Piezoelectric Accelerometer
General Operation and Installation Guide

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Certified to ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018

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Introduction

Thank you for choosing our accelerometers. To get the best performance from your sensor, please take a moment to familiarize yourself with the correct installation techniques before use. If you have any questions, our engineers and sales representatives are always glad to help.

1. Accelerometers

A charge-output piezoelectric accelerometer is abbreviated as PE. An Integrated Electronics Piezo-Electric (IEPE) accelerometer refers to a broad class of dynamic vibration sensors that combine a PE sensing element and an impedance-converter circuit within a single shielded enclosure. The piezoelectric element forms the mechanical part, while the impedance-converter circuit forms the electrical part.

1.1 IEPE Accelerometer

IEPE sensors must be powered by a constant-current source or connected directly to data acquisition and signal analysis instruments that provide a built-in constant-current supply. The main characteristics of IEPE sensors are as follows:

(1) An analog voltage output that is compatible with mainstream signal analysis, recording, and data acquisition equipment.

(2) A low-impedance output that can be transmitted over long cables in harsh environments without picking up interference.

(3) Two-wire operation over coaxial, twisted-pair, or ribbon cable, with no effect on signal quality.

(4) Fixed sensitivity that does not depend on cable type or length.

(5) A built-in self-check function that monitors the sensor's output bias voltage and helps identify certain faults.

1.2 TEDS accelerometer

A TEDS sensor has a Transducer Electronic Data Sheet (TEDS) embedded inside it, extending the "plug-and-play" advantage to traditional analog sensors. In accordance with the IEEE 1451.4 standard, an electronic data sheet containing the sensor's information and complete calibration data is stored in the sensor and can be read and recognized automatically by a compatible data acquisition system. TEDS is normally used only with low-impedance IEPE sensors, so a TEDS sensor is effectively an IEPE sensor with a built-in data table. The sensor can identify itself to the connected data acquisition system and configure its own parameters automatically.

Adding TEDS functionality to analog-output sensors offers several benefits:

(1) Faster setup. The sensor is plug-and-play, with no need to reconfigure or recalibrate the data acquisition system.

(2) Better diagnostics. Each sensor carries a unique identification code, and the TEDS stores its calibration parameters, which greatly improves diagnostic efficiency and lets a faulty sensor be replaced quickly.

(3) Easier resource management. Sensor data can be read directly with a reader/writer, eliminating paper records for greater convenience and speed.

(4) Automatic use of calibration data. With suitable acquisition software, the system can read the sensor's data directly, improving efficiency.

(5) Efficient large-scale deployment. When many sensors are used, each measurement node can be defined quickly, reducing manual effort.

1.3 PE (Charge) accelerometer

Because a PE sensor has no built-in electronics, it requires no external power supply, but it does need a secondary charge amplifier to convert its high-impedance signal into a low-impedance voltage signal. PE sensors have the following features:

（1） It must be paired with a secondary charge amplifier (some acquisition devices have one built in), and this secondary instrument adds relatively high cost.

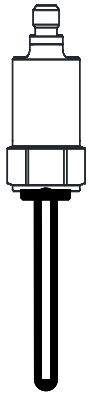
（2） The sensor itself costs less than an IEPE accelerometer and has a simpler structure, which gives it higher reliability.

（3） It is better suited to high- and low-temperature environments where electronic components cannot be used, to high-impact testing, and to low-cost test setups.

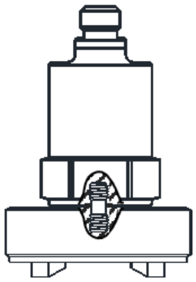
（4） Because a PE sensor outputs a high-impedance charge signal, it places very high demands on the signal cable. Even with low-noise cable, long-distance transmission is difficult and is easily affected by cable movement, so the sensor should not be placed too far from the charge amplifier.

2. Overview of Single-Axis Sensor Installation

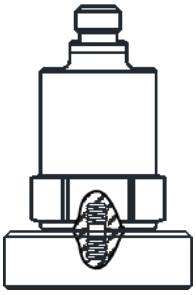
Because applications vary so widely, sensor mounting methods vary just as much. The mounting method and its rigidity directly affect the sensor's high-frequency performance, so the right method should be chosen to suit the operating conditions. Figure 1 shows six common mounting methods and their effect on the high-frequency performance of a typical piezoelectric accelerometer, for reference when making this choice. Note that low-frequency characteristics are determined by the sensor's built-in electronics and are not affected by the mounting method.



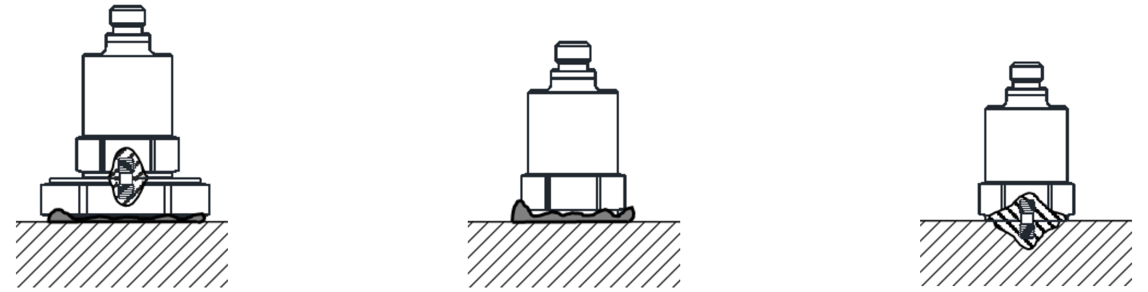
(1) Handheld or probe



(2) Dual-track magnetic mounting



(3) Flat magnetic installation



(4) Adhesive mounting base *(5) Direct adhesive installation* *(6) Stud installation*

