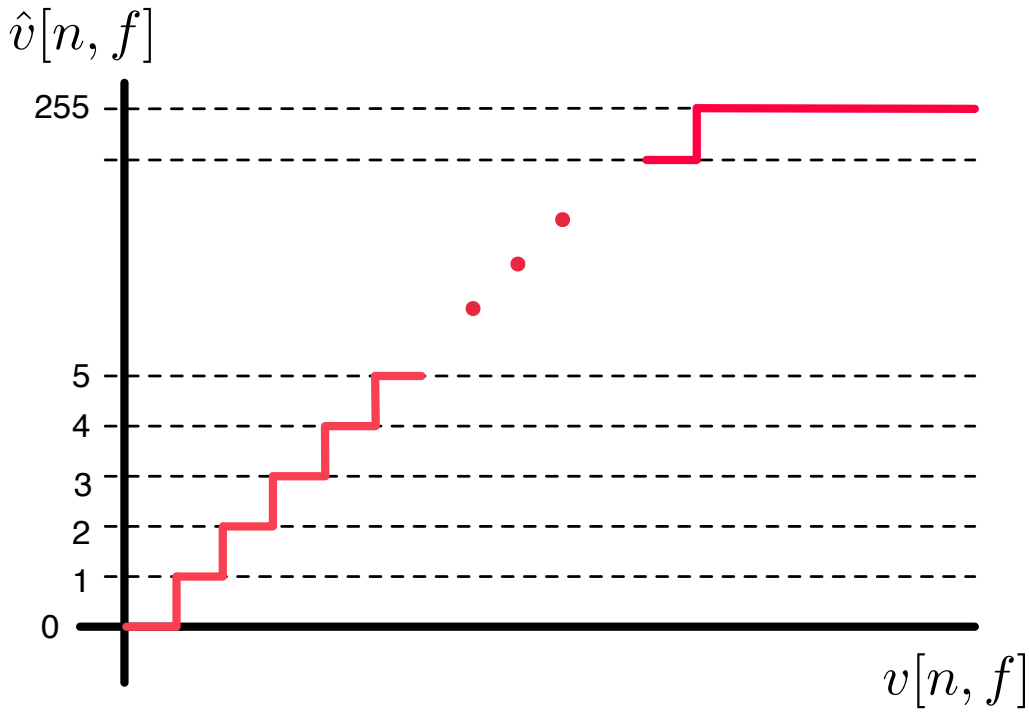
- Information (picture) is originally encoded in a signal by means of signal intensity at different frequencies (colors).
- A light sensor is composed by a grid of millions of little squares (pixels), each one kind of like a solar cell
  - Depending on the light intensity at a particular color (frequency), they generate an electrical signal.

$$v[n, f] = p(I[n, f])$$

  - $I[f, n]$ is the light intensity at frequency f rad/s at the n-pixel. Imagine we only consider three frequencies (colors): red, blue, green (RGB).
  - $v[n, f]$ is the voltage at the output of the n-pixel at frequency f.



- The signal $v[n, f]$ typically can take any real value in a certain range $[0, V]$.
- Digital electronics only allow a discrete number of levels. E.g. 256 levels per frequency are encoded in 8 bits ($2^8 = 256$).
- **Quantization**



- Imagine 256 color level and three frequencies (red, green, blue).
- Each quantized pixel $\hat{v}[n, f]$ needs 3×8 bits$= 3$ bytes.
- Imagine the camera has 5 megapixels.
- Each image requires a memory of $5 \times 10^6 \times 3 \approx 15$ MB.
- However the image file finally stored in the hard disk (jpg file) has a weight of only 0.5 MB.
- The **image has been compressed**.

The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form.

