System Data

Calibration Systems — Types 9636, 9610

USES:

- ❍ Vibration transducer calibration
- ❍ Fulfilment of legal and contractual obligations such as ISO 9000

9636:

- ❍ Primary system using laser light as an absolute reference
- ❍ For calibration results of the highest accuracy
- ❍ Recommended system for producing primary, transfer and working reference standards

9610:

- ❍ Secondary system using working reference standards from primary systems like the Type 9636
- ❍ Fast and easy high-accuracy calibration requiring little calibration skill
- ❍ Recommended system for calibrating large numbers of transducers

FEATURES:

- ❍ Turn-key delivery including installation and training

9636:

- ❍ Calibration accuracy: 50 to 499 Hz, 0.5%; 500 to 5 kHz, 0.8% at a 95% Confidence Level
- ❍ Easy-to-align Michelson interferometer with transverse mount for moving the interferometer in the horizontal plane

9610:

- ❍ Typical calibration time of 3 to 10 minutes
- ❍ PC-based semi-automatic software control
- ❍ Database with complete product data setup and room for a large number of measurements
- ❍ Calibration accuracy 5 to 10 Hz: 0.99%, 10 Hz to 4 kHz: 0.91%, 4 to 7 kHz: 1.4%, 7 to 10 kHz: 2.0% at a 95% Confidence Level

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Primary Vibration Transducer Calibration System Type 9636

The Primary Vibration Transducer Calibration System Type 9636 follows the guidelines given in ISO publication 5347, “Methods of calibration of vibration and shock pick-ups”, paragraph 6.2.1, “Calibration method by measuring displacement amplitude and frequency”.

The method is an absolute one in which the displacement amplitude is measured via laser interferometry.

The accelerometer to be calibrated is mounted on a vibration table, excited sinusoidally at a known frequency and the measured peak-to-peak amplitude of the displacement of the table permits the exact acceleration to be calculated.

The System Type 9636 is a turn-key system which is installed by a Brüel & Kjær calibration engineer.

Vibration Transducer Calibration System Type 9610

The Vibration Transducer Calibration System Type 9610 is an easy-to-use PC-based system which, after a few preliminary manual control settings, enables automatic calibration of a wide range of accelerometers and velocity pick-ups.

To ensure high calibration accuracy, special attention has been paid to system and standard verifications. The system verification involves a series of automatic measurements to check that the system is warmed up and producing stable measurement results.

The standard verification ensures that the Standard Reference Accelerometers Type 8305 and Calibration Sets Type 3506, which are used as charge and voltage standards, are within the tolerance for valid calibration measurements. The calibration system must pass the verification tests before a valid calibration can be performed.

The System Type 9610 is a turn-key system which is installed by a Brüel & Kjær calibration engineer.

Overview

Brüel & Kjær calibration systems have been developed to provide the best possible foundation for confidence in vibration measurements.

Calibration is a way in which to establish a link to a physical quantity within a defined degree of accuracy. For legal or contractual reasons you may require evidence of the accuracy of a transducer – perhaps with respect to international standards.

If you are using an accelerometer in a particular set-up or environment in which the performance of the accelerometer has not been documented in its calibration chart, it will be necessary to perform a calibration for that particular application.

Methods

Calibration information is often more than a sensitivity test. It may include frequency response, capacitance and weight as well as environmental effects.

Sensitivity calibrations can be divided into three distinct groups:

- Absolute methods, including laser interferometry and reciprocity techniques.
- Comparison methods, including the back-to-back method
- Calibrators, involving the use of a vibration exciter of known vibration level (simple instrument calibration, described elsewhere).

