

# MS9000 – DATASHEET

## Single axis analog accelerometer

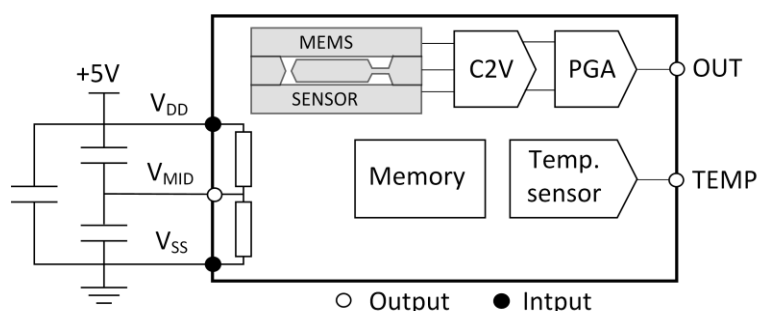
The MS9000 is a fully calibrated bulk capacitive accelerometer, specially designed for high performance inertial measurements.

Accelerometer long term bias repeatability and stability, robustness up to 6000g and low power are adapted for overall inertial requirements, even in harsh environments.

The sensor is packaged in a 20-pin LCC ceramic housing, thus ensuring a full hermeticity.



### Functional Block Diagram:



### Key features

- **Measurement Range :**  
+/- 2 to +/- 200g
- **Long term bias stability :**  
7.5 mg (+/-10g, max.)
- **Embedded temperature sensor :**  
for thermal compensation
- **Temperature range :**  
-55 to 125°C
- **Analogue ratiometric output :**  
From + 0,5V to + 4,5V
- **Low Consumption :**  
< 400  $\mu$ A @5 VDC

### Featured Applications (non-exhaustive)

#### Aerospace & Defense:

Inertial Measurement Units (IMU)  
 Avionics : FCS, autopilot, attitude systems  
 Platform Stabilization  
 GPS aided guidance & drone navigation

#### Naval & Land:

Antenna, sonar orientation  
 Ship navigation and control; ROV guidance,  
 Mobile Mapping  
 Train positioning (GPS dead reckoning)

## Accelerometer specifications

All values are specified at +20°C (+68°F) and +5.0 VDC supply voltage, unless otherwise stated

