SOUND & VIBRATION SYSTEMS SELECTION GUIDE

THE MODAL SHOP
MTS SYSTEMS CORPORATION

ABOUT THE MODAL SHOP

"SIMPLIFYING PEOPLE'S LIVES WITH SMART SENSING SOLUTIONS THAT HELP IMPROVE THE PERFORMANCE OF PEOPLE, PRODUCTS AND PROCESSES."

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 world-wide 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.

- MTS Headquarters, Eden Prairie, Minnesota
- PCB Headquarters, Depew, New York
- TMS Headquarters, Cincinnati, Ohio
- Worldwide PCB and Distributor Locations

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

- General Vibration Testing
- Electronic Assemblies
- Laboratory Experiments
- Biomedical Research
- Modal and Structural Testing

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

COMPLETE KIT

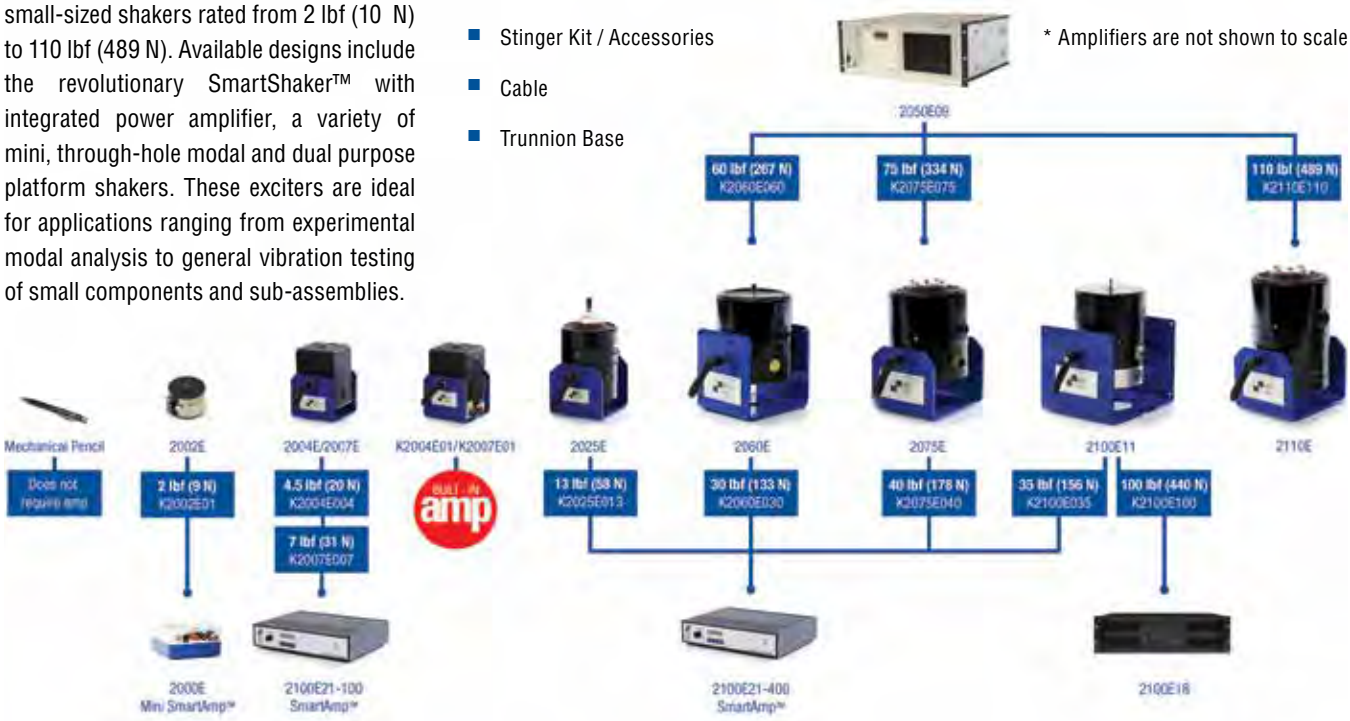
Heavy duty case and stingers included

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



	KIT MODEL	MAX FORCE lbf (N) pk	MAX FREQUENCY Hz [2]	STROKE in (mm) pk-pk	SHAKER MODEL	AMPLIFIER MODEL	STINGER KIT/ ACCESSORIES	APPLICATION
MINI	K2002E01	2 (9)	3 000	N/A	2002E	2000E	2000X08	Modal analysis, general vibration, small structures [circuit board to small appliance]
	K2004E004	4.5 (20)	11 000	0.2 (5)	2004E	2100E21-100	2110G06	
	K2004E01	4.5 (20)	11 000	0.2 (5)	2004E	Integrated	2110G06	
	K2007E007	7 (31)	9 000	0.5 (13)	2007E	2100E21-100	2110G06	
	K2007E01	7 (31)	9 000	0.5 (13)	2007E	Integrated	2110G06	
MODAL	K2025E013	13 (58)	9 000	0.75 (19)	2025E	2100E21- 400	2000X03	Modal analysis, small to medium structure [component to automotive]
	K2060E030	30 (133)	6 000	1.4 (36)	2060E	2100E21- 400	2000X03	Modal analysis, medium to large structures [washing machine to auto/aerospace]
