Operation manual

for the

Model 50
Infrasound Sensor

For use in the full infrasound band

Development, Calibration, and Production of Fine Infrasound Sensors

Chaparral Physics

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MADE IN ALASKA

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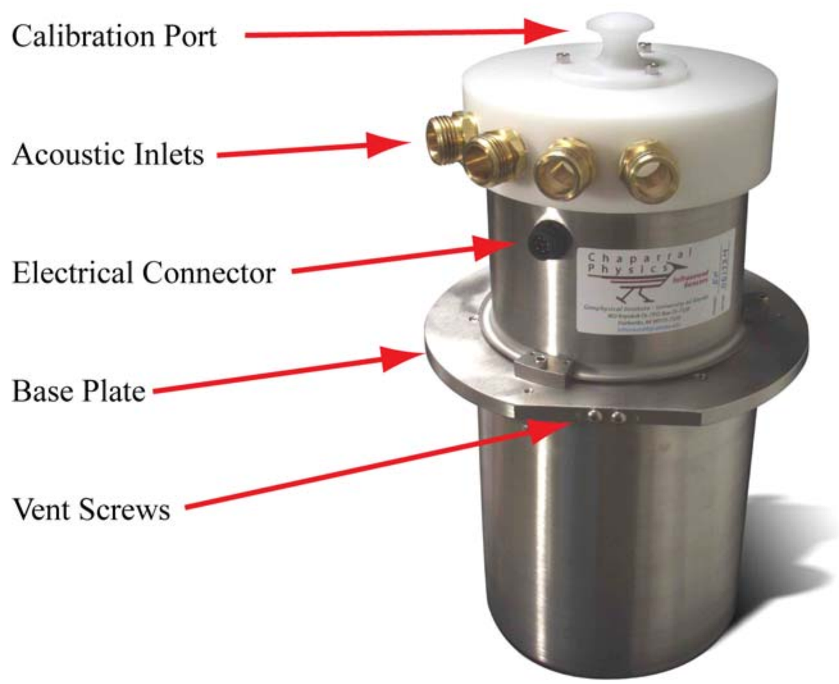
Chaparral Physics
Model 50 Infrasound Sensor

also referred to as a differential low air pressure sensor, an ultra low frequency microphone, or a microbarometer



A Chaparral Physics Model 50 infrasound sensor with 4 inlet ports

Chaparral Physics sensors combine rugged construction with wide bandwidth and low noise to ensure accurate measurements in the most demanding of environments. They have no need for altitude adjustments, and are carefully designed to reduce the effect of environmental temperature variations and mechanical vibrations. From the Ross ice-shelf in Antarctica through the rain forests of Central America to Alaska's tundra, Chaparral Physics microphones have proven their reliability and value as the finest infrasound measuring instruments in the world.

For installation suggestions, servicing, and repairs please contact:
chaparral@gi.alaska.edu or 907-474-7107 or

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Model 50
SPECIFICATIONS

Nominal Sensitivity:

High	2.0 volts/Pa @ 1 Hz, 18 Pa full scale range
Low	0.4 volts/Pa @ 1 Hz, 90 Pa full scale range

Individual sensor's calibrated value is +/-5% from nominal. Calibration value is traceable to the Los Alamos National Laboratory (LANL) calibration chamber.

Output:

Output type	Differential
Maximum	36 volts peak-to-peak (signal+ to signal-) ±9 volt max signal to ground
Frequency Response	Flat to within +0, -3 dB from 0.01 Hz to 50 Hz Flat to within +0, - 0.5 dB from 0.06 Hz to 10 Hz
Self-noise	Less then 0.10nPa^2/Hz @ 1 Hz, (-80dB Pa2/Hz, rel to 1 Pa) Less than 1mPa RMS, 0.02 to 50 Hz Less than 0.2 mPa RMS, 0.5 to 2 Hz,
Dynamic range	99dB high gain, 113dB in low gain @ 0.5 Hz to 2 Hz
Output Impedance	150Ω non-reactive, (recommend load >10kΩ) (Recommended less than 10,000pf loading)
Short circuit protected	signal+ to signal–, and signal to ground

