CRYSTAL INSTRUMENTS

# GROUND RECORDER SYSTEM (GRS)

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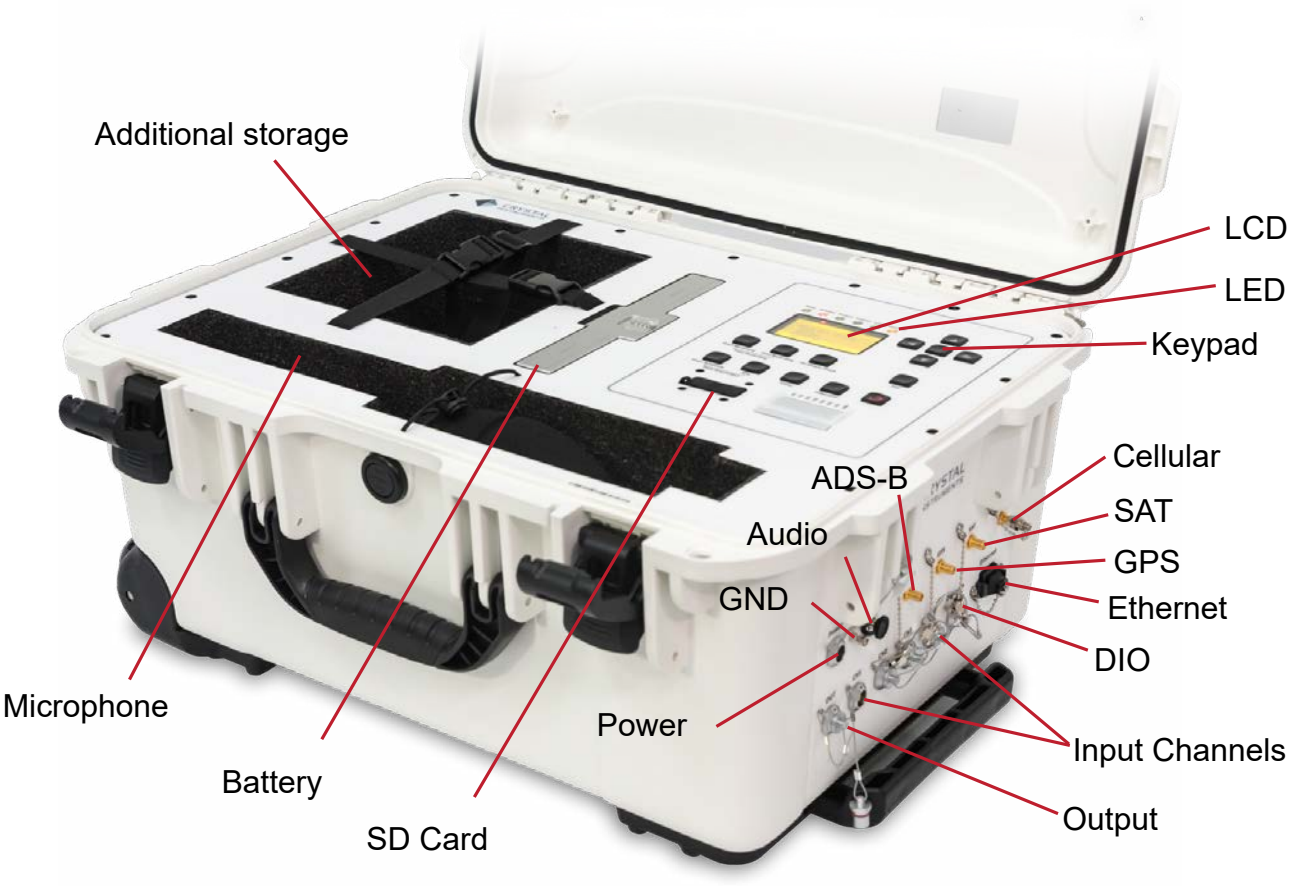
*World's first ruggedized portable dynamic measurement system featuring full integration with space technology.*

# Ground Recorder System

The GRS is a rugged, lightweight, battery powered dynamic data recorder and real-time dynamic signal analyzer with unparalleled performance and accuracy. It is ideal for a wide range of industries that require high grade acoustic and vibration measurements. These industries demand quick, easy, and accurate data recording in addition to real-time processing in the field.




