Measurement Uncertainty
with an introduction to Engineering Statistics

Course No. 132-4

FOR WHOM INTENDED Engineers, scientists and managers. This course will be of interest to personnel involved in SPC, Metrology, Biomedical, Aerospace, Automobile, Electronics industries and those making and understanding experimental test measurements in a wide range of other industries.

BRIEF COURSE DESCRIPTION Every measurement is made for a purpose: to make a judgment about something. It can be to judge the accuracy of an instrument or data, to accept or reject a product or to determine the price charged in everyday commerce. In order to have confidence that the measurement, which is actually only the best estimate of the quantity considered, is acceptable, an estimate of the uncertainty of the measurement also needs to be undertaken.

Course 132-4 starts with Part I, a one-day review of engineering statistics, covering all the usual topics in reliability and statistics and explains how the theory is applied in engineering.

In the study of basic statistics, students encounter equations which are not "user friendly." The volume of statistical formulas and the "number-crunching" has made the true learning and application of statistics difficult for most people. In this course, the actual evaluation of statistical formulas is done using programmable calculators such as the TI-82 and TI-83, which simplify the process and save hours of tedious work. This enables the student to devote more time to the overall understanding of basic statistics and applying the concepts learned.

Part II begins with an introduction to measurement uncertainty and to the terms associated with it. Then the accuracy and limitations of statistics are discussed, with examples of the various types of distributions encountered in statistical tests.

A discussion of sources of errors and their classification into random and systematic follow, before presenting the details of using traditional versus expanded uncertainty equations.

Equations for calculating the propagation of errors are presented next, along with a "special case" method that avoids the use of calculus in many cases. The course covers control charts and their applicability to uncertainty before covering a step-by-step process of calculating uncertainty for a typical application.

Methods of reporting uncertainty, along with how to state or interpret statements of uncertainty, confidence intervals and confidence levels and coverage factors, are covered in some detail.

Bonus Chapter "Examples of Calculating Uncertainty" is not presented in the classroom, and it is not included in the Complete On-Demand Course. However, it is provided in the course materials for self-study by interested students, and may be included in on-site presentations at the client's request.

Successful completion of this course will enable participants to understand, evaluate and express measurement uncertainty.

RELATED COURSES A one-day version of TTi's Course 435, Engineering Statistics, is the first day of this course. The Measurement Uncertainty content is available as Course 132.

DIPLOMA PROGRAMS This course is required for TTi's Metrology/Calibration Specialist (MCS) Diploma Program, and may be used as an optional course for any other TTi specialist diploma program.

PREREQUISITES There are no definite prerequisites for this course. However, this course is aimed toward individuals involved in a related technical field. An understanding of basic algebra will be useful.

TEXT Each student will receive 180 days access to the on-line electronic course workbook. Renewals and printed textbooks are available for an additional fee.

COURSE HOURS, CERTIFICATE AND CEUs Class hours/days for on-site courses can vary from 14–35 hours over 2–5 days as requested by our clients. Upon successful course completion, each participant receives a certificate of completion and one Continuing Education Unit (CEU) for every ten class hours.

ON-DEMAND OnDemand Internet Complete Course 132-4 features seventeen hours of video as well as more in-depth reading material. Most chapters of course 132-4 are also available as OnDemand Internet Short Topics. See our on-line course outline for details.

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Course Outline No. 132-4

Part I, Engineering Statistics

Introduction
- Definitions • Populations • Data Groups, Variables
- Class Intervals • Frequency Distribution
- Continuous Distributions • Continuous Distributions
  - Histogram: Equal Class Size, Unequal Class Size
- Frequency Curves
- Cumulative Frequency Curve or Ogive

Measures of Data Spread
- Central Tendency • Arithmetic Mean • Arithmetic Mean
- Median and Mode • Frequency Distributions

Measures of Dispersion
- Dispersion—Mean Deviation • Mean Deviation Example
- Variance • Variance—Example • Standard Deviation

Worked Example
- Raw Data • Classes • Exact Class Limits
- Frequency Distribution Graph
- Cumulative Frequency Distribution (cf)
- Arithmetic Mean for Grouped Data • Arithmetic Mean
- Median for Grouped Data Set
- Sample Standard Deviation of Grouped Data Set

Probability
- Probability Exercise • Random Data (Tossing Coins)
- Expressing Probability • Venn Diagram • Addition Rules
- Theory of Intersection • Rules of Multiplication
- Bayes Theorem • Hypothesis
- Test • Null Hypothesis (H_0)
- Critical Region • Test Statistic • Level of Significance

Distributions
- Binomial Experiment • Binomial Population • Variables
- Continuous Probability Distribution
- Normal Distribution • Standard Normal Distribution
- Gaussian (s-Normal) Distribution • One-Tailed Test
- Two-Tailed Test • Type I, II Errors
- Statistical Significance
- Confidence Intervals • Confidence Levels
- Computing the Standard Deviation—Example

More Distributions
- Chi-Square (χ^2) Distribution • Binomial Distribution
- Binomial Distribution Graph • Poisson Distribution
- Student's t-Distribution , Table: t-Distribution
- F-Distribution, Table: Critical Values for the F-test

Correlation and Regression
- Goodness-of-Fit Tests • Correlation • Scatter Diagram
- Regression Analysis • Regression • Least Squares
- Linear Regression

Part II, Measurement Uncertainty

Basic concepts
- Measured and Calculated Quantities • Measurement
  - Errors • Absolute Error • Error and Uncertainty

Definitions
- Definitions and application examples of terms
  - encountered in measurement uncertainty

Statistical concepts in measurement
- Probability • Error types • Distributions • f-test • t-test

Elemental Errors
- Type A Random Errors • Type B Systematic Errors
- Accuracy • Errors caused by Standard
- Measurand Errors • Environmental Condition Errors
- Method Errors/Operator Errors • Other External Sources
- Gross Errors • Error classification Example

Calculating Uncertainty: The Traditional Approach
- Traditional vs expanded formula • Confidence levels
- Combining Elemental Uncertainties • Student-t

Calculating Uncertainty: Expanded Equations
- Estimating Uncertainty—Principles
- Combined Uncertainty • Uncertainty Application

Propagation of errors
- Maximum possible error • Cantilever modulus example
- Sensitivities • Uncertainty in Calculated Quantity •
- Best Estimate • Radiation Heat Transfer Example
- Rod and Warehouse Examples • Special Case Equation

Control charts
- What is a control chart? • How to build a control chart
- Planning • Data Collection • Monitoring • Analysis

Uncertainty calculation
- Detailed step by step example

Reporting Uncertainty

(BONUS) Examples of Calculating Uncertainty
- Mass: Electronic Scale
- Dimensional: Measuring Device (Caliper)
- Pressure
- Chemical
- Electrical
- Temperature

Summary • Final Quiz

Award of Certificates for Successful Completion

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