User Guide

EpiSensor

Force Balance Accelerometer

Model FBA ES-T

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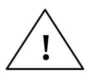
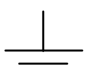
Symbols & Terms

The following symbols may appear on Kinematrics equipment or in this manual.



When you see this symbol, *pay careful attention.* Refer to the similarly marked, relevant part of this manual before servicing the instrument.



This symbol means a *low-noise earth ground*. The noted item should be grounded to ensure low-noise operation, and also to serve as a ground return for EMI/RFI and transients. Such a ground *does not work as a safety ground* for protection against electrical shock!

~ This symbol means an alternating current (AC) power line.

This symbol means a direct current (DC) power line derived from an AC power line.

This symbol indicates an electrostatic sensitive device (ESD), meaning that when handling the marked equipment you should observe all standard precautions for handling such devices.

These safety-related terms appear in this manual:

Note: statements identify information that you should consider before moving to the next instruction or choice.

Caution statements identify conditions or practices that could result in damage to the equipment, the software, or other property.

WARNING! statements identify conditions or practices that could result in personal injury or loss of life.

Specific Precautions

Follow the precautions below to ensure your personal safety and prevent damage to the EpiSensor.

Power Source

The EpiSensor must be supplied with power either from a recorder or from a customer-supplied ± 12V or ± 15V power supply (or a + 12V supply for the single-supply option).

If you plan to power the EpiSensor from a recorder, connect the recorder to a power supply/charger supplied by Kinemetrics, as described in each recorder's user manual.

To supply power directly to the EpiSensor, you need a low-noise, regulated ± 12V or ± 15V power supply (or a + 12V supply for the single-supply option) that is safely grounded and meets all applicable local regulations. The EpiSensor will be damaged if the power is connected with the wrong polarity.

User-Supplied Power/Charging System

If you supply your own power/charging system, be sure that the system provides the correct voltage and current required by the EpiSensor under all operating conditions. You are responsible for the safety of your charging system. If you get power from the mains supply, be sure you have supplied adequate grounding for all the equipment. If you supply your own batteries, follow the manufacturer’s safety recommendations.

Sensor Grounding and Cabling

⚠ In some cases the EpiSensor will be a long distance from the recorder. In these installations it is possible, due either to faulty AC wiring or extremely high earth-return currents, for a high potential difference to exist between the grounds at the two locations. When the cable is grounded at one end a potentially lethal voltage can exist between the other end of the cable and ground. Consider this danger during installation and get help from a qualified electrician if this danger exists.

Do Not Operate in Explosive Atmosphere

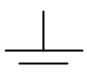
The EpiSensor provides *no explosive protection* from static discharges or arcing components. *Do not* operate the equipment in an atmosphere where explosive gases are present.

Sicherheit

Symbole & Begriffe

Diese *Symbole* können auf Kinemetrics Geräte oder in diesen Manuel erscheinen:

Bedeutet *Achtung*! Wenn sie dieses Symbol auf ein Gerät sehen, muss den gleich markierten Teil dieses Manuels beachet werden. *Bevor* irgend eine Unterhaltsarbeit angefangen wird, *muss* dieser Teil des Manuels gelesen werden. Wenn Sie dieses Symbol sehen, bitte besondere Achtung geben.



Bedeutet Erdung. Das erwaente Teil sollte geerdet werden, um eine “low-noise” operation zu versichern, und dann auch als Erdung für EMI/ FRI und Transienten und solch eine Erdung wird *nicht als Sicherheit gegen* elektrischen Schock dienen!

~ Bedeutet *Wechselstromzufuhr* (AC) mit Elektroschock Gefahr.

Bedeutet Gleichstromzufuhr von AC Versorgung herkommend.

Bedeutet *Elektrostatisch Sensibeles Element (ESD)* für dessen Handhabung alle vorbeugende Vorsichtsmassnahmen genommen werden müssen.

Folgende *Darstellungen* werden in diesen Manuel erscheinen:

Note: Darstellung welche Informationen Sie erhalten, die besonders beachtet werden müssen, bevor sie zum nächsten Schritt gehen.

Caution: Darstellung bei dem die Missachtung in der Regel Gefahr für Defekte und Störungen im Gerät, Programm oder Zubehör besteht.

WARNING! Darstellung bei dem die Missachtung in der Regel Verletzungs – oder Lebensgefahr besteht.

Spezielle vorbeugende Massnahmen

Alle vorbeugende Massnahmen müssen beachtet werden. Für Ihre persönliche Sicherheit, und um Schäden im EpiSensor zu vermeiden.

Stromversorgung

Die EpiSensor muss entweder mit Strom von einem Accelerograph oder Ihrer eigenen Stromquelle ±12 V versorgt werden.

Sollten Sie planen, die EpiSensor mit Strom von einem Recorder zu versorgen, verbinden Sie den Recorder mit unserem Kinemetrics Stromladegerät, wie es in unserem “User Manuel” beschrieben ist.

Um die EpiSensor direkt mit Strom zu versorgen, müssen Sie ein Ladegerät ±12 V, welches mit allen Sicherheitsbedingunge ausgestattet ist, benutzen.

Optionelles Stromversorgungs/Ladegerät

In manchen Fällen wird die EpiSensor eine lange Strecke von dem Recorder entfernt Sein, wo es dann möglich sein könnte, dass durch beschädigte AC-Wiring oder Hohe Erdbewegungen, ein Spannungsunterschied besteht. Es ist daher unbedingt notwendig, dass alle angeschlossenen Instrumente am gleichen Spannungspotential geerdet sind. Bitte folgen Sie den vom Hersteller gegebenen Empfehlungen.

Verkablung und Erdung vom Sensor

⚠ Wenn das Kabel an einem End geerdet ist, kann ein verhältnismässig grosser Unterschied in der Voltage bestehen, welcher sehr gefährlich ist. Bitte beachten Sie Diese Gefahr und wenn nötig, ziehen Sie das Gutachten eines qualifizierten Elektrikers Ein.

Nicht in explosionsgefährdete Umgebung gebrauchen

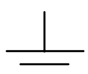
Der EpiSensor hat keinen Explosions-schutz von statischen Entladungen oder funkgefährdeten Bauteilen. Benutzen sie die Geräte nicht in Umgebungen mit explosiven Gasen.

Seguridad

Símbolos & Términos

Estos *símbolos* podrían aparecer en los equipos Kinemetrics o en este manual:

Significa *poner atencion!* Cuando Usted vea este símbolo en el instrumento, referirse a las partes de este manual marcadas similarmente. *Antes* de intentar cualquier servicio en este instrumento, Usted *tiene que* leer las partes relevantes de este manual. Si Usted ve este símbolo, ponga atención cuidadosamente.



Significa un *polo a tierra de bajo ruido*. El ítem referido debe estar polarizado a tierra para asegurar la operación a bajo ruido y además sirve como un retorno a tierra para el EMI/RFI y transitorios. Tal polo a tierra no trabaja como un polo a tierra de seguridad para protección contra choques eléctricos!

~ Significa una línea de energía de Corriente Alterna (AC).

Significa una línea de energía de Corriente Directa derivada de una línea de energía AC.

Significa una *Unidad Sensitiva a Electrostática* (*Electrostatic Sensitive Device* ESD), indicando que usted debe tener cuidado y observar todas las precauciones para el manejo de tales unidades.

Estos *términos* aparecerán en este manual:

Note: sentencias identificando información que Usted debe considerar cuidadosamente antes de dirigirse a la siguiente instrucción u opción.

> ***Caution:*** sentencias identificando condiciones o practicas que podrían resultar en daño del equipo, el software u otra propiedad.

WARNING! sentencias identificando condiciones o practicas que podrían resultar en una lesión personal o la perdida de la vida.

Los últimos dos términos mencionados arriba podrían también aparecer en el equipo Kinemetrics que Usted ha comprado, pero no necesariamente — indiferentemente, Usted debe definitivamente tomar notas serias de las precauciones y advertencias en este manual.

Precauciones Específicas

Siga las precauciones a continuación para garantizar su seguridad personal y prevenir daños al EpiSensor.

Fuente del poder

El EpiSensor debe ser alimentado con energía ya sea desde un registrador o desde una fuente de ± 12V provista por el usuario.

Si usted planea alimentar el EpiSensor desde un registrador, conecte el registrador a una fuente de poder/cargador suministrado por Kinemetrics, como se describe en cada manual del usuario para el registrador.

Para suministrar energía directamente al EpiSensor, usted necesita una fuente de poder de bajo ruido y regulado ± 12V, el cual debe ser apropiadamente conectado a tierra y cumplir con todas las regulaciones locales que apliquen.

Sistema de Poder/Carga Provisto por el Usuario

Si usted provee su propio sistema de poder/carga, usted tiene que estar seguro, que el sistema proporciona el voltaje correcto y la corriente requerida por el EpiSensor bajo todo las condiciones de operación. Usted es responsable por la seguridad de su sistema de carga.

Si usted deriva energía de suministro principal, usted tiene que asegurarse que ha provisto un polo a tierra adecuado para todo el equipo. Si usted suministra sus propias baterías, siga las recomendaciones de seguridad del fabricante.

Cableado y Polo a Tierra del Sensor

⚠ En algunos casos el EpiSensor estará a una distancia lejos del registrador. En estas instalaciones existe la posibilidad de una elevada diferencia de potencial entre dos localidades de polo a tierra, debido ya sea a fallas en el alambrado del AC o corrientes de un extremadamente alto retorno de tierra. Cuando el cable esta polarizado a tierra en uno de sus lados terminales, un voltaje potencialmente letal puede existir entre el otro lado terminal del cable y el polo a tierra. Considere este peligro durante la instalación y obtenga ayuda de un electricista calificado si este peligro existe.

No Opere en Atmósferas Explosivas

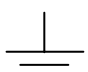
El EpiSensor no proporciona *ninguna protección explosiva* para descargas estáticas componentes que generen arcos eléctricos. *No operar* el equipo en una atmósfera de gases explosivos.

Sécurité

Symboles & Terminologie

Les *symboles* suivant peuvent figurer sur les équipements Kinemetrics ou dans ce manuel:

Signifie *Attention!* Quand vous rencontrez ce symbole sur un instrument, veuillez vous référer à la section de ce manuel signalée par la même marque. *Avant* même d'effectuer la première opération sur l'instrument, vous devez lire la section correspondante de ce manuel. Faite attention si vous voyez cet symbole.



- Indique une mise à la terre "faible bruit". Les objets portant cette marque doivent être reliés à la terre afin d'assurer un fonctionnement optimal. Elle est aussi utilisée pour les éléments de protection contre les interférences magnétiques, les perturbations hautes fréquences radio et contre les surtensions. Cette mise à terre *n'est pas une mise à terre de sécurit*é pour une protection contre les choques électriques!

~ Indique une *alimentation en courant alternatif* (AC).

⎓ Indique une Alimentation en courant continu (DC) dérivée d'une alimentation alternative

Indique la présence *d'un composant sensible aux décharges électrostatiques* (ESD), Cela signifie qu'il faut observer toutes les précautions d'usage en manipulant ce composant.

Les *termes* suivant apparaissent dans ce manuel:

Note: Indique la présence d'une information que vous devez particulièrement considérer avant de passer à la prochaine instruction or operation.

Caution: Indique une condition ou opération qui peut entraîner des dommages à votre équipement, au logiciel ou à d'autres propriétés .

WARNING! Indique une condition ou opération qui peut entraîner des blessures corporelles ou la perte de la vie.

Les deux derniers termes mentionnés peuvent apparaître sur les équipements de Kinemetrics que vous avez acquis, mais pas nécessairement — indifféremment, il est conseillé de prendre au sérieux les avertissements de ce manuel.

Précautions Spécifiques

Observez toutes les précautions suivantes afin d'assurer votre sécurité personnelle et d'éviter des dégâts aux composants de votre capteur EpiSensor.

Alimentation

Le EpiSensor doit être alimenté avec un courant de ±12 VDC fourni par l'enregistreur ou par votre propre système d'alimentation.

Si vous alimentez le EpiSensor avec l'enregistreur, connectez l'enregistreur en utilisant le système d'alimentation fourni par Kinemetrics, et decrit dans le manuel d'utilisation délivré avec l'enregistreur.

Pour fournir une alimentation au EpiSensor, vous avez besoin d'une source à faible bruit ± 12V avec une mise a la terre adéquate et qui remplit les conditions de la reglementation locale.

Option Systéme d' alimentation fourni par l'utilisateur

Si vous fournissez votre système d'alimentation, vous devez vous assurez que le système fournit une tension et un courant requis par le EpiSensor. Veuillez noter que vous serez seul responsible pour la sécurité de votre système d'alimentation. Si vous utilisez le courant du réseau d'alimentation principal, vous devez vous assurez d'installer les mises a la terre adéquates pour tout votre equipement. Si vous utilisez vos batteries, vous devez vous référer aux recommendations fournis par le fournisseurs.

Mise à la terre et connection du capteur

Dans certain cas, le capteur EpiSensor est installé à distance de l'enregistreur. Dans ces installations il est possible, soit a cause d'une connection défectueuse au système d'alimentation principale où d'un fort courant de retour à la terre, pour une difference de potentiel qui existe entre la mise à la terre aux deux locations. Quand le cable est mise à la terre d'un coté, une tension potentiellement fatale peut exister entre l'autre coté du cable et la terre. Considerez ce danger pendant l'installation et demandez l'aide d'un electricien si ce danger existe.

Ne Pas Utiliser en Atmosphère Explosif

Le EpiSensor ne comprend pas de protection contre les explosions dues aux décharges statiques ou aux composants pouvant provoquer des arcs. Ne pas utiliser ces composants en présence de gaz explosifs.

1. Introduction

This document is the *User's Guide to EpiSensor Model FBA ES-T,* an external, triaxial sensor. Kinemetrics also produces a uniaxial EpiSensor FBA, the FBA ES-U, and the FBA ES-SB (shallow) and FBA ES-DH (deep) triaxial borehole packages. Kinemetrics' strong motion accelerographs feature a triaxial EpiSensor Altus deck.

This manual refers only to EpiSensor Model FBA ES-T but will be referred to simply as the *EpiSensor* throughout the rest of this manual.

Kinemetrics is committed to ensuring a successful installation. For assistance with planning, installation, operation or maintenance, contact Kinemetrics at the locations listed in the front of this manual. Kinemetrics also has an extensive Services Group that can install, maintain, and analyze the data from your EpiSensor.

This chapter provides an overview of the EpiSensor and inspection instructions.

The EpiSensor FBA ES-T

The EpiSensor is a triaxial accelerometer optimized for earthquake recording applications. Inside the waterproof, anodized-aluminum housing are three orthogonally mounted low-noise EpiSensor force balance accelerometer modules.

The EpiSensor has user-selectable full-scale recording ranges of ±4g, ±2g, ±1g, ±1/2g or ±1/4g. The EpiSensor bandwidth of DC to 200 Hz is a significant improvement over earlier generations of sensors. The output voltage levels are user-selectable at either ±2.5V or ±10V single-ended, or ±5V or ± 20V differential.

The EpiSensor is normally powered with a ±12V external DC power source. It is optionally available with a single +12V supply option.

Full specifications for the unit can be found in the Appendix.

Inspecting the EpiSensor

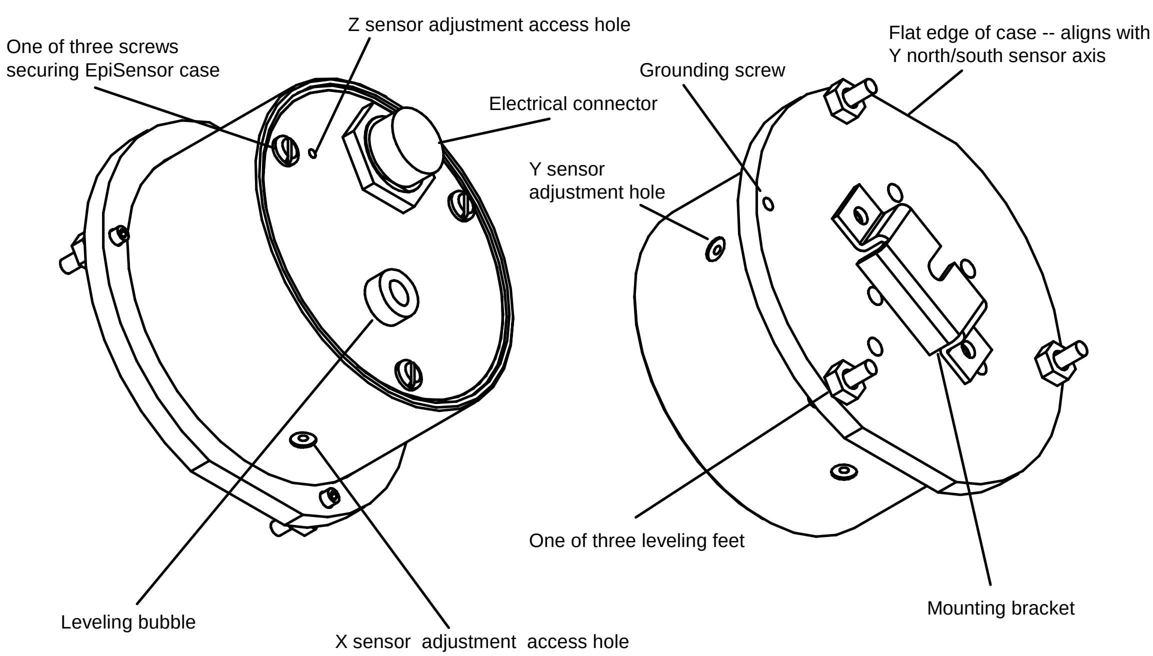
Note: If you expect to ship the EpiSensor again, save the shipping container and packing material. The shipping container can also function as a thermal shield for the EpiSensor, so do not throw the high density foam packing away!

Carefully remove the EpiSensor from its shipping container. Keep the shaped packing material.

Although Kinemetrics takes every precaution in packing its systems, shipping damage can still occur. If you find a problem, note the condition of the shipping container. Then contact the freight forwarder and Kinemetrics as soon as possible.

***Caution*: Damage to sensors**. Dropping the EpiSensor onto a hard surface can damage the sensors.

Figure 1: The EpiSensor



Examine the EpiSensor. Its case should appear securely sealed, showing no sign of dents or scratches, and the bubble level glass should appear undamaged.

2. Installation Basics

Requirements for Installation

Listed below are the tools, supplies and equipment required to install the EpiSensor in a typical configuration (remotely from a Kinemetrics recorder, and attached to that recorder via cable). However, certain installations may require additional tools, supplies or equipment, depending on specific sites and needs.

If you need to assemble the cable for the EpiSensor you will need additional tools and supplies. Refer to Chapter 6 for information on cable assembly.

These instructions assume that all civil engineering works (concrete pad, conduit, etc.) have been finished and that the EpiSensor has been correctly configured for your installation at our facility. If you need to change the full-scale range output level or select the low-noise option, refer to Chapter 3 before proceeding.

Required Tools

- Screwdrivers (1/8" flat blade, 1/4" flat blade)
- 5/64" or 2mm hex ball driver (for zero adjustment)
- Long-nose pliers
- AC-powered masonry percussion drill with 1/4" bit for drilling the anchor stud hole or fully charged battery-powered drill
- 7/16" open end wrench for 1/4-20 bolt
- Hammer
- Safety glasses
- 1/8" hex driver for leveling feet

Required Supplies

- Adequate length and appropriate type of pre-assembled cable for connecting the EpiSensor to the recorder. If custom cable is required, refer to Chapter 6. Depending on the length required, you might have purchased either Kinemetrics P/N 700045 or the Belden cable stocked by Kinemetrics as P/N 840356.
- Heat-shrink tubing (1/4" diameter), cable tie-wraps, and electrical tape.
- Mounting anchor (supplied with the EpiSensor).
- FerriShields (optional)
- EpiSensor Packing Foam for Thermal Shield (optional supplied with the EpiSensor)
- Heavy Duty Aluminum Duct Tape (optional for Thermal Shield)

Required Equipment

- Battery-powered digital volt meter (DVM)
- Compass for checking the orientation of the sensors.
- Camera to photograph the completed installations for the commissioning report (recommended).

Mounting & Orienting the EpiSensor

Determine which direction to orient the EpiSensor: true north or "aligned-with-structure." True north is typical of most free-field EpiSensor installations.

If the instrument is installed in a structure, it is normally aligned parallel to the structure's main axis. If possible, keep the same orientation for all EpiSensors installed in the same building.

Anchor the EpiSensor to a concrete floor or slab or a secure, structural element such as a steel beam in a building.

Note: To accurately record strong ground motions of > 0.1g, it is *essential* that the EpiSensor be anchored to the structure or slab. This is contrary to weak motion installations where sensors are just placed on the ground and leveled. In weak motion, the weight of the instrument and friction between the feet and floor ensure accurate reproduction of ground motion. This is not the case at high acceleration levels, which can cause an unsecured instrument to move relative to the ground.

Keep a permanent record of the orientation you choose. This information is crucial to the proper analysis of EpiSensor data.