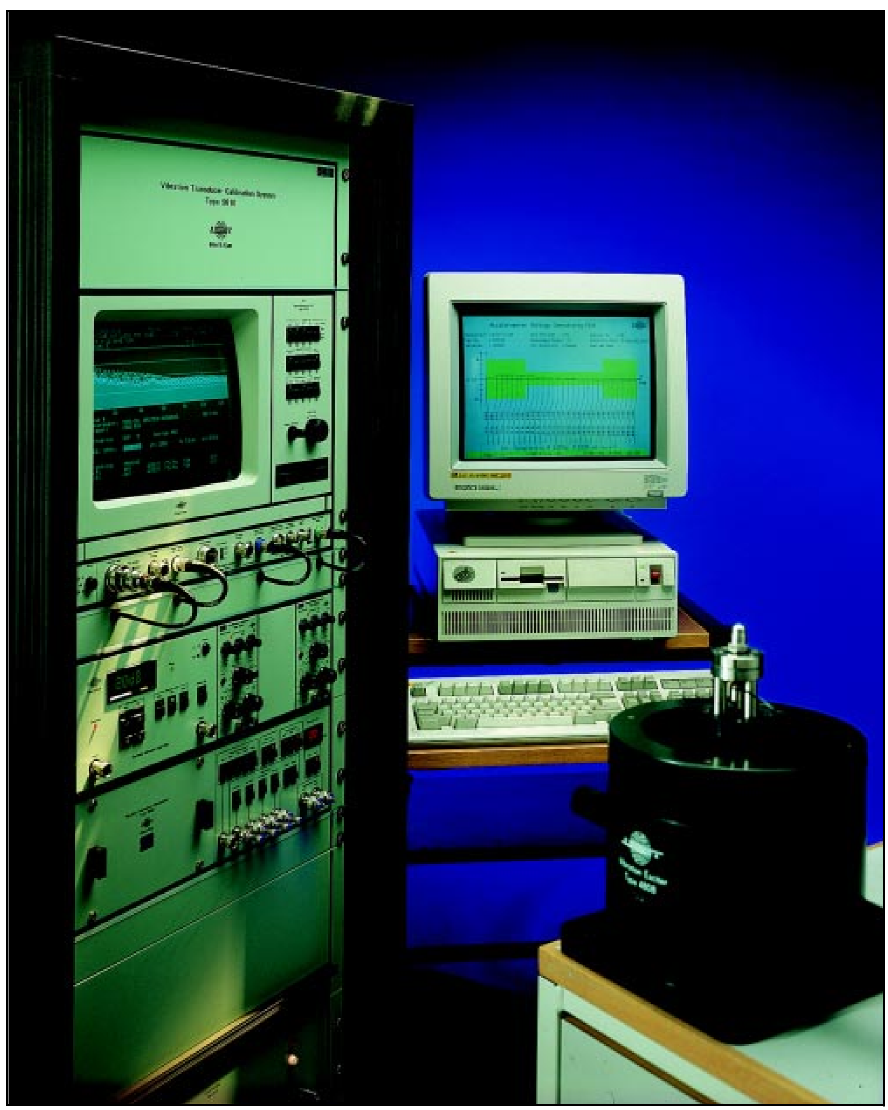

Fig.1 Calibration System Type 9610

Laser Interferometry (System 9636)

Principles

In this method of calibration, the accelerometer to be calibrated is mounted on a vibration table which is excited sinusoidally at a known frequency. Measurement of the peak-to-peak amplitude of displacement of the table permits the acceleration to be calculated. The sensitivity is obtained by measuring the electrical output of the accelerometer and dividing by the acceleration.

Frequency, the reciprocal of period, is measured in s^{-1} (Hz), while the displacement is measured in metres (in practice, sub-multiples of metres). As seconds and metres are SI base units, the output is measured in volts or coulombs, SI derived units. The method is therefore an absolute one.

At the calibration frequency of 160 Hz an acceleration of $10\,ms^{-2}$ RMS corresponds to 20.0 µm peak-to-peak displacement, and the most practical method of measuring this relatively small amplitude to much better than 1% is an optical interferometric one using a helium-neon laser with a wavelength of 632.8 nm.

The apparatus takes the form of a Michelson interferometer, with a beam splitter and two mirrors, one fixed and one formed of the upper surface of the accelerometer to be calibrated. A photodetector with a fast response is located in the re-combined light beam, where it detects a succession of intensity maxima and minima as the accelerometer motion alters the length of one of the light paths. The amplified output frequency of the photodetector is compared with the excitation frequency, using a frequency ratio counter.