| Parameters                                | MS9002.D       | MS9005.D         | MS9010.D       | MS9030.D       | MS9050.D        | MS9100.D       | MS9200.D       | Units              |
|-------------------------------------------|----------------|------------------|----------------|----------------|-----------------|----------------|----------------|--------------------|
| Full scale range                          | ± 2g           | ± 5g             | ± 10g          | ± 30g          | ± 50g           | ± 100g         | ± 200g         | g                  |
| Bias calibration                          | < 10           | < 25             | < 50           | < 150          | < 250           | < 500          | < 1000         | mg                 |
| One year bias stability @6000g[1]         | 1.5<br>(< 5)   | 3.75<br>(< 12.5) | 7.5<br>(< 25)  | 22<br>(< 75)   | 37.5<br>(< 125) | 75<br>(< 250)  | 150<br>(< 500) | mg typ.<br>(max.)  |
| One year bias stability @1000g[2]         | 0.3<br>(<1.5)  | 0.75<br>(<3.75)  | 1.5<br>(<7.5)  | 4.5<br>(<22.5) | 7.5<br>(<37.5)  | 15<br>(<75)    | 30<br>(<150)   | mg typ.<br>(max.)  |
| Switch on/off repeatability               | < 0.15         | < 0.375          | < 0.75         | < 1.5          | < 3.8           | < 7.5          | < 15           | mg max.            |
| Bias temp. coefficient [3]                | < 0.1          | < 0.25           | < 0.5          | < 1.5          | < 2.5           | < 5            | < 10           | mg/°C typ.         |
|                                           | ± 0.4          | ± 1              | ± 2            | ± 6            | ± 10            | ± 20           | ± 40           | mg/°C max.         |
| Scale factor sensitivity (K1)             | 1000 ± 8       | 400 ± 4          | 200 ± 2        | 66.6 ± 1       | 40 ± 1          | 20 ± 1         | 10 ± 1         | mV/g               |
| One year scale factor stability [1] & [2] | 300<br>(<1000) | 300<br>(<1000)   | 300<br>(<1000) | 300<br>(<1000) | 300<br>(<1000)  | 300<br>(<1000) | 300<br>(<1000) | ppm typ.<br>(max.) |
| Scale factor temp. coefficient [3]        | 100            | 100              | 100            | 100            | 100             | 100            | 100            | ppm / °C typ.      |
|                                           | -50/250        | -50/250          | -50/250        | -50/250        | -50/250         | -50/250        | -50/250        | min. / max.        |
| Input axis misalignment (Kp, Ko)          | < 10           | < 10             | < 10           | < 10           | < 10            | < 10           | < 10           | mrad max.          |
|                                           | 1              | 1                | 1              | 1              | 1               | 1              | 1              | % max              |
| Resolution / Threshold (@ 1Hz)            | < 0.1          | < 0.25           | < 0.6          | < 1.7          | < 2.8           | < 5.5          | < 11           | mg max.            |
| Non linearity                             | < 0.8          | < 0.8            | < 0.9          | < 0.9          | < 0.9           | < 1            | < 1 [5]        | % of FS max.       |
|                                           | < 0.02         | < 0.04           | < 0.09         | < 0.27         | < 0.50          | < 1            | < 2 [5]        | g max.             |
| Bandwidth [4]                             | 0to≥100        | 0to ≥100         | 0to ≥100       | 0to ≥100       | 0to ≥100        | 0to ≥100       | 0to ≥100       | Hz                 |
| Noise spectral density in band (0 ; 9kHz) | 18             | 18               | 18             | 18             | 18              | 18             | 18             | μV/√Hz typ.        |
|                                           | 24             | 24               | 24             | 24             | 24              | 24             | 24             | max.               |
| Resonant frequency                        | 1.4            | 2.9              | 3.7            | 6.3            | 11              | 15             | 26             | kHz                |

[1] See Glossary

[2] See Glossary

[3] Temperature coefficients are specified for a range of -40°C to 20°C, where temperature behavior is typically linear and coefficient are maximum.

[4] The bandwidth is defined as the frequency band for which the sensitivity has decreased by less than 3dB.

[5] The non-linearity specification for ±200g version is validated to maximum ±100g range.

## Electrical specifications

| Parameters                                 |                                                                                                                                                                                                                                                                                     |
|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input voltage (VDD – VSS)                  | 2.5 to 5.5 VDC. The standard voltage for calibration is 5.0 VDC.                                                                                                                                                                                                                    |
| Output voltage range                       | From 0.5 to 4.5 VDC @ 5.0 VDC input voltage (VDD/2 at 0g)                                                                                                                                                                                                                           |
| Operating current consumption              | < 400 $\mu$ A @ 5.0 VDC                                                                                                                                                                                                                                                             |
| Initialization & reset current consumption | Typ. 1500 $\mu$ A @ 5.0 VDC during the initialization phase (less than 35 ms at room temperature)                                                                                                                                                                                   |
| Reset                                      | The sensor is Brown out protected. A reset occurs when the power supply jumps more than -0.46 V with a slope >380V/s or if the power supply drops below 2.2V. The recovery time is typ. 25 ms (max 35 ms)                                                                           |
| Output load                                | Min. 50 k $\Omega$ at Vout (pin 8) and VMID (pin 5)<br>Max. 50 pF at Vout (pin 8) and Max. 100 $\mu$ F at VMID (pin 5)<br>Impedance value is minimum load value that accelerometer output can drive.<br>Capacitive value is maximal load value that accelerometer output can drive. |