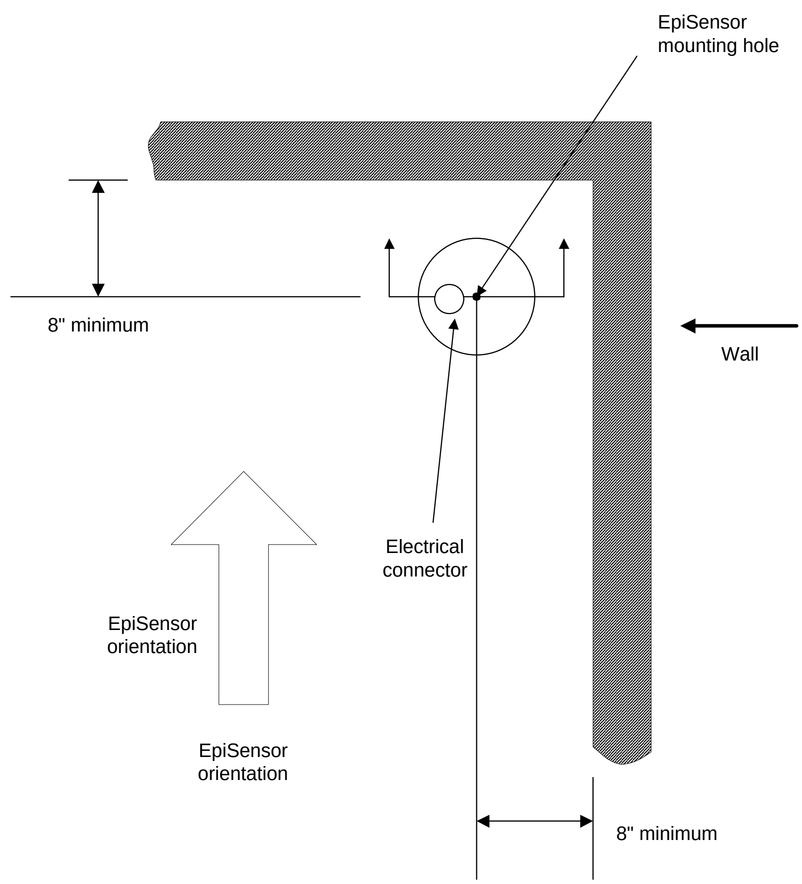
Use the EpiSensor mounting kit to attach the sensor to the mounting surface. The kit includes a heavy-duty wedge-type expansion anchor stud with 1/4-20 thread and a nut/washer unit.

Decide on the location of the EpiSensor, keeping in mind the working space dimensions in Figure 2.

Remember:
The anchor stud is 2-1/4" long and 3/8" to 1/2" must remain above the slab.

Use the following instructions and figures below to install the anchor stud.

Figure 2: Episensor mounting dimensions

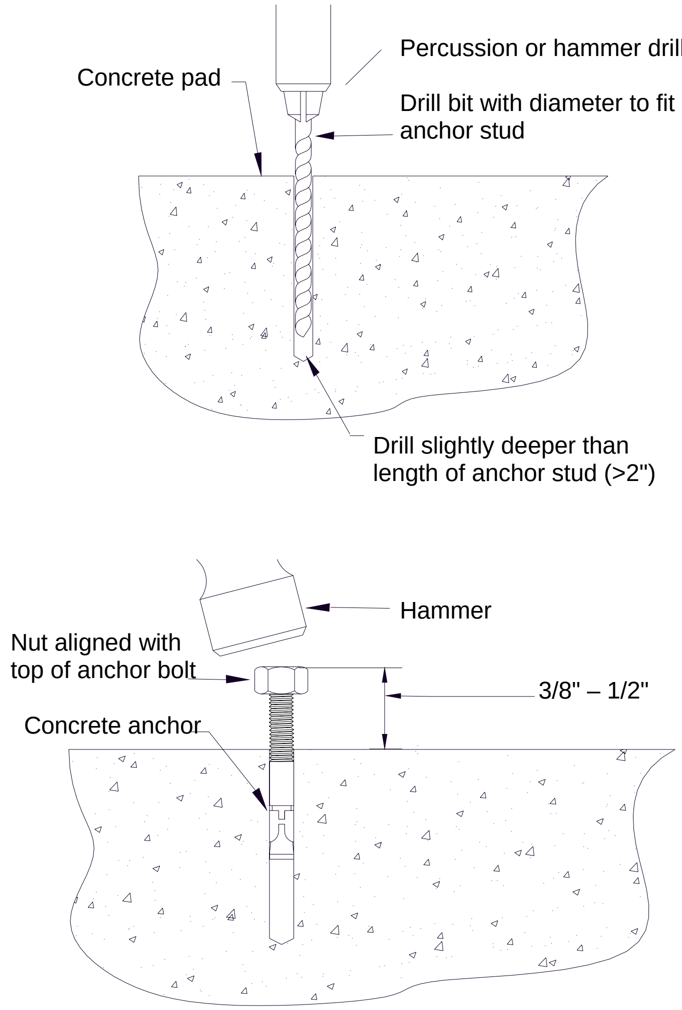


Note: Follow all recommended safety precautions when using power tools. We recommend wearing safety glasses while drilling.

1. Use a 1/4" (6.4mm) masonry bit and drill to a depth of at least 1-3/4" with a percussion or hammer drill (if possible).

Note: You may want to wrap a little masking tape 1-3/4" up from the point of the drill bit to mark how deeply to drill. The depth of the hole can be checked with a nail or narrow screwdriver. The hole should be vertical – take care not to drill at an angle!

Figure 3: Drilling EpiSensor mounting hole



2. Clean debris out the hole. (Blowing through a straw is an easy way to do this.)
3. Screw the nut/washer onto the stud until the top of the nut is flush with the top of the stud. This will make is easier to hammer in the stud and prevent damage to the threads.
4. *Gently* tap the top of the anchor stud with a hammer. The stud is now in position but not firmly seated.
5. Check that the leveling screws are only about halfway into their mounting holes on the lower flange of the EpiSensor.

6. Slip the EpiSensor mounting bracket around the anchor stud and push all the way to the rear. Be sure that the nut remains above the mounting bracket.
7. Align the Y arrow on top of the EpiSensor case with true north or the main axis of the structure.
8. The flats on the flange are parallel to the Y direction and can be used to ensure an accurate orientation. Tighten the stud nut "finger tight" with a 7/16" end-wrench and check the bubble level window.

Note: If you use a compass to determine the true north-south axis, make sure to correct for the difference between magnetic north indicated by the compass, and true north (magnetic declination). This deviation depends on your location; find the correct deviation on a local topographical map.

Installation is now a matter of adjusting the leveling feet so that the EpiSensor is level and tightening the anchor stud nut. Tighten the nut and make adjustments to the leveling feet gradually until the EpiSensor is level and the nut tightened to a torque of 20-26 inch pounds (2.26-2.94 N.m). As you tighten the nut, the stud will move slightly, forcing the locking cone to firmly grip the concrete.

Required Cables

If you purchased pre-made cables from Kinemetrics, you can proceed with the following instructions. If you are making your own cables, please see page 6-10 in the *Advanced Installations* section for instructions on custom cable fabrication.

Grounding the EpiSensor

Grounding sensitive instrumentation is a complex problem. It is difficult to give universally acceptable solutions for all installation types and site conditions because "grounding" really has five goals – some of which can be mutually exclusive. These goals are:

- Prevent life threatening voltages in or on the equipment
- Immunity from EMI/RFI interference (susceptibility)
- Prevent radiation of EMI/RFI from the equipment (interference)
- Prevent damage to the equipment from transient events such as lightning and ESD
- Low-noise Operation

Safety First

Obviously, the most important goal of any grounding scheme is to ensure the safety of operating personnel. Design and evaluate your grounding system with this in mind.

Since the EpiSensor contains no high voltage circuitry and is not connected to AC power, safety concerns arise from the instrument-end of the connection cable.

When using your own power system, be sure that AC power is fully isolated from the DC power supplied to the EpiSensor and that the power supply is safely grounded.

If the EpiSensor is separated from the recorder or power supply by a long distance, observe the precautions discussed in the section on long cables.

EMI/RFI

To prevent EMI/RFI susceptibility and interference, an overall shield should be provided and cables must be carefully constructed to ensure shields terminate to the connector to provide a full 360° termination. This provides a low impedance path for high frequency noise to ground and does not allow the high frequency to "leak" onto unprotected wiring in the cable.

The case of the instrument and the shields should generally be grounded to a low impedance earth ground.

The EpiSensor contains transient protection circuitry that will shunt damaging currents to its case ground connection and prevent damage from ESD and lightning-induced transients.

Use the stainless steel screw on the flange of the instrument as the case ground connection point. To be effective, this point must be connected to a low impedance earth ground.

Providing a low-impedance earth ground can be challenging, because a safety earth ground for AC wiring is not necessarily a good low impedance ground! A safety earth ground is designed to provide a path for AC fault current to flow to ground, trip the fuses in the power system and prevent electrocution.

Since AC power is only at 50 or 60Hz, the primary factor restricting the flow of current is the DC resistance of the ground. Lightning, ESD, and EMI/RFI are high frequency currents. The flow of these currents is restricted by the impedance of the ground at the frequency of interest, and rather than being dominated by DC resistance, the inductance of the connection is the primary component of this impedance.

Thus, we require both a low impedance ground and a low impedance connection to that ground. To provide low impedance connection to the ground:

Attach the EpiSensor grounding screw to the ground with a heavy-gauge wire 3 mm in diameter (<10 AWG) or thicker, or a tinned copper braid at least 1.2 cm (1/2") in width.

To be effective this wire or braid must be as short as possible and should have no sharp turns. The connection to the grounding point should have a large-area connection that is tightened and not subject to corrosion. Special clamps are available from electrical supply houses to make these connections.

The requirements and techniques for producing the low impedance ground will depend on the installation and its location. In a building or structure where close lightning strikes are unlikely, a metallic water pipe, exposed section of rebar, or an AC safety ground may be adequate.

For a remote installation subject to significant lightning activity such as a mountain peak, much greater effort is required to provide an adequate ground.

In lightning-prone conditions, a copper clad grounding rod inserted into the ground is an acceptable solution if the climate is relatively humid or if the rod is embedded in a marsh, clay, or wet sand ground where soil resistivity is less than 50-100 ohms.

A 1-cm (0.5") diameter rod 4 meters long (12 feet) will assure an acceptable grounding resistance of about 10 ohms. Grounding rods are generally available in a variety of lengths and can be connected together to get overall depths exceeding 12 meters (40 feet).

In dryer regions, arrays of copper rods driven into the earth help to reduce the grounding resistance. However, the total ground resistance is not reduced in direct proportion to the number of rods in the array, and the rods should be spaced apart by double their length to avoid "saturation."

In a high lightning threat area, a star configuration of radial metal straps buried just below the surface with a 2 meter grounding rod at the end of each radial is a good approach. A 6-to-8-leg star of 50 m (150 feet) length with a grounding rod at each end provides a ground resistance of less than 10 ohms even in a soil with resistively of several thousand ohms.

In desert areas, chemical doping and drip irrigation techniques may be required to provide adequate grounding.

The Grounds for Lightning and EMP Protection by Roger Block, second edition, published by Polyphaser Corporation provides an excellent practical treatment of grounding techniques.

In sites exposed to high levels of EMI/RFI, such as, hill top “Antenna Farms” additional EMI/RFI protection may be required. The Kinemetrics EpiSensor Protection Enclosure (KMI 301931) can be purchased for such sites.

Powering the EpiSensor

When the cable has been made and tested, you can apply power to the sensor. If you are providing power, please refer to Chapter 6 for detailed requirements.

First, apply power to the system *without* connecting the cable to the EpiSensor and then verify that the power connections are correct.

For a dual supply EpiSensor, verify that +12V is present on Pin J and –12V is present on Pin H, *both referenced to power common Pin K.*

For a single supply option, verify that +12V is present on Pin J referenced to power common Pin K. Be sure that Pin H is not connected in this configuration.

Caution: Connecting incorrect voltages or wrong polarities (> ± 15.75V) will seriously damage your EpiSensor, as will making a connection to Pin H in the single supply configuration.

Zero-Adjusting the EpiSensor

After the EpiSensor has been installed, leveled, and connected to the correct power, measure the DC offset of each accelerometer. The DC offset should be as close as possible to zero so that the recorded data has minimal offset. With minimal offset the full range of the EpiSensor and recorder can be utilized.

Methods of Measuring the DC Offset

If the EpiSensor is near the recorder, you may zero the accelerometers by using the recorder as if it were a DVM. If you are using an Altus recorder, use the AQ DVM command in QuickTalk's terminal mode.

If the EpiSensor is located at the end of a long cable, build a "break-out" cable in order to access and measure voltages in each of the wires in the EpiSensor cable. Be sure you are supplying the EpiSensor with ±12 VDC or +12 VDC for the single power supply option.

Performing the Zero Adjustment

Refer to Figure 9 to see the three access screws that, when removed, provide access to the zero adjustment screws on the sensor modules.

Make the first zero-adjustment on the Z-axis accelerometer. Use one of the methods described above to measure the sensor's zero output voltage.

Naturally, it is impossible to achieve zero offset. The table below will tell you the ES-T acceptable range for DC offset for each possible configuration. (If desired, smaller offsets can be achieved with some patience.)

To zero balance the Z-axis:

1. Remove the zero balance access screw on the top of the EpiSensor case.

2. *Gently* insert a hex ball (5/64" or 2mm) wrench, *perpendicular to the case,* as far as it will go into the adjustment hole and make very minimal adjustments – counterclockwise for negative adjustments and clockwise for positive.

   Important: Give the unit a moderate tap with a screwdriver handle. The adjustment screws can have a residual stress that may cause an offset in data during a large earthquake. Tapping eliminates this residual stress.

3. When the offset is in an acceptable range based on the above table, carefully remove the hex wrench and replace the access hole screw.

Note: One turn changes the output by about 1g.

Repeat this process for the X and Y axes.

Table 1: Reasonable zero offset voltages

Full-scale range	Single-ended ± 2.5V output	Single-ended ± 10Voutput	Differential low-noise amp.	Differential ± 20V output
1/4g	50 mV	200 mV	100 mV	400 mV
1/2g	25 mV	100 mV	50 mV	200 mV
1g	25 mV	50 mV	25 mV	100 mV
2g	25 mV	25 mV	25 mV	50 mV
4g	25 mV	25 mV	25 mV	25 mV

Note on Full-Scale Range

All of our full-scale ranges are stated as the voltage you would measure with a voltmeter between the + and – outputs for the sensor when full-scale acceleration is applied to the unit. For example, with a differential low-noise amplifier and output of ± 20V on a range of 1g, you would measure +20V if you applied 1g to the sensor. If you applied –1g you would measure –20V.

Thermal Insulation Shield (Optional)

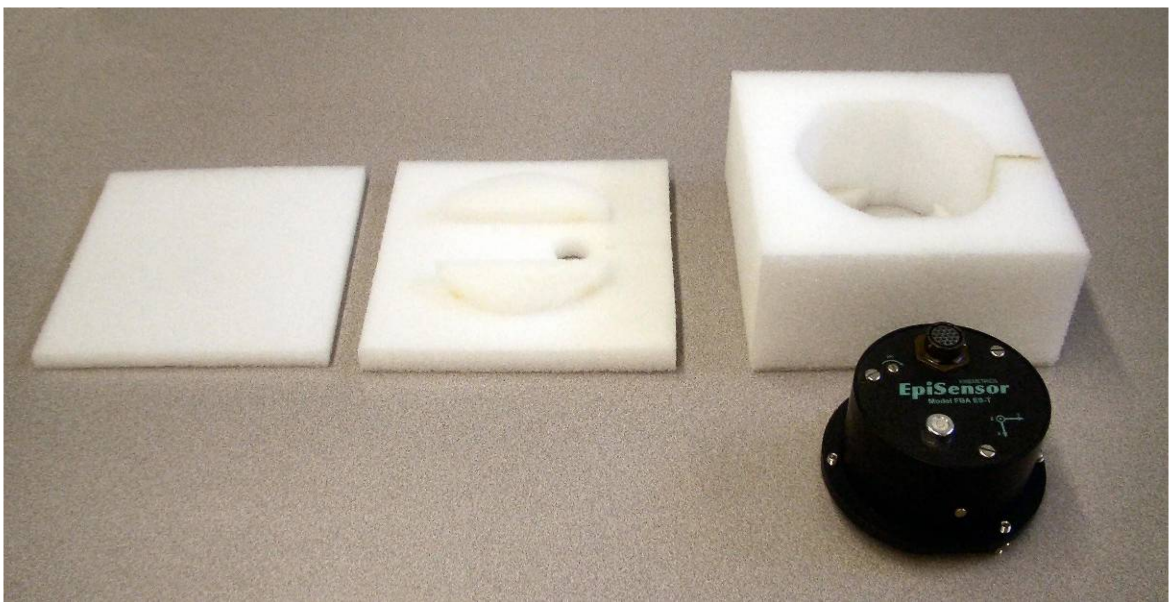
The EpiSensor possesses a very large dynamic range and increasingly we are finding customers are interested in recording both strong motion and weaker motion signals on the instrument. To fully exploit the performance of the instrument for recording weak motion it is necessary to treat it more like a broadband seismometer than a strong motion accelerometer! One important area is to thermally insulate the unit so that variations in ambient temperature and air currents do not cause “noise” by causing temperature induced variations of the zero level of the sensor. It is particularly important to prevent airflow from heating/cooling equipment from blowing directly on the sensor housing.

The best results are obtained by using thick insulation comprising glass wool insulation and thermal radiation barriers, such as “Space Blankets”. These are the techniques used to protect the VBB Seismometer that may be installed in the same location.

If this is not possible we have modified the packaging of the EpiSensor so the packaging can be re-used as thermal insulation to provide protection against direct airflow and to increase the thermal insulation of the device.

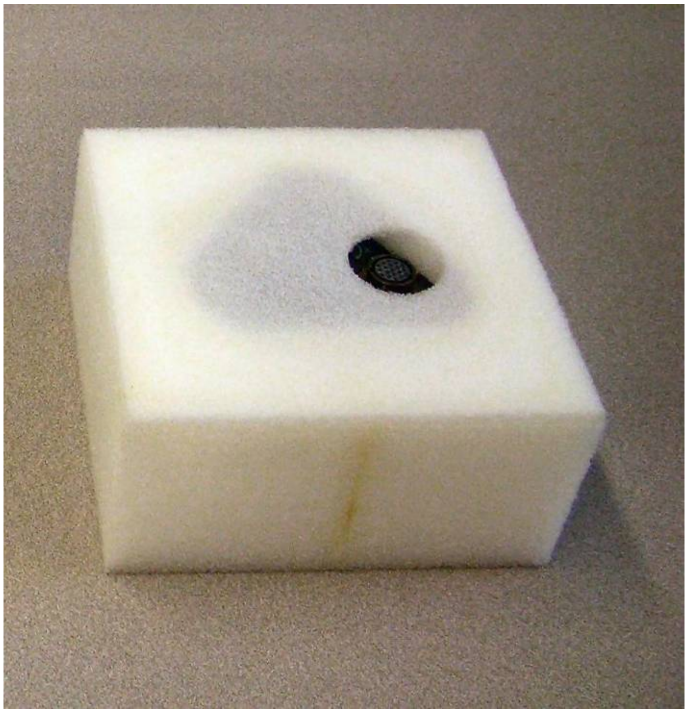
When removed from the box the EpiSensor is protected by a cubic package of high density cellular foam. Carefully remove this packaging and you will be left with the EpiSensor and the three packaging components shown in Figure 4 below.

