Measurements

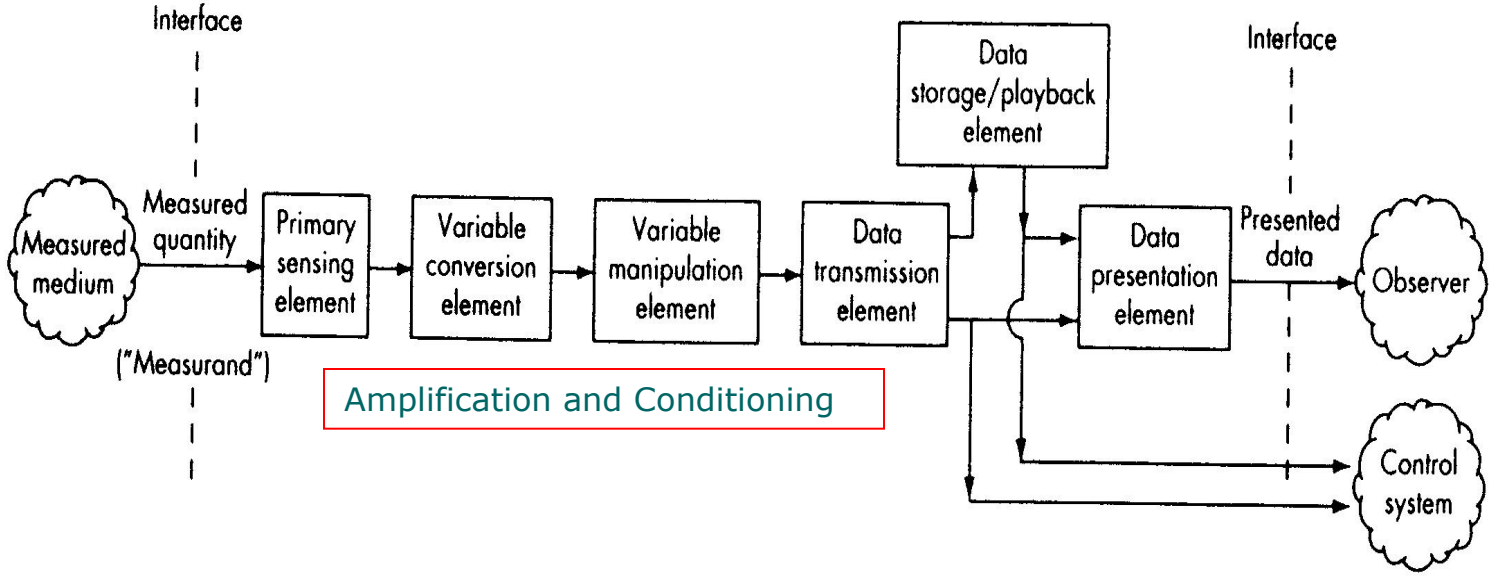
Part 1: Basic Principle of Measurements

Learning objectives

- To state sub-systems in a measurement system
- To understand main function in each sub-system
- To understand the basic properties of measurement systems
- To understand the basic operation of ADC and DAC

Basic components in a measurement system

Basic components in a measurement system are shown below:

