# BROADBAND SEISMOMETER MODELS KS-2000 AND KS-2000M

**OPERATION MANUAL** 



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# **Document History**

Date	ECN	Rev	Initials	Description
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# **Typographic Conventions**

When you see text like	This is what it means
\dir\dir\filename.ext	Data file name and extension with or without directory location included
\dir\dir\FILENAME.EXT	Executable file name and extension with or without the directory location included entered on the command line
{augument} {choice1   choice2}	Text inside braces is a <b>REQUIRED</b> command line argument, typed in as shown but with out braces. Vertical bar means a choice between two or more <b>REQUIRED</b> items in command line argument.
[augument] [choice1   choice2]	Text inside brackets are optional command line argument, typed in as shown but with out brackets. Vertical bar means a choice between two or more optional items in command line argument.
Italicized text	
CAPITALIZED TEXT	
Bold Text	Stress a word or words
Bold and Underlined text	Highly stress a word or words
CAPTITALIZED, BOLD, AND UNDEERLINED TEXT	Use <b>EXTREME CAUTION</b> when executing the procedure and/or command
KEY NAMES	Small capitals letters are used for keyboard key strokes A plus (+) indicates a combination of keys. Example: CRTL+C means hold down the CTRL key while pressing the C key.
Displayed Screen Text Next Line  Next to last Last line	Text as displayed and the screen. If 3 dots ( ) appear on a line then part of the example was intentional omitted If 3 dots ( ) appear at end of a line then part of that line was intentional omitted

## **1 GENERAL INFORMATION**

#### **1.1 Introduction**

This manual describes the installation, adjustment, and operation of the KS2000 and KS2000M Broadband Seismometers. It does not include repair or extensive fault isolation information. The seismometer is shown in Figure 1-1.

This section gives general information about the instrument.



Figure 1-1 KS2000 Broadband Seismometer

#### **1.2 Description and Purpose**

The KS2000 Broadband Seismometer is an orthogonal three-component surface mount seismometer. The seismometer weighs 7.7 kg. (17 lb.), and is 190.5 mm (7 1/2 in.) in diameter and 304.8 mm. (12 in.) high including leveling feet and handle. The instrument is designed for use in a surface vault that is well insulated, or other temperature stable environment.

The rest of this section gives general information about the instrument. Section 2 gives suggested installation information for surface mounting of the instrument. Section 3 describes signal, power and calibration wiring to the seismometer. Section 4 shows controls and describes adjustments of the seismometer. Section 5 describes the removing of cover and replacement of fuses. Section 6 describes operation of the seismometer. Section 7 lists shipping and handling information and, Section 8 gives a brief description of the principles of operation of the seismometer.

## 1.3 Specifications

Specifications of the instrument are listed in Table 1-1

#### Table 1-1 Specifications for Broadband Seismometer, Model KS2000

OPERATING CHARACTERISTICS	
Configuration	Three component, orthogonal Vertical, North, East
Output Signals	
Three seismic, Optional Velocity or Acceleration	Differential 40 V pp
Mass Position Monitor Signal – Three	Single ended 25 V pp
Sensitivity	
Seismic output Velocity Acceleration	2000 v/(m/sec) 220 v/(m/sec <sup>2</sup> ) -20° to 60°C (-4° to 140°F) Must be held stable to
Temperature Range	+/- 1°C for lowest hoise operation over bandwidth.
Frequency Range Seismic Outputs Velocity or Acceleration Mass monitor Outputs	Flat to –3 dB .01 to 50 Hz Flat to –3 dB .01 to 50 Hz Flat to dc to 50 Hz
Calibration Type Level	Flat to velocity or acceleration – jumper selectable Analog input – Voltage – Sine, Pulse ,etc 0-10 V pp
Power Voltage	9 to 18 V dc, about 1.5W
Physical Characteristics	
Dimensions Height with leveling feet and handle. Diameter	304.8 mm (12 in) 190.5 mm (7 ½ in)
Net Weight	7.7 kg (17 lb)
Shipping Dimensions	305 x 305 x 483 mm (12 x 12 x 19 in.)
Shipping Weight	9.1 kg (20 lb)

