

Characteristics of Instrumentation

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Signal acquisition

- Domain (Time, Volume, Frequency)
- Transducers, Calibration & Frequency response
- Interference & Signal to Noise Ratio
- Linearity, Sensitivity, Accuracy & Precision
- Damping
- Filtering
- Analog to Digital Conversion

Domain (Time, Volume, Frequency)

- In what domain is the signal you are trying to measure.
- Frequently overlooked is the accuracy and precision of the timing devices when for example measuring dynamic lung volumes.
- Clinical utility may be improved by moving from one domain to another (registering flow in the volume domain rather than time for example).

Transducers: Calibration & Frequency response

- Calibration is altering the performance of an instrument to a standard reference. *(for example adjusting a potentiometer or a software correction factor)*
- Validation is the application of a “standard” source signal and checking that the instrument responds within tolerance.
- Appropriate type of standard signal must be chosen for the type of transducer.

Q50

- Failure to accurately calibrate a wire mesh pneumotachograph, which consistently underestimates flow, may be caused by which of the following?
 - A the flow source provides too high a flow
 - B there is moisture accumulation in the mesh
 - C the pneumotach has a hole in the mesh
 - D turbulent flow has developed in the upstream side

Transducers: Calibration & Frequency response

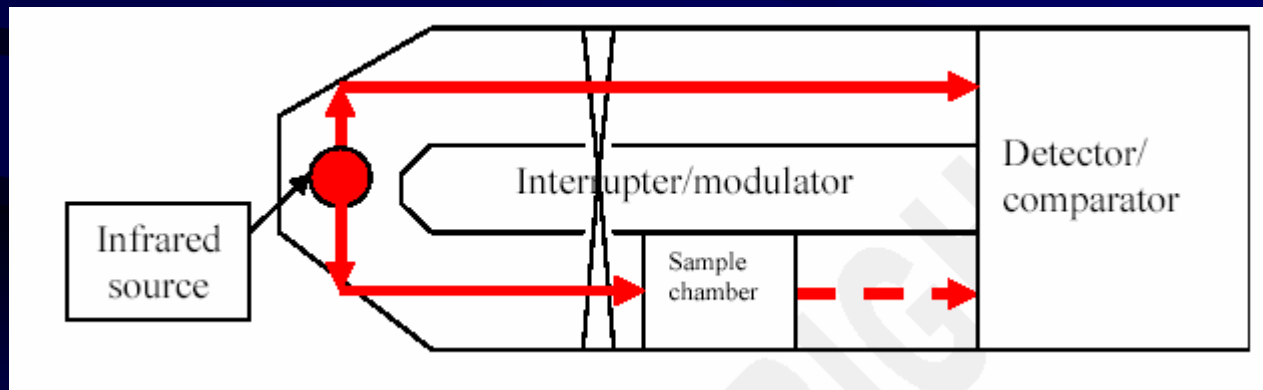
- The frequency response needs to be tuned to the signal frequency of interest.
- If the instrument frequency response of the instrument is too low it can appear similar to over damping and if too high a little like under damping.
- Resonant frequency

Q32 Instrument modification

- Changes to the breathing circuit will alter the calibration and this may be an alinear change.
- A system using a one way valve set up for helium dilution lung volumes is not satisfactory for FVC and FEV1 measurement because-
 - A the addition of O2 is not necessary
 - B the soda lime canister increases expiratory resistance
 - C Absorption of CO2 is not needed
 - D The recording system is inadequate

Interference & Signal to Noise Ratio

- Interfering substances must be removed before analysis (eg CO₂ & moisture in CO meter below)
- Or the ratio between the signal and the “noise” may be increased with filtering and tuned amplification.



NDIR CO gas analyser

Q42

- When setting up a system for measuring lung volumes by He dilution technique, which of the following components must be used?