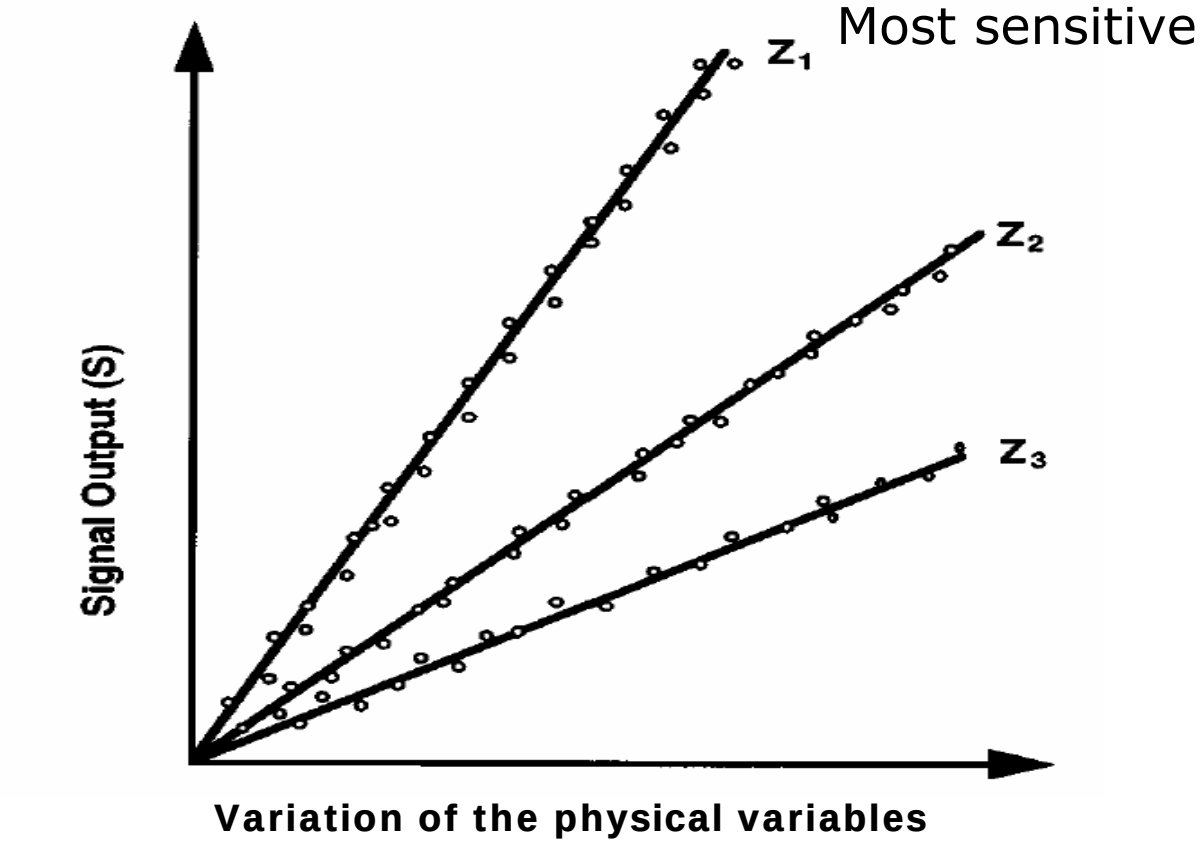


It is also important to mention that a power supply is an important element for the entire system.

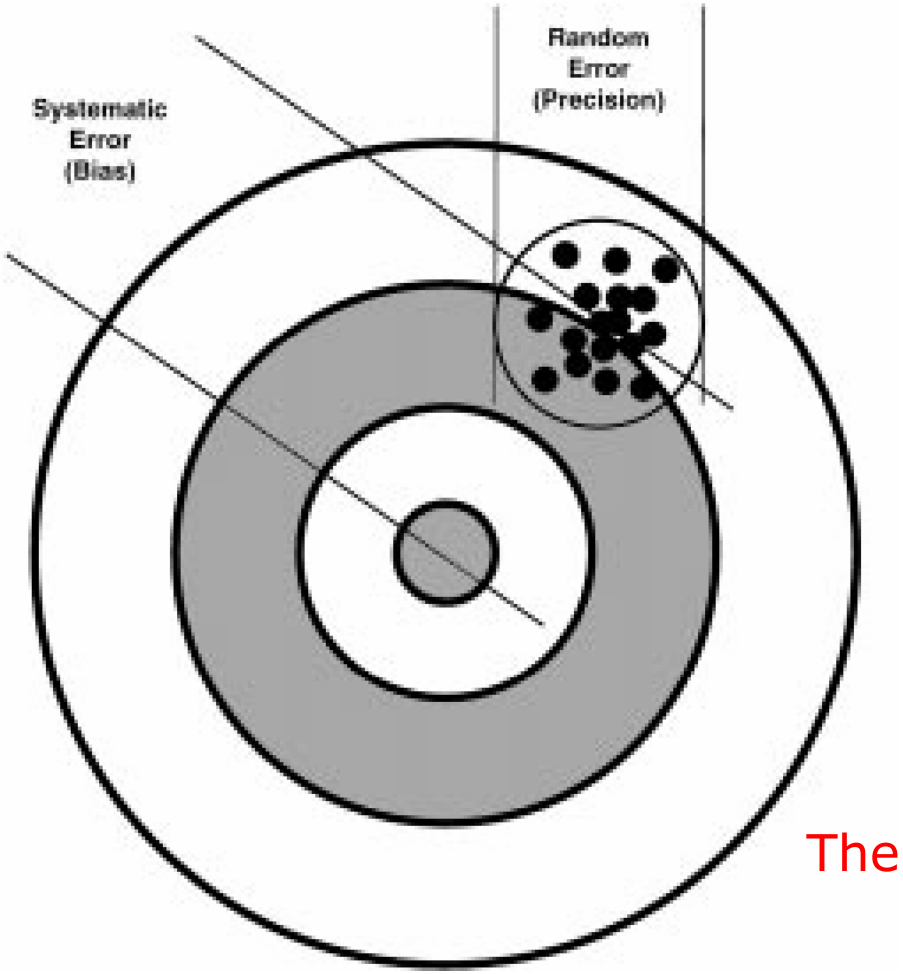
Major issues in instrumentation and measurement systems

- Sensitivity (deflection over the change in the variable)
- Accuracy (uncertainties)
- Precision (spread of readings, repeatability)
- Resolution (the smallest step that can be distinguished)
- Robustness (noise, disturbance, or drift)
- Response time (fast response/high bandwidth)
- Input impedance (loading effect)

