# 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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## 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 ($\nu$) • Mean, Median and Mode
Standard Deviation (s or $\sigma$) • 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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