

Sensor Box for Structural Health Monitoring Applications

Features

Accelerometer: 3-axis with industry-leading noise spectral density of $\leq 25 \mu\text{g}/\sqrt{\text{Hz}}$, low 0g offset drift, with selectable measurement ranges of $\pm 2\text{g}$, $\pm 4\text{g}$, and $\pm 8\text{g}$, minimal offset drift over temperature, long-term stability, and selectable sampling rate, from 30Hz to 2kHz.

Gyroscope: 3-axis with unprecedented stability at zero-rate level and sensitivity over temperature and time, with up to 8.75mdps resolution and 100Hz to 800Hz sample frequency.

Inclinometer: 2-axis with a high-accuracy, ultra-low noise, high stability, and repeatability, with selectable full scale of $\pm 0.5/\pm 1/\pm 2/\pm 3 \text{ g}$ featuring ultra-low noise $15 \mu\text{g}/\sqrt{\text{Hz}}$ performance and selectable sampling rate, from 12.5Hz to 800Hz, specifically designed for structural health monitoring applications.

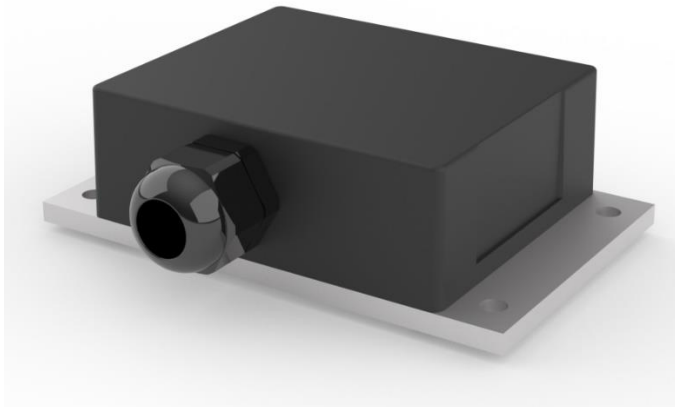
Magnetometer: 3-axis ultra-low-power high performance for automatic detection of box orientation.

Internal Thermometer

Synchronization between all devices ≤ 1 millisecond for 100+ devices on the same network.

Power and Data over One Cable: keep costs low by choosing to install using a low-cost CAT5 cable and RJ-45. Supports a cable length up to 250m.

Aluminum Case with IP68 Certification: the device can be embedded in concrete, or an iron base can be installed upon request, for soldering the device to the structure to prevent theft.



General Description

MonStr-O is a highly advanced device designed for use in structural health monitoring. It features an IP68 aluminum box that contains an extremely low-noise 3-axis accelerometer and a 2-axis inclinometer (both specifically designed for structural health monitoring), a 3-axis gyroscope, an internal thermometer, and (optionally) a 3-axis magnetometer for orientation detection. A synchronization engine that syncs the clocks of up to 100 MonStr devices on the network with a 1-millisecond precision. It features a single connector for both power supply and data transport with plug-and-play functionality. Simply connect one cable, and everything starts working automatically! The collected data are stored in an HDF5 database.



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Operational Temp. Range: -10°C to 70°C

Customizable Device Set-Up: sensor parameters for each device on the network can be customized depending on the application by selecting the dynamic range, sample frequency, etc. The acquisition software automatically customizes all devices.

Plug and Play Functionality: connect the devices to the central data collector and automatically start monitoring. Devices can be added or removed from the network at any time, even without stopping the network. Just plug in the MonStr-O, and data acquisition will begin.

Extremely Low Power Consumption: every MonStr-O draws a mere 0.6W.

No Costly Acquisition Systems: the only acquisition system needed is your PC!

Data Collected is Presented in an HDF5 Database: the same database used by NASA, optimized for big data and fast processing. Data can be easily stored and processed with third-party software or with our state-of-the-art software.

Vast Selection of Processing Algorithms: directly developed by our software division colleagues, ASDEA Software, a world-leading company in structural engineering software, with decades of experience in the field.

