
Applied Measurements

Course No. 166

FOR WHOM INTENDED Engineers, scientists, and managers. This course will be of interest to personnel involved in making or understanding experimental test measurements.

BRIEF COURSE DESCRIPTION This course provides the participant with the engineering concepts for the whole measurement system. It covers climatic measuring systems and reviews dynamic theory, which is essential for a better understanding of the measurand under consideration.

Transducers are discussed, as are the principles of the Wheatstone bridge, a basic tool for many measurement applications. The problems of signal noise, accuracy and error are covered in some depth before continuing on to spectral analysis, sampling and discussion of aliasing problems, filter types and anti-aliasing solutions.

The uncertainty surrounding the value of the measurand is discussed and an introduction to statistics as applied to engineering is covered.

One of the most difficult tasks for the measurement engineer is the selection of the proper instrumentation system. A procedure for attaining this goal is discussed and a typical instrumentation selection list developed.

While calibration is beyond the scope of this course, a procedure for calibrating a sensor device is developed and discussed.

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

PREREQUISITES Students should have completed TTI's Course 163 "[Instrumentation for Test and Measurement](#)" or the equivalent. This course is aimed toward individuals actively involved in related technical fields. An understanding of basic measurement theory is required.

TEXT Each participant will receive a [course workbook](#), 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 [registration forms](#), see TTI's web site.

Course Outline

Introduction to Measurement Engineering
Definitions • Preparing to Make Measurements • Open and Closed Loop Systems
Analog and Digital • Transfer of Energy • Measurement System Responses
Understanding Decibels (dB) and Octaves
Decibels • Power and Voltage Ratios • Conversions • Adding in dB
Reference Levels for decibel Notation • Octaves • $1/3$ Octave Bandwidth Levels
Climatic Measurements: Temperature • Humidity • Pressure • Flow
Review of Dynamic Theory: Laws of Motion • Weight, Mass and Gravity
Force, Mass and Acceleration • Work, Power • Energy
Linear and Angular Displacement; Linear Velocity • Tangential Acceleration • Torque
Stress and Strain • Simple Tension or Compression • Shear Strain
Transducers: Mechanisms • Displacement • Principles • Force Summing
Piezoelectric Transduction • Dynamic Sensors • Frequency Response
Acceleration Response • Vibration Transducers
Wheatstone Bridges: Basic Laws of Networks • Voltage Divider Circuit • Methods of Measurement • Voltage-Sensitive and Current-Sensitive Bridges • Constant-Current Bridges • Bridge Sensitivity • Three-Wire Bridge • Effects of Temperature • Shunt Calibration • Voltage Insertion Calibration • Strain Gage Compensation • AC Bridges—Classic Inductance, Capacitance Bridges
Reducing Signal Noise: Unwanted Signals • Shield Strategies • Twisted Pair • Electrical Noise: High Signal Source Impedance • Low Signal Source Impedance • Source Shunting • Parallel Conductors • Twisted Conductors • Microvolt-Level Signal Cables
Ground Loops • Eliminating Multiple Grounds • A Stable System Ground
Amplifier Guard Shield • Common-Mode Rejection
Accuracy and Error: Accuracy, Calibration and Error Assessment • Common Terms: Accuracy vs. Precision • Classification of Errors • Error Assessment • Improper Functioning of Instruments • Effect of Transducer on Process • Dual Sensitivity Errors
Minimizing Error
Spectral and Fourier Analysis: Spectral Analysis • Sinusoidal, Complex and Random Signals • Phase of Frequency Domain Components • Time and Frequency Domain
Fourier Analysis • Adding Two Signals—Using RMS Values • The Fourier Transform
Discrete Fourier Analysis • FFT • Classification of Types of Data • Random Signals
Correlation • Cross-Correlation, Coherence • Auto Spectral Density (ASD)
Power Spectral Density • Calculating RMS From PSD
Signal Analysis and Aliasing: Signal Acquisition • Shannon's Theorem and Corollaries
Aliasing Viewed as Folding • Where Does the Aliased Data Appear?
Example .. Sine Signal • Aliasing/Multiple Folding • Digitizing "Rules"
Interpolation ..When is it Needed?
Filters: Integrating and Differentiating Circuits • Acoustic Weighting • Bandpass Filter
Undamped (high Q) vs. Damped (low Q) Filters • Selective Filtering
Characteristics of Butterworth, Chebyshev and Bessel Filters • RC and LR Circuits
Anti-Alias Filters • Brick-Wall vs Real Filters • Aliasing Analysis
Anti-Alias Filters—Hardware • Filter "Construction" • How Filters Behave • Group Delay
Filter Cutoff Frequency • Sampling Ratio Calculation • FR/FD Ratio
Measurement Uncertainty and Introduction to Statistics
Error and Uncertainty • ISO Definitions • Simple Statistics of Measurement
Probability—Definitions • Data Distributions • Cumulative Frequency Curve Summation
Degrees of Freedom (ν) • Mean, Median and Mode • Standard Deviation (s or σ)
Variance (s^2) • Normal Distribution • Gaussian Curve • Confidence
Gaussian (s-Normal) Distribution • Special Definitions for Random Vibration
Computing the Standard Deviation—Example • Confidence Levels
Type B — Evaluations other than Statistical
Summary, Final Quiz, Award of Certificates for Successful Completion



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