	K2100E035	35 (156)	5 400	1.0 (25)	2100E11	2100E21- 400	2100E11-001	
	K2060E060 [1]	60 (267)	6 000	1.4 (36)	2060E	2050E09	2000X03	
	K2100E100 [1]	100 (440)	5 400	1.0 (25)	2100E11	2100E18	2100E11-001	
DUAL PURPOSE	K2075E040	40 (178)	6 500	1.0 (25)	2075E	2100E21- 400	2000X03	Dual purpose design, modal and general vibration testing
	K2075E075 [1]	75 (334)	6 500	1.0 (25)	2075E	2050E09	2000X03	
	K2110E110 [1]	110 (489)	6 500	1.0 (25)	2110E	2050E09 - FS	2000X03	

[1] Requires Cooling (included with kit)
[2] Load dependent

MODAL SHAKERS

- Modal Testing
- Appliances
- Automotive/NVH
- Aerospace/GVT

MODEL
2100E11

MODEL
2060E

MODEL
2025E

MODELS
2004E
2007E

SMARTSHAKER™
MODELS
K2004E01
K2007E01

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

MODEL NUMBER	MAX FORCE lbf (N) pk	MAX FREQUENCY Hz [2]	STROKE in (mm) pk-pk	WEIGHT lb (kg)
2100E11	100 (440)	5 400	1.0 (25)	33 (15)
2060E	60 (267)	6 000	1.4 (36)	37 (17)
2025E	13 (58)	9 000	0.75 (19)	13 (6)
2007E [1]	7 (31)	9 000	0.5 (13)	6 (3)
SmartShaker™ K2007E01 [1]	7 (31)	9 000	0.5 (13)	7 (3)
2004E [1]	4.5 (20)	11 000	0.2 (5)	6 (3)
SmartShaker™ K2004E01 [1]	4.5 (20)	11 000	0.2 (5)	7 (3)

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

STRUCTURAL TEST ACCESSORIES

IMPEDANCE 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

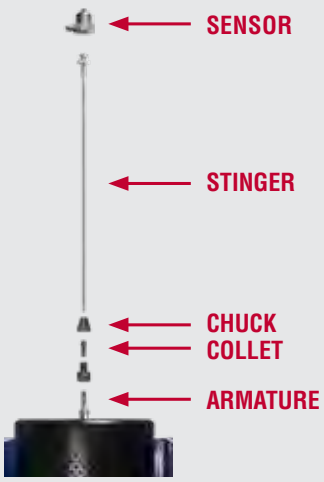
MODEL LASERTACH™ AND LT2

- 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**



DUAL PURPOSE VIBRATION SHAKERS

- Automotive Components
- Aerospace Devices
- Electronic Modules
- Sub-Assemblies
- Environmental Testing
- Vibration/Modal Testing

