DATASHEET

SF1500S.A – SF1500SN.A / Single axis best in class seismic accelerometer
30S.SF1500A.F.05.11

Energy

Mil/Aerospace

Industrial

- Inertial
- Tilt
- Vibration
- Seismic

Features

– ±3g linear output
– Best in class noise level of 0.3 $\mu g_{rms}/\sqrt{Hz}$ (Class B)
– Wide dynamic range of 117 dB (DC to 100Hz BW)
– Large frequency response (DC to 1500Hz BW)
– Analog servo accelerometer
– Self test input
– Demonstrated high reliability

The SiFlex^{TM} SF1500S.A and SF1500SN.a products combine a MEMS capacitive accelerometer, based on a bulk micro-machined silicon element in a ceramic package attached through an interconnect board to a custom mixed-signal ASIC to enable analog closed-loop force-feedback operation of the accelerometer. The multi-chip module (MCM) assembly is mounted to a printed circuit board consisting of power conditioning electronics employing linear regulators, output amplifiers and other support electronics.

The SF1500 operates from a bipolar power supply voltage that can range from ± 6V to ± 15V with a typical current consumption of 11mA at ± 6V. The linear full acceleration range is ± 3g with a corresponding sensitivity of 1.2V/g. It can operate over a wide temperature range from -40°C to +85°C and can withstand a shock of up to 1500g without performance degradation. The frequency response over the full scale range is DC to > 1500Hz.
The product is available with oscillator (SF1500S.A) or without oscillator (SF1500SN.A).

Accelerometer specifications

All values are specified at +20°C (+68°F) and ±15 VDC supply voltage, unless otherwise stated

	Units	SF1500S / SF1500SN
Linear output range	g peak	± 3
DC bias	mg max.	± 200
Scale factor / Sensitivity	V/g (differential)	1.2 ± 0.12 (2.4 ± 0.24)
Dynamic range (0.1 to 100 Hz BW)	dB typ. (min.)	117 (113)
Noise (10 to 1000 Hz) [2]	$\mu g_{rms}/\sqrt{Hz}$ typ. (max.)	0.3 (<0.5)
Frequency response [1]	Hz	DC to 1500
Cross-axis rejection	dB	> 46
Bias thermal coefficient	mg/°C typ.	-0.2
Sensitivity temperature coefficient	ppm/°C typ.	250 (ref ± 1g)
Input Resistance of Offset adjustment pin	KΩ	10
Linearity error	% max within ± 1g	< 1 (within ± 1g only)

[1]   The bandwidth is defined as the frequency band for which the sensitivity has decreased by less than 3dB
[2]   This product is not guaranteed or tested against bias step noise and/or popcorn noise. These effects can be observed in some parts during continuous recording of noise floor with spikes of few tens of µg at random and unpredictable time.

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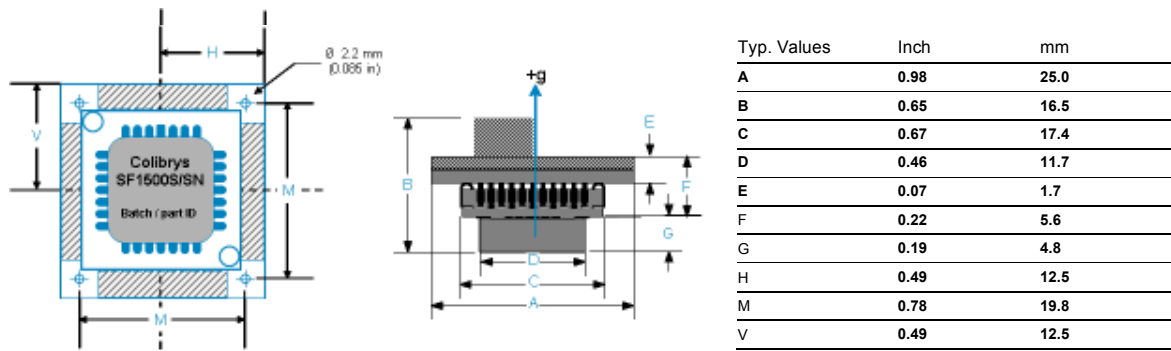
Environmental specifications

SF1500S / SF1500SN

Operating temperature range	-40°C to +85°C (-67°F to 255°F)
Shock resistance	Up to 1'500 g peak (0.5ms half-sine, single shock, not repetitive, in one direction o, p or 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

Packaging

The accelerometer assembly consists of the following subassemblies:

- The multi-chip module (MCM) assembly of the MEMS capacitive sensor element packaged in a custom ceramic package solder attached to the ASIC chip through an interconnect board. The sealing process of the MCM 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.
- A printed circuit board consisting of power conditioning electronics employing linear regulators, output amplifiers, other support electronics, 10 connection pins and mounting holes.

