Automated Accelerometer Calibration From 1 Hz To 50 kHz

Technical Paper 292

By Thomas Chandy, Lewis Ensor, and Roger Volk

AUTOMATED ACCELEROMETER CALIBRATION FROM 1 HZ TO 50 kHZ

Thomas Chandy, Lewis Ensor, and Roger Volk

AUTOMATED ACCELEROMETER CALIBRATION FROM 1 HZ TO 50 kHZ

THOMAS CHANDY, Marketing Manager, Electronics, Systems and Services, ENDEVCO®
LEWIS ENSOR, Consultant, ENDEVCO
ROGER VOLK, Technical Services Manager, ENDEVCO

INTRODUCTION

Research at many laboratories is aimed at obtaining solutions to unique measurement problems through improvements in frequency response of piezoelectric (PE), piezoresistive (PR), and variable capacitance (VC) accelerometers. The success of this research effort depends on the availability of calibration systems for these different types of transducers that can measure accelerations in low (less than 5 Hz) and high (greater than 10 kHz) frequency environments. To ensure minimum measurement uncertainty when calibrating accelerometers across an expanded frequency band, the fundamental issue to be kept in mind is that; an accelerometer calibration system is exactly that, a system consisting of electrical and mechanical components. No matter how well the individual components are designed, the measurement uncertainty of the system depends on how well the mechanical and electrical components of the system are integrated. The measurement technique selected should take into account the sources of uncertainty as all the system components, and their human user, interact with each other.

This paper presents the key issues that must be addressed in building a high-quality comparison calibration system that can calibrate accelerometers of many types, as well as velocity coils from 1 Hz to 50 kHz. Methods of minimizing systematic uncertainty, including automation and internal self-calibration of the measurement system, are examined in this paper.

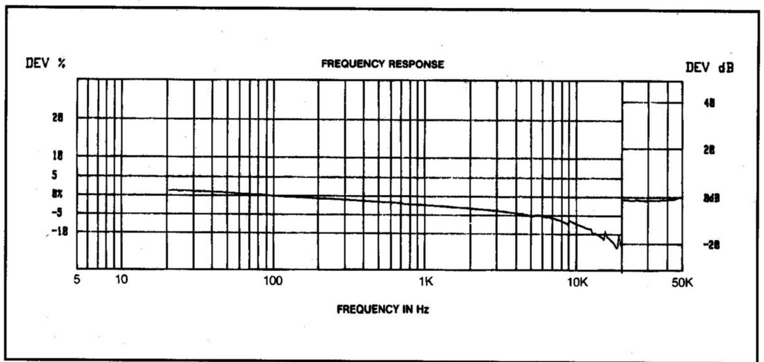
HISTORY

Point-to-point vibration calibrations are performed at frequencies from 1 Hz up to 25 kHz at the United States National Institute for Standards and Technology (NIST, formerly known as the NBS) and at other primary standards laboratories. Transducer sensitivity is calculated from measurements of the amplitude and frequency of vibration and transducer output. Typically, the amplitude of the vibration at these frequencies is measured using fundamental measurement techniques such as interferometry and/or reciprocity. The sensitivity is applicable only at the specific frequencies where the calibration is performed. In order to ensure that there are no minor resonances over the frequency range, calibrations must be performed at many frequencies. The frequency response results of high-quality reference accelerometers are expected to agree, within measurement uncertainty, with theory for a transducer spring-mass system performance with a zero damping ratio and no minor resonant frequencies.

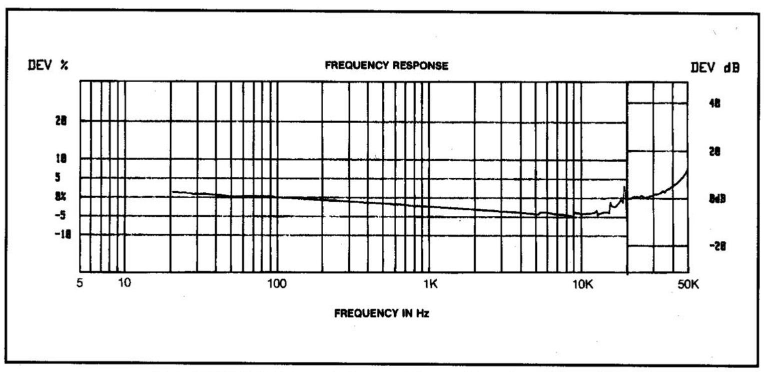
This method is very time-consuming and costly, and therefore is normally used only to establish the calibration of reference standard accelerometers at NIST and other primary standard laboratories.

Comparison calibrations are also performed at various laboratories at frequencies from 1 Hz to at least 50 kHz. The frequency may be continuously swept with an analog system, or single frequency calibrations may be performed. With the use of computer-controlled digital calibration systems, many calibrations may be performed at many different frequencies in a short period of time. This allows comparison calibrations to be routinely performed from 1 Hz up to 50 kHz on each transducer.

