## GENERAL DESCRIPTION

**The extremely robust and reliable HailFlow HF4 sensor is a highly specialized acoustic instrument for the detection of hail and the characterisation of hailstone size.**

■ HailFlow RF4 is a very low-power, maintenance-free, totally sealed and mechanically ultra-robust acoustic instrument with no mobile parts. It is able to detect hailstones up to 7.5 cm diameter and will survive the most extreme hail episodes.

■ The sensing part of the instrument is a three layers polished stainless disc supported by an unbreakable stainless-steel arm.

■ Impacts of hailstones (or any other lithometeors in the same range of kinetic energy) induce a measurable change in internal acoustic pressure.

■ The instrument includes a dedicated analog conditioning module, a digital I/O module and an analog restitution module. It can thus be connected to, or communicate conveniently with almost any external analog or digital central unit (data logger, industrial module interface, instrumentation DAQ, USB port). It features continuous or pulse analog voltage outputs, SDI-12 communication (meteorological standard communication protocol), TTL-Serial (3V3), RS-232 (with adaptor) or RS-485 (with adaptor).

■ The full configuration of the sensor can be customized at any time, in a non-volatile memory, with a Plug-and-Play computer connection thanks to the universal USB dongle accessory provided with the sensor and the free ISAW-Toolbox software suite. The sensor can also be configured remotely, using serial commands.
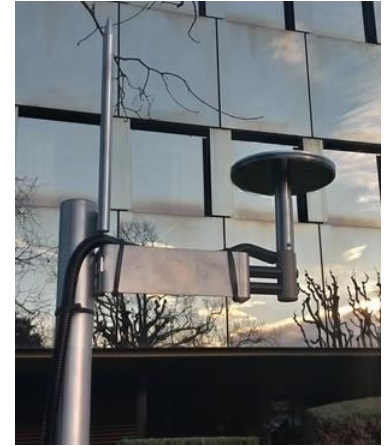
## KEY FEATURES

■ Maintenance-free & special design and construction to resist the highest winds, extreme temperatures, rime, sunlight, abrasion, ashes and even temporary submersion.

■ Lightweight, corrosion free, UV/Ozone stable, non-obstructable. Resistant to shock, vibration, lightning, corrosion, humidity, animals, insects and splashes. Operating temperature from −40 °C to 80 °C (−50 °C to 100 °C extended).

■ Very low power consumption: 2.1 mA continuous for a nominal operation (10% duty-cycle) or 21 mA for a continuous operation.

■ Plug-and-Play or totally configurable to fit any application.

■ Adaptable to any structure thanks to a range of very high standard stainless steel clamping accessories.

■ Directly connect the sensor to your central unit or configure any analog or digital communication through the USB dongle accessory.

■ Compatible with almost any external analog or digital central unit, with a very long extension cable (typ. up to 200 m), with IoT (LPWAN) transceivers, with industrial control systems (BMS, SCADA, etc.).

## TYPICAL APPLICATIONS

■ Meteorology (hail, solid precipitation, lithometeors)

■ High resolution hail monitoring and warning

■ Maritime and offshore applications (wind turbines, buoys)

■ Building and infrastructure surveillance and insurance

■ Roadside, railway, airport protection

■ Agriculture

■ Land management

■ Applied scientific research
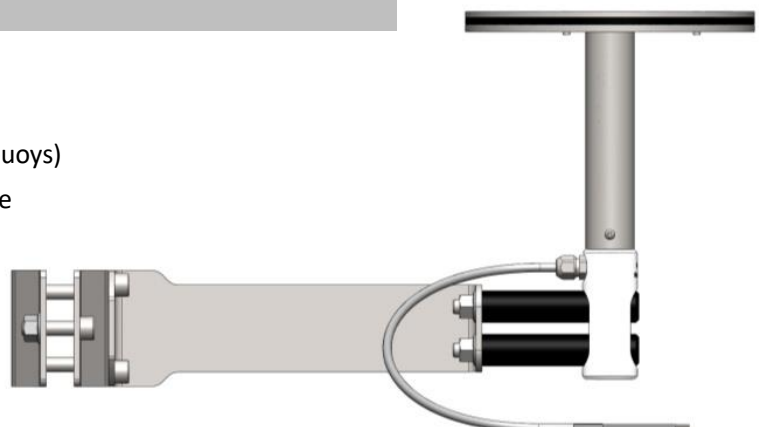
## OPERATING PRINCIPLE

■ The HailFlow HF4 sensor measures the **impact of individual solid particles** on a stainless-steel disc using a specialized microphone, signal processing and calculation. The sensing surface is a **200** mm diameter wind-omnidirectional head, containing the electronics of the system and mounted on a rigid foot.

