APPLICATION NOTE

How to Deal with Electrical Noise and Interference in the Measuring Chain using a NEXUS™ Conditioning Amplifier

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When making vibration measurements, it may happen that not all the signal measured comes from vibration of the object. Some of it may derive from electrical pollution in the environment. This application note describes some possible sources of spurious measurements together with recommendations on how to avoid them.

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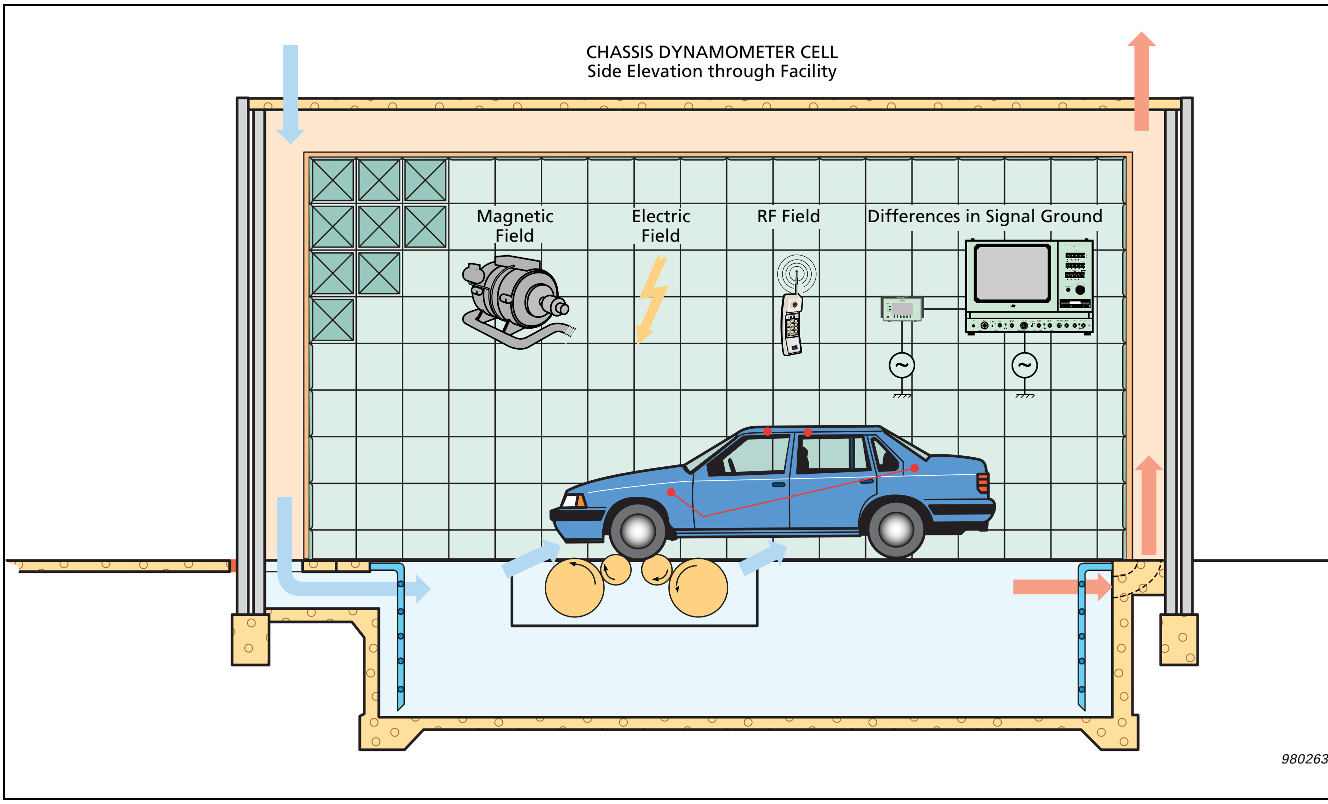
Electrical Noise Sources in a Dynamometer Test Cell

Fig. 1 Electrical noise sources in a dynamometer test cell



Definition of Terms

Common Mode Voltage

The voltage between the accelerometer’s housing and the conditioning amplifier’s ground connector is known as the measurement system’s common mode voltage. It may be caused by return currents from power-consuming equipment or from magnetic fields.