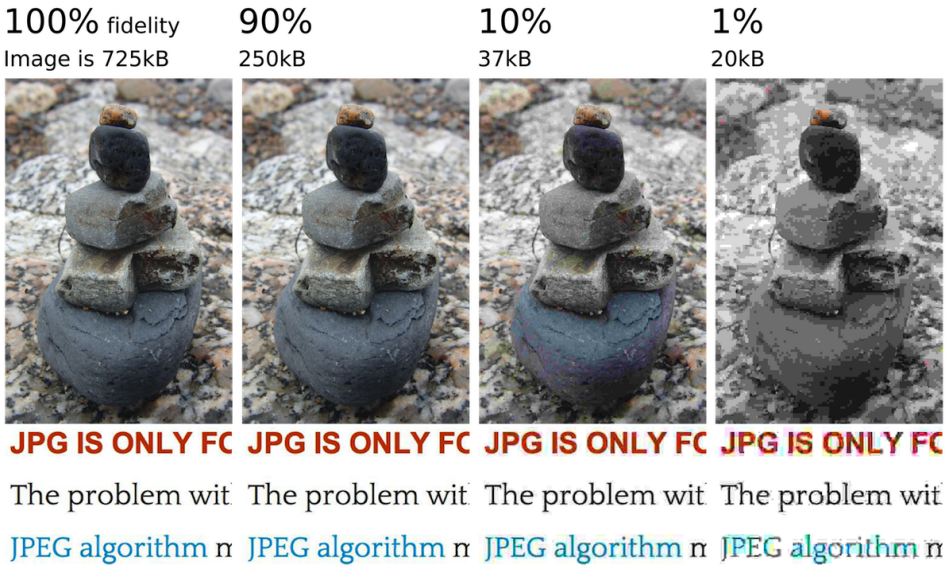
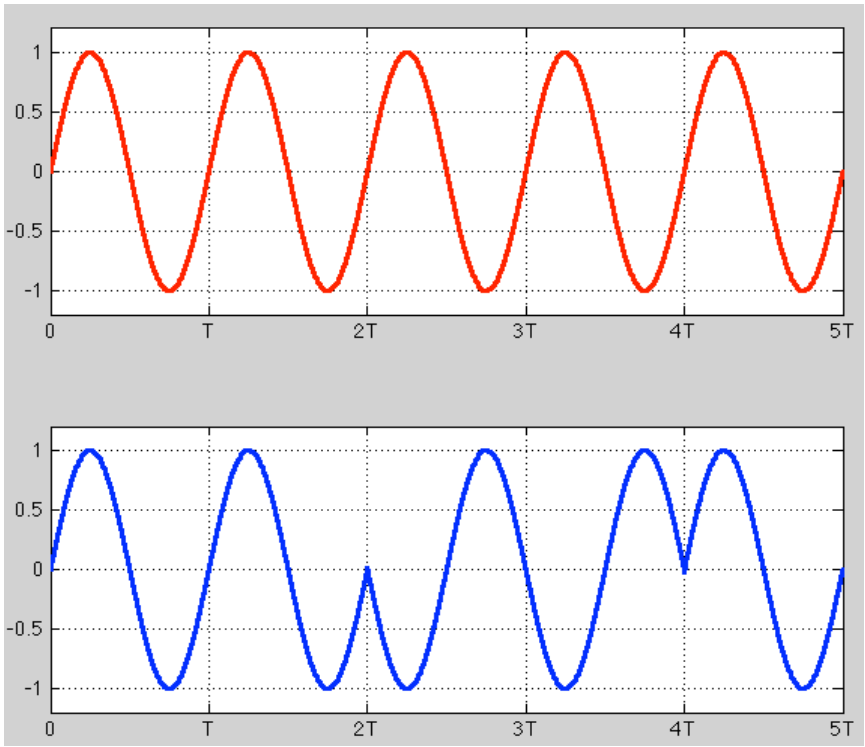