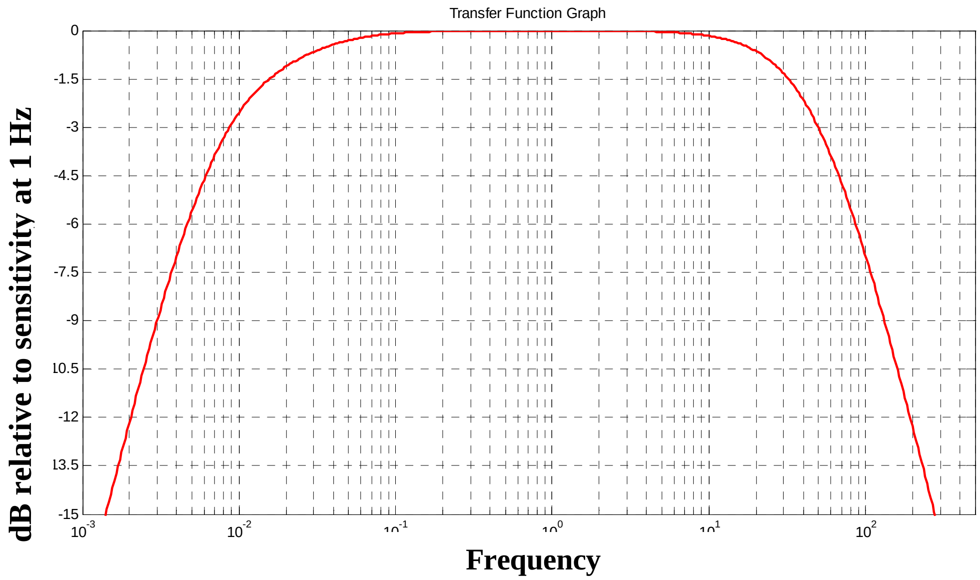
Power Requirements:

DC Source	12 volts (9-18 volts) DC, reverse voltage protected.
Current Drain	Less than 40 ma @ 12 v

Physical:	Sensor will function in any position or attitude. Sealed to IP-67 with acoustic inlets sealed and mating electrical connector or cap installed
Operating Temperature	-40º C to +65º C
Humidity	95% (non-condensing)
Dimensions	16.5" (42 cm) maximum height 9.9" (25 cm) maximum diameter
Weight	17.9 lbs (8.1 Kg), for 4-port version
Std Acoustic inlets	4 inlet ports (maximum 12), male, Garden-Hose-Thread, and a calibration port. Total fore-volume of a 4 port Model 50 with capped GHT inlets is ~55 cubic cm.

We reserve the right to modify and improve the sensor's performance.

Typical Frequency Response



This plot shows the roll off at either end of the nominal 0.02-50 Hz band pass of the Model 50. The red curve is the best fit of the data.

The transfer function is:

