Fundamentals of Vibration
For Design and Test Applications
Course No. 116/117

APPLICATIONS Random vibration and shock are important in most engineering applications where the product is exposed to transportation and to possible vibration and shock during service. An understanding of vibration and shock is crucial to improving the reliability of today's products, wherever electronic components appear.

FOR WHOM INTENDED Many engineers need specialized education to properly measure, quantify, and analyze this generally unfamiliar environment and to reproduce it in environmental test laboratories. This course is for test laboratory managers, design engineers, project managers and technicians. It also helps quality and reliability specialists and acquisition personnel in government and military activities and their contractors. It is designed to serve the needs of personnel in a wide range of industries where equipment problems may be encountered during the shipment and use of their product.

BRIEF COURSE DESCRIPTION (See Course Outline) This course covers a wide range of topics associated with vibration and shock applications in order to enable the course participants to acquire a basic understanding of the complex field of vibration and shock. Each of the subject areas covered in this course have expanded coverage in their own three day courses for those individuals who need a more thorough understanding for their application.

Lectures and videotaped physical demonstrations show for example: how structures behave when mechanically excited, how to use pickups to sense input and response forces and motions, how to read out and evaluate the resulting electrical signals.

The course commences with an introduction to vibration and its effects and then proceeds to cover basic theory needed to understand the rest of the material covered. While mathematics are kept to a minimum, it is necessary to cover a sufficient amount so that the concepts of vibration can be understood. The course presents some basic theory of data acquisition, electronic filters and measurement systems.

Various types of vibration exciters or shakers are discussed next. Random vibration theory, including power spectral density theory, is discussed and video demonstrations show the effects of sinusoidal and random vibration. Some basic theory of spectral analysis, filters and vibration measurement systems provides a background for understanding data acquisition and analysis topics. The course touches on test fixture design for vibration testing.

Different types of sinusoidal and random vibration testing are discussed next. Material fatigue and the correct use of S-N curves for designing product life testing and developing accelerated product development testing procedures are covered.

An introduction to modal analysis and testing theory and application is addressed and its use for product design. Environmental stress screening including HALT and HASS applications are addressed.

Mechanical shock applications, including design to withstand shock, are discussed in some detail. Environmental test standards and specifications are surveyed, along with methods for tailoring of requirements for the test department. Finally, the course addresses reliability topics

DIPLOMA PROGRAMS This course is required for TTi's Mechanical Design Specialist (MDS) Diploma Program. It may be used to satisfy the Course 116 requirement for TTi's Environmental Engineering Specialist (EES) or Dynamic Test Specialist (DTS) Diploma Programs. It may be used as an optional course for any other TTi Diploma Program.

RELATED COURSES Course 116, Vibration for Test Applications and Course 117, Fundamentals of Vibration for Design Applications, cover some of the same topics as course 116/117, but place differing degrees of emphasis on testing vis-a-vis design. These courses (or any TTi course) may be presented on-site at your facility, for a group.

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.

ONDEMAND INTERNET COURSE 116/117 features over nineteen hours of video as well as more in-depth reading material. All chapters of course 116/117 are also available as OnDemand Internet Short Topics. See the on-line course outline for details.

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Introduction
Overview, Vibration Test Equipment, Fixtures, Testing • Statistical Evaluations • Time-History Properties • Spectra • Shock Response

Introduction to Vibration
Design and Testing for Vibration and Shock • Rotational Unbalance Example • Vibration and Shock Examples Natural Frequency, Forcing Frequency and Resonance Prolonged Excitation of Natural Frequency

Basic Concepts and Terminology
Decibels • Power and Voltage Ratios • dB Conversions • Logarithmic vs. Linear Scaling • Sound Perception • Octaves 1/3 Octave Bandwidth • Center Frequency

Dynamic Force and Motion
Laws of Motion; Weight, Mass, Gravity, Weight Work, Power, Energy • Some Fundamentals of Dynamics Degrees of Freedom • Single-Degree-of-Freedom (SDoF) Radians Sinusoidal Waveform • Displacement, Velocity, and Acceleration Application of Decibel Ratios • Natural Frequency • Transmissibility Isolation • Damping • Vibration Isolators • Modal Testing, Analysis

Electronic Filters and Measurement Systems
Capacitors in DC Circuits • RC Time Constant • Filtering • Low-pass, High-pass and Bandpass Networks • Integrating and Differentiating Circuits • Understanding RMS • Complex Signals Pyroshock • Random Signals

