SOUND & VIBRATION SYSTEMS SELECTION GUIDE
ABOUT THE MODAL SHOP

“Our name was chosen to combine the science of modal analysis, or structural resonance testing, and the full-service attitude of our “shop-like” organization. Serving the sound and vibration measurement marketplace, our teams work with research, design and manufacturing engineers throughout the public and private sectors. From miniature MEMS structures to colossal space structures, we strive to provide the dynamic testing and monitoring communities with a single source to simplify all your sound and vibration measurement challenges.”

CALIBRATION CONFIDENCE

at the highest level – serving Metrology Laboratories around the globe, The Modal Shop’s laser primary vibration calibration sets the standard in vibration metrology confidence with world-class uncertainties. The Modal Shop is accredited to the ISO 17025 standard and is recognized worldwide for calibration quality and excellence. Our teams participate in developing global standards for calibration of sensors for vibration, shock, dynamic pressure and acoustic transducers.

CULTURE OF QUALITY

and responsiveness – operating within a hybrid quality management system, The Modal Shop Quality System integrates standards (and philosophies) from ISO 9001, Lean Manufacturing and Kaizen to ensure excellence. With a core commitment to Total Customer Satisfaction, expect fast, friendly service and reliable product performance within the global markets and sound and vibration testing, as well as precision dynamic calibration.

CRAFTSMANSHIP

in handmade attention to detail while building precise, yet robust dynamic testing components. Attention to minute details, like the tension of the coil windings on our precision calibration exciters, are the heart of the design and performance of every product from The Modal Shop. Striking the balance between performance, reliability and simplicity, The Modal Shop engineering elegance has been a cornerstone in earning market leadership.

THE MODAL SHOP AND PCB AROUND THE WORLD

Our name was chosen to combine the science of modal analysis, or structural resonance testing, and the full-service attitude of our “shop-like” organization. Serving the sound and vibration measurement marketplace, our teams work with research, design and manufacturing engineers throughout the public and private sectors. From miniature MEMS structures to colossal space structures, we strive to provide the dynamic testing and monitoring communities with a single source to simplify all your sound and vibration measurement challenges.

For information on offices in your region, visit: www.modalshop.com/sales

*Front cover photo taken in cooperation with Belgian Defense.
SYSTEMS
SELECTION GUIDE

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THANK YOU FOR CHOOSING THE MODAL SHOP

As your partner in sound and vibration testing and monitoring, we invite you to learn about the products and services in the following pages and on our website – **www.modalshop.com**. We look forward to helping you solve your toughest measurement challenges! The Modal Shop’s team of Application Engineers is just a call or click away. You can reach us at 513.351.9919 or **info@modalshop.com**.

**Video Vault**
We believe that you should have easy access to support, no matter where you are. Our site offers a growing list of product and application video tutorials, available 24 hours per day, 7 days per week at **www.modalshop.com/videos**.

**Article Archive**
An extensive selection of technical articles focusing on dynamic sensor technology, applications and calibration practices are available at **www.modalshop.com/articles** where new topics are added each month.

**Configuration Guides**
Online configuration guides are designed to help you determine which product will best suit the needs of your application. As always, The Modal Shop’s product teams are here to assist you in your decision-making process in person, over the phone, or email.

**Information and Downloads**
From application information to downloadable catalogs, datasheets and whitepapers, you can find a complete range of resources simply by visiting **www.modalshop.com** and navigating to your product area of interest.

**FAQ**
Whether you are interested in knowing how through-hole armatures work in modal shakers or the maximum payload of the Portable Vibration Calibrators, you can find the answers quickly and easily through Frequently Asked Questions pages in each product section.

**Regional Seminars**
As part of our commitment to the sound and vibration community, TMS Dynamic Calibration experts travel the world, offering seminars on dynamic sensor technology and calibration theory. Visit **www.modalshop.com/seminars** to see when a seminar will be at a location near you.
INNOVATION IN EXCITATION

MINIATURE SMARTSHAKER™ WITH INTEGRATED AMPLIFIER
MODELS K2004E01 AND K2007E01

The SmartShaker™ is a small, portable, permanent magnet shaker with a new generation of ultra-compact precision power amplifier integrated into its base. To initiate testing, simply plug the excitation signal from a dynamic signal analyzer or function generator directly into the BNC on the base of the shaker.

- Simplified testing with innovative integrated amplifier design
- Offers industry leading stroke of 0.5 in (1.27 cm) while providing up to 7 lbf (31 N) pk sine force
- Allows testing of payloads up to 2 lb (0.91 kg) by attachment to 10-32 mounting top
- Provides ease of setup with trunnion mounting base and EasyTurn™ handles

SMART FEATURES:
- SAFE STARTS IN MUTE TO AVOID TRANSIENTS
- SELECTABLE GAIN SETTINGS
- PROVIDES CLIPPING WARNING AND OVER TEMPERATURE/CURRENT SHUTDOWN

COMPLETE KIT
Heavy duty case and stingers included
SHAKER KITS

The Modal Shop’s family of shakers includes small-sized shakers rated from 2 lbf (10 N) to 110 lbf (489 N). Available designs include the revolutionary SmartShaker™ with integrated power amplifier, a variety of mini, through-hole modal and dual purpose platform shakers. These exciters are ideal for applications ranging from experimental modal analysis to general vibration testing of small components and sub-assemblies.