## *GRS Features*

- 24 in × 14 in × 8.3 in ruggedized & weatherproof enclosure
- Two external battery supplies guarantee 12 hours of full operation
- Solar panels can be used to power the GRS and charge its external batteries to facilitate continuous remote operation.
- Four input channels are available, serviced by two 24-bit ADCs. The DSP implements patented technology (**US patent number 7,302,354**) to achieve better than 150 dBFS.
- Built-in GPS receiver allows time synchronized data sampling with up to 100 ns accuracy using Crystal Instruments' patented (**US patent no. 11,611,946**) GPS time synchronization technology.
- Equipped with cellular and satellite modules to allow remote operation.
- Scheduling feature for full autonomous operation.


# Rugged, Weatherproof Enclosure

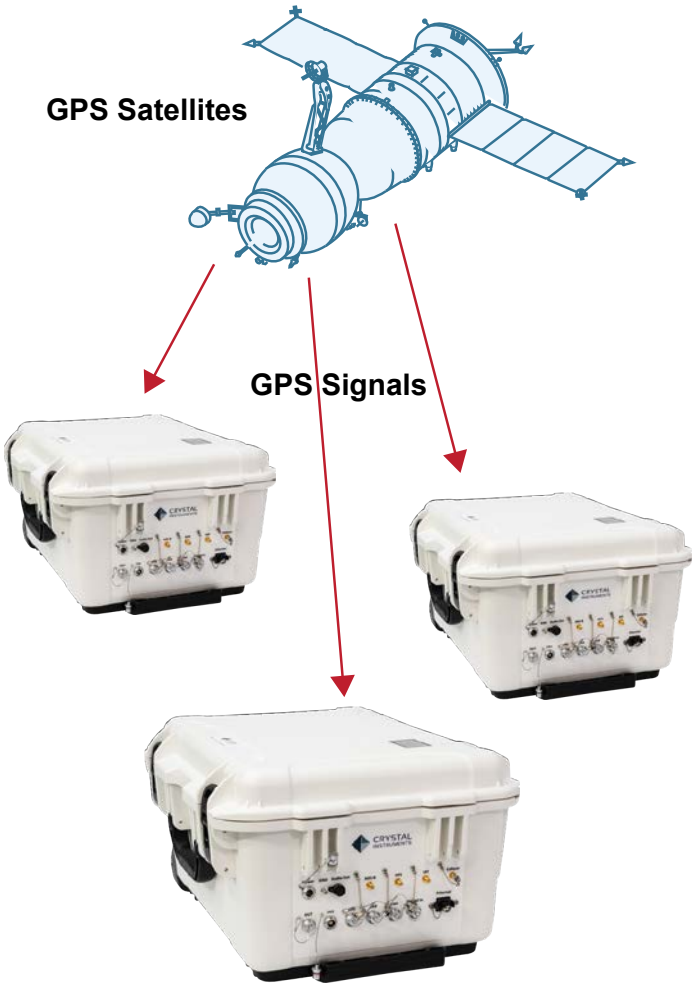
The GRS enclosure is ruggedized and weatherproof to protect the system and its accessories from extreme weather and severe environmental conditions. It is designed to sustain high winds, dust, and heavy rain.

All connectors are rated IP67. The LEMO connectors ensure stability during high winds or harsh environments in addition to providing dust and water protection. The enclosure structure is built using a combination of metal, plastic, and Pelican™ materials.

The GRS is operational in the temperature range of -20 °C (-4 °F) to 55 °C (131 °F). It can be powered ON and be fully operational after cold soaking for 24 hours or longer at 0 °F. The light-gray color of the enclosure is specifically designed to deal with harsh desert sunlight.

The GRS can conduct comprehensive system checks before any measurement is taken, including:

- Processor System check and Internal Hardware Resource check
- IEPE Sensor Loss - check if sensors are IEPE type
- TEDS - check if sensors are TEDS type
- Internal End-to-end Spectrum Measurement check
- SD Card, GPS, ADS-B, Memory checking





## GPS

A built-in GPS (Global Position System) receiver ensures accurate time and location information is always available. Recording data can be time stamped at the ADC clock level. High precision time stamping is implemented at the GRS hardware layer. This approach will eliminate the time latency and variance caused by software operations. The time stamps signals are stored during the same period when measurement recording signals are taken. A unique post processing software was developed to display and process those time stamped signals, which ensures a time stamp accuracy of 100 ns or better.