Impressive Selection of Presentation Software: with cloud computing capabilities, real-time charts, and smartphone apps to visualize data anywhere in real-time.

Applications

The MonStr-O network is an elegant solution for digital twinning, the future of structural health monitoring for all kinds of structures. Digital Twinning technology creates an exact finite element digital replica of a structure using dedicated modeling software (such as STKO developed by ASDEA Software).

Using AI and the data gathered by the MonStr-O sensors, the digital replica continuously updates to reflect changes to the structure in real-time. It can then model potential future behavior of the structure, simulate behavior under unusual stress (i.e., disaster situations), and be used for maintenance and renovation purposes.

The MonStr-O devices can be used to create digital twins of bridges, heritage buildings, residential structures, railways, etc.; the possibilities are endless!



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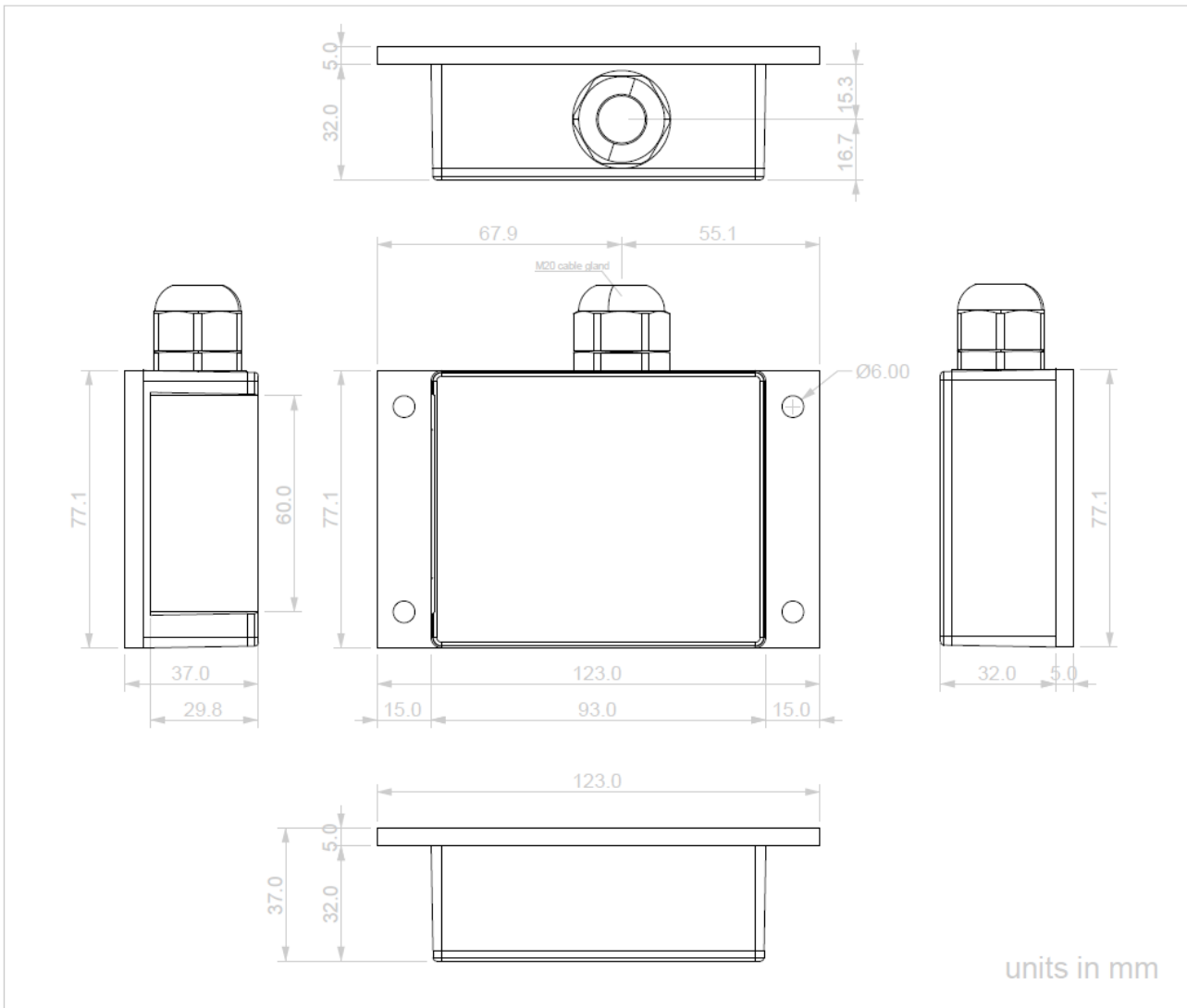