**ALL SHAKERS INCLUDE**
- Stinger Kit / Accessories
- Cable
- Trunnion Base

* Amplifiers are not shown to scale

<table>
<thead>
<tr>
<th>KIT MODEL</th>
<th>MAX FORCE lbf (N) pk</th>
<th>MAX FREQUENCY Hz (2)</th>
<th>STROKE in (mm) pk-pk</th>
<th>SHAKER MODEL</th>
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<td>DUAL PURPOSE</td>
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[1] Requires Cooling (included with kit)
[2] Load dependent

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<tr>
<th>SHAKER MODEL</th>
<th>AMPLIFIER MODEL</th>
<th>STINGER KIT/ ACCESSORIES</th>
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<tr>
<td>2002E</td>
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<td>2075E</td>
<td>2050E09</td>
<td>2000X03</td>
</tr>
<tr>
<td>2110E</td>
<td>2050E09- FS</td>
<td>2000X03</td>
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</table>
The Modal Shop’s modal shakers are a proven solution in test laboratories throughout the world. With force ratings from 4.5 to 100 lbf (20 to 440 N), these shakers are suitable for a wide range of modal analysis applications. When performing experimental modal analysis and structural testing, the choice of excitation function and system will make the difference between a good measurement and a poor one. For many applications, an electrodynamic shaker system is the ideal choice. The Modal Shop’s line of modal shakers is designed to be highly portable, rugged and easy to set up in order to facilitate the best testing results. The exciter size allows a diversity of placement locations relative to the test structure, while minimizing any unwanted interaction between the exciter and test structure.

### HIGHLIGHTS
- Ensures simple stinger setup and adjustment via through-hole armature design with chuck and collet attachment
- Easier test setup with lightweight and portable designs weighing from 7 lb (3 kg) to 37 lb (17 kg)
- Provides flexibility when mounting and aligning the shaker to the structure with trunnion base and EasyTurn™ handles
- Extended stroke and broad frequency range supply adequate input energy for modal applications

<table>
<thead>
<tr>
<th>MODEL NUMBER</th>
<th>MAX FORCE lbf (N) pk</th>
<th>MAX FREQUENCY Hz [2]</th>
<th>STROKE in (mm) pk-pk</th>
<th>WEIGHT lb (kg)</th>
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<td>2060E</td>
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<td>1.4 (36)</td>
<td>37 (17)</td>
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<td>2025E</td>
<td>13 (58)</td>
<td>9 000</td>
<td>0.75 (19)</td>
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<td>2007E [1]</td>
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<td>SmartShaker™ K2007E01 [1]</td>
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<td>9 000</td>
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<td>11 000</td>
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</tr>
</tbody>
</table>

[1] Models 2004E/2007E and SmartShaker™ have no through-hole armature
[2] Load dependent
STRUCTURAL TEST ACCESSORIES

IMPEDEANCE HEAD
MODEL TLD288D01
- ICP® impedance head (force/acceleration) for driving point measurements
- Force: 100 mV/lbf, ± 50 lbf
- Accel: 100 mV/g, ± 50 g
- Available with TEDS functionality

AIRRIDE® MOUNT
MODEL 8032S
- Provides extremely low mounting frequencies for large rigid body test structures
- Eliminates multiple mounting frequencies, as AirRide® natural frequency does not shift significantly with changes in load

LATERAL EXCITATION STAND
MODEL 2050A
- Combining lateral and vertical excitation distributes input energy and helps excite uncoupled lateral modes
- Provides versatility to adapt a modal shaker for horizontal input
- Ensures proper alignment with coarse and fine vertical adjustment

DIGITAL ICP® SIGNAL CONDITIONER
MODEL 485B39
- Powers ICP sensors while digitizing signals
- Pocket-sized, dual channel with standard USB digital output
- Plug & Play signal conditioning offers quick setup and simple usability with no driver installation needed

DIGIDUCER USB DIGITAL ACCELEROMETER
MODEL 333D01
- Piezoelectric ruggedness and dynamic range
- Eliminates need for data acquisition
- Flat response up to 8 kHz
- Plug & Play – record vibration data via laptop or tablet

ICP® LASER TACHOMETERS
MODEL LASERTACH™ AND LT2
- Operates with standard ICP® signal conditioning; simplifies cabling
- One pulse/rev eliminates need to oversample all channels for a high frequency tach
- Model LT2 offers continuous laser for jitter-free operation

TECH TALK: THROUGH-HOLE ARMATURE
The implementation of the through-hole armature shaker has simplified and improved modal testing. In the early days of modal testing, electrodynamic shakers were attached to the test structure with a long threaded stinger and used to apply low-level excitation. The rod was threaded directly to the top of the exciter and to the base of the reference force transducer, making difficult orientation, tedious alignment and customization of stinger lengths a part of every test. The through-hole armature design eliminates these problems. With a hole that runs the length of the shaker along the axis of actuation, a long stinger can be threaded to the force transducer attached to the test article, properly aligned and then clamped down with the chuck and collet at the appropriate length. This simple, time-saving feature is key to ensuring modern modal testing.

Check out videos and tutorials at www.modalshop.com/videos
The Modal Shop’s dual purpose shakers are ideal for both vibration testing of small components and modal analysis. Small and lightweight, yet powerful electrodynamic shakers, the dual purpose line provides up to 110 lbf (489 N) pk sine force across a wide frequency range.

In both the 2075E and 2110E models, a large 3.25 in (8.3 cm) diameter platform table is ideal for payloads up to 10 lb (4.5 kg). These units also offer a through-hole armature that includes a chuck and collet attachment, providing simple stinger setup if used for modal applications. The 2004E and 2007E miniature shakers, as well as the SmartShaker™, offer a 10-32 threaded mounting surface which allows for stinger or test article attachment.