MODEL
2110E

MODEL
2075E

MODELS
2004E
2007E

SMARTSHAKER™
MODELS
K2004E01
K2007E01

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 SmartShakerTM, 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

MODEL NUMBER	MAX FORCE lbf (N) pk	MAX FREQUENCY Hz [2]	STROKE in (mm)	WEIGHT lb (kg)
2110E	110 (489)	6 500	1.0 (25)	54 (25)
2075E	75 (334)	6 500	1.0 (25)	35 (16)
2007E [1]	7 (31)	9 000	0.5 (13)	6 (3)
SmartShaker™ K2007E01 [1]	7 (31)	9 000	0.5 (13)	7 (3)
2004E [1]	4.5 (20)	11 000	0.2 (5)	6 (3)
SmartShaker™ K2004E01 [1]	4.5 (20)	11 000	0.2 (5)	7 (3)

[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.

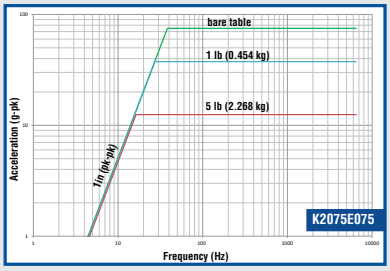
2. What are the required vibration levels?

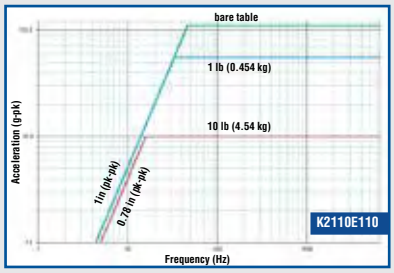
Check the acceleration and frequency requirements for the test. If the vibration specifications are provided in a different unit (e.g. velocity or displacement), convert into acceleration units. Use g peak for sine testing or g RMS for random testing. Any test requirements below the curve for a given 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:

$$d = 19.56\ a/f^2\ \text{[in, pk-pk]}\ \text{or}\ d = 496.82\ a/f^2\ \text{[mm, pk-pk]}$$





For more information about shaker system capabilities, visit:
www.modalshop.com/shakers

ON-SITE VALIDATION

- Test accelerometers, velocity sensors, proximity probes
- Verify alert/alarm levels
- Test complete measurement chains on plant floor

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)

TEST UNITS	
Acceleration	g pk, g RMS, m/s² pk, m/s² RMS
Velocity	in/s pk, in/s RMS, mm/s pk, mm/s RMS
Displacement	mil pk-pk, µm pk-pk
Frequency	Hz, CPM

PROXIMITY OPTION

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

PORTABLE SHAKER TABLES

LOW FREQUENCY CAPABILITIES

The 9200D Low Frequency Portable Shaker Table is designed for verifying critical vibration instrumentation used to protect slow speed rotating equipment as low as 0.7 Hz (42 CPM). The 9200D is supplied with a NIST traceable, ISO 17025 accredited calibration certificate.

Portable Shaker Tables from The Modal Shop are an ideal tool for on-site checking of accelerometers, velocity transducers and proximity probes over a wide operating frequency and amplitude range. The units are compact, battery-powered and completely self-contained vibration reference sources which can be conveniently used to calibrate individual sensors, vibration switches and data collectors.

Portable Shaker Tables are also used to validate the entire measurement channel of a condition monitoring or recording system. A built-in quartz reference accelerometer and digital closed-loop level control give the 9100D and 9200D enhanced stability. The 9100D offers best-in-class frequency range performance from 5 Hz to 10 kHz. The 9200D provides low frequency capabilities down to 0.7 Hz. Packaged in a rugged case, Portable Shaker Tables are always ready for travel to industrial test sites, bringing laboratory accuracy to the field.

