TMS THE MODAL SHOP, INC.
A PCB GROUP CO

Low-Frequency Portable Shaker Table

9210D

9210D

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Product Support

For answers to questions about Model 9210D, consult this manual or the accessory manual. For additional product support, contact The Modal Shop, Inc. at 800-860-4867 or 513-351-9919, 9 a.m. to 5 p.m. EST. If it is more convenient, fax your questions or comments to The Modal Shop at 513-458-2172 or email our sales staff at sales@modalshop.com.

Warranty

The Modal Shop, Inc. products are warranted against defective materials and workmanship for ONE YEAR from the date of shipment, unless otherwise specified. Damage to equipment caused by incorrect power, misapplication, or procedures inconsistent with this manual are not covered by warranty. If there are any questions concerning the intended application of the product, contact an Applications Engineer. Batteries and other expendable accessory hardware items are excluded.

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Introduction 1

1.1 Welcome

Thank you for choosing The Modal Shop, Inc.'s Model 9210D.

The Model 9210D Low-Frequency Portable Shaker Table provides a field-tested method for on-the-spot dynamic verification of accelerometers, velocity pickups and non-contact displacement transducers. Optional mounting fixtures and hardware needed to connect transducers to the 9210D mounting platform are available upon request.

A closed-loop control algorithm provides enhanced stability and accuracy of frequency and amplitude levels.

The 9210D incorporates a built-in sine wave oscillator, power amplifier, electrodynamic shaker, NIST-traceable reference accelerometer and digital display. The 9210D is completely self-contained and operates on battery or AC power.

The built-in reference accelerometer is attached permanently to the shaker armature, maximizing the accuracy between the reference accelerometer and the test transducer. The 9210D is designed to provide long-term reliable performance over the frequency range of 0.7 Hz to 2 kHz. The 9210D can be used for a variety of applications that include:

- *Verification and calibration of vibration transducers and related test systems*
- *Verification of connector and cabling integrity*
- *Verification of alert and alarm set points, digital integration*

1.2 Customer Support

The Modal Shop, Inc. is a PCB Group Company, and we are 100% committed to the PCB Group's pledge of "Total Customer Satisfaction." If at any time you have questions or problems with the 9210D system, please contact an Application Engineer at The Modal Shop, Inc.:

Telephone:	513-351-9919
Toll Free:	800-860-4TMS (4867)
Fax:	513-458-2172
Email:	techsupport@modalshop.com

1.3 Cautionary Notes

- *Loads of up to 800 grams (28.22 ounces) can be mounted directly to the 9210D mounting platform. Larger loads may be applied to the platform, however, if prolonged testing of a heavy load is planned, we recommend using an external transducer suspension system. Under these conditions, the vibration waveform should be viewed on the oscilloscope to aid in positioning the test transducer and platform to reduce distortion that can occur with very heavy weights.*
- *The 9210D should always be operated on a stable, flat surface. Any external motion disturbance of the 9210D body may affect the accuracy and stability of its*

shaker control and measurement. The susceptibility to external disturbance varies by frequency and number of integrations.

- *The 9210D is designed for field test applications, but care must be taken to maintain the integrity of the mounting platform assembly.*
- *Hearing protection recommended when operating the 9210D for an extended period of time.*

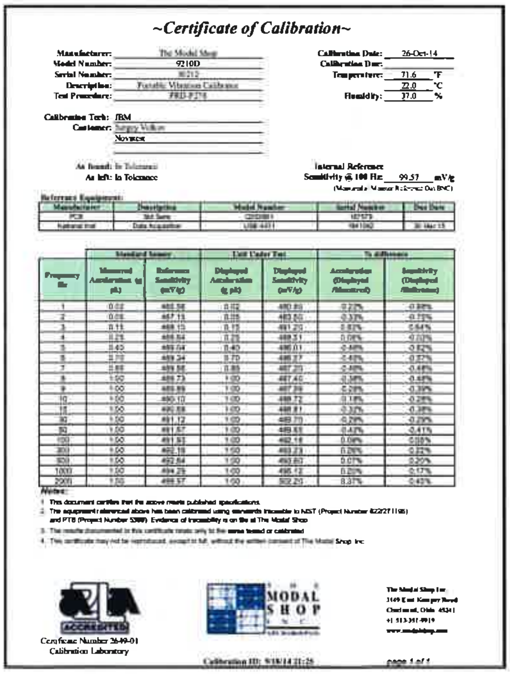
1.4 Supplied Accessories

Accessories pictured below are included with each 9210D Low-Frequency Portable Shaker Table.

1 – Mounting Pad (080A118)
2 – ¼-28 to ¼-28 Adaptor (081B20)
3 – 10-32 to ¼-28 Adaptor (081A08)

Power Supply and Plug Adaptors (9100-PS01)

A Certificate of Calibration is also included with every new unit. The Modal Shop, Inc. recommends annual recalibration of the 9210D unit. The Calibration Service Code is 9210-CAL01.

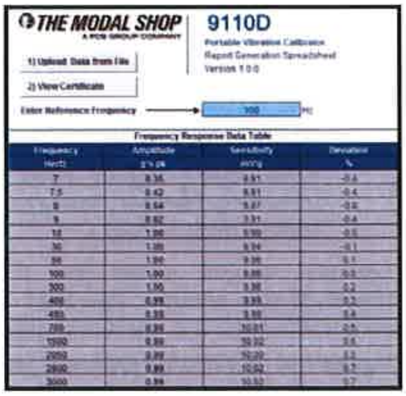


~Certificate of Calibration~

Model Number: 9210D
Calibration Date: 26-Oct-14
Temperature: 71.6 °F
22.0 °C
Humidity: 37.0 %
Calibration Tech: JBM
As left: In Tolerance
Internal Reference Sensitivity @ 100 Hz: 99.57 mV/g

9210D Calibration Certificate

The 9210D should be returned to The Modal Shop, Inc. periodically for recalibration. The 9210D Service Code is 9210-CAL01.



USB Flash Drive Pre-Loaded with Report Generating Worksheet

1.5 Optional Fixturing and Accessories

For operation in certain applications, such as calibration of non-contact displacement sensors, The Modal Shop, Inc. offers optional mounting fixturing. Reference the table below when ordering these optional adaptors and accessories.