Figure 4: EpiSensor & Packaging Components



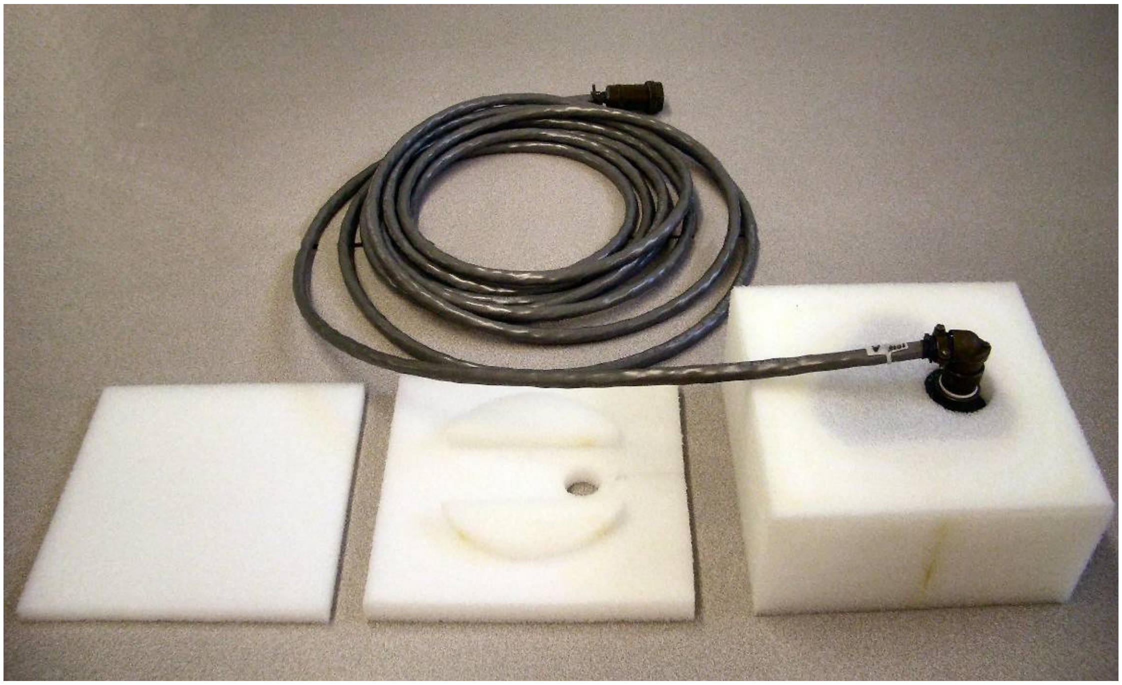
Now mount and zero the EpiSensor per the previous instructions. Before installing the cable place the large packing piece over the EpiSensor with the circular hole over the connector. This is shown in Figure 5 below.

Figure 5: Large Packaging Piece Installed



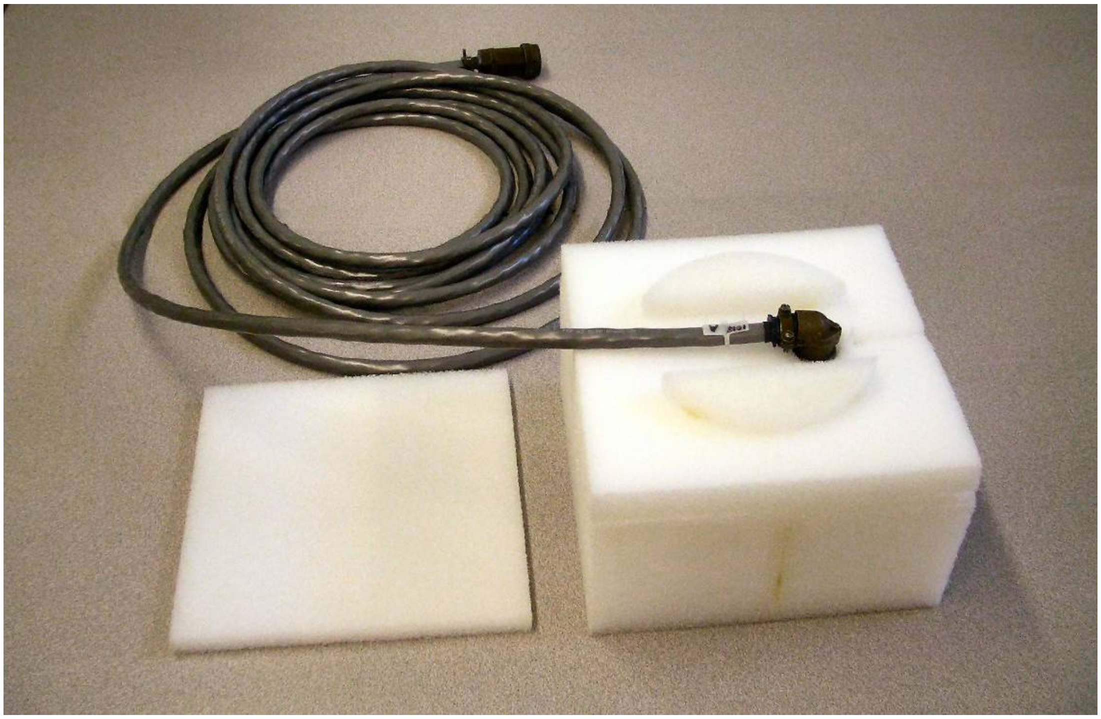
Now install the cable as shown in Figure 6 below:

Figure 6: Cable Installed



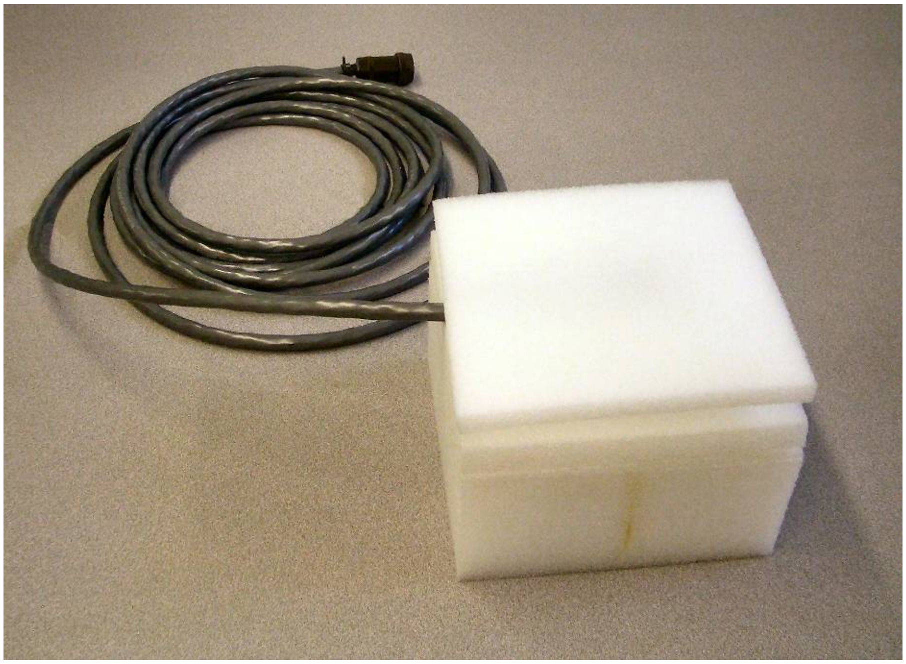
Now place the thin piece of foam with the hole and the slot over the EpiSensor placing the connector through the hole. This is shown in Figure 7 below.

Figure 7: Second Packaging Piece Installed over Connector Shell



Finally the last piece of packaging can be placed over the connector and cable as shown below in Figure 8. If this is done we recommend using aluminum duct tape to hold the packing together and also ensuring a joint with the floor to minimize convection currents.

Figure 8: Final Packaging Piece Installed



Our testing has shown that this simple measure can significantly reduce the short term variations due to changes in air temperature and air currents.

3. Operating Basics

The EpiSensor is designed as a very flexible low-noise accelerometer and can be configured to satisfy a wide variety of acceleration-sensing requirements.

Configurable options include:

- Full-scale acceleration sensitivity of sensor – 1/4, 1/2, 1, 2, and 4g
- Sensor can be configured as either low-power or low-noise
- Single-ended or differential output
- Output voltage can be ± 2.5V or ± 10V single-ended
- Output voltage can be ±5V or ±20V differential

This chapter discusses:

- EpiSensor operation
- Polarity conventions
- How to configure its operating modes
- Use of the calibration coil, which allows verification of the sensor's transfer function
- Power supply options

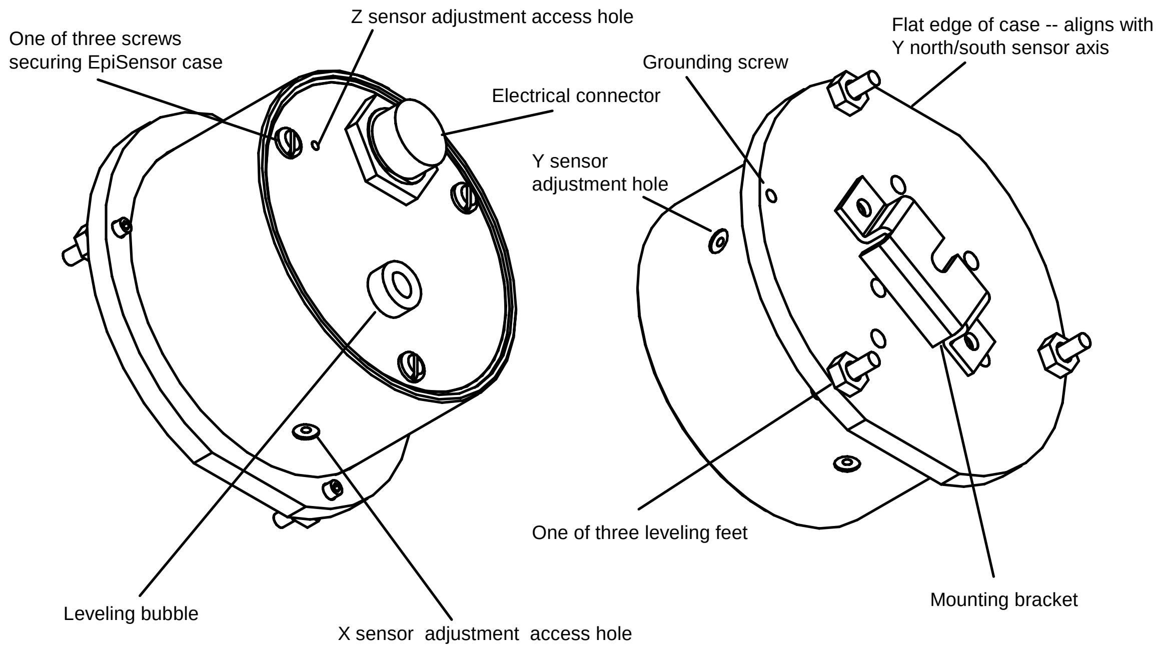
Polarity Conventions

Unlike previous generations of Kinemetrics force balance accelerometers, the EpiSensor uses a right-handed X Y, Z coordinate system with a positive output for acceleration along each axis. For information on polarity conventions, see page 5-6 in the *Reference* chapter.

In a free field situation, the EpiSensor will normally be aligned with X (channel 1) to the east, Y (channel 2) to the north and Z (channel 3) upward. The signal has the same polarity as the ground acceleration in the sensor coordinate system.

EpiSensor External Features

Figure 9: The EpiSensor.



The EpiSensor's anodized-aluminum exterior has:

- An O-ring-sealed cover to prevent moisture and dirt from entering the instrument
- Three access holes (covered by seal screws) through which the zero offset of the X, Y and Z sensors may be adjusted
- Three adjustable leveling feet
- A connector for the analog output voltages from the accelerometers and for supplying power and control signals to the EpiSensor
- A bubble level for leveling the unit
- External mounting bracket

Required Power

If you are using the EpiSensor with a Kinemetrics Altus instrument, the +/-12V power will be supplied from the recorder.

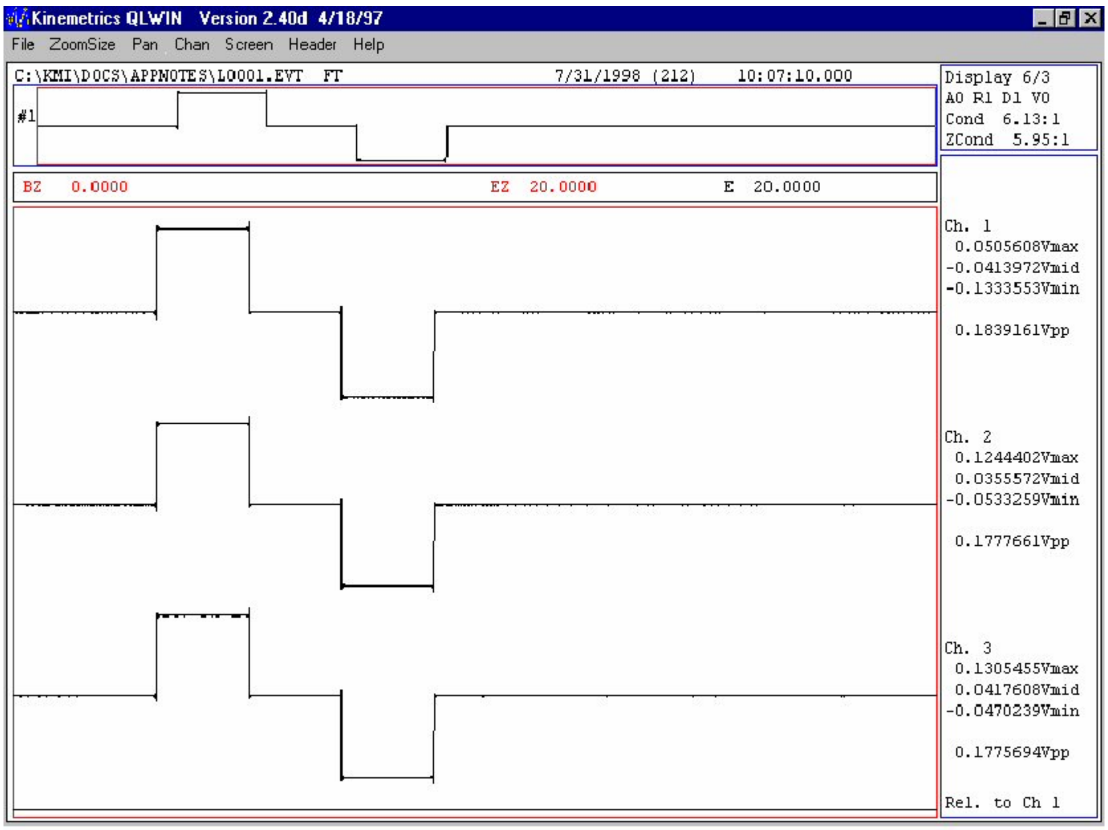
If you are using a Kinemetrics recorder with the EpiSensor configured to use the low-noise option, read the appropriate section in Chapter 6 to be sure your Altus instrument can provide sufficient current for the EpiSensor.

If you are using another recording system you will need to supply the correct power. Refer to Chapter 6, *Advanced Installation Topics*, for more information.

Performing a Functional Test with an Altus Recorder

Altus instrument firmware released after August 1, 1998 performs a dual polarity pulse test on EpiSensors as the standard functional test when correctly configured. This firmware is available at the Kinemetrics website.

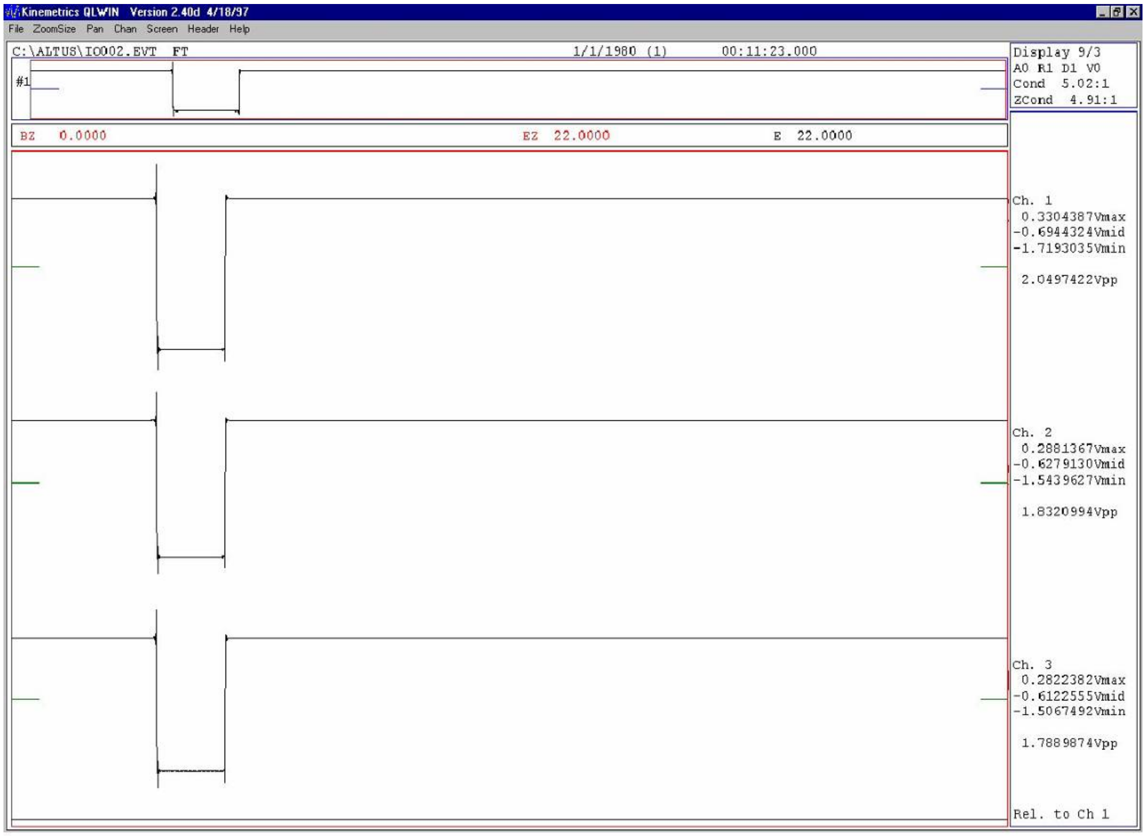
Figure 10: Display of functional test



The height of the pulse will depend on the full-scale setting of the instrument but will correspond to a g level of approximately 0.125g. The exact value will be 2.5V multiplied by the sensor module's calibration coil sensitivity value provided on the sensor's data sheet.

Altus software released prior to August 1998 supports functional tests on the earlier generation of Kinemetrics force balance accelerometers but does not support the EpiSensor. If you perform a functional test or sensor response test on an EpiSensor using older software, the record will appear as in the screen in Figure 11.

Figure 11: Display of functional test using software released prior to August 1998



The record looks like this because the calibration coil enable is only enabled during the undamped portion of the old FBA-11 style functional test

Sensor Response Test

The sensor response test for the EpiSensor, using Altus software released after August 1, 1998, measures the response of the sensor to white noise input. The digital-to-analog converter in the recorder drives the calibration coil with an analog voltage corresponding to a pseudo-random number sequence. The resulting file contains the information needed to compute the sensor response. For more information on the sensor response test consult the Kinemetrics website.

EpiSensor Configuration

This section describes how to configure the EpiSensor by placing 2-pin jumpers on specific headers located on either the EpiSensor modules (X, Y or Z axis) or the oscillator board (P/N 110375).

These jumpers are normally configured by Kinemetrics at the time of manufacture. If your EpiSensor is set to the correct range, the following instructions for re-configuring are unnecessary.

However, if you wish to change the settings, it is possible to do so in a laboratory environment.

Kinemetrics recommends that you do not attempt to change these jumpers in the field where debris or water could get into the unit.

To access these jumpers and the headers to which they connect, it is necessary to remove the EpiSensor casing.

Opening the EpiSensor Case

***Caution:* Potential electrostatic discharge (ESD) hazard to equipment**. Wear a grounded wrist strap with impedance of approximately 1 M Ω when handling the EpiSensor circuit boards to protect components from damage.

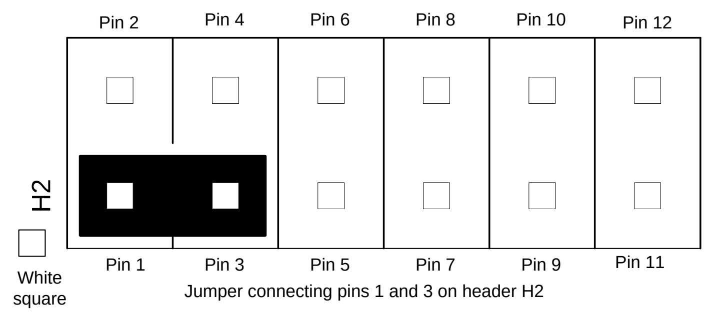
1. Loosen the nut at the base of the connector *without putting any torque on the connector itself.*
2. Remove the three large screws on top of the case.
3. Remove the nut.
5. Remove the X- and Y-axis seal screws from the side of the EpiSensor cover.
5. Gently lift the case off the EpiSensor.

Set the screws and the two O-rings aside in a safe place. The large O-ring is installed in the groove of the EpiSensor base and the small one goes around the base of the connector.

Pin Numbering System

In order to refer to specific jumper configurations, each individual pin on each header is designated by a number – even though those numbers are not all printed on the circuit boards. Figure 12 below is an example of how the pins are numbered. The name of the header – in this case H2 – is printed in white on the board and Pin 1 is identified with either a white square or a numeral 1. Use Pin 1 as a reference point to begin numbering the pins as shown in this example.

Figure 12: Pin numbering system.



Jumper Selectable Options

The features that are controlled by jumpers are:

- Full-scale range (set on module)
- Output voltage level of 2.5V or 10V
- Low-power or low-noise option
- Differential or single-ended output
- Power to the low-noise option
- Dual ± 12V or single 12V power supply (factory configuration only)
- Calibration coil connect or disconnect
- Access to the three calibration coils

The jumpers can be installed or removed with tweezers or your fingers. Additional jumpers are shipped with the EpiSensor to allow different configurations to be set. If you need more jumpers, they can be ordered from Kinemetrics as P/N 851152.