### HIGHLIGHTS
- Innovative dual purpose design integrates a platform table for traditional vibration testing and modal testing
- Provides flexibility and full rotation when positioning and aligning the shaker through trunnion base
- Offers necessary input energy for modal applications with extended stroke and broad frequency range
- Easily paired with a variety of accessories from The Modal Shop

<table>
<thead>
<tr>
<th>MODEL NUMBER</th>
<th>MAX FORCE lbf (N) pk</th>
<th>MAX FREQUENCY Hz [2]</th>
<th>STROKE in (mm)</th>
<th>WEIGHT lb (kg)</th>
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<td>9 000</td>
<td>0.5 (13)</td>
<td>6 (3)</td>
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<td>7 (3)</td>
</tr>
</tbody>
</table>

[1] Models 2004E/2007E and SmartShaker™ have no through-hole armature
[2] Load dependent
EXPANDED TEST CAPABILITIES

HORIZONTAL TABLE SYSTEMS
MODELS K2075E-HT AND K2110E-HT
- Based on 2075E and 2110E shakers
- Includes shaker, amplifier, lightweight magnesium table, and cooling package
- Expands dynamic testing capabilities for test objects larger or heavier than what can be mounted directly to a shaker
- Operates both vertically (no table) or horizontally with 6 x 7.5 in (15 x 19 cm) horizontal table
- Remove side loading from the shaker suspension

HEAD EXPANDER
MODELS 2000X01 AND M2000X01
- 7 in (18 cm) diameter head expander is specifically designed for use with the 2075E and 2110E shakers
- Allows attachment of larger, less dense, test loads by providing an increased mounting footprint
- Expander is machined from a special lightweight magnesium alloy casting with 32 mounting holes (10-32 or M5 threads) in a 1 in (2.54 cm) square pattern

INERTIAL SHAKER
MODEL 2002E
- Compact size allows easy set-up for difficult-to-access locations
- 2 lbf (10 N) sine force excitation
- Direct mounting requires no special fixturing support or manual alignment
- In-line fuse for overcurrent protection
- Wide frequency range from 20 Hz to 3 kHz
- Compatible with piezoelectric force transducers and shaker amplifiers

TECH TALK: SHAKER PERFORMANCE CURVES

Shaker performance curves, known as payload curves, are commonly used to select the right shaker system for a particular application. They describe the shaker system acceleration potential over a range of payloads and frequencies. Payload curves provide a graphical way to evaluate the compatibility between testing requirements and system capabilities. Visit www.modalshop.com/payload for more details.

1. What is the total payload for the test?
Add the mass of the test article to the mass of any adaptor or fixture required to attach it to the shaker table. The payload curves already take into account the mass of the shaker armature.

2. What are the required vibration levels?
Check the acceleration and frequency requirements for the test. If the vibration specifications are provided in a different unit (e.g. velocity or displacement), convert into acceleration units. Use g peak for sine testing or g RMS for random testing. Any test requirements below the curve for a given payload indicate a shaker candidate to serve the basic functions required for the testing.

3. Evaluate the shaker displacement range
Check the test frequency requirements to verify that the shaker’s stroke capability will not be exceeded. In the graph to the left, the stroke limit is shown by the slanted portion of the line. Using the acceleration levels (a) in g-pk units at low frequencies (f) in Hz, calculate the displacement using the following equations:
\[ d = 19.56 \frac{a}{f^2} \text{ [in, pk-pk]} \text{ or } d = 496.82 \frac{a}{f^2} \text{ [mm, pk-pk]} \]
ON-SITE VALIDATION

PORTABLE SHAKER TABLES
MODELS 9100D AND 9200D

Durable and proven systems used to provide on-site validation of vibration sensors, proximity probes and related vibration monitoring equipment. Ideal for use when performing a validation of the entire industrial measurement chain.

- 9100D – 5 Hz to 10 kHz (300 to 600 000 CPM)
- 9200D – 0.7 Hz to 2 kHz (42 to 120 000 CPM)

SUPPLIED WITH ACCREDITED CALIBRATION

TEST UNITS

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<tr>
<th>Test Units</th>
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<tr>
<td>Velocity</td>
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<td>Displacement</td>
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<tr>
<td>Frequency</td>
<td>Hz, CPM</td>
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</tbody>
</table>

PROXIMITY OPTION

9100-PPA01 fixture is used to check the static and dynamic output of an eddy current proximity probe.

- Test accelerometers, velocity sensors, proximity probes
- Verify alert/alarm levels
- Test complete measurement chains on plant floor
Tech Talk: Vibration Monitoring

Protecting process quality and critical plant machinery from damage or destruction is a constant concern in the industrial environment. Quality affects customer satisfaction and yield. Maintenance and shutdown related issues cost companies both time and money. Validating an installed monitoring system is key to ensuring overall success. Vibration sensors, cabling and data acquisition systems must be operating accurately to ensure facility and machinery safety.

Portable Shaker Tables from The Modal Shop perform on-site calibration of accelerometers, velocity sensors and proximity probes. Designed to withstand the harsh conditions of the industrial environment, the Shaker Table can be taken directly to the location of installed sensors, eliminating downtime and making regular calibration a viable option. The unit can validate the entire measurement channel from sensor through signal conditioning, acquisition system and display console, providing peace of mind that the entire system is accurate and functioning. Vibration monitoring alert and alarm trip points can also be tested to confirm function and accuracy of condition monitoring systems.

Portable Shaker Tables solve on-site vibration monitoring needs in a self-contained, battery powered unit. They generate calibrated vibration excitation levels and offer standardized, traceable results for each test. Rugged hardware, an easy-to-use system interface, extensive battery life and precision electronics have proven the 9100D and 9200D as ideal tools for field calibrations and validation of the monitoring measurement channel at sites around the world.

Avoid catastrophic failures by performing system validation with the 9100D
METEROLOGY MADE PORTABLE

PORTABLE VIBRATION CALIBRATORS
MODELS 9110D AND 9210D

Durable and proven systems used to provide on-site calibrations of dynamic sensors and alert systems. 9110D offers a wide operating range and the 9210D offers low frequency capabilities.

