Definitions & Glossary

A definition of all symbols currently used in this document is given hereafter

VDD, VSS	[V]	Voltages at the power supply connections (VSS=0, 2.5≤VDD≤5.5)
Vout	[V]	Sensor output voltage
VAGND	[V]	Half of the power supply; it corresponds to the output voltage at zero g
A_{FS}	[g]	Full scale range of the acceleration in the input axis (z) direction. The sensor operates to specification within the total range: $-A_{FS} \leq A_i \leq +A_{FS}$
Ai	[g]	Acceleration of the input axis (z)
Ap	[g]	Acceleration of the pendulous axis (y)
Ao	[g]	Acceleration of the output, pivot or hinge axis (x)

Glossary of parameters of the Data Sheet

g [m/s^2]
Unit of acceleration, equal to standard value of the earth gravity (Accelerometer specifications and data supplied by Colibrys use 9.80665 m/s²)

Bias [mg]
The accelerometer output at zero g

Bias stability [mg]
Maximum drift of the bias after extreme variation of external conditions (aging, temperature cycles, shock, vibration)

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 +50°C, where temperature behaviour 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 ($+A_{FS}$).

Bandwidth [Hz]
Frequency range from DC to F_{-3dB} where the variation of the frequency response is less than –3dB

Resonant frequency nominal [kHz]
Typical value of the resonant frequency of the mounted system

Noise [µV/√Hz]
Undesired perturbations in the accelerometer output signal, which are generally uncorrelated with desired or anticipated input accelerations

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MEMS Capacitive Accelerometers

Product Description

MS7000.3

30D.MS7X.F.08.07

General Description

The Colibrys MS7000 accelerometer has been initially designed and developed by Colibrys mainly to respond to stringent requirements of drilling for oil & gaz. Since then, the product has been largely integrated in vibration, inertial or tilt sensing applications. It is used where advanced specification are required (Instrumentation), when high reliability is asked (Avionis and Geophysics), and for a wide range of general applications (Industrial, Transportation or Civilian).
The main advantages of this motion sensor are the long term bias stability linked to a relative high bandwidth, the high reliability, the low temperature coefficient even without compensation and the low power.
This product has passed extensive qualifications and is successfully used for a wide range of applications such as down hole drilling applications, data logging or AHRS for civilian avionics where compliance to specifications are very severe.
Standard MS7000 products are available with a full-scale range of ±2g and ±10g (Table 1) but Colibrys has the experience and flexibility to offer a wide range of custom products upon request. Colibrys offers the capability to customize the performance such as shock resistance, bandwidth as well as the full-scale range of the products, which can vary from ± 1g to more than ± 100g.

Fig. 1 : Open view of a MS7000 product

Product description

The MS7000 product is a MEMS capacitive accelerometer based on a bulk micro-machined silicon element, a low power ASIC for signal conditioning and a micro-controller for storage of compensation values (Fig. 1).

The MS7000 is operating from a single power supply voltage (between 2.5V and 5.5V) with a low current consumption (< 200 µA at 3V). The output is a ratiometric analog voltage that varies between 0.5V and 2.5V for the full-scale acceleration range at a voltage supply of 3V. The sensor is fully self-contained and packaged in a TO8, 12 pins housing, thus insuring a full hermeticity. It operates over a temperature range of –40°C to 125°C and can withstand shocks up to 6000g without performance degradation. Long-term stability of bias and scale factor are typically less than 0.1% of full-scale range. For the ±2g version (MS7002.3), bias temperature coefficient is typically 200 µg/°C and scale factor temperature coefficient 200 ppm/°C without external compensation

Full scale range	± 2g	± 10g
TO8, 12 pins packaging	**MS7002.3**	**MS7010.3**

Accelerometer product features

The core of the accelerometer is the capacitive bulk micro-machined silicon sensor. An assessment has been made to determine which basic technology can at best satisfy the requirements for high performance MEMS accelerometer. Arguments clearly demonstrate that compared to the planar approach ("in plan" displacement of the proof mass), bulk technology ("out of plan" displacement of the proof mass) is the most successful approach to provide high end sensors.

The fundamental technology for the manufacturing of COLIBRYS accelerometers is based on the structuring of three silicon wafers. The center wafer supports the proof mass through a spring. This inertial mass is also the center electrode of the capacitive sensor. Upper and lower wafers constitute the fixed electrodes of the sensor (Fig. 2).

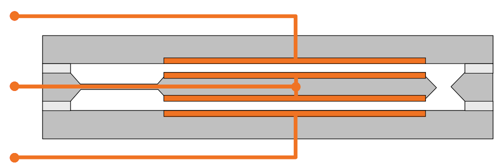

Fig. 2 : Cross section of a Colibrys accelerometer

The three wafers are bounded together by a process named ''Silicon Wafer Bonding'' (SFB). This bonding process insures not only a perfect balance between the various wafers of the system but also allows building a hermetic sealed cavity for the spring–mass system (fig. 3). The bonding process is done at high temperature (>1000°C) and at low pressure to ensure an optimal gas damping.