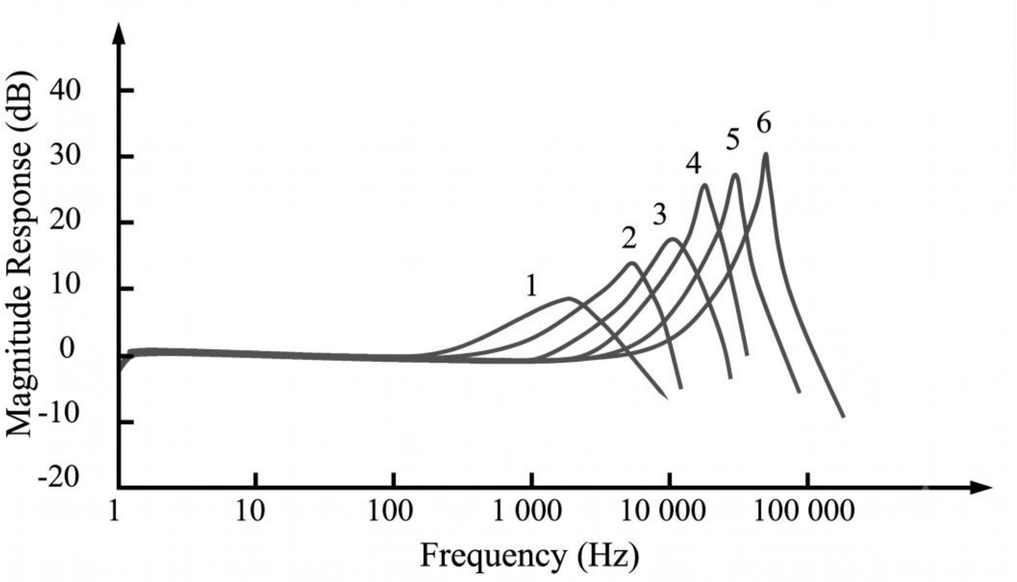
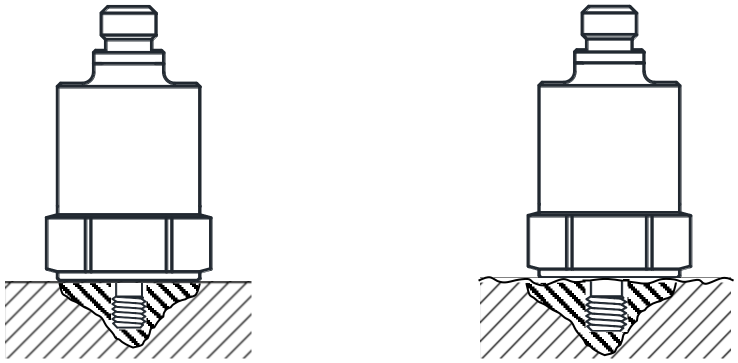


Figure 1: Mounting methods and their effect on high-frequency response (Response vs. Frequency)

2.1 Stud installation



(a) Correct installation method (Flat) *(b) Incorrect installation method (Rough)*

Figure 2: Stud installation

Studs are the usual choice for permanent, semi-permanent, and high-frequency installations. Stud mounting requires a smooth, flat contact surface; the sensor should not be mounted on a rough or uneven surface, because a poor fit between the sensor and the surface narrows its usable frequency range and reduces measurement accuracy.

The installation process is as follows:

(1) Choose a smooth, flat mounting surface. Drill a mounting hole at the center of the mounting area and tap the thread. A flatness within 3 μm is recommended. (If the test structure cannot meet this requirement, consider adhesive mounting or another method instead.) Inspect the area and remove any burrs or foreign matter from the contact surfaces.

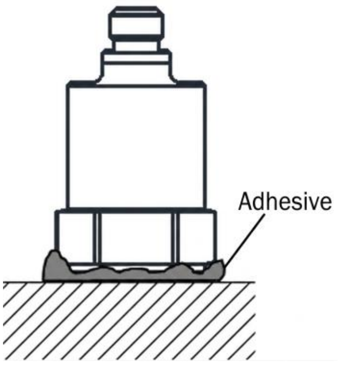
(2) Wipe the mounting surface clean, then apply a thin layer of coupling fluid (such as grease, oil, or petroleum jelly) to fill the tiny gaps between the two contact surfaces. This increases mounting rigidity and improves the vibration response.

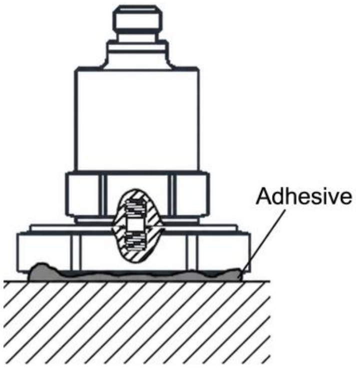
(3) Screw the appropriate mounting stud into the sensor base, then thread the other end into the tapped hole on the test surface. If the sensor has an integrated bolt, screw it in directly. Tighten the sensor to the recommended torque. A torque wrench set to the specified value must be used for this step: too little torque will prevent the sensor from coupling fully to the structure, while too much torque can cause the stud to fail.

The recommended tightening torques are listed in the table below:

Recommended stud tightening torque						
Nominal diameter	M3	M4	M5/10-32	M6	M8	M10
Tightening torque (N·m)	0.6	1.6	3.0	3.5	8.3	16.4
Guide to applied force (for reference)	Finger effort only	Finger effort only	Finger effort only	Finger effort only	Hand effort	Full-arm effort

2.2 Adhesive installation





(a) Direct adhesive installation *(b) Adhesive mounting base*

Figure 3: Adhesive installation

When mounting is temporary, or when studs cannot be used on the test surface, an adhesive can be used instead. For temporary mounting, adhesives such as hot-melt glue or wax are recommended because they are easy to remove. Epoxy and cyanoacrylate (super glue) give a more durable, secure bond, but they are harder to remove and clean up afterward than hot-melt glue. There are two adhesive methods: direct bonding, shown in Figure 3(a), and a bonded mounting base, shown in Figure 3(b).

2.2.1 Direct bonding and installation

Where space is limited, or to avoid damaging the structure under test, the sensor is often bonded directly to the test structure. The procedure is as follows:

(1) Choose a smooth, flat mounting surface. A flatness within 3 μm gives the best results.

(2) Apply adhesive evenly across the underside of the sensor so that it covers the entire base and bonds fully to the mounting surface. Press the sensor down and squeeze out any excess adhesive; too much adhesive can make the sensor hard to remove and may even affect the results. Excess adhesive can also seep into the threaded mounting hole in the sensor base and interfere with the next stud installation, so after removing the sensor, always clean the stud and the area around the mounting hole promptly.

2.2.2 Adhesive Mounting Base

In this method, the mounting base is attached to the test structure first, and the sensor is then fixed to the base. This makes the sensor easier to remove and also gives it some protection. Many mounting bases are made of anodized aluminum or epoxy-isolated stainless-steel housings, which can provide electrical isolation and reduce electrical interference traveling from the surface of the test object. The procedure is as follows:

(1) Prepare a smooth, flat mounting surface. A flatness within 3 μm gives the best results.