#### 1.4 Poles and Zeros

Velocity Channels, 120sec-50Hz		
Zeros radian/sec	Poles radian/sec	
0	-0.036 ± j 0.038	
0	-222 ± j 222	
Mass Monitor Channels, DC-50Hz		
Zeros radians/sec	Poles radians/sec	
	-222 ± j 222	

#### 1.5 Math Models

#### 1.5.1 Velocity Channel

$$\frac{E_{V}}{\dot{y}} = \frac{Ks^{2}}{\left(s^{2} + 2\lambda_{L}\varpi_{L}s + \varpi_{L}^{2}\right)\left(s^{2} + 2\lambda_{H}\varpi_{H}s + \varpi_{H}^{2}\right)}$$
 Volts/(meter/sec)

where,

$$\begin{split} \varpi_{L} &= .052 \text{ radian/sec} \\ \lambda_{L} &= .683 \\ \varpi_{H} &= .314.6 \text{ radian/sec} \\ \lambda_{H} &= .707 \\ \mathsf{K} &= \mathsf{S}_{V} \times \omega_{H}^{2} \\ \text{Zeros} &= 0 \text{ ; 0 radians/sec} \\ \text{Poles} &= -\varpi_{L}\lambda_{L} \pm j \varpi_{L} \sqrt{1 - \lambda_{L}^{2}} \quad ; \quad -\varpi_{H}\lambda_{H} \pm j \varpi_{H} \sqrt{1 - \lambda_{H}^{2}} \text{ radians/sec} \end{split}$$

#### 1.5.2 Mass Monitor Channel

$$\frac{E_{em}}{\ddot{y}} = \frac{H}{\left(s^2 + 2\lambda_H \overline{\omega}_H s + \overline{\omega}_H^2\right)} \text{ Volts/(meter/sec^2)}$$

where,

 $ω_{\rm H}$  = 314.6 radian/sec  $λ_{\rm H}$  = .707 H = S<sub>em</sub> x  $ω_{\rm H}^2$ Zeros = none Poles =  $-ω_{\rm H} λ_{\rm H} \pm j ω_{\rm H} \sqrt{1 - {\lambda_{\rm H}}^2}$  radians/sec

#### **1.6 Equipment Furnished**

Mating Connector Amphenol Bendix, PT06A-18-30S(SR)

#### 1.7 Equipment Required but not Supplied

Suitable vault or other containment.

Insulation or other means of thermally stabilizing installation.

# 2 INSTALLATION

#### 2.1 Introduction

Proper installation of the KS2000 is required for lowest noise performance of the instrument. Like all other broadband seismometers, the instrument is sensitive to temperature changes. Although the instrument is specified to operate over a large temperature range, the mass may need to be reset if the temperature varies by more than 1 or 2 degrees from the nominal mean installation temperature. To this end, all installation techniques are designed to minimize temperature variations of the installation. It is impossible to know all of the possible installation scenarios that users may encounter, therefore, the following suggestions should be regarded as general guide lines for the installation of the instrument.

#### 2.2 Protecting Against Atmospheric Changes

When the case is properly sealed, and all O-rings and screw seals are in place, the instrument is isolated from barometric pressure changes. A desiccant capsule absorbs any moisture that is trapped inside the enclosure.

If motorized mass position is used it is not necessary to open the cover of the instrument. For non-motorized versions, manual adjustment of the mass position is made through holes in the top and sides of the case. These holes are sealed with a seal washer under the head of the screw. Care must be taken that these washers are clean and in good repair when reinstalled.

#### 2.3 Mounting Seismometer

Proper mounting of the seismometer is essential to achieve the best performance of the instrument. The sensor is furnished with leveling feet that can be used to level the instrument on uneven surfaces. The feet may then be locked. However, for some permanent installations it may be preferable to remove the feet and grout the instrument to the mounting surface.