Ground Loop

A ground loop is a ground connection “round trip”. It is a galvanic connection from the screen of the input plug through the cable screen, through the accelerometer’s housing to a conducting structure, through the structure to the test system ground and further to the amplifier’s signal ground and finally through a single-ended input back to the screen of the input plug (see Fig. 2).

Single-ended Accelerometer and Single-ended Preamplifier Input

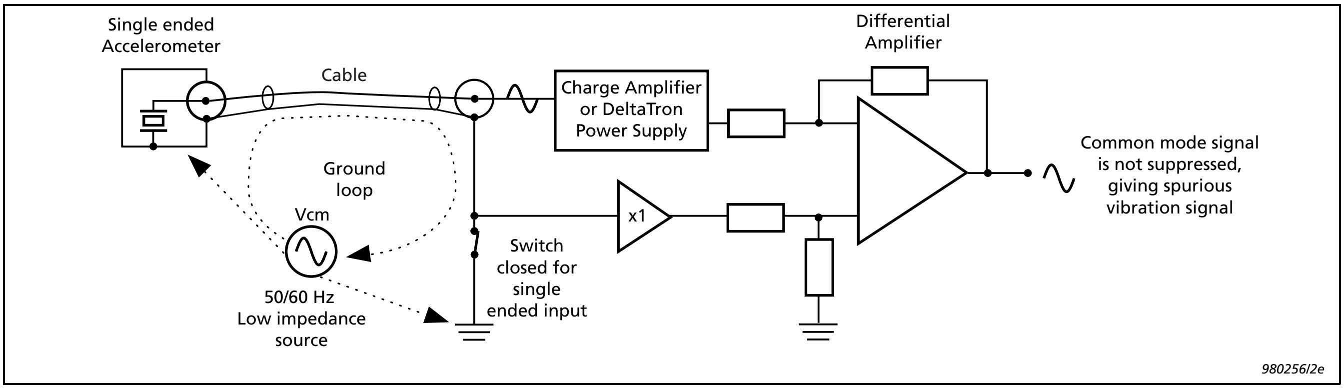
The accelerometer

The housing of the single-ended accelerometer is also the signal reference level. The output connector is coaxial.

The conditioning amplifier

At the coaxial input connector, the signal reference (the screen) is connected to the analogue ground (the ground connector).