## Environmental specifications

| Parameters                  |                                                                                                                     |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------|
| Operating temperature range | -55°C to +125°C (-67°F to 255°F)                                                                                    |
| Reliability                 | Results based on MIL-HDBK-217, notice 2, are available on request.                                                  |
| Shock resistance            | Up to 6'000 g (0.15ms half-sine, single shock, not repetitive, in one direction o, p or i)                          |
| Recovery time               | < 1ms (1000g, half-sine period 1ms, shocks in direction i)                                                          |
| Vibration                   | 20 g rms, 20-2000 Hz (random noise, 30 minutes in each direction o, p, i)                                           |
| ESD sensitivity             | Class 2 (requirements MIL-STD-883-G, 1 Method 3015.7), Human Body Model 2kV                                         |
| Ultrasonic cleaning         | The product can't be cleaned with ultrasonic bath. Such a cleaning process will largely affect the sensor integrity |

Pinout Description

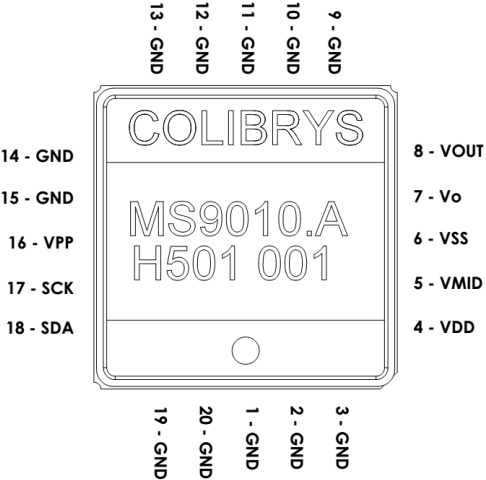


Figure 1: Pinout top view

| Pin | Description                                    | Notes                                                |
|-----|------------------------------------------------|------------------------------------------------------|
| 4   | VDD                                            | Power supply                                         |
| 5   | VMID                                           | Accelerometer output reference voltage ( $VDD / 2$ ) |
| 6   | VSS                                            | Ground                                               |
| 7   | VO                                             | Temperature sensor output                            |
| 8   | Vout                                           | Accelerometer output signal                          |
| 16  | VPP (Safran Colibrys internal calibration pin) | Must be connected to VSS                             |
| 17  | SCK (Safran Colibrys internal calibration pin) | Must be connected to VSS                             |
| 18  | SDA (Safran Colibrys internal calibration pin) | Must be connected to VSS                             |

Table 1: MS9000 pinout description

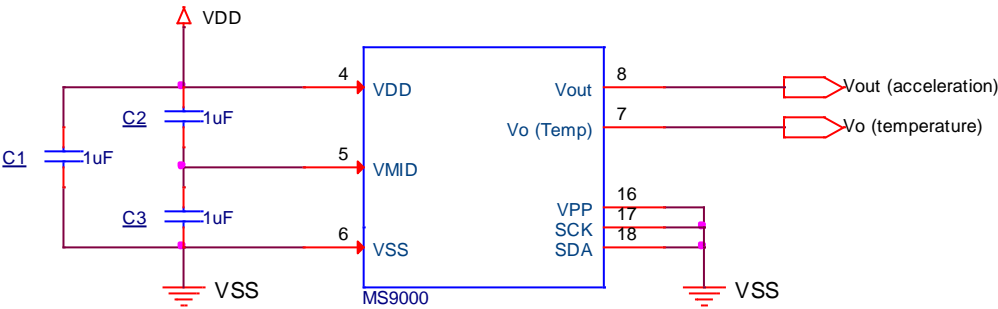


Figure 2: Proximity circuit & internal pull-up/down

It is strongly recommended to use decoupling capacitors [C] of 1  $\mu$ F each between VDD – VMID, and between VMID .VSS and VDD., placed as close as possible to the accelerometer. COG or X7R @ 5% capacitor types are recommended. On top, the VMID track should be as short as possible. Any other setup will potentially affect the bias calibration and stability.

## Dimensions and physical specifications

The packaging is a standard LCC ceramic housing with a total of 20 pins. The outline of the LCC20 ceramic package and the Center of Gravity (●) is illustrated in the figure below.