(2) Following steps 2 and 3 of the stud installation above, fit the sensor's mounting stud to

the appropriate mounting base.

(3) Apply adhesive to the underside of the mounting base. Press it down and slide it slightly side to side to ensure a tight fit, squeezing out any excess adhesive from beneath the base.

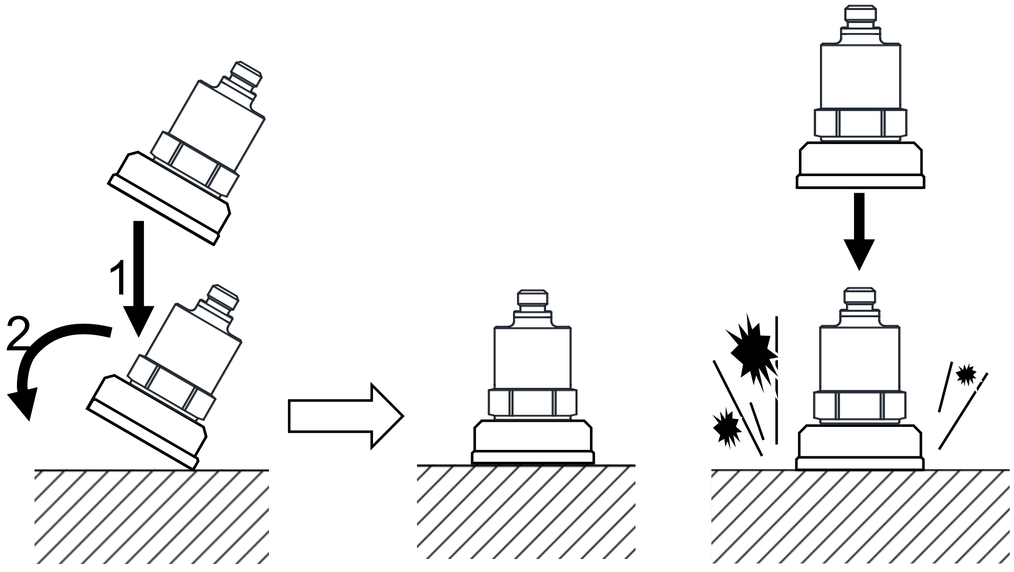
2.2.3 Adhesive installation and disassembly

Removing a bonded sensor is just as important as mounting it. Some strong adhesives can easily damage the sensor during removal. To avoid this, apply a solvent remover to the adhesive before taking the sensor off, and allow a few minutes for it to penetrate the bond. During removal, use a standard open-end wrench or a suitable removal tool to apply a gentle turning or shear force, easing the sensor off the test structure.

2.3 Magnetic installation

(a) Flat magnetic installation (b) Double-track (horseshoe-shaped) magnetic installation

Figure 4: Common magnetic installation methods



(a) Correct installation operation (b) Incorrect installation operation

Figure 5: Magnetic installation operation

For machine condition monitoring, predictive maintenance, on-site inspections, and vibration-trend testing, the sensor usually does not need to stay in place for long. In these cases, magnetic mounting offers a fast, convenient solution well suited to the task.

Magnetic mounts generally fall into two types: flat magnetic mounts and dual-rail (horseshoe-shaped) magnetic mounts. Flat magnetic mounts are mainly for smooth, flat surfaces. For curved surfaces such as motor housings and pipes, a dual-rail (horseshoe-shaped) mount provides better contact and is the better choice. If a magnetic mount must be used on a non-magnetic surface, first fix a magnetic mounting pad to the test surface, then attach the magnetic base to it.

The steps for magnetic mounting are as follows:

(1) Prepare a smooth mounting surface. A flatness within 3 μm gives the best results. After cleaning the surface and removing any burrs, apply a thin layer of silicone grease, engine oil, or a similar coupling fluid.

(2) Select the correct type of magnetic base, then confirm that the mounting surface is flat and smooth.

(3) Following step 3 of the stud installation above, fit the accelerometer's mounting stud to the magnetic base.

(4) Because magnetic mounts are strongly magnetic, they can produce a large acceleration shock as they snap into place. To prevent this inertial shock from damaging the sensor, slide or tilt the magnet gently to set the sensor assembly onto the test surface. Figure 5 shows the correct technique.

2.4 Handheld or probe tip installation

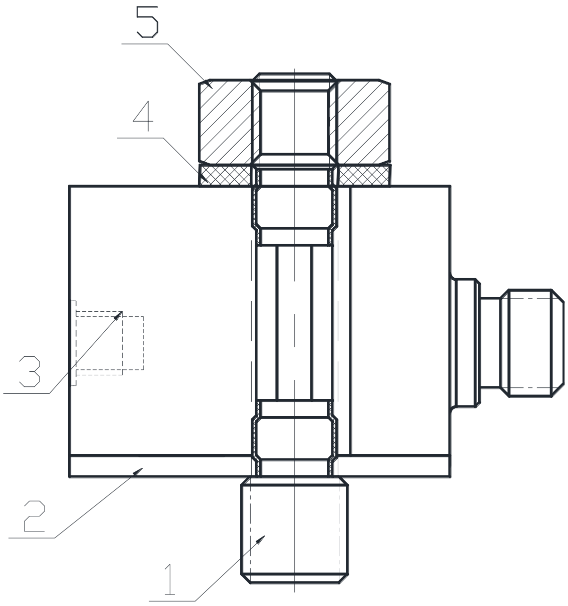
Handheld and probe-tip mounting offer low accuracy and poor repeatability, so they are generally used only for machine condition monitoring, for sensors that cannot be mounted because of access constraints, or for a quick survey of the magnitude and location of peak vibration, which then helps in choosing the correct sensor range and mounting position.

3. Overview of Three-Axis Sensor Installation

Mounting a three-axis sensor is similar to mounting a conventional single-axis sensor, but because three-axis sensors are typically used in more demanding conditions, studs are usually preferred. Using our own sensors as an example, this section briefly describes the stud installation of three-axis through-hole sensors and three-axis cube sensors, with a focus on ground-isolated mounting. An insulated mounting base protects the sensor and isolates it from ground when the sensor must be bonded to the part under test. Note that ground isolation affects the sensor's high-frequency response, so use it with care for high-frequency or high-acceleration impact measurements.

3.1 Overview of Three-Axis Through-Hole Sensor Installation

Figure 7 is a schematic of how a three-axis through-hole sensor is mounted.



