
Electrical Instrumentation/ Applied Measurements

Course No. 166/164

FOR WHOM INTENDED Engineers, scientists, and managers, as well as aides and technicians. This course will be of interest to personnel involved in making or understanding experimental test measurements. Some background in electronics is helpful but is not essential. The course will be tailored to student objectives.

OBJECTIVES This course provides a basic understanding of electrical measurement systems, as well as the engineering concepts for the whole measurement system. It provides an introduction to the many varieties of meters, 'scopes and transducers available, their operating principles, strengths and weaknesses. A variety of measurands and device types is covered, as well as signal conditioning, recording and analysis. It covers climatic measuring systems and reviews dynamic theory, which is essential for a better understanding of the measurand under consideration.

One of the course objectives is to give students enough applications information that they can select optimum meters, transducer, amplifier, recording and readout devices to assemble a system for routine measurements of electrical phenomena. 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 provided as an appendix

BRIEF DESCRIPTION OF COURSE Mainly lectures, supported by slides, transparencies, videos and sample hardware. Students are expected to participate in classroom discussions, as well as read text materials and class notes.

The course utilizes a non-mathematical approach to understanding concepts and mechanisms.

Participants are encouraged to bring a specific measurement problem to class for discussion.

DIPLOMA PROGRAMS This course is required for TTI's [Electronic Design Specialist \(EDS\)](#) and [Mechanical Design Specialist \(MDS\)](#) Diploma Programs. It satisfies the course 164 or 166 requirement(s) for TTI's [Data Acquisition & Analysis Specialist \(DAAS\)](#), [Electronic Telecommunications Specialist \(ETS\)](#), [Instrumentation Test Specialist \(ITS\)](#) and [Metrology/Calibration Specialist \(MCS\)](#) Diploma Programs, and may be used as an elective for any other TTI diploma program.

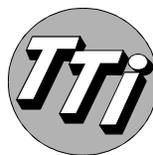
RELATED COURSES Course 164/166 combines [Course 164, Electrical Instrumentation for Test & Measurement](#) with [course 166, Applied Measurements](#). [Course 163](#) covers some of the same material, with more emphasis on dynamics.

PREREQUISITES there are no definite prerequisites, but participation in TTI's course "Electronics for Non-Electronic Engineers" or the equivalent would be helpful.

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 21–35 hours over 3–5 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.

INTERNET COMPLETE COURSE 166/164 features over 14 hours of video as well as more in-depth reading material. All chapters of course 166/164 are also available as OnDemand Internet Short Topics. See the on-line course outline for details.



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Electrical Instrumentation/ Applied Measurements

Course Outline No. 164/166

Part I: Instrumentation for Electrical Test & Measurement

Introduction: Accurate Measurements • Sensors and Systems

Components of an Instrumentation System

Functional Components of a Measurement Chain

Basic Radio Telemetry System • Carrier Modulation

Types of Data Signals: periodic, sinusoidal, complex, square, transient, random • Power Spectral Density • Average, peak and root-mean-square values

Digital measurement systems • Nomenclature, Codes

Noise: Gaussian Distribution • Weak Signal • Noise Calculations

Suppression for Sensor Signals • Noise Figure and Distortion

Electronic Noise Measurements • Phase Noise

Noise Types: Shot (or Schottky), Thermal (or Johnson), Flicker (1/f), Burst, Avalanche • Noise as a Vector • Noise Colors

Understanding decibels and Octaves • Logarithmic scale in graphs
Parameters of linear systems • Non-linearity and Distortion • Filters

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

Electrical laboratory practice: Safety • Grounds • Circuit protection devices • Input impedance, output impedance and loading

Power transfer and impedance matching

Analog and Digital DC and AC meters

DC and AC ammeters and voltmeters • Analog multimeters

How to use basic meters • Meter errors • Digital Electronic Meters

Digital Multimeter Operation: Agilent 3458A Digital Multimeter

Making Measurements with a Digital Multimeter: Voltage, Current,

Resistance • A/D and D/A conversion • Identifying Resistors

Guarded Voltmeter (optional):

Shields, Grounded measurement, Bridges

Oscilloscopes: Making measurements—Voltage, Time,

Frequency, Phase, Pulse • Lissajous patterns

Digital Oscilloscopes

Time and frequency measurements

Power and energy measurements: Power in AC circuits

Single-phase measurements • Polyphase • Higher frequencies

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

DC and AC signal sources: Batteries

DC power supplies: How to use • Oscillators

Sweep-frequency generators • Pulse generators

Function generators

Sensors/Transducers: Strain gauges, Silicon Transducer

Principles • Accelerometers • LVDT • Potentiometric and

Piezoelectric Transduction

Part II: Applied Measurements

Introduction to Measurement Engineering: Definitions

Preparing to Make Measurements • Open and Closed Loop

Systems • Analog and Digital • Transfer of Energy

Measurement System Responses

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, Angular Displacement, Velocity

Tangential Acceleration • Torque • Stress and Strain

Simple Tension or Compression • Shear Strain

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 Signal Cables

Ground Loops • Eliminating Multiple Grounds • Stable System

Ground • Amplifier Guard Shield • Common-Mode Rejection

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

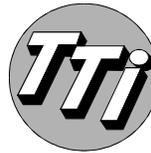
Appendix: Glossary of Terms

Standard Deviation Calculation Worksheet

Typical Instrumentation Selection Check List

Transducer Calibration • Analog Oscilloscope Controls

ASCII codes



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