Sensitivity



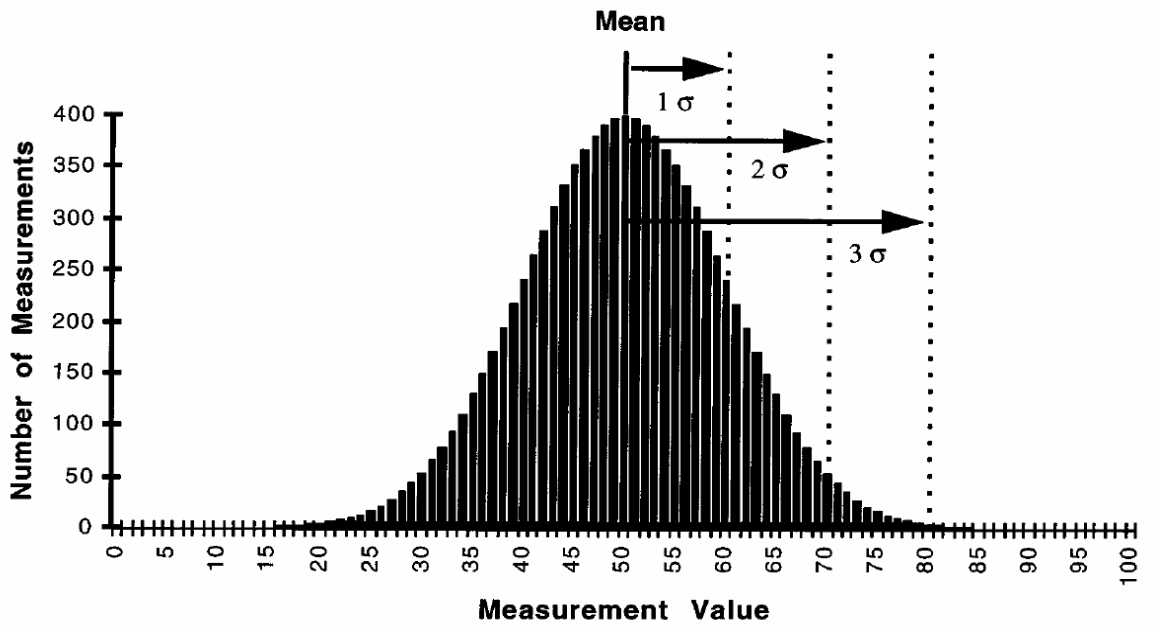
Accuracy vs Precision



High Precision, but low accuracy.

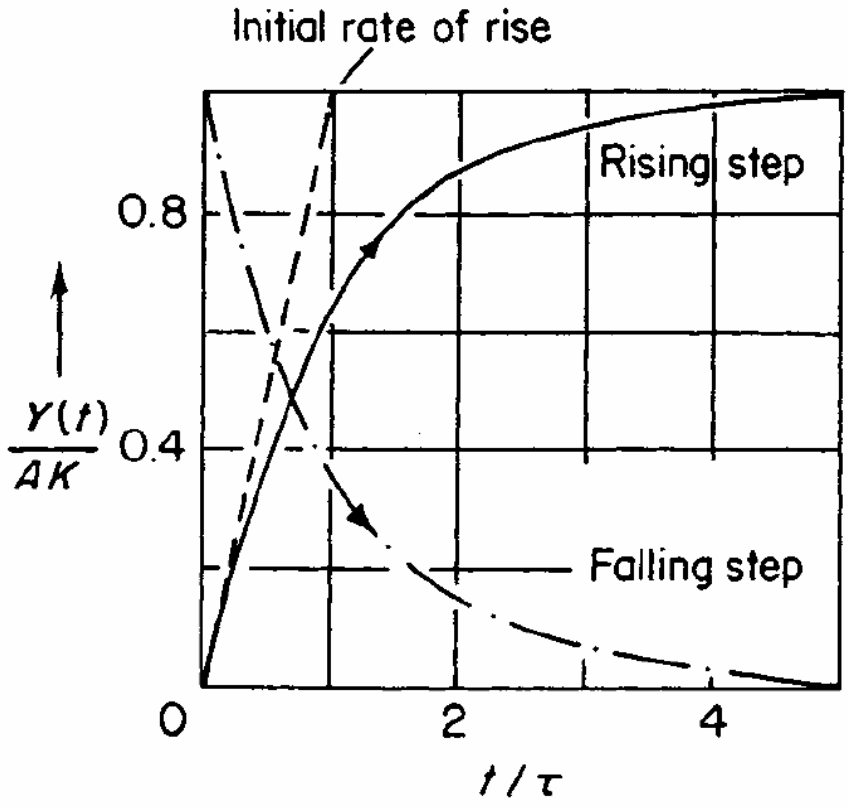
There is a systematic error.

Accuracy vs Precision (Cont)



High accuracy means that the mean is close to the true value, while high precision means that the standard deviation σ is small.