Fig. 2

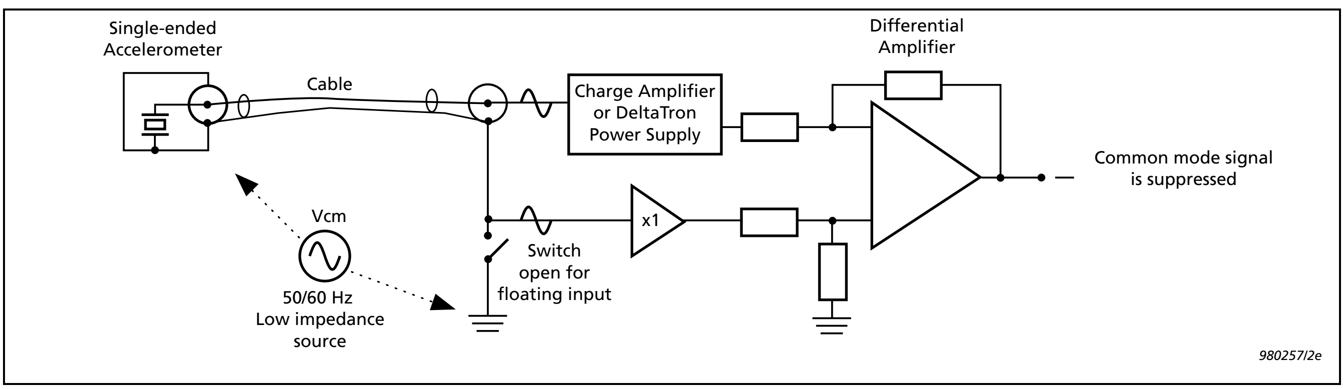


When to use a single-ended input

If the accelerometer (a single channel) is mounted so that it is insulated from the measurement object, the single-ended input should be used. Alternatively, the insulation may be placed elsewhere between the measurement object and the conditioning amplifier; this will normally be sufficient.

Single-ended Accelerometer and Floating Preamplifier Input

Fig. 3



The accelerometer

The housing of the single-ended accelerometer is also the signal reference level. The output connector is coaxial.

The conditioning amplifier

If, at the conditioning amplifier input, the signal reference (input screen) is not connected to the amplifier's analogue ground, then the input is said to be floating (see Fig. 3).

When to use a floating input

This method should be used if there are other current paths from the accelerometer housing to the ground connector than the one through the signal cable. This might be the case if the accelerometer housing is electrically connected to the ground connector on the amplifier or if it is part of a triaxial accelerometer where the accelerometer parts are connected.

If there is a second signal ground path, floating input should be used. If it is not certain whether a second path is present, then it is necessary to connect a ground wire from the accelerometer housing to the ground connector on the amplifier to ensure the presence of a good return path.

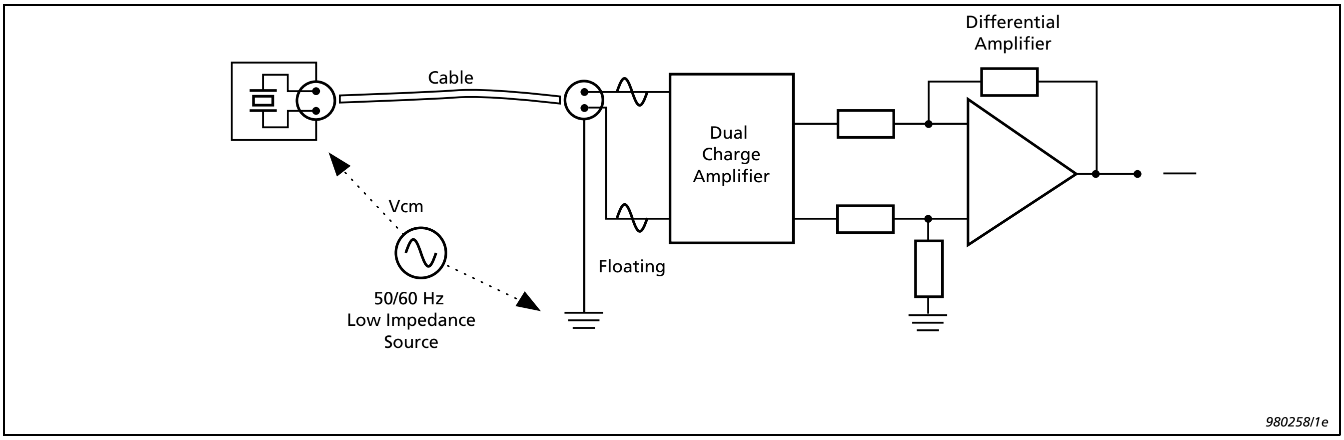
Level of common mode voltages

NEXUS Conditioning Amplifier has both single-ended and floating capabilities on both signal inputs and outputs. It can measure with common mode voltages of up to 4.2 V peak, and withstand transients of up to 8 kV without risk of damage.

A 30 m (100 feet) ground wire of 1.5 mm^2 (16 AWG) copper has an impedance of approximately 0.42 Ω at frequencies less than 1 kHz. So, a 4.2 V common mode voltage corresponds to a ground current of 10 A.