Accessory	Description
9100-PPA01	Proximity probe adaptor kit, supports probes with common case threads ranging from M6 to 3/8 in. Includes Mitutoyo micrometer and 9100-PPA02 nickel-plated 4140 steel target.
9100-MPPA01	Proximity probe adaptor kit, supports probes with common case threads ranging from M6 to 3/8 in. Includes Mitutoyo micrometer (metric) and 9100-PPA02 nickel-plated 4140 steel target.
9100-MNTKIT	Mounting accessory kit for 9100 Series Portable Vibration Calibrators, to adapt to ¼-28 threaded mounting platforms. Includes studs/inserts (¼-28, 10-32, 6-32 and 5-40) and bases (for adhesive, magnetic and custom thread patterns).
9105C	Transfer standard reference accelerometer and ICP® sensor signal conditioner, for calibration and system verification of the 9100 Series Portable Vibration Calibrators.

1.6 Replacement Accessories

Accessory	Description
9100-PS01	18-Volt, 1-amp power supply/charger for 9210D Portable Shaker Table, universal 100-240 V, 50/60 Hz.
9100-BAT01	Replacement battery for 9100 Series Portable Vibration Calibrators.
9100-PPA02	Target for 9100-PPA01 or 9100-MPPA01 proximity probe adaptor kit, nickel-plated 4140 steel.

9210D Operation 2

2.1 Basic Operation

Test Set-Up

1. Mount your sensor to the 9210D mounting platform.
   - The 9210D sensor mounting platform is threaded for a ¼-28 stud. Select an appropriate adaptor for mounting the sensor.
   - Press down slightly while tightening the sensor under test. The 9210D mounting platform features an integral wrench to prevent damage to the shaker from torque.
2. Connect sensor under test (SUT) to "Test Sensor In." Make sure that connections are secure. The SUT can also be connected to data acquisition for system verification (i.e. alert and alarm verification).
3. Power the unit ON by pressing and holding the **FREQUENCY** dial for 3 seconds.

Selecting Input Mode

4. The 9210D can accept ICP® as well as output voltage sensors. To toggle between ICP® and Voltage Mode: press the **FREQUENCY** button. Rotate the **FREQUENCY** button until **TEST SETTINGS** is highlighted, then press **FREQUENCY** again. Rotate until **SENSOR TYPE** selection is highlighted and press **FREQUENCY** once more to toggle between ICP® and Voltage. To return to basic operation, use the **FREQUENCY** button to highlight **BACK**, then press again when **BACK** is highlighted on the **CALIBRATION OPTIONS** menu.

   Note: ICP (or IEPE) mode sensors are the most popular type of accelerometer transducers and require a 2 mA to 20 mA constant current supply to operate. The 9210D unit supplies the necessary constant current to power up this class of sensors. Voltage output sensors are typically velocity sensors, but it could also be the voltage output of a signal conditioner associated with any type of vibration transducer (accelerometer, velocity or displacement sensor). Refer to the Sensor Signal Measurement Electronics section (SUT Input Characteristics and Considerations) for details.

Setting the Frequency

5. Select the desired frequency for testing by turning the **FREQUENCY** dial clockwise to increase or counterclockwise to decrease.
   - Slow Turns – setting will increase or decrease by single steps
   - Fast Turns – setting will increase or decrease by larger increments

Setting the Amplitude

6. Select the correct Amplitude Units for your test by pressing and releasing the **AMPLITUDE** dial. The following options are available:

Acceleration	Velocity	Displacement
g pk g RMS m/s^2 pk m/s^2 RMS	in/s pk in/s RMS mm/s pk mm/s RMS	mils pk-pk µm pk-pk

7. Select the desired amplitude for testing by turning the **AMPLITUDE** dial clockwise to increase, or counter clockwise to decrease the setting.
   - Slow Turns – settings will increase or decrease by smaller increments
   - Fast Turns – settings will increase or decrease by larger increments

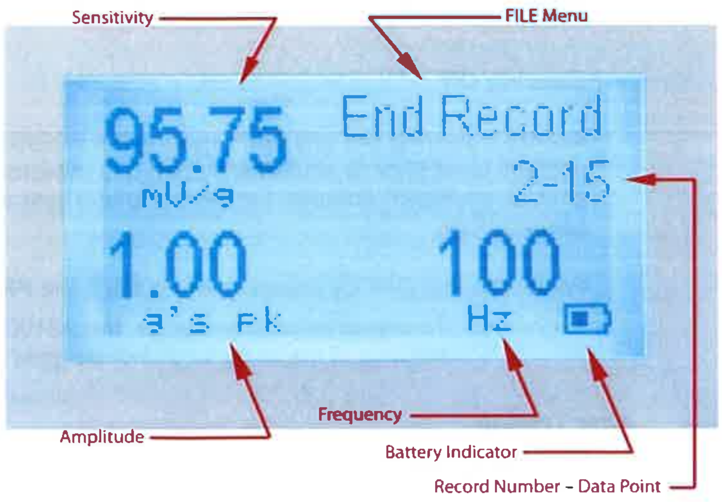
     - When the maximum amplitude level is needed, be sure the battery is fully charged.
     - The minimum recommended calibration amplitude is 0.01 g pk acceleration.
     - The 9210D features internal control to protect the shaker from hitting bottom, reaching its maximum stroke. Depending upon payload and frequency, motion may be limited to less than the stated max peak to peak displacement of 400 mils (10.1 µm). If the shaker does hit bottom, immediately reduce the amplitude to prevent damage to the unit.

Record and Save Calibration Points

8. Once the frequency and amplitude are set to desired values, with the file menu set to "Save Point," press the **FILE** dial to store the calibration data point.
9. Repeat steps 5, and 7 through 9 to set the frequency and amplitude to increment to the next calibration data point and save.

Completing and Storing Record to Memory

10. Once all data points have been saved in a record and record is complete, rotate **FILE** dial and press it to select "End Record."
    - The screen will prompt with:



11. Rotate the **FILE** dial to "Edit" to enter the model number, serial number and axis. The **FILE** menu for this screen also includes the tools "Next" and "Back."
    - Push the **FILE** dial to choose "Next," which goes to the next save screen.

    To "Save" the record without inputting an annotation, press the **FILE** dial two more times.

12. Rotate the **FILE** dial to "Edit" and press to store any annotations or additional notes (such as technician initials, etc):
    - Turn the **FILE** dial to the left and right to select each individual letter or number you wish to input as part of an annotation. Push the **FILE** dial to save each character.
    - Rotate the **FILE** dial and select "Save." This will save all data points in the listed record number. The record number shown on the screen increments automatically.