- **9110D** – 5 Hz to 10 kHz (300 to 600 000 CPM)
- **9210D** – 0.7 Hz to 2 kHz (42 to 120 000 CPM)

WHY CALIBRATE & VERIFY?

Complete end-to-end testing verifies that alert/alarm trip points and time delays are functioning properly, meeting “recommended best practice” requirements for insurance and ISO 9001 quality standards. In route-based monitoring, accurate accelerometer output is critical through the entire frequency range as the same sensor is used on multiple machines. Finally, this unit provides a means of checking electronic vibration protection switches, as often no self-test function is available.

INCLUDED ACCESSORIES

- Universal charger and power supply
- Mounting wrench
- Sensor mounting studs
- Mounting pad
- USB flash drive
- Excel® calibration template
- Accredited calibration certificate

CALIBRATE AND GENERATE ISO COMPLIANT CERTIFICATES

The 9110D and 9210D calculate and display test sensor sensitivity on the readout screen in real time. The unit has a built-in ICP® or voltage test sensor input for direct connection and readout of the most common types of accelerometers and velocity transducers. The unit’s internal memory stores up to 500 calibration records and data is easily transferred to a computer through a USB flash drive. This allows for the creation and printing of ISO 17025-compliant customizable calibration certificates and reports using the supplied Microsoft Excel® worksheet template.

STORE UP TO 500 RECORDS AND GENERATE A TRACEABLE CALIBRATION CERTIFICATE WITH INCLUDED TEMPLATE
As input frequency changes, vibration amplitude is kept constant by the unit’s internal digital closed-loop control.

Software and user interface display calibration data in real time.

Laboratory reference

Easy data transfer

Field portability

Interested in full automation?

For a portable and automated calibration solution, learn more about Model K9145D10. The kit includes a 9110D, USB DAQ, laptop, and industry leading 9155 calibration software.

www.modalshop.com/portable-automation
Our Air Bearing Calibration shakers represent the de facto global standard in calibration-grade hardware while continuing the award-winning PCB tradition of providing superior performance characteristics and ease of use alongside exceptional value and simplicity.

- Wide frequency range of 2 Hz to 50 kHz (calibration from 5 Hz to 20 kHz)
- Drastically reduces uncertainty by virtually eliminating transverse motion
- Integral quartz ICP® reference ensures low noise operation with long-term stability
- Lorentz force coil enables rapid centering of sensors with varying mass
- High stiffness beryllium insert yields high frequency calibration

PRECISION CALIBRATION SYSTEMS

AIR BEARING VIBRATION CALIBRATION SHAKER
SHAKER MODEL K394B30 AND K394B31 INCLUDED IN SYSTEM OPTION 9155D-830 AND 9155D-831

RUGGED, RELIABLE DESIGN PROVEN IN PCB® PRODUCTION LINES

REDUCED UNCERTAINTY

ALLOW HIGH THROUGHPUT WITH SIMPLE MOUNTING AND SETUP

RUGGED, RELIABLE DESIGN PROVEN ON PCB Piezotronics production lines

EXCEEDS ISO 16063-21 REQUIREMENTS
ACCELEROMETER CALIBRATION WORKSTATION

The Accelerometer Calibration Workstation Model 9155 is a turnkey solution that provides all the necessary components out of the box. Principal components include a Windows® PC Controller, software, printer and 24-bit data acquisition card and software. System options allow custom configuration of the modular system with a variety of calibration-grade exciter systems, accelerometer signal conditioning, test software modules and mounting accessories.

To learn more about how a 9155 system can meet your specific needs, visit www.modalshop.com/configure for a custom calibration configuration guide or contact The Modal Shop’s Calibration Team.

CALIBRATION EXCITERS

SMARTSTROKE™ LOW FREQUENCY SHAKER
SHAKER MODEL 2129E025; SYSTEM OPTION 9155D-771 AND 9155D-779
- Achieves significantly faster calibration times with SmartStroke™ technology
- Improves signal to noise ratio at low frequency with 10 in (25 cm) stroke length
- Both options utilize a stable, quartz ICP® low frequency reference accelerometer
- Option 9155D-779 offers improved ultra low frequency using patented optical encoder reference technology from 0.1 – 10 Hz (Patent 8,577,641)

PNEUSHOCK™ SHOCK CALIBRATION EXCITER
EXCITER KIT MODEL K9525C
SYSTEM OPTION 9155D-525
- Easy amplitude linearity calibration of shock and crash sensors from 20 to 10 000 g
- Controlled and consistent impacts using state-of-the-art pneumatic actuator
- Easy refinement of impulse shape and frequency content using a wide variety of impact anvils
- Superior impact control through drive pressure and impulsive duration control

HIGH PAYLOAD CALIBRATION SHAKER
SHAKER MODEL 2075E-875
SYSTEM OPTION 9155D-875
- Supports heavy payload and hard line cabled transducers with sturdy flexure armature
- Includes test sensor mounting platform with integral stability, quartz ICP® reference accelerometer and paired signal conditioning
- Operates from 10 to 10 000 Hz
- Ideal for seismic and modal applications