The mounting surface should be sound and well coupled to the bedrock or other formation that is to be monitored by the seismometer. Preferably the instrument should be thermally coupled to the ground. Instruments that are directly buried for short-term applications or located in permanent underground vaults that are only a meter or more below the surface will be well isolated from atmospheric temperature changes. Direct buried instruments should be located in well-drained locations to prevent water from seeping into the connector. If moisture is a problem, the potting of the main connector should be considered.

Instruments that are located in vaults or caves or other underground structures should be well insulated to prevent air currents around the outside of the instrument from causing turbulence inside the instrument. Dissipating a few watts of power in the top of the vault will often stratify the air in the vault and reduce turbulence. Wrapping the seismometer in microfoam insulation and placing a thick wall (10 cm.) wooden box over the seismometer provides insulation and a long thermal time constant.

## **3 WIRING AND CONECTION INFORMATION**

Table 3-1 lists the pin number assignments of the mating connector for the KS2000 seismometer, as viewed from solder cup side of the connector.

Pin No.	Function	Wire Style / Type
F	Signal Ground	BLK 1 twisted pair
W	VEM+	WHT 1 twisted pair
G	V+	WHT 2 twisted pair
Z		Shield
Х	V-	BLK 2 twisted pair
Н	VCAL-	BLK 3 twisted pair
Y	VCAL+	WHT 3 twisted pair
J	VCALEN	Jumper to NCALEN
М	Not used	
b	NEM+	WHT 4 twisted pair
N	N+	WHT 5 twisted pair
R		Shield
С	N-	BLK 5 twisted pair
Р	NCAL-	BLK 6 twisted pair
d	NCAL+	WHT 6 twisted pair
S	NCALEN	WHT 7 twisted pair
A	Not used	
Т	EEM+	WHT 8 twisted pair
В	E+	WHT 9 twisted pair
D		Shield
U	E-	BLK 9 twisted pair
С	ECAL-	WHT 20 twisted pair
V	ECAL+	BLK 10 twisted pair
E	ECALEN	Jumper to NCALEN
е	12V	WHT 11, WHT 12 twisted pair
f	12COM	BLK 11, BLK 12 twisted pair
K	Not used	
L	Not used	
а	Not used	
g	CENTER ENABLE	BLK 7 twisted pair

Table 3-1 Mating Connector Pin Assignments, KS2000 Broadband Seismometer

# Broadband Seismometer - Models KS-2000 and KS-2000M Operation Manual



Figure 3-1 Mating Connector Pin Locations, Solder Cup Side

# **4 ADJUSTMENTS AND CONTROLS**

#### 4.1 Leveling Seismometer.

A bubble level located in the top of the case of the seismometer will indicate when the seismometer is level. Three leveling feet are located on the bottom of the seismometer. A lock ring on each foot is used to lock each foot when the seismometer is level. Note that very small changes in level will greatly affect the mass position of the horizontal channels. The seismometer must be mounted and leveled before the mass position adjustments are made.

#### 4.2 Mass Lock

The instrument does not have a mass lock. Stops inside the instrument constrain motion of the mass against ordinary shocks. Hard drops on a hard surface can damage the seismometer. See Section 7 for shipping and packaging information.

#### 4.3 Mass Position Adjust – Manual

The mass position adjust screws are located as shown in Figure 4-1. Remove the sealed plug screws to expose the adjustment screw that is just inside the cover. Connect a dc voltmeter between the appropriate mass monitor jacks on the CI-2000 controller interface unit. See Figure 3-1 and Table 3-1,. Very carefully adjust mass position adjust screw to zero the voltage at the appropriate pin. Note that this is a very sensitive adjustment, and requires patience and practice to set zero to within 1.0 V dc. After the adjustment is made, replace the seal screw making sure that the seal washer is clean and in good repair. After the seismometer has reached thermal equilibrium, it may be necessary to readjust the mass position. For seismometers located in remote locations it will be preferable to use the KS2000M.