■ The sensor intercepts the falling hailstones (or other lithometeors) and a high-resolution impulse detector converts the acoustic signal of each individual impact into a voltage, proportional to the **momentum of the impact transferred to the sensing surface** (the higher the transfer of momentum to the sensing surface, the higher the impulse acoustic response caught by the microphone). For each individual impact, the momentum that is transferred to the sensing surface can be considered to depend mostly on the hailstone size.

■ The sensitivity and the internal processing of the sensor are set to distinguish between **15 classes of hailstone diameter, ranging from 0.5 to 8 cm** (see table opposite), with a capability of counting up to **25 solid impacts per second**. This function, that is comparable to the so-called disdrometry (DSD) function for rain, provides a statistic value result, defined as a distribution expressing the percentage of hailstones situated in as many drop-size classes, according to a classification table (see opposite). The sensor's classification table for hailstone-size includes **15 classes** of equal intervals. The lower marker of the smallest class is a diameter of **0.5 cm** and the upper marker of the biggest class is a diameter of **7.5 cm**. The upper and lower markers typically correspond of the thresholds of respectively the detection and saturation of the sensor, with a margin of operation (hailstones with a diameter of less than 0.5 cm and more than 80 mm may still be detected).

■ **Note:** the sensor is not sensible to rain at all.

| Class # | Class Label | Hailstone Diameter Min. - Max. (mm) | | |
|---------|-------------|------|---|------|
| 1 | 10.0 | 5.0 | - | 10.0 |
| 2 | 15.0 | 10.0 | - | 15.0 |
| 3 | 20.0 | 15.0 | - | 20.0 |
| 4 | 25.0 | 20.0 | - | 25.0 |
| 5 | 30.0 | 25.0 | - | 30.0 |
| 6 | 35.0 | 30.0 | - | 35.0 |
| 7 | 40.0 | 35.0 | - | 40.0 |
| 8 | 45.0 | 40.0 | - | 45.0 |
| 9 | 50.0 | 45.0 | - | 50.0 |
| 10 | 55.0 | 50.0 | - | 55.0 |
| 11 | 60.0 | 55.0 | - | 60.0 |
| 12 | 65.0 | 60.0 | - | 65.0 |
| 13 | 70.0 | 65.0 | - | 70.0 |
| 14 | 75.0 | 70.0 | - | 75.0 |
| 15 | 99 | 75.0 | - | |

## HAIL MEASUREMENT OUTPUT

The output of the hail detection function is:

■ **Digital outputs:** a set of 36 semicolon-separated values as:

```
HAILSTONE;<counter>;<unit>;<hit_count>;<unit>;<unit>;<class>;<distrib>;<class>;
<distrib>;<class>;<distrib>;…;<class>;<distrib>
```

where  $<counter>$ is a frame counter incremented at each result
$<unit>$ is the unit of the following values in the frame: "hit"
$<hit\_count>$ is the number of hailstones [hit]
$<unit>;<unit>$ are the units of the following pairs of values in the frame: "mm;%"
$<class>$ is the fixed hailstone size class in millimeters [mm] (see table below)
$<distrib>$ is the percentage of hailstones within the class [%]

Example:

```
HAILSTONE;9322;hit;7;mm;%;10;0;15;0;20;0;25;0;30;0;35;14;40;14;45;29;50;29;55;
14;60;0;65;0;70;0;75;0;99;0
```

■ **Analog outputs:** a voltage proportional to the maximum count rate reached during one acquisition duration A over the writing interval W (full-range corresponding to 25 counts/sec.).