<table>
<thead>
<tr>
<th>OPTION</th>
<th>RANGE</th>
<th>SHAKER MODEL</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>9155D-525</td>
<td>20 – 10 000 g</td>
<td>9525C</td>
<td>Shock</td>
</tr>
<tr>
<td>9155D-771</td>
<td>0.5 – 500 Hz</td>
<td>2129E025</td>
<td>Low Frequency</td>
</tr>
<tr>
<td>9155D-779</td>
<td>0.1 – 500 Hz</td>
<td>2129E025</td>
<td>Ultra Low Frequency</td>
</tr>
<tr>
<td>9155D-830</td>
<td>5 – 15 000 Hz</td>
<td>K394B30</td>
<td>Broad Frequency</td>
</tr>
<tr>
<td>9155D-831</td>
<td>5 – 20 000 Hz</td>
<td>K394B31</td>
<td>Extended High Frequency</td>
</tr>
<tr>
<td>9155D-875</td>
<td>10 – 10 000 Hz</td>
<td>2075E-875</td>
<td>Heavy Payload</td>
</tr>
</tbody>
</table>
VIBRATION CALIBRATION SYSTEMS

The Accelerometer Calibration Workstation Model 9155 allows accurate back-to-back comparison calibration of ICP® (IEPE), charge, piezoresistive, capacitive and voltage mode accelerometers in accordance with ISO 16063-21 (2003). Every system is delivered with its reference calibrated directly by The Modal Shop’s ISO 16063-11 compliant, A2LA accredited Laser Primary system, assuring world-class uncertainties. Factory acceptance test (FAT) and site acceptance test (SAT) by trained calibration professionals ensure proper installation of every 9155 system around the globe.

HIGHLIGHTS

- Accelerometer calibrations in under one minute per axis
- Uncertainties as low as 0.75% with laser primary
- Calibrations are NIST or PTB traceable
- Modular system fits any application
- Compliance to ISO 16063-11, -21, -22 vibration calibration standards
- System offers ISO 17025 compliant customizable certificates
- Back-to-back comparison calibration as low as 0.75% uncertainty

<table>
<thead>
<tr>
<th>UNCERTAINTY*</th>
<th>FREQUENCY RANGE</th>
<th>SYSTEM OPTION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75 %</td>
<td>100 Hz and 159 Hz</td>
<td>9155D-830 or 831</td>
<td>Reference Frequency</td>
</tr>
<tr>
<td>3.0 %</td>
<td>0.25 – &lt;0.5 Hz</td>
<td>9155D-779</td>
<td>Optical Encoder Reference</td>
</tr>
<tr>
<td>1.1 %</td>
<td>0.5 – &lt;1 Hz</td>
<td>9155D-779</td>
<td>Optical Encoder Reference</td>
</tr>
<tr>
<td>0.8 %</td>
<td>1 – &lt;10 Hz</td>
<td>9155D-779</td>
<td>Optical Encoder Reference</td>
</tr>
<tr>
<td>1.2 %</td>
<td>10 – &lt;100 Hz</td>
<td>9155D-830 or 831</td>
<td>ICP® Primary Reference Accelerometer</td>
</tr>
<tr>
<td>1.0 %</td>
<td>&gt;100 – 1 000 Hz</td>
<td>9155D-830 or 831</td>
<td>ICP® Primary Reference Accelerometer</td>
</tr>
<tr>
<td>1.4 %</td>
<td>&gt;1 000 – 5 000 Hz</td>
<td>9155D-830 or 831</td>
<td>ICP® Primary Reference Accelerometer</td>
</tr>
<tr>
<td>1.9 %</td>
<td>&gt;5 000 – 10 000 Hz</td>
<td>9155D-830 or 831</td>
<td>ICP® Primary Reference Accelerometer</td>
</tr>
<tr>
<td>2.2 %</td>
<td>&gt;10 000 – 15 000 Hz</td>
<td>9155D-830 or 831</td>
<td>ICP® Primary Reference Accelerometer</td>
</tr>
<tr>
<td>2.8 %</td>
<td>&gt;15 000 – 20 000 Hz</td>
<td>9155D-831</td>
<td>ICP® Primary Reference Accelerometer</td>
</tr>
</tbody>
</table>

* 95 % confidence interval (coverage factor of k=2)

TECH TALK: WHY CALIBRATE?

When considering accelerometer calibration and intervals you must ask, “What is the cost of failure?” If the test is a simple learning experiment in a university measurements course, the cost of retaking the data may be nothing. Many lab tests allow easy access or re-access to the test structure coupled with redundancy in the measurement channels. Here, the cost of a single bad measurement is low.

Costs can, however, escalate rapidly depending on certain factors. If the test structure is a prototype costing millions of dollars, every extra day spent in development escalates cost. Another extreme category is the “one shot” test. Channels are checked, double checked, calibrated, re-verified and data is backed up concurrently. The measurement has to be correct.

Another motivation for calibration is measurements made for legal purposes. Health and human exposure measurements used in legal proceedings for noise or vibration must withstand the scrutiny of the legal system.
VIBRATION CALIBRATION SYSTEM OPTIONS

The modular nature of the 9155 Accelerometer Calibration System allows systems to be configured or expanded to meet the needs of your laboratory or testing facility. In addition to a variety of exciters, a range of hardware and software choices are available to expand your capabilities. From options to perform a resonance check or a laser primary calibration to a range of sensor signal conditioning options, the 9155 system can be customized to fit a variety of testing needs.