#### 4.4 Mass Position Adjust - Electric Motor (KS2000M Only)

The KS2000M seismometer is equipped with motorized mass position adjustments. A separate motor is use for each axis. To center the masses of the KS2000M, the CENTER ENABLE pin must be momentarily shorted to signal ground (use pin F and <u>not</u> 12COM). This can conveniently be done with the CI-2000 controller interface, by toggling the MASS CENTERING / INITIATE switch.

<u>Allow 10 minutes for mass centering after the switch is toggled</u>. Course centering (within ±0.5 V) is achieved very quickly, and the centering of each channel may be observed using the CI-2000. However, fine centering (within 50 mV) takes several minutes to execute after course centering is complete. Warning: Do not enable calibration during the centering of the unit. Although no harm will be done to the unit, the power consumption becomes excessive.



Figure 4-1 Location of Mass Position Screw Adjustments

## **5 REMOVING COVER AND REPLACLING FUSES**

#### 5.1 Cover removal

Reference Figure 5-1. Remove the connector nut. Remove the six socket head screws that hold the cover in place. Screw three of the screws just removed into the three threaded holes that are located at 120 degrees apart around the edge of the cover. Turn the three screws approximately equal amounts to force the cover up from the case. Gently grasp the handle and remove the cover being sure to not damage the O-ring. Remove the three screws and set the cover aside.

The cylindrical case may be removed from the bottom plate in a similar manner. Horizontal mass position seal screws must be removed, before removing the cylindrical case.



Figure 5-1 Cover and Case Removal

#### 5.2 Cover Installation

Check that the O-ring is clean and properly lubricated with any good quality O-ring lubricant (Dow Corning No. 55 O-Ring Lubricant or equivalent). Make sure that the cable assembly is properly connected to the Power Board. Hold the cover over the case and work the large connector through the hole and turn it so that it fits into the underside recess of the cover. Make sure that the connector O-ring is in place. Set the cover onto the case and install connector nut. Align six holes in cover with holes in case making sure to not pull the connector loose from the Power Board. Install the six socket head screws and tighten uniformly to draw the cover onto the case. Tighten the connector nut.

#### 5.3 Replace fuses.

Remove the cover as described in paragraph 5.1. The fuses F1, and F2 are located as shown in Figure 5-2 for the KS2000. The fuses are in a slightly different location on the KS2000M, but are labeled and easily found. Fuses are inserted into spring loaded sockets and are NOT soldered in place.

Replace fuses as required and replace cover as described in paragraph 5.2. The KS2000 uses <sup>3</sup>/<sub>4</sub> Amp fuses for F1 and F2. The KS2000M uses 1 Amp fuses for F1 and F2.



Figure 5-2 Location of Fuses within the KS2000

## **6 OPERATION**

#### 6.1 Beginning Operation

Once the seismometer is properly installed, connected to power and the recording system, apply power and adjust mass position as described in Section 4. Some time will be required for the instrument to reach thermal equilibrium. This stabilization can take hours to several days depending on the installation. Monitor the mass position, and readjust as necessary.

#### 6.2 Long Term Operation

Long term operation of the seismometer requires no routine maintenance other than occasional monitoring and adjusting mass position, and running routine calibrations as required by the user.

#### 6.3 Calibration

#### 6.3.1 Calibration Activation

Independent calibration circuits are provided for each channel. The calibration circuit is connected through independent relays. These relays should be turned off for normal operation.