Setting the Full-scale Range

The full-scale range is configured by putting jumpers on headers X1 and X4 on the feedback board of individual FBA modules. Both jumpers must be set correctly or the sensor will not function properly. The location of the headers is shown in the figure on the next page.

The following table shows the sensitivities available for the jumper-selectable ranges.

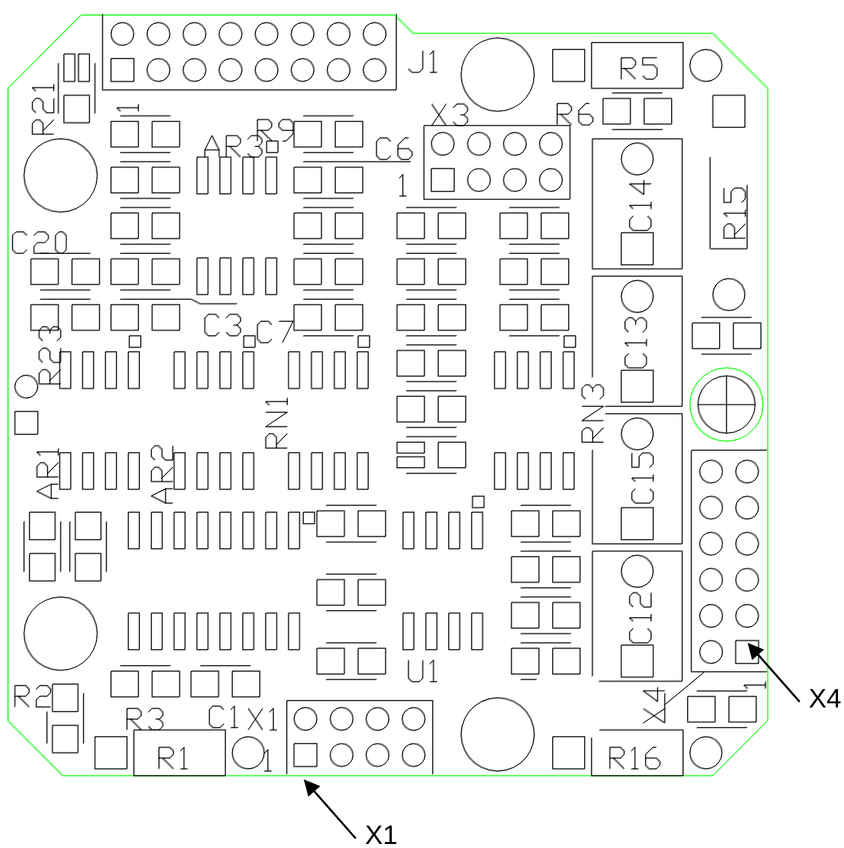
Table 2: Range/sensitivity calculations

Full-scale range	Single-ended ± 2.5V output	Single-ended ± 10V output	Differential ± 5V output	Differential ± 20V output
1/4g	10 V/g	40 V/g	20 V/g	80 V/g
1/2g	5 V/g	20 V/g	10 V/g	40 V/g
1g	2.5 V/g	10 V/g	5 V/g	20 V/g
2g	1.25 V/g	5 V/g	2.5 V/g	10 V/g
4g	0.625 V/g	2.5 V/g	1.25 V/g	5 V/g

Voltage values stated are as measured across each channel's output pins. L-M, A-B, C-D for axes X, Y, and Z respectively. Pins L, A, and C are (+) and pins M, B, and D are either (-) or ground depending on whether configured for a differential or single-ended connection to the recorder.

For best performance, a differential connection to the recorder should be used if the recorder supports differential input connections.

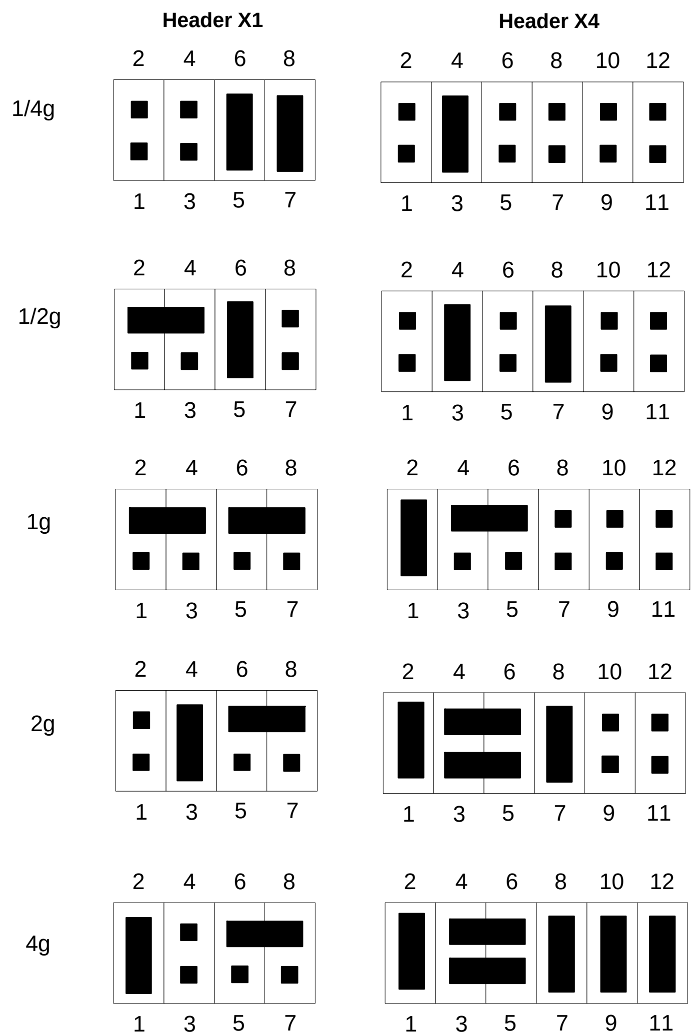
Figure 13: Feedback board



Configure each range by installing jumpers (indicated by the black rectangles) as shown in the figure below.

Note: For clarity, we have numbered each connector pin in the figure below, however, only #1 will appear on the actual feedback board.

Figure 14: Full-scale range jumper settings



Headers and Connectors on Oscillator Board

The following two figures show the location of all of the headers and connectors on the oscillator board used to configure the following options.

Figure 15: Top view of oscillator board

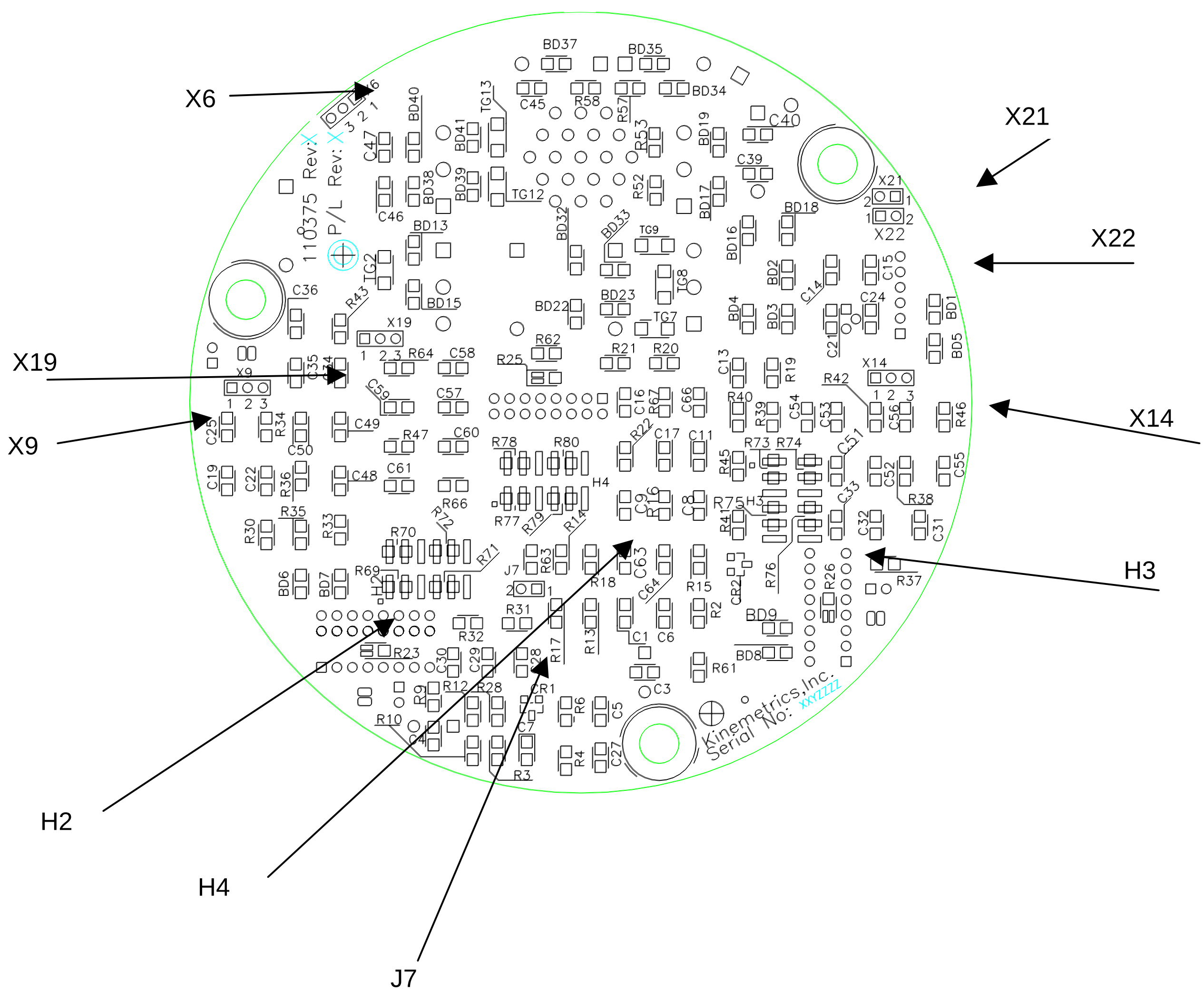
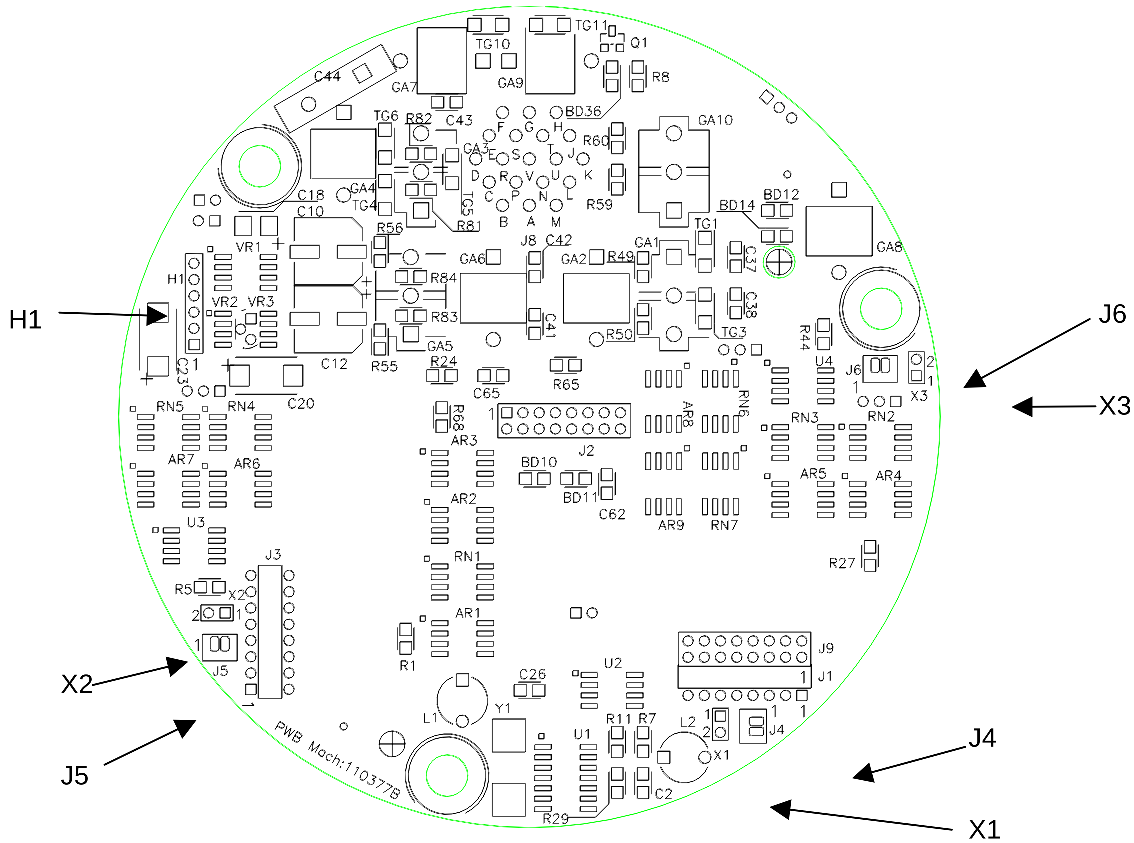


Figure 16: Bottom view of oscillator board with headers indicated



Output Voltage Level

There are three, 3-pin jumper-header configurations that control the output voltage level. While referring to Table 3, install one jumper at each connector location to select the voltage output level for that axis. For the 2.5V output, install the jumper between pins 1 and 2; for the 10V output, between pins 2 and 3.

This output level refers to the voltage from the pin to ground. Thus, if you configure the unit for a 2.5V output voltage level and a single-ended output, you would get an output voltage of 2.5V for the full-scale signal. If you selected a 2.5V output voltage and a differential output, you would get an output voltage of 5V for a full-scale input, +2.5V with respect to ground on the positive output pin and -2.5V with respect to ground on the negative output pin.

Table 3: Output voltage-level jumper settings

Axis	Header	2.5V Output	10V Output
X	X9	1-2	2-3
Y	X14	1-2	2-3
Z	X19	1-2	2-3

Power & Noise Configurations

There are three 12-pin jumpers that route the sensor output signals to the desired amplifier – low-power or low-noise. They also configure the output as either single-ended or differential.

Note: When using the low-noise amplifier, be sure that jumpers are also installed across headers X21 and X22 to the power amplifier. Refer to the table below to configure the amplifier.

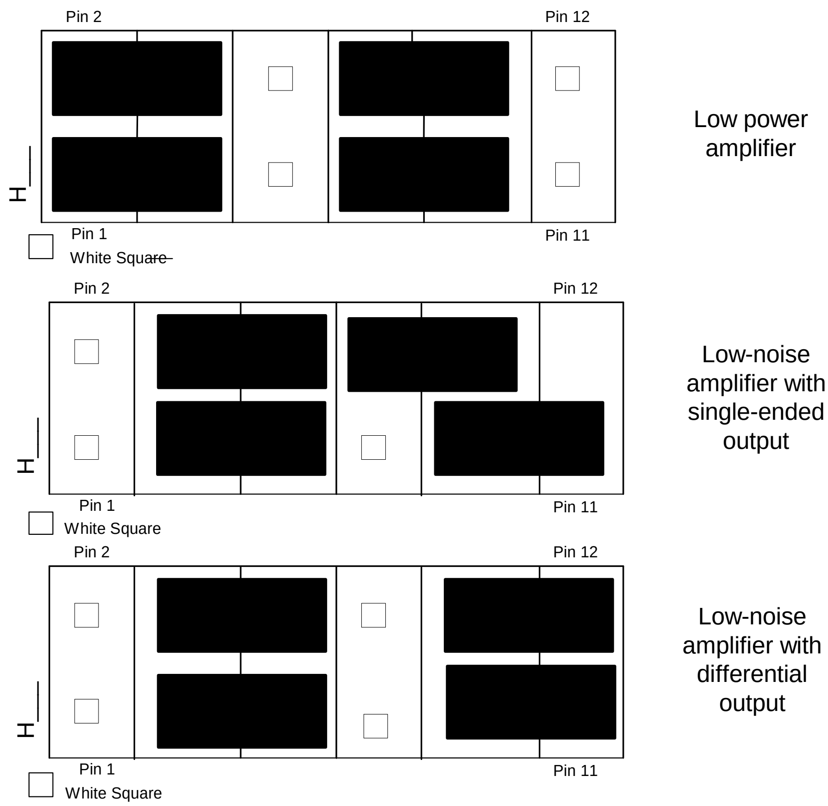
Table 4: Amplifier configuration

Axis	Header	Low-power Amplifier *	Single-ended low-noise amplifier	Differential low-noise amplifier
X	H2	1-3 2-4 7-9 8-10	3-5 4-6 9-11 8-10	3-5 4-6 9-11 10-12
Y	H3	1-3 2-4 7-9 8-10	3-5 4-6 9-11 8-10	3-5 4-6 9-11 10-12
Z	H4	1-3 2-4 7-9 8-10	3-5 4-6 9-11 8-10	3-5 4-6 9-11 10-12
Power Jumper	X21 and X22	Out	In	In

** Differential operation of the low-power amplifier is not possible.*

The figure below shows the jumpers installed for each of the three valid configurations.

Figure 17: Jumper configurations



Low-Noise Power Control

X21 and X22 are 2-pin headers that apply power to the three low-noise amplifiers. These jumpers control all three axes, X, Y and Z.

Important: Remove them to conserve power when using the low-power option.

Table 5: Function of headers X21 and X22

Jumper	Function
X21	Connects +12V supply to X, Y, and Z axis low-noise amplifiers
X22	Connects -12V supply to X, Y, and Z axis low-noise amplifiers

Power Supply Options

The triaxial EpiSensor is offered in two power supply configurations; the standard dual supply configuration and the optional single supply configuration. The jumpers for these options are set at the factory and should not be changed.

Caution*: Damage to instrument**. When the EpiSensor is configured for single-supply operation, ***do not connect any power source to pin H of the connector. This pin is connected to the PGP (instrument case ground) which connects to the EpiSensor's case – if it is connected to pin H the power source will be shorted.

Calibration Coil

Each EpiSensor module is equipped with a calibration coil. This coil is isolated from other EpiSensor circuitry and accurately emulates the effect of an acceleration on the system. This coil can be used to verify both the static acceleration sensitivity of the EpiSensor and the dynamic response of the system. When used with Altus recorders, the calibration signals are automatically applied to the sensor. Access to the individual coils for calibration verification is discussed below.

Calibration Coil Disconnect

X1, X2, and X3 are 2-pin headers that, when jumpers are installed, connect the three calibration coils of the X, Y, and Z sensors to the CALDAC (or STEP, as it is sometimes called) signal from the recorder. For test purposes, these jumpers can be removed to allow direct access to the calibration coils.

For example, a spectrum analyzer or function generator's noise output can be connected directly to the calibration coil for transfer function measurements. Normally, these jumpers must be installed in order to allow recorders that can control the calibration coils to generate functional test records.

Table 6: Calibration coil disconnect header

Header	Axis
X1	X
X2	Y
X3	Z

These headers are located on the bottom of the oscillator board.

Calibration Coil Test Connector

Small, white connectors are used for access to the individual calibration coils for X, Y and Z sensor calibration. They can be purchased from Kinemetrics (P/N 851461) or from the manufacturer – (Molex P/N 51021-0200).

Table 7: Calibration coil test headers

Connection	Axis
J4	X
J5	Y
J6	Z

If you wish to excite the calibration coil through these connectors, install a 1kΩ series resistor in the input line to obtain the same sensitivity in V/g as shown on the sensor calibration data record. If you wish to use a current source to calibrate the unit, the nominal sensitivity is 0.11 g/mA and the resistance of the calibration coil and sensitivity setting resistor is approximately 600Ω. Do not apply high currents (>5 mA) for more than 20 seconds.

Caution: If any signal source is to be connected to J4, J5 or J6, the corresponding headers, X1, X2, and X3, (described in the previous section) must be removed or the sensor could be damaged.

These connectors are located on the bottom of the oscillator board.

Closing the EpiSensor Case

Caution: **Potential electrostatic discharge (ESD) hazard to equipment**. Wear a grounded wrist strap with impedance of approximately 1 M Ω when handling the EpiSensor circuit boards to protect components from damage.

1. Be sure that the large O-ring is firmly lodged in the O-ring groove on the base of the unit and that the connector’s O-ring is in its groove around the base of the connector.

Note: If the unit has not been serviced for a year or longer, apply a light coat of silicone grease to the O-rings.

2. Gently re-install the outer case by sliding it over the connector while aligning the three large screw holes with the corresponding holes in the internal spacers.

3. After checking that the O-ring is not pinched, screw the three large seal screws through the cover and tighten to a torque of 18-20 inch pounds (2.26-2.94 N.m).
4. Re-install the connector nut and tighten to a torque of 18-20 inch pounds (2.26-2.94 N.m).
5. Re-install the two small seal screws in the X and Y zero-adjust access holes on the side of the EpiSensor case.

