

The units are shipped with a mounting kit containing four 2-56 x 3/8 inch spacers, eight 2-56 x 3/16 inch cap screws and an Allen wrench for the 2-56 cap screws. The screws should be hand tightened and a thread locking compound should be used to minimize loosening during vibration. Although the Si-Flex accelerometers have been designed to withstand high shock levels (see specific model

datasheets for specifications), 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.

Quality system

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

Definitions & Glossary

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

-V _{OUT}	Inverted output signal.
+V _{OUT}	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 +V _{OUT} or -V _{OUT} .
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.

Glossary of parameters of the Data Sheet

Acceleration (g)

Unit of acceleration, equal to a standard value of gravity (Units are calibrated using the gravity at our facility in Stafford, Texas 77477, USA.) 1g = 9.806 m/s².

Bias (g)

The accelerometer output with no input acceleration present.

Bias stability (g)

Maximum drift of the bias after extreme variation of external conditions (aging, temperature cycles, shocks, vibrations).

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 +85°C, where temperature behaviour is linear.

Scale Factor / Sensitivity (V/g)

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

DC Linearity

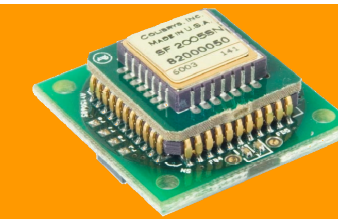
The maximum deviation of accelerometer output from the best linear fit over a +/- 1g DC range. The deviation is expressed as a percentage of the full scale output.

Bandwidth (Hz)

Frequency range from DC to F_{±3dB} where the variation of the frequency response is less than ±3dB.

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.



MEMS Capacitive Accelerometers

Product Description

Si-Flex™ Series

30D.SFX.D.03.09

General Description

The SiFlex™ accelerometer has been designed and developed by Colibrys Inc. for "strong motion" seismic sensing applications. This MEMS capacitive product is the world best in class "digital geophone", largely used for seismic and vibration sensing when extreme low noise measurement is required. Features such as wide dynamic range, excellent bandwidth, low distortion, high shock tolerance, and thermal stability make it ideal for applications such as earthquake and seismology measurements, homeland and border security or structure monitoring. Used as a tilt sensor, it also provides a very high resolution of measurement.

This product exists in two versions (Table 1):

- The SF1500S / SF1500SN offers unmatched noise performance allied with robustness. This ± 3g MEMS

sensor provides an extremely low noise of 300ng_{rms}/√Hz and is ideal for strong motion measurements.

- The SF2005S / SF2005SN still offers a very low noise performance (800ng_{rms}/√Hz) for a larger full scale (± 4g). This makes it ideal for seismic sensing and structure monitoring where higher accelerations have to be measured.

Product description

The SiFlex™ 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 closed-loop force-feedback operation of the accelerometer (Fig. 1). 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 and SF2005 operate from a bipolar power supply voltage that can range from ± 6V to ± 15V with a typical current consumption of 12mA at ± 6V. The linear full acceleration range varies from ± 3g for the SF1500 to from ± 4g for the SF2005 with a corresponding sensitivity of 1.2V/g and 0.8V/g respectively. Both units can operate over a wide temperature range from -40°C to +125°C and can withstand a shock of up to 1500g without performance degradation. The frequency response over the full scale range is DC to >1000Hz.

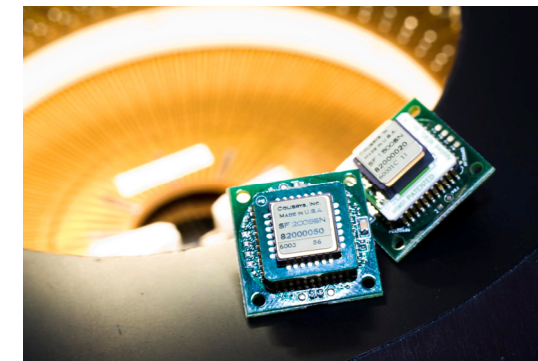


Fig. 1 : SF2005 and SF1500 products

Full scale range	± 3g (with oscillator)	± 3g (without oscillator)	± 4g (with oscillator)	± 4g (without oscillator)
Products	SF1500S.A	SF1500SN.A	SF2005S.A	SF2005SN.A