To activate the calibration circuit, connect the calibration enable line (\_CALEN) to common. Calibration circuits may be enabled individually or all at the same time. Apply the desired calibration signal to \_CAL+ and \_CAL-. Calibration signals can be any analog voltage signal (e.g. sine, random, etc.). Calibration circuit input is differential with 20K Ohm input impedance. Maximum calibration signal is 10 V pp

The calibration circuit will produce a calibration signal that is flat to acceleration or velocity for constant calibration signal amplitude. This option is jumper selectable, and is set at the factory to constant acceleration unless specified otherwise. The acceleration calibration produces a larger calibration signal and is most useful in noisy environments. The velocity calibration is best used in very quite locations.

The jumpers are located on the Loop Board and the cover, case and Power Board must be removed to get to these jumpers. It is recommended that that this change is made only in the laboratory by a competent technician. The Loop Board is the lower board in the stack.

Be sure all inter-board connectors are properly made and seated in place when the Power Board is replaced.

Both Mass Monitor and Velocity channel sensitivity as well as the frequency response can be determined with the calibration signal.

#### 6.3.2 Mass Monitor Sensitivity using Acceleration Input.

Let  $E_{cal}$  be the sinusoidal calibration input signal and  $E_{em}$  be the Mass Monitor output signal for the channel under test. Then the acceleration sensitivity  $S_{em}$  of this channel is

$$S_{em} = \left(\frac{m(Rcal + Rcoil))}{2}\right)\left(\frac{\bar{r}}{r_c}\right)\left(\frac{1}{G}\right)\left(\frac{E_{em}}{E_{cal}}\right)$$

where,

m = suspension mass – kg

 $R_{cal}$  = calibration resistor – Ohms

R<sub>coil</sub> = Feedback coil resistance – Ohms

 $\bar{r}$  = pivot center to center of gravity distance – meter

 $r_c$  = pivot center to center of feedback transducer coil distance - meter Gain of cal. circuit = 2

G = Motor constant of feedback transducer – Newton/Ampere

For the KS2000 parameters, and at a signal frequency of 1 Hz.

$$\mathbf{S}_{em} = 3472 \left(\frac{1}{G}\right) \left(\frac{E_{em}}{E_{cal}}\right).$$

The constant G for each channel can be obtained from the customer data sheet furnished with each instrument.

#### 6.3.3 Velocity Channel Sensitivity $S_v$ using Acceleration Input.

Let  $E_{cal}$  be the sinusoidal calibration input signal and  $E_V$  be the Velocity Channel output signal for the channel under test. Then the velocity sensitivity  $S_V$  of this channel is

$$S_{V} = \frac{(2)(\pi)(f)m(Rcal + Rcoil)}{2} \left(\frac{\bar{r}}{r_{c}}\right) \left(\frac{1}{G}\right) \left(\frac{E_{V}}{E_{cal}}\right)$$

where,

f = frequency of signal - Hertz

m = suspension mass - kg

 $R_{cal}$  = calibration resistor - Ohms

R<sub>coil</sub> – Feedback coil resistance - Ohms

 $\bar{r}\,$  = pivot center to center of gravity distance - meter

 $r_c$  = pivot center to center of feedback transducer coil distance - meter

Gain of cal circuit = 2

G = Motor constant of feedback transducer – Newton/Ampere For the KS2000 parameters, and at a signal frequency of 1 Hz.

$$S_{v} = 21815 \left(\frac{1}{G}\right) \left(\frac{E_{v}}{E_{cal}}\right).$$

The constant G for each channel can be obtained from the customer data sheet furnished with each instrument.

#### 6.3.4 Velocity Calibration using S<sub>V</sub> Velocity Calibration.

Let  $E_{cal}$  be the sinusoidal calibration input signal and  $E_V$  be the Velocity Channel output signal for the channel under test. Then the velocity sensitivity  $S_V$  of this channel is

$$\mathbf{S}_{\mathrm{V}} = \left(\frac{\mathbf{m}}{2 \times \mathbf{G} \times \mathbf{C}_{\mathrm{cal}}}\right) \left(\frac{\overline{\mathbf{r}}}{\mathbf{r}_{\mathrm{c}}}\right) \left(\frac{\mathbf{E}_{\mathrm{v}}}{\mathbf{E}_{\mathrm{cal}}}\right)$$