1 - Mounting bolt; 2 - Lower mounting plate; 3-Three-axis through-hole sensor; 4 - Install gaskets; 5 - Nut

Figure 6: Installation diagram of the three-axis through-hole sensor

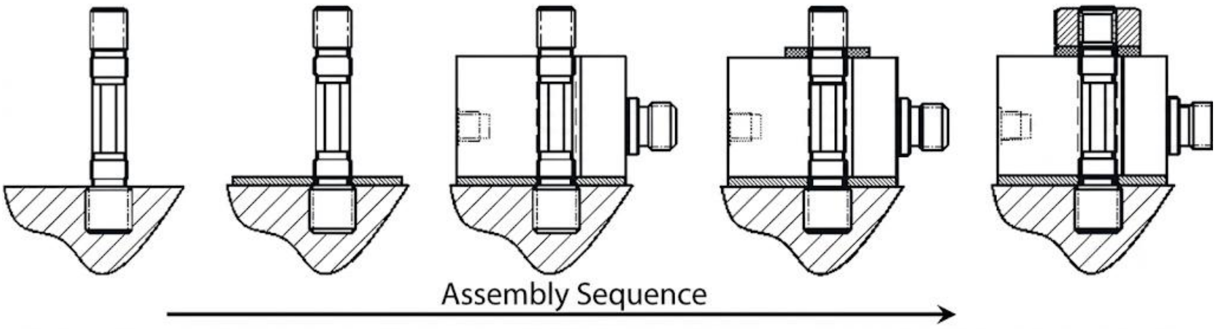


Figure 7: Installation process diagram

The installation process is as follows:

（1） The mounting surface for a multi-axis sensor must also be flat. To meet the sensor's high-frequency response specification, the flatness of the mounting surface should be better than 0.01 mm.

（2） When drilling and tapping the mounting surface, the full thread depth must be slightly greater than the engaged length of the stud bolt (by at least 1 to 2 thread pitches), and the thread must be perpendicular to the mounting surface to within 0.05 mm.

（3） Screw in the mounting bolts by hand; the threaded portion should not protrude above the mounting surface.

（4） Fit the lower mounting plate so that the bolt passes through the hole in the insulating sheet.

（5） Fit the sensor so that the bolt passes through its through-hole, with the marked face pointing up, then rotate the sensor to align its X and Y axes with the directions to be measured. If a lower mounting plate is used, rotate it at the same time so that all of its edges line up with the sensor.

（6） Screw the bolt in by hand and adjust its height so that the heat-shrink section of the bolt sits slightly above the top face of the sensor.

（7） Fit the mounting washer over the mounting bolt. (If no insulating sheet is used, the related steps above can be skipped.)

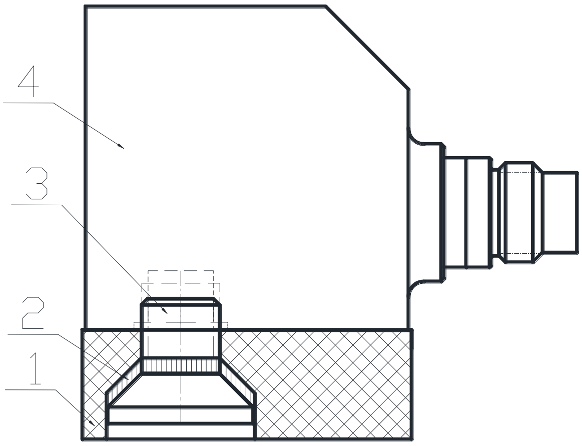
（8） Check again and adjust the bolt height so that the insulating sleeve does not extend above the top face of the mounting washer or sensor.

（9） Apply a thread-locking compound if required.

（10） Fit the nut and tighten it to the recommended installation torque.

3.2 Overview of Three-Axis Cube Sensor Installation

Figure 8 is a schematic of how a three-axis cube sensor is mounted.



1 - Lower mounting plate; 2 - Insulating pad; 3 - Mounting stud; 4 - Three-axis cubic sensor;

Figure 8: Installation diagram of the three-axis cube sensor

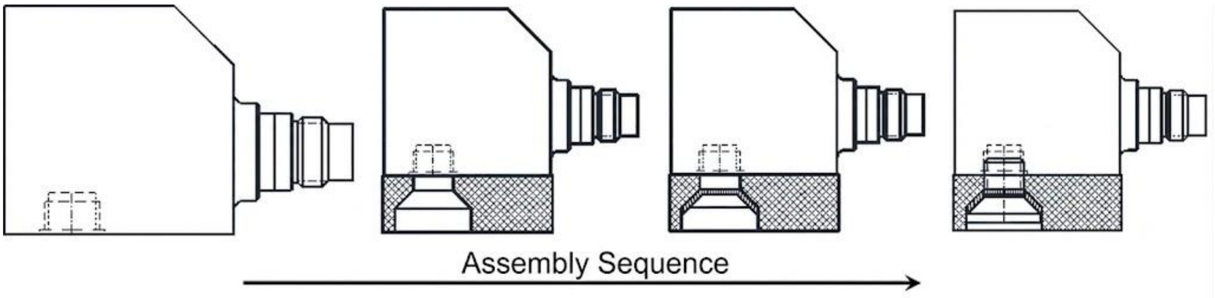


Figure 9: Installation process diagram

The installation process is as follows:

（1） Place the flat side of the insulating base against the bottom face that corresponds to the sensor's Z-axis, and align the holes in the insulating base with the Z-direction mounting screw holes in the sensor. At the same time, keep the two sides of the insulating base parallel to the sensor's sides, or center the sensor in the slot of the insulating base.

（2） Make sure the insulating sleeve is on the mounting screw or inside the hole of the insulating base. In high-vibration applications, consider a medium- to low-strength thread-locking compound, applying a thin amount (using a toothpick or pin) into the sensor's mounting screw holes. Then pass the screw through the insulating base and tighten it into the Z-direction mounting screw hole in the sensor. Refer to the recommended tightening-torque table for the correct torque.

3.2.1 Removal of the insulated mounting base

The procedure for removing the three-axis sensor's mounting base is as follows:

（1） Use tweezers or another pointed tool to lift the bonded isolation sheet from its edge, then peel it off as needed. This isolation sheet can normally be reused several times. If the outer side of the isolator already has sensor adhesive on it, before reusing it make sure the entire isolation sheet sits lower than the adhesive surface of the insulating base; otherwise it will affect the sensor's usable frequency range. Replace the isolation sheet with a new one if necessary. Note: when bonding a sensor that uses an insulating base, the cross-slot on the head of the mounting screw must be covered with an isolation sheet. Without it, the cross-slot fills with adhesive, and the screw can no longer turn, so the sensor will not work properly.