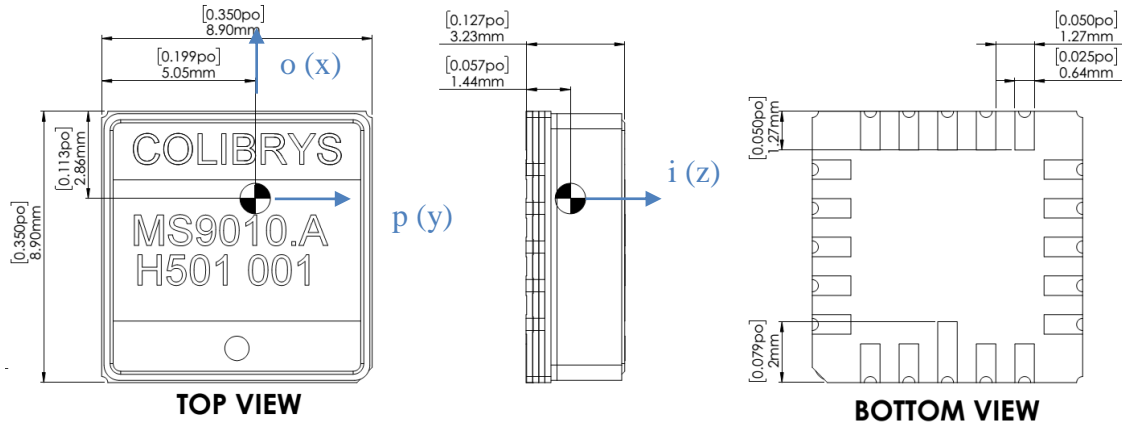


Figure 3: Package mechanical dimension. Units are mm [inch]

| Parameters                         |                                                                                                                                                                                                                                                                      |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Packaging                          | Non-magnetic, LCC, 20 pin housing                                                                                                                                                                                                                                    |
| Lead finishing                     | Au plating: 0.5 to 1.5 $\mu\text{m}$<br>Ni plating: 1.27 to 8.89 $\mu\text{m}$ (typ. 3 to 5 $\mu\text{m}$ )<br>W (tungsten): 10 to 15 $\mu\text{m}$                                                                                                                  |
| Hermeticity                        | The product has been qualified according to MIL-STD-883-G. Hermetic sealing is systematically qualified at 5·10 <sup>-8</sup> atm·cm <sup>3</sup> /s                                                                                                                 |
| Weight                             | < 1.5 grams                                                                                                                                                                                                                                                          |
| Size                               | Typ. 8.9 x 8.9 x 3.23 mm (0.35 x 0.35 x 0.127 inch)<br>Max. 9.2 x 9.2 x 3.5 mm (0.354 x 0.354 x 0.138 inch)                                                                                                                                                          |
| Proximity effect                   | The sensor is sensitive to external parasitic capacitance. Moving metallic objects with large mass or parasitic effect at proximity of the accelerometer (mm range) must be avoided to ensure best product performances.                                             |
| Reference plane for axis alignment | LCC must be tightly fixed to the PCB, using the bottom of the housing as reference plane for axis alignment. Using the lid as reference plane or for assembly may affect specifications and product reliability (i.e. axis alignment and/or lid soldering integrity) |

Table 2: Physical Specifications

## SMD recommendation

A recommended land pattern for LCC20 is shown in the Figure 4: It should be tested and qualified in the manufacturing process. The land pattern and pad sizes have a pitch of 1.27mm and the pin 1 is longer to ensure the right orientation of the product during mounting. After assembly, the orientation can be controlled from the top with an extra point printed on the lid which correspond to pin 1.