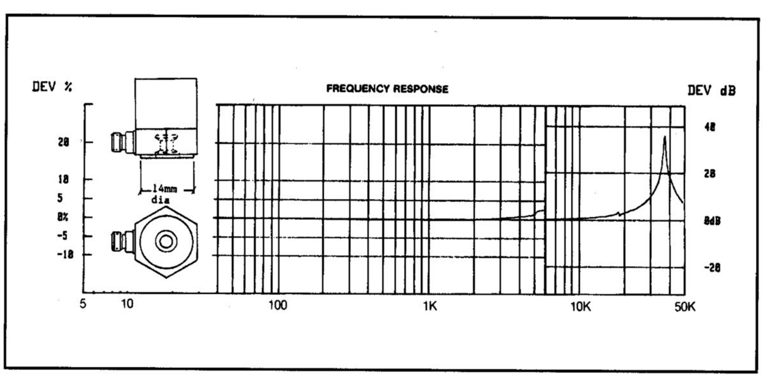
ENDEVCO CORPORATION, 30700 RANCHO VIEJO ROAD, SAN JUAN CAPISTRANO, CA 92675 USA (800) 982-6732 (949) 493-8181 fax (949) 661-7231
www.endevco.com Email:applications@endevco.com
0101



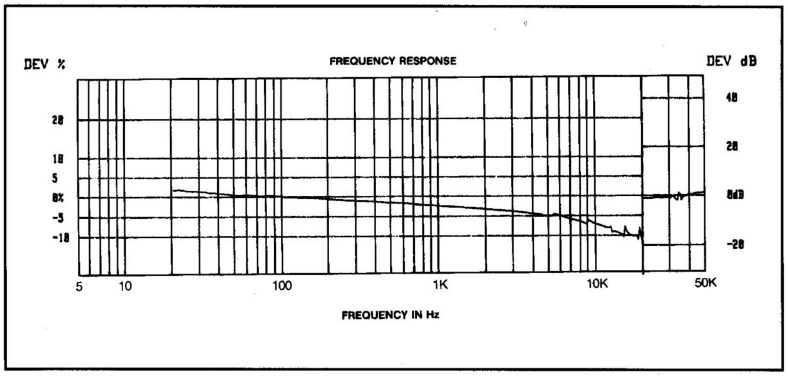
Model 2250AM1-10 Accelerometer, mounted on shaker table
Figure 1A



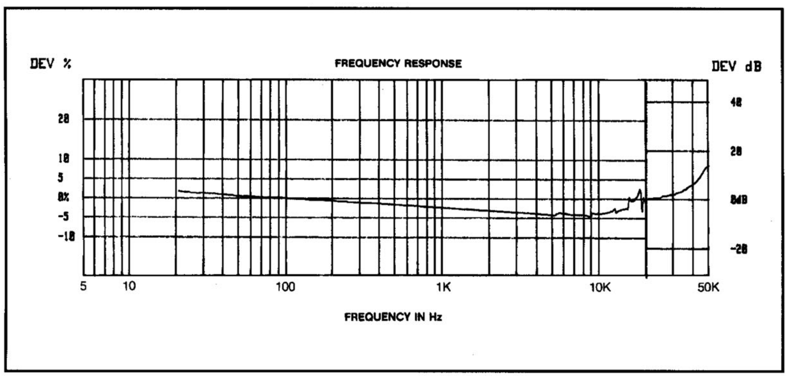
Model 2250AM1-10 mounted on steel fixture, 16mm hex x 10mm high
Figure 1C



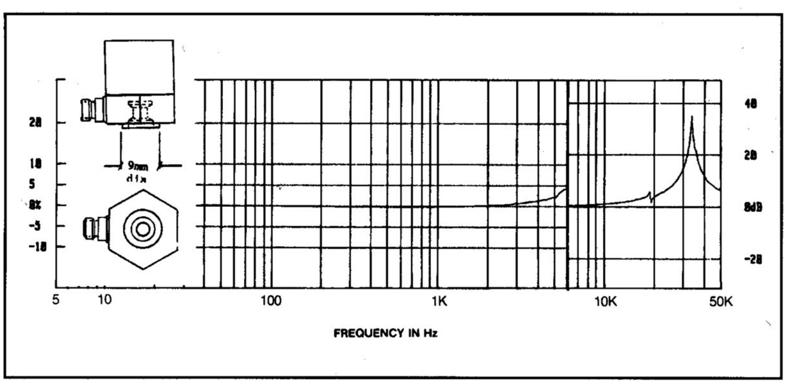
Frequency response of Model 2272 Accelerometer
Figure 2A



Model 2250AM1-10 mounted on beryllum fixture, 16mm hex x 10mm high
Figure 1B



Model 2250AM1-10 mounted on aluminum fixture, 16mm hex x 10mm high
Figure 1D



Frequency response of Model 2272 Accelerometer with reduced mounting area

The comparison is performed relative to a "back-to-back" reference accelerometer. Some accelerometers have been routinely calibrated, for many years, up to 15 kHz, 20 kHz and even 30 kHz. For example, Endevco Models 7240A and 7259A Accelerometers are calibrated to 20 kHz and 30 kHz, respectively. However, for data above 10 kHz the sensitivity that was used for the reference accelerometer was the computed response from theory. Therefore, no uncertainty was reported in the past for calibrations performed above 10 kHz.

