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Seismic Monitoring System for Nuclear Power Plants

CONTENTS

INTRODUCTION

According to regional, national and international regulations, Nuclear Power Plants (NPP) need to be able to mitigate potential effects of an earthquake.

Such mitigation can be achieved by utilising specific instrumentation for monitoring the earthquake ground motions and the response of the plant features to these motions.

This type of instrumentation is called Seismic Monitoring System (SMS).

Main functions of the SMS are:

- Detection of any (significant) earthquake at plant location
- Providing data records of acceleration at defined locations
- Performing OBE/SSE exceedance evaluation
- Providing a report to the plant operator after an event
- Periodical self test execution

GeoSIG delivers complete SMSs for NPP applications. These systems:

- Fully comply or exceed regional, national and international nuclear regulatory requirements
- Come with comprehensive certification and documentation, which can as well be supplied tailored for any particular requirement
- Include powerful industrial computer for complex data processing based on different algorithms including response spectra analysis
- Perform automatic analysis and evaluation of the earthquake impact on monitored structures
- Provide comprehensive and fast notification and reporting features
- Warrant the robustness, reliability and functionality to serve its main purpose
- Include self diagnostic and testing features to assure continuous system readiness to act once in a life
- Present simplicity of operation, maintenance and upgrade

This document provides an overview of the SMS supplied by GeoSIG.

Upon request several more detailed documents are available, such as:

Sample Operator Report

Sample Design Report

Qualifications and Certificates

Regulatory Compliance

Reference Letters

Detailed Technical Notes on Example Systems

Terms and Conditions

Qualifications

Certified for compliance to following standards or guides:

Seismic:	NRC RG 1.12 Rev.3, NRC RG 1.166, IEC 60068, IEEE 344, IEEE 323
EMC:	NRC RG 1.180, EPRI TR-102323, MIL-STD 461, IEC 61000, IEEE 1050

Project-specific qualification tests can be performed upon request.

OVERVIEW

The core of the **GeoSIG Seismic Monitoring System** (SMS, or SAS for Alarm System) is a Central Processing Unit (CPU) rack mounted in a seismically- and EMC-safe cabinet together with an industrial PC and relevant peripherals.

Detection / Recording Units (DRUs) consisting of accelerometers, seismometers or complete seismic station packages are placed at remote locations that are connected to the CPU through shielded copper or fibre optic cables.

The system has been designed in a way that it is not bound to a single topology. There could be only the sensors or both sensors and data acquisition out in the field.

GeoSIG, **unlike any other supplier, can offer three different and versatile solutions** for the seismic instrumentation of Nuclear Power Plants.

Decentralised Recording

Sensors and recorders are on sites

Increased reliability due to independent recording
Error-free digital data transmission within the plant
Optimised cost of data cables
Preferable for new installations

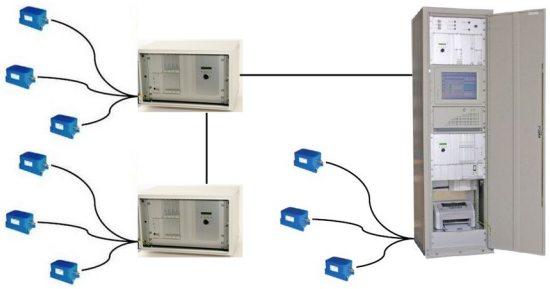
One is the **Decentralised System**, where each measuring point has a seismic sensor together with a dedicated recorder and there is a system central controlling the overall operation and providing system intervention and maintenance.

Second one is the **Centralised System** where only the seismic sensors are located at the measuring points and all other functionality are provided by the system central.

Centralised Recording

Only sensors are on sites

Simple devices in controlled area (analog sensors)
Simplified diagnostics and maintenance
In most cases, existing cables can be reused
Preferable for system upgrade projects

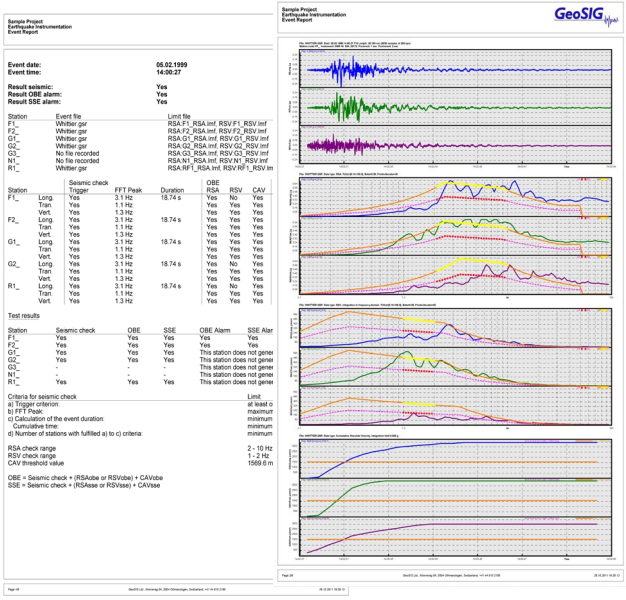


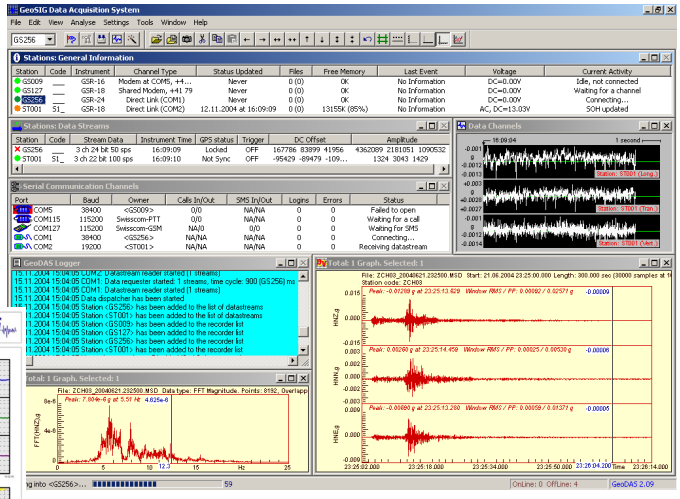
Cost-optimised solution suitable for monitoring of nuclear power plants operating multiple units

And finally the **Cascaded System**, which is a combination of the decentralised and centralised systems to provide a more flexible deployment.