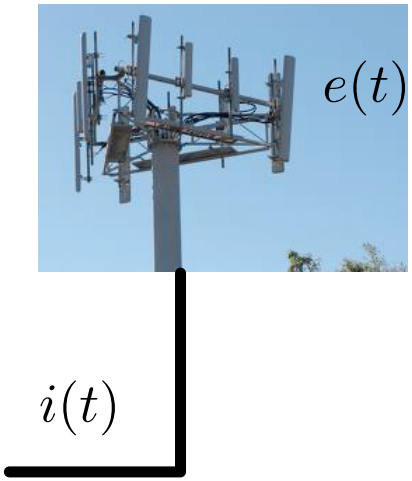
Figure: Source:
https://sites.google.com/site/keremitgsnotes/chapter-6/compression

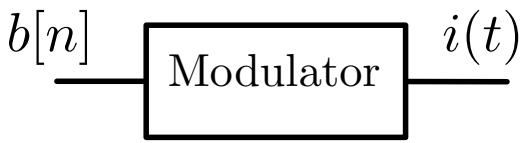
- Bits are encoded in a electromagnetic signal for transmission.
- We create an electric current signal $i(t)$ over an antenna, which creates a electromagnetic field $e(t)$ of similar properties (amplitude, frequency, ...).

$$i(t) = (2b[n] - 1)\sin(2\pi f t)$$



$b[0] = 1 \quad b[1] = 1 \quad b[2] = 0 \quad b[3] = 0 \quad b[4] = 1$





To sum up

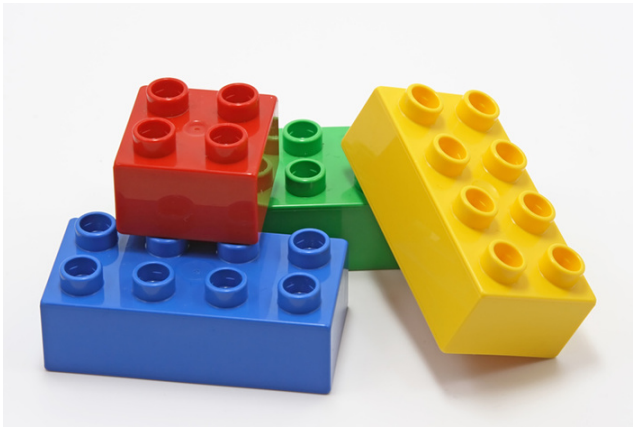
- The notions of signal and systems are extremely general concepts.
- Range of applications and problems is huge.

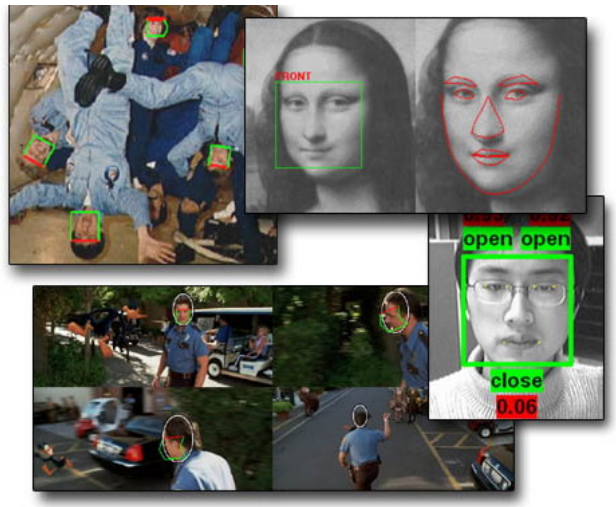
Where should we start?

> An important and fundamental notion in dealing with signals and systems is that by carefully choosing subclasses of each with particular properties that can then be exploited, we can analyze and characterize complex signals and systems in great depth.
> *Alan Oppenheim*

In other words, we will start with basic definitions and concepts to understand and design complex systems.

MATHEMATICAL FRAMEWORK+BASIC BUILDING BLOCKS





FOUNDATIONS OF ADVANCED SIGNAL PROCESSING.

Some cool examples in Pattern Recognition:

- Google Vision API: https://cloud.google.com/vision/
- Object Recognition using Deep Learning: https://www.youtube.com/watch?v=dAl2gimGIpU
- Simple introduction to Machine Learning: https://medium.com/@ageitgey