4. Maintenance

Recommended Maintenance

The EpiSensor is designed for many years of unattended use, but we recommend that you perform the following checks a minimum of once a year. If the EpiSensor is connected to an Altus recorder equipped with a modem, this maintenance check can be performed remotely and more frequently. See the Altus recorder manual for more details.

Adjust the Accelerometers

If the offset of the EpiSensor modules measures more than the suggested limit shown in Table 1, they should be adjusted. Refer to *Chapter 2* for instructions on adjusting the zero offset.

Complete a Functional Test

Kinemetrics recommends that you perform a functional test on the accelerometer at each service visit to check that the unit is operational and to keep as a baseline record for future visits. Refer to *Chapter 3* for instructions on performing the functional test. If the unit is connected to an Altus or other Kinemetrics recorder, refer to the recorder's manual for instructions on performing the functional test. Refer to *Chapter 6* if the unit is connected to a non-Kinemetrics data acquisition system.

Calibration

The EpiSensor is very stable and maintains its calibration in the field for many years. A functional test will provide a good indication of whether the sensor is working properly. A further quick check of the calibration can be performed in the field by simply tilting the sensor $+90^0$ and -90^0 in each axis. By tilting the sensor, an acceleration of ± 1g can be measured.

Kinemetrics can supply a tilt table and training in order to perform more accurate calibrations/verifications in the field. Kinemetrics can also provide on-site or factory calibrations traceable to national standards.

Desiccant Replacement

The EpiSensor contains a small package of desiccant that is designed to maintain a low humidity level inside the unit. If the case is open for a long period of time, opened repeatedly for inspection or adjustment, or in very humid conditions, the desiccant may be incapable of absorbing more moisture. This is shown by the ink on the desiccant pack turning from its original blue to pink. When this happens it should be replaced.

New desiccant can be ordered from Kinemetrics as P/N 700403. Be sure to follow electro-static discharge (ESD) precautions when the sensor case is opened.

Instructions for opening and closing the EpiSensor case are provided in Chapter 3.

Caution: **Potential electrostatic discharge (ESD) hazard to equipment**. Wear a grounded wrist strap with impedance of approximately 1 M Ω when handling the EpiSensor circuit boards to protect components from damage.

Troubleshooting and Repair

If your EpiSensor does not appear to be working, we suggest you first check that the cabling and power supply are correct. If the problem persists we recommend you return the unit to Kinemetrics for repair and re-calibration.

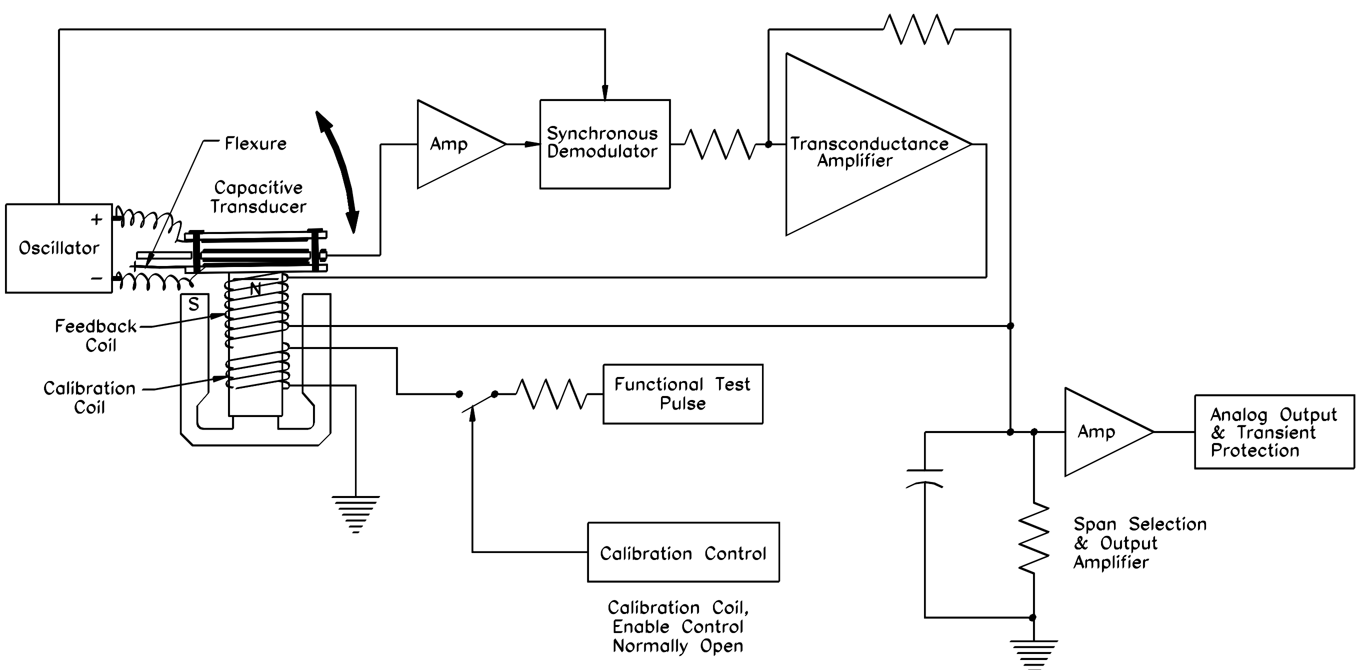
5. Reference

Theory of Operation

The EpiSensor consists of three orthogonally mounted force balance accelerometers (FBAs) – X-axis, Y-axis and Z-axis – inside a sensor casing. Each accelerometer module is identical and plugs into a board that provides the final output circuit and the carrier oscillator.

The figure below shows a simplified block diagram of the major components of each of the FBAs.

Figure 18: Simplified block diagram of an accelerometer



Working Principle

- The oscillator applies an AC signal of opposite polarity to the two moving capacitor plates (also referred to as "the moving mass"). When the accelerometer is "zeroed" and when no acceleration is applied, these plates are symmetrical to the fixed central plate and no voltage is generated.
- An acceleration causes the coil and capacitive sensor plates, which are a single assembly mounted on mechanical flexures (springs), to move with respect to the fixed central plate of the capacitive transducer.
- This displacement results in a signal on the center plate of the capacitor becoming unbalanced, resulting in an AC signal of the same frequency as the oscillator being passed to the amplifier.
- The amplifier amplifies this AC signal.
- This error signal is then passed to the demodulator where it is synchronously demodulated and filtered, creating a "DC" error term in the feedback amplifier.
- The feedback loop compensates for this error signal by passing current through the coil to create a magnetic restoring force to "balance" the capacitor plates back to their original null position.
- The current traveling through the coil is thus directly proportional to the applied acceleration. By passing this current through a complex impedance consisting of a resistor and capacitor, it can be converted to a voltage output proportional to acceleration with a bandwidth of approximately 200 Hz.
- Selecting a particular resistor value sets the full-scale range. The resistor values are determined by a high accuracy network, so the range can be set at 0.25g, 0.5g, 1g, 2g, and 4g without re-calibrating the sensor span.
- The capacitor and overall loop gain are selected along with the resistor to ensure an identical transfer function on each range. *This is why two sets of jumpers must be changed together to modify the range.*
- The voltage output of the resistor capacitor network is set at 2.5V for the acceleration value corresponding to the particular range. For example, with the 2g range, a 1g acceleration would cause a 1.25V output, on the 4g range, 1g would result in a 0.625V output.

This voltage is then passed into the amplifier:

- The low-power amplifier amplifies this signal by either 1 or 4 (selected by jumpers) to give a single-ended output of either ±2.5V or ±10V. A precision resistor network also determines this gain value.

- The low-noise amplifier (selected by jumpers) provides a lower noise output at the cost of additional power. This amplifier again amplifies the signal by 1 or 4 to give a single-ended output of either ±2.5V or ±10V.
- A second amplifier is also present which inverts the signal from the first and can be connected to the negative output lead (via jumpers). This allows the unit to give a differential ±5V or ±20V to match the input to 24-bit digitizers.

Features

- Each EpiSensor module is equipped with a calibration coil. Applying a current to this coil simulates the effect of an acceleration applied to the sensor. This provides a much more thorough check of the sensor's performance than older techniques that merely stimulate the feedback circuitry.
- The calibration coils are open circuit in normal use to prevent cross talk and noise pick-up. To utilize the calibration coil remotely from outside the unit, the calibration coil enable signal must be activated by applying a DC voltage of +5V to +12V with respect to ground.
- A voltage signal applied to the calibration line with CCE is active will cause all three EpiSensor modules to respond with an acceleration output of approximately 0.05 g per volt applied. The exact calibration coil sensitivity is provided on the data sheet of each module.
- This voltage mode will normally be used for checking the response of the sensor remotely from a digitizer. If you wish to use a current source to drive the calibration coils in a laboratory setting, they may be accessed by removing the EpiSensor's case.
- All external connections are passed through double-stage transient protection. This protection consists of a gas arrestor between the line and protective ground. This is followed by a series impedance and solid-state low-voltage transient protection device connected between the line and protective ground.
- These elements protect the sensor from the effects of lightening induced transients and electro-static discharge (ESD). Each line is also filtered to prevent the entry of electro-magnetic interference or radio frequency interference (EMI/RFI) to the sensor.
- Optionally, the unit can be equipped with a +12V to ±12V converter module allowing the EpiSensor to be powered from a single 12-15V supply.

Pole Zero Representation of the EpiSensor

EpiSensor accelerometers are closed-loop, force-feedback sensors measuring the relative displacement of a moving mass (plates) with respect to the sensor case. The sensor's transfer function (TF) depends almost entirely on the electronic components rather than on the mechanical components of the sensors. The influence on the transfer function of the mechanical damping, spring elements and internal RC low-pass filter in the trans-conductance amplifier stage within the closed-loop path of the sensor are negligible for most applications.

We have determined a good empirical model of the system, which uses two pairs of conjugate poles to represent the transfer function of the instrument. If this transfer function is corrected for the DC sensitivity of the sensor, the amplitude agreement is within ±.0.5 dB over the bandwidth of the sensor. The phase agreement is within ± 2.5° in the 0-100 Hz band and within ± 5° over the full bandwidth of the instrument. This model can be represented as:

$$\frac{V(s)}{A(s)} = \frac{k1*k2}{(s-p_1)(s-p_2)(s-p_3)(s-p_4)}$$

where $k1 = 2.46 \times 10^{13}$

k2 = Sensitivity of sensor in V/g (from Table 3-1)

s is the Laplace transform variable

$p_1 = -981 + 1009i$ (Pole 1)

$p_2 = -981 - 1009i$ (Pole 2)

$p_3 = -3290 + 1263i$ (Pole 3)

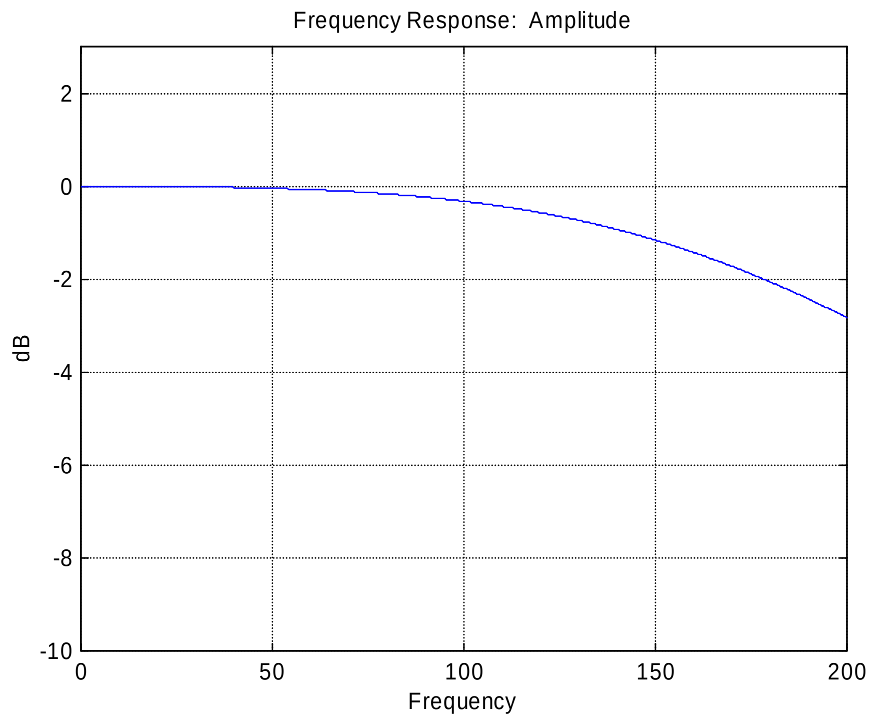
$p_4 = -3290 - 1263i$ (Pole 4)

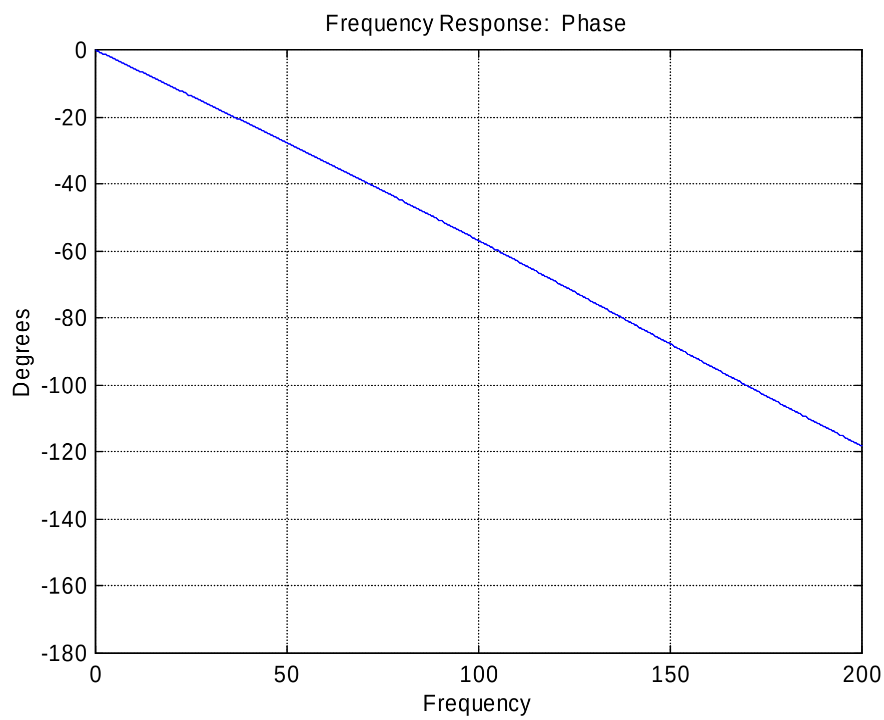
V (s) is the Laplace transform of the output voltage

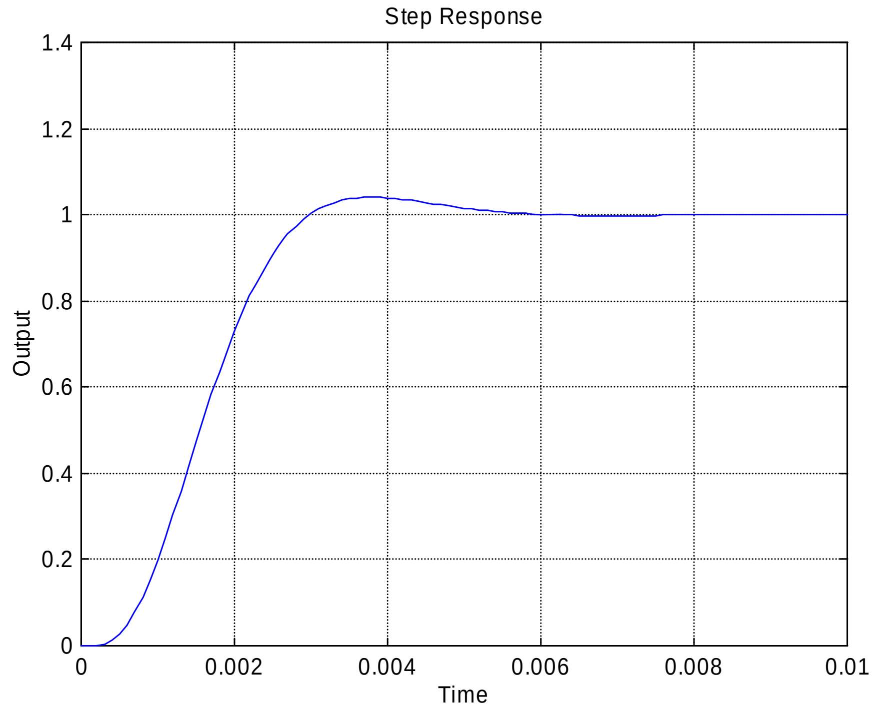
A (s) is the Laplace transform of the input acceleration

Figure 19 on the next page show the amplitude, phase and step response of this pole zero representation. Additional references to pole zero responses and damping are available on the Kinematrics website. Application Note 39 gives the response of the FIR filters used in the Altus Recorders. The FIR filter response dominates the overall system response at sample rates up to 250 samples per second.

Figure 19: Amplitude, phase, and step response of the EpiSensor response model







Polarity Conventions

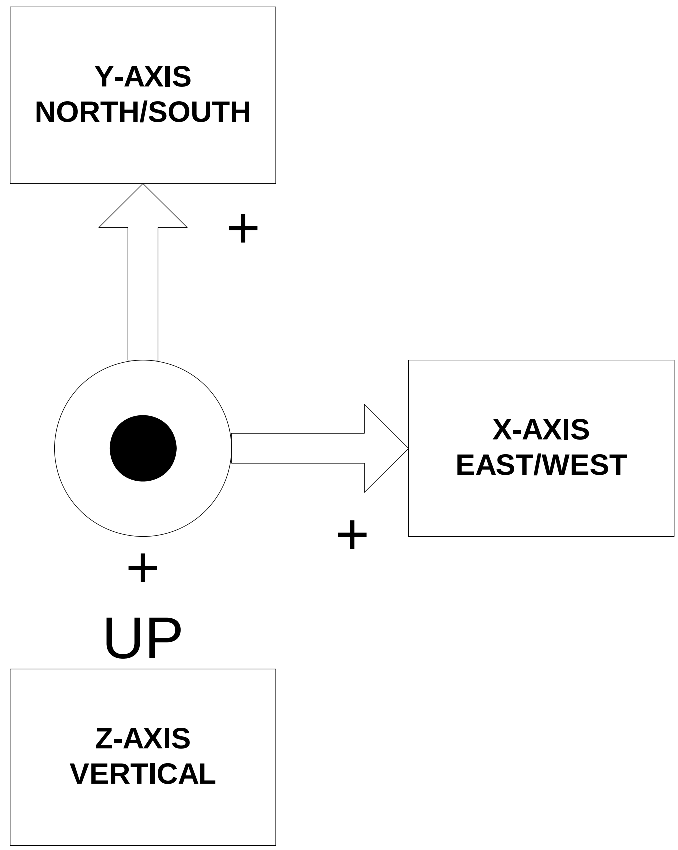
Unlike previous generations of Kinemetrics force balance accelerometers, the EpiSensor uses a right-handed X Y, Z coordinate system with a positive output for acceleration along each axis.

The EpiSensor will normally be aligned with X (channel 1) to the east, Y (channel 2) to the north and Z (channel 3) upward. The signal has the same polarity as the ground acceleration in the sensor coordinate system.

Positive polarity is the international standard in weak motion seismology. With Kinemetrics' decision to adopt a positive polarity with the EpiSensor FBA, it is now the standard in strong motion seismology as well.

Previous Kinemetrics FBA designs used an alternate coordinate system (L, V, T) and produced a negative output for positive acceleration along each axis. With modern feedback sensors, this historical convention dating from the days of passive seismic sensors is losing acceptance. Today's user requires an accelerometer that produces useful data without regard to the internal workings of the sensor. The extended bandwidth, flat frequency response and polarity of the EpiSensor meet these demands.

Figure 20: X, Y and Z coordinates



Electrical Interface

Table 8: Input connections

Pin	Name	I/O	Description
L	X + signal	Output	+ X axis signal output
M	X – signal	Output	– X axis signal output
N	X shield		X shield
A	Y + signal	Output	+ Y axis signal output
B	Y – signal	Output	– Y axis signal output
P	Y shield		Y shield
C	Z + signal	Output	+ Z axis signal output
D	Z – signal	Output	– Z axis signal output
R	Z shield		Z shield
E	Cal	Input	Calibration input to excite the calibration coils of all three sensors. Only active when calibration coil enable (CCE) is active. A voltage of 2.5V will produce a nominal output equivalent to an input of .125g.
F	CCE	Input	Calibration coil enable. Normally the CCE must be disconnected or set at a voltage below 0.5 volts. To enable the calibration coil apply a signal of +5 to +12 volts to this pin. Can be driven to –12 volts in the disable state.
J	+ 12 V	Input	+12 VDC power input.
H	– 12 V	Input	– 12 VDC power input. (Leave disconnected when running with +12V single power supply option)
K	Power common	Input	Power connection
U	PGP ground		Instrument case ground
G	Ground		
S	Ground		
T	Ground		
V	Ground		

6. Advanced Installations

This chapter contains information on various advanced installation topics that may apply to your system. Kinemetrics' Service Group can provide additional information on these topics.

