API 670 Industrial Seismic Accelerometer

SA6200A

SAFETY MANUAL

Contents

1. Purpose

The purpose of this Safety Manual is to document all the information specifically related to the safety aspect of the Metrix SA6200A industrial seismic accelerometer. This device is certified for use as component in a functional safety system. This Safety Manual is then required in order to enable the integration of the devices into a safety related system with the objective to be in compliance with the requirements of the IEC 61508-2 Annex D.

The information contained in this Safety Manual is valid for the models indicated in paragraph 6.

When the SA6200A industrial seismic accelerometer is included in a Safety Instrumented Function, the integrator shall evaluate the performance of the device into the SIF loop, in order to ensure its proper implementation.

The instructions and information contained in this manual are valid only for the SA6200A industrial seismic accelerometer. In case of integration in a Safety Instrumented System, the Logic Solver and Final Element information will be provided by the specifics Safety Manuals.

1.1. Disclaimer and warning

By using this device, you hereby signify that you have read this disclaimer and warning carefully and that you understand and agree to abide by the terms and conditions herein. Integrating this device into a Safety Instrumented System, you agree that you are solely responsible for your own conduct while using this device, and for any consequences thereof. You agree to use this device only for purposes that are proper and in accordance with all applicable laws, rules, and regulations, and all terms, safety prescriptions and precautions, practices, policies and all additional revisions or guidelines that Metrix has made and may make available.

2. Symbols used in this Manual

This manual contains some symbols that are used to focus the user's attention on safety-related aspects. The following symbols are used:

WARNING!

This symbol identifies instructions that must be respected in order to avoid damages to things or to the personnel involved during the use of the SIS.

CAUTION

This symbol identifies instructions that must be followed to avoid malfunctioning of the SIS.

IMPORTANT

This symbol identifies important information that is necessary to understand the meaning of an operation or an activity.

WARNING!

Read the Safety Manual to become familiar with the features of this device before operating. Failure to operate the device correctly can result in damage to the device, personal property, and cause serious injury. This is a sophisticated safety-related device. It must be operated with caution and common sense and requires some basic mechanical ability. Failure to operate this device in a safe and responsible manner could result in injury or damage to the device, compromise the overall safety of the equipment under control or other property. This device is not intended for use by not functional safety qualified and properly trained personnel. Do not use with incompatible components or alter this device in any way outside of the documents provided by Metrix Instruments Co.

3. Required skills and qualifications

This manual is addressed to qualified personnel authorized for installation, operation, and maintenance of Metrix SA6200A industrial seismic accelerometer. As required by the IEC 61508-1 an appropriate level of competence shall be considered taking into account all relevant factors including safety engineering knowledge appropriate to the technology, knowledge of safety regulatory framework and previous experience.

IMPORTANT

In case of unqualified interventions, or if the advice of this manual is neglected, causing disturbances of Safety Functions, personal injuries, property or environmental damages may occur for which Metrix Instrument Co. cannot take liability.

4. Terms, definitions and abbreviations

4.1. Terms and definitions

Architecture

Arrangement of hardware and/or software elements in a system.

Architectural constraint

This reports the maximum SIL achievable based on the SIF's subsystems architecture alone. This is calculated solely based on Type A or Type B device selection, redundancy (hardware fault tolerance), and the safe failure fraction (calculated or conservatively assumed if no data is provided). It does not pertain to Systematic Capability or certification. This is calculated as indicated, using respective IEC 61508 or IEC 61511 tables.

Architectural Type

- Type A equipment or (sub)system: "Non–complex" (sub)system or equipment according 7.4.3.1.2 of IEC 61508-2.
- Type B equipment or (sub)system: "Complex" (sub)system or equipment according 7.4.3.1.3 of IEC 61508-2.

Diagnostic Coverage

Fraction of dangerous failures rates detected by diagnostics. Diagnostics coverage does not include any faults detected by proof tests.

Functional Safety

Part of the overall safety relating to the EUC and the EUC control system that depends on the correct functioning of the E/E/PE safety-related systems and other risk reduction measures.