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

METROLOGY MADE PORTABLE

- Accelerometers
- Proximity probes
- 4-20 mA velocity transmitters
- Electronic vibration switches
- PLC, DCS and SCADA systems
- Analyzers and online systems

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

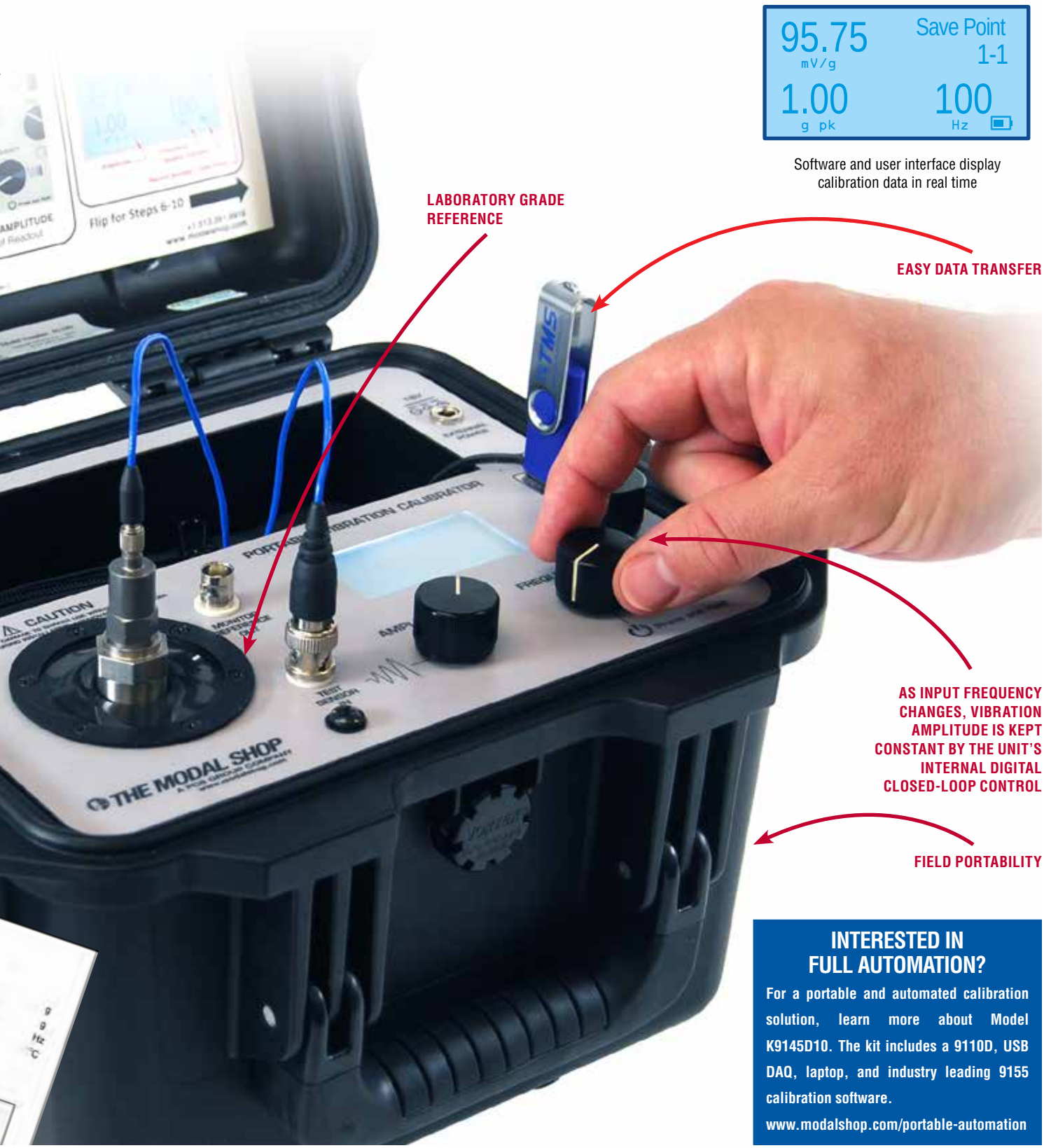
- Universal charger and power supply
- Mounting wrench
- Sensor mounting studs
- Mounting pad
- USB flash drive
- Excel® calibration template
- Accredited calibration certificate