A fully automated computer-controlled vibration calibration system, and an Endevco calibration service are now available, for accelerometers of various types including PE, PE with integral electronics such as the Endevco Isotron®, PR, and VC, as well as for velocity coils. Calibrations can be performed from 1 Hz to 50 kHz. Some important aspects of the system design and sources of measurement uncertainty are discussed below. Measurement uncertainties from 1 Hz to 25 kHz have been improved and documented.

EQUIPMENT REQUIREMENTS

In building a high-quality accelerometer calibration system, the design and selection of the various electrical and mechanical components of the system is critical to its performance. Of equal importance is the integration of these components into a system with its own unique set of operating procedures. Self-calibration must be included in the system if measurement uncertainties are to be controlled for the components. A key feature is computer-controlled automation of system operation and self-calibration. Sensitivity to operator technique is thereby greatly reduced and all component settings and levels are repeatable and accurately documented. At Endevco we approached the hardware selection process from three perspectives:

- Reference transducers
- Vibrators
- Electronics

REFERENCE TRANSDUCER REQUIREMENTS

High resonant frequency:

For lower measurement uncertainty, a reference transducer is best used at frequencies less than $^1/_3$, and ideally at less than $^1/_5$ its resonant frequency. In this range its sensitivity is more nearly flat and repeatable. In addition, distortion from third harmonic signal generator power amplifier output is then not within calibration range. Harmonic distortion from accelerometer outputs is observed to be much larger than one might expect from the small distortion on the power amplifier output waveform. However, remember that the accelerometer sensitivity at resonance is typically more than 100 times the sensitivity value at a frequency of $^1/_3$ the resonant frequency. Therefore, 0.1% power amplifier distortion results in 10% accelerometer output distortion due to third harmonic distortion. Distortion may also be observed to a lesser degree from second, fifth and other harmonics. Thus, for calibration at higher frequencies the resonant frequency of the reference transducer should be appropriately high. We use the Endevco Model 2270M7A with f_n = 80 000 Hz for calibrations from 5 Hz to 25 kHz and resonant frequency searches up to 50 kHz.

Table 1 shows the importance of a high resonant frequency in the reference accelerometer selected for 20 kHz applications. The sensitivity of an accelerometer at 20 kHz, for example, will be 6% higher if its mounted resonant frequency changes 2% from 30 kHz to 29.4 kHz. However, the sensitivity at 20 kHz will be only 0.3% higher if a change of 2% occurs from 80 kHz to 78.4 kHz. Changes in the mounted resonant frequency of accelerometers do occur, especially if proper care and procedure are not observed during installation.

Theoretical sensitivity deviation at 20 kHz versus resonant frequency (Fn)

Fn Changes, %	Fn, kHz	20 kHz Sensitivity Dev., %
0	30.0	+80
-1	29.7	+83
-2	29.4	+86
-5	28.5	+97
0	40.0	+33
-1	39.6	+34
-2	39.2	+35
-5	38.0	+38
0	80.0	+ 6.7
-1	79.2	+ 6.8
-2	78.4	+ 7.0
-5	76.0	+ 7.4

Table 1

Mass loading:

At high frequencies another source of increased measurement uncertainty is mass loading. It is important to note that the resonant frequency of the vibrator assembly is reduced with the addition of accelerometers and fixtures. For example, the resonant frequency due to the housing stiffness of a typical "back-to-back" reference accelerometer with the unit under test (UUT) mounted is less than 30 kHz. This is much lower than the 50 kHz achieved with the system discussed in this paper. This high frequency is made possible by building the Endevco Model 2270M7A Reference Transducer into the vibrator armature. Using a lightweight (17 gm) transfer standard such as the Endevco Model 2270M8 further minimizes the measurement uncertainty resulting from mass loading.

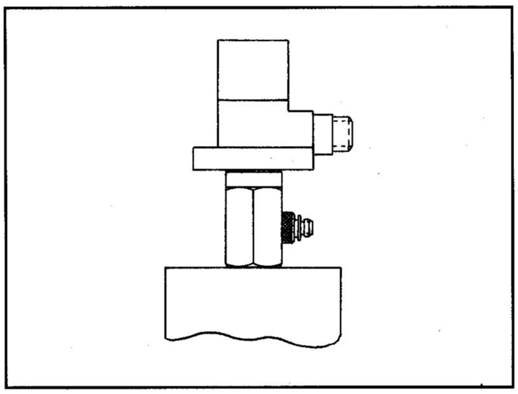
Signal-to-noise ratio:
At low frequencies, on the other hand, the overriding issue determining measurement uncertainty is signal-to-noise ratio. The reference accelerometer must have high sensitivity to provide a large signal at the low accelerations that are generated at low frequencies. In addition, the reference accelerometer should have a flat, low frequency response. We use the Endevco Model 7751-500 with a sensitivity of 500 mV/g and a low frequency response that is within 5% at 1 Hz as our reference accelerometer in the 1 Hz to 200 Hz frequency range.