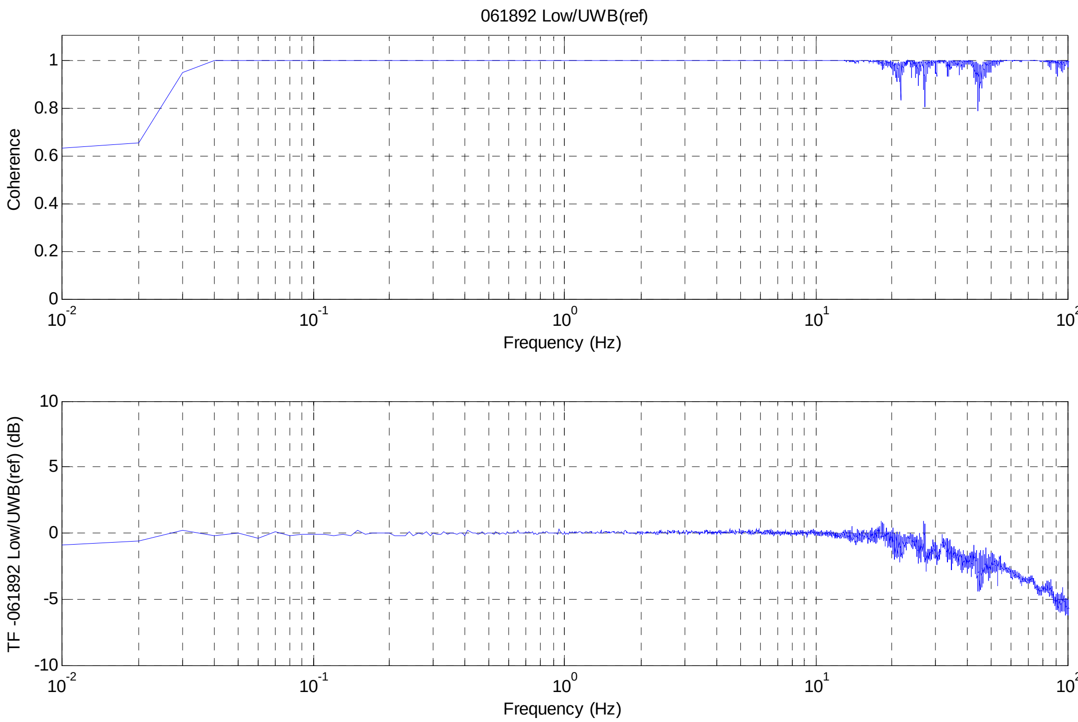
$$H(f) = K\frac{Poly(zeros)}{Poly(poles)}$$

Transfer function is only valid below 500Hz.

Table 1: Poles and Zeros for Model 50

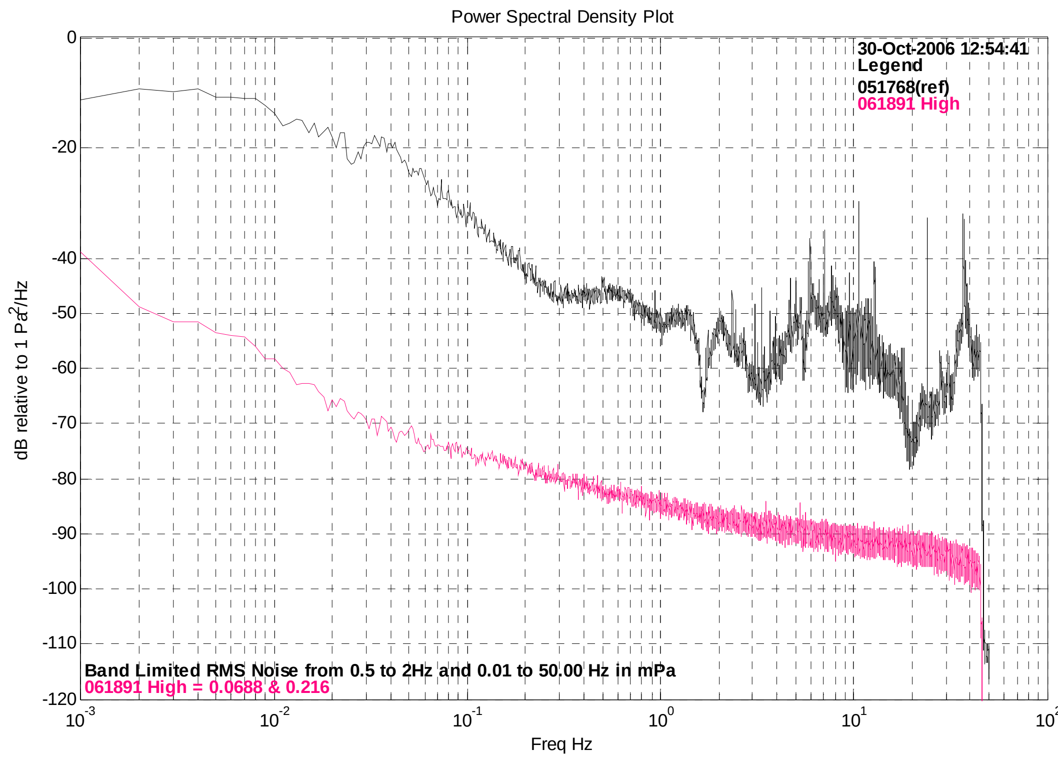
Poles	Zeros	K
0	0	314.1
-314.0	0	
-0.188	-0.17	
-0.044		