（2） Use flat-jaw pliers or a wrench fitted with a protective plate to grip the two faces of the insulating base gently, loosen the mounting screw with a medium Phillips screwdriver, and then separate the screw and insulating base from the sensor. Note: there should be an insulating washer on the tapered side of the screw. Do not remove this washer from the mounting screw.

3.2.2 Installation Precautions

Below are some important precautions to observe during installation.

（1） All three-axis cube sensors ship with a bonded insulating mounting base already fitted directly to the sensor. If you plan to use a bonding method that attaches the sensor directly to the object under test, do not separate the insulating base from the sensor. Instead, bond the sensor together with its insulating base directly to the measurement point on the test object.

（2） When bonding a sensor to a test piece, choose a reasonably flat mounting surface, wipe it clean with alcohol or another solvent, and remove any grease. Press the sensor with its base firmly onto the surface to be measured, then apply fast-curing adhesive or another bonding agent into the gap and hold it tight until the adhesive cures.

（3） If screw mounting is used, pay close attention to the flatness of the mounting surface and the perpendicularity of the threaded hole to that surface. These two factors limit the sensor's usable measurement frequency range.

（4） When removing the sensor from the test piece, turn the insulating base with a wrench (avoid turning the sensor body directly with a wrench, as this can damage it), or insert a flat pry bar under the edge of the base and lift it gently.

（5） To remove a small amount of adhesive, soak it in acetone and then lift it off mechanically with a plastic card, which minimizes damage to the bonded surface of the insulating base. Removing the adhesive by other mechanical means can damage the insulation and the flatness of the mounting surface, which in turn affects measurement results.

（6） Before using the sensor, when measuring its frequency response characteristics, the sensor must be separated from the mounting base. The frequency response specification given for the sensor refers to the bandwidth measured under optimal rigid-mounting conditions. The high-frequency cutoff differs from that obtained with the insulated-base bonding method.

（7） When acquiring high-frequency signals during measurement, the sensor must be separated from the mounting base. Adhesive mounting with an insulating base is not recommended in this case; it is better to use screws, or to fix the sensor directly (without the insulating base) to the measurement point.

4. Instructions for Installing and Operating Impact Sensors

For impact sensors, both secure mounting and proper cable fixation are essential. Mounting the sensor correctly and securing its cable will extend the sensor's service life.

As shown in Figure 10 below, bending the cable back and securing it to the sensor body greatly reduces cable movement during impact, with tape applied underneath to hold it in place.

As shown in Figure 11 below, when the cable is not secured to the sensor body, it shakes during impact and introduces signal interference; over time, repeated impacts can bend the cable and cause it to break at the root.

As shown in Figure 12 below, the side-exit cable on this sensor is fixed to the sensor body at the factory, so during installation you only need to secure the cable itself.

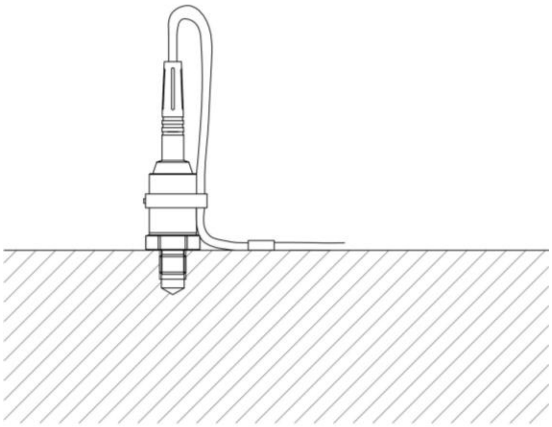


Figure 10: Correct mounting of an impact sensor

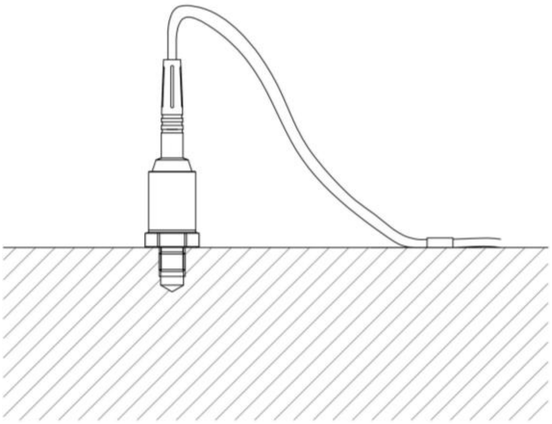


Figure 11: Incorrect mounting of an impact sensor

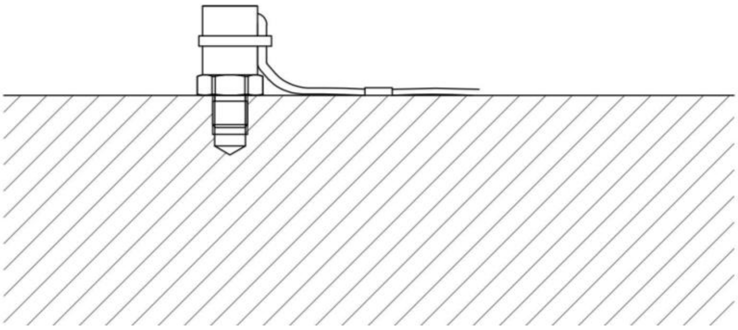


Figure 12: Side-exit cable mounting

Installation Precautions for Impact Sensors:

（1）Ensure the threaded mount is secure, and confirm the sensor is tight before testing.

（2）Do not force the sensor off during removal and do not strike it; avoid damaging the mounting threads.

（3）Keep the cable's bend radius as small as practical, and secure the connected cable firmly to prevent signal fluctuations caused by cable movement.

（4）On split-type sensors, apply a thread-locking compound to the output connector to keep it from loosening after repeated impacts.

（5）During use, protect the cables from being crushed or severed by heavy objects.

5. Cable and Equipment Connection Operation Instructions

Checking the cable and its installation is a step that is often overlooked, yet correct cable installation directly affects the reliability and accuracy of the measurement. It also helps extend the cable's service life.