VIBRATOR REQUIREMENTS
HIGH FREQUENCY

High axial resonant frequency:
The vibrator (shaker) is a key element in providing quality, uniaxial, sinusoidal, acceleration calibration. The Endevco Model 2901 Air Bearing Electrodynamic Vibrator that we use incorporates the Endevco Model 2907 Armature with a high axial resonant frequency of near 50 kHz, and therefore provides a nearly flat operating range up to 25 kHz.

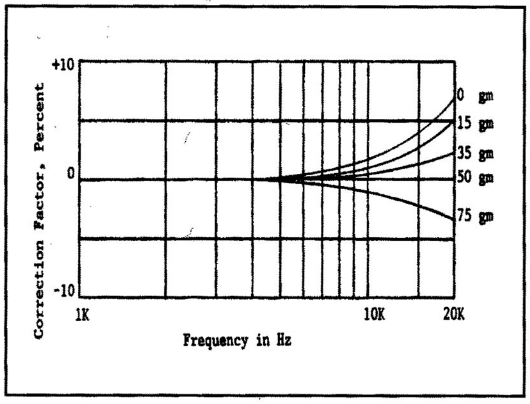
Beryllium armature:
Comparison calibration requires that both the reference accelerometer and the unit under test (UUT) experience the same acceleration. Any adaptor fixture will act as a spring between the UUT and the armature surface. The softer the spring, the lower the resonant frequency of the spring mass system represented by the fixture plus UUT. Thus, at high frequencies, the stiffness of the mounting table, and/or the fixtures, controls the relative motion between the two accelerometers. The effect of relative motion may be observed in the data in Figures 1(A) through 1(D), where mounting adaptors of identical dimensions but different materials were used. Relative motion errors of greater than 10% were observed at 20 kHz when the steel or aluminium fixture was used. More accurate results are obtained when the adaptor used was made from a very stiff material such as beryllium; the data approaches the results with the accelerometer mounted directly to the vibration table. It is important to note that the Model 2907 Armature used with this system is made of beryllium and the Model 2270M7A Reference Accelerometer is built into this armature. The high stiffness (modulus of elasticity) of the vibrator mounting table between the internal built-in reference accelerometer and the UUT results in reduced relative motion at high frequencies. In addition, the mounting thread configuration provides for direct mounting contact to the vibrator table of the UUT base for various thread sizes and pitches. Intermediate adaptor fixtures are typically not required.

Large mounting surface:
The relative motion between the reference accelerometer and UUT is also affected by the weight of the UUT and the mounting surface coupling area. Therefore, with a heavier UUT, a proportionally lower resonant frequency will result, thus more relative motion. Similarly, if the surface mounting area of the UUT is reduced, stiffness is reduced and the mounted resonant frequency will also be reduced, resulting in larger deviations in sensitivity versus frequency (see Figure 2). Note that with the base seating area, shown in Figure 2B, the resonant frequency is reduced. Therefore, if the UUT base surface is not completely seated on the mounting table (see Figure 3), larger deviations will again result, due to a decrease in the mounted resonant frequency. To minimize measurement uncertainties resulting from insufficient mounting area, the Model 2907 Armature has a 5 cm (2 inch) diameter to accommodate large UUT base patterns.



Typical reduced seating area accelerometer mounting
Figure 3

Low mass loading effects:
The design of the Model 2901 Calibration Shaker also contributes to minimizing mass loading effects, first by incorporating the built-in Model 2270M7A reference standard in the Model 2907 Armature and second, by using a 130 gm mass armature, which is quite large for a high frequency shaker. Comparison calibrations have been performed to determine the effects of UUT weight on the relative motion of the Model 2901 Vibrator. For these calibrations a small accelerometer was mounted on the center of the vibrator table. Weights were fabricated with a hole in the center to allow mounting to the vibrator



Model 2901 Shaker, relative motion calibration
Figure 4

without removing the accelerometer. Figure 4 shows the calibrated relative motion corrections up to 20 kHz for the vibrator. Calibration of the vibrator relative motion is also performed when the transfer standard accelerometer is installed to perform a system calibration. However, this calibration applies for an UUT with a weight identical to that of the transfer standard. A separate transfer standard would be required for each UUT weight if the relative motion curves discussed previously were not employed. The relative motion curves can be stored in the controller data base and corrections for mass loading made automatically from this data when calibrations are being performed.

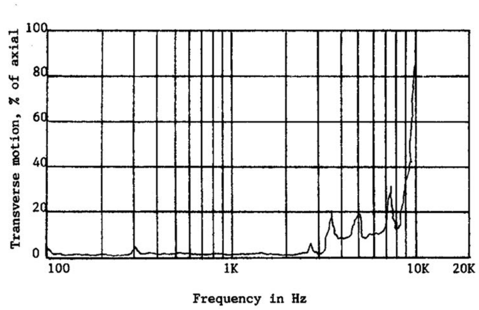
Transverse motion:
Transverse and rotational motion generated by the vibrator results in increased measurement uncertainty. The UUT and the reference accelerometer are unlikely to have the same transverse sensitivity and orientation relative to the transverse motion. The two accelerometers may not even experience the same magnitude of the erroneously-generated motion. Therefore, to minimize measurement uncertainty, the vibrator must maintain low transverse motion over the calibration frequency range. Transverse stiffness of most mechanical structures, including vibrators, is much lower than axial stiffness. Therefore, if a vibrator with an axial resonant frequency that was much lower than that of the Model 2901 were used, it is likely that it would exhibit several transverse resonant frequencies below 20 kHz. This can be observed in Figure 5A, which presents the large transverse motion generated in several frequency regions from a typical calibration shaker (<u>not</u> the Model 2901) that is specified for use in providing low uncertainty calibrations up to 10 kHz. On the other hand, it can be seen in Figure 5B that the Model 2901 Vibrator exhibits no large transverse resonant frequencies up to 20 kHz.