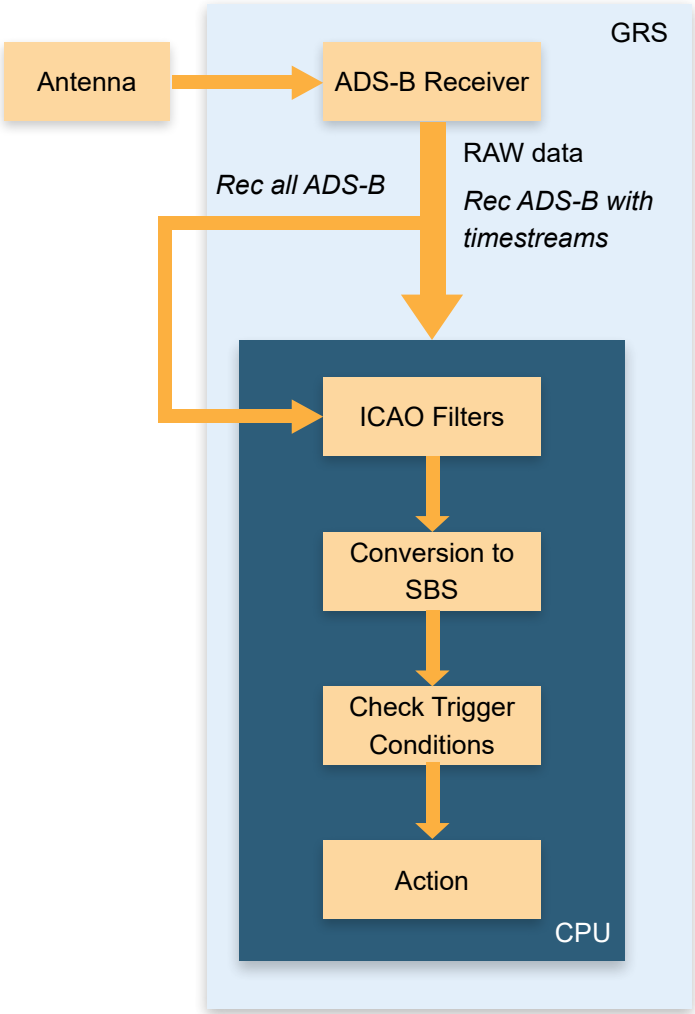
Accurate time stamping allows time streams collected among different GRS units to be synchronized, allowing users to perform an otherwise impossible signal analysis.

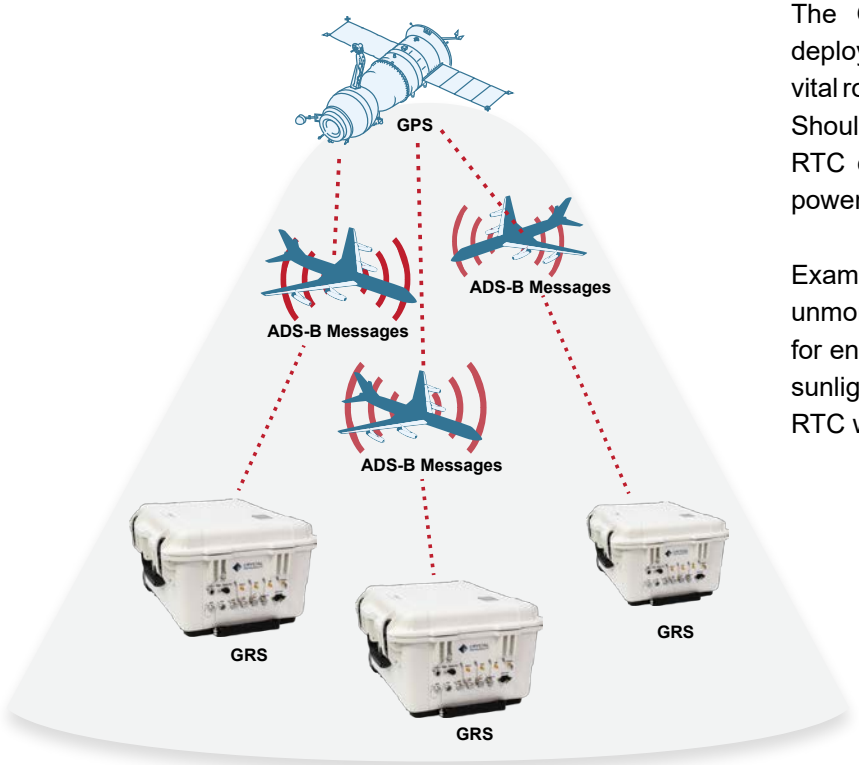
## Master Schedule

The GRS includes a scheduling function that can execute a sequence of actions and repeat actions at specified intervals. This feature not only saves time and effort but also ensures that the system operates consistently and reliably, reducing the risk of human error and increasing overall efficiency.