Hardware Fault Tolerance

A hardware Fault Tolerance of N means that N+1 is the minimum number of faults that could cause a loss of the Safety Function. In determining the hardware fault tolerance no account shall be taken of other measures that may control the effects of faults such as diagnostics.

Mean Repair Time

Expected overall repair time.

Mean Time to Restoration

Expected time to achieve restoration.

Mode of operation

Way in which a SIF operates which may be either low demand mode, high demand mode or continuous mode:

- Low Demand Mode: mode of operation where the SIF is only performed on demand, to transfer the process into a specified safe state, and where the frequency of demands is no greater than once per year.
- High Demand Mode: mode of operation where the SIF, is only performed on demand, to transfer the process into a specified safe state, and where the frequency of demands is greater than once per year.
- Continuous Mode: where the mode of operation where the SIF retains the process in a safe state as part of normal operation.

MooN

SIS, or part thereof, made up of "N" independent channels, which are so connected, that "M" channels are sufficient to perform the SIF.

Probability of dangerous Failure on demand PFD_{AVG}

Average probability of dangerous failure on demand.

Probability of dangerous Failure per Hour PFH

Average probability of dangerous failure within 1 h.

Proof Test

Periodic test performed to detect dangerous hidden faults in a SIS so that, if necessary, a repair can restore the system to an "as new" condition or a close as practical to this condition.

Safe Failure Fraction

Property of a safety related element that is defined by the ratio of the average failure rates of safe plus dangerous detected failures and safe plus dangerous failures.

Safe State

State of process when safety is achieved (IEC 61511-1).

State of the EUC when safety is achieved (IEC 61508-4).

Safety Integrity

Ability of the SIS to perform the required SIF as and when required.

Safety instrumented function (SIF)

Safety Function to be implemented by a safety instrumented system (SIS).

Safety Integrity Level (SIL)

Discrete level (one out of four) allocated to the SIF for specifying the safety integrity requirements to be achieved by the SIS.

Safety instrumented system (SIS)

Instrument system used to implement one or more SIFs.

Systematic Capability

Measure (expressed on a scale of SC 1 to SC 4) of the confidence that the systematic safety integrity of a device meets the requirements of the specified SIL, in respect of the specified Safety Function, when the device is applied in accordance with the instructions specified in the device safety manual.

λ

Failure rate (per hour) of an entity (component or system).

λ_D

Dangerous failure rate (per hour) of an entity (component or system).

λ_S

Safety failure rate (per hour) of an entity (component or system).

λ_{DU}

Dangerous undetected failure rate (per hour) of an entity (component or system).

λ_{DD}

Dangerous detected failure rate (per hour) of an entity (component or system).

4.2. Acronyms and abbreviations

BPCS	Basic Process Control System
DC	Diagnostic Coverage
E/E/PE	Electrical / Electronic / Programmable Electronic
EUC	Equipment Under Control
FIT	Failure In Time
HFT	Hardware Fault Tolerance
IEC	International Electro-Technical Commission

MRT	Mean Repair Time
MTTR	Mean Time to Restoration
PFD	Probability of Failure on Demand
PLC	Programmable Logic Controller
PTC	Proof Test Coverage
SC	Systematic Capability
SFF	Safe Failure Fraction
SIL	Safety Integrity Level
SIS	Safety Instrumented System

5. Reference documents and standards

The following table shows the Standards useful for the Safety Manual realization:

Doc ID	Standard Code	Standard title
[D1].	IEC 61508-1:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: General requirements
[D2].	IEC 61508-2:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems
[D3].	IEC 61508-4:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 4: Definitions and abbreviations
[D4].	IEC 61508-5:2010	Functional safety of electrical/electronic/programmable electronic safety related systems - Part 5: Examples of methods for the determination of safety integrity levels
[D5].	IEC 61508-6:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3
[D6].	IEC 61508-7:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 7: Overview of techniques and measures

The following table shows the documents useful for the Safety Manual issuing:

Doc ID	Project Document Name	Document Code	Version
[D7].	Datasheet	1009516	November 2020, Rev. V
[D8].	Installation Manual	M9313	November 2020, Rev. M
[D9].	Hazardous Installation Manual	1668055	January 2017, Rev. B
[D10].	SIL Certificate	MTXI-6200A-ENS-B01	--
[D11].	Safety Assessment Report	25-MTX-6200A-FSA-01	--

6. Products introduction

SA6200A is a general-purpose accelerometer designed for use on a wide variety of machine types. It has a broad frequency response of 0.5 Hz to 10 kHz (+/- 3dB), 50g range, and a mounted resonance of 13 kHz.