Accessories:
As previously discussed, mounting fixtures are to be avoided whenever possible. When required, special design features should be used to minimize added calibration uncertainties. When the active mass of an accelerometer is not centered at the center of the mounting hole pattern, a centering fixture will improve calibration uncertainties due to transverse motion. For example, a fixture is available to allow bolt mounting of triaxial accelerometers such as the Endevco Models 2223, 2228, etc. for calibration of the x- and y- axes. The design positions the accelerometers such that the center of gravity of the active mass is coincident with the center line through the vibrator armature and reference accelerometer. In addition, beryllium is used to minimize relative motion uncertainties at high frequencies. This design principle, which is also applied to mounting fixtures that are available for calibrating certain asymmetric style accelerometers and velocity coils, minimizes the measurement uncertainty due to vibrator transverse motion effects and approaches "back-to-back" configuration.

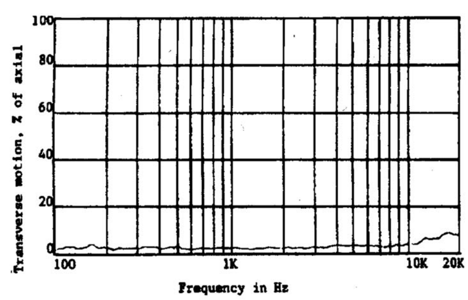
VIBRATOR REQUIREMENTS
LOW FREQUENCY

Signal-to-noise ratio:
At low frequencies signal-to-noise ratio is again the over- riding issue determining vibrator selection just as it is in reference transducer selection. The vibrator can contribute to increasing the signal by generating larger accelerations at low frequencies, which is only possible through an increased stroke. Typical calibration vibrators with strokes of 1 inch peak-to-peak or less will generate accelerations of less than 0.2 g at 2 Hz and 0.05 g at 1 Hz. In contrast the Endevco Model 29603 Air Bearing Electrodynamic Vibrator has a stroke of over 6 inch peak-to-peak, generating accelerations of 1.2 g at 2 Hz and 0.3 g at 1 Hz. This contributes to an increase in the signal at 1Hz by a factor of at least six times that available with conventional vibrators.

Other features:
Other sources of measurement uncertainty at low frequencies are waveform distortion, transverse motion, stray magnetic fields and temperature variations at the shaker table. The Model 29603 Long Stroke Vibrator, which can handle large transducers, however, has good waveform distortion, very low transverse motion (typi-



Transverse motion of typical shaker for precision calibration up to 10,000 Hz
Figure 5A



Transverse motion of Model 2901
Calibration Shaker
Figure 5B

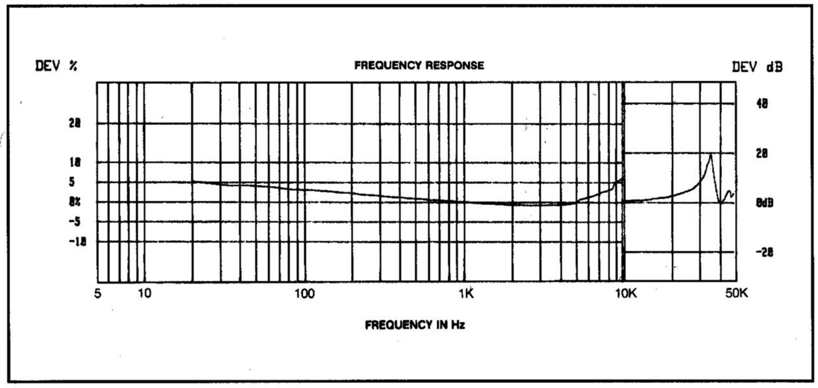
cally less than 1%), low magnetic fields at the vibrator table, and very low temperature changes at the table, even when run continuously at maximum output for long periods of time. The vibrator is also equipped with optical over-travel stops that ensure that it cannot be damaged as result of over-driving.