Because the light traverses the path to each mirror twice, displacement of a moving mirror a distance of half a wavelength at right angles to the mirror plane is sufficient to effect one complete intensity fluctuation cycle at the photodetector. Thus if the peak accelerometer excursion is A_0, the total displacement of the moving mirror is $2A_0$ and the number of fringes counted in one traverse is $4A_0/\lambda$. The number of fringes counted in one vibration cycle would be $8\,A_0/\lambda$. With the excitation conditions described, the average fringe frequency is 28.5 kHz. However, the instantaneous fringe frequency will vary from zero at the peak displacement of the accelerometer (when its velocity is also zero) to a maximum of 44.7 kHz at its mid-position (when its velocity is also maximum).

Laser interferometry enables the double displacement of the exciting vibration to be measured to very high accuracy. However, deriving the sensitivity of an accelerometer from this involves other measurements, as well as assumptions (such as the assumption of excitation purity) whose errors are cumulative. The net error is estimated at ± 0.5% at a 95% confidence level. Laser calibration requires a fairly heavy investment in specialised equipment, and is therefore not well suited for calibration by the average accelerometer user.

Environmental Conditions

The Primary Vibration Transducer Calibration System Type 9636 is designed to be operated under stable and well-defined environmental conditions. The system should be mounted in a vibration free environment such as a basement with a stable floor, which is resting directly on the ground. The shaker and interferometer require heavy foundations, and in order to keep shaker vibration from reaching the interferometer there must be a separate foundation for each.

It might be useful to consult the paper "ISA RP52.1, Recommended Environments for Standard Laboratories" for some ideas as to the recommended levels for environmental vibrational noise.

Rack Mounting

The individual instruments in the Primary Vibration Transducer Calibration System Type 9636 are mounted in a 19 inch instrumentation rack. A master power switch at the base of the rack, controls the AC power for all instruments in the system except for Power Amplifier Type 2707 which is separately powered with three-phase 380 V or 440 V AC. The instruments are carefully installed in the rack and tested to eliminate any possible ground loops.

Instrumentation

The Michelson Interferometer consists of a beam splitter (semi-reflecting mirror), a reference mirror and a photodetector. The laser beam is directed at the surface to be calibrated. The beam splitter is located in the laser beam's path and directs some of the light reflected from the accelerometer on to a photodetector. Another part of the laser light reaching the photodetector comes via the beamsplitter and the reference mirror of the interferometer, thus generating fringes at the detector.

The Sine Generator Type 1051 generates the selected calibration frequencies for the Power Amplifier Type 2707.

The Power Amplifier Type 2707 amplifies the sine signal generated by the Sine Generator Type 1051 to provide the Vibration Exciter Type 4811 with sufficient power to excite the transducers at the g-levels required for calibration.

The Reference Accelerometer Type 8305 is laser calibrated at various frequencies at the Danish Primary Laboratory of Acoustics (DPLA). The 8305 is used for checking the function of the system as well as for round-robin testing in cooperation with other primary laboratories.

The Precision Conditioning Amplifier Type 2650 is used to condition the transducer output signal before measurement with the RMS voltmeter.

The Measuring Amplifier Type 2636 amplifies the output from the Photodetector. The output signal from the 2636 is then used as an external clock signal for the ratio Counter.

The Ratio Counter WQ 1011 calculates the ratio between the frequency of the Sine Generator Type 1051 and the output of the photodetector.

The High-precision RMS Voltmeter WQ 1010 is used for the accurate measurement of output signals from the transducers and transducer amplifiers.

The Signal Analyzer Unit Type 2035 is used for checking the harmonic distortion of the accelerometer signal and for finding the minimum (J1) points during Bessel measurements. The analyzer is equipped with two 25 kHz input modules and a generator module.

The Two-channel Rack Mounted Oscilloscope WQ 1139 is used during the laser beam adjustment procedure. One channel is connected to the accelerometer signal output and the other channel is connected to the detector output. These signals need to be displayed during the laser beam adjustment procedure to obtain the best possible detector signal.