**Note:** For hail detection, it is recommended to set the sensor operation a duty-cycle of 100% (or close to 100%, or at least with a small stand-by duration between two successive acquisitions), so that a short duration event could not remain undetected or too much underestimated because of a too-long stand-by mode of the sensor.
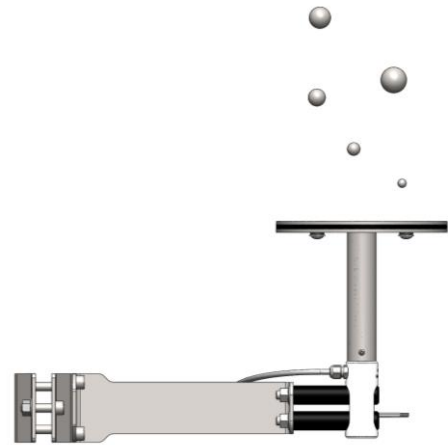
## SENSOR CALIBRATION

■ **Each sensor is factory calibrated** individually at the firmware and electronic levels, using a full chain acoustic calibrator that tunes the sensor to the desired nominal acoustic sensitivity with an accuracy of at least ± 3%. A second and final round of calibration, taking into account the global vibroacoustic response of each individual sensor, is performed under a controlled kinetic energy fall with a concluding precision of ± 5%, this performing to a said ± 10% global precision of the instrument to the momentum of a calibrated elastic impact.

■ **Note:** The hailstone impact can be inelastic as the hailstone may break and explode during the impact. In this case, a part of the kinetic energy of the shock is dissipated into the hailstone itself, and thus not transferred to the instrument. Also, other factors, such as the density (air-ice mixture) and the shape (round, angular) of the hailstones can induce other minor biases in the classification in nominal hailstone size classes.
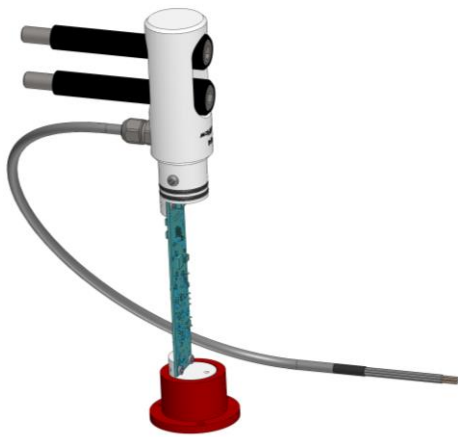


*Factory acoustic calibration*



*Factory kinetic energy fall*

## FIELD CHECKING

■ The sensor can be checked at any moment by vertically dropping a calibrated 25 mm diameter polypropylene ball (provided with the sensor) from a 1 m falling height. The ball provides the sensor with an excitation similar to the transferred momentum of the **impact of a 1.5 to 2.0 cm diameter hailstone at terminal velocity**, and is thus a convenient way to read and check the validity of the output of the sensor (and possibly the full reading chain of the instrument).

**Field checking ball**



Ø 25 mm
$\rho = 0.91$ g/cm$^3$
Falling height H = 1 m
Momentum 33 g×m/s
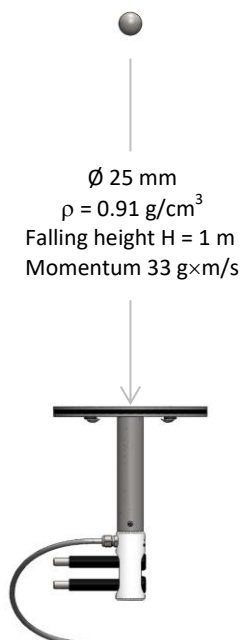


*Field checking result in scope mode. This signature is similar to the response of the sensor to the impact of a 1.5 to 2.0 cm diameter hailstone at terminal velocity.*

## SPECIFICATIONS

### ■ MEASURING CHARACTERISTICS

| Measuring characteristics | |
|---|---|
| Measuring surface | 200 mm outer diameter disc |
| Precipitation detected by the sensor | Solid only (hail).<br>15 classes, from 0.5 cm (minimal detectable diameter) to ≥ 7.5 cm (possible saturation of the instrument).<br>Counting of the number of hailstone impacts up to 25 impacts per second. |
| Measurement accuracy | For a given controlled elastic momentum impact (such as spheres of equal diameter, density, Young modulus, falling speed and incidence angle) , the response of the sensor varies typically by ± 10%, depending on the spatial position of the impact on the disc and on the sensor (± 10% variability between two sensors). |
| Particle velocity | Not measured. |

### ■ MAXIMUM RATINGS

| Voltage ranges and measuring scales | |
|---|---|
| Voltage outputs | Continuous analogue voltage or pulse analog voltage, user selectable +0 to +2.5V or +0 to +5V are available. Pulse threshold, integrator timeout and duration are also user selectable. The continuous analog voltage persists on the outputs so that output voltages can be read at any time. |
| Hail scaling | Sensitivity @voltage range +2.5V: [100 mV/(hits/s)] i.e. +2.5V corresponds to 25 hits/s |
| | Sensitivity @voltage range +5V: [200 mV/(hits/s)] i.e. +5V corresponds to 25 hits/s |