## Real-time Clock

A dedicated battery-powered Real Time Clock circuitry is designed to recover the system from hardware failures caused by intermittent mechanical shock, over-heating, freezing, or loss of the main battery power. The system can wake itself up at a preset period using the RTC and its counter. The RTC battery is independent from the main power battery and has a lifespan of approximately 10 years.




**Automatic Dependent Surveillance - Broadcast (ADS–B)**

Automatic Dependent Surveillance – Broadcast (ADS–B) is a surveillance technology used by aircraft to determine and periodically broadcast their position with satellite navigation or other sensors, which allows location tracking.

The GRS is equipped with an Aerobits TT-MC1b module to acquire and process ADS-B signals within a 200-mile radius. The module is configured to send data in RAW format. The GRS processor then converts the RAW messages into the SBS-1 base station format.

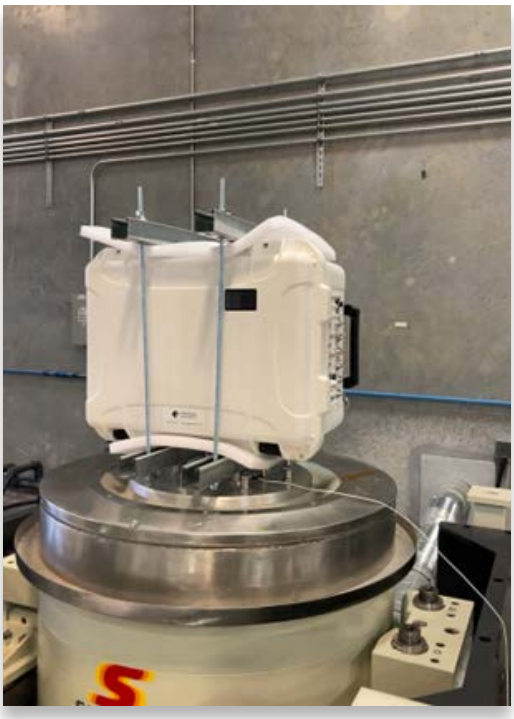
Integrating the ADS-B receiver with the GRS board ensures connection stability and tolerance to shock and vibration forces. Users can also turn off the module and conserve power when not needed.

An interface to connect an antenna is available external to the enclosure through a SMA – female connector. The IP67 antenna ports provide the GRS protection from water and dust during outdoor deployment. Any antenna with a SMA – male connector can be connected to the GRS.

**Failure Protection**

The GRS is specifically engineered for remote deployment, with its second real-time clock playing a vital role in the system's failure protection mechanism. Should an unexpected system shutdown occur, the RTC can initiate a reboot, given that an adequate power supply is present.

Example scenario: the GRS is deployed at an unmonitored location and depends on solar panels for energy. If the solar panels do not receive enough sunlight, the GRS will shut down. The autonomous RTC will persistently prompt the system to restart.

The GRS is designed for remote deployment and the second real-time clock serves as a crucial component of the system's failure protection mechanism. In the event of an unexpected system shutdown, the RTC can power on the system if there is sufficient power available. Consider a scenario where the GRS is installed in an unattended location and relies on solar panels for power. If the solar panels are not receiving a sufficient amount of light, the GRS will shut down. However, the second RTC will continuously send signals to the GRS processor to turn on. As soon as the solar panels generate sufficient power, the GRS will automatically reboot itself.

**Vibration & Shock Durability**

The GRS has undergone and passed shock and vibration tests compliant with the IEC 60068-2-27 International Standard – Shock Testing and -64 International Standard – Basic Environmental Testing.