This also allows to avoid any surface contaminant like water molecules in particular and to relax all surface

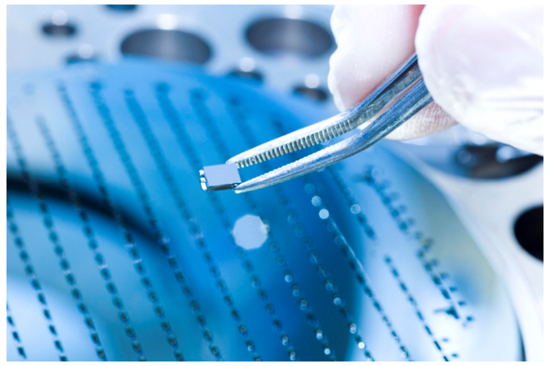

Fig. 3 : MEMS Silicon sensor

stresses that could be present prior bonding.
This is essential to avoid any sticking effect of the seismic mass to the fixed electrodes in case of chock for instance. Drift effects of the extraction voltage due to humidity effects and other contaminants are also removed.
The measurement range of the “spring – mass” system is adaptable. Variations of open loop measurement ranges are obtained by modifying the thickness of the spring.Under acceleration or tilt, the inertia makes it move between the upper and lower plates and change the values of the capacitors. This differential variation of the sensing capacitors is measured through the interface circuit, which uses a self-balancing capacitor bridge to translate the signal into a calibrated voltage output, using the compensation parameters (offset, gain and non-linearity) that are stored in the microcontroller

Basic accelerometer operation

The standard calibration voltage for the MS7000.3 is (VDD-VSS) = 3V. Therefore, all specifications are valid for this supply voltage, unless otherwise stated. Upon market request, the calibration of the product at a different voltage (i.e. 5V) is possible.
Anyway, even if calibrated at 3V, the MS7000 can be used with a nominal input voltage, which can vary between 2.5V and 5.5V.
In such a case, the nominal output signal will vary according to the following equation:

$$Vout = (VDD - VSS) / 2 + Ai * (K1 * VDD / 3) \quad (1)$$

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

According to this equation [(1)], the bias and scale factor are ratiometric to the power supply voltage. A reference voltage VAGND 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, within the specified error margins.

The following model describes each sensor:

$$Vout = k_1 * (k_0 + A_i + k_2 A_i^2 + k_3 A_i^3 + k_p A_p + k_o A_o + k_{ip} A_i A_p + k_{io} A_i A_o + E)$$

where

- Ai, Ap and Ao are the accelerations for each axes of the sensor
  - i: input axis (z axis)
  - p: pendulous axis (y axis)
  - o: output axis, also named pivot or hinge axis (x axis)
- K1 is accelerometer scale factor [V/g]
- K0 is bias [g]
- K2 is second order non linearity [g/g^2]
- K3 is third order non-linearity [g/g^3]
- Kp is pendulous cross axis non linearity [rad]
- Ko is output cross axis non linearity [rad]
- Kip, Kio are cross-coupling coefficients [rad/g]
- E is the residual noise [g]

Sensor connections & power supply requirements

The detailed block diagram is given in the next figure (Fig. 4)

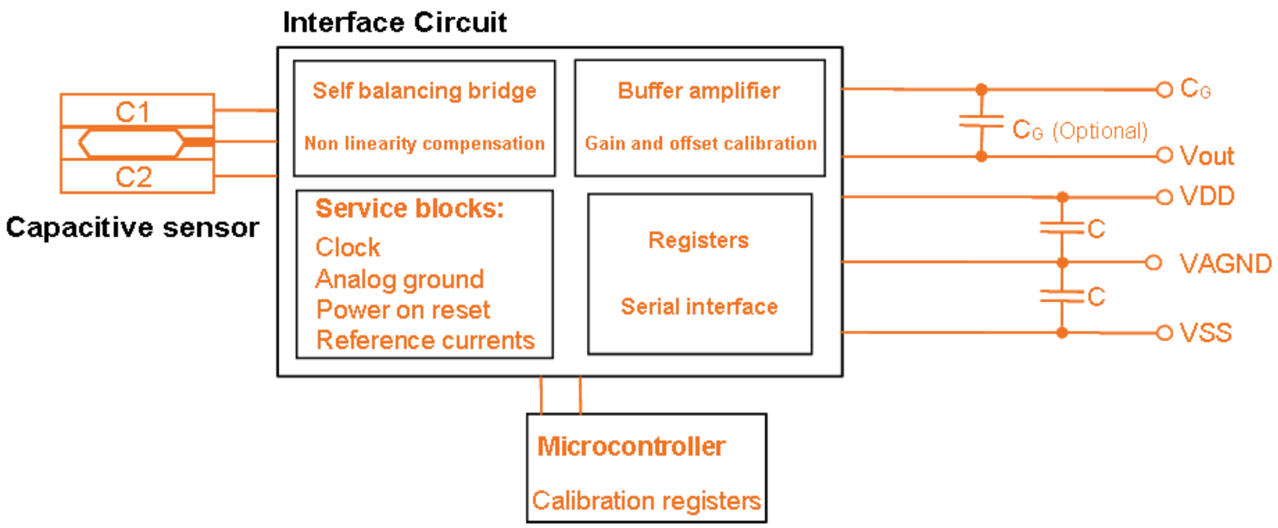

Fig. 4 : Block diagram

It is strongly recommended to use decoupling capacitors [C] of 1µF each between VDD and VAGND and between VAGND and VSS, placed as close as possible from the accelerometer. COG or X7R @ 5% capacitor types are recommended. On top of that, the VAGND track should be as short as possible. Any other setup will directly affect the bias calibration.