Transfer Records to USB Flash Drive

13. Rotate **FILE** dial and press to select "Tools."
14. Rotate **FILE** dial and press to select "USB Menu."
    - A USB flash drive must be connected to the unit. The USB must be formatted to FAT32. You can use the 9210D or a PC to format the flash drive.
15. To copy all data points and records to a USB Flash Drive, rotate **FILE** dial and press to select "Copy All Records."
    - This will leave current records on unit memory and also create a copy on the USB.
16. To move all data points and records to USB, rotate **FILE** dial and press to select "Move All Records."
    - This will remove current records on unit memory and move onto the USB.

Note: The USB hardware may not always recognize a USB flash drive if it is plugged into the USB port while the 9210D is in sleep mode. The Modal Shop, Inc. recommends connecting the USB drive while the 9210D is on and operational.

Powering Off

Before powering the unit OFF, reduce the vibration amplitude. The 9210D retains the settings used prior to shut down when it is powered back ON. Reducing the amplitude prior to shutdown ensures the sensor under test will not be jarred when the 9210D is powered ON.

Power the unit OFF by pressing and holding the **FREQUENCY** dial for 3 seconds.

- To preserve battery charge, the 9210D will automatically power off after 20 minutes of inactivity when not plugged into the charger.

After Testing

Plug the 9210D into an AC power source when not in use. This will ensure the batteries are fully charged for your next test and will also help to maximize the lifespan of the batteries.

Periodic calibration checks are recommended.

- A dedicated "verification sensor" can be used to check the system readings and results. By using a dedicated sensor, you can ensure that the system is providing the same result during each test.
- The 9210D should be returned to The Modal Shop, Inc. for regular recalibration (recommended annually - Service Code 9210-CAL01) or for any maintenance or repair. The most current factory recalibration date is displayed on the LCD screen during the 9210D boot-up sequence.

Settling Time and Distortion

As the calibration frequency decreases, the required settling time for the shaker feedback control system increases. When calibrating at low frequencies, allow ample time for the control system to converge to the target amplitude and minimize the distortion. At the minimum frequency of 0.7 Hz, complete settling may take as long as 3 minutes. The settling time may also increase with heavier test sensors.

If harmonic distortion occasionally appears unusually high after settling, it may be possible to reach a lower distortion by re-adjusting the frequency, or resetting the system, and allowing another settling period.

To minimize distortion, calibrate at amplitude less than the maximum allowed amplitude.

Report Generation Workbook

Calibration data can be saved into the 9210D's internal memory and easily exported to a personal computer using a USB Flash Drive.

The 9210D Low-Frequency Portable Shaker Table includes a pre-formatted USB Flash Drive with a Microsoft Excel Report Generation Workbook for the creation of customizable calibration certificates. The Excel file provides an intuitive interface which allows a user to create and print a calibration certificate with just a few mouse clicks. In order to use the file, make sure macros are enabled, otherwise Excel won't be able to load data and create the certificates.

The Excel workbook consists of the following worksheets or tabs:

- **FRData** – Use this tab to create frequency response certificates in just two steps:
  1. Clicking on the **"Upload Data from File"** button prompts the user to select and import a ".CSV" calibration data file previously created by the 9210D.
  2. Once data is loaded into the table, click **"View Certificate"** to see and print a calibration certificate containing the frequency response data (the reference frequency for the calibration certificate is 100 Hz and can be changed by the user as needed)
- **LINData** –Use this tab to create linearity response certificates. The worksheet applies linear regression to interpolate the data. The **Max Linearity** is calculated for the worst deviation of a particular point from the best-fit straight line (BFSL) of all tested points. The table also displays the specific results at each test level.

The LINData worksheet has two tables. The left table should be used for creating dynamic linearity data calibration certificates in just two steps:

1. Click on **"Upload Data from File"** to select and import a ".CSV" calibration data file previously created by the 9210D.

2. Once data is loaded into the table, click **"View Certificate"** to see and print a calibration certificate containing the linearity response data. The worksheet expects the data points to be taken at the same frequency. A checkbox option labeled **"Set Y-intercept to zero"** is available to force the interpolation to go through the origin point.

The right table in the LINData worksheet is used to enter static linearity data as measured with the aid of a micrometer (supplied with the 9100-PPA01 or the 9100-MPPA01 proximity probe adaptor kits) and a DC voltmeter (not included):

1. Enter units for displacement (typically mils or µm) and output (DC voltage).
2. Enter data as measured with the micrometer and voltmeter.
3. Once data is entered into the table, click **"View Certificate"** to see and print a calibration certificate containing the static linearity response data.

- **FRCert** - Displays the frequency response calibration certificate using the current data and information from FRData.
- **LINCert** - Displays the linearity response calibration certificate using dynamic linearity data from LINData.
- **SLINCert** - Displays the linearity response calibration certificate using static linearity data from LINData.

Additional Features

Delete

The "Delete" feature can be found under the **FILE** dial > "Delete." When "Delete" is selected, the shaker will stop moving and four options will appear:

1. "Delete Point" will delete a current point.
2. "Delete Record" will delete the entire current record.
3. "Delete All" will delete all data points and all records that are stored on the internal unit memory.
4. "Back" will return to the main screen.

USB Options

The "USB Options" feature can be found under the **FILE** dial > "Tools" > "USB Menu" > "USB Options." When "USB Options" is selected, the following information will appear on the screen:

- "Status" – USB flash drive connected or not connected.
- "Partition" – Format of USB flash drive connected to the unit.
- "Available" – Memory space available on the USB flash drive.
- "Required" – Space required to save all records on the USB flash drive.

And the following actions are available:

- "Eject Drive" will safely eject the USB flash drive from the unit.
- "Format USB" for formatting the USB flash drive. (FAT32 partition)
- "Back" to go back to the USB Menu.

Date and Time

The "Date and Time" feature can be found under the **FILE** dial > "Tools" > "Options" > "Date and Time."

1. Press the **FILE** dial to select "Adjust."

2. Turn the **AMPLITUDE** dial to the select the current month, day and year and push the **FREQUENCY** dial to confirm or the **AMPLITUDE** dial to change.
3. Press the **AMPLITUDE** dial to select "yes" this is correct.
4. Turn the **AMPLITUDE** dial to select the current hours and minutes then push the **FREQUENCY** dial to confirm the time is correct.
5. Press the **AMPLITUDE** dial to select "yes" this is correct.

Calibration Interval

The "Calibration Interval" can be adjusted under the **FILE** dial > "Tools" > "Options" > "Calibration Interval."

1. Select "Adjust" and press **FILE** dial.
2. Turn **AMPLITUDE** dial to select number of months for Calibration Interval.
   - *Suggested Best Practice: 12 months*. The calibration interval can be defined to be anywhere from 1 to 72 months, or set up to never expire.
3. Press **FREQUENCY** dial to confirm selected Calibration Interval.