ELECTRONICS REQUIREMENTS

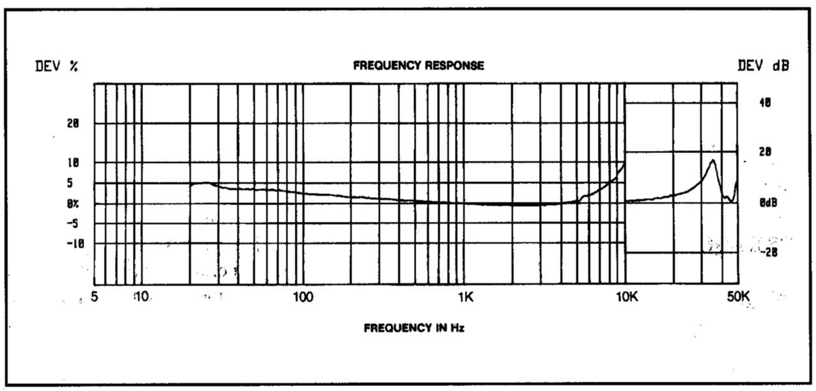
Signal conditioning:
Engineers and scientists involved in dynamic measurement use a variety of transducers. Accelerometers most commonly used include PE, Isotron, PR or VC. Velocity coils are another form of transducer used in such applications. Many facilities use combinations of accelerometer types, or sometimes combinations of acelerometers and velocity coils. A high quality automated calibration system should be capable of calibrating all of these types of transducers with relative ease. The Endevco CCAS™ family of computer-controlled low-noise signal conditioners was therefore selected. CCAS signal conditioners can accept signals from all of these different transducer types, and enables the user to use a single system to calibrate practically any type of accelerometer or velocity coil. Every setting on the CCAS is programmable, including gains, current levels for Isotron accelerometers, excitation voltages for PR accelerometers, shunt calibration for PR accelerometers, signal conditioner isolation, etc. We are therefore able to provide an extremely flexible calibration console while eliminating extensive set up time by an operator when switching from one type of transducer to another.

Ground loops:
Ground loop problems caused at power line frequencies are well known phenomena. Another source of measurement uncertainty, perhaps not as often acknowledged, comes from the power amplifier output. The driving coil is capacitively coupled to the armature of the vibrator. Therefore, a potential exists at the armature table. When the reference and UUT accelerometers both have their output low sides common with their housing mounting bases, a ground loop exists unless their respective signal conditioners do not have a common input ground. If a ground loop is present, the signal coupled from the power amplifier produces an error signal at the calibration frequency. The error signal will add or subtract according to the phase angle. The error signal normally increases as the frequency increases, due to the decrease in capacitive impedance. However, the error signal may decrease as the frequency increases when the vibrator approaches a resonance. This is because less voltage is required from the power amplifier near resonance to produce the required acceleration level, hence less potential for capacitive-coupled error.

The most severe effects of this ground loop error signal are observed when the UUT has a very low sensitivity. With the 0.8 pC/g accelerometer sensitivity in the calibration shown in Figure 6A, an error of about +3% at 10 kHz is observed in Figure 6B for data obtained when a ground loop was present.



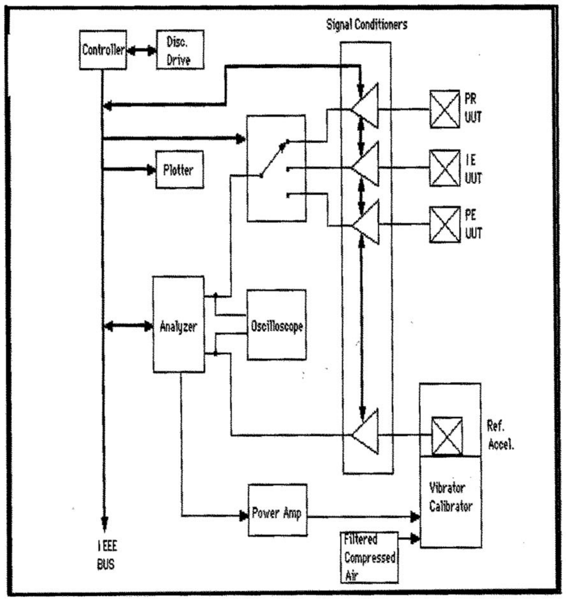
Frequency response of Model 2225 Accelerometer with 0.8 pC/g sensitivity at 1000 Hz
Figure 6A



Frequency response of Model 2225 Accelerometer with 0.8 pC/g sensitivity at 1000 Hz, with a ground "loop" created by common ground, both at reference and test accelerometer mounting and at signal conditioners
Figure 6B

It is important to observe correct grounding to ensure accurate calibration. Insulated mounting and isolated signal conditioners are typical methods employed to reduce ground loop problems. The Endevco Models 28952 and 28962 Calibration Systems go a step further by automatically performing a measurement (after the accelerometer is mounted and connected) to determine the ground conditions, and setting the signal conditioners appropriately. This eliminates the possibility of improper selection by the operator.