The system provides high modularity and flexibility so that an upgrade is simplified and that, as much as possible, existing elements can be reused.

State of the art **GeoDAS** software is utilised in the CPU. GeoDAS monitors all DRUs in parallel, through the dedicated communication links that are provided by the system hardware.





For each measuring channel the recording threshold and the alarm limit values can be set individually. Detailed response spectrum limits can be fully defined along with other parameters as required by relevant regulations or customised user requirements.

Continuously monitoring the DRUs, the CPU detects seismic events, generates associated alarms, and automatically processes the recorded data. It performs periodical tests on the system and monitors the system-wide state of the health as well as analyses the detailed cause of any malfunction. **A fully automated Detailed Operator Report is provided a few minutes after the occurrence of an earthquake**.

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SYSTEM CENTRE

SMS, Seismic Monitoring / Alarm System

GeoDAS Software

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DATA SHEET

SMS / SAS

Seismic Monitoring / Alarm System

Overview

Since 1992, GeoSIG has supplied SMS solutions to the nuclear industry. Our design philosophy has always focused on systems that are robust, long-lasting, and require minimal maintenance. Decades of field experience and compliance with regulatory codes have guided this approach. Because installations must remain in service for many decades, long-term reliability and supportability are built into the design. A testament to this is that, in more than 30 years, only two generations of SMS have been introduced, ensuring proven performance and continued product support.

At the core of the SMS / SAS is a central processing unit (CPU) with a multi-channel digital recorder, rack-mounted in an industrial cabinet together with an industrial computer and peripherals. Accelerometers, seismometers, seismic stations or sensor packages, referred to as Detection / Recording Units (DRUs), are placed at remote sites and connected to the CPU. The system is not tied to a single topology: there may be only sensors, or both sensors and data acquisition in the field. These options, detailed in the specifications section, allow flexibility while reusing existing elements where possible. Built-in redundancy of the recorders and power supply are standard.

The CPU monitors all DRUs in parallel using dedicated communication links. It continuously checks their status, detects seismic events, generates alarms, and automatically processes recorded data. Periodical tests are performed, with the overall system health monitored and the causes of any malfunction analysed. Results are delivered in a report within minutes after an event. The CPU uses GeoDAS software, allowing recording thresholds and alarm limits to be set individually for each channel. Project-specific limits and parameters can be fully defined to meet regulatory or customised requirements.

Key Features*

- Recording, advanced analysis and annunciation according to project specific or international regulations
- Automatic exceedance evaluation
- Reporting and alerting via relays, visual and audible tools as well as printed matter
- Project specific Automatic Event Processing (AEP), Nuclear (NPP), or other features
- Up to 36 triaxial analog sensors and unlimited number of seismic field recorder stations
- 24 or 32-bit event-based and/or continuous recording
- Common timing and triggering within the system
- Completely over-voltage protected
- Continuous system-wide SOH monitoring
- Seismically and EMC proven design
- Comprehensive configuration of the whole system via the enhanced computer interface

*The information provided is a typical overview. For each project a specific description is provided outlining the relevant system.

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SMS/SAS Seismic Monitoring / Alarm System

Typical System Specifications

Sensor

SMS/SAS system offers the most flexible sensor connectivity options to cater for the needs of any measuring requirement. Any matching type of sensor can be connected to the system.

Digitiser

A/D converter:	24 bit to 32 bit ADC
Dynamic range:	137 dB to 150 dB @ 50 sps
Sampling rates:	up to 2000 sps
Bandwidth:	DC to 1000 Hz

Data Recording

Pre-event time:	Adjustable*
Post-event time:	Adjustable*

Triggering

Type:	Level (threshold) or STA/LTA trigger, project specific triggers also available
Filtering:	User configurable

Data Storage

Type:	2 - 128 GByte per 3 channels and/or HDD, SDD in the computer

Data Analysis

GeoDAS software provides various analysis functions like filtering, FFT, response spectra, etc. Other commercially available evaluation software packages may be used alternatively.

*: Any value is useable, as long as it does not lead to data loss because of incorrectly configured or conflicting parameters.

SMS-SAS is compliant with the latest NRC RG 1.12 Rev. 3 of 2017

Timing

Standard clock accuracy: Free running, based on TCXO NTP accuracy <4ms (<1ms in a closed network): GPS System accuracy <1 µsec.

Indicators

LED, push button and/or flat-screen indicators, may vary with each product, based on requirements

Self Test / State of Health

The warning option provides independent warning / error outputs (relay contacts) based on user selectable criteria. As separate acquisition module in the CPU with its own power supply, remote sensor and cable; or independent DRUs with integral relays and CPU connection.

Seismic Switch /Warning/ Alarm Options

The warning option provides independent warning / error outputs (relay contacts) based on user selectable criteria. As separate acquisition module in the CPU with its own power supply, remote sensor and cable; or independent DRUs with integral relays and CPU connection.

Communication Channel Options

Ethernet TCP/IP, landline, GSM/GPRS/UMTS/3G/4G, serial

Power Supply

AC/DC power supply:	230 VAC / 50 Hz or 115 VAC / 60 Hz
External battery option:	Rechargeable, 4 x 24 VDC, 24 or 40 Ah

Housing

19" cabinet in different sizes, floor standing or wall mounted

These specifications provide a typical overview. For each project a specific description is provided outlining the relevant system.

Centralised Recording

Advantages:
Simple devices in controlled area (analog sensors).
Simplified diagnostics and maintenance.
Higher compatibility with existing systems for upgrade

Decentralised Recording

Advantages:
Independent recording units increase redundancy and reliability.
Link from remote to central can use Fiber Optics.
Digital transmission between remote and central locations.

Cascaded / Hybrid Recording

Combination of the decentralised and centralised systems to provide a more flexible deployment.