Traceability

The "Traceability" feature can be found under **FILE** dial > "Tools."

1. Press **FILE** dial to select "Traceability." A screen with the following information will appear:
   - Model
   - Serial Number
   - Firmware Revision Number
   - Calibration Date
   - Reference Sensor Sensitivity
   - PRD-P
   - NIST Traceability Number
   - PTB Traceability Number
2. Press the **FILE** dial to go back to main screen and the shaker will go back to shaking.

2.2 Calibration Options

Selecting the Frequency Units

1. Press the **FREQUENCY** button to access the **CALIBRATION OPTIONS** menu.
2. Turn the **FREQUENCY** button until **TEST SETTINGS** is highlighted, then press the **FREQUENCY** button.
3. Use the **FREQUENCY** button to highlight the Frequency Unit, press to toggle between Hz and CPM.

Pre-Comp

The pre-comp feature reduces distortion and inaccuracy by negating the effects of low-frequency harmonics. By default this feature is enabled.

External Source Input

As an option, it is possible to drive the 9210D by using an external signal source or a function generator. First, connect a signal source to the External Source BNC Input located on the top left corner of the unit.

- To toggle between internal and external source, press the **FREQUENCY** button to enter the **CALIBRATION OPTIONS** menu, then use the **FREQUENCY** button to highlight **TEST SETTINGS**. Press **FREQUENCY** again to enter the menu and highlight the source selection, pressing **FREQUENCY** again to toggle internal/external.
- When in external signal mode, the vibration amplitude is measured and displayed on the screen, however, the frequency and amplitude of the shaker is controlled by the external source, not by the 9210D. The frequency of the input signal is not displayed on this mode.

Do not exceed 1V RMS! Overdriving the unit may cause clipping, unwanted distortion and damage to the unit.

Customizing Available Amplitude Options

By default, ten different amplitude scales can be toggled by pressing the **AMPLITUDE** button. But the amount of scales can be reduced by selecting the desired amplitude options in the **CALIBRATION OPTIONS** menu.

1. Press the **FREQUENCY** button to access the **CALIBRATION OPTIONS** menu.
2. Turn the **FREQUENCY** button until **AMPLITUDE UNITS** is highlighted, then press the **FREQUENCY** button.
3. Use the **FREQUENCY** button to highlight each amplitude scale; press to toggle on/off. By default, all scales are on as indicated by a filled-in circle to the left. A hollow circle indicates the scale will not be available when pressing the **AMPLITUDE** button while in normal calibration mode.

Sensor Readout

By default, the sensor readout displayed is mV per engineering unit (EU) where the displayed EU matches selected scale (i.e. mV/mm/s for metric velocity). This displays the SUT sensitivity. Comparison with the SUT manufacturer's specification is the quickest method of determining proper sensor performance.

The readout can be changed to display only mV RMS read from the SUT without dividing by amplitude. To toggle this setting the **FREQUENCY** button is used: press to enter "Calibration Options" menu, highlight "Test Settings" and press to enter menu. Highlight "sensor readout" selection to toggle between mV/EU and mV.

Note: When sensor readout is set to mV this is the RMS value output from the SUT. Conversion must be made to peak or peak-to-peak depending upon desired results. See section 2.4 for Definition of RMS, Peak and Peak-to-Peak and for conversion factors.

2.3 Definition of Frequency Units

- Hertz (Hz) is defined as the number of periodic cycles per second and it is a standard unit for measuring signal frequency.
- CPM stands for Cycles Per Minute. CPM is commonly used for testing industrial sensors that monitor rotational vibration. 1 Hz=60 CPM

2.4 Definition of Amplitude Units

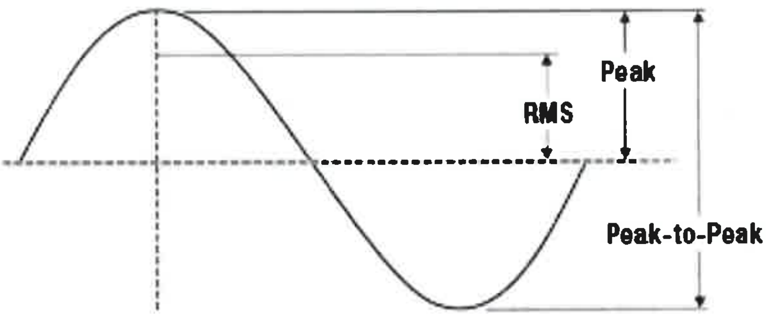


Figure: Sinusoidal Wave

- Root Mean Square (RMS) is a calculation that takes the square root of the average of the squared amplitudes from a set of data. This type of measurement takes all amplitudes of a signal into account rather than just one, making it an accurate tool for an overall calculation.
- Peak (pk) bases calculations on the highest value of the signal generated during testing. For a sinusoidal wave (as is produced by the 9210D), the peak value is calculated by RMS*√2. The 9210D does not measure a true peak value, but instead estimates the value mathematically based upon the RMS value.
- Peak-to-Peak (pk-pk) is a calculation of the difference between the highest positive peak and the lowest negative peak of a recorded sine wave. The pk-pk value is calculated as two times the peak value.
- Gravitational acceleration (g) is the acceleration experienced naturally by objects in earth's gravitational field. It is approximately equal to 9.80665 m/s^2.

2.5 Mounting Basics

Connecting Sensor to 9210D Platform

1. Mating surfaces of the mounting platform and sensor should be flat, parallel and free of dirt, paint, epoxy, scratches, etc.

2. Threads in platform, sensor and adaptor (if needed) must match to ensure a proper fit and that testing is free of errors. Clean any worn threads with a tap or die and coat them in a silicone grease for best results.

3. An adaptor may be needed to connect the sensor to the armature. The 9210D platform requires a ¼-28 thread.

4. Silicone grease can be applied to the mating surfaces and threads to ensure good mechanical coupling.

Tightening and Loosening Connections

1. When tightening or loosening the connection between the sensor and the 9210D mounting platform, press down on the sensor under test. The 9210D features an integral wrench, ensuring the armature is not damaged due to torque.

2. It is important to keep sensors and fixtures centered and straight when attaching them to the 9210D mounting platform. This will ensure a stable, even connection and eliminate potential alignment issues.

Input/Output

EXTERNAL SOURCE IN Input BNC

It is possible to drive the 9110D by using an external signal source or a function generator. First, connect a signal source to the **EXTERNAL SOURCE IN** BNC Input located on the top left corner of the unit. To enable the **EXTERNAL SOURCE IN** input, press the **FREQUENCY** dial to toggle through the units until the **Ext Sig** mode is selected on the display.