where,

m = suspension mass - kg

C<sub>cal</sub> = calibration capacitor - Farads

 $\bar{r}$  = pivot center to center of gravity distance - meter

 $r_c$  = pivot center to center of feedback transducer coil distance - meter

Gain of cal. circuit = 2

G = Motor constant of feedback transducer – Newton/Ampere

For the KS2000 parameters the equation is

$$S_v = 1.724 \times 10^5 \left(\frac{1}{G}\right) \left(\frac{E_v}{E_{cal}}\right)$$

It is assumed in the above equation , and it is true for the KS2000 seismometer, that

$$\frac{1}{2 \times \pi \times C_{cal}} \rangle \rangle R_{coil}$$

#### 6.3.5 Mass Monitor Calibration using Velocity Calibration.

Let  $E_{cal}$  be the sinusoidal calibration input signal and  $E_{em}$  be the Mass Monitor output signal for the channel under test. Then the acceleration sensitivity  $S_{em}$  of this channel is

$$S_{em} = \left(\frac{m}{2G(2 \times \pi \times f)C_{cal}}\right)\left(\frac{\bar{r}}{r_{c}}\right)\left(\frac{E_{em}}{E_{cal}}\right)$$

where,

f = frequency of signal - Hertz

m = suspension mass - kg

C<sub>cal</sub> = calibration capacitor - Farads

 $\bar{r}$  = pivot center to center of gravity distance - meter

 $r_c$  = pivot center to center of feedback transducer coil distance - meter Gain of cal. circuit = 2

G = Motor constant of feedback transducer - Newton/Ampere

For the KS2000 parameters the equation becomes

$$S_{em} = 2.744 \times 10^4 \left(\frac{1}{G}\right) \left(\frac{1}{f}\right) \left(\frac{E_{em}}{E_{cal}}\right)$$

## **7 SHIPPING INFORMATION**

The factory-shipping box should be retained for shipping to the field or for return to the factory should it become necessary. The KS2000 does not use a mass lock therefore it is important that the factory shipping box or equivalent be used for transporting the instrument.

## **8 PRINCIPLES OF OPERATION**

The basic KS2000 seismometer configuration is shown in

Figure 8-1. Earth vibrations provide an input to the block labeled SUSPENSION. The suspension consists of an inertial spring-mass combination oriented to respond to either vertical or horizontal vibration. The displacement of the mass relative to the frame is proportional to the earth or frame acceleration. This relative motion is measured by a capacitance bridge transducer. The bridge is excited by a sinusoidal voltage. This combination produces a suppressed-carrier amplitude-modulated signal that is proportional to the mass and the frame.

The bridge imbalance produces a positive or negative signal phase for positive or negative earth acceleration. The IF preamplifier located on each module provides gain and drive capability for a short cable run to the loop amplifier and demodulator. This signal is further amplified and synchronously demodulated by the loop electronics. The output at this point is a voltage analog of the mass with respect to the frame.

Feedback is applied to the coil-magnet transducer through two paths. The resistive path provides position feedback that tends to restore the mass to its rest position. This action produces a force that almost exactly balances the input force caused by the earth acceleration. Velocity feedback flows through the second path (capacitor, Cv) to damp the suspension. The combination of these feedback paths produces response at the loop output circuit that is flat to acceleration from dc to 50 Hz.

This acceleration signal is ac coupled to the bandpass filter/integrator circuit to produce either an acceleration response or a velocity response that is flat from .01 to 50 Hz. This amplifier is a chopper-stabilized circuit that is synchronized to the loop carrier signal.

An auxiliary signal is taken from the loop output prior to the integrator. This low level signal is flat from dc to 50 Hz, and is used to monitor mass position. This output is not a low noise output and will have 1/f noise at low frequencies.

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Figure 8-1 Block Diagram of KS2000