*Passed tests include:*

**Random Vibration**

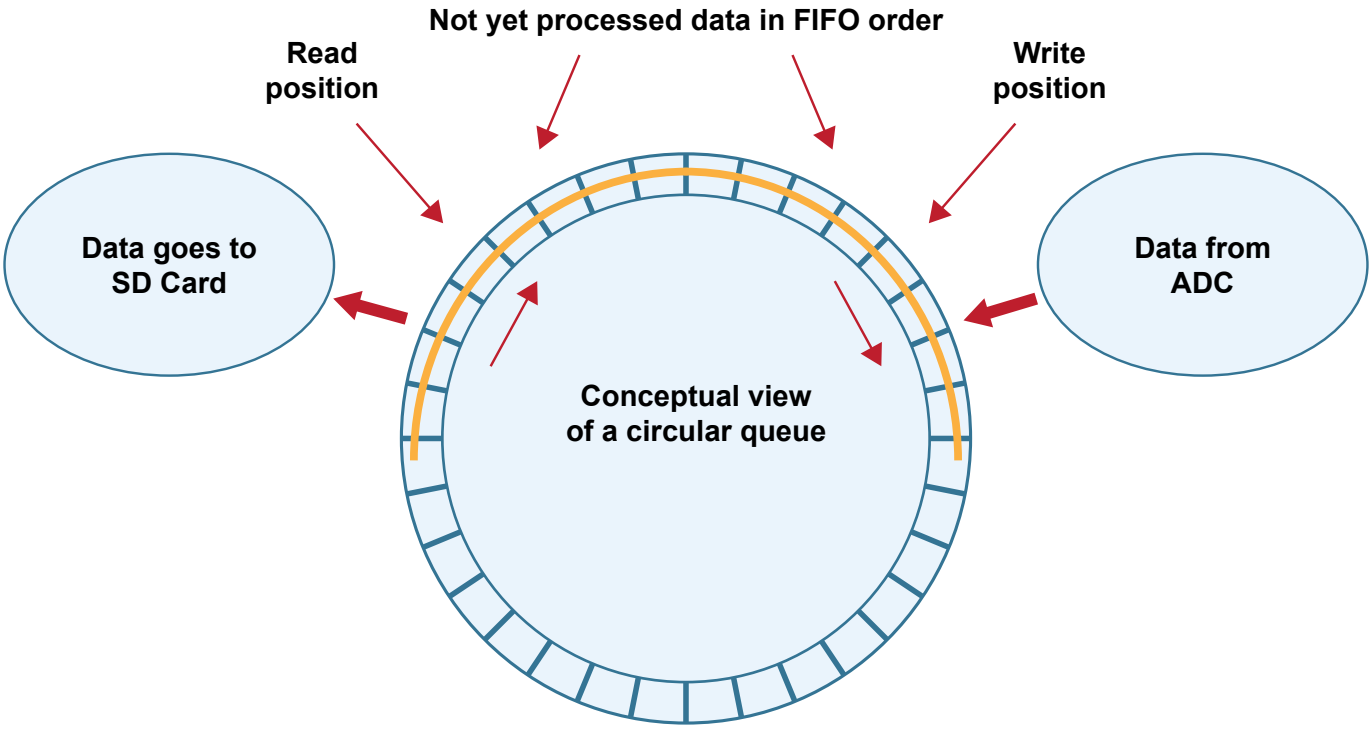
- Overall RMS: 5 g
- Frequency Range: 10 Hz – 500 Hz
- Duration: 10 minutes per axis
- Axes: X, Y, Z

**Shock Test**

- Shock Type: Half-Sine
- Peak: 30 g
- Number of Pulses: 2
- Direction: ±Z

**Shock Test**

- Shock Type: Half-Sine
- Peak: 50 g
- Pulse Width: 3 milliseconds
- Direction: ±Z





**Digital Inputs**

There are six digital input channels inside of the enclosure and two on the outside of the enclosure. All inputs can be used to generate various software events such as starting or stopping a recording.

**Recording**

The GRS is equipped with four input channels. Each analog input is serviced by two 24-bit ADCs and a DSP implementing the patented technology of US patent number 7,302,354 to achieve better than 150 dBFS. Both low and high range ADC channels can be recorded in the dual ADC mode.

The GRS is capable of recording for several months with its available storage.

**Circular Buffer**

The Circular Buffer function is included in the GRS, which allows the system to record up to 150 seconds of pre-trigger data when a trigger is received. This time period is sufficient to capture events leading up to the trigger.

User push button

Digital Input

RTC (Real Time Clock)

On Power Up

ADS-B message

SAT Com message

4G-LTE message

A list of ***Events*** that can cause ***System Actions.***

Master Schedule

| Start CSA |
| --- |
| Start Post Processing CSA |
| Initiate GRS Self-test |
| Initiate End-to-End Self Test |

CSA Operations

| Arm for trigger |
| --- |
| Start/Stop Recording |
| Enable/Disable Output Source |
| Initiate/Reset Run Schedule |
| Save Signals |

