LA-ConGA physics
Introduction to Measurement Systems - Sensores

by Dennis Cazar Ramírez

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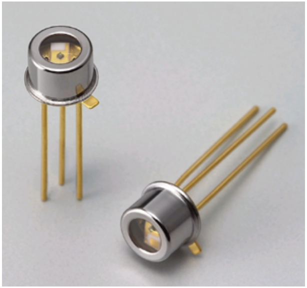


Sensors

Introduction

- Sensors are the first components of a measurement chain.
- They convert the physical and chemical variables of a process or an installation into **electrical signals** that almost always begin as **analog signals**.

Sensors

Basic definitions

- The quantity to be measured being the **measurand**, which we call m.
- the sensor must convert m into an electrical variable called s.
- The measurement s can be an impedance, an electrical charge, a current, or a voltage.

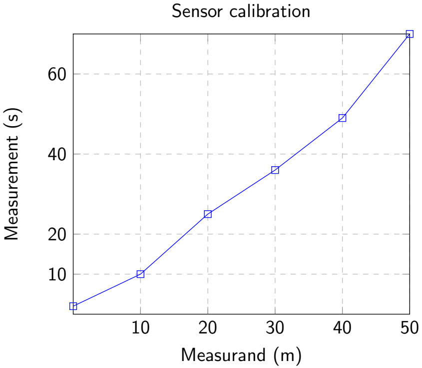
$$s = f(m)$$

- $f(m)$ depends on:
    - the physical law determining the sensor
    - the structure and purpose of the sensor
    - the sensor's environment
- The expression $f(m)$ is established by calibration.

Sensors

Finding $f(m)$

By using a standard or unit of measurement, we discover for these values of m electrical signals sent by the sensor s and build a **calibration curve**



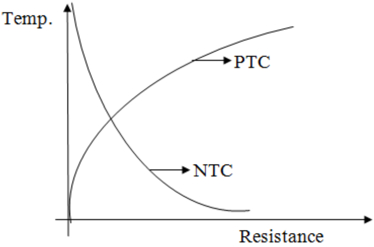
Sensors

Sensitivity

- We call sensitivity S the derivative $f'(m)$.
- In order to make sensitivity independent of the value m, the sensor must be linear:

$$s = S \cdot m + s_0$$

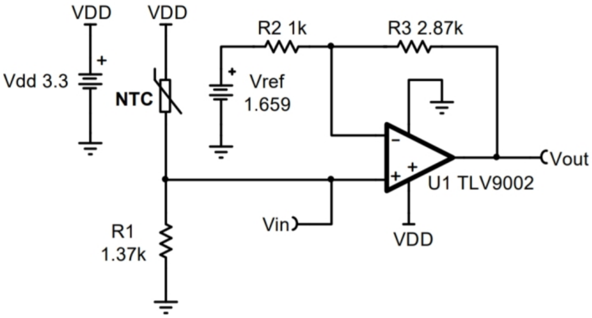
- where s_0 is the value of the signal s when $m = 0$



Sensors

Passive sensors

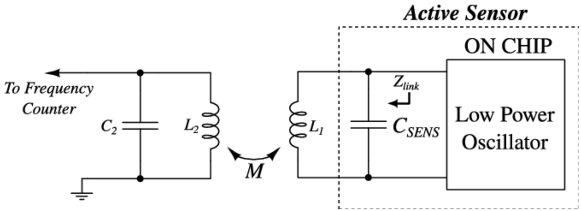
- **Passive sensors:** the delivered electrical signals of passive sensors are impedance variations because these sensors require an electrical energy source in order to read *s*.
- Passive sensors are part of a circuit called **the conditioner**



Sensors

Active sensors

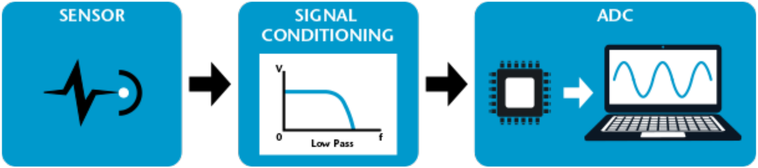
- Active sensors require an external power source in order to control current and/or voltage to accomplish a purpose.
- Active sensors might transmit energy or drive a signal.
- They record the response of the medium as a signal *s*



Sensors

Measurement chain

- **measurement chain:** in general, the signal cannot be used directly. We call a **measurement chain** the range of circuits or devices that amplify, adapt, convert, linearize or digitalize a signal before output readings.



- **calibration:** we distinguish between calibration carried out on the sensor itself and the global calibration carried out on the conditioner and the measurement chain;