CE Compliant Installations

The EpiSensor has not yet been CE certified.

Using EpiSensors with Altus Instruments

The Altus K2, Mt. Whitney and Etna can all power the EpiSensor in its low-power configuration. (Low-power amplifier, +/-2.5V single-ended output, any range.) The K2 and the Mt. Whitney can also power multiple EpiSensors in the low-power configuration.

The Makalu (formerly known as the Everest) recorder can power EpiSensors in any configurations and can accept the +/-20V differential input.

Generally there is no reason to use the low-noise amplifier with standard Altus instruments, as the noise floor of the sensor in the low-power configuration is below the digitizer noise floor. There are two exceptions to this rule:

- You have an Altus instrument with a gain board and plan to use either a dual-gain configuration or a high-gain channel. This is explained below.
- You have a long cable run, or a high noise environment, and would like to benefit from the improved common mode rejection of a differential output.

In these situations you must be sure that the Altus instrument can supply sufficient power to the EpiSensors.

The Etna

The only reason to use the differential output with the Etna is to take advantage of its superior common-mode rejection in a high noise environment.

When using the differential output, the EpiSensor will need either a separate power supply or should use its single supply option and take power from the Etna's +12V. This is because the Etna can supply only +/-40mA on each +12 and –12V power line.

The K2 & Mt. Whitney

The 6-channel K2 and Mt. Whitney can supply 75 mA from the +12 and –12V power lines for the sensors and any gain boards. Gain boards draw approximately 5mA per rail. There is more than enough power for a single EpiSensor connected to a 6-channel ADC/DSP board with additional gain boards.

If you wish to use two EpiSensors on a 6-channel board you need to work out the current requirement as shown in Table 10. In general, the system will probably supply adequate quiescent current for both sensors with low-noise amplifiers enabled, but there may be a problem with the dynamic current at high g levels.

If this is the configuration you wish to use, we suggest using one of the following solutions:

- Run only one of the EpiSensors on the low-noise setting
- Contact Kinemetrics about modifying the ADC/DSP board to supply more power
- Use the single supply option on the EpiSensors, powering the units from the +12V battery power on the K2 or Mt. Whitney
- Build your own power supply unit

Dual Gain Systems

Some users may want to use an EpiSensor and a 6-channel K2 with gain boards as a dual gain system – for example, to record 2g strong motion on channels 1 to 3, and a high gain channel on channels 4 to 6. To do this you will need to build a special "Y" cable that allows one triaxial sensor package to be connected to two-recorder input connectors.

The first of these is wired exactly per the instructions in this chapter. The second only wires the signal connections for the X, Y, and Z outputs from the EpiSensor. Set the EpiSensor for low-noise 20V differential output. On the gain board for channels 1 to 3 (strong motion) set the gain board as an attenuator with a gain of 0.125 and the gain to 1. See the gain board manual for instructions on setting the gain board. This will reduce the 20V differential input to the 2.5V input required for the ADC at full-scale.

Configure the gain board on the high gain channel with no attenuation and a gain set according to your desired full-scale range on the high gain channel – remembering that the 20V differential output already represents an effective gain of eight.

For example, if you set a gain of 10 on the gain board you would have a total gain of 80 and the full-scale would be 0.025g. (Gains higher than 30 on the amplifier will actually tend to reduce the dynamic range and will worsen the offset problem.) The final concern is the offset of the EpiSensor, which needs to be adjusted as close to zero as possible for this system to work.

Long Cables

In its low-power configuration (low-power amplifier 2.5V single-ended output), the EpiSensor can be used with the normal Kinemetrics cable (P/N 840356 or Belden 9874) for distances up to 1,000 feet with a variety of instruments.

If the EpiSensor is used with an Altus recorder, this distance can be extended up to 2,000 feet. For cable runs of this length, we recommend installation in a grounded metal conduit. If the cable is not installed in its own conduit and maximum resolution is required, it should not be run alongside cables carrying heavy AC or transient currents.

For runs longer than 2,000 feet, Kinemetrics P/N 700045 cable is recommended; it can be used for distances up to 3,000 feet with the low-power configuration.

When using the low-noise amplifiers and the differential 5V output, distances are somewhat reduced as shown in the Table 9.

Cable lengths must be reduced considerably for the low-noise and 20V differential option. The EpiSensor requires a minimum operating voltage of 11.5V to be sure it can supply the +/-10V output with respect to ground. In the worst case, the standard Altus unit's power output is only 11.6V.

This limits cable length to 50 feet for the standard Belden cable (P/N 9874) and 100 feet for the Kinemetrics 700045 cable. Note that this configuration will seldom be used with standard Altus recorders because the output does not match the 2.5V input of the recorder.

These calculations for the 2g operating range are provided in the following tables. These figures are a conservative limit for all other ranges except the 4g range.

User-Supplied Cable

If you are using your own cable, be sure that is has sufficient conductors of the required wire gauge for your installation and that it provides adequate shielding to maintain the noise performance of the EpiSensor. The conductors used for the signals and the control signals (Cal and CCE) carry little current. The table in the section above shows the resistance and calculated voltage drop for different lengths of cables when using an Altus recorder. You can substitute your own values to calculate the allowed cable length.

In order to exceed these lengths, use a regulated power supply that supplies 12-15 V. Calculate the voltage drop in the cable at the maximum supply current and make sure that it meets the minimum operating voltage for the chosen configuration.

Table 9: EpiSensor cabling requirements (1 foot = 0.3048 meters)

Sensor Type	EpiSensor low-power, 2g, 2.5V S/E	EpiSensor low-noise, 2g, 5V differential	EpiSensor low-noise, 2g, 20V differential
Sensor minimum operating voltage	10.0	10	11.5V
Maximum supply current	30.0	52	70mA
Minimum supply voltage	11.6	11.6	11.6V
Allowed cable voltage drop	1.6	1.6	0.1V
One-way allowed cable drop	0.8	0.8	0.05V
One-way allowed resistance at full-scale output	26.7	15.4	0.7 Ohms

Cable AWG	Cable Resistance per 1000 Feet	Low-power 2g, 2.5V Single-ended Maximum Cable Run in Feet	Low-noise 2g,5V Differential Maximum Cable Run in Feet	Low-noise 2g, 20V Differential Maximum Cable Run in Feet
24	27.70	950	550	20
22	17.50	1500	880	40
20	10.90	2400	1400	60
18	6.92	3850	2200	100
16	4.35	6100	3500	160
14	2.73	9700	5500	260

Grounding

CE

The cable assembly technique used for connecting the EpiSensor to an Altus instrument is designed to allow future compliance with the requirements of the emissions and immunity standards (EN 55022

Class A, EN 50082-2) of the European Community. If grounding the cable shield at both ends with long cable results in excess noise in the instrument, the cable shields can be disconnected from the PGP connection (Pin U) at the EpiSensor end. This may be required if significant current flows in the shield between the two grounds. This may result in better system noise performance. However, Kinemetrics cannot be responsible for any EMI/RFI emissions that may occur due to this change in the cabling. The EpiSensor should still be grounded using the grounding stud on the flange.

If changing the cabling does not solve the problem, the case grounds can be reconnected to the EpiSensor and the EpiSensor can be isolated. To isolate the EpiSensor, place the mounting feet on isolation washers, do not connect the case ground strap, and use an insulating washer between the mounting nut and the mounting bracket.

While this procedure may improve noise performance, leaving the EpiSensor case ungrounded greatly degrades its ability to survive lightning induced transients and can lead to a safety hazard if the location has poor AC wiring.

A hybrid ground connection can also be used:

1. Ground the EpiSensor with the grounding strap.
2. Open the connector at the EpiSensor end of the cable.
3. Connect the cable shields and the PGP wire to one side of a 0.1 μF, 200 V film capacitor.
4. Connect the other side of the capacitor to the EpiSensor's PGP connection (Pin U).
5. Cover the wire and the capacitor with shrink tubing.

This connection can still result in a safety hazard but it does give the EpiSensor a low impedance path for lightning induced transients.

Note: This technique provides a single point ground for low frequency signals at the recorder end of the cable, but at high frequencies the capacitor conducts, providing an effective AC ground for EMI/RFI signals.

> ***WARNING!*** **Potential lethal voltages**. In these configurations, potentially lethal voltages can exist between the conductors on the cable or the exposed metal parts of the EpiSensor. These occur due to differences in ground potential between the location of the recorder and the location of the EpiSensor. Faulty electrical wiring returning large currents to ground normally causes these differences. *It is the user's responsibility to ensure that hazardous conditions are not created and that all local electrical safety regulations are observed.*

Use with Non-Kinemetrics Data Loggers

If you are using the EpiSensor with a non-Kinemetrics data logger you must match the power, calibration and output of the EpiSensor with that of the recorder. Kinemetrics Services Group can provide help with this and can also supply conversion boxes to interface to some commonly used seismic instrumentation.

Power Supply

The standard EpiSensor requires a well-regulated, low-noise ±12V (± 5%) or ±15V (±5%) supply that can provide adequate current for the configuration you are using. The supply should be low-noise – less than 50 mV of ripple.

The single supply option can tolerate a relatively wide input range from 10 to 18 VDC. The supply should be low-noise and have less than 100 mV of ripple to ensure low-noise performance of the sensor.

Caution: Incorrect power to the EpiSensor can cause incorrect readings and may damage the sensor. If the voltage is too low the EpiSensor will not attain its full-scale output and the data will be corrupted. Never supply more than +/-15.75V to the unit and be sure the connections are the correct polarity. The EpiSensor has no protection against reversed polarity connections. Reversed power connections will severely damage the instrument!

The **single supply** option requires 10-18V DC supplied to the positive power connection. Exceeding 18 VDC will damage the instrument as will reversing the connections. Do not connect anything to the negative power connection terminal when using the single supply option – damage to the power supply or instrument could result. If less than 10V is applied the EpiSensor will not attain its full-scale output and the data will be corrupted.

The current required for the EpiSensor can be calculated using the table below. The supply should be capable of supplying the maximum load for the sensor under operating conditions. The quiescent current is the best figure to use for sizing batteries or solar charging systems.

Table 10: Current requirements

Sensor Quiescent Current	Dual ±12V Supply	Single 12V Supply
Low-power unit	12 mA	65 mA
Unit with low low-noise amplifiers enabled	35 mA	130 mA

Sensor Full-scale Output Current	1 Axis	3 Axes
Restoring current for coils per g	2.5 mA/g	7.5 mA/g
Output amplifier load at ±2.5V single-ended or ±5V differential full-scale	0.7 mA	2.1 mA
Output amplifier load at ±10V single-ended or ±20V differential full-scale	6.6 mA	20 mA

To calculate the worst case maximum current required, take the full-scale range that the unit is set at and multiply by 7.5mA. This will give the current required to "balance" the applied acceleration.

Add to this the output amplifier load for the output you have selected.
For a dual supply add this number to the quiescent current to get the worst case current.

For a single supply option, multiply the current by 4 to account for the 50% efficiency of the DC to DC converter and voltage ratio and then add this current to the quiescent current.

The maximum current load on a dual supply for an EpiSensor set to a 2g full-scale range with a 20V differential low-noise output is calculated as below:

$$(7.5\text{ mA} \times 2) + 20\text{ mA} + 35\text{ mA} = 70\text{ mA}$$

For the single supply option:

$$((7.5\text{ mA} \times 2) + 20\text{ mA}) \times 4) + 130\text{ mA} = 270\text{ mA}$$

These values are very conservative because in normal situations all three axis of the EpiSensor are unlikely to see 2g of acceleration at the same time. Further examples are found in Table 11:

Table 11: Current requirements

Examples	Quiescent Dual ±12V Supply	Max Load Dual ±12V Supply	Quiescent Single 12V Supply	Max Load Single 12V Supply
EpiSensor 1g low-power amplifier 2.5V single-ended output	12 mA	25 mA	65 mA	104 mA
EpiSensor 2g low-noise amplifier, 20V differential output	35 mA	70 mA	130 mA	270 mA
EpiSensor 0.25g low-noise amplifier 20V differential output	35 mA	57 mA	130 mA	218 mA

Output Voltage

The EpiSensor output is user-selectable, as is the output amplifier. Select the EpiSensor output that matches the recorder input. If possible use a differential input connection for optimum performance. Configuring the correct range and output is described in *Chapter 3*.

The output impedance of the EpiSensor is 50 Ω to ensure the unit is stable under capacitive loading from a long cable. Normally data loggers have an input impedance of 100 kΩ or more, so the 50Ω output impedance is insignificant.

Calibration Sequence

To produce a functional test sequence the recorder must control the Cal and CCE line to the EpiSensor.

Even if the recorder cannot produce a functional test it is still very important that these lines be held at the correct potential. The Cal line is not connected to the sensor unless the CCE line is active, but to provide the best noise performance it should not be left floating. We suggest that the CCE line be grounded to power common when the calibration coil is not in use.

The CCE line drives a transistor that operates an analog switch that connects the Cal line to the sensor module calibration coil. The transistor will turn on the analog switches at voltages between +5 to +12V. The transistor is not activated at voltages below 0.5V. This means a CMOS driver can drive the line or an open collector output pulled up to 12V.

A transistor-transistor logic (TTL) level will probably work if the sensor is close to the digitizer. *It is very important that the CCE line is not enabled when the calibration feature is not in use and that it is not powered when the unit is not powered.*

This is because the Cal line is connected to all the sensor coils during the calibration sequence, which can result in both additional noise and cross coupling between the sensors. The easiest way to prevent power conflicts from the CCE line is to connect it to the power common or the –12V supply of the EpiSensor.

To produce a functional test sequence, the data logger needs to control both the Cal and the CCE lines. The voltage applied to the Cal line should be limited to +/-10V. The sensor should reproduce any signal applied by the digitizer within the voltage limits and the bandwidth of the sensor. Thus, the calibration sequence can range from the simple pulses described below to single frequency sine waves or chirped sine signals.

Be certain that the Cal line is not active when the EpiSensor is not powered – this could damage the unit.

If the data logger cannot perform a functional test, a simple test box can be built to simulate the desired calibration sequence.

A suggested sequence is as follows:

1. Apply 0V to the Cal line
2. Turn CCE to +12V
3. Wait 2 seconds
4. Apply +2.5V to Cal for 2 seconds
5. Change Cal to <-2.5V for 2 seconds
6. Change Cal to 0V for 2 seconds
7. Turn CCE off by connecting it to 0V

This will produce a positive pulse followed by a negative pulse.

Caution: The CCE line must not be enabled during normal operation – severely degraded noise performance can result. Applying voltage to the Cal line when the unit is not powered will result in damage. Applying voltage above the power supply lines to the Cal line will also damage the unit.

Ground Loop Prevention

When the EpiSensor is used with non-Kinemetrics digitizers it is essential that the ground connections be carefully planned in order to prevent ground loops. Please see the section in this chapter on grounding.

This is especially important when using a PC-based data acquisition system. We recommend using the differential output of the EpiSensor to prevent common mode problems. When using single-ended output, the signal returns (-X, -Y, -Z) should be connected to the negative input of the analog front-end's differential or instrumentation amplifier and not to circuit common.

The common connection should return to the power supply through only one path. When using a separate mains power supply for the EpiSensor, be very careful that it does not provide a separate ground return through the AC mains ground to the data acquisition computer. Use a star ground configuration for your system with the EpiSensor power supply, data acquisition system and PC all grounded at the same point.

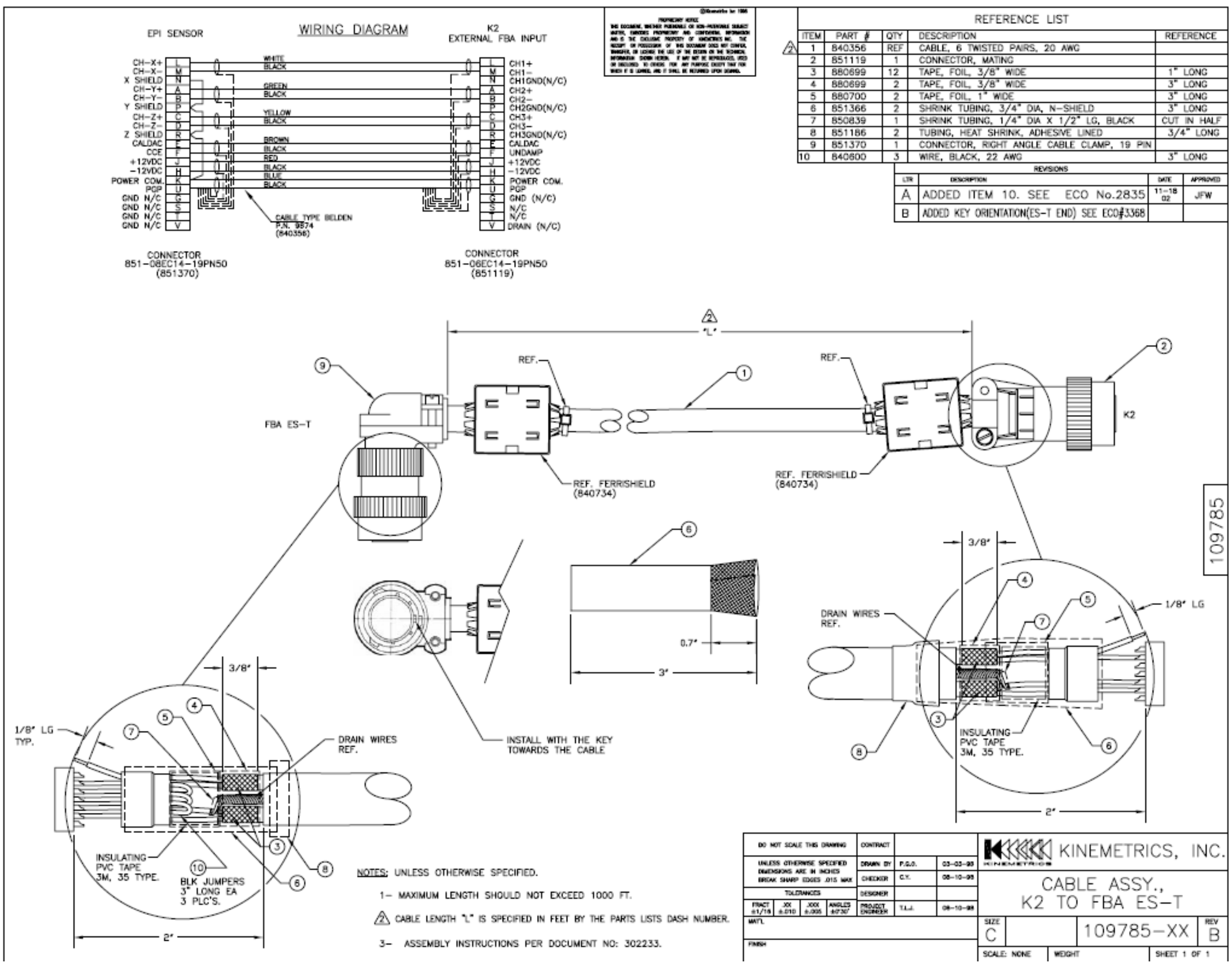
In our experience, most noise problems with any installation are normally a result of power grounding or cable shielding!

Custom Cable Assembly

This section provides instructions for assembling an EpiSensor-to-Altus recorder cable based on a Belden cable (P/N 840356).

The instructions assume the cable has already been pulled and routed through appropriate conduit. If possible, Kinemetrics recommends that cables be routed in grounded metal conduit. Alternatively, plenum-rated cables can be used.

