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DESIGNED FOR ACCURACY, BUILT FOR TRUST

TS9002P (Performance) – DATASHEET

Single axis analog accelerometer

TS9002P is a breakthrough toward advanced tilt, low g inertial MEMS for high stability measurements. This accelerometer is based on a new MEMS element, realized with the latest Colibrys technology and designed for high bias and scale factor stability, enhanced temperature behavior and improved vibration rectification performance requirements. TS9002P is interfaced with an low consumption ASIC , adapted for long term stability. This integrated electronic provides an acceleration-proportional output voltage as well as a temperature for further temperature compensation to be performed at the system level. TS9002P is Fit Form compatible to MS9000.

It operates from a single power supply voltage (between +2.5V and +5.5V) with low current consumption (< 0.5mA at 5V). The output is a ratiometric analog voltage that varies between +0.5V and +4.5V for the full-scale acceleration range at a voltage supply of +5V. The sensor is fully self-contained and packaged in a 20-pin LCC ceramic housing, thus insuring a full hermeticity.

Features

- ±2g linear output
- Very low intrinsic temperature sensitivity
- Excellent long term stability better than 500 µg
- High resistance to shocks (6000g)
- Individually calibrated
- Brown out protected
- Extra small 20 pin LCC ceramic package with hermetic sealing (8.9mm x 8.9mm). Same as MS9002 product family
- RoHS compliant suitable for lead free soldering process and SMD mounting

Accelerometer specifications

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

Parameters	TS9002P	Units
Full scale range	± 2	g
Bias calibration @ 20ºC	< 10	mg
Bias temperature coefficient @ 20°C	± 200	µg/°C (max)
One year composite repeatability [1]	< 500	µg (1σ)
In run bias stability (48h) @ 20°C	< 100	µg (max)
Scale factor calibration @ 20ºC	1000 ± 8	mV/g
Scale factor temperature coefficient @ 20°C	75 ± 100	ppm/°C (max)
One year composite repeatability [1]	< 300	ppm (1σ)
Input axis misalignment (Kp, Ko)	< 10'000	µrad
One year composite repeatability [1]	< 1000	µrad (max)
Non linearity	< 0.8%	% of FS (max)
Vibratioon rectification @ 20°C	< 800 [60-2000Hz]	µg/g2 rms (1σ)
Bandwidth @ 20ºC [2]	> 200	Hz
Noise spectral density in band @ 20ºC	30	µg/√Hz (max)

[1] The one year composite repeatability represents the residual error stability defined according to IEEE 528-2001 and under following environmental conditions: turn on / on, storage at -55°C and 85°C, -40°C to 125°C T cycling, vibration, shock (6000g, 0.2ms single shock in all directions).
[2] The bandwidth is defined as the frequency band for which the sensitivity has decreased by less than 3dB

Environmental specifications

Parameters	TS9002P
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, survivability	Up to 6'000 g (0.2ms half-sine, single shock and multiple shocks in direction o, p or i. Typically 10 shocks)
Recovery time after shock	< 1ms (after 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 not be** cleaned with ultrasonic bath. Such a cleaning process will affect the sensor integrity

Packaging

The packaging is a standard LCC ceramic housing with a total of 20 pins. The precise dimensions are given in the next figure and the weight of the final product is typically less than 1.5 grams.

The glass frit sealing process is qualified according to the MIL-STD-883-G and systematical leak tests are performed up to $5 \cdot 10^{-8}$ atm·cm^3/s.

SMD Mounting

TS9002P side view   TS9002P top view   TS9002P side view   TS90002P top view
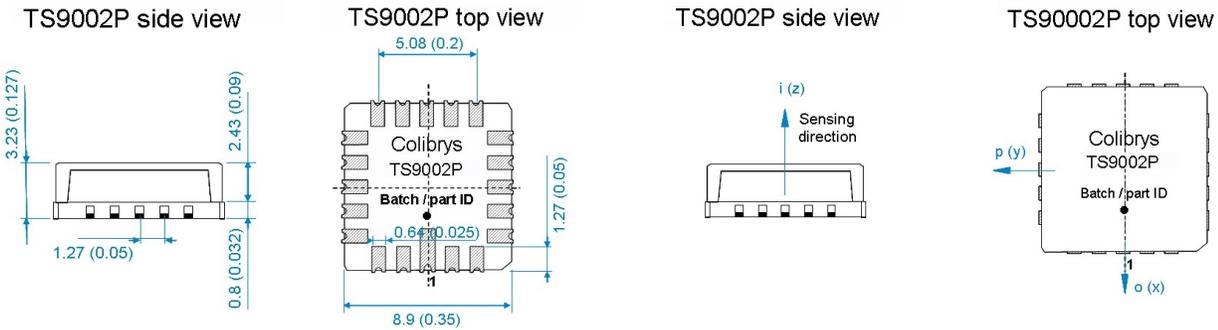
The TS9000 is RoHS compliant suitable for lead free soldering process and SMD mounting. It must be tightly fixed to the PCB, using the bottom of the housing as reference plane to ensure a good axis alignment. The stress induced by the soldering of the LCC package is a specific MEMS concern, especially when it comes to high-end capacitive sensors. In order to obtain good stress homogeneity and the best long term stability, all the leads of the accelerometer must be soldered to the pads of the PCB. See the Colibrys Application Note "LCC-48 housing, soldering conditions" available on our web site for more information about the LCC mounting process in general.