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 best satisfy the requirements for high performance MEMS accelerometer. Arguments clearly demonstrate that compared to the planar approach ("in plane" displacement of the proof mass), bulk technology ("out of plane" displacement of the proof mass) is the most successful approach to provide high end sensors and probably the best solution for extreme low noise sensors.

The two center wafers are fusion bonded to form the middle electrode which consists of the proof mass, the suspension springs and the mass support frame. The two outer wafers provide the outside electrodes and are metal thermo-compression bonded to the mass frame wafers. The completed sensor is housed in a custom ceramic package sealed under vacuum.

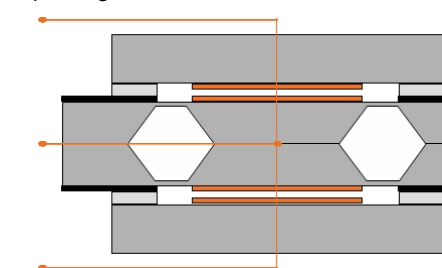


Fig. 2 : Cross section of a Colibrys Si-Flex accelerometer

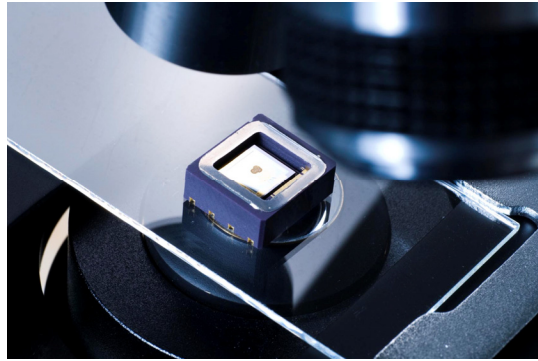


Fig. 3 : View of the micro machined silicon sensor in ceramic package

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.

Basic accelerometer operation

The output signal is a DC-coupled acceleration-proportional signal with a typical sensitivity of 0.8V/g for the SF2005 and 1.2V/g for the SF1500 and a bipolar output ranging nominally over $\pm 4.2V$. The output of the sensor follows a $g \cdot \sin(\theta)$ 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 accelerometers through the gravity field as described by IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Pendulous, Analog Torque Balance Accelerometer Document Number IEEE 337-1972, 01-Jan-1972 ISBN: 1559376171. 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.

$$a = V_{out}/K1 - K0 \quad (1)$$

$$a_{corrected} = g - g^2 K2 - g^3 K3 \quad (2)$$

where

- a is the acceleration ($1g = 9.806 \text{ m/s}^2$)
- V_{out} is the output signal (Volts)
- K0 is bias (g)
- K1 is accelerometer scale factor (V/g)
- K2 is second order non linearity (g/g^2)
- K3 is third order non-linearity (g/g^3)