Differential Accelerometer and Differential Preamplifier Input

Fig. 4



The accelerometer

The piezoelectric element is isolated from the housing in the differential accelerometer. This means that in principle a ground loop is broken at the accelerometer. However, stray capacitance C_s in the accelerometer (see Fig. 5) will introduce substantial common mode signals, and any imbalance in the stray capacitance ($C_{s1} - C_{s2}$) will create a small "false vibration signal".

The conditioning amplifier

The matching differential amplifier will suppress the common mode signal from the accelerometer but not the "false vibration signal" (that, once converted to "vibration" will always remain "vibration").

When to use a differential system

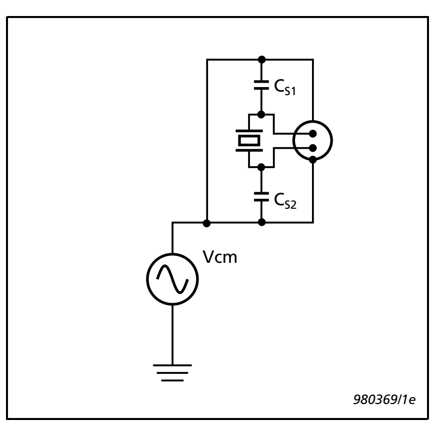
If common mode voltages of higher levels occur, i.e., more than the single-ended system with floating input can handle, then a differential system must be used.

When ground leads are used to ensure that the accelerometers and the conditioning amplifiers are grounded together, then they can carry a return current from the various metal parts in the test cell. By using differential accelerometers and amplifiers, this internal grounding can be avoided. In situations where there are very large magnetic fields, e.g., in power stations, it could be that such a return path is not desirable.

Level of common mode voltages

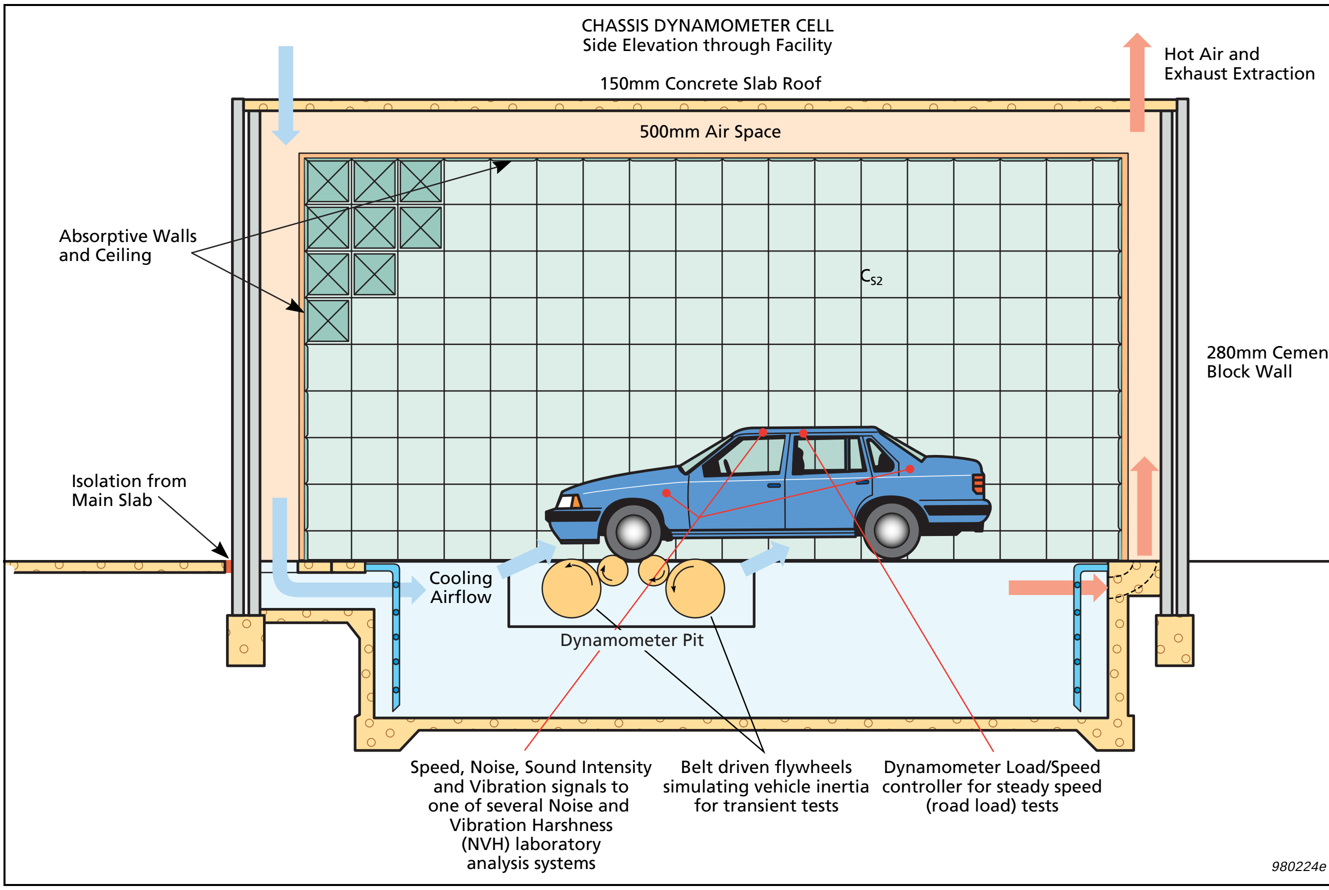
In theory there are no limits. But problems with "false vibration" coming from a common mode voltage are often greater with this system compared to the previously mentioned system.