It consists of a temperature stabilized piezo-electric sensor and an amplifier packaged together in a 316 stainless steel case. The built-in amplifier provides a high level, industry-standard 100mV/g low-impedance, constant-current output that is compatible with vibration monitoring systems, electronic switches, and 4-20mA signal conditioners.

The device meets the requirements of API 670, standard which covers the minimum requirements for a Machinery Protection System measuring radial shaft vibration, casing vibration, and other machine-related parameters.

Figure 1 – SA6200A external view

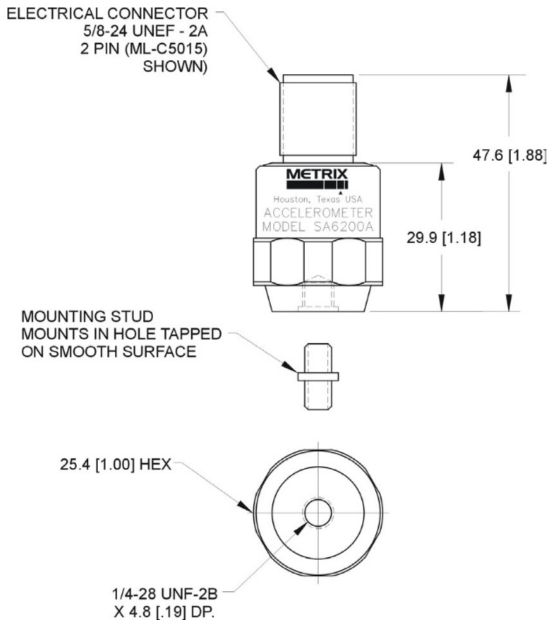


Figure 2 – SA6200A outline and dimensions

Electrical Connector 5/8-24 UNEF-2A 2 PIN (MIL-C-5015) shown. Note that the connections are non-polarity sensitive (IPT®).

6.1. Products family identification

This Safety Manual is valid for SIL rated version listed in this paragraph.

For a SIL rating version, the first digit in the A option shall be "S".

SA6200A	-	A	B	C

A	Hazardous Area Certification*
0	Non-agency approved
1	CSA US/CA, Class 1, Div 1, Groups A, B, C, & D, T3 Intrinsically Safe(1) when connected per dwg 9352
2	ATEX, Ex ia IIC T3 Ga Intrinsically Safe(1) when connected per dwg 9352
3	CSA US/CA Class 1, Div 2, Groups A, B, C, & D, T3 non-incendive when connected per dwg 9031
4	ATEX, Ex nA IIC T3 Gc non-incendive when connected per dwg 9031
5	CSA US/CA, Class 1, Div 2, Groups A-D, T3 (non incendive) CSA US/CA, Class 1, Div 1, Groups A-D, T3 (I.S. w/barrier) ATEX/IECEx Ex nA IIC T3 Gc (non incendive) ATEX/IECEx Ex ia IIC T3 Ga (I.S. w/barrier)
6	IECEx, Ex ia IIC T3 Ga Intrinsically Safe(1) when connected per dwg 9352
7	IECEx, Ex nA IIC T3 Gc non-incendive when connected per dwg 9031
8	EAC Ex nA IIC T3 Gc (non incendive) EAC Ex ia IIC T3 Ga (I.S. w/barrier)
NOTES: (1) When wired using approved barrier (not included).	
B	**Mounting Stud**
0	1/4-28 UNF
1	M6 x 1.0
2	1/4-20 UNC
3	None
5	1/4-28 UNF & M6 x 1.0
C	**Connector Type**
1	2-pin hermetic plug

* For SIL approval, add an "S" prefix to the desired Hazardous Area Certification (Option A).