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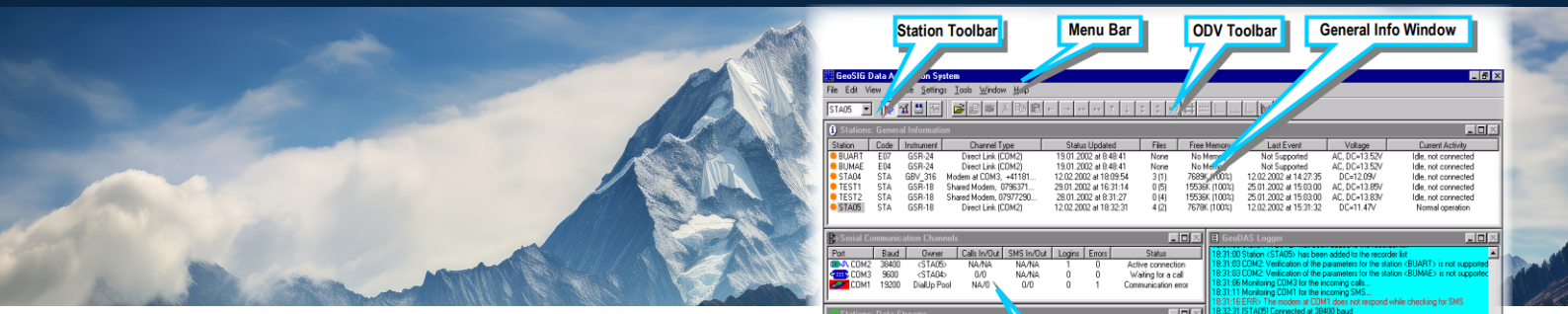
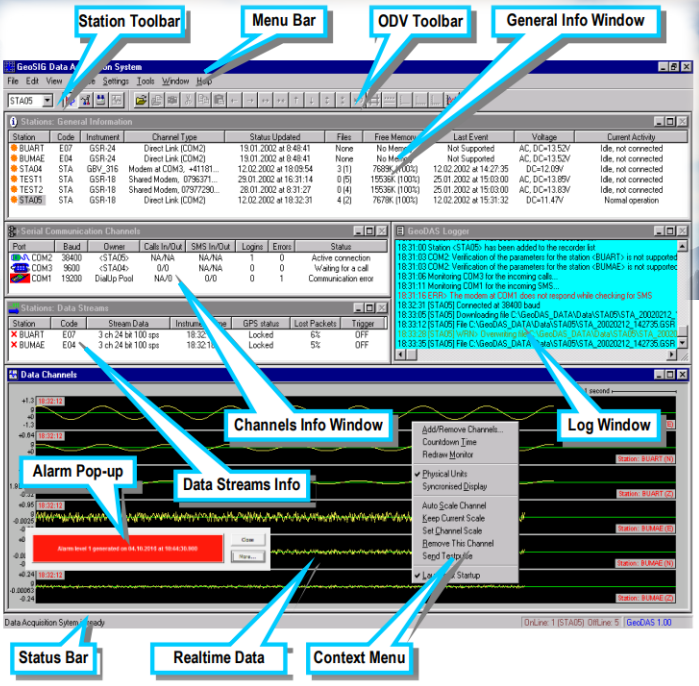


GeoDAS Software



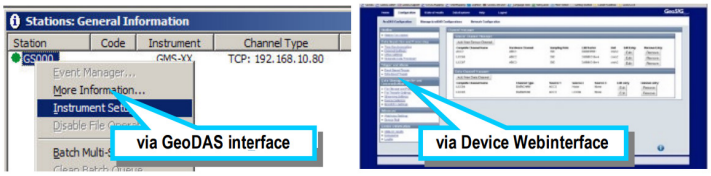
Overview

GeoDAS software is a graphical Microsoft Windows-based application running under Windows OS. Virtual machines or wrapper applications can be used to enable its many features to run under Linux, Mac OS, Unix and other operating systems too.

GeoDAS, when compared to any similar application, provides the most comprehensive, intuitive and versatile features available in the earthquake, seismic, structural, dynamic and static monitoring and measuring industry.

GeoDAS has been designed to meet requirements with respect to almost every possible application and can integrate/interact with many other software.

Versatile Instrument Setup



General Tasks - COM*

- Instrument, network, and system setup
- State of Health (SOH), logging and permanent or periodical monitoring of instrument/system status
- Communication links administration and monitoring supporting SEEDlink and GSBU datastreams
- Real-time data viewer and recorder with alarm and notification features
- File manipulation and format conversion into ASCII, SUDS, SAC, SEISAN, ARTeMIS, MATLAB
- Off-line data viewing and inspection

-BASE* *is a package excluding specific basic cables and hardware*

Data Analysis - DAP*

Manual data analysis functions are:

- Lowpass filter
- Highpass filter
- Baseline correction
- Integration
- Differentiation
- Vector Sum
- Cumulative Absolute Velocity (CAV)
- Time-domain filtering
- Effective values
- Damping
- Power spectra
- FFT magnitude
- Terzband spectra
- Response spectra
- JMA intensity
- STA/LTA ratio
- Signal characteristics
- Analysis templates

-ECD* *is the combined package of GeoDAS-COM and GeoDAS-DAP conveniently provided together.*

*: optional features

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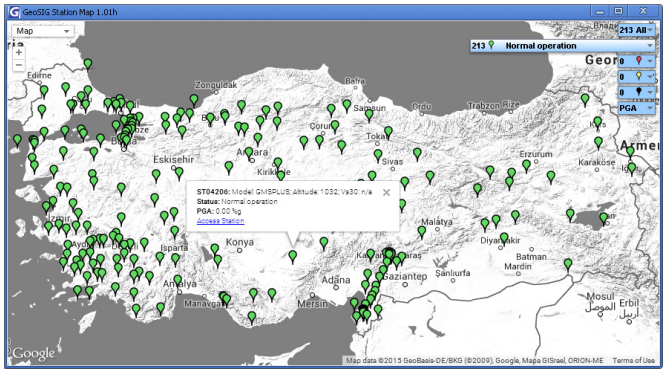
GeoDAS Software

Specifications

Advanced Station Map - ASM*

Display of stations with colour-coded state of health on Google Maps or on a fixed image with associated coordinates with direct access to each station's setup / web interface.