The precise dimensions are given in the next figure and the weight of the final product is typically smaller than 6.7 grams

Typ. Values	Inch	mm
A	**0.98**	**25.0**
B	**0.65**	**16.5**
C	**0.67**	**17.4**
D	**0.46**	**11.7**
E	**0.07**	**1.7**
F	0.22	5.6
G	0.19	4.8
H	0.49	12.5
M	0.78	19.8
V	**0.49**	**12.5**

Mounting

The SF1500 is suitable for subsequent multi axis assembly. In order to accurately measure acceleration signals, the SF1500 must be firmly attached for adequate mechanical coupling, using the bottom of PCB as reference plane to ensure a good axis alignment. The SiFlex^{TM} units have four mounting holes located in the corners of the PCB. The stress induced by the assembly 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, the PCB must be carefully assembled.
Although the Si-Flex accelerometers have been designed to withstand high shock levels (see specification) care should be exercised when handling the bare OEM assemblies. High intensity, short duration shocks which exceed product specifications can easily be generated over short drop heights when hard surfaces come into contact with the ceramic sensor package.

Physical specifications

SF1500S / SF1500SN

Packaging	Ceramic MCM on PCB assembly
Hermeticity	The MCM of 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	< 6.7 grams
Size	Typ. 25 x 25 x 14.5 mm (0.98 x 0.98 x 0.57 inch)
Reference plane for axis alignment	The PCB module must be tightly fixed to its final housing, using the bottom of the PCB as reference plane for axis alignment and the four holes located in the corner of the PCB. Using the lid as reference plane or for assembly may affect specifications and product reliability (i.e. axis alignment and/or lid soldering integrity)

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Principle of operation

The core of the accelerometer is the capacitive bulk micro-machined silicon sensor. 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 external fixed electrodes of the sensor

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

Applied acceleration or tilt to the sensitive axis changes the inertia, causing the mass to move between the upper and lower electrodes, which results in a change to the values of the capacitors. This differential variation of the sensing capacitors is measured by the custom ASIC. As changes in capacitance are sensed, a restoring electrostatic force is applied to maintain the proof mass in a central (neutral) position. The output signal of the sensor is derived directly from the correction signal used to keep the center-mass in the neutral position. This correction signal is linearly proportional to the acceleration applied (by the ground motion) to the sensor. This type of closed-loop design generally provides better output linearity than open-loop sensors.

The output signal is a DC-coupled acceleration-proportional signal with a typical sensitivity of 0.8V/g for the SF2006SN and a bipolar output ranging nominally over ±4.2V. The output of the sensor follows a g * sin(θ) response as it rotates through gravity and can measure the vertical tilt angle (θ) with a high degree of accuracy.

Si-Flex™ accelerometers are calibrated by precisely rotating the accelerometer through the gravity field as described by IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Pendulous, Analog Torque Balance Accelerometer. The resulting sine wave is analyzed and processed to provide the calibration coefficients K1, K0, K2, and K3.

The equations below show how the voltage output and calibration data are used to determine acceleration. Equation (1) is a basic calculation suitable for most applications. Equation (2) corrects for non-linearity using the K2 and K3 terms of each accelerometer. The high accuracy equation is typically used only for measurements greater than 1g requiring minimal distortion.

$$a = Vout/K1 - K0 \tag{1}$$
$$a_{corrected} = g - g^2 k2 - g^3 k3 \tag{2}$$

where

–	a	is the acceleration (1g = 9.086 m/s^2)
–	Vout	is the output signal (Volts)
–	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]

Note: The accelerometer scale factor K1 is provided as a single-ended output value. If +Vout and –Vout are used together as a differential output, the scale factor will be 2 * K1.

Electrical specifications

SF1500S / SF1500SN	
Input voltage (VDD – VSS)	±6 to±15 VDC
Output voltage range (differential)	1.2 ± 0.12 (2.4 ± 0.24)
Operating current consumption	Quiescent current of typ. 11.7 mA @ 6VDC
Input resistance of offset adjustment pin	10 kΩ

Both the (+) and (-) power supplies must be applied simultaneously to the input pins (within 50 ms). The power supply should have less than 100 µV√Hz noise in order to avoid the possibility of adding noise to the output of the sensor. The ASIC and on-board electronics operate on ± 5V DC provided by internal power conditioning circuitry, reducing the effects of power supply variations on sensor operation. The input power supply connections are reverse polarity protected by a diode bridge. Should reverse polarity power be applied, the unit will self-correct and start normally. The output of the Si-Flex accelerometer is fully buffered and ready to connect to common inputs found on many analog to digital converters, oscilloscopes and digital multi-meters. The nominal output impedance for the Si-Flex accelerometers is typically 10 Ohms.
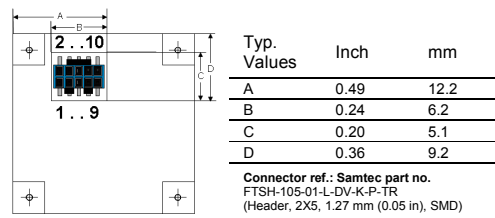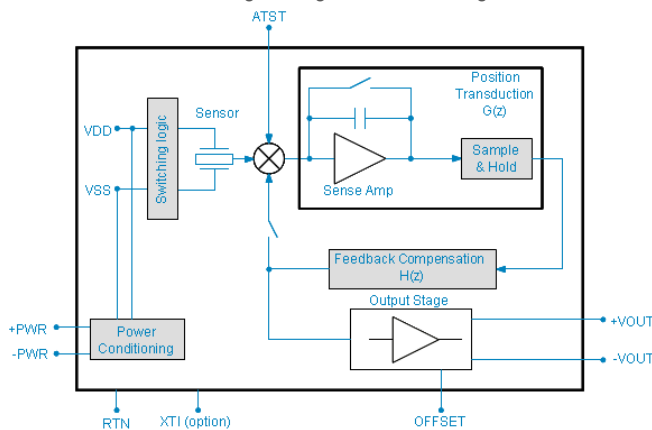
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Self test function