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

VIBRATION CALIBRATION LABORATORY IN A BOX



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

PRECISION CALIBRATION SYSTEMS

- Reduce uncertainty
- Allow high throughput with simple mounting and setup
- Rugged, reliable design proven on PCB Piezotronics production lines
- Exceeds ISO 16063-21 requirements

AIR BEARING VIBRATION CALIBRATION SHAKER

SHAKER MODEL K394B30 AND K394B31
INCLUDED IN SYSTEM OPTION 9155D-830
AND 9155D-831

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

ACCELEROMETER CALIBRATION WORKSTATION

Model 9155 Automated Accelerometer Calibration Workstation system shown to the left with options -100, -443, -445, -478, -830

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

OPTION	RANGE	SHAKER MODEL	APPLICATION
9155D-525	20 – 10 000 g	9525C	Shock
9155D-771	0.5 – 500 Hz	2129E025	Low Frequency
9155D-779	0.1 – 500 Hz	2129E025	Ultra Low Frequency
9155D-830	5 – 15 000 Hz	K394B30	Broad Frequency
9155D-831	5 – 20 000 Hz	K394B31	Extended High Frequency
9155D-875	10 – 10 000 Hz	2075E-875	Heavy Payload

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

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

* 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.

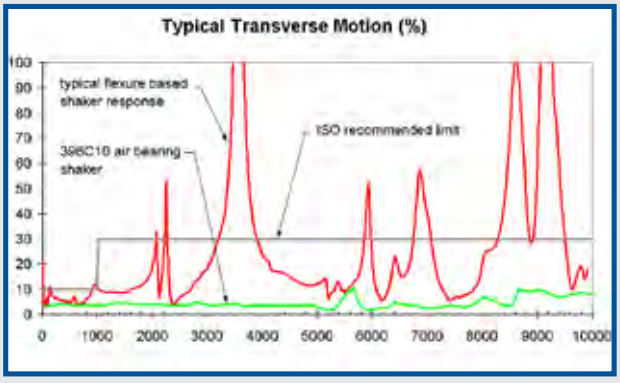
OPTION	DESCRIPTION
9155D-100	Rack Integration (system components in 19 in equipment rack)
9155D-120	Shaker Mount Option (provides wood pedestal to support calibration shaker)
9155D-350	Automated Label Printing (includes label printer)
9155D-400	Automated TEDS Sensor Support (requires 9155D-443)
9155D-442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

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.



Plot details show transverse motion measured on air bearing shaker and flexure shaker vs ISO recommended limits

DYNAMIC PRESSURE CALIBRATION SYSTEMS

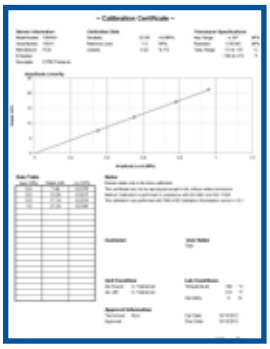
Dynamic pressure sensors are typically calibrated by varying the amplitude rather than the frequency of the input. To service the wide range of pressure events measured by dynamic pressure sensors, The Modal Shop offers five different systems that calibrate sensors designed for acoustic measurements, 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.

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 SENSOR CALIBRATION SYSTEMS		
MODEL NUMBER	**RANGE psi (MPa)**	**UNCERTAINTY**
K9903C	150 (1)	±1.5 %
K9907C	1 000 (6.9)	±1.5 %
K9913C	15 000 (103)	±4.1 %
K9905D	80 000 (550)	±2.0 %



Model K9903 Calibration Certificate

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

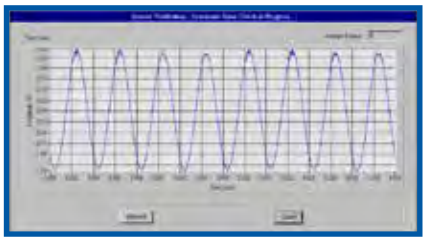
PRESSURE CALIBRATION METHODOLOGY

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.