- 1 Water absorber
- 2 CO2 absorber
- 3 O2 analyser
- 4 CO2 analyser

– A - 2 only

– B - 1 and 2

– C - 2 and 4

– D - 3 and 4

Q48

- When setting up gas and water absorbers for single breath TLCO using CO and He analysers, which of the following is the correct order of the absorbers?
 - A silica gel, soda lime
 - B Soda lime, silica gel
 - C CaSO_4 (drierite), soda lime
 - D silica gel, CaSO_4 (drierite)

- Q90 A response in which the output is a straightline function of the input descriptive of:

- A linearity
- B maximum gain
- C frequency response
- D hysteresis

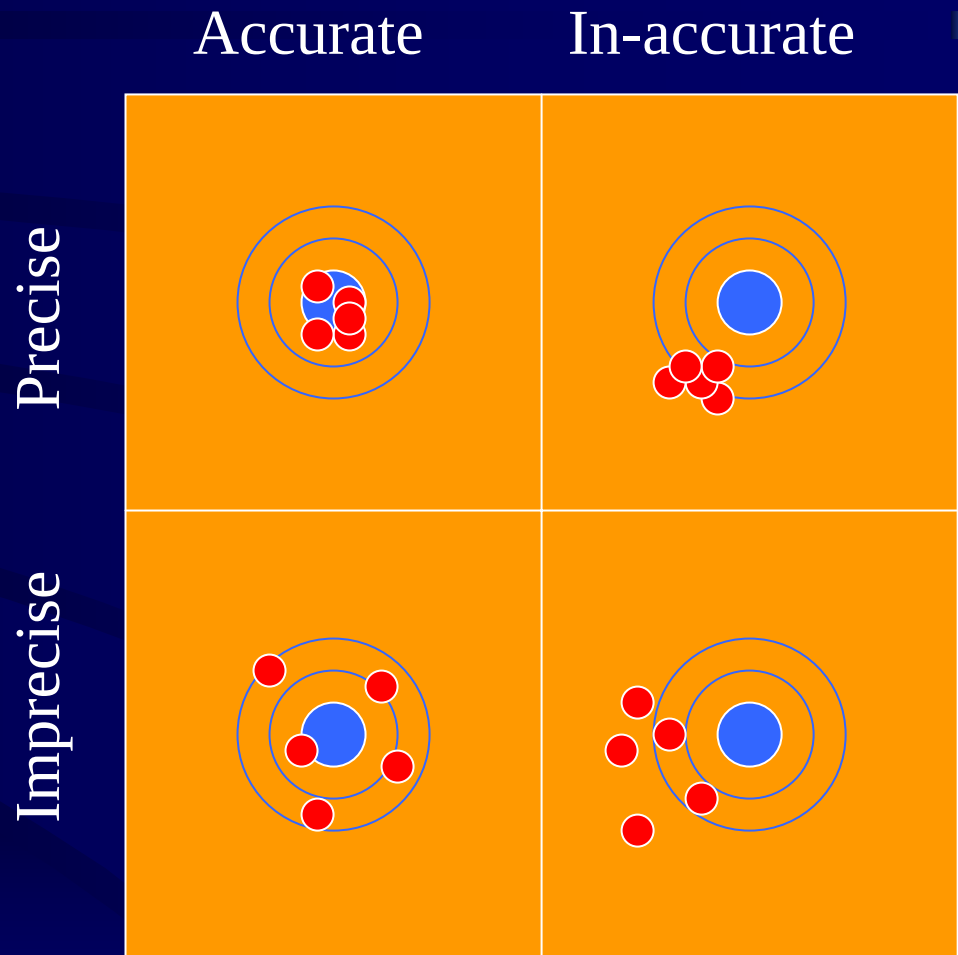
- A device is linear if for every change in the input signal there is a change of equal relative magnitude in the output signal.