### ■ MECHANICAL DATA

| Mechanical data | |
|---|---|
| Material | Stainless steel, plastic and anodized aluminum (breakdown voltage > 40 V/µm) |
| Installation | Universal mounting kit provided (ordering reference: HFBRA) |
| Weight | 3.2 kg without mounting kit<br>5.4 kg with mounting kit |
| Dimensions (H×W×D) | 260 mm × 450 mm × 200 mm with mounting kit |

### ■ INTERFACES

| Interfaces | |
|---|---|
| Analog | Pulse and continuous (and persistent) voltages, 0-2.5V or 0-5V |
| SDI-12 | Yes, 1.3 certified (fully complies with the NR Systems SDI-12 Verifier) |
| Serial 3V3 TTL | Yes |
| Modbus RTU (RS485) | Yes, with the Modbus adapter accessory |

### ■ POWER SUPPLY

| Supply | Ratings |
|---|---|
| Voltage | 6 V to 30 V DC (9.6 V and 16 V DC in case of powering through the SDI-12 terminals) |
| Current | < 1 mA in stand-by mode and 20 mA max in acquisition mode.<br>For a typical nominal duty-cycle of 10%: 2.1 mA (20 mA for duty-cycle of 100%). |

### ■ ENVIRONMENTAL CONDITIONS

| Environmental conditions | |
|---|---|
| Temperature range | -40°C to +80°C.<br>Can even operate over this range. |
| Relative humidity | 0 to 100% |
| Protection | IP67, survive to 1 m temporary immersion in salt water |
| Standards | EN 61326-1: 2013, CE compliant<br>2014/30/EU, CE compliant |

## WIRING & I/O MAPPING

■ The sensor can simply be used by reading DC outputs (+0 to +2.5V or +0 to +5V continuous or pulse analog voltages available). Note that the continuous DC analog voltages are persistent on the outputs so that output voltages can be read at any time (the reading interval from your peripheral is independent from the duration of the time integration of the sensor).

| Wire | Signal | User selectable | Plug and Play Default factory settings |
|------|--------|-----------------|----------------------------------------|
| White | Power | No | Positive power supply (6 to 30) VDC |
| Brown | Signals GND | No | OUT1 GND, OUT2 GND and SDI-12 GND |
| Green | OUT1 | ■ Disabled<br>■ Hailstone count (Persistent, +0V to full-scale +2.5V or +5V)<br>■ Hailstone count (Pulse, +0V to full-scale +2.5V or +5V) | Hailstone count (Persistent, +0V to full-scale +2.5V or +5V) |
| Yellow | OUT2 | ■ Disabled<br>■ Hailstone count (Persistent, +0V to full-scale +2.5V or +5V)<br>■ Hailstone count (Pulse, +0V to full-scale +2.5V or +5V)<br>■ Raw signal (±2.5V) (Note: direct, unfiltered AC output of the sensor) | Hailstone count (Pulse, +0V to full-scale +2.5V or +5V) |
| Blue | SDI-12 | ■ Disabled<br>■ Hailstone count and hailstone disdrometry | SDI 12 bus active, address: 0, Hailstone count and hailstone disdrometry |
| Grey | RX | ■ Disabled<br>■ Hailstone count and hailstone disdrometry | RS-232 active, Hailstone count and hailstone disdrometry |
| Pink | TX | | |
| Black | Power GND (0V) | No | Power GND (0V) |

■ The USB dongle accessory and the ISAW-toolbox software suite allow you to get introduced to the sensor by immediately establishing a connection with a computer or laptop, realizing a quick and simple communication start test, accessing all settings menus and seeing live data with a simple scope utility. You also have permanent access to the configuration and communication setups of the sensor directly in a terminal console mode. Remote access is also possible by using other standard serial communication modes (Serial 3V3 TTL, RS-232, Modbus RTU RS-485 or extended SDI-12 commands).