Fig. 5 Electrical diagram of a differential accelerometer showing stray capacitances



Description of the Chassis Dynamometer Test Cell

Fig. 6 Chassis dynamometer cell



The test cell was a semi-anechoic chassis dynamometer test rig. The rollers of the rig were provided with "road surface" and were driven by an electric motor. The measurement object was a 4 seat vehicle equipped with summer tyres. The aim of the test was to determine the damping provided by a standard mounting block from one of the vehicle's sub-suppliers. The rollers drove the front wheels of the vehicle at a speed of 50 km/hr. Accelerometers were mounted on the "sub-frame" that is situated under the chassis between the front wheels and that supports the engine.

Measurement of Magnetic Field

The magnetic field was measured using a Brüel & Kjær Inductance Coil Type B & K 111397 with a useful frequency range of 50 Hz to 2000 Hz. The largest overall field that was measured was just over the left roller. Elsewhere the signals were generally much smaller or too small to measure.

Using Standard Multimeter

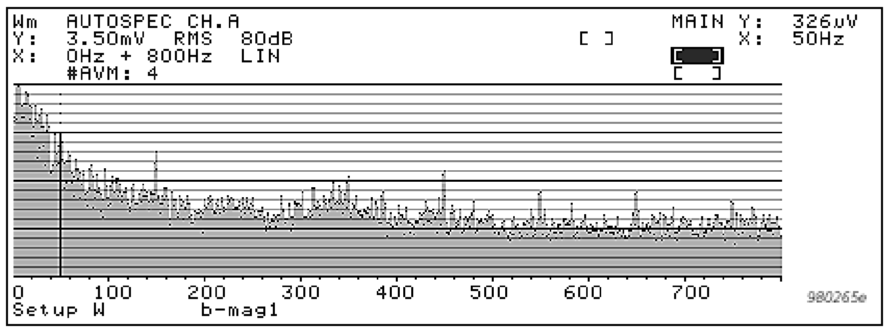
The largest measured coil voltage was 15 mV RMS corresponding to approximately 1.7 A/m. The frequency was indicated as 10 Hz. However, this value was rather unstable. As a reference, the voltages measured along the side of the Brüel & Kjær Signal Analyzer Unit Type 2035 were between 60 and 80 mV corresponding to approximately 1.6 A/m (the conversion between these millivolts and the corresponding A/m is frequency dependent).