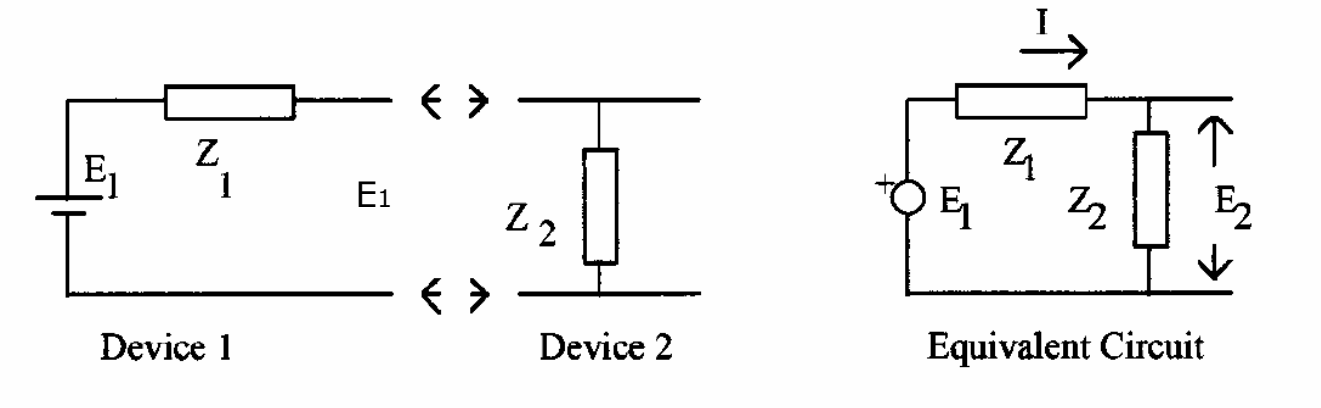
Response time



One would like to have a measurement system with fast response.

In other words, the effect of the measurement system on the measurement should be as small as possible.

Finite input impedance (loading effect)