6.2. Specifications

INPUTS	
Supply voltage	18 – 28 V_{DC} Metrix patented IPT® independent polarity allows voltage to be connected without regard to polarity
Excitation Current	2 to 20 mA
Circuit-to Case Isolation	500 Vrms
OUTPUTS	
Output voltage	Proportional to vibration: 100 mV/g (10.2 mV/m/s²) 50 g full scale range (± 5 V)
Accuracy	± 2% (repeatability)
Sensitivity (± 5 %)	100 mV/g (10.2 mV/m/s²)
Frequency Response	2 to 5 kHz (± 5 %) 1.5 Hz to 7.5 kHz (± 10 %) 0.5 Hz to 10 kHz (± 3 dB)
Resonant Frequency	13 kHz
Resolution	0.003 g rms

PHYSICAL	
Operating Temperature	-54°C to +121°C
Sensitive Axis	Same as mounting stud axis
Axis Orientation	Any
Enclosure Material	316 stainless steel
Enclosure Rating	IP54
Connector Types	2-pin hermetic plug
Humidity	100% condensing

IMPORTANT

The information listed in the above table are extracted by datasheet [D7] and shall be considered for reference only. In case of mismatch, the datasheet has the priority on the present table.

7. Reliability and Safety characteristics

Safety Function(s)	To monitor constantly the EUC vibration level at the portion where the device is installed and to provide an analog voltage output proportional to the measured vibration (mV/g).
Installation	Refer to [D8], [D9]
Lifetime	When using in the prescribed manner indicated in [D8] and/or in [D9], the device can operate in safety applications up to 20 years.
Interface	SA6200A industrial seismic accelerometer could require intrinsically safe barriers as interfaces toward the SIS, depending on the installation area. Refer to [D8] and/or [D9] for further details about recommended IS barrier.
MRT	4 hours This is estimation considering skilled personnel for maintenance, availability of spare parts and adequate tools on site.
Common Cause Failure	β = 5 % This value is valid for the 1oo2 architecture. The values for the other architecture shall be calculated according to IEC 61508-6, Table D.5.

WARNING!

Modifications to the hardware are not permitted. Do not use other connectors than the ones listed in [D7].

WARNING!

To avoid potential hazards, use this product only as specified. Only qualified personnel should perform installation, uninstallation and wiring procedures. If you suspect there is damage to this product, have it inspected by qualified personnel.

WARNING!

Interface devices, such as intrinsically safe barriers, could modify the SIS safety. The End-User shall take into account this possibility during calculation of the whole safety loop implementing the SIF.

WARNING

Do not touch exposed electrical connections and components when power is present.

7.1. Typical placement

The SA6200A industrial seismic accelerometer measures seismic vibration at the attachment point on the machine, using engineering units of mV/g (millivolts per g, where g is the gravitational acceleration, ≈ 9.81 m/s^2).

The device's sensitive direction is through the long axis of its cylindrical body. It will not measure side-to-side motion.

Typical mounting is shown in the following figure.

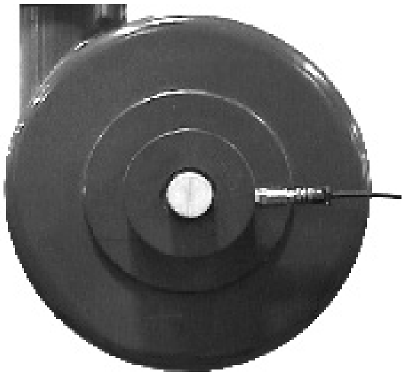


Figure 3 – SA6200A typical mounting

CAUTION

The mounting of the apparatus into an installation must be carried out in such a way that metallic body of the accelerometer is reliably connected to the system earth.

CAUTION

Do not use a pipe wrench when installing the accelerometer. A pipe wrench can apply extreme forces to the body and potentially damage electronic components.

7.2. Reliability and Safety

The reliability parameters have been obtained considering the SA6200A industrial seismic accelerometer as element of a safety-related system with the Safety Function(s):

To monitor constantly the EUC vibration level at the portion where the device is installed and to provide an analog voltage output proportional to the measured vibration (mV/g).

