SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)

Coimbatore-35

DEPARTMENT OF BIOMEDICAL ENGINEERING

23BMT203 - BIOMEDICAL TRANSDUCERS AND SENSORS

UNIT I - Fundamental of Measurement

II Year/ IV Sem

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ASP / BME / SNSCT

BIOMEDICAL TRANSDUCERS AND SENSORS

- ✓ Signals and Noise in the Measurement
- ✓ Characteristics of the Measurement System (Static & Dynamic),
- ✓ Determination of Absolute Quantity
- ✓ Standards, Calibration,
- ✓ Accuracy and Error
- ✓ Units of Measurement Quantities.
- ✓ Physiological parameter and its measurement constraints.

Determination of Absolute Quantity

- ✓Standard and Calibration
- ✓Accuracy and Error
- ✓Types of Error
  - ✓Random Error
  - ✓Systematic Error
  - ✓Quantization Error
  - ✓Dynamic Error

Determination of Absolute Quantity

- Measurements can determine absolute values in physical or chemical units or relative values when exact quantities are unnecessary.
- Absolute measurements require system calibration unless the system includes a built-in standard.
- Measurement accuracy depends on the error, which is the deviation from the true value.
- Errors arise from factors like unreliable standards, poor calibration, noise contamination, inadequate system characteristics, and improper data processing.
- Errors can be classified as random, systematic, quantization, or dynamic.

Determination of Absolute Quantity

Standard and Calibration

- A measurement system can be calibrated using either an intrinsic standard or a reliable standard instrument. Examples include a mercury column for pressure, the ice point of pure water (0°C), and the melting point of gallium (29.771°C) for temperature.
- Stable and well-calibrated instruments, such as crystal-resonator thermometers, can serve as standards with high precision (±0.01°C) for biomedical applications.
- Calibration requirements depend on system linearity. Linear systems need only two-point calibration, while nonlinear systems require multi-point calibration.
- If a system is nonlinear but stable, calibration can determine key parameters in a simple formula, such as a quadratic function, using minimal data points.
- Real-time curve fitting can be performed when connected to a computer.

Determination of Absolute Quantity

Accuracy and Error

- Accuracy refers to how close a measured value is to the true value, with the difference termed as error.
- When measuring a wide range of values, errors may vary, making relative error (error-to-true value ratio) a useful measure of system performance.
- Proper calibration minimizes error to a limit set by reproducibility, but long-term drift can degrade accuracy.
- Recalibration restores accuracy, and regular calibration ensures long-term measurement reliability.

Determination of Absolute Quantity

- ✓Types of Error
  - ✓Random Error
  - ✓Systematic Error
  - ✓Quantization Error
  - ✓Dynamic Error

Determination of Absolute Quantity

Random Error

- Random error occurs unpredictably in repeated measurements due to noise and short-term fluctuations.
- These errors are symmetrically distributed around the true value, meaning that averaging multiple measurements helps approximate the true value.
- Random errors often follow a normal distribution, as explained by the central-limit theorem, where many small, uncorrelated errors combine.
- The standard error decreases with the square root of the number of measurements, making signal averaging an effective method to minimize random errors.

Determination of Absolute Quantity

Systematic Error

- Systematic error is a consistent bias in repeated measurements caused by factors like low-frequency noise, system drift, poor calibration, nonlinearity, or digital rounding.
- It can be detected by comparing measurements from two different systems but cannot be reduced through repeated measurements and averaging.
- Recalibration at proper intervals helps minimize systematic errors over time.
- When environmental factors like climate changes are suspected, using two identical measurement systems one for the object and one for a standard can help cancel out common systematic errors, improving accuracy.

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Determination of Absolute Quantity

Quantization Error

- Quantization error occurs when an analog value is converted to digital, resulting in a difference between the original and converted values.
- This error corresponds to ±1 in the least-significant bit and depends on the measurement level.
- If the measurement value is high enough, quantization error is negligible, but at lower levels, it becomes significant.
- To minimize this error, the input level should be properly adjusted to match the input range of the analog-to-digital converter.

Determination of Absolute Quantity

Dynamic Error

- Dynamic error occurs when a measurement system cannot respond quickly enough to rapid changes in the object quantity, causing a lag between the input and output.
- The output depends on the past history of the input rather than the instantaneous value.
- The step response of a system helps estimate dynamic error, with first- and second-order systems characterized by parameters like settling time.
- Dynamic error can be minimized by allowing sufficient time after abrupt changes for the system to stabilize.