Low-noise cable is the most common choice for sensor signal lines. It has a semiconductor layer applied over the insulation inside the cable, which drains away charges generated by cable friction and provides some shielding. This reduces the interference picked up by the high-impedance signals from charge-type sensors. Voltage-type sensors output low-impedance signals, so interference is much less of a concern; they can use ordinary coaxial, twisted-pair, or ribbon cable. Even so, low-noise cable still minimizes signal interference. For harsh environments such as high or low temperatures or oil contamination, PTFE cable is generally used; for normal environments, PVC low-noise cable is suitable. LNS offers a wide range of cable sizes, constructions, and materials, including standard coaxial low-noise cable, high-temperature coaxial low-noise cable, standard four-core low-noise cable, high-temperature four-core low-noise cable, waterproof four-core cable, waterproof eight-core cable, standard two-core industrial cable, high-temperature two-core industrial cable, high-temperature metal-jacketed cable, and more.

5.1 Common Cable Classification for Sensors

By temperature rating: standard cable (-20 to 60°C), high/low-temperature cable (-40 to 250°C), flexible cable (-40 to 120°C)

By construction: low-noise coaxial cable (φ1, φ1.6, φ2, φ3, φ5), four-core shielded cable (φ3)

5.2 Cable installation

The installation process is as follows:

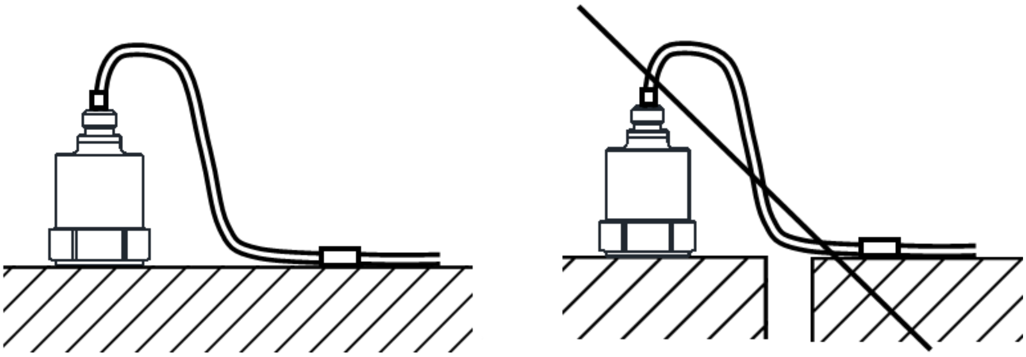
(1) Confirm the correct cable is selected. IEPE sensors work with any standard two-wire or coaxial cable. Industrial applications usually call for twisted-pair cable to reduce electromagnetic and RF interference. PTFE-jacketed cable withstands corrosive environments and higher temperatures.

(2) Connect the cable to the accelerometer. Before connecting, apply a small amount of

thread sealant to the connector threads to help keep the cable secure during testing. In damp, oily, or dirty environments, the connection can be sealed with silicone rubber, an O-ring, or flexible heat-shrink tubing.

(3) Route the cable to the signal conditioner, secure it nearby with tape or clips, and keep cable movement to a minimum.

(4) Connect the other end of the cable to the signal conditioner, charge amplifier, or data acquisition recorder. Before connecting, briefly short the signal pin to the ground pin or housing to dissipate any charge built up in the cable and prevent a signal surge into the downstream equipment.



(a) Correct installation method *(b) Incorrect installation method*

Figure 10: Cable installation

After mounting the sensor, secure the signal cable and tighten the connector between the sensor and cable so it cannot loosen during testing. When securing the cable, leave a little slack at the connector so it is not held under tension.

Securing the cable offers several benefits:

(1) If the sensor works loose and detaches from the test structure, the cable holds it so it does not fall to the ground and get damaged.

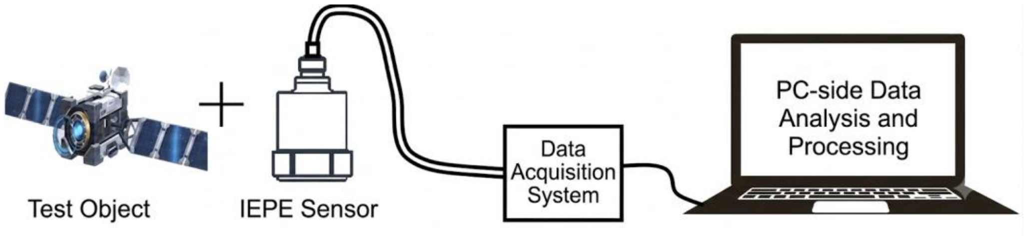
(2) An unsecured cable can shake during measurement and strike the test structure, creating a new source of vibration. This matters especially during modal testing.

(3) Bending or stretching the cable can cause local changes in capacitance or charge between the conductor and the shield, which introduces noise.

5.3 Equipment connection and operation

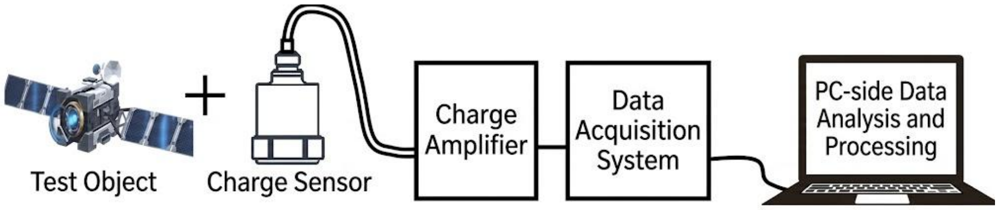
Check the sensor connection

(1) IEPE sensors / TEDS sensors



After power-up, a green LED on the constant-current source or acquisition device indicates that the sensor connection is normal and the system is working. A red LED indicates an open circuit in the wiring; check and replace the cable or sensor. A yellow LED (or both lights on) indicates that the constant-current supply is low or the wiring is shorted; check the battery level and the connection between the cable and sensor, then charge or replace the cable or sensor as needed.

(2) PE (Charge) sensor



After power-up, a green LED on the charge amplifier or acquisition device indicates that the sensor connection is normal and ready to operate. A red LED indicates a short circuit or low-impedance condition; inspect the cable or sensor and replace it if necessary.

Once all devices are powered on and the system is set up, allow at least 3 minutes for everything to stabilize before starting signal acquisition.

6. Sensor Connections

6.1 Block diagram of a PE sensor measurement system

Figure 14 is a block diagram of a measurement system connecting a PE sensor to a charge amplifier. In a PE sensor, the sensing element and the electronics are separate, so additional connections are required. When long cables are needed in practice, a charge converter can be added in series between the PE accelerometer and the signal-conditioning circuit. The charge converter is essentially a standalone unit that performs the same function as the charge amplifier built into an IEPE accelerometer: it converts the high-impedance charge signal from the PE sensor into a low-impedance voltage signal.

