
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, Bio-medical, 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 every day 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.

The course concludes with specific examples of applications involving various measured quantities.

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

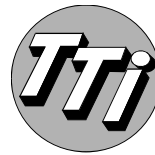
CERTIFICATE PROGRAMS This course is required for TTI's [Metrology Specialist Certificate \(MSC\) Program](#), and may be used as an elective for any other [TTI specialist certificate program](#).

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 participant will receive a set of [course notes](#), which contains most of the viewgraphs used during the presentation.

COURSE HOURS, CERTIFICATE AND CEUs Open courses meet seven hours per day. Upcoming presentation dates can be found on our current [open course schedule](#). 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.

For [schedules](#), [general information](#) and a [registration form](#), see TTI's web site.



Technology Training, Inc.

(a tti group company)

Toll-free telephone:

866-884-4338 (866-TTi-4edu)

805/715-2638 • FAX 805/715-2650

E-mail: Training@ttiedu.com

<http://www.ttiedu.com>

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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

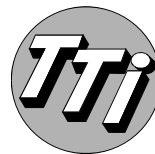
Reporting Uncertainty

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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Toll-free telephone:

866-884-4338 (866-TTi-4edu)

E-mail: Training@ttiedu.com

<http://www.ttiedu.com>