Other Capabilities*

GeoDAS also offers special functions, as well as automated data analysis that is required for particular applications or to be activated in special cases

- Strong Motion Data Processing – SMD *
- OBE / SSE event checks & reports - NPP *
- Support for ADC boards - ADC *
- Post-processing, reporting, notification *
- Static measurements, rainflow counting - STM *
- Automatic Event Processing - AEP *
- Automatic File Conversion to special formats - AFC *
- Customer specific file and stream handling *

*: optional features

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RECORDER

scai - GMS series, Independent Recorders

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DATA SHEET

scai GMS series

Data Acquisition System

Overview

With its optimised installation, operation and maintenance philosophy ***scai*** offers the real possibility to measure any dynamic motion with an abundance of features and options.

Highly reduced cost of ownership and user-friendly approach in the design make ***scai*** the perfect choice for the most advanced user.

Numerous optimisations within the architecture and the design yields unprecedented performance for seamless and fast execution of all system processes.

Fully compatible with existing GeoSIG sensors and can co-exist and co-perform in the same network as the GMS series recorders.

The simple upgrade path makes ***scai*** "future proof".

User-replaceable modular plug-in electronic boards make *scai* extremely maintainable and future-proof

Applications

- Seismic and earthquake recorder
- Structural Health Monitoring (SHM)
- Real-time seismology for free-field and urban areas
- High-density earthquake monitoring networks
- Shake/hazard mapping based on instrumental data
- Earthquake Early Warning and Rapid Response
- Damage estimation, disaster management
- Seismic alarm and safe shutdown
- Ambient vibration testing (optionally fully wireless)
- Induced vibration monitoring and notification
- Building code compliant Instrumentation

Key Features

- Modular electronics for user repair and upgrade
- 3 or 6* channels, up to 2000 sps sampling rate
- Low noise individual 32-bit digitser Δ–Σ ADC per channel
- Internal built-in and/or external sensor options
- Wired, Wi-Fi*, cellular*, satellite* links
- Power over Ethernet and wide power range
- Smart satellite* or network timing
- USB for storage and communication devices*
- Continuous data recording to ringbuffers
- Flexible configuration of multiple triggers
- Simultaneous data streaming to several clients
- Virtual signals from realtime processed sensor signal
- Rugged aluminium housing with easy installation
- Web interface compatible with smartphones / tablets
- Simple and secure remote access over Internet
- Alarm output with up to 4 dry-contact relays*
- Internal battery*, low power consumption
- Hot swappable SD card
- Third generation of NetQuakes recorders

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scai GMS series Data Acquisition System

Specifications

Use and Versatility

An intuitive web interface is available for easy configuration and interaction as well as display of live data graphs and state of health information, using any web browser. The device configuration file in XML format alternatively can be edited on site through the instrument console, exchanged by replacing the memory card, remotely from a server, or through SSH from anywhere around the world. Modular plug-in electronics structure provides highly increased serviceability and maintenance as well as easy hardware field upgrades or replacements.

Data Analysis

scai can perform real-time single/double integration, differentiation, HP/LP/BP filtering, decimation, peak/average calculations on the physical sensor signal and can provide these as real-time virtual signal. All recording and monitoring features can be applied on the virtual signals, simultaneous to the physical signals.

Sensor

Internal: ***scai*** can include select GeoSIG sensors internally. In that case the model name changes accordingly and the sensor levelling is achieved via the three levelling screws of ***scai***'s single bolt mounted base plate.

External: All GeoSIG sensors and any other third-party sensors with following specifications can be connected to ***scai*** as external sensor(s):

Sensor output:	Differential:	± 20 V, ± 10 V, ± 2.5 V
	Single ended*:	0 - 20 V, 0 - 10 V, 0 - 2.5 V
	Current loop*:	4 - 20 mA
Power to sensor:		15 or 24 VDC / 600 mA

Digitiser

Channels:	3 or 6*
A/D conversion:	24 bit Δ–Σ converters individual for each channel
DSP:	32 bit output word length
Dynamic range:	
Overall:	146 dB per-bin @ 1 Hz rel. full-scale RMS 137 dB @ 50 sps peak-peak RMS to RMS shorted input noise
Wide-band:	
0 - 500 Hz:	118 dB RMS full-scale peak to RMS shorted input noise
ANSS:	
0.002 - 50 Hz:	127 dB RMS full-scale peak to RMS shorted input noise
0.01 - 15 Hz:	132 dB RMS full-scale peak to RMS shorted input noise
15 - 30 Hz:	133 dB RMS full-scale peak to RMS shorted input noise
Sampling rate:	configurable up to 6 channels @ 2000 sps supports 2 different simultaneous sample rates each channel can have different sampling rates
Max. bandwidth*:	0 to 1000 Hz standard (other optional)
Anti-aliasing Filter:	Analog and digital FIR (finite impulse response)

Indicators

LED indicators:	RGB LEDs for Power, System, Data, Network and Sensor

Triggering

Several Trigger Sets can be defined in the instrument. Each set can be flexibly configured regarding the source of trigger, main and advanced trigger parameters, trigger processing and selected channels for storage. A voting logic based on the monitored channels can be defined.

Trigger Filter:	Fully independent high-, low- or bandpass trigger filters
Level:	Freely user configurable threshold
STA/LTA:	Freely user configurable STA/LTA trigger and de-trigger ratios
Schedule / Manual:	After start-up, at a given date/time, after event or manual
Early Warning (EEW)*:	JMA Earthquake Early Warning
Common trigger:	Common triggering among separate units over Ethernet TCP/IP networks

Event Recording

Pre-event memory:	1 - 720 seconds typical; freely user configurable
Post-event duration:	1 - 7200 seconds typical; freely user configurable

Event Summary and Parameters

Content:	PGA, PGV, PGD, SA (at 0.3, 1, 3 Hz)
Transmission delay:	User defined from trigger time

Data Stream

Protocol/Compatibility:	GSBU, SeedLink, Earthworm*

Ring Buffer (Continuous Recording)

Usage:	User can request an event from any period of the ring buffer by specifying the start time/date and the duration from the console or remotely from a server.
Method:	Ringbuffer files with freely configurable duration which can be uploaded automatically to data server.