Typical Transfer Function



Top plot shows coherence between a special Chaparral Physics ultra wide band sensor, and a Model 50 (sn061892), both in low gain. Bottom trace shows the ratio between the two sensors, vertical axis is in units of dB.

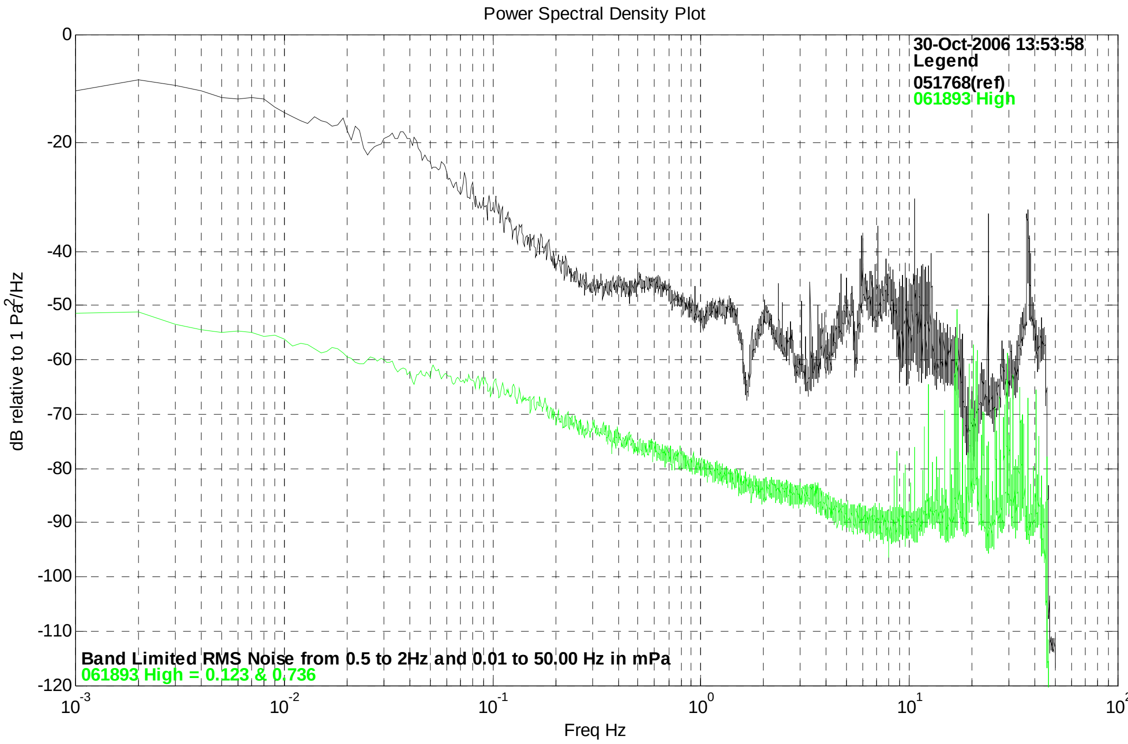
Typical Sensor Self-noise vs. Frequency, #1



The black trace is from Chaparral Physics, Model 2.2 (sn 051768), open to atmosphere, the Pink trace is from a Model 50 (sn 061891) sensor, capped inlets (no acoustic input), in low gain. The self noise is approximately the same in both high and low gain once the output is converted to Pa. This test was done in a building with high thermal noise but no vibration.

This test was conducted at 100 samples per second digitizer rate, with an anti-alias filter at ~45 Hz.