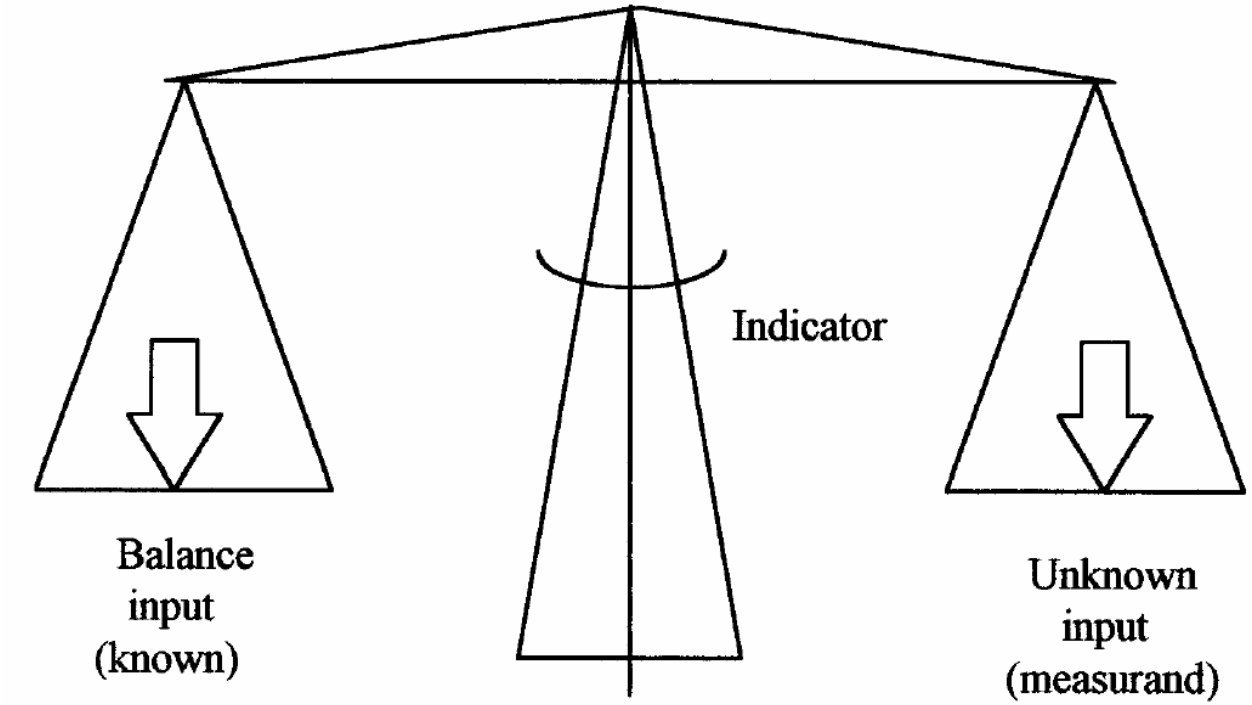


Before connection

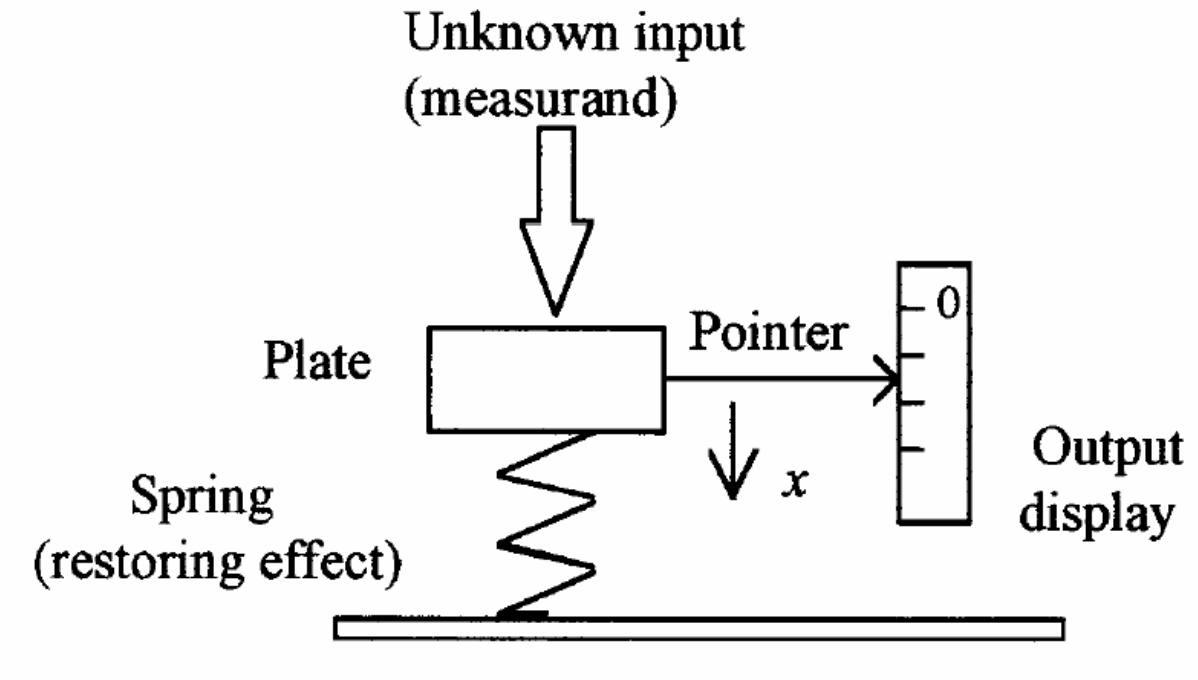
After connection

$$E_2 = E_1 \frac{1}{1 + Z_1 / Z_2}$$

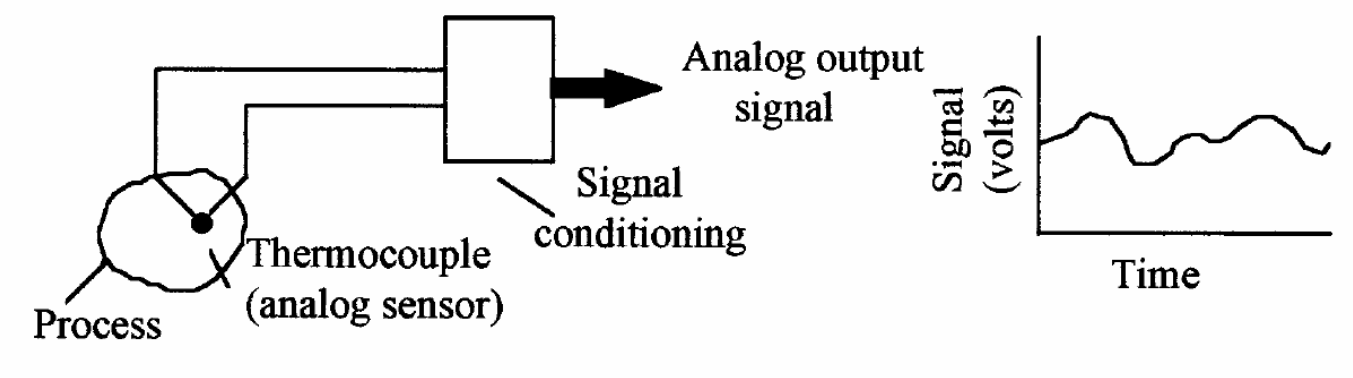
Null instruments



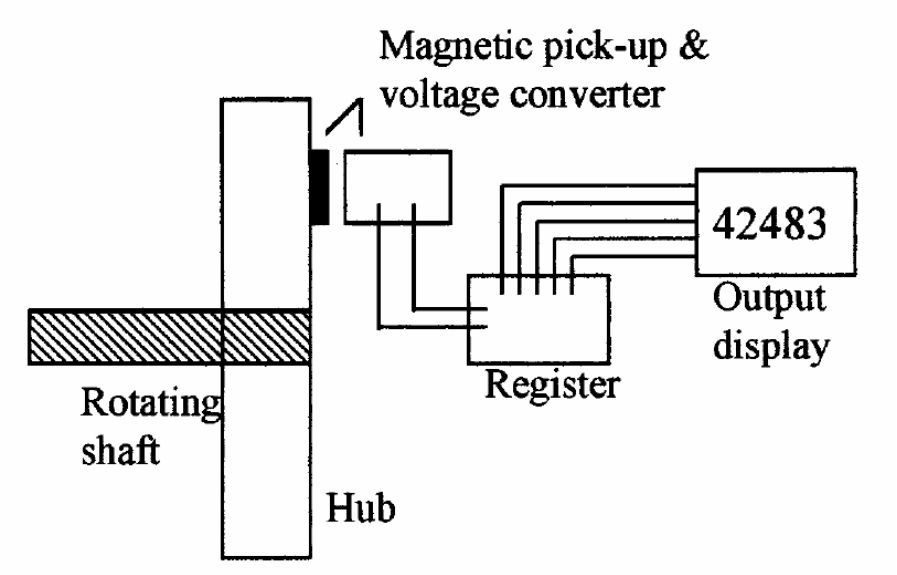
Deflection instruments

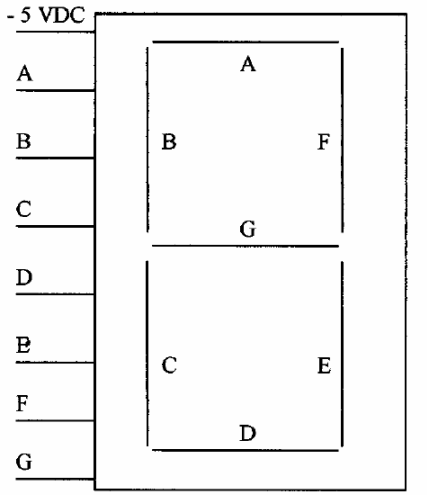


Analog instruments



Digital instruments





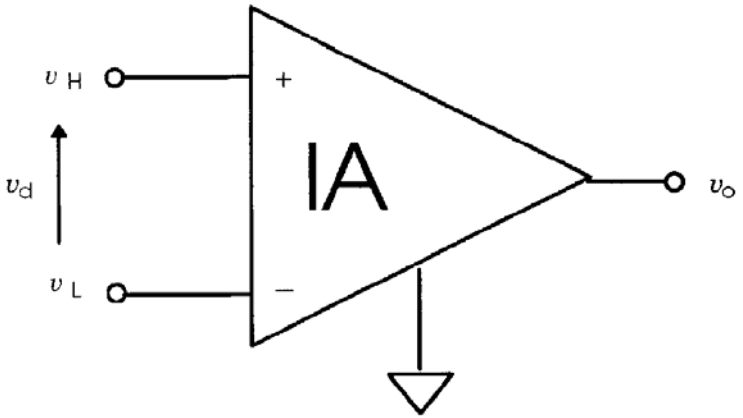