Figure 1: Product outline and mechanical specs

Mechanical Specifications

The MonStr-O is enclosed in an IP68 certified aluminum case.

The M20 cable gland allows the connection of the external cable, ensuring the IP68 feature.

The base of the enclosure has M6 holes to allow the installation of the device using M6 screws. The standard base is made of aluminum, but an iron base can be selected.

The iron base can be soldered directly to the structure, preventing theft. During installation, the device can also be directly sunk into the concrete of the structure.

The device is operational in the -10°C to 70°C temperature range.

Sensors Specifications

Accelerometer		
Parameter	Test condition/Comments	Unit
Range	Remote Selection Enabled	± 2g ± 4g ± 8g
Sample frequency	Remote Selection Enabled	2000 Hz, 500 Hz Low Pass Filter 1000 Hz, 250 Hz Low Pass Filter 500 Hz, 125 Hz Low Pass Filter 250 Hz, 62.5 Hz Low Pass Filter 125 Hz, 31.25 Hz Low Pass Filter 62.5 Hz, 15.625 Hz Low Pass Filter 31.25 Hz, 7.813 Hz Low Pass Filter
Sensitivity	at ± 2g at ± 4g at ± 8g	3.9 µg 7.8 µg 15.6 µg
Noise	at ± 2g at ± 8g	22.5 µg/√Hz 25 µg/√Hz

Table 1: Accelerometer specifications

Gyroscope		
Parameter	Test condition/Comments	Unit
Range	Remote Selection Enabled	± 245 dps ± 500 dps ± 2000 dps
Sample frequency	Remote Selection Enabled	800 Hz, 110 Hz Low Pass Filter 400 Hz, 50 Hz Low Pass Filter 200 Hz, 50 Hz Low Pass Filter 100 Hz, 25 Hz Low Pass Filter
Sensitivity	at 245 dps at 500 dps at 2000 dps	8.75 mdps 17.50 mdps 70 mdps

Table 2: Gyroscope specifications

Thermometer		
Parameter	Test condition/Comments	Unit
Range		-40°C to 125 °C

Table 3: Thermometer specifications

Inclinometer		
Parameter	Test condition/Comments	Unit
Range	Remote Selection Enabled	± 0.5g ± 1g ± 2g ± 3g
Sample frequency	Remote Selection Enabled	12.5 Hz 26 Hz 52 Hz 104 Hz 208 Hz 416 Hz 833 Hz
Low-pass filter	Remote Selection Enabled	Sample frequency /2 Sample frequency /4 Sample frequency /10 Sample frequency /20 Sample frequency /45 Sample frequency /100 Sample frequency /200 Sample frequency /400 Sample frequency /800
Sensitivity	at 0.5g at 1g at 2g at 3g	15 µg 31 µg 61 µg 122 µg
Noise		15 µg/√Hz

Table 4: Inclinometer specification

Magnetometer		
Parameter	Test condition/Comments	Unit
Range		16 gauss
Sample frequency		1000 Hz, 110 Hz Low Pass Filter
Sensitivity	at 16 gauss	0.6 mgauss

Table 5: Magnetometer specifications

Connectivity Specifications

Cable and Mechanical Connector

MonStr-O features a low-cost female RJ45 connector, significantly decreasing connection costs.

To further cut costs, a CAT5 4 twisted pair Ethernet cable can be used.

To connect the MonStr-O, simply connect an RJ45 male connector to a CAT5 cable, plug it into the device, and tighten the cable gland. This combo is inherently low-cost and extremely versatile.