1. When in **Ext Sig** mode, the vibration amplitude is measured and displayed on the screen, however, the frequency and amplitude of the shaker is controlled by the external source, not by the 9210D. The frequency of the input signal is not displayed on this mode.
2. The amplitude and sensitivity values displayed on the screen are for reference only. The measurements are not accurate while in **Ext Sig** mode and do not fall under the published specifications for the product.

Do not exceed 1V RMS! Overdriving the unit may cause clipping, unwanted distortion and damage to the unit.

Monitor Reference Output

The 9210D is controlled by an internal shear mode quartz reference accelerometer. The voltage output of the reference accelerometer can be monitored through the available Monitor Reference BNC Output by connecting it to a readout device (e.g. voltmeter or oscilloscope).

Diagnostic Screen

The diagnostic screen can be displayed by holding down the file button for approximately 2 seconds. This screen displays information about the operation of the 9210D. The information found in this menu is displayed in real time:

Reference ICP Bias V
Test Sensor Bias V
Test Sensor Type: Either Voltage or ICP
Signal Type: Internal or External
Reference THD
Sensor THD

Exit the diagnostic screen by pressing the file button.

TEST SENSOR IN Input BNC

The 9110D provides the capability to measure the test sensor's voltage signal, replacing the need for an external DMM or data acquisition. The input electronics can be configured for either Voltage or ICP mode as described in Step 4 of "Basic Operation" earlier in this manual.

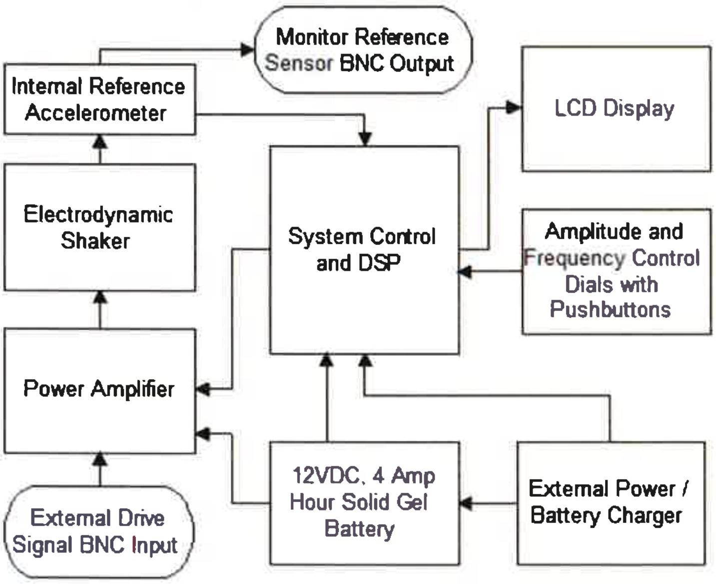
The **TEST SENSOR IN** input BNC is capable of measuring a voltage input of up to 10V pk-pk. As an ICP sensor signal conditioner, it measures up to 10V pk-pk AC signal while supplying 5mA ICP constant current at 25V DC. While in ICP mode, the input circuit is also monitoring the ICP sensor Bias Voltage and will indicate a Bias Fault when the DC voltage is below 2V DC or above 15V DC. The open circuit voltage of the ICP supply will be 25V DC. This open circuit and the ICP Bias Voltage may be checked using the diagnostic menu.

Theory of Operation 3

3.1 Instrumentation

The Model 9210D Low-Frequency Portable Shaker Table internal electrical system is comprised of several different mechanisms:

- *Electrodynamic Shaker*
- *Power Amplifier*
- *Reference Accelerometer*
- *Signal Generation Electronics*
- *Sensor Signal Measurement Electronics*
- *LCD Digital Display*
- *2 Dials with Detent and Integrated Push Buttons*
- *12 VDC, 4 Amp Hour Solid Gel Battery*
- *External Charger*



The LCD display continuously shows the frequency of the shaker drive signal and the vibration amplitude of the mounting platform as measured by the reference accelerometer. The reference accelerometer is a PCB Piezotronics ICP® quartz shear sensor, integrated into the mounting platform. A calibration "standard" maintained by The Modal Shop, Inc. is used to calibrate the 9210D as a complete system and provides NIST traceability.

The power amplifier is specially designed to provide the current required to drive the electrodynamic shaker.

The electronic signal processing system produces a variable frequency sine wave, which becomes the source of the driving signal to produce the vibration at the mounting platform. The frequency of the shaker drive signal is controlled by the front panel **FREQUENCY** dial. The amplitude of the shaker drive signal is controlled through a feedback loop, to maintain the stability of the actual motion. Adjusting the front panel **AMPLITUDE** dial adjusts the target vibration amplitude.

Pressing the **AMPLITUDE** dial toggles the amplitude measurement units through the following default choices. The available amplitude units can be customized, see page 10 for more information:

Acceleration	Velocity	Displacement
g's pk g's RMS m/s^2 pk m/s^2 RMS	in/s pk in/s RMS mm/s pk mm/s RMS	mils pk-pk µm pk-pk

Turning the **FILE** dial activates the file menu. Turn the **FILE** dial to toggle between the below options and press the dial again to select.

Save Point	End Record	Delete	Tools
	Next Edit Back	Delete Point Delete Record Delete All Back	USB Menu Options Traceability Back

Below are the options to choose from when the USB Menu is selected. Turn the **FILE** dial to the proper option and press it to select.

Copy All Records	Move All Records	USB Options
		Eject
		Format USB
		Back

Below are the options to choose from when the Options menu is selected. Turn the **FILE** dial to the proper option and press it to select.

Date and Time	Calibration Interval
Adjust	Adjust
Back	Back

Pressing and holding the **FILE** dial will return to the main calibration screen from any new level.

3.2 Battery and Charger

The Model 9210D can be operated from AC line power or from its internal rechargeable battery. When the external power supply is connected, it becomes the primary power source, operating the unit while simultaneously charging the battery.

Battery power is supplied by a sealed solid gel lead acid 12 VDC rechargeable battery. The battery can be permanently damaged if completely drained. To prevent damage, the 9210D will automatically shut off when the battery power level gets too low. Keeping the battery fully charged ensures the unit is always ready for use.

Under mild operating conditions, a fully charged battery will allow the 9210D to operate for up to 14 hours. The charge life of the battery depends on both the length of use and the amount of power (dependent upon payload, frequency and amplitude) required for a particular test. When testing requires high vibration levels, the charge life will be shorter than during less rigorous testing. For example, continuous testing of 100 gram payload at 10 g pk will drain the battery charge in approximately 1 hour.