MODBUS RTU RS485
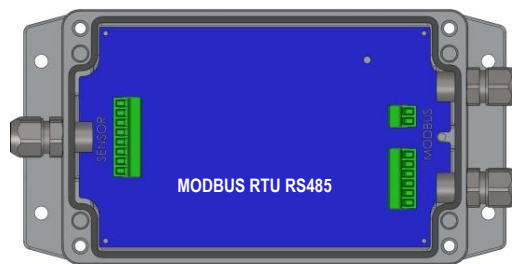
■ When adding or replacing an ISAW sensor, it is possible to pre-configure it in order to achieve Plug and Play functionality without any on-site configurations. The sensor is totally stand-alone, so that the full lifetime operation of the sensor on your installation doesn't require any software installation or maintenance.

■ When choosing an SDI-12 interface for your sensor, you can configure the data frame content you need, set the address of your choice, connect more than one ISAW sensor (as well as other SDI sensors) to a single data recorder and use extension cables up to typically 150 m with a very low current drain.
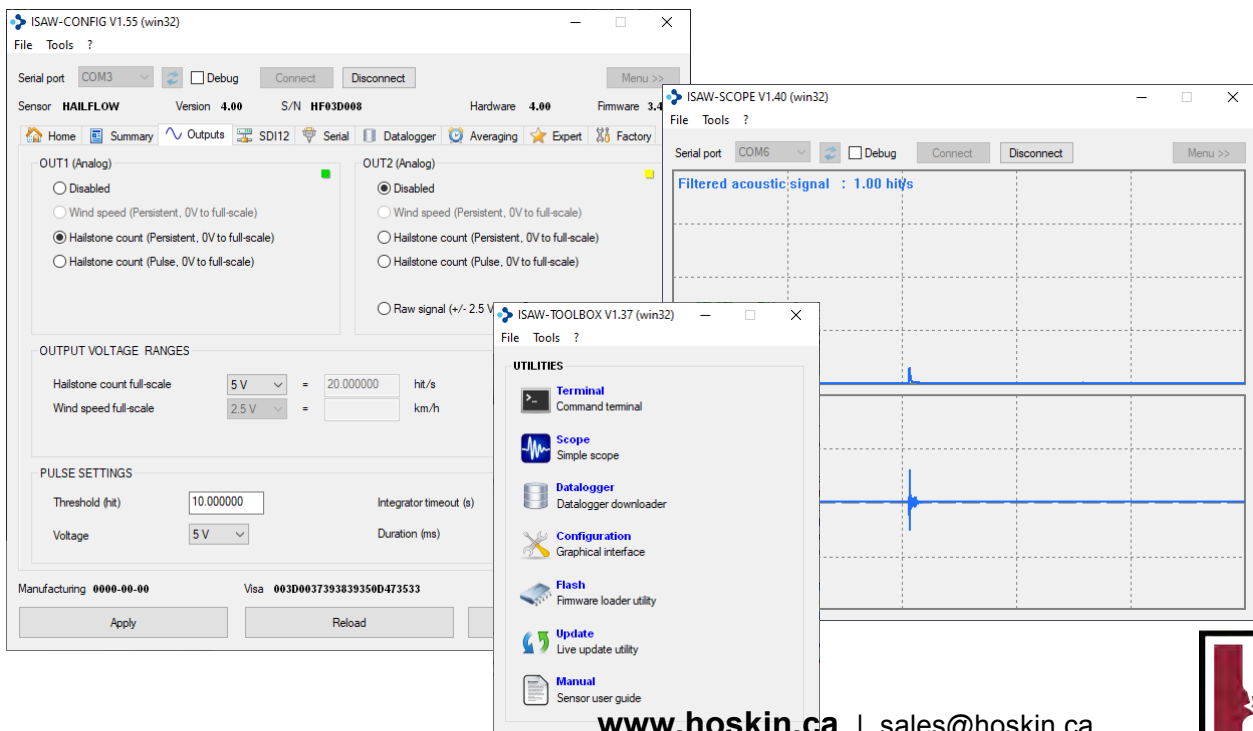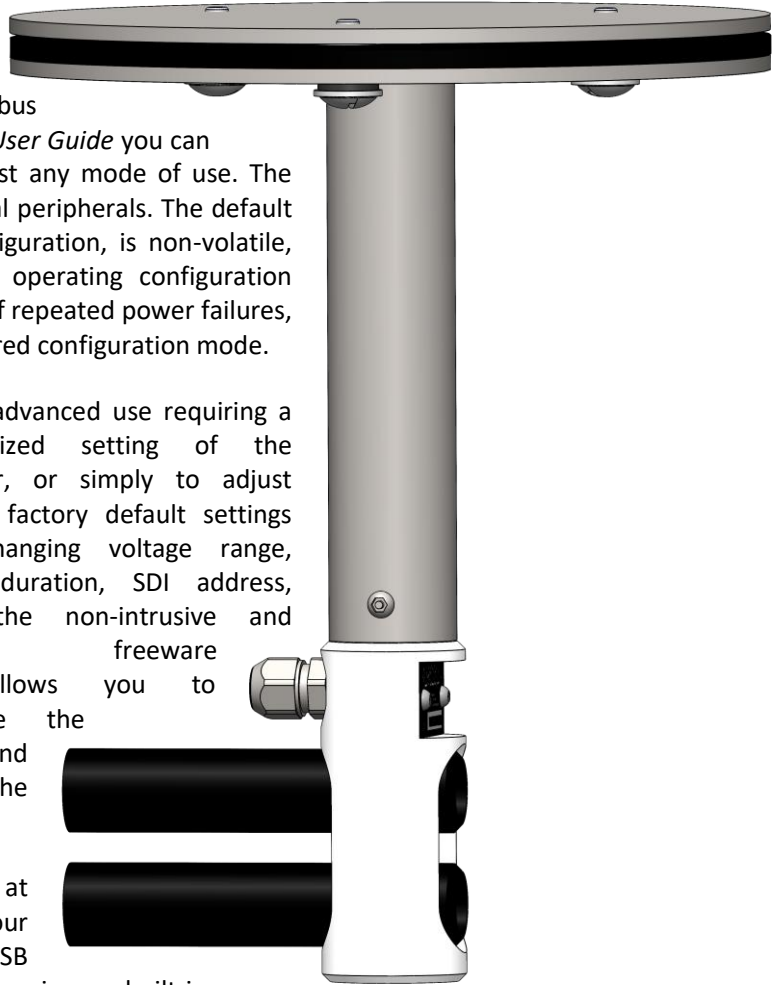
## CONFIGURATION