Post Processing Operations

| Initiate Post Processing |
| --- |
| Save Processed Data |

Power Operations

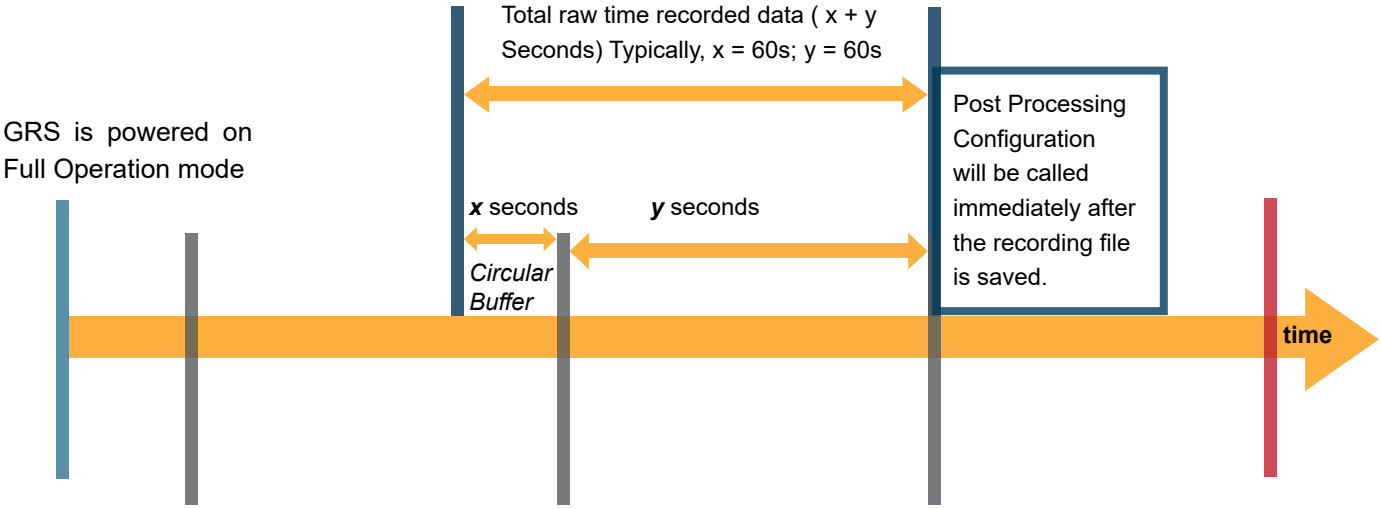
| Set to sleep |
| --- |
| Set to Hibernate |
| Auto Power ON |

***System Actions*** that can be triggered by ***Events.***


# Triggered Recording

Trigger events are defined as user-configurable conditions that are based on several types of inputs fed to the GRS. The inputs can be based on various sources including input channels and peripheral components.

Trigger events and system actions create a powerful system that allows deployment of the GRS in remote areas with minimal user intervention. A wide range of available trigger events and system actions along with an efficient configuration allow users to execute desired functions for several days or weeks when the GRS is left unattended.




## Arm

Scheduled Test begins -

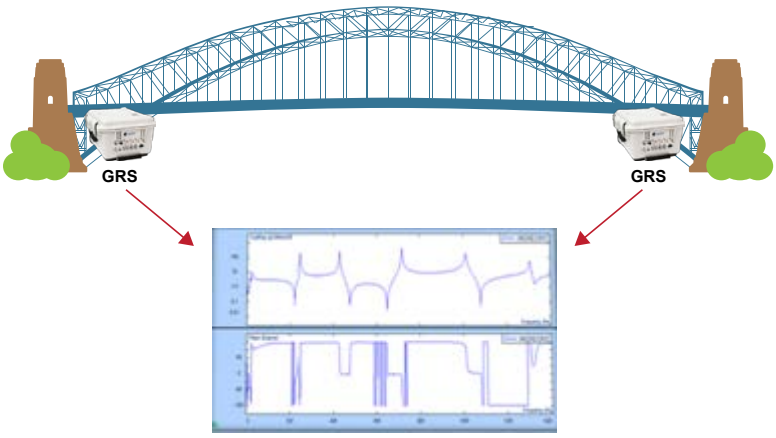
- Schedule Trigger armed
- Start Continuous Circular
- Recording for *x* seconds

## Trigger

From any of the trigger sources

ADS-B message to Stop Recording OR Schedule Stop Recording after ***y*** seconds.