The self-test function allows testing of sensor functionality. A 5V CMOS TTL level pulse of 10 ms duration (for example) injects a signal into the feedback loop that servos the proof mass to a new position. This in turn is reflected as a 10 ms pulse of approximately 800 mg observed in the output signal. This is a true self-test. If for instance the sensor is non-functional, if there is an open or short cut in the output cabling, or there is no DC power to the device, the self test operation will not yield a signal change on the output. The applied logic level high to this pin must be +4 volts minimum and the logic low must be less than 0.5 VDC. The signal is ratiometric to the applied voltage.

The self test feature is intended only as a functional check and not for calibration purposes.

Sensor connections and power supply requirements

The detailed block diagram is given in the next figure:

Typ. Values	Inch	mm
A	0.49	12.2
B	0.24	6.2
C	0.20	5.1
D	0.36	9.2

Connector ref.: Samtec part no.
FTSH-105-01-L-DV-K-P-TR
(Header, 2X5, 1.27 mm (0.05 in), SMD)

Pin	SF1500 Description	Notes
1	- Vout	Inverted output signal
2	+ Vout	Output signal
3	ATST	Sensor self test input
4 – 8	RTN	Signal return (common)
5	OFFSET	Used to remove DC offset
6	XTI	Oscillator input
7	NC	Not connected
9	-PWR	Negative power supply
19	+PWR	Positive power supply

For the SF1500SN.A, the external oscillator should have the following specifications: 4.000MHz or 4.096MHz square wave output with 50% (range 40-60%) duty cycle and a 5V CMOS level voltages (low < 0.8V, high >4V). Note: do not apply XTI prior to applying both positive and negative power supply voltages.

The DC offset adjustment allows the user to remove inherent sensor offset or DC offset due to gravity. This signal is not applied as feedback to the accelerometer. It is used only to cancel offset in the output amplifier buffer. A positive voltage applied to this input will remove a corresponding negative offset in the accelerometer output. The signal should not need to be any larger than K0 + K1 or about ± 1.5 Volts. Extreme care should be taken when connecting an offset adjustment voltage to this pin as this input has a gain of one and any noise on the offset adjust voltage will appear on the output of the sensor. Therefore, the noise spectral density on this pin from the applied source should be ≤100 nV/√Hz. If this input is not used, it should be connected to signal ground at the sensor with as short a lead as possible to prevent EMI noise from being injected into the output.

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.

– SF1500S.A and SF1500SN.a products are complaints with the Swiss LSPro : 930.11 dedicated to the security of products
  Note:
  – *SF1500 accelerometers are available for sales to professional only*
  – *Les accéléromètres SF1500 ne sont disponibles à la vente que pour des clients professionnels*
  – *Die Produkte der Serie SF1500 sind nur im Vertrieb für kommerzielle Kunden verfügbar*
  – *Gli accelerometri SF1500 sono disponibili alla vendita soltanto per clienti professionisti*

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

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Glossary of parameters of the Data Sheet + Definitions

-VOUT	Inverted output signal.
+VOUT	Output signal.
ATST	Sensor self test input. A minimum signal of 4 volts is required to produce an output. This input should be maintained at logic low or connected to RTN when not in use. This input can be connected to multiple sensors if one test signal is desired for multiple sensor channels.
RTN	Signal Return (common). All of the signal-return lines are tied together on the board. Separate connection points are provided for various inputs to optimize noise due to cabling. Use this as a signal-return for single-ended operation with either +VOUT or –VOUT.
OFFSET	Used to remove DC coupled to gravity. This input should be tied to RTN if unused.
XTI	External oscillator input for products without the oscillator option. No Connection for products with the oscillator option.
N/C	No Connection. This pin is not used for this device. Do not connect to it.
-PWR	Negative power supply. -6 to -15 VDC can be used. Reverse polarity protected.
+PWR	Positive power supply. +6 to +15 VDC can be used. Reverse polarity protected.

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 or -5% for vibration sensors

Noise [ng$_{peak}$/√Hz]

A measure of the Power Spectral Density (PSD) of the white noise on the accelerometer output caused by either the electronics or by Brownian motion of the proof mass.

Colibrys reserves the right to change these data without notice.