■ Configuration includes measuring settings (e.g. averaging durations), power settings, communication and mapping settings (e.g. analog and/or digital outputs, voltage scales, duty-cycle, bus address, etc.). Following the instructions in the *ISAW User Guide* you can adapt the default configuration at any time to almost any mode of use. The sensors are compatible with both analog and/or digital peripherals. The default configuration, as well as any other customized configuration, is non-volatile, ensuring that your sensor remains in the desired operating configuration whatever the powering scenarios. Thus, even in case of repeated power failures, the sensor will always restart automatically in the desired configuration mode.
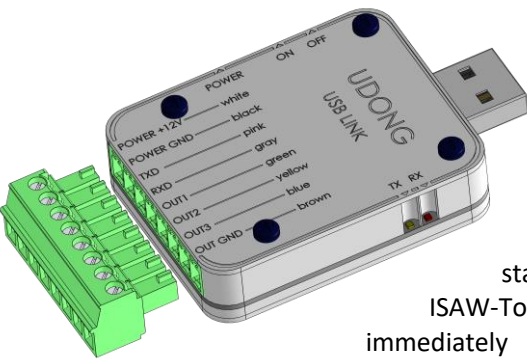
■ For advanced use requiring a customized setting of the sensor, or simply to adjust some factory default settings (e.g. changing voltage range, pulse duration, SDI address, etc.), the non-intrusive and standalone freeware ISAW-Toolbox allows you to immediately configure the sensor exactly to your needs and load this configuration permanently in the non-volatile memory of the sensor.

■ Free download the ISAW-Toolbox software suite at www.isaw-products.com. Connect the sensor to your computer using the USB dongle accessory. The USB dongle has an 8-pin quick connector for the sensor's wires, a built-in power converter, and a USB plug for direct connection to a Windows, Linux, or Mac OS machine.