IMPORTANT

The design of each Safety Instrumented Function shall meet the requirements listed in the reference standards that shall be selected by taking into account the specific application.

Specific activities necessary to investigate and reach a judgment on the adequacy of the Functional Safety achieved by the E/E/PE safety-related system or compliant items (elements/subsystems) has been conducted by an independent assessor. The following tables show the safety parameters of the devices listed in paragraph 6.1. For a detailed explanation of the parameters meaning, application and associated assumptions refer to paragraphs 7.3-7.5.

Configuration	Safety Function	λ_S	λ_{DU}	λ_{DD}	Type	Systematic Capability (SC)
SA6200A	See above	**0**	**64**	**102**	**A**	**3** (Route 1_S)

Table 1: Reliability parameters for SA6200A industrial seismic accelerometer (all configurations)

NOTES:

- Route 1_H and Route 2_H have been applied when evaluating architectural constraints.
- All failure fates are in FIT (Failure In Time, 1 FIT = 1 failure / 10^9 hours).
- The device can be used for applications up to SIL 2, with HFT = 0.
- If external out-of-range diagnostics is not available, then λ_{DD} = 0 and λ_{DU} = λ_D = 166.

7.3. Systematic Capability

Techniques and measures to control and avoid systematic failures during the different phases of the lifecycle have been evaluated and found to be sufficient to meet the requirements of SIL 3 in accordance with IEC 61508:2010, Parts 1-7. The compliance with the requirements has been achieved following the compliance Route 1_S.

The Systematic Capability provides a quantitative estimation of the robustness of the device against systematic failures resulting from design, project management and documentation quality. An appropriate group of techniques and measures to prevent the introduction of faults during the design and development phases are in place.

To control systematic faults the maintenance and test requirements formalized at design stage must be followed.

In order to preserve the Systematic Capability, the SA6200A industrial seismic accelerometer must be used following the constraints reported in this Safety Manual in term of authorized personnel, installation, operating conditions and maintenance.

WARNING!

The declared Systematic Capability level is valid only if the requirements and limitations reported in this Safety Manual are fulfilled.

7.4. Random Safety Integrity

The failure rates shown in the previous table (Table 1) are resulting from the FMEDA analysis, a FMEA extension that combines standard FMEA techniques with extension to identify online diagnostics techniques and the failure modes relevant to Safety Instrumented System design.

The failure rates shall be used for PFH / PFD_{AVG} estimation, taking into consideration parameters such as redundancy, architectural constraints, diagnostic capability, also introduced by the whole system, including the considerations about the proof test and its effectiveness, mean time of restoration, up to the maintenance capability and its minimum characteristics.

The assumptions associated with these failure rates are as follows:

- Failure rates are constant, wear-out or infant mortality contributions are not included;
- The tabulated failure rates are expressed in Failures in Time (FIT): 1 FIT = 10^{-9} h^{-1}.

The device total failure rate $\boldsymbol{\lambda}$ is given by $\boldsymbol{\lambda = \lambda_S + \lambda_{DU} + \lambda_{DD} + \lambda_{RES}}$ where $\boldsymbol{\lambda_{RES}}$ is the failure rate of (residual) failures not classified as safe or dangerous.

The dangerous undetected failure rate $\boldsymbol{\lambda_{DU}}$ is due to faults that cause the failure of the Safety Function. The Safety Function fails when the output signal is no more reliable, and the machine under control is not tripped even if the dangerous vibration threshold is reached.

The two main phenomena leading to undetected failures are drift and non-linearity. As consequence, a wrong signal is sent to the Logic Solver. Until the signal will be within a plausibility range, the Logic Solver will be unable to detect the failure (unless several sensors are used in MooN architectures such as 1oo2 or 2oo3, with cross-comparison techniques).

The dangerous detected failure rate $\boldsymbol{\lambda_{DD}}$ value considered in this manual is due to faults causing output signal under-range or over-range. $\boldsymbol{\lambda_{DD}}$ and $\boldsymbol{\lambda_{DU}}$ shall be separately considered only if the (external) Logic Solver diagnostics is able to detect these faults and react. Otherwise, all the dangerous failures shall be considered as undetected ($\boldsymbol{\lambda_{DU} = \lambda_D}$).