Storage Memory

Size and Type:	8 GByte Removable SD Card, FAT32 or EXT4 formatted Higher capacity on request*
Management:	Intelligent management of memory card capacity using storage policy to define reserved space per file type.
Recording format°:	miniSEED and extended miniSEED with information encapsulated into blockette 2000
Estimated Capacity:	Sampling rate [sps] x 0.4 [MB/day/3 channel] (example: 40 MByte/day/3 channel @ 100 sps) typical, since the data is compressed, capacity depends on the context of the data.

Self Test

- Permanent self-monitoring of hardware and software components without affecting their normal operation
- User-configurable periodical state of health (SOH) report based on comprehensive test of instrument, which can be requested at any time.
- User configurable periodical sensor test.
- Advanced sensor testing with sine, saw, and square wave injections.
- Logging of temperature and humidity inside the unit.

Timing

Internal clock:	Intelligent Adaptive Real Time Clock (IARTC)
Sources:	Network Time Protocol (NTP), GNSS (GPS, GLONASS, BeiDou and Galileo) with external antenna up to 5 m cable, or with external module up to 100 m cable*
Free running drift:	
without any source:	± 0.5 ppm @ constant +25 °C ± 2.5 ppm @ -10 to +50 °C
after learn (source disconnect):	± 0.02 ppm @ constant +25 °C ± 0.1 ppm @ -20 to +50 °C
Accuracy:	
running free:	calculate from above drift
with NTP:	< ± 0.5 ms
with GPS and ICC:	< ± 0.001 ms
Common time:	NTP grade timing accuracy among separate units over Ethernet TCP/IP networks

Power

Input voltage:	9 - 48 VDC
Power over Ethernet:	90 - 260 VAC / 50 - 60 Hz to 15 VDC switched UL approved external power block*
Consumption:	130 mA @ 12 VDC for 3 channels 200 mA @ 12 VDC for 6 channels
Internal battery*:	7.2 Ah for > 24 h autonomy with intelligent charger, higher autonomy is available with external batteries

Communication and Connectivity

Configuration, Data Retrieval:	Ethernet, Wi-Fi*, Serial line (console), Removable SD card, USB-storage*
Network Requirements:	Fixed or Dynamic IP on Ethernet LAN and/or Internet connection with Ethernet interface or OpenVPN, upload to HTTPS and SFTP severs, Wi-Fi (b/g/n) network with WEP, WPA, WPA2 security and Enterprise Mode*
Security:	GeoDAS proprietary protocol over SSL, Checksum and software handshaking
Connectors:	Power, Ethernet, Multicom (USB and Serial RS-232), SD card*, Sensor(s), GPS*, Alarm*, Option*, Intercon*, Wi-Fi*, micro-USB console*

Alarm and Notification

This provides a seismic switch functionality. SMS notification is available.*

Alarms:	4 independent solid state relay contacts for trigger alarm and/or error (user selectable). NO or NC contacts available. With 1 acknowledge input
Alarm levels:	Freely user configurable based on event triggers
Relay Hold-On:	1 to 60 seconds, typical; freely user configurable
Capacity:	The contacts are suitable for a low voltage control. In case a large load must be switched then external relays should be implemented.
Max voltage:	60 V / 250 mA per relay

Modem / WAN Interfaces*

External peripheral modules for cellular 3G/4G, SHDSL, Fibre optic, etc, are available.

Environment / Reliability

Operational temperature:	-20 to +70 °C▼
Storage temperature:	-40 to +85 °C▼
Humidity:	0 to 100% RH (non-condensing)
MTBF:	> 500'000 hours (based on GMS series)

Housing

Type:	Cast aluminium housing
Connectors:	Metallic circular screwed, or MIL-style*
Size (handles included):	296 x 175 x 140 mm (W x D x H)
Size with base plate:	296 x 225 x 156 mm (W x D x H)
Weight:	4.7 kg (optional < 4 kg*), 1.3 kg base plate, 0.3 kg internal sensor, 2.6 kg internal battery, ask for other options*
Protection:	IP65 (NEMA 4), IP67 (NEMA 6)*
Mounting:	Base plate with single bolt, surface mount. When base plate levelled and fixed, ***scai*** can be replaced without re-levelling.
Easy Transport*:	Portability accessories are available to facilitate short-term measurements.

*: optional; ▼: use of an internal battery may degrade this specification;
°: Retrieved data can be in the following formats depending on transmission, software and storage method used: miniSEED, DAT, ASCII, SEISAN, SUDS, SAC, SEG-2, Matlab, Artemis

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SENSORS

AC-73-NPPss Force Accelerometer

AC-73-DH Force Balance Accelerometer

AC-73-NPPss

Accelerometer Package

Overview

The AC-73-NPPss is a complete accelerometer package designed for demanding nuclear applications. At its core, it features the AC-73-NPP, a high-precision true mechanical force-balance triaxial accelerometer designed for broadband earthquake monitoring and other applications that require a highly sensitive and rugged sensor with minimal maintenance. The sensor is securely mounted in a stainless-steel protective enclosure, providing durability, compliance with nuclear power plant requirements, and ease of installation.

Enclosure Design

The enclosure is constructed from 316L stainless steel, offering excellent resistance to corrosion, even in harsh environments. Additionally, it is rated IP65, providing a high level of protection against dust and water ingress.

Beyond protection, the enclosure also enhances ease of use. It features an integrated cable wire terminal for straightforward installation and connection.

Sensor Technology

At the core of the AC-73-NPP is an advanced true electro- mechanical mass-spring system with a moving coil, which significantly improves the signal-to-noise ratio. The magnetic system and capacitive position sensors ensure symmetrical control for precise electronic centering of the mass. In its resting state, the accelerometer remains balanced with no electrical output.