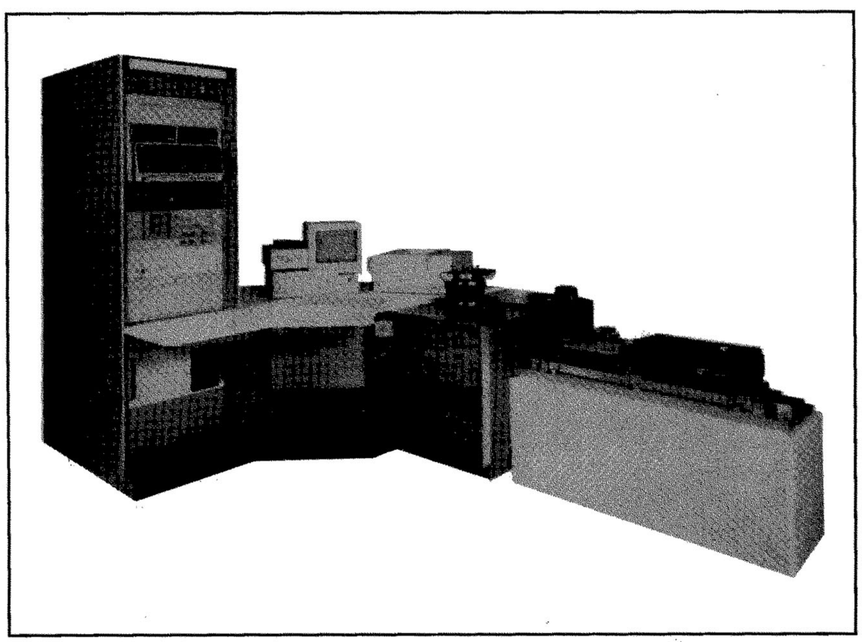
Automatic self-calibration:
The frequency response of the signal conditioner at different gain settings is a source of measurement uncertainty. The specified limits for typical signal conditioners for gain versus frequency at all gain settings are not adequate to meet the desired low measurement uncertainties of our calibration system. Therefore the system design incorporates an automatic self-calibration procedure to minimize this source of uncertainty. An end-to-end electrical comparison calibration is automatically performed over the entire frequency range to 50 kHz for each input channel at each gain range. The electrical calibration results are stored and applied to each UUT vibration calibration. The automatic self-calibration interval is user-selectable. The self-calibration procedure can also be initiated on demand.



System block diagram
Figure 7

In addition, each time an UUT is calibrated, the system gain ratio is automatically electrically calibrated at the user selected reference frequency for whatever gain is required. This procedure not only minimizes measurement uncertainty resulting from variations in the frequency response of different signal conditioners, but also virtually eliminates uncertainties due to signal condioner gain variations due to range accuracy, power line variations, temperature variations and stability over long time periods.

Gain versus frequency:
At resonance the output of an UUT may increase to more than 100 times the value at lower frequencies. Thus, if a constant signal conditioner gain setting were to be used for the entire sweep from the lowest calibration frequency through the resonant frequency, this gain would have to be very low. The signal conditioner gain would have to be set to $^1/_{100}$ of the value that could be set at the lower frequencies, in order to maintain the signal within full scale limits when resonance occurs. Thus the signal level would be less than 0.01 times full



Calibration system layout
Figure 8

scale during the lower frequency portion of the sweep, leading to increased measurement uncertainty due to decreased signal-to-noise ratio.

Noise and harmonics:
The system configuration is shown in the block diagram in Figure 7, and layout in Figure 8. In the calibration process the shaker is stimulated with a sinusoidal function, and the fundamental response of the test and reference accelerometers to that function is measured. The response will contain the original sinusoid and also noise, harmonics, possibly dc, as well as the accelerometer response to transverse resonances of the shaker that might be excited by the harmonics. The principal problem is to keep these unwanted components to a minimum, and to filter out those that are present in the response without imposing any other gain or phase change to the signals.

The low noise characteristics of the CCAS signal conditioners contibute significantly to increasing signal-to-noise ratio and minimizing noise as a source of measurement uncertainty. In addition, the system uses a Digital Analyzing Voltmeter (DAV) to measure the ratio of the UUT and the reference channel outputs. The DAV uses a technique known as correlation filtering of both channels simultaneously, to discriminate between the various components of the signals and to provide fast and precise measurement of the amplitude and phase response of the accelerometers to a single frequency sinusoidal vibration. This technique involves taking the signal and multiplying it with a pure sinusoid at the stimulation frequency, and integrating the result. This extracts the fundamental response, removes the extraneous signals, provides the response in the form $(a + jb)$ and minimizes measurement uncertainties due to noise, harmonics, and other extraneous signals. The quality of the filtering can be improved by increasing sample size. Sample size is adjustable by the user.

Environmental effects:
Variations in temperature and humidity are also a source of measurement uncertainty. Mil Std 45662A requires that temperature and humidity be recorded each time a calibration is performed. This is done automatically by the system. Temperature probes on both the Model 2901 High Frequency Vibrator as well as on the Model 29603 Low Frequency Vibrator and a humidty probe on the console are automatically monitored and recorded by the system at the time of each calibration, and the environmental information is printed on the calibration certificate.

System calibration:
As discussed earlier, a transfer standard is used to calibrate the entire system. The transfer standard shall have been previously calibrated, traceable to an absolute calibration method. The calibration values for the transfer standard are put into the system controller data base and maintained until some future recalibration of this standard. Both magnitude and phase values are entered where available. The transfer standard is mounted on the vibrator and a "console recalibration" is selected by the operator. A vibration sweep is generated by the computer, and the sensitivity of the vibrator reference standard is redetermined based on this comparison calibration and an electrical system calibration generated. The new vibrator reference standard sensitivity values for both magnitude and phase over the frequency range are stored in the system controller data base to be applied to UUT calibrations.