IMPORTANT

If the Logic Solver is not able to detect over-range and under-range of output signal, all the dangerous failures shall be considered as undetected ($\lambda_{DU} = \lambda_D$).

The safe failure rate λ_S represents failures of elements or subsystems that play a part in implementing the Safety Function, as they result in the spurious operation of the Safety Function or in the increase of the probability of spurious operation of the Safety Function to put the EUC (or part thereof) into a safe state or maintain a safe state.

The residual failure rate λ_{RES} includes the NO PART and NO EFFECT failure rates, that is failure of a component that plays no part in implementing the Safety Function (NO PART) and failure of an element that plays a part in implementing the Safety Function but has no direct effect on the Safety Function (NO EFFECT).

The integration in the SIS, the whole SIS validation, and the PFH / PFD_{avg} calculation of the whole safety loop implementing the SIF is under End-User responsibility, together with the verification of the compliance with the allocated target SIL.

7.5. Hardware Safety Integrity

The constraints on hardware Safety Integrity have been verified in order to achieve a sufficiently robust architecture taking into account the level of element and subsystem complexity following the compliance Route 1_H.

Route 1_H is based on Hardware Fault Tolerance and Safe Failure Fraction concepts. According to Route 1_H, in order to determine the maximum Safety Integrity Level that can be claimed, the Safe Failure Fraction shall be calculated for the item under analysis using the failure rate data.

The maximum allowable Safety Integrity Level that can be claimed in terms of architectural constraints can be determined according to IEC 61508-2:2010, subclause 7.4.4.2, tables 2 and 3. Different tables are used if the element is classified as type A or B.

SA6200A industrial seismic accelerometer has been classified as **type A** element according to the requirements specified in IEC 61508-2:2010, subclause 7.4.4.1.2.

An element can be regarded as type A if, for the components required to achieve the Safety Function:

a) the failure modes of all constituent components are well defined; and

b) the behavior of the element under fault conditions can be completely determined; and

c) there is sufficient dependable failure data to show that the claimed rates of failure for detected and undetected dangerous failures are met.

8. Requirements for implementation into a SIS

SA6200A industrial seismic accelerometer shall be connected to a signal conditioner that:

- reads the accelerometer 100 mV/g analog output signal,
- reacts, if a dangerous condition is detected (e.g., trip the machine if the vibration dangerous threshold is reached),
- if possible, detects accelerometer faults through its output signal and reacts consequently.

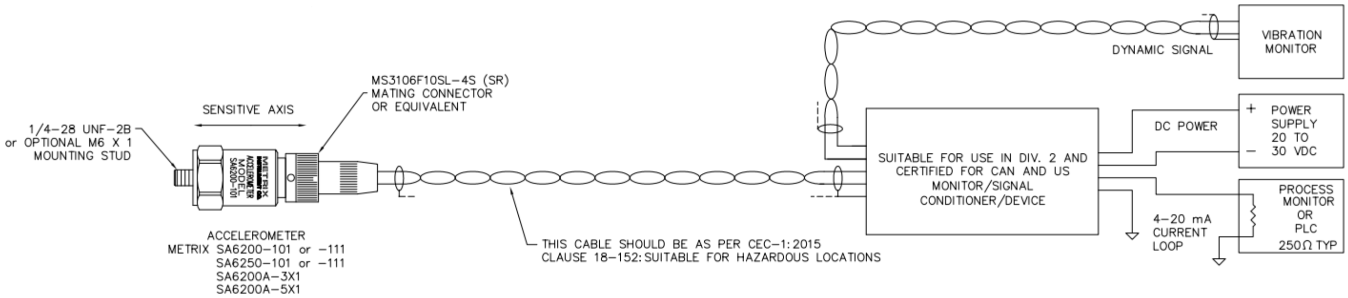
WARNING!

Machine under control must be tripped if the accelerometer output signal is out of the normal operating range.

8.1. Connection to signal conditioner and calibration

The SA6200A industrial seismic accelerometer requires a power supply with a constant current. This is usually achieved through an external conditioning device. If it does not provide power, an external power supply must be provided.