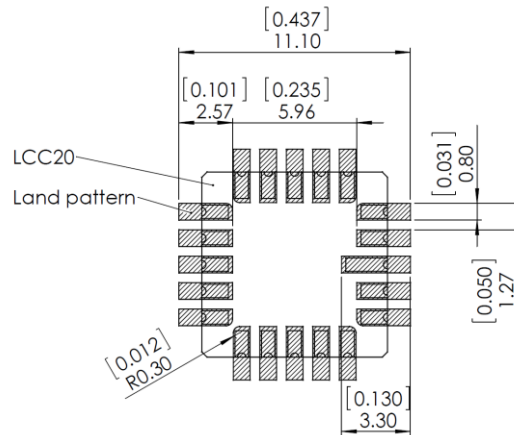


Figure 4: LCC20 land pattern recommendation (unit are mm/[inch])

The MS9000 is suitable for Sn/Pb and Pb-Free soldering and ROHs compliant. Typical temperature profiles recommended by the solder manufacturer can be used with a maximum ramp-up of 3°C/second and a maximum ramp-down of 6°C/second: The exact profile depends on the used solder paste.

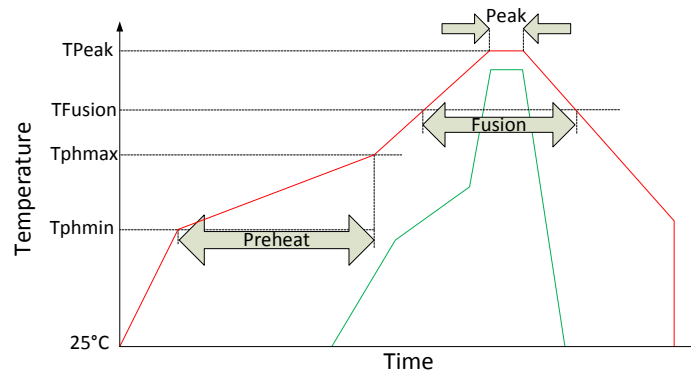


Figure 5: Soldering Temperature Profile

| Phase   | Sn/Pb          |                        | Pb-Free        |                        |
|---------|----------------|------------------------|----------------|------------------------|
|         | Duration [sec] | Temperature [°C]       | Duration [sec] | Temperature [°C]       |
| Peak    | 10-30          | 235-240                | 20-40          | 245-250                |
| Fusion  | 60-150         | 183                    | 60-150         | 217                    |
| Preheat | 60-120         | Min : 100<br>Max : 150 | 60-180         | Min : 150<br>Max : 200 |

Table 3: Soldering temperatures & times

The degolding process applied to the products is excluded from Safran Colibrys recommendations. And if applied, cancels any products warranty and liability.



**Note: Ultrasonic cleaning is forbidden in order to avoid damage of the MEMS accelerometer**

The cleaning process of electronic boards sometimes involves ultrasounds. This is strongly prohibited on our sensors. Ultrasonic cleaning will have a negative impact on silicon elements which generally causes damages.

## Handling and packaging precautions

### Handling

The MS9000 is packaged in a hermetic ceramic housing to protect the sensor from the ambient environment. However, poor handling of the product can induce damage to the hermetic seal (Glass frit) or to the ceramic package made of brittle material (alumina). It can also induce internal damage to the MEMS accelerometer that may not be visible and cause electrical failure or reliability issues. Handle the component with caution: shocks, such as dropping the accelerometer on hard surface, may damage the product.



**It is strongly recommended to use vacuum pens to manipulate the accelerometers**

The component is susceptible to damage due to electrostatic discharge (ESD). Therefore, suitable precautions shall be employed during all phases of manufacturing, testing, packaging, shipment and handling. Accelerometer will be supplied in antistatic bag with ESD warning label and they should be left in this packaging until use. The following guidelines are recommended:

- Always manipulate the devices in an ESD-controlled environment
- Always store the devices in a shielded environment that protects against ESD damage (at minimum an ESD-safe tray and an antistatic bag)
- Always wear a wrist strap when handling the devices and use ESD-safe gloves



**This product can be damaged by electrostatic discharge (ESD). Handle with appropriate precautions.**

### Packaging

Our device are placed for shipment and SMD process in trays. They are packed in sealed ESD-inner bag. We strongly advice to maintain our device in its original OEM sealed ESD inner-bag to guarantee storage condition before soldering them.