A "Battery Life" indicator is displayed on the LCD screen to approximate the unit's remaining charge life. Replacement batteries (Model #9100-BAT01) and power supplies/chargers (Model # 9100-PS01) are available from The Modal Shop, Inc.

When operating the 9210D at high amplitudes and heavy payloads with the battery charger plugged in, the current draw to the shaker and amplifier can be large enough to overload the charging circuit resulting in an unstable output signal. Operating the 9210D under these conditions can result in damage to the electrical components in the system. In order to reestablish a stable output signal, turn down the amplitude level of the 9210D or unplug the charger.

Handling and Storage

It is recommended that the unit be kept "on charge" when in storage. The internal battery should provide long-term service under normal operating conditions. The Modal Shop, Inc. does not recommend that the battery be removed for shipping or storage for periods of more than 3 months.

It is recommended that the shipping lock be installed whenever the shaker is being transported. The shipping lock will help prevent damage in a case where the unit is dropped.

Specifications and Performance 4

4.1 General

Frequency Range (operating, 100 gram payload)	0.7 Hz – 2 kHz	42 - 120k CPM
Maximum Amplitude (100 Hz no payload)	2 g pk	19.6 m/s^2 pk
	12 in/s pk	305 mm/s pk
	400 mils pk - pk	10.1 µm pk – pk
Maximum Payload[1]	800 gram	800 gram

[1] Operating range reduced at higher payloads. Reference manual for full details

4.2 Accuracy of Readout

MEASURED WITH 10 GRAM QUARTZ REFERENCE ACCELEROMETER

Acceleration and Velocity (2 Hz to 2 kHz)	± 3%
Acceleration and Velocity (0.7 Hz to 2 kHz)	±1 dB
Displacement (2 Hz to 15 Hz)	± 6%
Displacement (0.7 Hz to 30 Hz)	± 2 dB
Amplitude Linearity (100 gram payload, 100 Hz)	< 1% up to 10 g pk
Waveform Distortion (1 Hz to 5 Hz)	Typically < 15%
Waveform Distortion (5 Hz to 20 Hz)	Typically < 10%
Amplitude Linearity (>20 Hz to 2 kHz)	Typically < 7%

4.3 Units of Readout

Amplitude	Acceleration	g pk	m/s^2 pk
		g RMS	m/s^2 RMS
	Velocity	in/s pk	mm/s pk
		in/s RMS	mm/s RMS
	Displacement	mils pk - pk	µm pk - pk
Frequency		Hz	CPM
Test Sensor Sensitivity		mV/EU[1]	mV (RMS)

[1] EU can be [g], [m/s^2], [in/s], [mm/s], [mils] or [µm].

SUT Specifications

SUT Input Voltage Range	10V AC pk-pk
SUT ICP Current	5 mA
SUT Bias Offset Measurement Range	0-25 V DC
SUT Bias Fault Voltage Limits	2V / 15V DC

4.4 Power Requirements

Internal Battery (sealed solid gel lead acid)	12 VDC, 4 amp hours	12 VDC, 4 amp hours
AC Power (for recharging battery)	110 – 240 Volts, 50 - 60 Hz	110 – 240 Volts, 50 - 60 Hz
Operating Battery Life[2]		
100 gram payload, 100 Hz, 1 g pk	14 hours	
100 gram payload, 100 Hz, 10 g pk	1 hour	

[2] As shipped from factory in new condition

4.5 Temperature

Operating	32° - 122° F	0° - 50° C

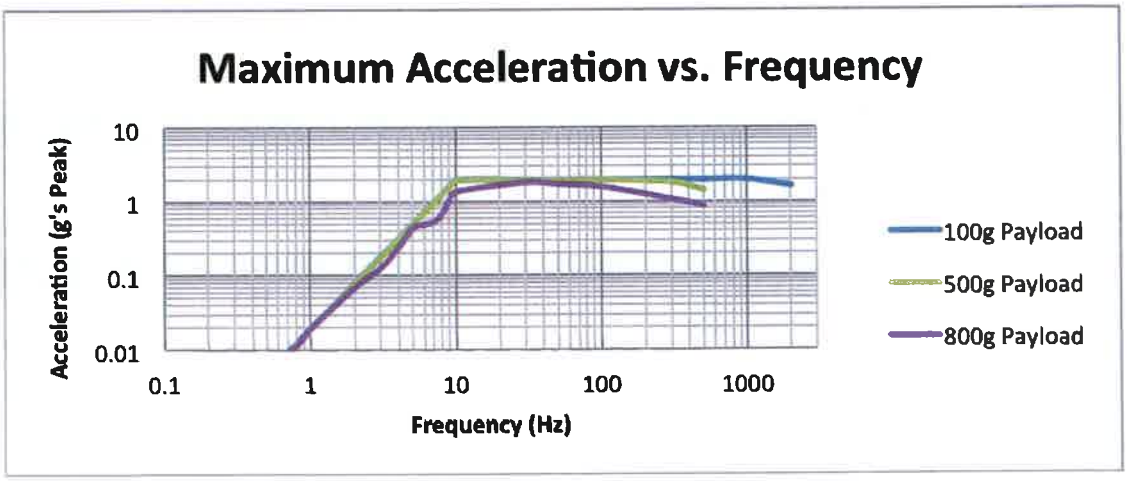
4.6 Physical

Dimensions (H x W x D)	8.5 in x 12 in x 10 in	22 cm x 30.5 cm x 28 cm
Weight	18 pounds	8.2 kg
Sensor Mounting Platform Thread Size	¼ - 28	

4.7 Shaker Loading

Maximum advisable vibration levels are dependent upon the maximum frequency of operation and the payload. The chart below shows the maximum vibration levels as a function of both frequency and payloads. Payloads exceeding 800 grams should not be tested on the Model 9210D.

Excessive loads may result in damage to the moving coil and flexure. Care must be taken when testing payloads with large footprints, particularly those with an offset center of gravity. Severe rocking modes can produce high transverse motion and lateral loads on the moving coil and flexure, resulting in damage. When fitting test transducers and fixtures onto the mounting platform, aim to keep the center of gravity directly above, and in line with the center axis of the ¼-28 threaded hole. This is a safeguard against side loading the shaker.



5.1 Operation Verification and Recalibration

As with all calibration systems, periodic verification of the system's performance is strongly recommended. This is best done by calibrating a dedicated verification accelerometer each day that the unit will be used. This practice confirms proper calibration of the equipment at the time of use. A precision accelerometer with a quartz sensing element is recommended for performing operational verification, for example the 9105C transfer standard available from The Modal Shop, Inc.