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

Sensor connections & power supply requirements

The detailed block diagram and electrical connections are given in Fig. 4

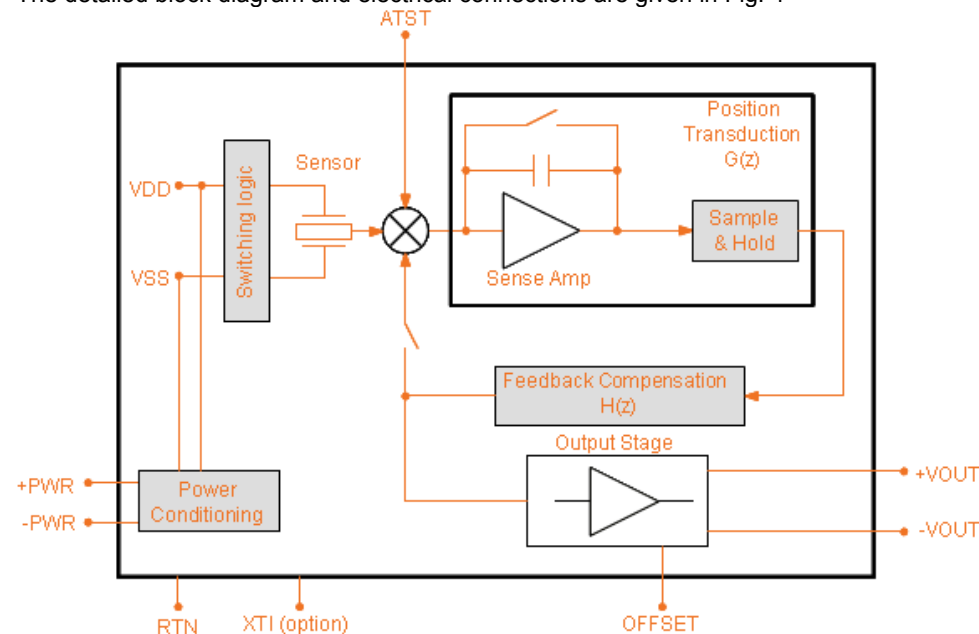


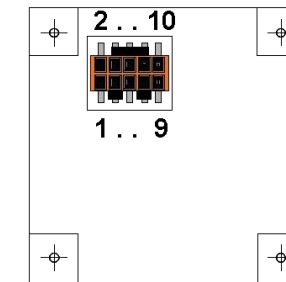
Fig. 4 : Block diagram

Both the (+) and (-) power supplies must be applied simultaneously to the input pins (within 50 ms). The power supply should have less than $100 \mu V/\sqrt{Hz}$ noise in order to avoid the possibility of adding noise to the output of the sensor. The ASIC and on-board electronics operate on $\pm 5V$ 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. A 10cm un-

terminated mini-ribbon cable is provided with a single mating connector for the SF1500 and SF2005 (connector Samtec part no. FTSH-105-01-L-DV-K-P-TR).



Electrical connections

P1	-Vout	Inverted output signal
P2	+Vout	Output signal
P3	ATST	Sensor self test input
P4, P8	RTN	Signal return (common)
P5	OFFSET	Used to remove DC offset
P6	XTI	Oscillator input. N/C for SF1500S and SF2005S
P7	N/C	Not connected
P9	-PWR	Negative power supply
P10	+PWR	Positive power supply

Oscillator option

The Si-Flex™ SF1500 and SF2005 are both available in two configurations
 - with a built-in oscillator: SF1500S.A, SF2005S.A
 - without a built in oscillator: SF1500SN.A, SF2005SN.A
 The option with oscillator employs a ceramic resonator operating at a frequency of 4.000MHz. The oscillator option is ideal for single axis operation and only requires power as an input.
 For users that may require a closely mounted tri-axial

sensor configuration, an option without an oscillator is available. This option allows operation without any oscillator beat-note interference between units. In this case, pin 6, XTI is the external oscillator input. The 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). Do not apply XTI prior to applying both positive and negative power supply voltages.

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 serves 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 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.

DC offset adjustment

This pin 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 $\leq 100 \text{ nV}/\sqrt{Hz}$. 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.

Packaging

The accelerometer assembly consists of the following subassemblies:
 1) a piggyback assembly of the MEMS capacitive sensor element packaged in a custom ceramic package solder attached to the ASIC chip through an interconnect ceramic board
 2) a printed circuit board consisting of power conditioning electronics employing linear regulators, output amplifiers, other support electronics, 10 connection pins, and mounting holes.

Mounting and handling

In order accurately measure acceleration signals, the SiFlex 1500 and SF2005 should be firmly attached to the device for adequate mechanical coupling. The SiFlex units have four mounting holes located in the corners of the printed circuit board.

