Lecture 05.01 Design-stage uncertainty analysis

Design stage uncertainty analysis is the type of analysis done when designing a measurement system, before actual measurements are made, to predict the uncertainty in measurements made by the system being designed. It comes from different sources in a measurement system which will now be considered. Often, at this stage, we do not classify each uncertainty as systematic or random.

Zero-order uncertainty

Zero-order uncertainty u_0 is uncertainty due to instrument resolution, which is "arbitrarily" considered to be

instrument uncertainty
elemental error

Some instruments have error estimates in their manuals; this is called *instrument uncertainty* u_c. Occasionally, this is given as a single value, but more often several contributing *elemental errors* are given, such as linearity error (due to nonlinearities) and hysteresis error (due to a lack of symmetry in a measurement's increase versus its decrease).

root-sum-squares (RSS) method

The *root-sum-squares (RSS) method* allows us to estimate the total instrument uncertainty u_c due to the elemental uncertainties u_k (with number of elements K) as

The RSS method can be used to combine design-state uncertainties of concatenated (series) instruments for a measurement, as well (e.g. a force measurement with a force-to-voltage transducer and a multimeter).

The confidence/probability level $P\%$ depends on the confidence of each error estimate (ideally, they all have the same confidence). If none is given, it is common to use 95%.

design-stage uncertainty

The *design-stage uncertainty* u_d for an instrument is defined as

$$u_d = \sqrt{u_0^2 + u_c^2} \qquad (P\%). \tag{05.1}$$

This is an estimate of our uncertainty based solely on information about the instruments. This should be considered an estimate of our *minimum* uncertainty. Factors we will later consider will add uncertainty.

Example 05.01-1 force measurement with a load cell and a digital voltage measurement

Estimate the design-stage uncertainty for the measurement of a force with a load cell (including amplifier) that transduces force to voltage and a digital voltage measurement via an analog input of a microcontroller. The following tables include specifications from each instrument's manual.

load cell	
range	$[0, 60]$ N
sensitivity	0.1 V/N
linearity error	0.15 mV/N
sensitivity error	0.25 mV/N

μC AI	
range	$[0, 5]$ V
ADC resolution	12 bits
absolute accuracy	50 mV