Delivery Conditions

The system is delivered with all the electronics installed in a rack (except the analyzer) and air vibration isolators for the interferometer. The two foundations on which the shaker and interferometer are mounted are not included. Service and instruction manuals are included with all the instruments. How to use the system is described in a System Instruction Manual included with the turn-key system from Brüel & Kjær Customized Systems.

Training and Installation

Before shipment from Denmark, a performance test is carried out on the system. The system is then installed and verified at the customer's site, after which training will commence. The total installation and training time is approximately one week. (Subject to discussion according to customers background and special wishes.)

General Comments

The Reference Accelerometer Type 8305 is calibrated at the Danish Primary Laboratory of Acoustics. An additional calibration at another institute like PTB or NIST can be arranged with system delivery, but is not included in the standard proposal.

Back-to-back Calibration by Substitution (System 9610)

In traditional back-to-back calibration, the device under test is mounted back-to-back with a working standard accelerometer, and the combination is mounted on a suitable vibration source. The input acceleration to each accelerometer is identical. Consequently, the ratio of their sensitivities is simply the ratio of their outputs. The accuracy obtained with the back-to-back calibration method is improved by using the substitution technique.

Two back-to-back measurements. are made. Initially, the transfer function between the working standard accelerometer and the standard reference accelerometer is measured and stored. Then the transfer function between the device under test and the working standard is measured and stored.

During the two measurements, the working standard accelerometer remains fixed to the exciter head, while the standard reference accelerometer and the device under test are individually compared to it. The method of back-to-back calibration by substitution offers the following advantages:

- ❍ Cancellation of systematic errors contributed by the electronics.
- ❍ Only the standard reference accelerometer and the precision attenuator need to be recalibrated.
- ❍ Many mounting configurations are possible because the device under Test is mounted on the adaptor plate/working standard, not directly on the reference transducer.
- ❍ Simultaneous calibration over a wide frequency range by random excitation.

The accuracy of the presented FFT-calibration technique is comparable to that attained by dedicated comparison systems.

Instrumentation

The 9610 system uses two vibration exciters. Type 4808 covers the frequency range 5 Hz to 5 kHz, and Type 4809 covers 10 Hz to 10 kHz. The vibration exciters can be supported by an optional stand mounted on a granite block on vibration isolation pads. The stand rests on shock absorbers and levellers, or wheels.

A fixture mounted on top of the Type 4808 vibration exciter houses the working standard accelerometer. The standard reference accelerometer or the device under test is mounted on top of the fixture. No fixture is used with the Type 4809 vibration exciter; the working standard is mounted directly onto the exciter table, and the standard reference or the device under test is mounted on top of the working standard.

The 9610 system includes two matched Reference Standard Calibration Sets Type 3506. One set is used as a reference. The other is used in verification measurements to check the reference. Each calibration set consists of a Standard Reference Accelerometer Type 8305 and a Conditioning Amplifier Type 2626, which are laser calibrated as a pair.

The Signal Analyzer Type 2035 measures the autospectra of the transducer signals and the cross-spectrum between them. It then calculates the transfer function between the two signals. The analyzer also generates the random noise signal supplied to the vibration exciters.

The Precision Attenuator Type 5936 is used in the calibration system to minimize systematic error by eliminating range switching in the analyzer.

The Vibration Transducer Multiplexer Type 5923 is especially designed to interface between the transducers and other instruments.

The system includes an IBM-compatible PC and laser printer. Vibration Transducer Software WT 9301 runs on the PC and controls the calibration system.

9610 Software

System 9610 calibration software is a user-friendly program that minimizes manual operations, automating and simplifying the transducer calibration procedure. The software includes on-screen help, plus built-in checks to prevent errors. A comprehensive database contains all relevant data for the vibration transducers. When a particular transducer is selected for calibration, the nominal sensitivity is automatically set, along with the frequency range and tolerance limits for the calibration measurement. The software then selects either accelerometer charge, voltage, or velocity pick-up calibration. The user is prompted to configure the system properly, and to set the correct control values on the conditioning amplifiers.

The software also features a calibration database, which contains a history of calibrations for each transducer, including relevant data for the two matched Reference Standard Calibration Sets Type 3506.

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