Linearity and Sensitivity

- Some devices are inherently a-linear, for example a pneumotach. Linearity is commonly achieved electronically or through software. (check frequently and any time the software is changed).
- Sensitivity - can the device detect the smallest clinically relevant signal change. (again remember your domain eg oximeter for sleep that averaged data over 90secs! Technically accurate and precise, Clinically useless)

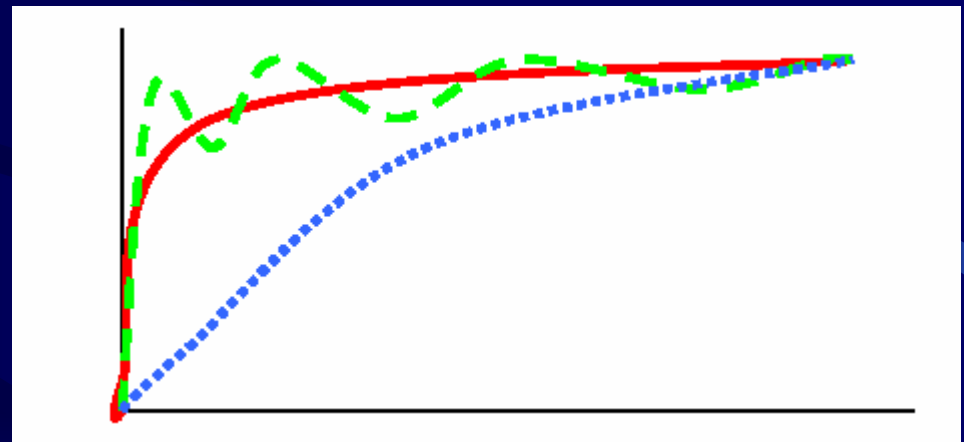
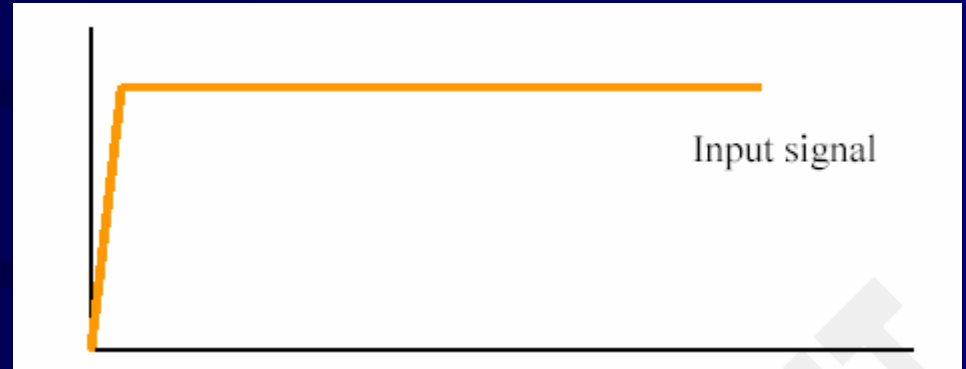
Accuracy & Precision

- *Accuracy* - how close is the device to the true signal.
- *Precision* - how reproducible is the measurement from the same source signal?



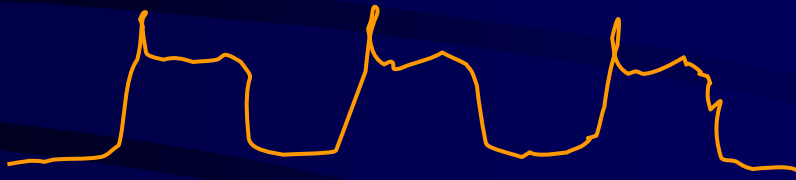
Damping

- Over damping- usually produces undershoot.
- Under damping- usually produces overshoot.
- Optimal damping should produce best representation.



Q81

- A square wave signal is applied to a strip chart recorder and the tracing shown below is obtained, What does the tracing indicate?