<table>
<thead>
<tr>
<th>OPTION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>9155D-100</td>
<td>Rack Integration (system components in 19 in equipment rack)</td>
</tr>
<tr>
<td>9155D-120</td>
<td>Shaker Mount Option (provides wood pedestal to support calibration shaker)</td>
</tr>
<tr>
<td>9155D-350</td>
<td>Automated Label Printing (includes label printer)</td>
</tr>
<tr>
<td>9155D-400</td>
<td>Automated TEDS Sensor Support (requires 9155D-443)</td>
</tr>
<tr>
<td>9155D-442</td>
<td>Signal Conditioning ICP® (includes PCB Model 442A102)</td>
</tr>
<tr>
<td>9155D-443</td>
<td>Signal Conditioning Dual Mode Charge Amplifier (ICP®/Charge) (includes PCB Model 443B101)</td>
</tr>
<tr>
<td>9155D-445</td>
<td>Signal Conditioning Capacitive Sensor (includes PCB Model 445B101)</td>
</tr>
<tr>
<td>9155D-478</td>
<td>Signal Conditioning Piezoresistive (includes PCB Model 478A30)</td>
</tr>
<tr>
<td>9155D-501</td>
<td>Automated Linearity Check, up to 40 g pk (requires 9155D-830 or 9155D-831)</td>
</tr>
<tr>
<td>9155D-550</td>
<td>Automated Resonance Test, up to 50 kHz (requires 9155D-830 or 9155D-831)</td>
</tr>
<tr>
<td>9155D-575</td>
<td>Laser Primary System (includes two dual pass laser interferometers and accessories)</td>
</tr>
<tr>
<td>9155D-600</td>
<td>Automated Velocity Sensor Calibration</td>
</tr>
<tr>
<td>9155D-610</td>
<td>Automated Displacement Sensor Calibration</td>
</tr>
<tr>
<td>9155D-650</td>
<td>Automated 4-20 mA Velocity Sensor Calibration</td>
</tr>
</tbody>
</table>

TECH TALK: SENSOR AND CALIBRATION TIPS

The Modal Shop’s Dynamic Sensors & Calibration Tips electronic newsletter offers an ideal opportunity for you to learn more about the theory and best practices used in sensor applications and calibration. Articles and papers, like the one below covering the topic of shaker transverse motion, are published to our website. Visit www.modalshop.com/articles for more information.

Transverse Motion in Calibration
ISO 16063 Part 21 (2003) defines the back-to-back comparison technique for accelerometer calibration. Included in its most recent revision is a recommendation for acceptable limits on shaker transverse motion characteristics. The effect of high transverse inputs can be devastating to accurate accelerometer calibration. The differences between mechanical flexure-based electrodynamic shakers and air bearing shakers result in effects on calibration accuracy and uncertainty, as shown in the graph to the right.

![Typical Transverse Motion (%)](plot.png)

Plot details show transverse motion measured on air bearing shaker and flexure shaker vs ISO recommended limits
Dynamic pressure sensors are typically calibrated by varying the amplitude rather than the frequency of the input. To service the wide range of pressure events measured by dynamic pressure sensors, The Modal Shop offers five different systems that calibrate sensors designed for acoustic measurements, atmospheric blast experiments, gas turbine exhaust fluctuations, internal combustion engine measurements and hydraulic or fuel line measurements. These systems have been proven in tens of thousands of factory calibrations performed at PCB Piezotronics, and this rich metrology heritage is leveraged with a digital hardware and software platform that is shared with the 9155 system.

By combining PCB’s factory calibration hardware with The Modal Shop system software and expertise, pressure calibration systems meet the needs of the most discerning user. These turnkey systems reproduce the factory calibration techniques of pressure sensors for customers with the added advantage of a single point for product support and Total Customer Satisfaction.

### PRESSURE SENSOR CALIBRATION SYSTEMS

<table>
<thead>
<tr>
<th>MODEL NUMBER</th>
<th>RANGE psi (MPa)</th>
<th>UNCERTAINTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>K9903C</td>
<td>150 (1)</td>
<td>±1.5 %</td>
</tr>
<tr>
<td>K9907C</td>
<td>1 000 (6.9)</td>
<td>±1.5 %</td>
</tr>
<tr>
<td>K9913C</td>
<td>15 000 (103)</td>
<td>±4.1 %</td>
</tr>
<tr>
<td>K9905D</td>
<td>80 000 (550)</td>
<td>±2.0 %</td>
</tr>
</tbody>
</table>

### LOW PRESSURE

**MODEL K9903C**
- Maximum pressure: 150 psi (1 MPa)
- Options available for lower pressures
- Pneumatic calibration media
- ‘Step’ pressure input
- 5 ms using manual release valve
- Automated Pressure Controller

### MEDIUM PRESSURE

**MODEL K9907C**
- Maximum pressure: 1000 psi (6.9 MPa)
- Compressed air or industrial helium media
- ‘Step’ pressure input
- Fastest rise times using poppet valve mechanism

### HIGH PRESSURE

**MODEL K9913C**
- Maximum pressure: 15 000 psi (103 MPa)
- Silicon oil media
- ‘Impulse’ pressure input
- 3 ms rise time with 7 ms pulse duration using drop mass

### HIGHLIGHTS

- Assures accurate, traceable calibrations
- Integrated system includes all necessary components
- Windows® PC supplies familiar, intuitive user interface
- Set up tests, acquire data, save results and print reports quickly with precision and automation
- Define pass/fail criteria for each test and automatically recall them from the internal database
PRESSURE CALIBRATION METHODOLOGY

Of the many pressure sensor designs available, two stand out for their excellence in measuring dynamic, rather than static, pressure. Piezoelectric pressure sensors excel at high frequencies and pressure levels and are inherently rugged for the most demanding environments. Condenser microphones offer unparalleled sensitivity for acoustic measurements in the audible frequency range. Since these two designs are uniquely suited for dynamic measurements, the best calibration techniques for them require a dynamic, rather than static, input.

Dynamic calibration inputs are classified as periodic (steady state and repeating) and aperiodic (transient). Periodic inputs are used by the 9350C for lower level pressure signals and aperiodic inputs are used at higher pressure levels. A dynamic calibration technique characterizes the sensor with measurements closest to its application in the field.

This allows for the sensor output to be validated in a way that is consistent with, or at least similar to, the intended field measurements.