Typical Sensor Self-noise vs. Frequency, #2



The black trace is from a Chaparral Physics Model 2.2A (sn 051768), open to atmosphere, the Green trace is from a Model 50 (sn 061893) sensor, capped inlets (no acoustic input), in low gain. The self noise is approximately the same in both high and low gain once the output is converted to Pa. This test was conducted inside a large building with good thermal stability but with lots of vibration as indicated by the noise above 10 Hz.

This test was conducted at 100 samples per second digitizer rate, with an anti-alias filter at ~45 Hz.

Installation Suggestions for the Model 50 sensors

The Chaparral Physics Model 50 infrasound sensor is a physically robust scientific instrument that can be successfully deployed in a variety of environments. While it will adequately function in nearly any setup that meets the specifications found in this manual it takes some care and consideration to obtain maximum performance, data quality, and sensor longevity.

Infrasound sensors are inherently sensitive to rapid temperature fluctuations (ideal gas law), vibrations (Newton's second law), and elevation change (vertical atmospheric pressure gradient). While Chaparral Physics sensors are designed to significantly reduce the environmental noise from these physical limitations a careful installation can further reduce them to the point where they fall below the noise floor.

Infrasound sensors produce the best data in a dry environment with thermal and mechanical stability. Steps to provide these conditions should be part of every permanent installation plan. The most effective installations utilize an insulated enclosure or vault that seals out wind and rain. This provides both the environmental stability necessary and allows waste heat from the electronics to guard against condensation.

For quick set-up the Model 50 sensor can be installed directly in the environment, even in the rain. Care must be taken though to ensure that water does not enter the acoustic inlets and reach the diaphragm. Water on the diaphragm will cause the sensor to function improperly or become damaged. This will be easier to prevent if the sensor is supported above the ground with any hose or pipe connections sloping down and away from the sensor. The electronics are only sealed when the vent screw and cap or mating electrical connector are installed. This style of installation will result in noisier data, but can be a good solution for rapid installation of an array or when the signals of interest are large relative to the noise floor.

Installation Instructions

CHECK LIST

- Unpack and inspect sensor for shipping damage.

  Important: Do not disassemble the sensor.

- **Read entire manual.**

- Assemble electrical cable with the supplied mating connector as shown on page 11, *Model 50 Cable Connection*. Check the power on the connector pins for correct voltage and polarity.

- Place sensor in the chosen location.

- Install the two vent screws referred to on page 10, *Vent Screws*. During shipping the two vent screws are stored in the threaded "storage holes" provided on the base plate. Store the extra vent screws in safe location.

- Connect wind noise reducing array to acoustic inlet(s).

- Connect the electrical cable and turn on power supply for the sensor.

- Check that your recording or display apparatus is functioning properly.

- When removing sensor, reverse the steps above.

- **Retain heavy-duty box and shipping materials to return sensor for recalibration or repair.**

Important:

Read before first use of sensors or before further shipments of previously installed sensors

Vent Screw

The Model 50 has a sealed electronic chamber and a very high resistance leak to the back volume. In order to relieve any pressure differential that may be caused by temperature or altitude changes, the Model 50 has been designed with two vents in the base plate.