Introduction to Random Vibration
Sinusoidal, Complex and Random Vibration • Demonstration: Effects of Random Vibration • Statistics Applied to Random Vibration • Probability • Normal Distribution • Continuous Probability Distribution • Random Data • Time-History Properties Spectra • Comb Filter Analogy • Spectral View • Computing and Graphing Power Spectral Density

Introduction to Vibration Exciters (Shakers)
Mechanical Shakers • Electrohydraulic (EH) Shakers Electrodynamic Shakers • Armature • Force Rating, Available Acceleration • EH Displacement and Velocity Limits • Maintenance Piezoelectric Shakers • Table/Head Expanders • Oil-Slip Tables Combined Environmental Reliability Testing (CERT)

Introduction to Test Fixtures
Purpose of a Fixture • Fixture Fabrication Methods • Typical Fixtures • Evaluating Fixtures • Orthogonal Motion and Crosstalk Fixture Design Criteria • Example

Introduction to Power Amplifiers
Harmonic Distortion • Non-Linearity Distortion • Shaker Armature Electrical Resonance • Resonant Loads

Vibration Measurement
Ideal Transducer • Velocity Sensing • Optical Wedge—Estimating Displacement • Displacement Sensor • Strain Measurement Problems with Strain Gages • Wheatstone Bridge • Measuring Vibration Displacement, Velocity • Accelerometers • Mounting Methods • Cables • Signal Conditioning • Charge Mode Sensors and Amplifiers • Selecting a Measurement System

Basics of Spectral Analysis
Time and Frequency Domain • Spectral Analysis • Fourier Transforms • Phase Component • Spectrum Analyzers • PSD Transfer Functions • Data Acquisition • Shannon's Theorem Nyquist Frequency • Aliasing • FFT Distortion • Windowing

Vibration Testing
Types of Vibration Testing: Development, Qualification, Acceptance, Screening, Reliability, Durability and Functional Tests • Accelerated Testing • Vibration Testing Control • Function Generators • Control Accelerometer • Unwanted Table Movement, Axial Resonance • Multiple Degrees of Freedom Testing

Sine Vibration Testing
Sine Vibration Testing • Closed Loop Control • Sine Sweeps Control of Vibration Systems

Random Vibration Testing
Calculating RMS From PSD • Gaussian Random Signal Standard Deviation • Statistical Degrees of Freedom • Accuracy/Confidence vs. DOF • Time and Frequency Domain Terminology • Transfer Functions • Sine on Random (SoR) and Random on Random (RoR) Tests • Overtest Protection

Fatigue
S-N Curve • Stress Concentration • Fracture Mechanics, Toughness • Crack Propagation • Failure Models, Mechanisms • Time-Dependent Failures • Inverse Power Law • Fatigue Damage • Miner's Hypothesis

Modal Analysis:
Applications • Modes • Theoretical Approach • Exciting a Structure Impulsively • Structural Dynamic Relationships, Modal Testing and Measurement

Accelerated Testing
Step Stress Tests • Margins • Assumptions • Forcing Functions • Linear vs. Nonlinear Product Response • Coffin-Manson Inverse Power Law • Cautions • Unrealistic Failure Modes and Mechanisms • Synergistic Failure Exaggeration Cycles • Traps and Pitfalls

Environmental Stress Screening
Exponential Failure Model • What is ESS? • ESS vs. Test Objective: Remove Flawed Equipment • Myths • ESS Process Plan • Step Stress Tests • Highly Accelerated Stress Screening (HASS) • Highly Accelerated Life Testing (HALT)

Introduction to Mechanical Shock
What is Shock? • Causes, Effects and Remedies of Shock Transient or Shock Tests • Transient Duration • Shock Pulses: Half-Sine, Trapezoidal, Sawtooth • Transient Testing • Use of Electrodynamic Shakers • Shock Test Machines: Pendulum, Pneumatic Drop, Free-Fall • MIPS Table • Transient Tests: Analysis Options • Shock Response Spectrum (SRS) • SRS Mechanical Analog • Element Dynamic Response • Filter Elements • SRS Analysis • SRS vs. Fourier Analysis

Design to Withstand Shock
Shock Resistant Design • Isolation • Ideal Isolators Examples • Protective Packaging • Harmful Environments Product Fragility Damage Boundary • Step Velocity and Step Acceleration

Standards vs. Specifications
Standards vs. Specifications • Prominent Standards

Introduction to Reliability
Statistics of Life Tests • Reliability, Availability, Maintainability (RAM) • Engineering and Management Tasks • Quality

Summary • Final Quiz

Award of Certificates for Successful Completion

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