Seven segment display

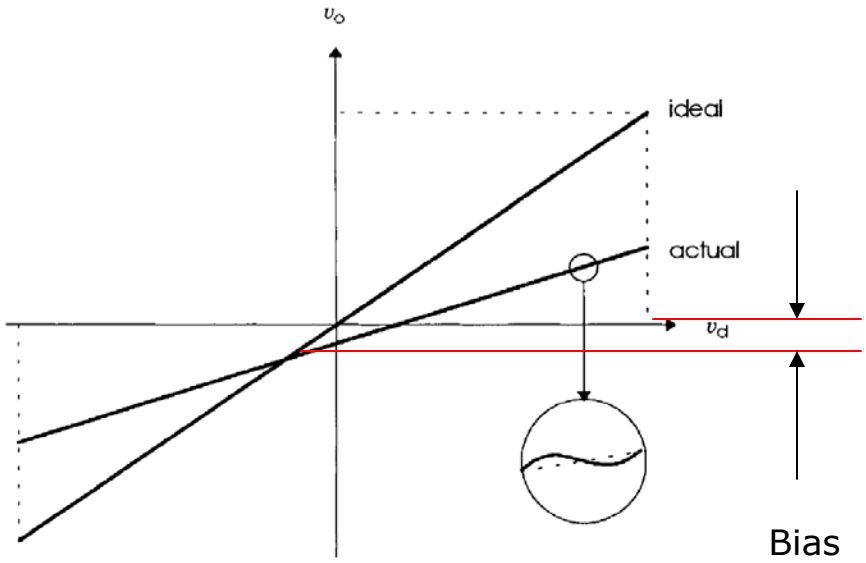
Sensing elements

- The portion of a measurement system that responds directly to the physical variable being measured.
- Sensing elements are usually based on some physical phenomenon of materials to the change in the environment.
- Typical physical variables are:

  Temperature, Level, Flow, Pressure, Force, Length, Acceleration, Velocity, Frequency, Time, …..