## Temperature compensation

The MS9000 delivers an output signal without any internal temperature compensation. The intrinsic temperature coefficient is quite small but can be further improved through a calibration, using the temperature provided by the internal temperature sensor. Third order compensation is generally required for a coherent modeling of a MS9000.D.

### Temperature sensor specifications:

|                        |                                        |
|------------------------|----------------------------------------|
| Output Voltage at 20°C | Typ: 1.632 V                           |
| Sensitivity            | Typ: -11.77 mV/°C                      |
| Long term stability    | Max -0.03°C to +0.09°C (1000h @ 150°C) |
| Accuracy               | ± 5°C (From -40°C to 125°C)            |

## Principle of operation

The standard calibration voltage for the MS9000.D is (VDD-VSS) = 5V. Therefore, all specifications are valid for this supply voltage unless otherwise stated. Upon market request, the calibration of the product at a different voltage (between 2.5V and 5.5V) is possible.

In such a case, the nominal output signal will vary according to the following equation:

$$V_{out} = (VDD - VSS) / 2 + A_i * (K_1 * VDD / 5) \quad (1)$$

$$VMID = (VDD - VSS) / 2 \quad (2)$$

According to this equation (1), the bias and scale factor are ratiometric to the power supply voltage. A reference voltage VMID is also provided at half of the power supply and corresponds to the output voltage at zero g. All sensors are calibrated to match the ideal response curve in term of offset, gain and non-linearity.

At every power-up, the microcontroller, used as memory, transfers the calibration parameters to the ASIC and then goes in a sleep mode. During this initialization phase, which takes less than 50ms, the current consumption goes up to max. 1,5mA @ 5V and at room temperature. Then, the normal operating current is set and remains less than 400µA under similar conditions.

The following model describes each sensor:

### Accelerometer model

$$\frac{OUT}{V_{DD}} * 5.0 = K_1 (K_0 + A_s + K_2 \cdot A_s^2 + K_3 \cdot A_s^3 + K_p \cdot A_p + K_h \cdot A_h + K_{sp} \cdot A_s A_p + K_{sh} \cdot A_s A_h + E)$$

$A_s$ ,  $A_p$ ,  $A_h$  are the accelerations for each axes of the sensor with:

Input Axis (SA): Sensitive axis

Pendulous Axis (PA): Aligned with the proof mass beam and perpendicular to the input axis

Hinge Axis (HA): Perpendicular to the input and pendulous axes. Direction of the dot.

$K_1$  is accelerometer scale factor [V/g]

$K_0$  is bias [g]

$K_2$  is second order non-linearity [g/g<sup>2</sup>]

$K_3$  is third order non-linearity [g/g<sup>3</sup>]

$K_p$  is pendulous cross-axis [rad]

$K_h$  is output cross-axis [rad]

$K_{sp}$ ,  $K_{io}$  are cross-coupling coefficients [rad/g]

$E$  is the residual noise [g]



## Glossary of parameters of the Data Sheet

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**g [m/s<sup>2</sup>]**

Unit of acceleration, equal to standard value of the earth gravity (Accelerometer specifications and data supplied by Safran Colibrys use 9.80665 m/s<sup>2</sup>)

**Bias [mg]**

The accelerometer output at zero g

**One Year Bias and Scale Factor Stability [mg /ppm]**

Evolution of the Bias and Scale Factor values (K0 and K1) measured at sensor level mounted on sockets at 20°C after applying following tests:

- 100 times turn on / on,
- 72 h of storage at -55°C, unpowered
- and 10 days of storage +85°C unpowered,
- 10 times -40°C to 125°C Temperature cycling unpowered,
- 10 times -55°C to 85°C unpowered harass,
- vibration (20grms, random 20 to 2KHz) unpowered,
- single shock (6000g [1] or 1000g [2], 0.15ms) in one axis, unpowered

**Bias temperature coefficient [μg/°C]**

Maximum variation of the bias calibration under variable external temperature conditions (slope of the best fit straight line through the curve of bias vs. temperature). Bias Temperature Coefficient is specified between -40°C and +20°C, where temperature behavior is linear.