Brüel & Kjær test their instruments with 80 A/m. CE labelling for industrial environment requires fulfilment of specifications at 30 A/m at 50 Hz.

Using Signal Analyzer Unit Type 2035

A 800 Hz FFT analysis of the magnetic field close to the vehicle is shown in Fig. 7.

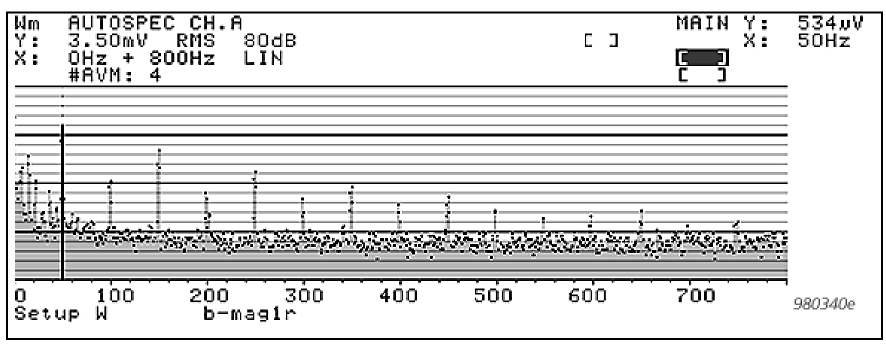
Fig. 7 Frequency analysis of magnetic field immediately above left roller under the front wheels



A corresponding measurement in a "quiet" region of the control room of the test cell is shown in Fig. 8.

A family of mains frequency and its harmonics is clearly seen. This arises from the equipment and power cabling in the control room.

Fig. 8 Frequency analysis of magnetic field in a "quiet" part of the control room



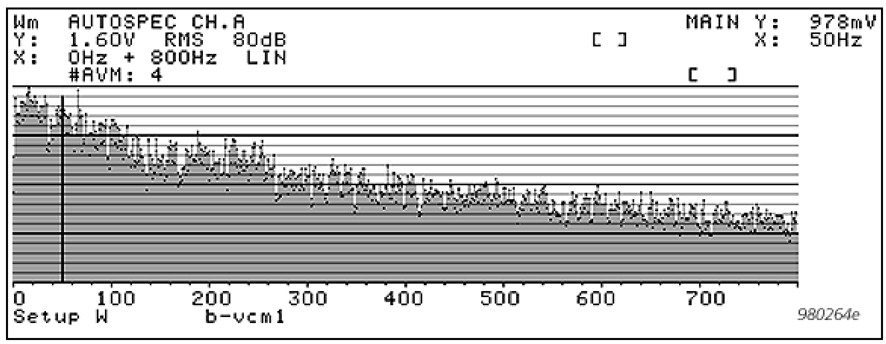
Measurement of Common Mode Voltage

The common mode voltage between the vehicle's chassis (one pole fixed to the battery terminal) and the floor of the test cell was measured with a standard multimeter. A frequency analysis was then performed using Brüel & Kjær Signal Analyzer Type 2035. The floor of the test cell was grounded to the measurement system ground which was also connected to the shield on the input cables.

When a cable from the chassis was held near the floor of the test cell, a small spark was produced. The spark seemed to be slightly smaller than that produced by the Electrostatic Discharge Pistol belonging to Brüel & Kjær's Quality Assurance Department used for CE certification measurement, but dramatically smaller than the spark from the Surge Test which is also performed on all new Brüel & Kjær instruments. It is a well-known fact that the relative motion of tyres on the rollers of a dynamometer produces a charge on the vehicle just like a Van der Graf generator. Tyres with steel cording are particularly liable to produce large static charges in such cells. It is possible that noise transients produced by ignition appear in the measured common mode voltage.