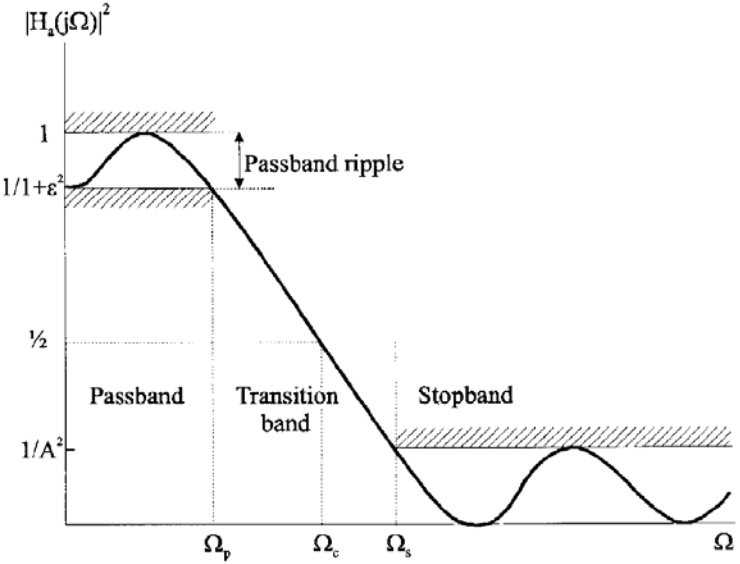
Signal amplification and conditioning



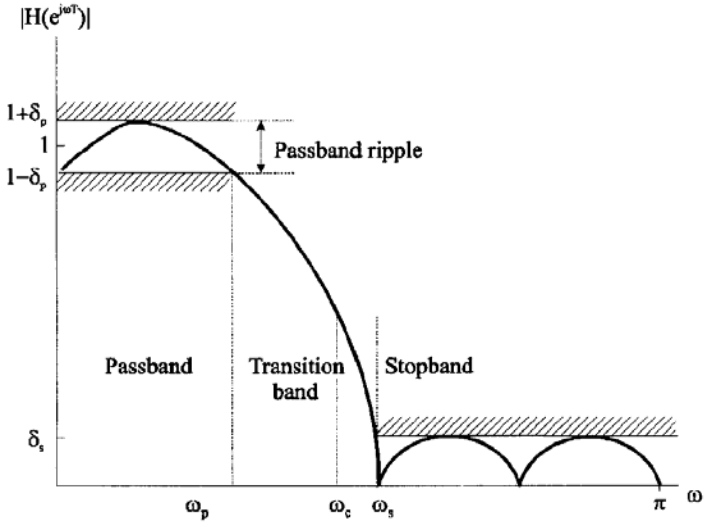


The amplitude of the sensed signal is usually very small. It needs to be amplified before being processed/displayed.