The RJ45 can also be mounted to the cable in the field with minimum time and effort. The cable length can be customized on-site, avoiding waste.

Both power supply and data are delivered via the same cable. Simply connect the cable, and MonStr-O is ready to work.

Data Transport

Data is collected using an Ethernet connection based on TCP/IP.

Every MonStr-O is IEEE 1588 protocol compliant, enabling all devices in the network to sync their clocks to 1ms accuracy, meaning all collected data are coherent time-wise.

This feature was developed to ensure temporal coherence, as it is fundamental for data processing. The high temporal accuracy ensures the completeness of data analysis, creating an accurate picture of the health status of the monitored structure.

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Power Supply

The devices are powered using Power over Ethernet (PoE). Two modes are available:

- Standard mode, with cable length up to 100m
- Extended mode, with cable length up to 250m

MonStr-O consumes an impressively low 0.6W.

Network Specifications

Network

It is possible to connect up to 100 MonStr-O devices on the same network. Projects needing to connect more than 100 nodes should contact ASDEA Hardware for a technical evaluation.

Acquisition System

All MonStr-O devices on the network are directly connected to a central acquisition system that collects and analyzes all the data.

This central device is composed of:

- an Ethernet switch with the appropriate number of Ethernet ports to connect and power the MonStr-O devices;
- Your PC for collecting and processing all the data coming from the MonStr-O devices in the network

Compared to other available systems on the market, the MonStr-O network reduces cost and complexity by being designed to work with average PCs and common, low-cost ethernet switches. You get cutting-edge technology using tools you may already possess or can acquire readily with little expense.

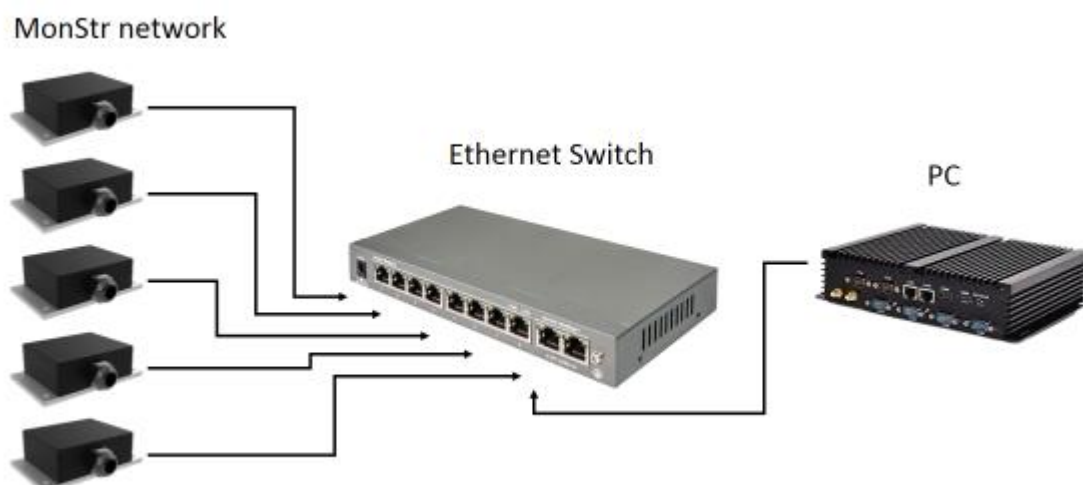


Figure 2: MonStr network diagram



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Network Set-up

Plug and Play

The entire network is designed to be plug-and-play. Simply connect the MonStr-O devices and the central PC to the same Ethernet switch, power up the switch and the PC, and the system will start working automatically, acquiring and analyzing data. All required software is pre-installed, pre-configured, and auto-running.

It is also possible to add MonStr-O devices on an already working network without stopping it: just plug in the new device, and the PC will automatically detect and manage the acquisition.

Sensor Feature Customization

All the sensor features listed in Table 1, Table 2, Table 4, and Table 5 are automatically configured by the PC used for acquisition. You can choose to either:

- configure the same features on all devices,

or

- configure each device with a specific set of features.