Results of the verification should be compared to previous results obtained with that dedicated, controlled accelerometer. If the calibration result of the verification sensor changes, the 9210D should be evaluated further to determine the root cause of the discrepancy.

Field repair of the 9210D is not possible, so if performance of the 9210D is out of specification, it should be sent back to The Modal Shop, Inc. for evaluation, repair and recalibration. Please contact The Modal Shop, Inc. at info@modalshop.com or +1.513.351.9919 for a Return of Material Authorization (RMA) number.

5.2 Standard Checks for Transducers

Linearity and frequency response checks should be performed periodically to validate transducer functionality. Linearity is a check to determine if the output sensitivity (mV/Unit of vibration, i.e., mV/g), remains constant from a minimum operating level to higher operating levels. This check is typically made at 100 Hz. The transducer manufacturer usually specifies this frequency on the transducer's original calibration certificate. Frequency Response is a check to determine that the output sensitivity (mV/Unit of vibration), or actual reading, is maintained over an expected operating frequency range. The 9210D's integral reference sensor is typically held at a constant level for the frequency response test.

The following typical transducer checkout tables outline typical test frequencies and vibration levels for checking accelerometers and velocity transducers. These should meet most general purpose requirements for verifying the functionality of transducers and measuring systems.

Typical Accelerometer Checkout

Set the 9210D to these or similar levels to perform the following checks:

Linearity Check (Typical Test Frequency = 100 Hz)					
9210D Amplitude (g)	0.2	0.5	1.0	1.5	2.0
Reported Level					

Frequency Response Check (Typical Test Level = 1 g)							
9210D Frequency (Hz)	1	50	100	200	500	1000	2000
Reported Level							

Typical Velocity Sensor Checkout

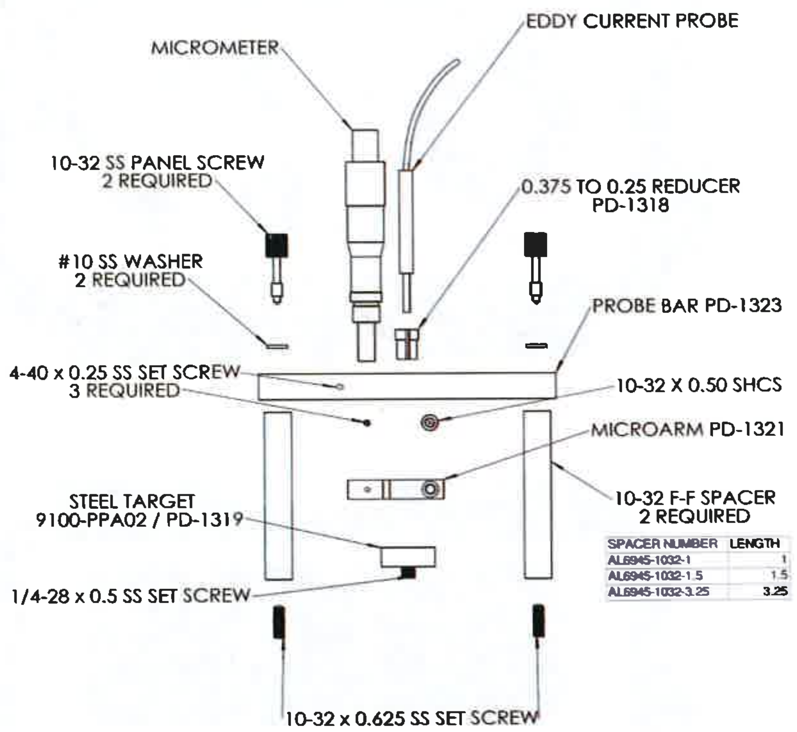
Set the 9210D to these or similar levels to perform the following checks:

Linearity Check (Typical Test Frequency = 100 Hz)					
9210D Amplitude (in/s)	0.2	0.5	1.0	2.0	5.0
Reported Level					

Frequency Response Check (Typical Test Level = 0.2 in/s)					
9210D Frequency (Hz)	1	10	50	100	500
Reported Level					

5.3 Non-Contact Displacement Sensor Calibration

Non-contact displacement sensors, also known as proximity probes, Eddy current probes or simply displacement probes, can be checked for accuracy, linearity and frequency response. Proximity probe systems require the use of the optional 9100-PPA01 (or 9100-MPPA01) proximity probe adaptor kit, shown on the next page. The following sections detail the procedure for performing linearity and frequency response checks on a non-contact displacement sensor.



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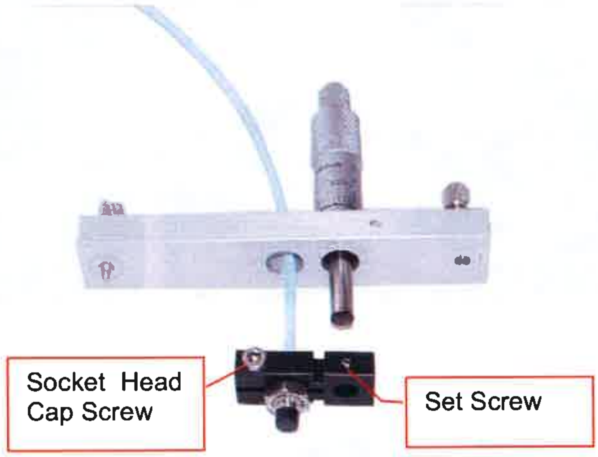
5.4 Non-Contact Displacement Sensor Test Set-Up

Note: The calculations in these instructions are based on a 200 mV/mil Eddy current proximity probe to provide an example based on nominal sensitivity. In some cases the proper proximity probe, extension cable and proximitor must be matched in order to obtain the expected output from this type of transducer.