Noise reduction and filtering



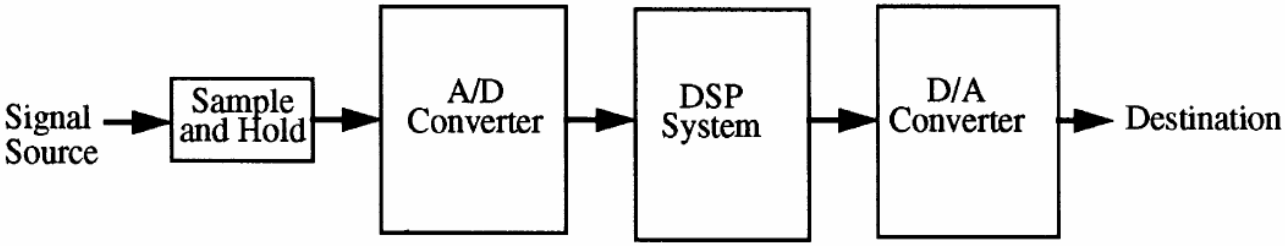
Analog lowpass filter



Digital lowpass filter

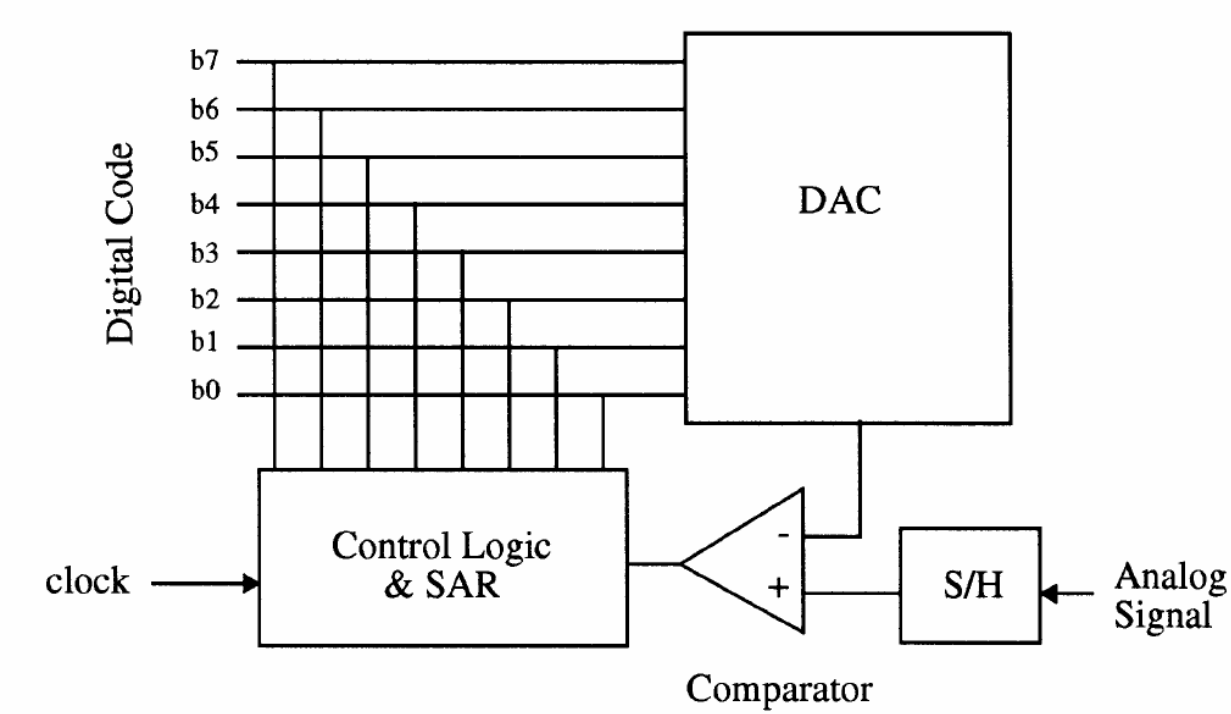
Analog to digital (ADC) & digital to analog (DAC) conversions

In many applications, one has to convert analog signals to digital forms for further processing. This can be achieved through Analog to Digital Converter (ADC).

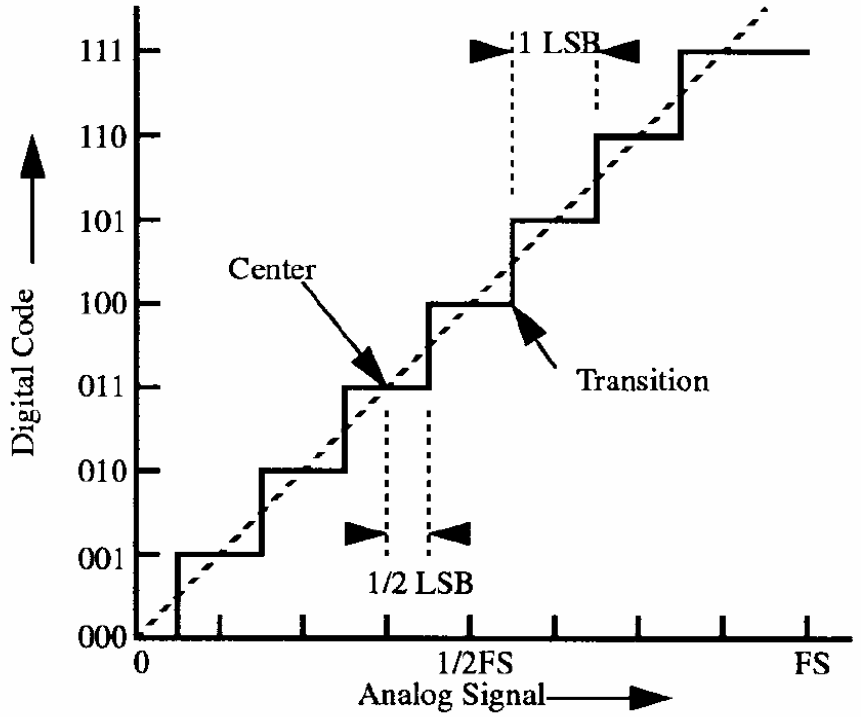


In some control applications, we also need Digital to Analog Converter (DAC).

Basic principle of Analog to Digital Converter (ADC)



Example of a three bit (ADC)



N-bit digital signal

$$D = \frac{A_{sig}}{FS} = \frac{b_n}{2^n} + \frac{b_{n-1}}{2^{n-1}} + \ldots + \frac{b_1}{2^1}$$

Analog signal

$$A_{sig} = FS\left(\frac{b_n}{2^n} + \frac{b_{n-1}}{2^{n-1}} + \ldots + \frac{b_1}{2^1}\right)$$

FS: Full Scale LSB: Least Significant Bit

Measurements considered in this course

- Temperature
- Level
- Pressure
- Flow
- Neutron flux