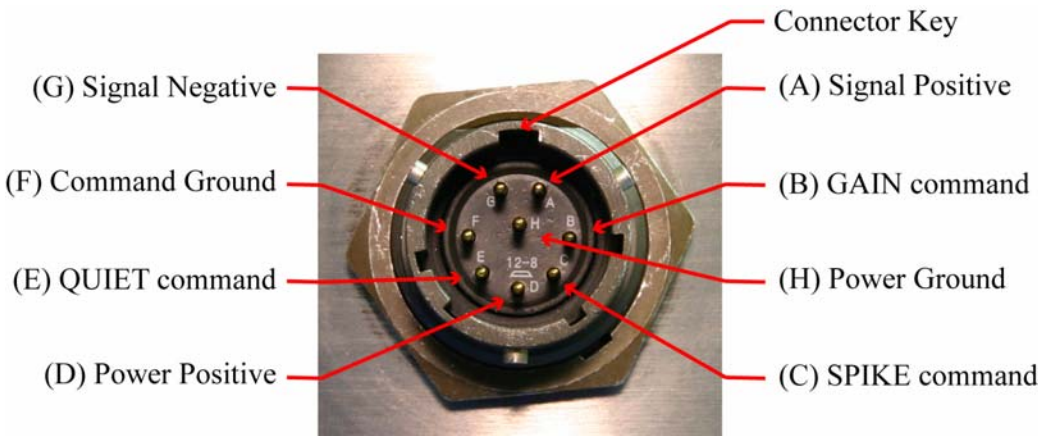
The vent screws must be removed before shipping or transporting the units, or when moving between large temperature differentials. During storage or shipping place the vent screws in the storage holes of the sensor so they will not get lost. The vent screws may be installed immediately upon arriving at the new altitude, however, when moving the sensor between large temperature differentials it is best to wait until the sensor has reached the local ambient temperature before re-installing the vent screws. Four vent screws are included with each sensor and only these special screws with their integral o-ring should be used for the purpose. A light coating of grease should be used on the o-ring to assist sealing. The rubber o-ring will wear with use so inspect the vent screw and replace as needed. These screws can be purchased from McMaster-Carr (www.mcmaster.com) part # 90825A800.

Vent Screw showing rubber o-ring

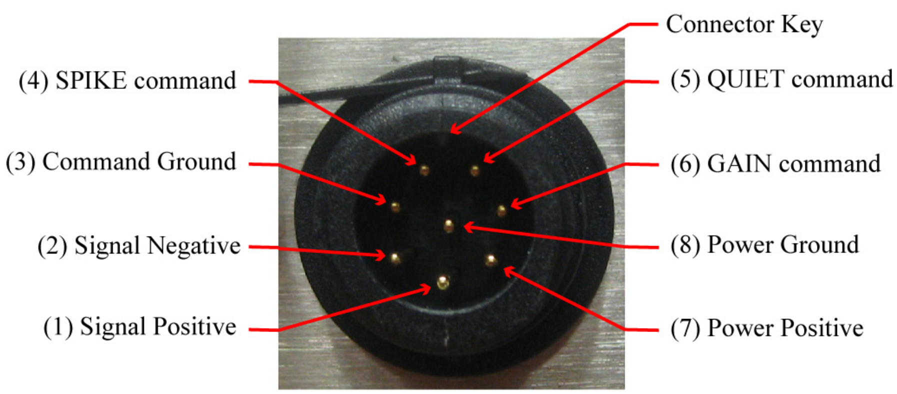
MODEL 50 Cable Connection

Your sensor has one of the two following connectors depending on which option was chosen during purchase.

Looking at the connector on the outside of the Model 21 microphone.



The connector is a PT07E-12-8P. The mating connector is a PT06E-12-8S-SR or a MS3116F12-8S; these two part numbers are functionally equivalent. This is an environmental connector and is sealed with or without the dust cap.



The connector is a Bulgin Buccaneer 400 series. The mating connector is part # PX0410/08S/6065 for 6.0 to 6.5mm diameter cables. Bulgin can supply other cable clamp fittings for other cable diameters. The connector is IP68 rated when mated or capped.

Chaparral Physics recommends that users connect the signal ground of the digitizer or recording device to the power ground of the power supply and to leave pin 3, the command ground of the sensor, disconnected from the digitizer. The command ground should only be used to control the three command pins. The power ground and command ground are connected inside the sensor.

To activate any of the commands connect the command pin to the command ground pin with a switch or relay. If it is more convenient, connecting to the power ground will also activate the command. All of the command pins float at ~12volts when they are not activated.

Understanding the GAIN Command

To activate the GAIN command, connect the GAIN command pin to the command ground pin. The switch or relay that activates the GAIN command **must** be able to sink 0.1 mA of current and have a resistance greater then 200 kOhms when off.