### ACOUSTIC CALIBRATION PRODUCTS

<table>
<thead>
<tr>
<th>MODEL NUMBER</th>
<th>SUPPORTS</th>
<th>INPUT SIGNAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>9917C AND 9000A</td>
<td>Condenser Microphones, Array Microphones</td>
<td>Steady State, Variable Frequency</td>
</tr>
<tr>
<td>9350C</td>
<td>Condenser Microphones, Preamplifiers, Sound Sources</td>
<td>Steady State, Variable Frequency</td>
</tr>
</tbody>
</table>

### ULTRA HIGH PRESSURE

**MODEL K9905D**
- Maximum pressure: 80 000 psi (550 MPa)
- Hydraulic calibration media
- ‘Step’ pressure input
- Quasi-static method available for ballistics sensors and brass calibration

### COMPACT MICROPHONE

**MODELS 9917C AND 9000A**
- Compatible with both condenser and array microphones
- IEC 61094-5 compliant
- Simple, fast broadband acoustic calibration
- Model 9000A applications include vibration and velocity calibration, large sensor verification, and more

### PRECISION ACOUSTIC

**MODEL 9350C**
- Calibrates condenser measurement microphones, preamplifiers, and sound sources
- IEC 61094-6 and IEC 60942 compliant
- Simple automated easy-to-use GUI

*Systems not shown to scale.*
Primary vibration calibration utilizes a laser interferometer as reference, providing traceability to a physical constant (wavelength of light) and the lowest possible measurement uncertainty. Secondary calibration techniques use a transfer standard or reference accelerometer to calibrate another accelerometer under test and provide traceability to the primary standard. Reference accelerometers, often called “double ended” or “piggy-back” standards, are designed specifically to carry a sensor under test to perform a secondary back-to-back calibration. Transfer standards are designed specifically to calibrate working standard reference accelerometers. All calibration standard kits include a quartz ICP® accelerometer paired with PCB ICP® signal conditioner, calibrated directly against The Modal Shop’s A2LA accredited laser primary calibration system.

### CALIBRATION REFERENCE STANDARD KITS

<table>
<thead>
<tr>
<th>TRANSFER STANDARDS (SINGLE ENDED)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MODEL NUMBER</strong></td>
</tr>
<tr>
<td>9105C01</td>
</tr>
<tr>
<td>9105C11</td>
</tr>
<tr>
<td>9105C21</td>
</tr>
<tr>
<td>9105C31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>REFERENCE ACCELEROMETERS (DOUBLE ENDED)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MODEL NUMBER</strong></td>
</tr>
<tr>
<td>9106C01</td>
</tr>
<tr>
<td>9106C11</td>
</tr>
<tr>
<td>9106C21</td>
</tr>
<tr>
<td>9106C31</td>
</tr>
</tbody>
</table>

### TECH TALK: INTERLABORATORY COMPARISON

The Modal Shop’s Interlaboratory Comparison (ILC) Program is designed to help laboratories achieve proficiency confidence in vibration calibration results, publish reliable uncertainty levels and meet ISO 17025 certification requirements. With anonymous participation and blind results, the program provides precision data with confidentiality. After enrolling with The Modal Shop, the participating accelerometer calibration laboratory will:

1. Receive comparison accelerometer to calibrate
2. Calibrate sensor over 0.5 Hz to 20 kHz range
3. Return accelerometer and results to The Modal Shop
4. Receive a report comparing the results of 7 different laboratories
5. Opportunity for expert discussion on practices, variances, and other process improvements

Visit [www.modalshop.com/ILC](http://www.modalshop.com/ILC) for more information.

### HIGHLIGHTS
- Low noise ICP® electronics simplify connectivity
- Quartz offers best long-term stability
- Hermetic package ensures long-term reliability
- Low 0.2% measurement uncertainty at reference frequency
**ACCREDITED CALIBRATION SERVICES**

The Modal Shop's in-scope, in-house calibration laboratory holds accreditation to ISO / IEC 17025:2005 and ANSI / NCSL Z540-1-1994, internationally recognized standards which specify general requirements necessary to exhibit technical competence in carrying out various testing and calibration methods. Accordingly, The Modal Shop can be your partner in a well-documented transducer calibration program.

As part of this accreditation, The Modal Shop offers primary and secondary calibration of accelerometers, as well as services for condenser microphones, impulse force hammers, force sensors and associated signal conditioning electronics.

**CALIBRATION SERVICE OPTIONS**

The Modal Shop provides a wide range of vibration, force, acoustic, system, and signal conditioning calibration services. As your partner, The Modal Shop can provide an accurate, controlled, and confident transducer calibration program. Please visit [www.modalshop.com/scope](http://www.modalshop.com/scope) for more information on our A2LA ISO 17025 Scope of Accreditation and for applicable calibration services.

### ACCELEROMETER CALIBRATION SERVICES

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCS-A001</td>
<td>Calibration of accelerometer, single axis amplitude and phase response from 5 Hz to upper 5% frequency, NIST traceable. A2LA accredited.</td>
</tr>
<tr>
<td>MCS-A001T</td>
<td>Calibration of accelerometer, triaxial amplitude and phase response from 5 Hz to upper 5% frequency, NIST traceable. A2LA accredited.</td>
</tr>
<tr>
<td>MCS-A004</td>
<td>Calibration of accelerometer, single axis, low frequency phase and amplitude response from 0.5 to 10 Hz, NIST traceable. A2LA accredited. Includes 100 Hz reference frequency calibration.</td>
</tr>
<tr>
<td>MCS-A004T</td>
<td>Calibration of accelerometer, triaxial, low frequency phase and amplitude response from 0.5 to 10 Hz, NIST traceable. A2LA accredited. Includes 100 Hz reference frequency calibration.</td>
</tr>
<tr>
<td>MCS-A065</td>
<td>Primary calibration via laser interferometry per ISO 16063-11 from 5 Hz to 20 kHz at up to 45 specific user defined frequencies. A2LA accredited.</td>
</tr>
<tr>
<td>MCS-31</td>
<td>High g shock accelerometer calibration using PneuShockTM to max 10,000 g range, NIST traceable. A2LA accredited.</td>
</tr>
</tbody>
</table>

### HANDHELD AND PORTABLE CALIBRATION

- **MCS-A009** Calibration of handheld calibrator, models 394C05, 394B06 and 394C06.
- **9100-CAL01** Calibration of 9100 Series Portable Vibration Calibrator. A2LA accredited.

