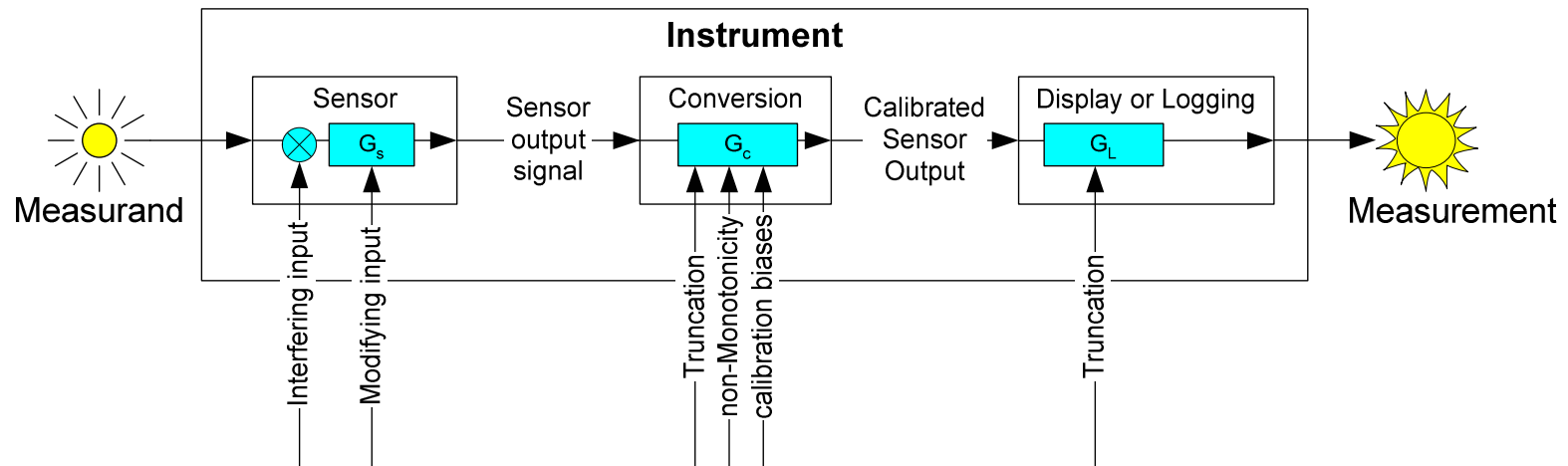


General Sensor Characteristics

- Sensor concept
- Error
- Static calibration
- Uncertainty

Sensor concept



- Transducer – Device which converts a sensed physical manifestation of a measurand to a signal representation of the measurand. Normally an energy conversion occurs. The process may be active or passive.
- Sensor – Device which provides a signal related to a measurand. This device may contain one or more transducers.
- Instrument – A device that processes and displays or logs a measurand. This device may contain sensors and other signal processing and display or logging devices.

Error and Calibration

- Definitions

- Measurand - The object of a measurement
- Measurement – A particular determination of the measurand
- Inaccuracy - Difference between true value and a measurement.
- Imprecision / Random Error - Difference between a measurement and mean value of a measurand
 - Normally specified as $\pm ks$ limits where s = std. dev., k = coverage factor (normally =2 unless a reason otherwise)
- Bias - Difference between true value and mean value of a measurement. Bias is normally largely a function of adjustable parameters of the instrument
- Calibration - Determination of the relationship between the output of an instrument and the measureand and use of that information to eliminate bias. (AKA “static calibration”)

Error and Calibration

- Inaccuracy (Computational definition)

- Inaccuracy is the sum of Bias and Imprecision.

$$E_{inaccuracy} = B + E_{imprecision}$$

- Calibration - Sets $B = 0$

- Uncertainty – A specification of the magnitude of the bounds of error remaining after calibration

- Sensitivity (static)

- Ratio of change in output to change in input

for:

$$q_0 = k_{static} q_i \quad \frac{\partial q_0}{\partial q_i} = k_{static}$$

- (dimensions?) Note that static sensitivity has units.

Error and Calibration

- Independent nonlinearity - deviation of the input to output relationship from a best fit straight line in the dimension of the output.
 - Generally specified as
 - \pm % Full Scale
 - \pm % Reading
 - May be used to specify inaccuracy (common)
- Hysteresis - A response characteristic where the relationship between input and output (calibration) changes with the sign of the time rate of change of the output. Also known as deadband
- Drift - Rate of change of bias
 - Specified with respect to time, temperature or other modifying input. Eg. $^{\circ}\text{C/hr}$

Error and Calibration

- Threshold - Minimum deviation from zero input detectable by an instrument
- Resolution - Minimum deviation in input causing a measurable change in output
- Span - Range of the measurand that an instrument is designed to measure
- Dynamic range - ratio of largest to smallest dynamic input that an instrument is designed to measure
 - May be specified in db = $20 \log (\text{largest/smallest})$

Static Calibration

- Method

- 1. Identify all variables of importance including modifying and interfering inputs
- 2. Fix all input variables except the measurand.
- 3. Vary the measurand while recording the instrument output.
 - The levels of the input must be known and if measured should be traceable to a standard.
- 4. Repeat 2 and 3 above for each measurand
- 5. Document the input/output relationships for each measurand
- 6. Use repeated measurements of the same true value of the measurand to determine imprecision (may be required over the range)
- 7. Adjust if possible the instrument to remove bias or specify the calibration curves for this use
- 8. Specify the remaining inaccuracy of the instrument

Characteristics of uncertainty

- Composed of:
 - A. Factors described by statistical methods (random error)
 - B. Factors described by other methods (scientific judgment)
- See CIPM or NIST for definitive calculation methods
 - NIST document can be found at:
</home/mstone/5413/downloads/Lab1/tn1297s.pdf>
- A. and B. combined is known as “combined standard uncertainty”
- Both A and B may be composed of many elements.
 - See Fraden, Table 2.2

Law of propagation of uncertainty

- “Where uncertainty is composed of additive factors, the combined standard uncertainty should be computed as a root sum of squares”
- $$u_c = \sqrt{u_1^2 + u_2^2 + u_3^2 + \cdots + u_n^2}$$
- Expanded uncertainty: $U = ku_c \quad k = 2$
- Specification of uncertainty: $Y = y \pm U$ where Y is the measurand and y is a measurement.

Calculating uncertainty as a function of multiple u_i

- If u_c can be expressed a function of multiple inputs:

$$u_c = f(u_1, u_2, u_3, \dots, u_n)$$

- Then u_c can be expressed as a function of the uncertainties of each of the inputs:

$$u_c = \sqrt{\left(\Delta u_1 \frac{\partial f}{\partial u_1}\right)^2 + \left(\Delta u_2 \frac{\partial f}{\partial u_2}\right)^2 + \left(\Delta u_3 \frac{\partial f}{\partial u_3}\right)^2 + \dots + \left(\Delta u_n \frac{\partial f}{\partial u_n}\right)^2}$$