Key Features

- True electro-mechanical force balance triaxial accelerometer
- Dynamic range 165 dB
- Selectable full scale ± 0.5, ± 1, ± 2 or ± 4 g
- Bandwidth from 0 (DC) to 200 Hz
- Voltage or current-loop output options
- TEST SIGNAL Function facilitates easy and comprehensive sensor self-verification
- Seismic monitoring for Nuclear Power Plants and other critical or industrial facilities

During ground motion, the AC-73-NPP generates an electrical signal proportional to the current used to keep the mass centered. This output is precisely calibrated, ensuring highly accurate acceleration measurements with minimal noise. The symmetrical positioning system, combined with the force- balance accelerometer principle, maintains stable scaling and calibration even under extreme conditions.

The AC-73-NPP supports DC response, enabling simple field testing and recalibration via tilt tests. Additionally, it accepts a test signal which allows for a full system check, ensuring proper operation and accuracy.

The sensor can operate from a 10 up to 36 VDC power supply, with an electrically isolated power input to prevent ground loops and reduce noise interference.

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AC-73-NPP Accelerometer

Specifications

General Characteristics

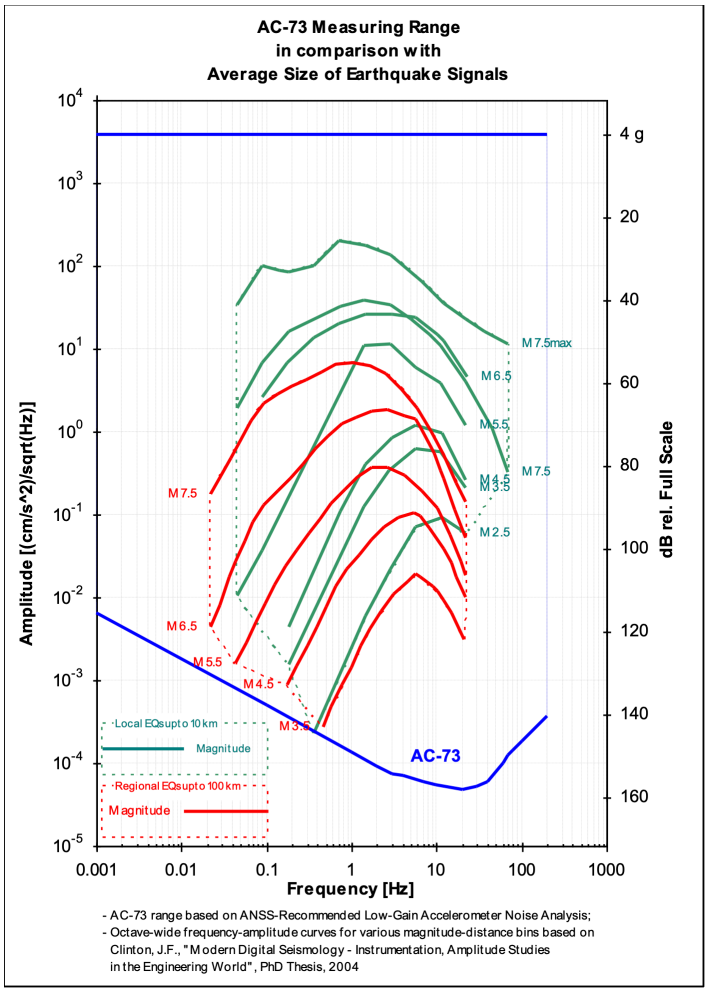
Application:	Seismic monitoring for Nuclear Power Plants and other critical or industrial facilities
Configuration:	Triaxial, floor-mounted
Full scale range:	± 0.5, ± 1 , ± 2, ± 4 g, jumper selectable

Sensor Element

Type:	True electro-mechanical force balance triaxial accelerometer
Dynamic range:	> 165 dB correlated mean RMS noise amplitude (per-bin) with respect to 4 g full scale
Non-linearity:	< 0.1 %
MTBF:	4.1M h with a reliability of 97.9%
Cross axis sensitivity:	< 0.5 %
Bandwidth:	0 (DC) to 200 Hz
Damping:	0.7 ± 0.1 critical
Offset drift:	0.0005 g / °C
Span drift:	200 ppm/ °C

AC-73-DH-NPP version is based on AC-73-NPP series and is rated for utilisation in the nuclear industry.

Full scale output:	± 10 V differential (20 Vpp) (see options)
Sensitivity:	2.5 to 20 V/g
Measuring range:	See plot



Power

Supply voltage:	10 to 36 VDC with soft-start circuitry
Consumption @ 15 VDC:	Typical: 50 mA Max excitation: 250 mA
Overvoltage protection:	All external interfaces are protected

Environment/Housing

Housing type:	Cast aluminium Sealed access cover
Dimensions:	195 x 112 x 95 mm
Weight:	3.0 kg
Index of protection:	IP 65, optional IP 68
Temperature range:	- 20 to +70 °C (operating) - 40 to +75 °C (non-operating)
Humidity:	0 to 100 % (non-condensing)
Mounting:	Single-bolt mounting with 3 levelling bolts adjustable within ± 10°
Mating connector:	Metallic shielded

Options

Any options may be reflected on the P/N of the delivered device.

Full scale output:	0 to 20 mA or 4 to 20 mA current loop
Connector:	Cable inlet (no frame connector)

A custom sensor structure for harsh environment can be provided.

Stainless Steel Enclosure

Specifications

Material:	Stainless steel 316L
Dimensions:	400 x 400 x 120 mm
Weight:	17 kg
Index of protection:	IP 65
Mounting:	Base plate with four bolts
Electrical interface:	Screw wire terminal Earthing screw Cable inlet for sensor cable

Option:
A custom enclosure for harsh environment can be provided.

Qualifications

Certified for compliance to following standards or guides:

Seismic:	NRC RG 1.12 Rev.3, NRC RG 1.166, IEC 60068, IEEE 344, IEEE 323
EMC:	NRC RG 1.180, EPRI TR-102323, MIL-STD 461, IEC 61000, IEEE 1050

Project-specific qualification tests can be performed upon request.

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AC-7X-DH Force Balance Accelerometer

Overview

The AC-73-DH sensor package is a true electro-mechanical triaxial downhole accelerometer designed for broadband earthquake monitoring as well as applications requiring highly sensitive and rugged sensors with minimum maintenance and a simple method for periodic testing.