The parameters that best suit your particular application are already calculated for you, but you can also decide to customize the parameters to suit your particular needs.

The dedicated software interface allows you to change the feature configuration with ease.

Software and System Output

Collected Data

All collected data is written in an HDF5 database. The HDF5 database is built for storing a huge and heterogeneous data set while enabling fast I/O and storage. It is state-of-the-art for big data and fast processing and is commonly used by high-tech companies, such as NASA.

Every database is identified with a microsecond resolution timestamp to collocate the data temporarily.

The acquisition system is also ntp compliant, keeping the system clock constantly and automatically updated.

Processing Algorithm

The fast and automated modal analysis can extrapolate Eigenfrequencies, Damping, and Eigenmodes.

State-of-the-art modal analysis algorithms are used for time and frequency domains for single and multisetup analyses. For the frequency domain both Complex Mode Indicator Function (CMIF) and Operational Polyreference Least Squares Complex Frequency (Operational Poly-LSCF) are used. Instead, for the time domain, choose between Unweighted Principal Component (SSI*- UPC), Principal Component (SSI*- PC), Canonical Variate Analysis (SSI*- CVA), and Covariance Analysis (SSI*- COV).

*SSI = Stochastic Subspace Identification

Ordering Guide

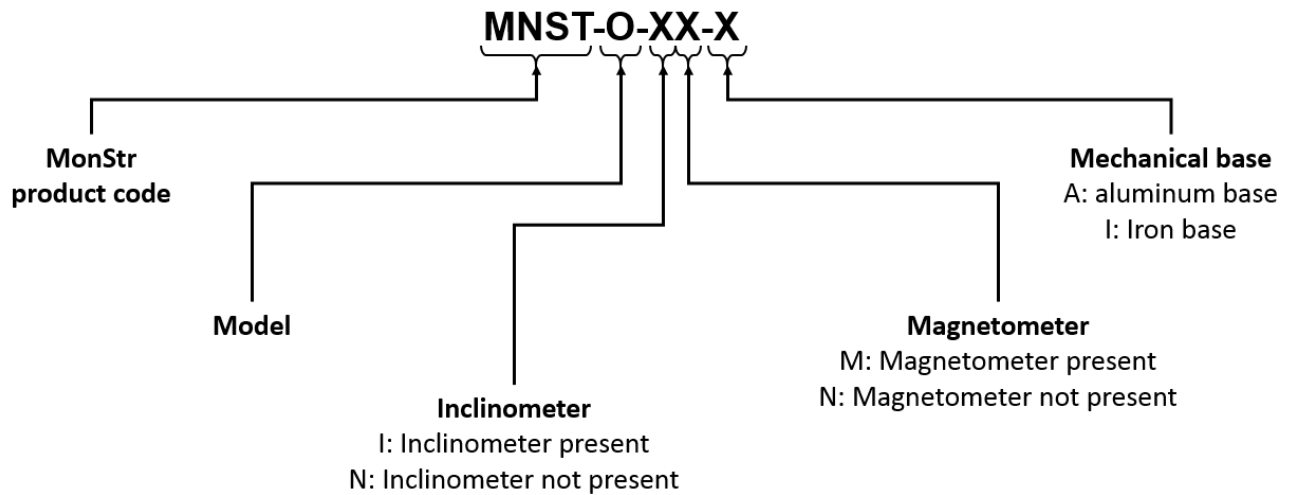


Figure 3: MonStr part number description.

Available Models	
Part Number	Description
MNST-O-NN-A	NO inclinometer, NO magnetometer, aluminum base
MNST-O-NM-A	NO inclinometer, magnetometer present, aluminum base
MNST-O-IN-A	inclinometer present, NO magnetometer, aluminum base
MNST-O-IM-A	inclinometer present, magnetometer present, aluminum base
MNST-O-NN-I	NO inclinometer, NO magnetometer, iron base
MNST-O-NM-I	NO inclinometer, magnetometer present, iron base
MNST-O-IN-I	inclinometer present, NO magnetometer, iron base
MNST-O-IM-I	inclinometer present, magnetometer present, iron base

Table 6: Available MonStr models