Physical specifications

Parameters	TS9002P
Packaging	Non magnetic, LCC, 20 pin housing
Lead finishing	Au plating: 0.5 to 1.5 µm Ni plating: 1.27 to 8.89 µm (typ. 3 to 5 µm) W (tungsten): 10 to 15 µm
Hermeticity	The product has been qualified according to MIL-STD-833-G. Hermetic sealing is systematically qualified at $5 \cdot 10^{-8}$ atm·cm^3/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) 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 insure 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)

Principle of operation

The standard calibration voltage for the TS9002P 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:

$$\text{Vout = (VDD - VSS) / 2 + Ai} \cdot \text{(K1} \cdot \text{VDD / 5)} \quad \text{(1)}$$
$$\text{VAGND = (VDD – VSS) / 2} \quad \text{(2)}$$

According to this equation (1), the bias and scale factor are ratiometric to the power supply voltage.
A reference voltage VAGND is externally generated and provides half of the power supply, corresponding 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:

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

where

- Ai, Ap, Ao   are the accelerations for each axes of the sensor with:
  - 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/g2]
- K3   is third order non-linearity [g/g3]
- 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]

Electrical specifications

| Parameters	TS9002P
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 μA @ 5.0 VDC
Initialization & reset current consumption	Typ. 1500 μA @ 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 impedance / load	Min. 50 kΩ at Vout (pin 8) and VAGND (pin 5)
	Max. 50 pF at Vout (pin 8) and Max. 100 μF at VAGND (pin 5)

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)

Temperature compensation

The TS9002P 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 TS9002P.

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Sensor connections and power supply requirements

The detailed block diagram is given in the next figure
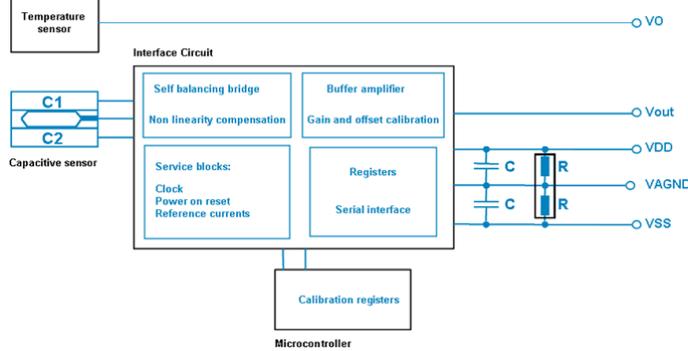

Components in the LCC20 packaging:

– 1-axis silicon MEMS sensor
– ASIC
– Microcontroller
– Temperature sensor
– Pull down resistor

External components to the LCC20

– Decoupling capacitors [C]
– Match resistors [R]

It is mandatory to implement two very high precision matched resistors [R] of 10 kΩ each outside the LCC package, as close as possible to the accelerometer between VDD and VAGND and between VSS and VAGND. This ultra-high precision resistive divider is used as internal reference voltage by the interface circuit. More precise information is available on the dedicated application note "VAGND Reference on MS9000" (30TN.VAGND MS9X.x.xx.xx).

It is also necessary to use decoupling capacitors [C] of 1μF each between VDD and VAGND and between VAGND and VSS, placed also as close as possible from the accelerometer. COG or X7R @ 5% capacitor types are recommended. On top, the VAGND track should be as short as possible. Any other setup will potentially affect the bias calibration and stability.
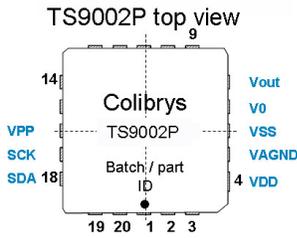
Pin	TS9002P Description	Notes
4	VDD	Power supply
5	VAGND	Accelerometer output reference voltage
6	VSS	Ground
7	VO	Temperature sensor output
8	Vout	Accelerometer output signal
16	VPP (Colibrys internal calibration pin)	**Must** be connected to VSS
17	SCK (Colibrys internal calibration pin)	**Must** be connected to VSS
18	SDA (Colibrys internal calibration pin)	**Must** be connected to VSS

Quality

– Colibrys is ISO 9001:2008, ISO 14001:2004 and OHSAS 18001:2007 certified

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

– TS9002P products comply with the EU-RoHS directive 2002/95/EC (Restrictions on hazardous substances) regulations

– TS9002P products are compliant with the Swiss LSPro : 930.11 dedicated to the security of products

Note:
   – *TS9002P accelerometers are available for sales to professional only*
   – *Les accéléromètres TS9002P ne sont disponibles à la vente que pour des clients professionnels*
   – *Die Produkte der Serie TS9002P sind nur im Vertrieb für kommerzielle Kunden verfügbar*
   – *Gli accelerometri TS9002P sono disponibili alla vendita soltanto per clienti professionisti*

– Recycling : please use appropriate recycling process adapted to electrical and electronic components

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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 residual error after 4th order compensation under 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 at 20°C

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 generally at 20°C. Expressed as the change of the characteristic per degree of temperature change; a signed quantity, typically in ppm/°C for scale factor and μg/°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 or -5% for vibration sensors

Resonant frequency nominal [kHz]

Typical value of the resonant frequency of the mounted system

Noise [μV/√Hz or μg/√Hz]

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

Colibrys reserves the right to change these data without notice.