A charge amplifier is another common option for charge sensors. It offers more functions, such as conditioning the input signal, attenuating or amplifying the output, and high- and low-pass filtering.

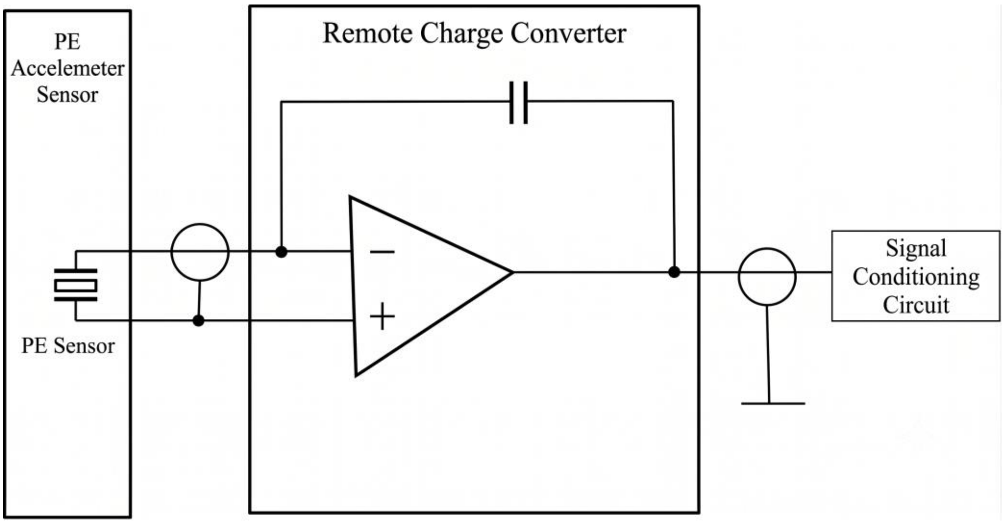


Figure 11: Block diagram of the measurement system connecting the PE sensor to the charge amplifier

6.2 IEPE Sensor Circuit

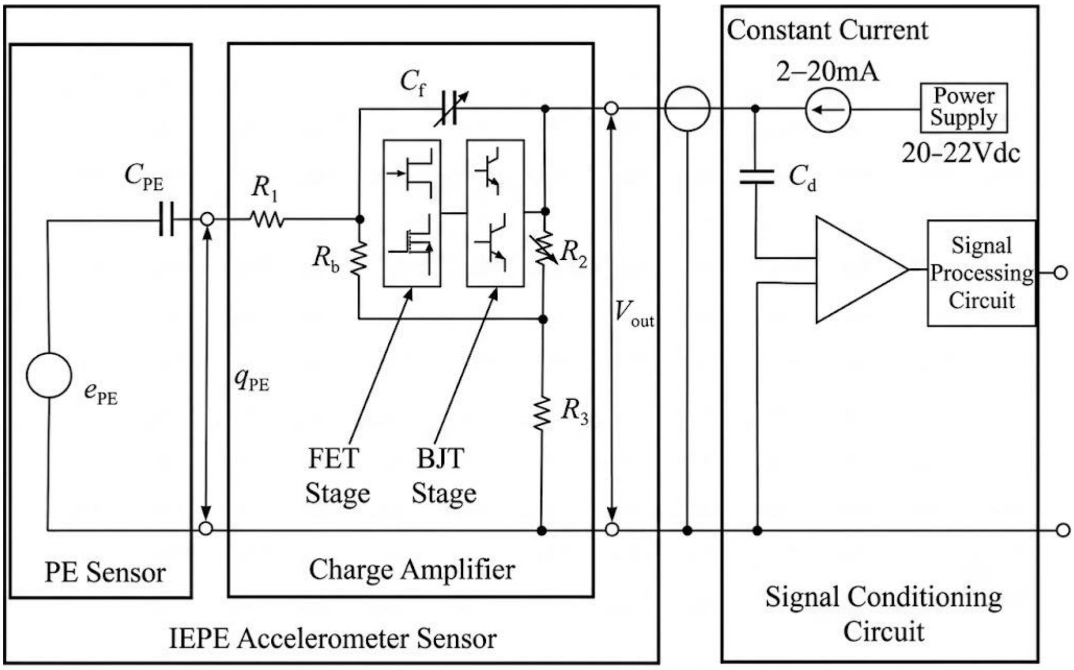


Figure 12: Basic structure of IEPE sensor circuits and connection of signal conditioning

All IEPE sensors require a constant current signal conditioner to function properly. The power supply is an 18 to 30 VDC regulated current source. A current-limiting circuit regulates the supply and provides the constant-current excitation the IEPE sensor needs to operate. In general, battery-powered units offer portability and low-noise measurement, while line-powered units allow continuous monitoring.

Figure 15 shows how the basic IEPE sensor circuit connects to the signal-conditioning circuit. In Figure 15, *ePE* and CPE represent the PE sensor's open-circuit output voltage and intrinsic capacitance, respectively. *ePE* is directly proportional to the charge sensitivity of the PE sensor (QPE) and inversely proportional to its capacitance CPE. In the charge-conversion circuit, *Cf is the feedback capacitance, and Rb is the bias resistor (typically a very high value, such as* 10^9 *Ω*). Resistors R2 and R3 form a voltage divider. Together, the bias resistor Rb and divider resistors R2/*R3 form a DC negative-feedback circuit that gives* the amplifier a stable static operating point, FET bias voltage, and a corresponding output bias voltage VB across the specified operating temperature range (-55 to +125°C). VB can be adjusted over a certain range by changing the values of R2 and R3. This lets FET devices with varying parameters be used without strict selection.