### IMPACT HAMMER CALIBRATION SERVICES

- **MCS-H002** Calibration of 086 Series instrumented hammer or similar, NIST traceable. A2LA accredited.
- **MCS-H003** Calibration of 288 Series Impedance Head, NIST traceable. A2LA accredited.

### ACOUSTIC CALIBRATION SERVICES

- **MCS-1** Calibration of 130 Series array microphone and preamplifier pair.
- **MCS-2** Calibration of standard precision condenser microphones. A2LA accredited.
- **MCS-9** Calibration of precision microphone/preamplifier pair. A2LA accredited.
- **MCS-56** Calibration of speakerphone.

### SIGNAL CONDITIONER ELECTRONICS CALIBRATION SERVICES

- **MCS-E004** Calibration of 480 Series (480E06, 480E09, 480D06, and 480D09) with multiple gain x1, x10, x100.
- **MCS-E010** Calibration of 481 Series (Models 533, 583, 584, 478A16 and 478A17) 16-channel signal conditioner.

For the full list of calibration services, visit [www.modalshop.com/calibration-services](http://www.modalshop.com/calibration-services)
The Modal Shop’s Sound and Vibration Rental Program provides a single source for varied – and often difficult to procure – dynamic test equipment, sensing systems and expertise. Whether you simply need a single accelerometer and cable, a complete vibration shaker kit or a complex sound level meter system, The Modal Shop can help. As more test engineers are restrained with limited capital budgets, The Modal Shop’s Rental Program expands existing capabilities and ensures the viability of particular models prior to purchase for permanent test setups.

### WHY RENT?

- Try before you buy – eliminate concerns of buying the wrong thing
- Remain flexible – take on projects with a large and wide variety of equipment
- Choose from a wide variety of units and use the right sensor, every time
- Avoid ownership costs of capital investment and calibration
- Eliminate hassle and cost of repairs, storage, warranties and calibration
- Ship calibrated equipment worldwide – keep your equipment back in the lab
- Obtain a wealth of knowledge from a team of experts trained and ready to help

### DOWNLOAD OUR RENTAL SELECTION GUIDE

Interested in learning more about rentals from The Modal Shop? The in-depth Sound and Vibration Rental Selection Guide offers 30+ pages of information on our extensive equipment inventory. Visit [www.modalshop.com/rental-guide](http://www.modalshop.com/rental-guide) to download a copy or email us at rental@modalshop.com to request a printed version.

Expert application support from the TMS Application Engineering Team is only a call, click or email away.
FROM SENSORS TO SYSTEMS

ACCELEROMETERS
- Single axis and triaxial
- Digiducer USB Digital Accelerometer
- General purpose, miniature, shock, seismic and more
- Low frequency and high temperature units
- ICP®/IEPE, charge mode, capacitive, and MEMS
- TEDS and water-resistant options
- Cabling and mounting accessories

MICROPHONES
- Precision condenser and array
- 0 V prepolarized and 200 V historic
- Freefield, pressure and random response
- Power supplies, cabling, windscreens, stands, and other accessories
- Specialty units

SOUND LEVEL METERS
- Type 1 / Class 1 standalone meters
- Logging, community noise, 1/1 and 1/3 octave
- Event logging and event sound recording
- Complete kits for unattended monitoring
- Options for room acoustics, FFT and audiometry

SPECIALTY ACOUSTICS
- Hydrophones
- Sound intensity probes and kits
- Probe mics for high temperature
- Acoustic calibrators: speakerphones, pistonphones
- Building acoustics: sources and tapping machines

EXCITATION
- Full range of impact hammers
- Complete modal shaker kits
- Amplifiers, stinger kits and more
- Vibration control systems

STRUCTURAL TEST ACCESSORIES
- Signal conditioning
- Calibration equipment
- AirRide® supports
- Visualization software
- Data acquisition
- Cabling and mounting equipment

OTHER TRANSDUCERS
- Dynamic force and strain
- Dynamic pressure
- Rotational speed/tachometer
- Force limited vibration systems
- Torque telemetry systems
- Torque and angle transducers
MTS Sensors, a division of MTS Systems Corporation (NASDAQ: MTSC), vastly expanded its range of products and solutions after MTS acquired PCB Piezotronics, Inc. in July, 2016. PCB Piezotronics, Inc. is a wholly owned subsidiary of MTS Systems Corp.; IMI Sensors and Larson Davis are divisions of PCB Piezotronics, Inc.; Accumetrics, Inc. and The Modal Shop, Inc. are subsidiaries of PCB Piezotronics, Inc.

The Modal Shop, Inc. offers structural vibration and acoustic sensing systems and services for various applications in design and test laboratories as well as manufacturing plants. An extensive sound and vibration rental program, precision calibration systems, and both modal and vibration shakers are designed to simplify test phases. Non Destructive Testing Systems help manufacturers provide 100% quality inspection of metal components. The Modal Shop, Inc. is a subsidiary of PCB Piezotronics, Inc., and PCB® is a wholly owned subsidiary of MTS Systems Corporation.