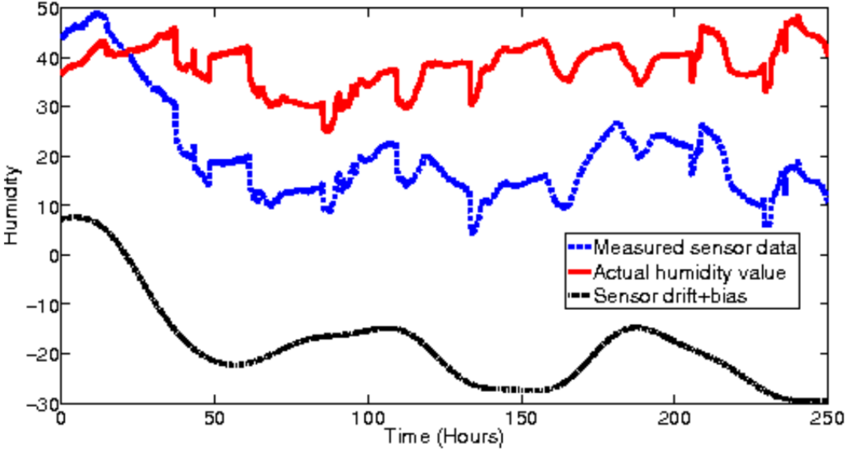
Sensors

Drift and response time

- **drift of sensor:** sometimes we find a specific instance of an influence variable that plays a role in measurement in one of two ways. It may cause long-term drifts that modify $f(m)$. This influences the drift of a sensor.
- Alternatively, the influence variable may modify the sensor's capacity to respond to measurement variations in time. This variable affects **response time**.
- The frequency range in which the sensor shows a constant sensitivity is called the **band pass**. Response time and the band pass are closely related.

Drift example

- drift of a sensor can be corrected with recalibration or redundance



Systematic Errors

Systematic errors are always due to faulty sensor knowledge or utilization. This kind of error is detected by comparing the mean values of the same measurand, given by two different sensors.

The most frequent causes of systematic errors are:

- incorrect or non-existent calibration due to an aging or altered sensor;
- incorrect usage: some examples include failure to reach steady state, a defect or error of one of the conditioner parts, or a modification of the measurand by the sensor itself;
- inadequate data processing: examples are error in linearization in the measurement chain or amplifier saturation in the measurement chain.

Obviously, detecting systematic errors leads to their elimination.

Random Uncertainties

We can know the cause of random uncertainties without being able to anticipate the measurement value. Their evaluation is always **statistical**.

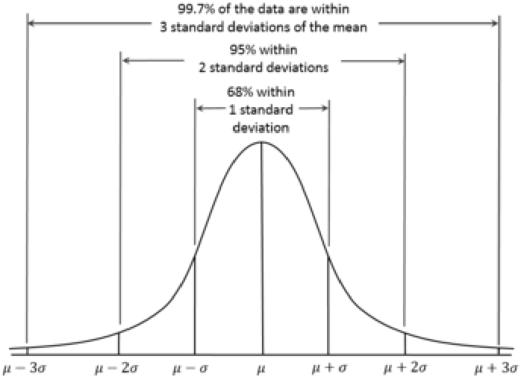
- They are due to the presence of signals or interference; the amplitude of these is random and they are called, rather vaguely, “noise”, for example
  - fluctuating supply sources
  - electromagnetic signals picked up by a sensor element, conditioner or measurement chain
  - thermal fluctuation, etc
- There are many other causes of random uncertainties, such as reading errors, defects in sensor mobility and hysteresis

Unlike systematic errors, random errors can never be completely avoided

Evaluating random uncertainties

two statistical problems must be analyzed:

- the evaluation of uncertainties
- deciding how to analyze and treat these uncertainties.



Example

We have two series of measurements of the same sensor (temperature in celcius)

- 59.5; 60.2; 60.6; 60.1; 59.6; 58.9; 60.9; 59.2; 60.1; 60.3
- 60.1; 60.6; 59.8; 58.7; 60.5; 59.9; 60.0; 61.2; 60.2; 60.2

Estimate

- The mean and standard deviation of each series.
- The confidence interval of 90%,

Signal or Noise?

Chauvenet's criteria

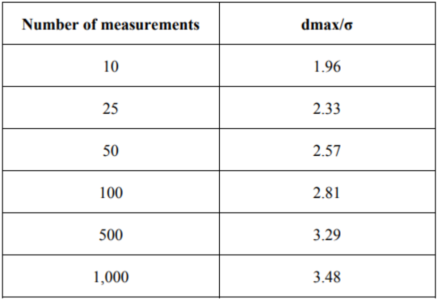
- Sometimes, when carrying out a series of measurements on the same measurand, a result may occur that deviates significantly from the mean value obtained through prior measurements.
- In such a case, it is hard to know if this measurement was produced by a rare but important increase in the random uncertainty or by an unforeseen phenomenon that has causally modified the measurand.
- We must then decide if, in fact, the measurand has been modified.

Chauvenet's criteria specifies that a non-random phenomenon has modified the measurand if the probability of obtaining the measurand, calculated with the help of the Gaussian distribution, is less than $\frac{1}{2}n$, with n being the number of measurements.

Chauvenet's Criteria

In practice

Chauvenet's criteria for a Gaussian distribution. Deviation from the mean value beyond which the engineer must consider if a measurand has been modified



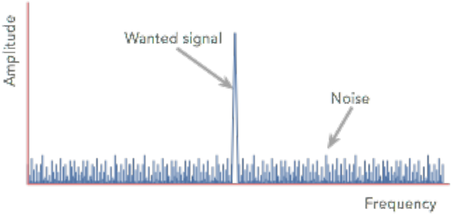
Number of measurements	**dmax/σ**
10	1.96
25	2.33
50	2.57
100	2.81
500	3.29
1,000	3.48

- Where d_{max} is the deviation limit to the mean value

Chauvenet's Criteria

Defining a baseline

Suppose that a sensor has an analog output of $0V$ without any environmental interference.



- We can carry out 500 measurements and find a deviation type of $265mV$
- If one measurement has a value superior to $265 \times 3.29 = 872mV$ we can consider as a signal.
- We must then set the threshold of the system to the value of $872mV$