At every power-up, the microcontroller 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. 1mA @ 5V at room temperature. Then, the normal operating current consumption remains less than 400µA under similar conditions.

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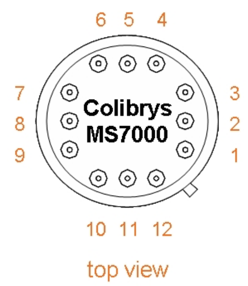
If an un-stabilized voltage is used (e.g. a battery), the output voltage has to be divided by the input voltage in order to obtain a calibrated signal according to equation (1). This normalization can be done for instance, by using the same voltage to power the sensor and to reference the external A/D converter.

Bandwidth control

To help you in your development phase, Colibrys offers a simple way to control the output bandwidth of the sensor. By adding a capacitance C_G between pin C_G and Vout of the accelerometer, you can control the first order filter of the internal buffer amplifier of the main ASIC of the MS7000. Unfortunately, this solution is very sensitive to the temperature and therefore difficult to implement in a production phase if a precise and stable bandwidth is required.

Without extra capacitor, the buffer amplifier has a cut-off frequency of typically 3.8 kHz (min 2.2 kHz).
If no bandwidth control is required (preferred solution), the C_G pin (pin 3) must remain unconnected.
Note: this pin is sensitive to humidity. To insure a good stability of the complete system, it is recommended to control correctly the humidity level of the accelerometer enclosure.



Pin	Description	Remarks
1	NC	Not connected
2	Vout	Accelerometer output signal
3	CG	Bandwidth adjustment
4	VSS	Ground
5	VAGND	Accelerometer output reference voltage(VDD/2)
6	VDD	Power supply
7	NC	Not connected
8	NC	Not connected
9	VPP (Colibrys internal calibration pin)	**Must** be connected to VSS
10	SDA (Colibrys internal calibration pin)	**Must** be connected to VSS
11	SCK (Colibrys internal calibration pin)	**Must** be connected to VSS
12	NC	Not connected

Fig. 5 : MS7000.3 electrical connections

Packaging

The packaging is a standard TO8 housing with a total of 12 pins.

Sealing process is qualified at 5·10-8 atm·cm3/s (requirements MIL-STD-883-E).

The precise dimensions are given in the next figure (Fig. 6) and the weight of the product is typically of 2.6 grams

Grounding

For low noise operation, the case should be connected to the system’s ground. This can be done either through pin 1 or through the mechanical mounting of the TO8 housing. Note that the housing has no electrical connection to any part of the accelerometer circuitry.

Mounting

MS7000 accelerometer in TO8 must be tightly fixed to the PCB, using the bottom of the housing as reference plan for axis alignment. Note that excessive stress to housing and extreme soldering conditions may affect specifications.

ESD

ESD sensitivity: Class 2, per MIL-STD-883-E method 3015.7 requirements (human body model, 2kV)

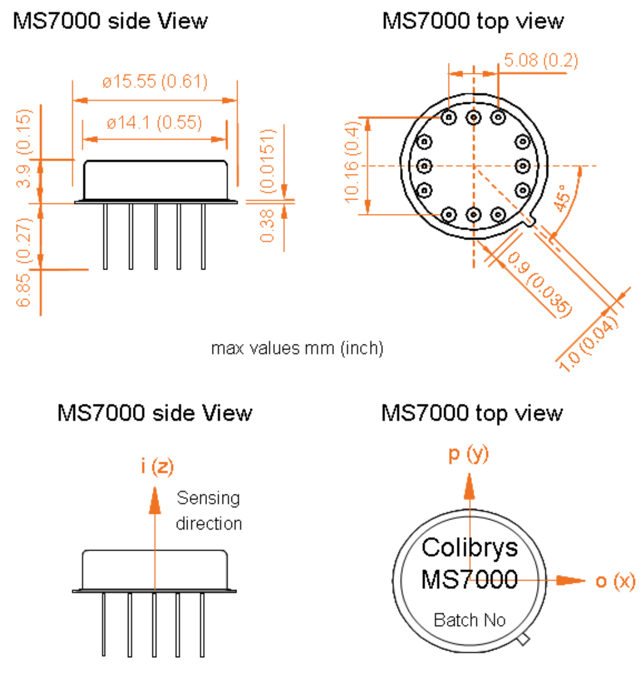


Fig. 6 : MS7000 TO8 packaging

Quality system

Colibrys is ISO 9001.2000, ISO 14001 and OHSAS 18001 certified; copy of each certificate is available on request

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