GRS scheduled Low Power mode



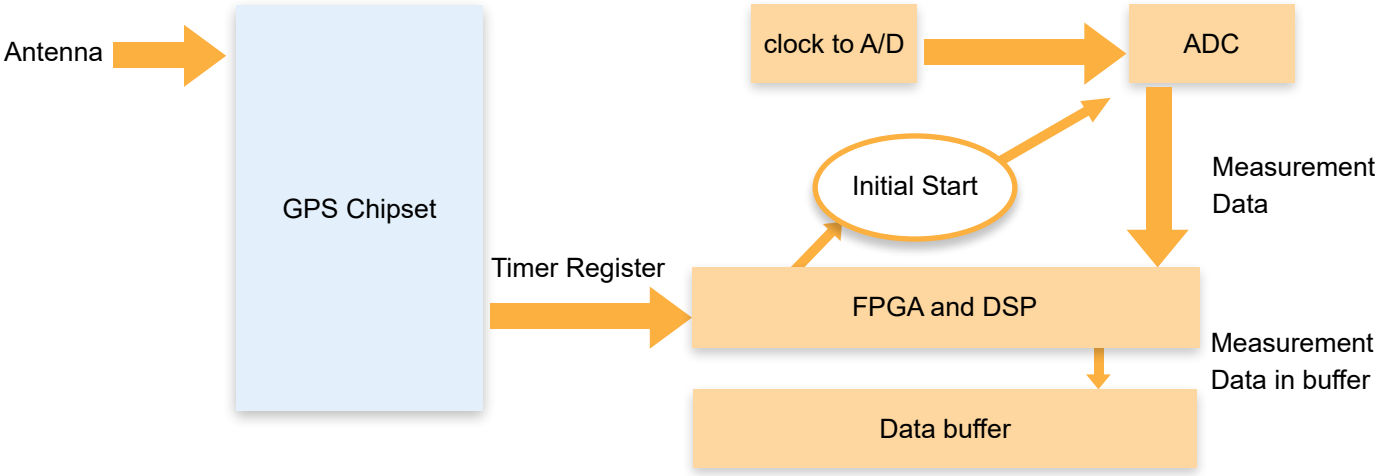

*Compute the frequency response, phase, cross spectrum, or coherence functions between two distant points*

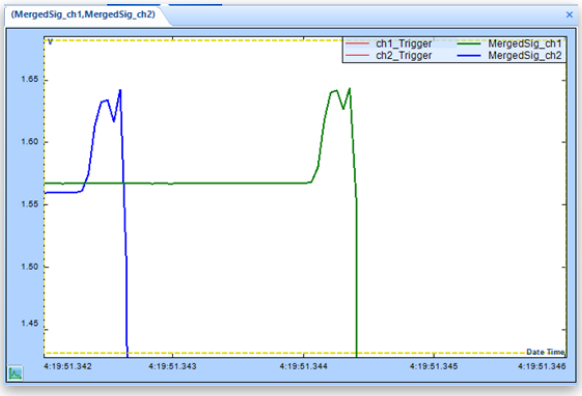
Users can manually initiate a Start Recording command or use a range of sources with user-defined conditions.

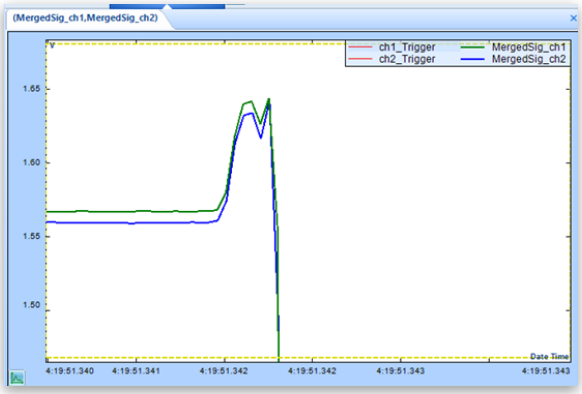
**Memory & Encryption**

The GRS accurately measures and records both dynamic and static signals. The SD card storage simultaneously records four channels for both ADCs at a data rate of up to 102.4 kHz while performing real-time frequency and time domain calculations.

All data stored to the external SD card can be set to be encrypted. The USA Federal Information Processing Standard Publication 140-2, (FIPS PUB 140-2) is a U.S. government computer security standard used to approve cryptographic modules. The GRS implements an encryption algorithm created according to the FIPS PUB 140-2 standard.




# Signal Analysis with Timestamped Data

Multiple GRS data acquisition systems can acquire data simultaneously while they are physically spread out over hundreds of miles. These units do not share any direct hardware connections, but each will receive GPS signals. Accurate time stamping technology implemented with a GPS time base will line up acquired signals on the same time base in Crystal Instruments PA (post processing) software.

A diagram of how time stamping works in the GRS system is illustrated.

*Example:*
The provided example demonstrates how signals are plotted after the sampling rate correction is applied using attached time stamp signals

.
The first plot depicts two signals in the time zone of the triggering point. Each signal was captured using different GRS units.