The rugged mass suspension moving coil system improves the signal to noise ratio. The magnetic system and capacitive position sensors offer symmetrical controls for the accurate electronic centring of the mass. At rest the accelerometer mechanism is in balance and no electrical output is generated.

In case of a ground motion, AC-73-DH yields an electrical output proportional to the current used to keep the mass centred. This output signal is precisely calibrated to provide a signal at the utmost accuracy and with a lowest possible noise level. The symmetrical positioning system incorporated with the force balance accelerometer principle, the accelerometer faithfully keeps its scaling and calibration even under extreme conditions.

The DC response allows the sensor to be tilt tested or recalibrated in the field. With the help of the test line the AC-73-DH accelerometer can be completely tested assuring proper operation and accurate acceleration measurement. This test line is internally connected to the external world only when a given command is sent to the sensor to avoid any noise pick-up through the test input.

Key Features

- True electro-mechanical force balance accelerometer
- Built-in compass as well as tilt, temperature and humidity sensors
- Extremely robust downhole housing
- Suitable for borehole diameters of 100 mm and larger
- Proprietary iSensor™ interface
- Dynamic range 165 dB
- Full scale range: ± 0.5, 1, 2, 3 or 4 g
- Bandwidth from DC to 200 Hz
- Integrated bubble level

The AC-73-DH is equipped with electronic offset adjustment features that make its installation very user friendly. This powerful feature allows the users to install the AC-73-DH without mechanical offset adjustment and fine levelling.

The advanced iSensor™ interface allows easy deployment using built-in hardware like compass as well as tilt, temperature and humidity sensors.

The sensor can be powered from 14 to 18 VDC source with the advantage that its power input is insulated from the sensor's electronic ground. This avoids ground loops and reduces noise induced through the power supply.

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AC-7X-DH Force Balance Accelerometer

Specifications

General Characteristics

Configurations***:

	Triaxial	Biaxial	Uniaxial	Axes	Alignment**
AC-73 or AC-73i*:	■			X – Y – Z	H – H – V
AC-72-H or AC-72i-H*:		■		X – Y	H – H
AC-72-HV or AC-72i-HV*:		■		X – Z	H – V
AC-71-H or AC-71i-H*:			■	X	H
AC-71-V or AC-71i-V*:			■	Z	V

* i : Internal sensor ** H: Horizontal, V: Vertical

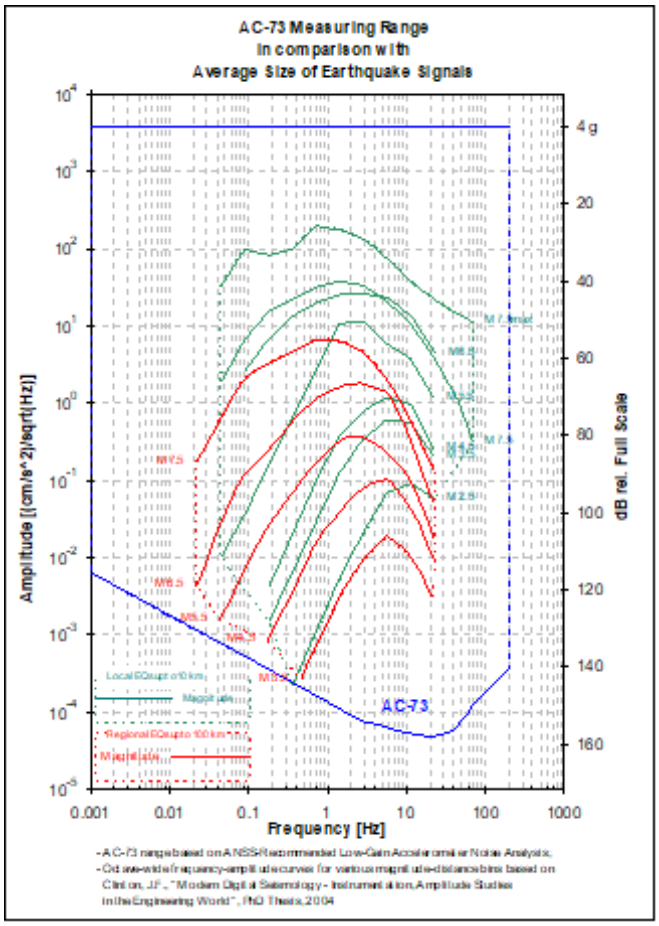
***: add "D" after number of channels for digital version

AC-73-DH-NPP version is based on AC-73-NPP series and is rated for utilisation in the nuclear industry.

Full scale range:	±2 std., ± 0.5, 1, 3 or 4 g

Sensor Element

Type:	True electro-mechanical force balance accelerometer
Dynamic range:	165 dB (per bin rel. full range) 156 dB (per bin rel. full scale rms) 134 dB (0.02 – 50 Hz, integrated PSD)
Nonlinearity:	< 0.1 %
Cross axis sensitivity:	< 0.5 %
Bandwidth:	DC to 200 Hz
Damping:	0.7 ±0.1 critical
Offset drift:	0.0005 g / °C
Span drift:	200 ppm / °C
Full scale output:	0 ±10 V differential (20 Vpp)
Hysteresis:	< 0.001 % of full scale
Sensitivity:	2.5 to 20 V/g
Output impedance:	100 ohms



iSensor™ Interface

iSensor™ interface is a state-of-the-art innovative and proprietary hardware and software interface developed by GeoSIG, which allows through its special computer software the operation, control, logging and data export for the built in:

- compass
- tilt sensor
- temperature sensor
- humidity sensor

Power

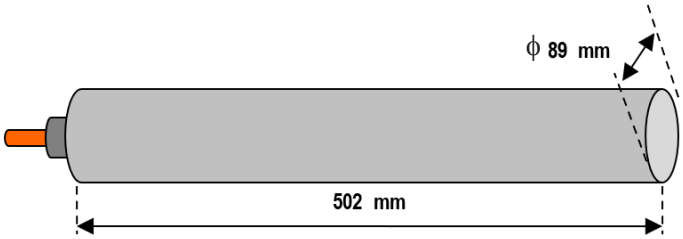
Power input:	Insulated
Supply voltage:	14 to 18 VDC, single supply
Consumption:	80 mA typical, 120 mA max. @15 VDC
Overvoltage protection:	All pins are protected with double stage barrier