Operator technique sensitivity:
A factor often overlooked which can greatly affect the reliability of data is the operator. There are so many sources of measurement uncertainty that even the most experienced and careful calibration technician can make an error, or forget a step or setting essential to minimizing uncertainty, especially if he or she is handling a variety of transducer types and models. The approach we have taken in minimizing operator technique sensitivity can be termed "total automation." This approach provides on the one hand total flexibility when the console is in the "engineering mode," and on the other hand total rigidity when the console is in the "calibration mode."

In the "engineering mode" every setting on the console is accessible to the user, including frequency range, gain settings, signal conditioner isolation, sample size, acceleration levels, and so on. A detailed analysis shows that the measurement uncertainty values are also dependent upon the performance characteristics of the UUT to be calibrated. This is because the uncertainty sources such as transverse motion, temperature, etc. affect a specific transducer model in varying magnitudes in proportion to its sensitivity to the environmental error source. The user can therefore use the "engineering mode" to set up the console for the calibration procedure that will ensure minimum measurement uncertainty for a particular model of transducer. This set-up can now be stored in the "calibration mode" data base.

In contrast, in the "calibration mode" access to console settings is password-protected. This password system allows selection of various security levels of access to the data base. Thus, once the correct procedure for calibrating a particular transducer model has been defined this procedure can be "locked in." Consequently, with the exception of transducer mounting technique, the calibration procedure for that model will be repeatable.

Transducer mounting technique and surface conditions can also affect the uncertainty of the measurement and then repeatability of calibrations, particularly at high frequencies. A thin application of a lubricant or acoustic couplant, such as Endevco Part EHX 268, will minimize variations caused by friction and surface imperfections, and a torque wrench should be used to ensure repeatability in the installation of the transducers. These factors cannot be automated, and remain under the control of the operator.

Data storage:
The system is equipped with an optical disk drive that stores data from each calibration performed onto a removable 400 Mbyte optical disk. The use of large capacity storage makes the system ideal for statistical analysis and audits under the framework of a Total Quality Management (TQM) environment.

System measurement uncertainty:
The measurement uncertainties for the Endevco Model 28952 Calibration System are based on the relative motion curves being applied, the temperature being recorded at the time of the calibration, and UUT specifications of:

Less than	5.0	% transverse sensitivity
Less than	0.6	% sensitivity change per 10°C
Less than	5.0	equivalent g base strain output at 250 µstrain
Greater than	0.3	pC/g or 0.15 mV/g sensitivity
Less than	200.0	gms weight up to 10 kHz
Less than	75.0	gms weight up to 20 kHz
Greater than	25.0	kHz resonant frequency up to 10 kHz
Greater than	50.0	kHz resonant frequency up to 20 kHz

Calibration of accelerometers with characteristics outside these limits may result in increased uncertainties.

The systematic and random uncertainties were analyzed using root sum squared techniques, along with factors from statistical tables, to achieve a 99% confidence level. Total transfer uncertainty is determined to be $\pm$ 1.0% up to 10 kHz and $\pm$ 1.8% up to 20 kHz for the conditions described. The actual measurement uncertainty of the UUT will depend on the uncertainty asssigned to the traceable transfer standard used to calibrate the console.

System support:
A 9600 baud modem and remote communication software are incorporated into the system to provide the capability of communication between the system and the users' central computer network. This also provides the capability for rapid system support from the users' primary metrology facility to secondary or tertiary laboratories, or from Endevco to the user.

SUMMARY

A fully automated computer-controlled vibration calibration system is available for comparison calibration of sensitivity and phase for PE, IEPE, PR and VC accelerometers, as well as velocity coils at frequencies from 1 Hz to 50 kHz. The very high resonant frequency of the vibrator and internal reference accelerometer used from 5 Hz to 50 kHz, and the long stroke of the vibrator and the high-sensitivity and flat low-frequency response of the reference accelerometer used from 1 Hz to 200 Hz are key features of the system. These superior characteristics allow calibration to be carried out in a relatively "flat" operating range, which minimizes the magnitude of correction factors, thereby increasing repeatability and minimizing measurement uncertainty. Self-calibration of the entire system is automatically implemented at an user-selected preset time interval, or on demand by the operator. The operating conditions and procedure for each model number UUT can be pre-programmed in the system's password-protected data base. Operator technique sensitivity is virtually eliminated.

REFERENCES

1. K.T. Chandy, L. Ensor, and R. Volk, "High Frequency Accelerometer Calibration," Proceedings of the Institute of Environmental Sciences, New Orleans, April, 1990.

2. K.T. Chandy, L. Ensor and R. Volk, "Automated Accelerometer Calibration from 1 Hz to 50 kHz". Proceedings of the ADPA, Tennessee Valley Chapter, NCSL Symposium on ATE - Measuring Tommorrow, Huntsville, Alabama, June, 1990.

3. Mil-Std. 45662A

ENDEVCO
AN AMPHENOL COMPANY

10869 NC Highway 903, Halifax, NC 27839 USA

endevco.com | sales@endevco.com | 866 363 3826