**Scale factor sensitivity [mV/g]**

The ratio of the change in output (in volts) to a unit change of the input (in units of acceleration); thus given in mV/g

**Scale factor temperature coefficient [ppm/°C]**

Maximum deviation of the scale factor under variable external temperature conditions

**Temperature sensitivity**

Sensitivity of a given performance characteristic (typically scale factor, bias, or axis misalignment) to operating temperature, specified as worst case value over the full operating temperature range. Expressed as the change of the characteristic per degree of temperature change; a signed quantity, typically in ppm/°C for scale factor and g/°C for bias. This figure is useful for predicting maximum scale factor error with temperature, as a variable when modelling is not accomplished

**Axis alignment [mrad]**

The extent to which the accelerometer's true sensitive axis deviates from being perfectly orthogonal to the accelerometer's reference mounting surface when mounted to a flat surface

**Resolution, Threshold [mg]**

Value of the smallest acceleration that can be significantly measured

**Non-linearity [% of FS]**

The maximum deviation of accelerometer output from the best linear fit over the full operating range. The deviation is expressed as a percentage of the full-scale output (+AFS).

**Bandwidth [Hz]**

Frequency range from DC to F-3dB where the variation of the frequency response is less than -3dB or -5% for vibration sensors

## Resonant frequency nominal [kHz]

Typical value of the resonant frequency of the mounted system

## Noise [ $\mu\text{V}/\sqrt{\text{Hz}}$ ]

Undesired perturbations in the accelerometer output signal, which are generally uncorrelated with desired or anticipated input accelerations

## Quality

Safran Colibrys is ISO 9001:2015, ISO 14001:2015 and OHSAS 18001:2007 certified.

Safran Colibrys is compliant with the European Community Regulation on chemicals and their safe use (EC 1907/2006) REACH.

MS9000 products comply with the EU-RoHS directive 2011/65/EC (Restrictions on hazardous substances) regulations.

Recycling : please use appropriate recycling process for electrical and electronic components (DEEE)

MS9000 products are compliant with the Swiss LSPro : 930.11 dedicated to the security of products

Note:

- MS9000 accelerometers are available for sales to professional only
- Les accéléromètres MS9000 ne sont disponibles à la vente que pour des clients professionnels
- Die Produkte der Serie MS9000 sind nur im Vertrieb für kommerzielle Kunden verfügbar
- Gli accelerometri MS9000 sono disponibili alla vendita soltanto per clienti professionisti

Safran Colibrys complies with due diligence requirements of Section 1502, Conflict Minerals Survey, of the US Dodd-Frank Wall Street Reform and Consumer Protection Act and follows latest standard EICC/GeSI templates for Conflict Minerals declaration



## Disclaimer

Safran Colibrys reserves the right to make changes to products without any further notice.

Performance may vary from the specifications provided in Safran Colibrys' datasheet due to different applications and integration. Operating performance, including one year stability, must be validated for each customer application by customer's technical experts. The one year stability specification expressed in the datasheet is valid only in the defined environmental conditions (cf One year stability glossary), and the performance at system level remains the customer's responsibility.

Stress in excess of the environmental specifications in the datasheet can cause permanent damage to the device. Exposure to the maximum ratings for an extended period of time (especially Shocks) may degrade the performance and affect reliability.

USE OF THE PRODUCT IN ENVIRONMENTS EXCEEDING THE ENVIRONMENTAL SPECIFICATIONS SET FORTH IN THE DATASHEET WILL VOID ANY WARRANTY. SAFRAN COLIBRYS HEREBY EXPRESSLY DISCLAIMS ALL LIABILITY RELATED TO USE OF THE PRODUCT IN ENVIRONMENTS EXCEEDING THE ENVIRONMENTAL SPECIFICATIONS SET FORTH IN THE DATASHEET.