The following figure schematizes an example of the typical wiring for single-accelerometer applications:



The signal conditioner must be correctly calibrated before installation, using a linear calibration curve that allows associating the 100 mV/g signal values to the corresponding vibration ones (in/s^2 or mm/s^2).

The SA6200A has been factory calibrated for a 100 mV/g vibration level on loop power with a max output of 5 V. If the calibration is in doubt, the unit can be verified in the field by following the procedures outlined below. Note that there are no Zero and Span adjustments on the SA6200A.

Test	Description	Vibration Level	SA6200A Output
Zero Verification	In absence of vibration, the output voltage should be 4 mA ± 0.1 mA. If the ambient vibration exceeds 2% of full scale, the SA6200A should be removed from the machine and placed on a vibration free surface for this measurement. Often a piece of foam can be used to isolate the SA6200A from external motion.	0.0 g (i.e., no vibration)	0 mV (± 1 mV)
Span Verification	Subject the SA6200A to a known vibration under 50g. If you are using a portable vibration shaker, the output should be 100 mV/g.	1 g	100 mV (± 5 mV)

9. Proof Test

The Proof Test interval shall not exceed 5 years. The SA6200A industrial seismic accelerometer shall be tested verifying that the correct functioning has not been compromised by the continuous exposition to vibration.

IMPORTANT

The Proof Test interval shall be chosen taking into consideration the main characteristics of each Safety Function where the industrial seismic accelerometer is involved. This selection it's under the sole responsibility of who is in charge to implement the SA6200A into the SIS and shall not exceed 5 years.

9.1. Description of the test

This test is executed in order to verify the device correct response.

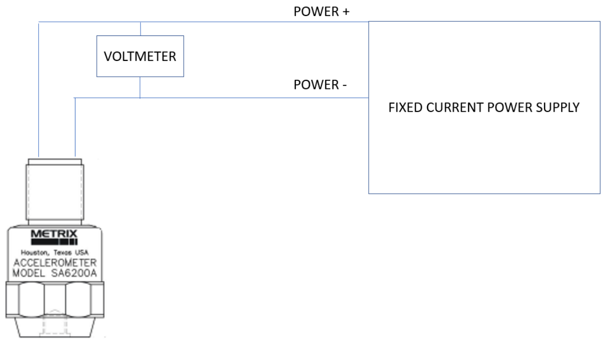
The accelerometer is mounted on a shaker and exposed to vibrations with different amplitude at the fixed frequency of 100 Hz. For every amplitude value, the corresponding accelerometer output voltage value shall be compared with the values reported in the table below. This test allows to verify if the signal voltage output is correct (100 mV/g).

9.2. Test Instrument and equipment

- Shaker
- Power supply
- Digital multimer

9.3. Test procedure

- Unscrew the accelerometer from its mounting location.
- Screw in the accelerometer into the appropriate adapter on the shaker.
- Connect the accelerometer to the power supply, and the digital multimeter as shown in the following figure.



- Acquire the accelerometer output maintaining the frequency constantly at 100 Hz and changing the vibration amplitude from 0 to 100 (% of the full-scale range).

Amplitude [g]	Output [mV pk]
0	0
1	100
3	300
5	500
10	1000
30	3000
50	5000

NOTES:

1) Output values in case of 24 Vdc power supply, 100Hz frequency and varying amplitude.
2) When comparing the output values, consider a 5% tolerance.

9.4. Test results

The result of the test can be considered positive if the measured values are the same specified in the table above (considering a 5% tolerance). In this case, remount the industrial seismic accelerometer on the machine under control, following the instruction given in [D8].

Otherwise (i.e., if there is no value correspondence) the test is not passed, and the industrial seismic accelerometer must be replaced with a correct functioning one.

9.5. Proof Test coverage

Following the above procedure, the Proof Test coverage is up to 98%.

WARNING!

Even if the Proof Test has been properly carried out, wrong or inappropriate maintenance may compromise the accelerometer. Follow the instruction detailed in the user manual is mandatory to ensure the correct operability of this equipment and consequently of the whole SIS.