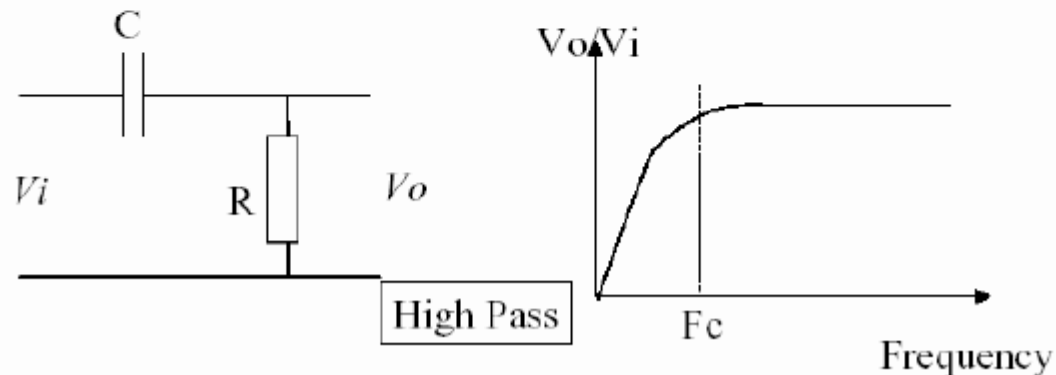
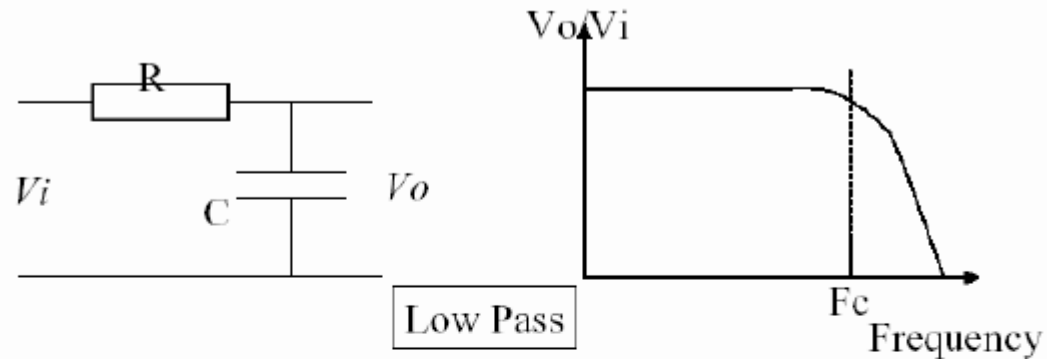
- A Overshoot
- B Undershoot
- C Damping
- D Sine wave generation

Filtering

- Electronic or software filtering of data can significantly improve the signal by removing noise.
- Beware of the threshold at which the filter is set, and also that a variable signal is often composed of harmonics some of which may be affected by a filter to a greater degree than others.
- Combinations of filters can be used to produce an optimal signal “window”

Filtering

- Hi Pass or low frequency filter
- Lo Pass or high frequency filter



Analog to Digital Conversion

- Digital information (a Binary digIT or “bit”) consists of 0s and 1s,
 - a bit can have only 2 states $\sim$ 0 or 1.
- If a an A-D board has 4 bit resolution, then the possible combinations of 0s and 1s are represented by the number of states (2) raised to the power of the number of bits (4) or 2^4 . In other words 16 possible combinations of 0 and 1 (0001, 0010, 0011, etc.).
- Hence the instantaneous value of any analogue signal can be represented by 1 of only 16 combinations of 0 and 1.
- For a 12 bit resolution system the number of combinations becomes 2^{12} or 4,096!

Q43 Analog to Digital Conversion

- Suppose we have to digitise an analogue signal and our 8bit converter can take a signal between 0 and 10Volts.
- With 4bit A-D; $2^4=16$ segments
 - 10volts/16 segments = 625.00millivolts resolution
 - Variations in the signal that are less than 625 mV we simply cannot detect.
- With 8bit A-D; $2^8=256$ segments
 - 10volts/256 segments = 3.91millivolts resolution
 - WOW! now we can detect changes as subtle as 3.91mV (or 0.0391V)
- Remember when we are talking physiological signals every mV counts.

Q43

- If the spirometer shows a 1 volt change for every two litres then the smallest volume we can discriminate between is represented by $0.0391(\text{V}) \times 2000(\text{mL})$
- or 80mL answer D.
- If we had used the 4bit converter the resolution would have been $0.625 \times 2000 = 1250\text{mL}$!

Digital Data Transfer

- PCI A/D Board
 - Interrupts, Bus speed, data acquisition rate, DMA
- Serial communications
 - Baud rate, parity, data bits, stop bit.
- USB 2.0
 - Daisy chain, speed, O/S timing
- Intelligent devices

References & Resources

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