Figure 21: EpiSensor to Altus recorder cable



Initial Assembly of the Altus Recorder End

To assemble the recorder-end of the 840356 cable, open the assembly kit and pick out the parts listed in Table 12 and illustrated left-to-right in Figure 22. Keep the other parts in the assembly kit bag; you will need them later. To install mating connector P/N 851119, you require the following:

Table 12: Parts for recorder mating connector assembly

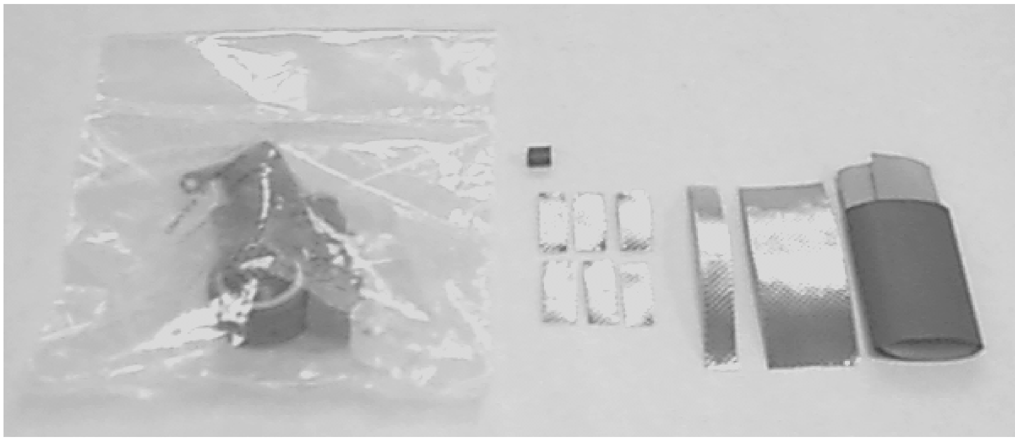
Part Name	KMI P/N	Commercial P/N	Description of Item/s
Mating connector	851119	851-06EC14-19PN50	1 connector
Foil tape	880699	1183 (3/8" wide)	6 pieces, 3/8" x 1"
Foil tape	880699	1183 (3/8" wide)	1 piece, 3/8" x 3"
Foil tape	880700	1183 (1" wide)	1 piece, 1" x 3"
Shrink tubing	850839	FIT 221-1/4"	1 piece, cut 1/4" long
Shrink-n-Shield tubing	851366	SST-20	1 piece, 3" long
Thermofit tubing	851186	DWP-125 3/4-black	1 piece, 3/4" long

Required tools and supplies:

- Soldering iron (approx. 50 watts)
- Solder
- Wire cutters
- Wire strippers
- PVC insulating tape
- Utility knife
- Heat gun
- 3½-digit DVM with 200 ohm range or equivalent

Caution: Be careful when working with the foil tape – it is very sharp.

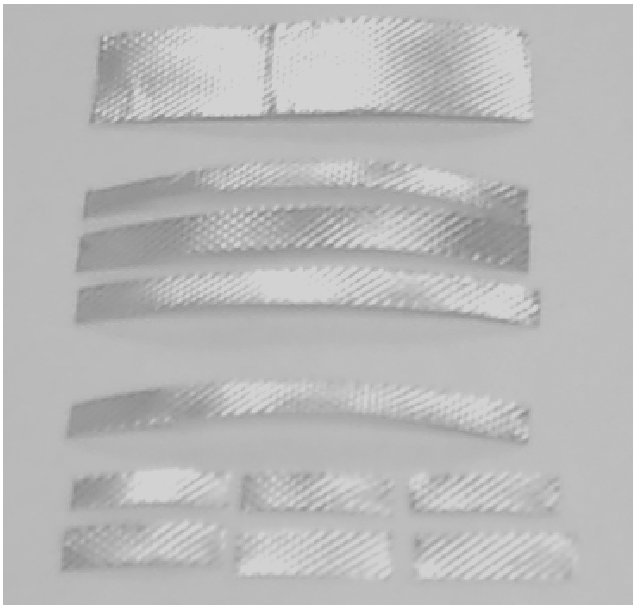
Figure 22: Parts for recorder-end mating connector assembly



Note: In place of the 3/8" foil, you may have received two 1"-wide foil tapes. If your kit contains this substitution, then make tape that is approximately 3/8" wide as follows:

1. Divide one of the 1" x 3" pieces into thirds the long way (as shown in the middle grouping in Figure 23), so you have three 3"-long pieces.
2. Divide two of the approx. 3/8"-wide strips into 1"-long segments (as shown in the bottom grouping in Figure 23). When finished, you should have 6 pieces approx. 3/8" x 1" and 1 piece approx. 1/4" x 3".

Figure 23: Preparing 3/8"-wide foil tape from 1" foil tape



With the parts you need pulled out of the kit and the proper width of tape prepared, begin assembling the recorder-end mating connector.

1. Strip off 3/4" of the outer black rubber tubing on one end of the Shrink-N-Shield tubing (shown on the right side of Figure 24). While stripping this off, be careful not to nick the remaining tubing or the cloth/screen mesh.
2. Gather the parts listed in Table 13 and slide them a couple of feet up over the cable's outer jacket so they are out of the way until needed. Slide them over the jacket in the listed order, top to bottom. If you are not sure which pieces of the connector to use, see Figures 24 -26 to help identify the correct parts.

Table 13: Part order, recorder cable end

Part Name	KMI P/N
Thermofit tubing	851186
Connector strain relief grommet	Part of 851119
Connector back shell	Part of 851119
Shrink-n-Shield tubing	850839
Connector's plastic grommet ring	Part of 851119

Cable Assembly Instructions

- When the recorder end of the cable is attached, proceed to the *Initial Assembly of the EpiSensor End* section on page 2-17.
- When that is done, return to this section and repeat the *Identical Assembly Procedures* for the EpiSensor below.
- To finish the cable, go to the instructions in the *Final Assembly of the EpiSensor End* on page 2-19.

Identical Assembly Procedures

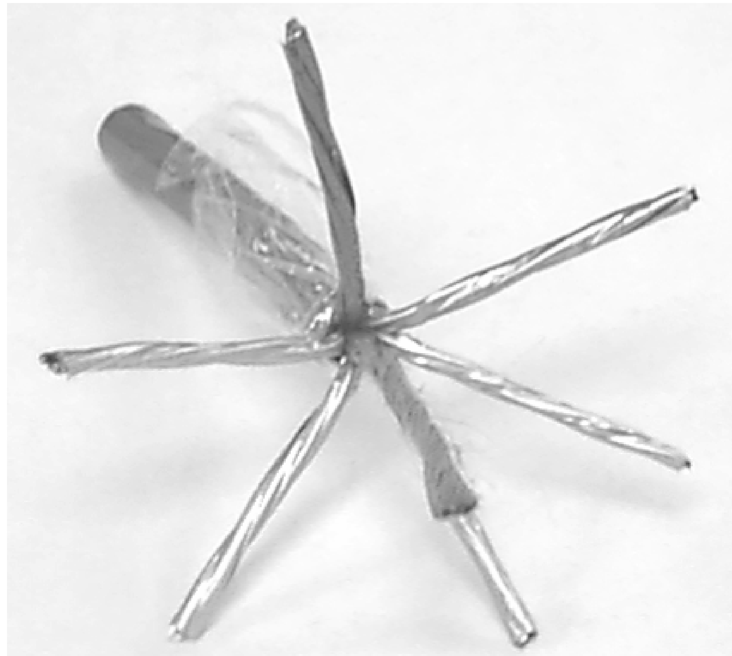
The following assembly procedures and illustrations are exactly the same for both ends of the cable through the end of this section.

Complete these identical procedures on both ends of the cable.

1. Using a utility knife, strip and remove 2" of the cable's outer PVC jacket.
2. Fold back the cellophane and white string covering the shielded wires.

3. Spread the shielded pairs of wire outward from the center rope cord, as shown in Figure 24.

Figure 24: Recorder cable end with outer PVC jacket removed



4. Cut off and discard the center rope, cellophane and white string. Cut them back as near as possible to the "new" end of the cable outer jacket, as shown in Figure 25.

Figure 25: Recorder cable end with rope and cellophane removed

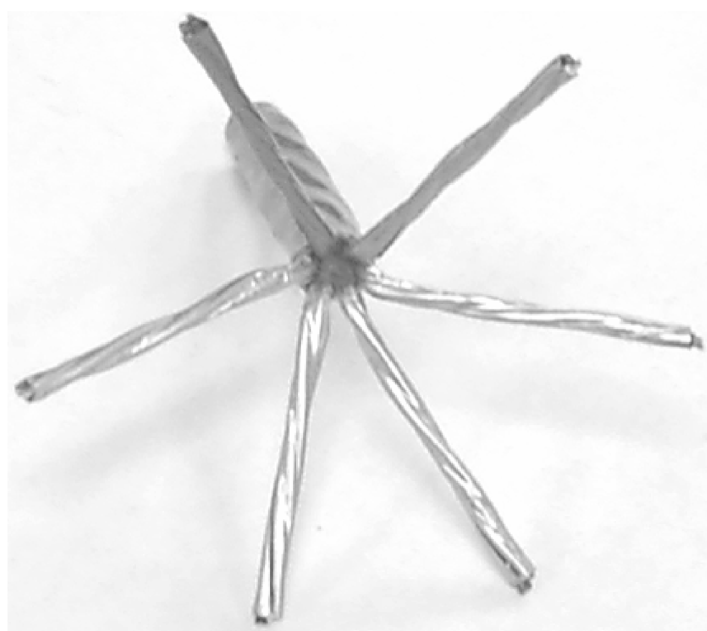
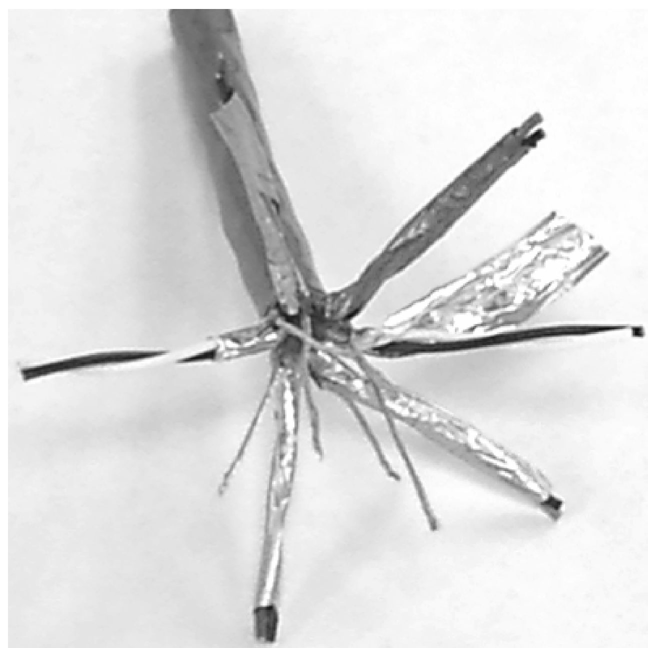


Figure 26 illustrates the steps described below:

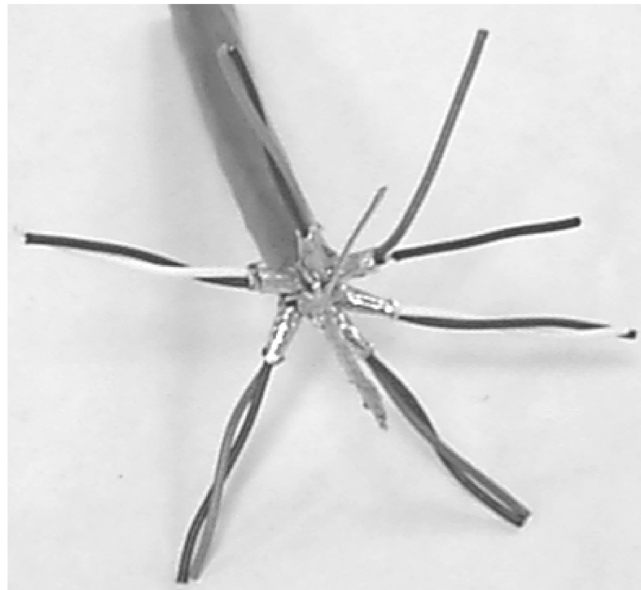
1. Cut off all but 3/8" of foil shield from each of the twisted-wire pairs.
2. Separate out the non-insulated, stranded drain wires and pull them toward the cable center.
3. Rewrap the 3/8" foil shield around the twisted pairs.
4. Take the six pieces of 3/8" x 1" foil tape. One at a time, take each and – beginning as close as possible to the pulled-out drain wires and the cable's outer jacket – wrap it tightly around a foil shield. Make sure your wrapping flows in the same spiraling direction as the shield you are wrapping it around. Wrap all six foil shields identically.
5. Bring all the drain wires together and twist them together in the center of the cable.

Figure 26: Detail of foil shields, drain wires and foil tape



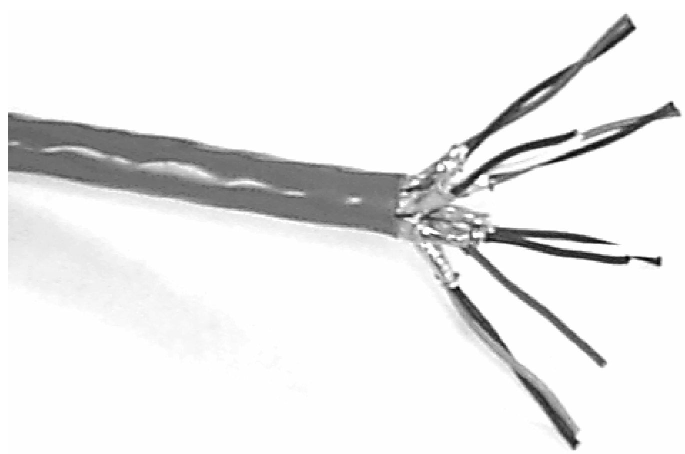
6. Break out one of the drain wires from the twisted group at 3/8" and bend it toward the blue and black twisted pair, as shown in the center of Figure 27.
7. At the 3/8" break-out point, quickly, but carefully, apply solder to the clustered drain wires.
8. In the blue-and-black twisted pair, strip off 1/16" of the black insulation, just above the foil tape and solder tinning. This will leave 1/16" of exposed wire in the black lead.

Figure 27: Drain wires twisted together



9. Wrap and solder the single drain wire to the stripped area of the black wire, then trim off all excess drain wires, as shown in Figure 28.

Figure 28: Drain wire-to-black wire connection

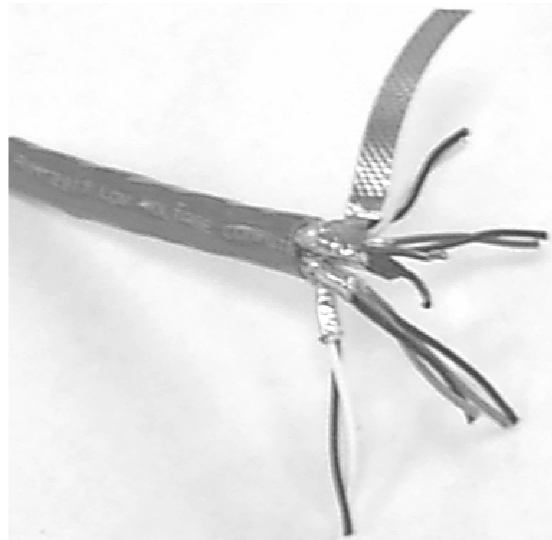


10. Apply 1/4"-diameter by 1/4"-long shrink tubing over the soldered area of the drain wires and black wire, as shown in Figure 29.

The cable is now ready for 3/8" x 3" foil-tape wrapping:

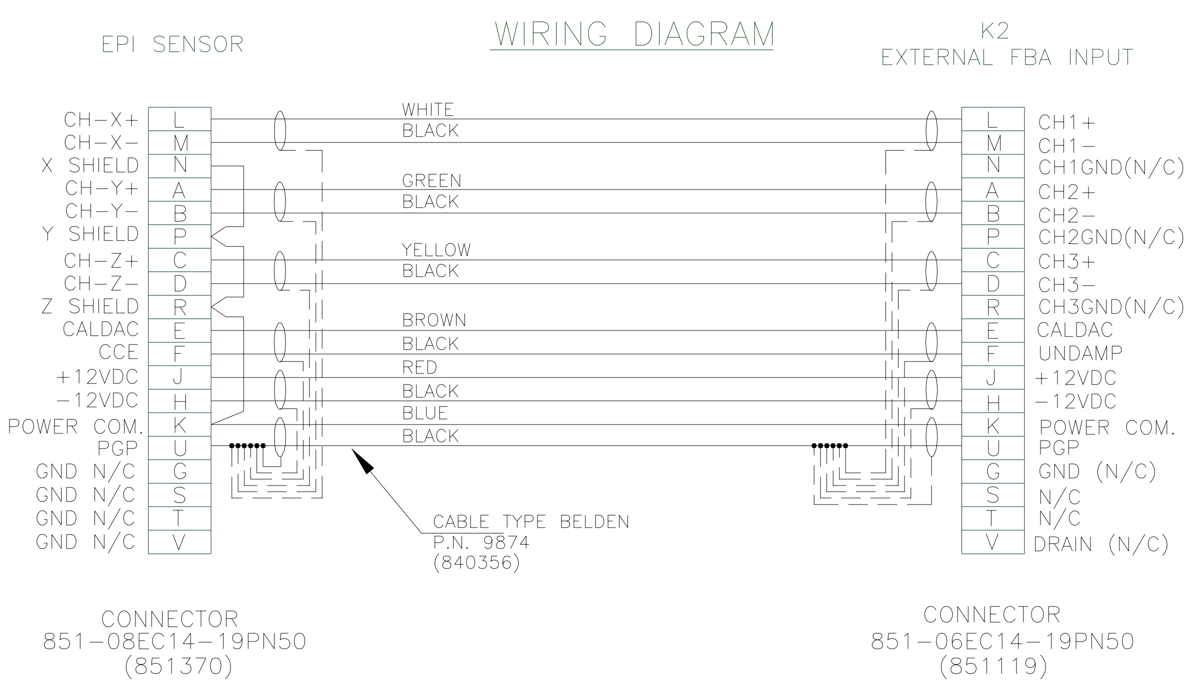
1. Tightly wrap the foil tape around the twisted-together drain wires in the center, as shown in Figure 29.
2. While gathering the twisted-wire pairs toward the center of the cable, bring the tape tightly over the outside of all of them. See Figure 31, Figure 32 and Figure 33.

Figure 29: Outer foil tape and drain-wire shrink tubing



3. Now insert the twisted pairs of wires into the grommet. Use the schematic in Figure 30 to find the proper wire-to-solder cup locations. ***Be sure to follow the proper half of the schematic below***, depending on whether you are currently assembling the recorder end or the EpiSensor end of the cable.

Figure 30: Schematic of EpiSensor cable to both mating connectors



4. Once the wires have been run through the correct holes in the grommet, strip 1/8" off the wire tips, then solder tin them as shown in Figure 31.

Figure 31: Foil tape and stripped-and-tinned wires

Final Assembly of the Recorder End

To complete the final assembly of the recorder end of the cable, solder the wires into the recorder mating connector:

1. Start at the bottom and work toward the top (pin A marks the top), soldering the wires into the connector.

Note: When cool, the soldered joints should have a smooth, shiny surface. Use enough solder to just fill the connector cup.

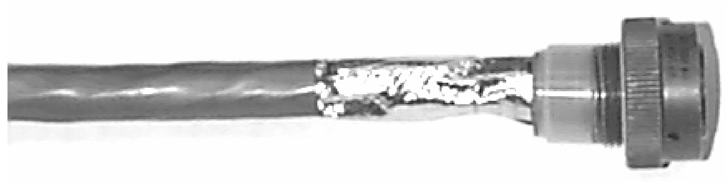
2. When done with the soldering, slide the grommet and plastic grommet ring forward and up against the connector head (shown on the right side of Figure 32).
3. Then apply two turns of insulating PVC tape between the back of the grommet and the foil tape (also shown in Figure 32).

Figure 32: Wrapping the connection with PVC tape

Tightly wrap 1" x 3" foil tape around the cable between the back of grommet and end of the cable outer jacket, as shown in Figure 33.

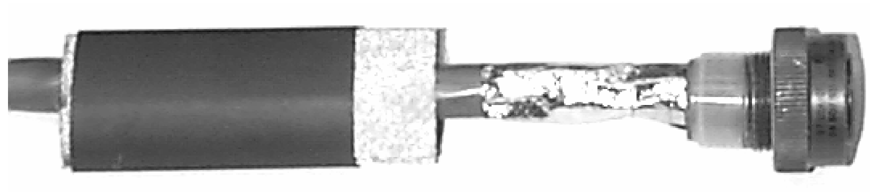
Note: The foil tape must be in tight contact with the 3/8"-wide foil tape.

Figure 33: Wrapping foil tape around outside of the connection



Slide the Shrink-N-Shield tubing forward, as shown in Figure 34, then up over the plastic grommet ring.

Figure 34: Slipping Shrink-n-Shield tubing into place



Carefully place the tubing so its cloth shield is up against-but not covering over-the connector threads, as shown in Figure 35.

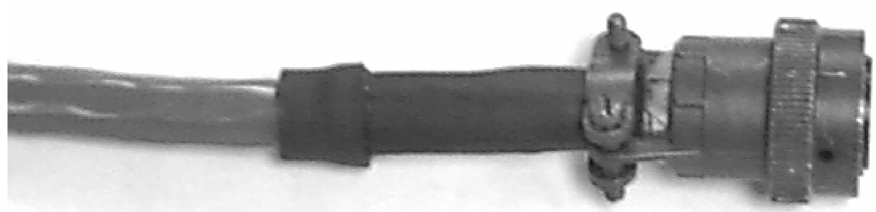
Figure 35: Shrink-n-Shield tubing in correct position (after shrinking)

Using even heat, shrink the tubing until it is tightly in place over the foil tape (as shown in Figure 35), and begin the final assembly process:

1. Slide the connector shell forward and screw-tighten it onto the connector head.
2. Slide the connector strain relief grommet forward.
3. Check the resistance from the connector shell to the shields at the other end of the cable. The resistance will vary depending on cable length, but should be very low (<0.3 Ω / 100').
4. Place the two halves of the cable clamp in place, then tighten its screws.
5. Slide the Thermofit tubing into place and then shrink it

The completed recorder-end connector assembly appears in Figure 36.