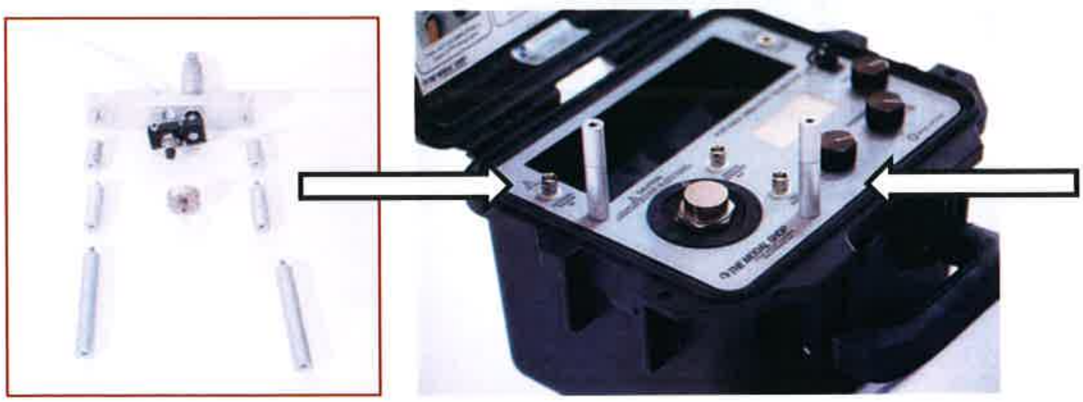
1. Remove the (2) 10-32 pan head screws on the user panel of the 9210 Low-Frequency Portable Shaker Table (white arrows in picture below).

2. Install the steel target into the shaker on the mounting platform.

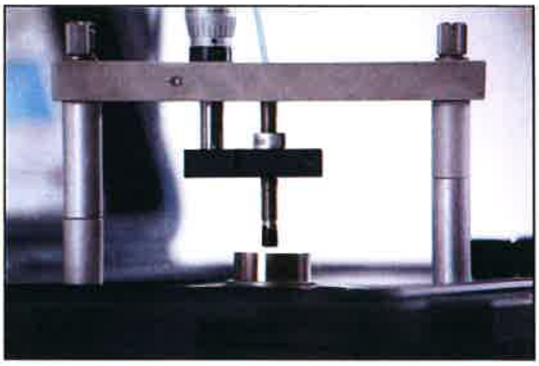
3. Install the non-contact displacement sensor in the microarm after stringing the probe through the probe bar as shown in the picture below. Please note: An 8-mm non-contact displacement sensor with 3/8-24 threaded case will mount directly while a 5-mm non-contact displacement sensor with a ¼-28 threaded case requires the supplied bushing. Slide the non-contact displacement sensor into the microarm; tighten the socket head cap screw inside the microarm to lightly squeeze the probe to ensure the probe is held securely.



4. Carefully lay out the assembly to resolve the required spacer or spacers to hold the non-contact displacement sensor the proper distance for the target as shown below. The non-contact displacement sensor will need to be held so that the sensor will contact the target and must be capable of traveling 200 mils before the micrometer runs out of travel. Non-contact displacement sensors come in various lengths so adjustability has been designed into the assembly. Attach selected spacer or spacers using set screws provided, leaving threaded holes exposed.



5. Finalize the assembly by attaching the probe bar, microarm, non-contact displacement sensor and micrometer on top of the spacers and secure with provided panel screws.



5.5 Non-Contact Displacement Sensor Frequency Response Check

IMPORTANT: The 9210D powers up at the unit's previous frequency and amplitude settings. Prior to using the 9210D for calibrating non-contact displacement sensors, set amplitude to a low level to avoid damaging the sensor with large displacements.

1. Set the micrometer to 0 mils, release the microarm with the set screw and slide the microarm down the barrel of the micrometer. Tighten the set screw to hold the microarm and probe when the probe makes contact with the target.

   Note: A piece of paper or metal shim can be used to improve accuracy of zero position. If utilizing this method, set the micrometer to the thickness of paper or shim and lower microarm and non-contact displacement sensor onto the shim until friction is felt between the shim and the target and the probe, then secure with the set screw.

2. With the non-contact displacement sensor powered up and the output wired to a voltmeter set to DC voltage, adjust the micrometer so the gap between the probe tip and the steel target is around 50 mils. If you are using a 200 mV/mil proximity probe, the voltmeter should read between -8 and -11 Volts DC. Fifty mils is the typical recommended gap setting for non-contact displacement sensors, and will ensure that you are in the sensor's linear output range. Consult your non-contact displacement sensor's user manual for additional information.

3. Press and hold the **AMPLITUDE** dial to power the unit on and set the test frequency to 100 Hz using the **FREQUENCY** dial.

4. Increase the vibration level to 5 mils peak-to-peak using the **AMPLITUDE** dial. Check the non-contact displacement sensor system output using an AC voltmeter or a vibration monitoring system indicator for the correct level ± 5%. If the displacement system output sensitivity is 200 mV/mil, the AC voltmeter should read approximately 353.5 mV RMS (70.7 mV x 5 mils). An oscilloscope should read approximately 1 V peak-to-peak (200 mV x 5 mils).

5. Make corresponding measurement checks at other frequencies in the 30 Hz to 100 Hz range.

6. Continue making corresponding measurement checks in the 100 Hz to 150 Hz range.

7. Turn the vibration level to minimum, and turn the power OFF when calibration checks are complete. Remove the displacement sensor and then store the proximity probe fixture and the target.

5.6 Non-Contact Displacement Sensor Linearity Check

Note: Reference steps 1-5 of "Non-Contact Displacement Sensor Test Set-Up" section earlier in this manual (page 21) for set-up instructions.

1. Power on the probe driver and connect a digital voltmeter to the output.
2. Set the micrometer to the number of mils corresponding to the center of the linear range for the probe being tested.
3. Loosen the set screw holding the probe in the adaptor.
4. Move the probe toward the target until the DC voltage, measured at the driver output, corresponds to the recommended gap voltage for the transducer under test (7.5 to 12 VDC typical).
5. Retighten the set screw.
6. Adjust the micrometer to the specified minimum gap reading and record the voltage on the voltmeter. Do not let the probe touch the target.
7. Increase the gap with the micrometer in either 5- or 10- mil steps and record the voltage at each step.
8. Divide the voltage output at each step by the number of mils per step. This value when converted to millivolts DC corresponds to the transducer sensitivity, typically 200 mV/mil.
9. Upon completion of tests, remove and store the probe adaptor and the target.

5.7 Maintenance

Recalibration and certification is recommended on an annual basis. Service of internal parts should only be performed by factory personnel. If the unit is removed from the case, the NIST calibration is void. Recertification can only be performed after re-assembly.

5.8 Declaration of Conformance

The Modal Shop, Inc. declares that:

- Model 9210D Low-Frequency Portable Shaker Table is in accordance with the following directives:
  - 89/336/EEC The Electromagnetic Compatibility Directive and its amending directives has been designed and manufactured to the following specifications:
  - Generic Emissions Standard (EN 50081-1: 1992 Part 1: Residential, commercial and light industry)
  - Generic Immunity Standard (EN 50082-1: 1977 Part 1: Residential, commercial and light industry and EN 50082-2: 1995 Part 2: Industrial environment).

Mark I. Schiefer
Chief Technical Officer