The time difference shown above is caused by using the nominal sampling rate of each GRS unit, which may vary slightly. The second plot shows the same transient event at the end of recording after the first order correction is applied to the sampling rate of both signals.

| Analog Input Channels | |
|---|---|
| Number of Analog Input Channels | 4 |
| Connector Type | 2-pin LEMO Connector |
| Coupling | AC, DC, or IEPE (ICP©) |
| IEPE Power | 28 V/10 mA |
| TEDS | IEEE 1451.4 compliant |
| Input Range | ±10 V, ±500 mV, Auto Switching, Dual Range |
| ADC Type | Sigma-Delta ADC |
| ADC Resolution | 2 x 24-bit per input channel |
| Frequency Accuracy | Better than ±50 ppm |
| Sampling Rate | 0.48 Hz to 102.4 kHz, with 54 stages |
| Maximum Bandwidth | 45 kHz |
| Input Impedance | 480 kΩ |
| AC Coupling | Analog high-pass filter (-0.06 dB@1.0 Hz, -3 dB @ 0.09 Hz) |
| Input Protection Voltage | ±40 V |
| Analog Anti-Aliasing Filter | -3 dB @ 500 kHz |
| Digital Anti-Aliasing Filter | 110 dB of alias attenuation |
| Pass-Band Ripple | Less than 0.05 dB |
| Digital Filter | Digital high-, low-, and band-pass filters |
| Dynamic Range | 155 dBFS max, 150 dBFS typical, 140 dBFS min<br>Tested in the Dual ADC mode |
| THD (High Range ADC) | -92 dB at 1 kHz<br>-81 dB at 8 kHz |
| THD (Low Range ADC) | -90 dB at 1 kHz<br>-91 dB at 8 kHz |
| Crosstalk | Less than -120 dB at 1 kHz |
| Amplitude Channel Match | Less than ±0.05 dB |
| Phase Channel Match | Less than 0.1 degrees at 20 kHz |

**Noise**

*Audio BW is defined as 20 Hz to 20 kHz.*
*Full BW high frequency is 15 Hz to 40 kHz.*
*All noise specs are typical.*

| Low Range ADC | | High Range ADC | |
|---|---|---|---|
| Audio BW | Full BW | Audio BW | Full BW |
| 5 µVrms | 7 µVrms | 70 µVrms | 100 µVrms |

30 nV/√Hz at 1 kHz (Low Range ADC)
500 nV/√Hz at 1 kHz (High Range ADC)

| Output Channel (Analog Signal Source) | |
|---|---|
| Number of Output Channels | 1 |
| Connector Type | 2 Pin LEMO |
| Frequency Range | DC to 45 kHz |
| DAC Resolution | 24 bits |
| Output Dynamic Range | 140 dB (1 µV to 10 V) |
| Anti-Imaging Filtering | 160 dB/octave digital filter and analog filters |
| Digital Filter | High-pass and low-pass digital filters |
| Types of Output | DC, Sine, White Noise, Pink Noise, User defined Waveform (Arbitrary Waveform) |
| Output Voltage Range | ±10 V |

| Environmental and General Specification | |
|---|---|
| Power Consumption (Max) | 13 W |
| Internal Battery | Two pieces 94 WH rechargeable Li-ion type (Removable), totally 188 WH |
| Operating Time | 12 hours (Full-up mode) with internal battery |
| Charging Time | 5 hours with 15V / 3A<br>6 hours with 100 W Solar Panel (14 V) |
| Power Supply | DC power 15 V (±10%) / 3 A<br>CI provides AC voltage adapter. |
| Safety Standard | EN 61326 1997+A1 1998+A2 2001<br>EN61000-3-2 2000<br>EN61000-3-3 1995 + A1 2001 |
| Internal Sensors | Temperature |
| Cooling | Water Pipes and Heat sink, No cooling fan on the enclosure; One small cooling fan on CPU. |
| Temperature | |
| - Operational | -20 °C to +55 °C ( -4 °F to 131°F) |
| - Storage | -40 °C to +70 °C (-40°F to 158°F) |
| Vibration | |
| - Shock Non-operation, 6 sides | 50 g, 3 ms half-sine; 30 g, 11 ms half-sine; 50 g, 50 ms (315 in/sec) half-sine |
| - Random Operational, 3 sides | 0.3 grms from 5–500 Hz |
| - Random Non-operational, 3 sides | 5 grms from 10–500 Hz |

| Enclosure Specification | |
|---|---|
| Dimensions | 21.5 in × 14 in × 8.3 in (54.5 cm × 35 cm × 21 cm) |
| Weight | 32 lbs including batteries |
| Transparent Panel | A rectangular transparent panel is mounted on the surface of enclosure. The user can see the Status Panel and LEDs mounted inside without opening the enclosure. |

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