LA-ConGA physics
Introduction to Measurement Systems - Sensors II

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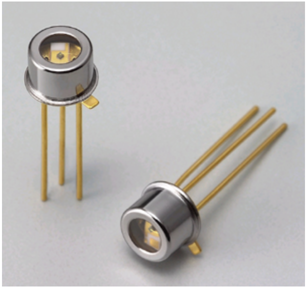


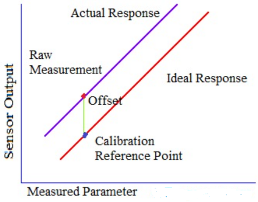
- Calibration is an operation that establishes the relation between the measurand m and the electrical output variable s .
- This relation depends not only on the measurand but also on influence variables.

Where there are no influence variables, **simple calibration** is used.

Multiple calibration is necessary with influence variables.

There are two possible methods of simple calibration. These are:

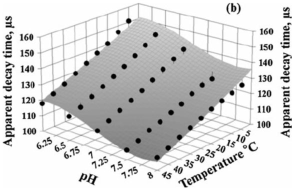
- direct calibration: the measurand values come from standards or reference objects through which we know the measurand, with a given uncertainty
- comparison calibration: with this method, we compare the measurements of the sensor to be calibrated with measurements made by another sensor that already has been calibrated and is being used as the reference. This means that its calibration is linked to standards and that the corresponding uncertainty is known.



Sensors II
Multiple Calibration

The existence of influence variables that may vary throughout measurement means we must set calibration parameters for different values of these variables.

- for sensors that show hysteresis, calibration must be carried out in a series of specific steps of measurand values
- for sensors with dynamic variables, we determine the response as a function of frequency



Band pass and response time

Harmonic response

- The response of a sensor to a measurand that varies sinusoidally over time is particularly important, from it we deduce the response to all measurand variations in time.
- This is the sensor's transitory response.
- The response of a temporal pulse is given by its Fourier transform:

$$h(t) = \frac{1}{\sqrt{2\pi}} \int_0^{\infty} S(\omega) exp(-j\omega t) d\omega$$

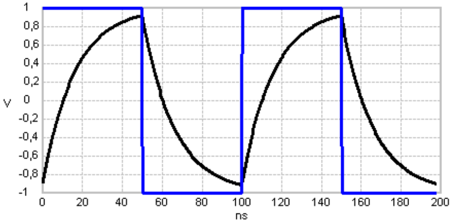
- where $S(\omega)$ is the sensor sensitivity exposed to a sinusoidal measurand

Lack of knowledge about this response can lead to systematic errors, even when carrying out stationary measurements

Sensors II
Band pass

- When using sensors, the idea of band pass can be introduced through a discussion of distortion phenomena observed during measurement.
- If the measurand has a periodic temporal evolution described as in the figure below that can be represented by:

$$s(t) = S_0 m_0 + \sum_i S(\omega_i) m_i cos(\omega_i t + \phi_i)$$



- Generally, a sensor order is the order of the differential equation that governs its dynamic sensitivity $S(\omega)$.
- The simplest example is that in which an equation linking s to m in dynamic state is a first order differential equation

$$m(t) = A \cdot \frac{ds}{dt} + B \cdot s$$

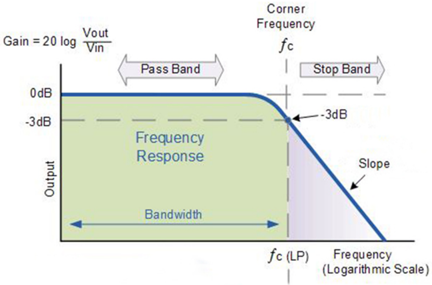
- In this instance A and B are time-independent
- the sensitivity s of the sensor as a function of frequency f is written as:

$$|s| = \frac{m_p}{B} = \frac{1}{\sqrt{1 + \left(\frac{f}{f_c}\right)^2}}$$

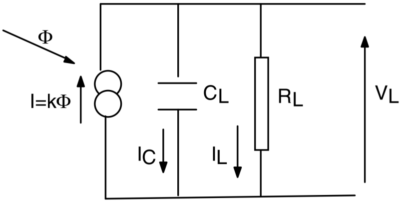
- The phase ϕ as a function of frequency f is written as:

$$\phi = -arctg\left(\frac{f}{f_c}\right)$$

- The amplitude response is often given in the form of attenuations in decibels $\delta = 20log_{10}(s(\omega)/s_0)$



- An example of a first-order sensor is the photodiode.



- From this basic design, we can deduce

$$I = I_C + I_L = C_L \frac{dV_L}{dt} + \frac{V_L}{R_L} = k\Phi$$

- cut-off frequency is:

$$f_c = \frac{1}{2\pi R_L C_L}$$

Sensors II

Response time

The response time of the sensors is always influenced by the measurement chain

- We can also establish that the sensitivity S_0 is

$$S_0 = k \cdot R_L$$

- which means the product (gain $\times$ band pass) is constant

We see that usually large band pass and strong gains do not exist together in most sensor measurement chains.

Activity

The heartbeat measurement circuit

- A type of Heartbeat Measurement Device consists of an electronic circuit that monitors heartbeat by clipping onto a finger tip.
- It does this by shining light through your finger and measuring how much light is absorbed

- We are going to explore this application