**www.hoskin.ca** | sales@hoskin.ca

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## CONFIGURATION EXAMPLE

| Parameter | Description | Value |
|---|---|---|
| sens-type | Sensor type | HAILFLOW |
| sens-version | Sensor version | 4 |
| sens-date | Sensor manufacturing date | 12.02.2020 |
| sens-sn | Sensor serial number | HF20A001 |
| hw-version | Hardware version | 1.4 |
| hw-date | Hardware manufacturing date | 12.02.2020 |
| hw-sn | Hardware serial number | 0022001C3134333009473834 |
| hw-dev-id | Hardware device identifier | 0x416 (STM32L151CBT6) |
| hw-extflash | Hardware flash identifier | 0xC22013 (MX25L4006E) |
| fw-version | Firmware version | 3.42 |
| fw-build | Firmware build info | Feb 11 2020 at 23:14:37 by GCC 7.2.1 |
| cfg-ident | Config identifier | _HF_ |
| cfg-version | Config version | 0.27 |
| range-hail | Hail range (2V5\|5V) | 5V |
| fscale-hail | Hail fullscale (hit/s) | 20 |
| thld-hail | Hail noise threshold (mV) | 5 |
| out1-mode | OUT1 mode (off\|hail\|pulse) | hail |
| out2-mode | OUT2 mode (off\|hail\|pulse\|raw) | off |
| sdi12-mode | SDI12 mode (off\|hail) | hail |
| sdi12-addr | SDI12 address | 0 |
| serial-mode | SERIAL mode (off\|hail) | hail |
| logger-mode | Data logger mode (off\|on\|cyclic) | off |
| logger-cfg | Data logger field config | 0x181F |
| logger-usage | Logger record count usage | 0 |
| logger-capa | Logger record count capacity | 0 |
| avg-a | Acquisition duration (s) | 6 |
| avg-c | Cycle duration (s) | 6 |
| avg-m | Measurement duration (s) | 600 |
| pulse-thld | Pulse threshold (mm) | 10 |
| pulse-to | Pulse integrator timeout (s) | 3600 |
| pulse-ms | Pulse duration (ms) | 50 |
| pulse-lvl | Pulse level (2V5\|5V) | 5V |
| lin-xc1 | Hail coeff XC1 | 5.1 |
| lin-xe1 | Hail exponent XE1 | 0.333333 |
| calib-date | Calibration date | 12.02.2020 |
| calib-hail | Hail calibration factor | 1 |
| cons-idle | Console idle timeout (s) | 10 |
| sys-clk | System clock type (internal\|external) | external |
| sys-speed | System clock speed (4MHz\|8MHz\|16MHz\|32MHz) | 16MHz |
| sys-uptime | Sensor uptime (s) | 140 |
| sys-status | System status | OK |
| misc-pwrdly | Power delay before acquisition (ms) | 100 |
| misc-dbg | Debug status field | 0x0000 |
| misc-admin | Administrator status | no |
| misc-scopemode | Non persistent scope mode | no |

## GENERAL CONDITIONS

### ■ ORDERING

The HailFlow HF4 sensor is available with or without mounting kit, and a set of complementary accessories (tripod mast, Modbus adapter, cable extension) allows you to select the equipment that perfectly matches your operating situation (see *HF4 Catalogue)*.

### ■ SHIPPING

Eco-friendly packaging, worldwide shipping within 1-5 days a.r.o., URGENT BUSINESS shipping mode.

### ■ CONDITIONS OF USE

Always remember that ISAW sensors are acoustic instruments and could thus potentially be affected by structure-borne vibrations issuing from the supporting structure (for example, a steel cable impacting repetitively on a metal mast when subjected to wind); or to a lesser extent by parasitic low-frequency noise from the immediate environment (for example, excessive proximity to heavy traffic or machinery could lead to parasitic signals). It is recommended that you pay attention to avoiding possible parasitic noise when mounting the project.

### ■ DISCLAIMER

When using ISAW sensors, IAV Technologies SARL is not responsible for the choice, selection, relevance and usage appropriateness of the sensor's installation site; nor for the usage, interpretation, and extrapolation of the information made available to the users. Any known system issues that may induce dysfunction or skew the measurements are reported to the users through documentation updates. To continually improve the system, the ISAW Products division of IAV Technologies SARL reserves the option to continuously evolve the sensor's hardware, software, and user recommendations.

### ■ WARRANTY

ISAW sensors are repairable products and benefit of a two-year warranty. The sensor, the USB dongle accessory and the mounting accessories are designed and produced with the highest standards. The equipment has a total of more than 100 mechanical and electrical spare parts and 250 electronic components. In case of failure, DO NOT TRY to open the sensor. Opening is destructive unless it is done at the factory for repair. None of the moving or user-serviceable parts require routine maintenance. Opening the unit will void the warranty. In the event of failure, before returning the unit, we recommend that you:

1. Check all cables and connectors for continuity, bad contacts, corrosion, etc.
2. Conduct a bench test e.g. using the Scope utility.
3. Contact us directly for advice.