Measurements were made using a standard RMS multimeter with an input impedance of 10 MΩ//100pF. This showed a voltage of 12 – 14 V AC, and a fluctuating DC voltage from ±12 – 14 V DC. The short circuit current read-out was maximum 100 µA. It is an easy job to short circuit this voltage source by a ground wire.

Fig. 9 Frequency analysis of common mode voltage

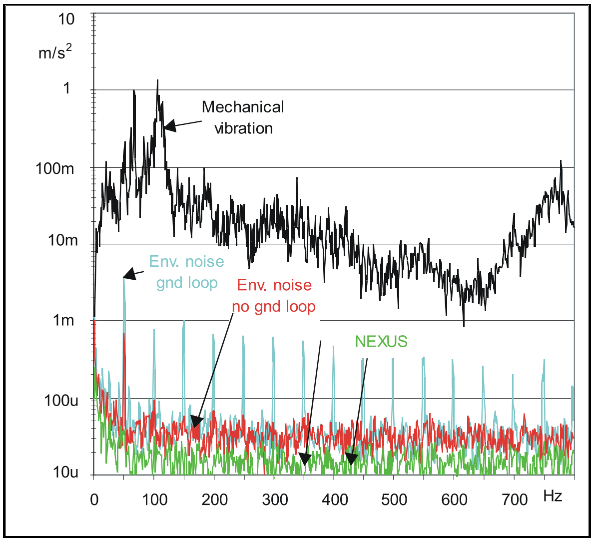


Measurement of Vibration and Noise

The following measurements (see Fig. 10) were performed on the sub-frame in the test cell:

1. Mechanical vibration (black curve): the result of a vibration measurement made using Triaxial Accelerometer Type 4321 to obtain the vibration. This signal consists of the vibration and the environmental noise which has no effect in this case.
2. Environmental noise signal with ground loop (blue curve): the result of a vibration measurement made using a dummy triaxial accelerometer (0 pC/ms^{-2}) to obtain the environmental noise signal only. This is done with a single-ended input to NEXUS and with the accelerometer grounds coupled together, hence a ground loop is achieved.
3. Environmental noise and no ground loop (red curve): the result of a vibration measurement performed the same way as the aforementioned but with floating input selected on NEXUS to break the ground loop.
4. NEXUS Type 2692 noise (green curve): the result of a vibration measurement performed in an electrically silent area with 1 nF termination. This is the way manufacturers normally specify noise in their Product Data sheets. The NEXUS inherent noise is a little lower than the environmental noise with no ground loop. This is due to the capacitive load from the 6 m cabling in the test cell.

Fig. 10 Signal and noise conditions in the test cell. In this case where a ground loop was present, you can see that the signal to noise ratio was improved from approximately 20 dB to approximately 45 dB. This improvement was achieved by using floating input (red curve) on the conditioning amplifier instead os single-ended input (blue curve). In a case like this, similar improvement can also be obtained by insulating the accelerometers. This is, however, not possible if one uses a triaxial accelerometer where the signal grounds are connected together.



Why NEXUS is Suitable as Sound and Vibration Conditioner in a Harsh Environment

- Good EMC (electromagnetic conformance) protection on all inputs and outputs
- Fulfils CE certification requirements for both Light Industry and Industrial Environment
- Common mode voltage suppression made possible with floating input and output. This dramatically reduces ground loop problems
- Functions within a large temperature and humidity range
- Mechanically robust

Recommendations on How to Avoid Electrical Noise and Interference

The apparatus

Use apparatus with CE certification only and ensure that the CE certification is without reservation for destructive tests. Look also for immunity specification on measuring equipment.

The installation

All equipment should be supplied from the same mains supply.

Ground the equipment, measurement object, metal floor, etc., together.

Find out how the currents might flow in your signal cabling between equipment. Differences in signal references (signal grounds) might easily occur. Use single-ended and floating of input/output to remove or at least suppress the voltage differences between the signal references.

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