The purpose of the GAIN command is to best match the output of the sensor with your digitizer. With the GAIN command off the senor will be in low gain. When the GAIN command is activated the sensor will be in high gain.

Recommendations:

- If you have a 24 bit digitizer use low gain exclusively. The bit resolution of this digitizer is such that small signals are still easily resolved and low gain provides increased dynamic range.
- If you have a digitizer with 18 bits or less use high gain by default. If you expect signals that will exceed the dynamic range of high gain, then switch to low.

Nominal Sensitivity:

High	2.0 volts/Pa @ 1 Hz, 18 Pa full scale range
Low	0.4 volts/Pa @ 1 Hz, 90 Pa full scale range

Understanding the SPIKE Command

To activate the SPIKE command, connect the SPIKE command pin to the command ground pin. The switch or relay that activates the SPIKE command **must** be able to sink 12 mA of current and have a resistance greater then 20 kOhms when off.

The purpose of the SPIKE command is to provide a remote test of the sensor's proper operation and gain setting.

When the SPIKE command is activated and released, the sensor generates two steps with an exponential decay resulting in spikes at the output, hence the name. Activating the SPIKE command produces a negative going step, which in time will decay to the acoustic input signal. Releasing the command generates a positive step which will again decay to the acoustic input.

To observe the spike results cleanly, Chaparral Physics recommends that the sensor's acoustical inlet(s) be capped. In addition, since capping may pressurize the sensor, wait until the signal is at zero to ensure the pressure inside the sensor's fore and back volume have stabilized before applying the SPIKE command. Use of the SPIKE command will slightly change the sensor's acoustic calibration for the duration of the command. This function is only to check the sensor for correct operation.

The height of the resultant step above or below the signal without the step should be a constant value over time. The nominal values are ±5 volts in high gain, and ±1 volt in low gain, however, individual microphones and special order microphones differ. Please refer to the calibration sheet for your specific unit. **Any significant change from the expected spike value indicates a problem in either the sensor or the data recording apparatus.** If the change is due to the sensor, then it can be considered to be no longer in calibration. The spike is unrelated to the absolute atmospheric pressure and its value should remain constant regardless of atmospheric pressure.

Be sure to release the SPIKE command before attempting to use the microphone for normal use. It will take up to 30 minutes for the sensor to return to normal after the SPIKE command is released.

Users should record the spike voltage with their own recording apparatus and save the values for reference. This is important because depending on how you calculate the value of the spike it may not be identical to the value measured at the factory. The spike value given in the calibration sheet was measured by a digitizer with a 1 MΩ input impedance @ 100 samples per second. With the negative transition at index zero, 20 samples are averaged 10 samples before the transition, and 5 samples are averaged 5 samples after the transition.

Understanding the QUIET Command

To activate the QUIET command, connect the QUIET command pin to the command ground pin. The switch or relay that activates the QUIET command **must** be able to sink 28 mA of current and have a resistance greater then 10 kOhms when off.

The purpose of QUIET command is to force an electrical quiet to check for changes in sensor electronic noise.

The QUIET command allows the sensor's self noise to be checked while the sensor is still installed normally. This is accomplished by replacing the infrasound sensing capacitive element with a fixed capacitor, thus removing the sensing element from the microphone system.

After initiating the QUIET command and a settling period, only the electronic self-noise is available; no infrasound signals will be present in the output. This is similar to placing a very effective cap on the acoustic inlet(s), but the results will not include the noise generated by the sensing element. **This test is useful for determining if the sensor or the data recording apparatus has developed noise problems.** If the noise value changes the microphone may have a problem and should be checked further for proper operation.

The QUIET command may be used along with the SPIKE command. Wait until the output has settled, then trigger the SPIKE. You may find that the SPIKE values are different with the QUIET command asserted; this is normal as the QUIET command may slightly decalibrate the microphone while active. However, the SPIKE should behave in a similar manner with or without the QUIET command asserted.

Be sure to release the QUIET command before attempting to use the microphone for normal use. It will take up to 30 minutes for the sensor to return to normal after the QUIET command is released.