6.3 TEDS Sensor Circuit

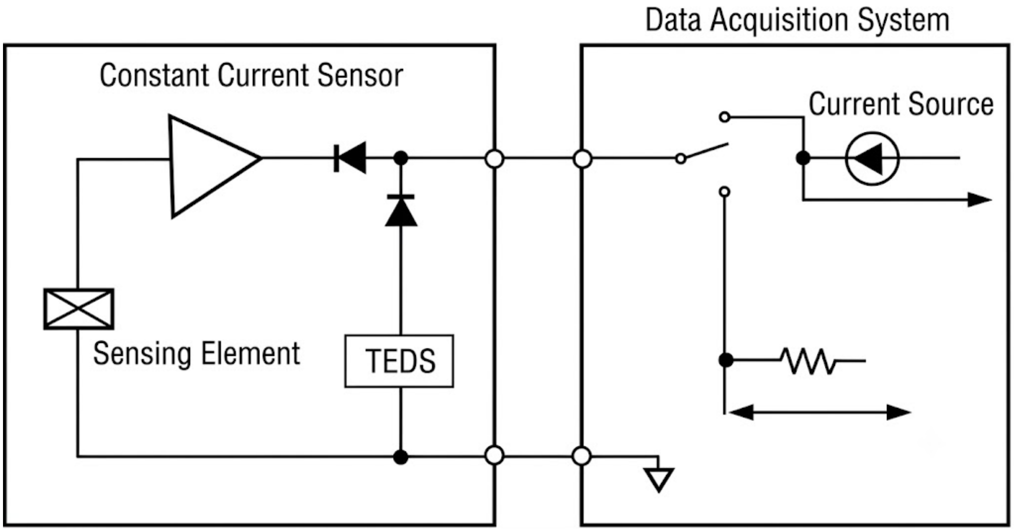


Figure 136: TEDS sensor equivalent circuit principle

7. Calibration of the accelerometer

By their very nature, the piezoelectric properties of the sensing materials degrade over time (mainly in ceramic elements; quartz crystals show very little degradation). Prolonged use at high temperatures speeds up this degradation, so output sensitivity drifts to some degree over time. Prolonged over-range vibration or shock can also alter or damage the mechanical structure—for example, cracking the piezoelectric material, damaging the internal circuit, or shifting components—which can change the frequency response or produce abnormal output. Use in harsh environments can contaminate the connectors, lowering the insulation impedance and degrading the sensor's low-frequency performance.

Given these operating principles and conditions, many manufacturers, including LNS, recommend a one-year calibration cycle for accelerometers. All test accelerometers should therefore be recalibrated on a one-year cycle.

7.1 Back-to-back calibration theory

Back-to-back calibration is the most widely used method for determining the sensitivity of a piezoelectric accelerometer. The test accelerometer is mounted back-to-back with a standard sensor, both are vibrated at the same time, and their outputs are compared. The output ratio (UT/UR) therefore equals the ratio of their sensitivities. The sensitivity Q of the standard sensor is known, and UT/UR is measured by the calibration system, so the exact sensitivity S of the sensor under test is:

$$S = Q(U_T/U_R)$$

In an actual calibration test, the calibration system can measure the sensor's sensitivity along with its amplitude- and phase-versus-frequency characteristics directly.

7.2 Sensor calibration equipment

A sensor calibration system must be stable and reliable, with high accuracy and repeatability. LNS uses several sets of calibration equipment from internationally recognized brands to ensure accurate, repeatable results, and performs cross-checks of calibration data where necessary to guarantee the accuracy of the data specifications shipped with each product. Standard sensors are sent regularly to a national primary metrology institute for traceable recalibration.

Because back-to-back calibration requires both sensors to experience exactly the same acceleration, the test sensor must be mounted rigidly and correctly onto the standard sensor. A sensor with a mounting hole is bolted directly to the reference standard; tighten it to the recommended torque for the screw size. Apply a thin layer of silicone grease (petroleum jelly) between the mating surfaces to fill any imperfections and increase mounting rigidity. A sensor without a threaded hole must be bonded to the standard sensor. To reduce cable movement, fix the cable at a point near the shaker so it does not interfere with the results. A typical test setup is shown in Figure 17.

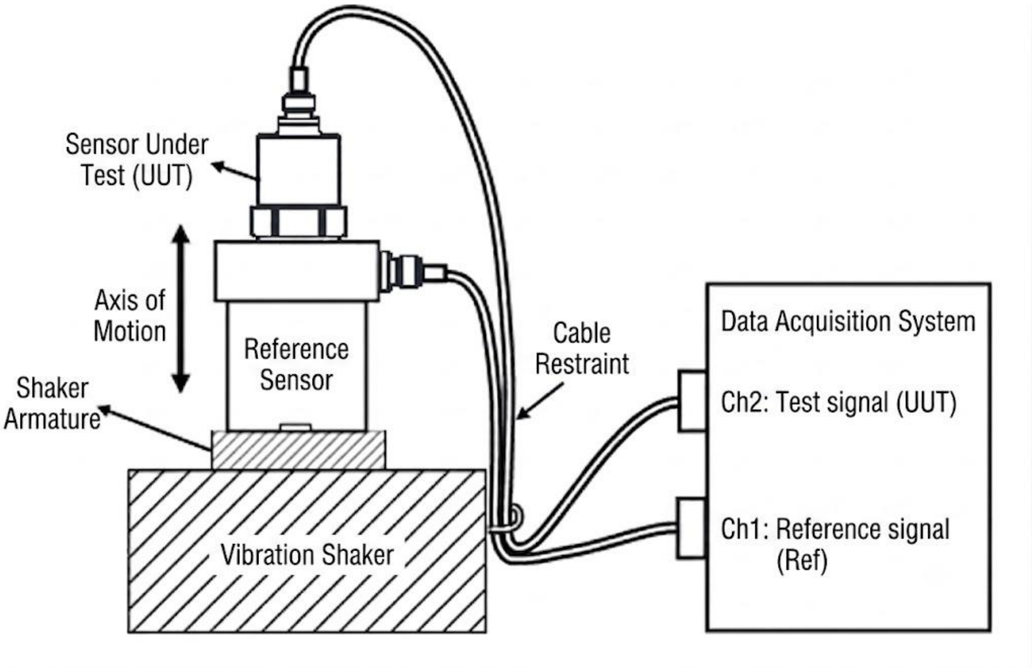


Figure 17: Back-to-back calibration and installation diagram

7.3 Common Issues in Metrology Testing

During calibration, the measured results sometimes differ noticeably from the factory calibration data. Below are some common issues seen in sensor testing.

(1) For threaded sensors, both mating surfaces must be flat and free of foreign matter, and coupling fluid must be applied during mounting. Tighten the sensor to the recommended torque; otherwise the frequency response can be affected, causing large high-frequency deviations.

(3) For three-axis sensors, do not pick the mounting surface arbitrarily; use the reference surface, preferably with screws. When bonding, align the sensor with the center of the standard sensor to preserve its frequency response.

(4) For previously used sensors, clean the mounting surface thoroughly so it stays smooth and flat; otherwise the standard sensor may be damaged and the measured frequency response will deteriorate.

(5) Over long-term use, the calibration cable connectors tend to attract coupling fluid, which lowers their insulation and affects the sensor's low-frequency performance.

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