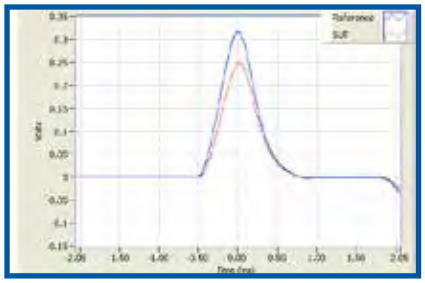
Dynamic calibration inputs are classified as periodic (steady state and repeating) and aperiodic (transient). Periodic inputs are used by the 9350C for lower level pressure signals and aperiodic inputs are used at higher pressure levels. A dynamic calibration technique characterizes the sensor with measurements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

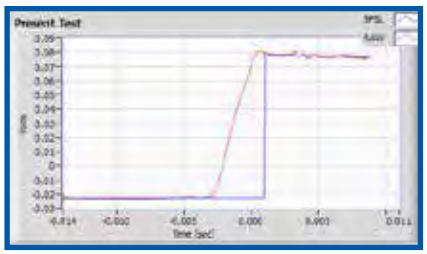
ACOUSTIC CALIBRATION PRODUCTS		
MODEL NUMBER	**SUPPORTS**	**INPUT SIGNAL**
9917C AND 9000A	Condenser Microphones, Array Microphones	Steady State, Variable Frequency
9350C	Condenser Microphones, Preamplifiers, Sound Sources	Steady State, Variable Frequency



Periodic Measurement from 9350C



Impulse Pressure Rise – Transient



Step Pressure Rise – Transient

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.

CALIBRATION REFERENCE STANDARD KITS

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.

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

TRANSFER STANDARDS (SINGLE ENDED)	
MODEL NUMBER	**RANGE**
9105C01	Broad Frequency 5 – 11 000 Hz
9105C11	Extended High Frequency 5 – 20 000 Hz
9105C21	Low Frequency 0.1 – 4 000 Hz
9105C31	Shock 100 – 10 000 g

REFERENCE ACCELEROMETERS (DOUBLE ENDED)	
MODEL NUMBER	**RANGE**
9106C01	Broad Frequency 5 – 14 000 Hz
9106C11	Extended High Frequency 5 – 20 000 Hz
9106C21	Low Frequency 0.5 – 3 500 Hz
9106C31	Shock 100 – 10 000 g

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** for more information.

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.

Certificate Number 2649.01 Calibration Lab

In conjunction with sister company PCB Piezotronics, The Modal Shop and PCB have available the industry's most extensive calibration test services and equipment offerings.

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** for more information on our A2LA ISO 17025 Scope of Accreditation and for applicable calibration services.

ACCELEROMETER CALIBRATION SERVICES	
MCS-A001	Calibration of accelerometer, single axis amplitude and phase response from 5 Hz to upper 5% frequency, NIST traceable. A2LA accredited.
MCS-A001T	Calibration of accelerometer, triaxial amplitude and phase response from 5 Hz to upper 5% frequency, NIST traceable. A2LA accredited.
MCS-A004	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.
MCS-A004T	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.
MCS-A065	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.
MCS-31	High g shock accelerometer calibration using PneuShockTM to max 10 000 g range, NIST traceable. A2LA accredited.

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 calibraiton services, visit **www.modalshop.com/calibration-services**

TEST EQUIPMENT RENTAL

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** 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

PCB PIEZOTRONICS
MTS SYSTEMS CORPORATION

HOCHWERTIGE MESSTECHNIK UND BERATUNG AUS EINER HAND

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MTS SENSORS

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.