Operating Environment

The Model 50 sensor is a differential pressure sensor operating down to 0.01 Hz. To perform at these frequencies requires a large reference volume and a high resistance acoustic leak. Because of this, Model 50 sensors should be operated in a temperature-stable environment. While operating temperature does not affect the sensor itself, rapid temperature changes (>1°/hour) will affect the sensor's output signal.

Once powered in a temperature-stable environment, the Model 50 sensor will begin to operate after about 30 seconds of turn-on transients. While it will be ready for calibrated use in approximately 60 minutes, full sensor specifications will not be achieved until the unit has equilibrated to its environment.

Please contact Chaparral Physics for further information or clarification if needed.

Seismic Sensitivity

Chaparral Physics sensors are relatively immune to seismic or vibrational noise. However, one must remember that any change in elevation is a pressure change, since there is almost no difference between a microbarometer and a microaltimeter. For example, data will register during a large earthquake, not because of the vibrations themselves, but because the earthquake caused the ground to move up and down.

Since the Model 50 builds on Chaparral Physics's unique technology it is expected that the Model 50 will have a seismic response similar to the Model 5. The French DASE and the Comprehensive Nuclear-Test-Ban Treaty Organization's International Monitoring System have jointly studied and published a paper on the responses of the MB2000 and the Chaparral Physics Model 5. The paper's abstract notes the difference between the sensors tested, and highlights the low seismic sensitivity of the Chaparral Physics sensor:

> "*The MB2000 mechanical response has been found to be similar to that of the strong motion Guralp accelerometer CMG5T (flat in acceleration from DC - 50Hz) with sensitivity 0.802 V/m/s^2. The Chaparral5 microbarometer has about 40 times less sensitivity to mechanical vibrations than the MB2000.*"

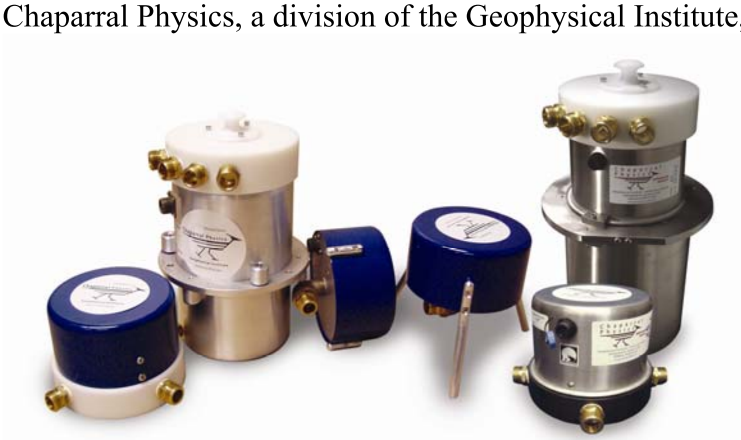
A link to the full paper can be found on Chaparral Physics website chaparral.gi.alaska.edu.

Selection and Use of Infrasound Sensors

Infrasound sensors are generally used in multiple-sensor-array configurations. To obtain good results the sensors used in an array should be matched for response and phase. All Chaparral Physics sensors are well matched over their specified pass band for use in multiple-sensor arrays. Chaparral Physics sensors differ slightly from each other outside of their stated band pass. It is also not recommended that different sensor types or brands be mixed into a single array, as the useful bandwidth will be limited to the portion where all of the sensor bandwidths overlap.

Warranty

The sensor is warranted for a period of one year from the original date of shipment as stated in the Chaparral Physics *terms and conditions*. For the full terms and conditions of sale see the document on the Chaparral Physics website. **Warranty is void if the unit is opened without prior express permission of Chaparral Physics.** Calibration is void and the unit may fail to function if opened, tampered with, or adjusted in any manner. There are no user serviceable parts or adjustments inside the unit.



Chaparral Physics Models 2.5, 5.1, 2.2 no-leg, 2.2, 25, and 50.