Figure 36: Completed assembly of recorder-end of cable 840356



Testing Connector Assembly #1

Now do a "buzzing out" test on the recorder-end of the cable to make sure the correct wires are connected to the correct solder cups (per the schematic in Figure 30), and that none of the wires were shorted in the assembly process.

For this testing procedure you need:

- A digital voltage meter
- A utility knife
- A wire stripper
- A test lead jumper with clips

To prepare the EpiSensor-end wires as response conductors:

1. Strip back 2" of the cable’s outer jacket.
2. Cut off that 2", along with the cellophane, white string, and foil shields that it covered.
3. Separate the drain wires and insulated conductors.
4. Strip off 1/8" of insulation from all of the insulated wires.
5. Make sure to position each wire so that its exposed surface has ***no*** contact with any other wire.

Now, using the DVM, test the connection of the conductor pairs in the recorder-end of the assembly: First set the DVM to measure resistance in the range of several hundred ohms. Then:

1. At the recorder end of the cable, connect one DVM lead to connector pin L (at the top right in Figure 35). Then, with the other DVM lead, check that all other pins in that connector are infinite with respect to pin L.
2. At the EpiSensor end of the cable, have another technician take the white-black wire pair and use a test-lead jumper to connect the white wire to the black wire.
3. When that is done, the DVM at the recorder end should show that pin L is now connected to pin M. The DVM should measure $<2.5\Omega$ per 100' of cable. If it does, have the other technician remove the test jumper at the EpiSensor end of the cable.

4. Disconnect the DVM lead from connector pin L on the recorder end and, with the other DVM lead still connected to pin M, confirm that pin M is infinite with respect to all the other connector pins.

You have now "buzzed out" the top two connections (L and M) shown in Figure 30, for the two wires in the white-black pair. Now repeat Steps 1 through Step 4, but test connector pins A and B and the two wires in the green-black pair.

Follow Steps 1 through 4 for each pair of connector pins and wire-pairs in he remaining five pairs of wires and 10 connections shown in Figure 30. Carefully check that all other pins in the connector are infinite with respect to the connector pin you are testing, that the two wires in each pair can be linked at the EpiSensor end without problems, and that the pin is infinite with respect to all the other connector pins. As you test, carefully follow the right end of Figure 30.

Caution: Do not proceed to the shield-to-shell testing until all the pairs of insulated conductors have passed the four test steps above.

Once you’ve completed testing all the pairs of insulated conductors, test the connection of the wire shields to the recorder end of the connector shell.

1. At the EpiSensor end, take the white-black pair of wires and use a test lead jumper to connect the white wire to the exposed drain wires.
2. When that is done, the DVM at the recorder end should show that pin L is connected to the recorder-end connector shell and to pin U. The DVM should measure $<1.5\Omega$ per 100' of cable. If so, remove the test jumper at the EpiSensor end of the cable.
3. At the recorder end, disconnect the DVM lead from connector pin L and confirm that the connector shell and pin U are infinite with respect to all other connector pins.
4. With the preliminary cable testing completed, disconnect all test equipment.
5. At the EpiSensor end, gather the 2" of wires, shields, cord, etc., that you stripped back; cut off these exposed elements and discard them.

Caution: Do not connect the recorder connector to the recorder until you have installed the EpiSensor connector and have completed the final testing described at the end of the cable assembly process.

If all the recorder-end connections passed the above test, proceed to the next section.

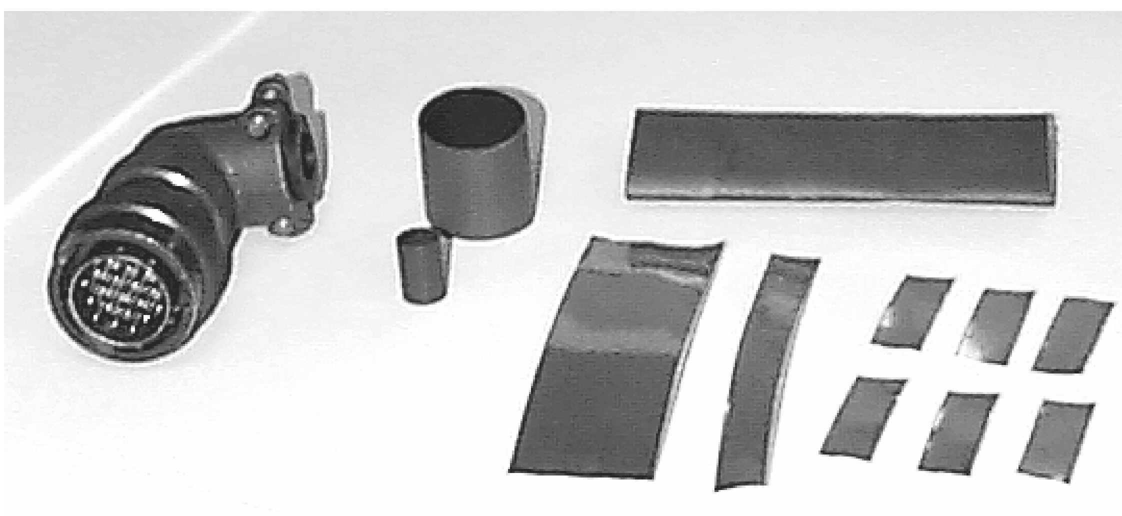
Initial Assembly of the EpiSensor End

Now that the connector on the recorder end of the cable, you should now have only those items necessary for assembling the EpiSensor end of the cable left in the assembly kit. To make sure, select the parts listed in Table 14 and illustrated left-to-right in Figure 37. To install EpiSensor mating connector P/N 850407 on the EpiSensor end of the 840356 cable, you will require:

Table 14: Parts for EpiSensor-end mating connector assembly

Part Name	KMI P/N	Commercial P/N	Description
Right-angle mating connector	851370	851-08EC14-19	1 connector
Foil tape	880699	1183 (3/8" wide)	6 pieces, 3/8" x 1"
Foil tape	880699	1183 (3/8" wide)	1 piece, 3/8" x 3"
Foil tape	880700	1183 (1" wide)	1 piece, 1" x 3"
Shrink tubing	850839	FIT 221-1/4"	1 piece cut 1/4" long
Shrink-n-Shield tubing	851366	SST-20	1 piece, 3/4" x 3"
Thermofit tubing	851186	DWP-125 3/4" black	1 piece, 3/4" long
#22 black wire	840600	UL1429-22-1934-0	3 pieces, 3" long

Figure 37: Parts for EpiSensor-end mating connector assembly

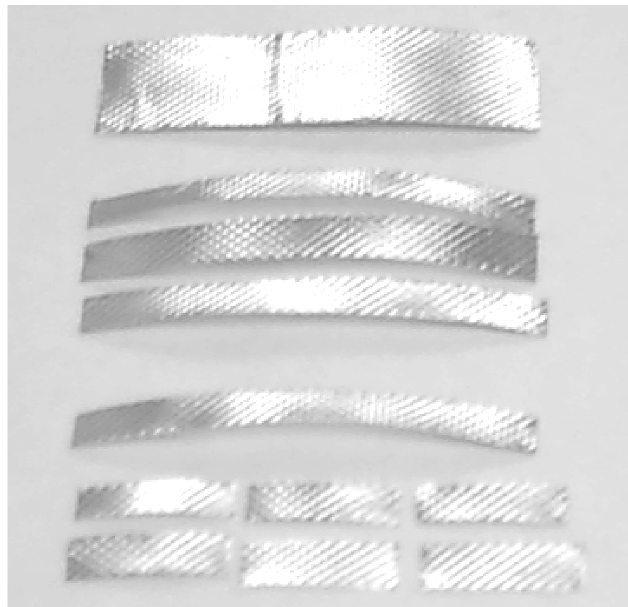


Note: In place of the 3/8" foil tape you may have received two pieces of 1"-wide foil.

If your kit contains this substitution, then do the following:

1. Divide one of the 1" x 3" pieces into thirds the long way (as shown in the middle grouping in Figure 38), so you have three 3"-long pieces.
2. Then divide two of the approx. 3/8"-wide strips into 1"-long segments (as shown in the bottom grouping in Figure 38). When finished, you should have 6 pieces approx. 3/8" x 1" and 1 piece approx. 1/4" x 3".

Figure 38: Preparing 3/8"-wide foil tape from 1" foil tape



To assemble the EpiSensor-end mating connector:

Gather the parts listed in Table 15 and slide them over the cable’s outer jacket-a couple of feet up it, so they are out of the way until needed. *Make sure to slide them over the jacket in the same order as listed, top to bottom, in the table.* Refer to Figure 42 if you need help in identifying these components.

Now return to the *Identical Assembly Procedure* section and prepare the cable for final assembly of the EpiSensor end.

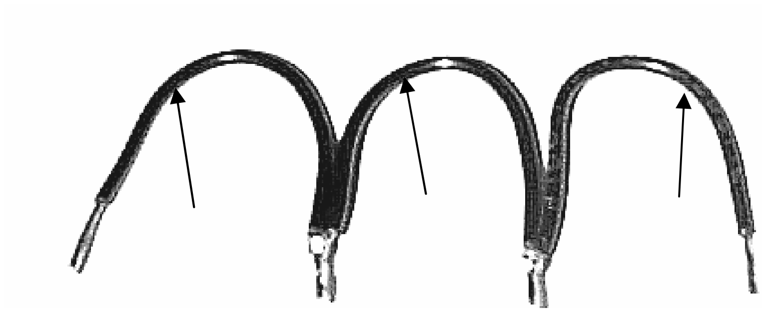
Table 15: Slide parts over cable jacket in this order:

Part Name	KMI P/N
Thermofit tubing	851186
Connector strain relief grommet	Part of 851370
Connector back shell	Part of 851370
Shrink-n-Shield tubing	851366

Final Assembly of the EpiSensor End

The wires in the "daisy chain" below are designated as #1, #2 and #3 for the purpose of these instructions.

Figure 39: Example of a daisychain



Wire 1 *Wire 2* *Wire 3*

1. Insert wires through grommet in appropriate letter location using the EpiSensor end of the schematic in Figure 30.
2. Cut 3 2" lengths of the 22-gauge stranded wire and strip about 1/4" of insulation off each end.
3. Carefully tin one end of each wire
4. Wrap the untinned end of wire #1 around the tinned end of wire #2. Now wrap the untinned end of wire #2 around the tinned end of wire #3.
5. Lightly tin the joined ends of wires #1/#2 and wires #2/#3, just enough so that they will not fray, and insert them all through the grommet.

(The tinned end of wire #1 will eventually be inserted into pin R.)

6. Lightly tin the one remaining untinned end of wire #3.

7. Insert the single, unjoined end of wire #1 into pin R.
8. Insert the joined end of wire #1/#2 into pin P.
9. Insert the joined end of wire #2/#3 into pin N.
10. Insert the remaining single end of wire #3 into the pin K grommet alongside the blue wire.

The next step is to wrap the end of wire #3 in pin K around the blue (power common) wire.

1. Push all but the blue and black wires out of the way.
2. Strip all but 1/4" of insulation off the blue wire.
3. Wrap the black wire around the blue wire and solder into place.
4. Continue inserting the wires into grommet pins as indicated in Figure 30. *Be sure to follow the EpiSensor end of the schematic drawing.*

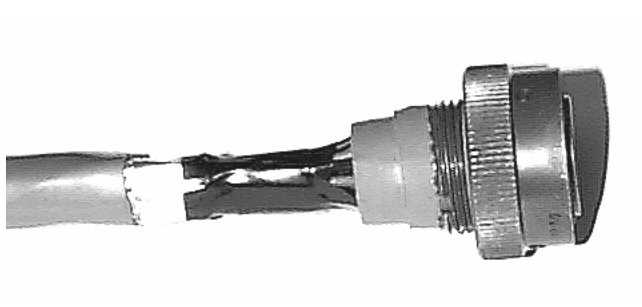
To solder the wires into the EpiSensor connector:

1. Start at the bottom and work toward the top (pin A marks the top), soldering the wires into the connector.

Note: When cool, the soldered joints should have a smooth, shiny surface. Use enough solder to just fill the connector cup.

2. Then slide the grommet forward and up against the connector head (shown on the right side Figure 40).
3. Apply two turns of insulating PVC tape between the back of the grommet and the foil tape (also shown in Figure 40).

Figure 40: Connection wrapped with PVC tape



4. Now, between the back of the grommet and the end of the cable outer jacket, tightly wrap 1" x 3" foil tape around the cable, as shown in Figure 41.

Note: The 1"-wide foil tape must be in tight contact with the 3/8"-wide foil tape.

Figure 41: Wrapping foil tape around outside of the connection

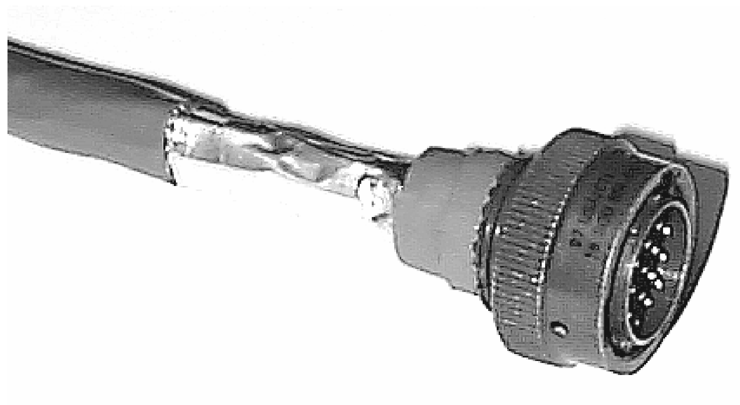
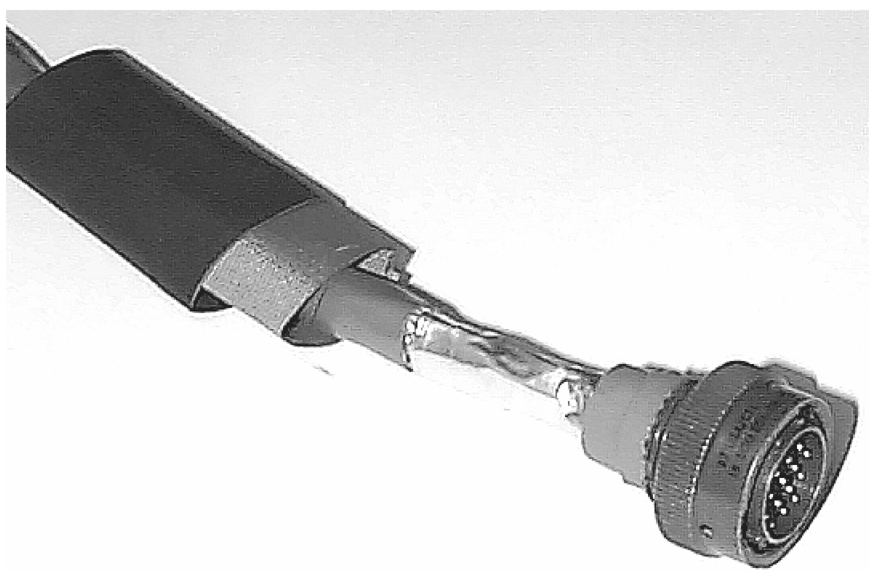
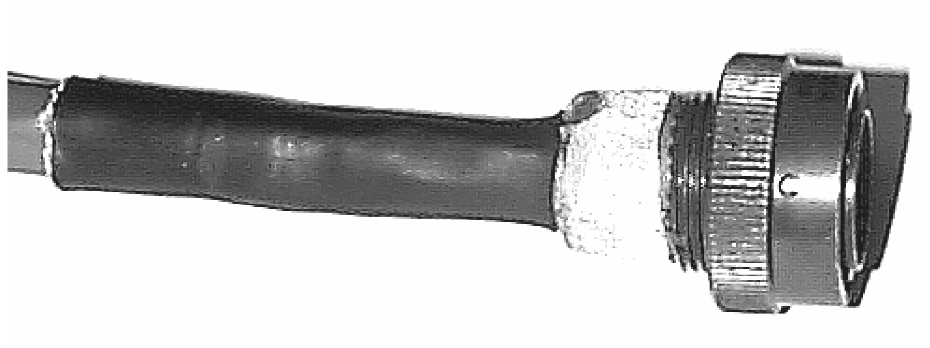


Figure 42: Cable with Shrink-n-Shield tubing (outer tubing trimmed back to show screen mesh)



Slide the Shrink-n-Shield tubing up over the grommet. Then position it carefully, so it covers up to – but does not overlap – the connector threads (as shown in Figure 43).

Figure 43: Shrink-n-Shield tubing shrunk and in position



Now, using even heat, shrink the tubing until it fits tightly in place over the Shrink-n-Shield and foil tape (as shown in Figure 43), and begin the final assembly process:

1. Slide the connector back shell forward toward the connector.
2. Tighten the backshell onto connector.
3. Bend cable back into the connector backshell.
4. Slide the cable strain relief grommet over the Shrink-n-Shield into cable clamp position.
5. Install and tighten cable clamp into place, put back cover into place and secure with small screw.
6. Now slide up the Thermofit tubing and shrink into place.
7. Place the two halves of the cable clamp in place, then tighten its screws as shown in Figure 44.

Figure 44: Completed assembly of EpiSensor end of cable 840356

Testing Connector Assembly #2

You should also do a "buzzing out" test on this end of the cable, to make sure you connected the proper wires to the proper solder cups (per the schematic in Figure 30), and that no wires have gotten shorted in the assembly process.

Check the resistance from the connector shell to the connector shell at the other end of the cable. The resistance will vary depending on cable length, but should be very low (<0.3 Ω / 100').

To do this test, use the pins in the assembled connector at the recorder end as response conductors.

1. Set the DVM to measure resistance in the range of several hundred ohms.
2. At the EpiSensor-end, connect one DVM lead to connector pin L (top left in Figure 30). Then, with the other DVM lead, check that all other pins in that connector are infinite with respect to pin L.
3. At the recorder end of the cable, have another technician take the connector and use a test-lead jumper to connect connector pin L to connector pin M.
4. Now the DVM at the EpiSensor-end should show that pin L is connected to pin M (the DVM should measure < 2.5 Ω per 100' of cable. If it does, have the other technician remove the test jumper at the recorder end.
5. Disconnect the DVM lead from connector pin L and, with the other DVM lead still connected to pin M, confirm that it is infinite with respect to all other connector pins.

You have now "buzzed out" the top two connections (L and M) shown top left in Figure 30, for the two wires in the white-black pair.

Repeat Step 1 through Step 4, but test connector pins A and B and the two wires in the green-black pair.

Follow Steps 1 through 4 for each pair of connector pins and wire-pairs in the remaining five pairs of wires and 10 connections shown on the left side of Figure 30.

With the exception of K, N, P and R, check that all pins in the connector are infinite with respect to the connector pin you are testing. Now check that pins K, N, P and R are connected to one another and are infinite in respect all other pins.

Note: Do not proceed to the shield-to-shell testing until all the pairs of insulated conductors have passed the four test steps above.

To test the connection of the wire shields to the EpiSensor-end connector shell:

1. At the recorder end, have another technician take the recorder connector and use a test-lead jumper to connect pin L to the recorder-end connector shell.
2. The DVM at the EpiSensor-end should show that pin L is now connected to the recorder-end connector shell and to pin U. The DVM should measure < 1.5 Ω per 100' of cable. If it does, have the technician remove the test jumper at the recorder end.
3. Disconnect the DVM lead from connector pin L and confirm that your connector shell and pin U are infinite with respect to all the other connector pins.

With the final cable testing completed, disconnect all test equipment. The fully assembled cable is ready to connect to the recorder and the EpiSensor.

7. Appendix

Table 16: EpiSensor specifications

Type	**Triaxial force balance accelerometer**
Dynamic range	155 dB + (EpiSensor noise model available from Kinemetrics)
Bandwidth	DC to 200 Hz
Calibration coil	Standard
Full-scale range	User-selectable at ± 0.25g, ± 0.5g, ± 1g, ± 2g or ± 4g
Full-scale output	User-selectable at: ± 2.5V single-ended; ± 10V single-ended; ± 5V, ± 20V differential
Linearity	< 1000µg /g^2
Hysteresis	< 0.1% of full scale
Cross-axis sensitivity	< 1% (including misalignment)
Zero point thermal drift	< 2% of full-scale, -20^0 to +70^0 C
Zero point drift	< 500µg / ^{0}C
ESD, RF, EMI protection	Double-stage transient protection with gas arrestor elements
Quiescent power consumption	12 mA from ± 12V (standard amp); 35 mA from ± 12V (low noise amp)
Operating temperature	-20^0 to +70^0 C (-40^0 to +85^0 C with reduced performance)
Housing	Watertight anodized aluminum case with leveling feet and leveling bubble.
Connection	Single military-style metal connector
Dimensions	3" (H) x 5" (D)
Weight	Approximately 4 lbs.