Connector Pin Configuration

Pin 1-2, 3-4, 5-6	Signal output for axis X, Y, Z
Pin 7-8	Test input, Digital 0/12 V / GND
Pin 9-10	12 VDC insulated power supply input
Pin 11-12	iSensor™ interface (RS-485)
Case	Shield connection

Environment/Housing

Housing type:	Austenitic stainless steel
Housing size:	ϕ89 mm x 502 mm
Weight:	7.5 kg (typical configuration)
Index of protection:	Watertight up to 10 bar (100 m)
Temperature range:	-20 to +70 °C (operating) -40 to +75 °C (non-operating)



Standard AC-7x-DH Full scale ± 2 g, with cable inlet and surface junction box

Options

Cable & connector:
- See separate cable and connector options sheet
- Connector on user specification can be mounted at cable end

Surface control unit:
- iSensor interface

Ordering Information

Specify: Type of AC-7x-DH, full scale range, depth of deployment, cable length, and other applicable options

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REFERENCE LIST

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Selected NPPs Instrumented with GeoSIG Instruments

In the past decades, GeoSIG Instruments have been delivered to numerous NPP's in many countries worldwide. Some of the NPP's around the world, which are instrumented with GeoSIG Instruments, are listed below.

Country	Project
Argentina	Atucha
Argentina	Embalse
Armenia	Metsamor
Belgium	Doel
Belgium	Tihange
Bulgaria	Kozloduy
Canada	Gentilly
Canada	Pickering
China	Tianwan
Czeck Republic	Temelín
France	Marcoule
Germany	KMK Mülheim-Kärlich
Hungary	Paks
Lithuania	Ignalina - Modernization
Lithuania	Ignalina
Slovak Republic	Bohunice
Slovak Republic	Mochovce
Slovenia	Krško
South Korea	ASTS for 6 Reactors
South Korea	Shin-Kori Unit 5 & 6
South Korea	Shin-Kori Unit 3 & 4 Extension
South Korea	Shin-Wolsong Unit 3 & 4 Extension
South Korea	ASTS for 20 Reactors
South Korea	Shin-Kori Unit 3 & 4
South Korea	Waste Storage Facility (LILW)
South Korea	Waste Storage Facility (LILW)2
South Korea	Shin-Wolsong
South Korea	Shin-Kori Unit 1 & 2
South Korea	Wolsong - Upgrade
South Korea	Ulchin Unit 5 and 6
South Korea	Kori
South Korea	Wolsong Unit 1 & 2
Spain	José Cabrera (Zorita) - Upgrade
Spain	Trillo
Spain	Vandellos
Spain	José Cabrera (Zorita)
Switzerland	Mühleberg

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Country	Project
Switzerland	Leibstadt Phase 2
Switzerland	Beznau Phase 2
Switzerland	Gösgen Phase 2
Switzerland	Gösgen Phase 1
Switzerland	Leibstadt Phase 1
Switzerland	Beznau Phase 1
Taiwan	Maanshan
United Arab Emirates	Barakah
USA	Susquehanna - Upgrade
USA	Arkansas Nuclear One
USA	Beaver Valley Unit 2
USA	Braidwood
USA	Byron
USA	Callaway
USA	Clinton
USA	Connecticut Yankee
USA	Crystal River
USA	Davis-Besse
USA	Diablo Canyon
USA	Enrico Fermi
USA	Hanford N-Reactor
USA	Hatch
USA	Humboldt Bay
USA	Kewaunee
USA	LaSalle County
USA	Marble Hill
USA	Millstone Unit 3
USA	Monticello
USA	Palo Verde
USA	Peach Bottom
USA	Point Beach
USA	Prairie Island
USA	Rancho Seco
USA	Salem
USA	Savannah River
USA	South Texas Project
USA	Susquehanna
USA	Trojan
USA	Wolf Creek
USA	Zion

GeoSIG
swiss made to measure

COMPANY PRESENTATION

Company Brochure

Who we are

GeoSIG Ltd provides earthquake, seismic, structural, dynamic and static monitoring and measuring solutions.

As an ISO certified company, GeoSIG is a world leader in the design and manufacture of a diverse range of high quality, precision instruments for vibration and earthquake monitoring.

Switzerland's early clockmakers were known for their high quality, precision craftsmanship, making famous the terms "Swiss quality" and "Swiss made." Historically, the best clockmakers often also built scientific instruments, as for a long time they were the only craftsmen around trained in designing precision mechanical apparatus.

Since its founding in 1992, GeoSIG has maintained this insistence for high quality, precision workmanship. It has established a permanent and strong position at the top tier of the industry. With significant experience in the development of systems for scientific, engineering and industrial applications, GeoSIG has supplied thousands of systems in successful operation around the world.

Our values

Our main objective is to provide measuring solutions that meet customers' requirements. We accomplish this by providing highly versatile products in terms of features, functions, quality and reliability at an optimum price-to-performance ratio. The design and development of all GeoSIG systems are centred on obtaining the highest possible levels of performance, durability and reliability — qualities which are inherently associated with the words 'Swiss quality'.

Our team of talented individuals with a diverse range of expertise makes GeoSIG a formidable force in supporting our network of highly dedicated Partners around the world. Competing at a global platform, civil engineers, seismologists and earthquake engineers can rely on our dedication for providing a high quality service —from design and manufacture to sale and support — with an unreserved commitment to customer satisfaction.

From accelerometers to digital seismic recorders like the *Digital Sensor System* or *scai* and *nair,* GeoSIG instruments are at work today in more than 100 countries around the world with well-known projects such as the NetQuakes installation with USGS and Øresund Bridge in Denmark. More than 300 major installations in dams, nuclear power plants and major structures on every continent are a testimony to our global presence and our ability to provide solutions to cater for demanding applications.

Our presence around the world