COLIBRYS
SMART SENSING SOLUTIONS

APPLICATION NOTE

MEMS accelerometers for building & structural health monitoring

30N.SHM.A.05.11

SF2006 Class B seismic sensor

Features

SF2006SN.A

- Very low noise level (0.9µg/√Hz)
- Wide dynamic range (112 dB @ 100Hz BW)
- DC to 1000Hz frequency response
- ±5g linear output
- Harsh environment (shock, vibration, temperature)
- Self test

Introduction

Structural Health Monitoring systems (SHM) are increasingly being installed throughout the world, most especially in areas vulnerable to high level seismic activity for seismic pre-mapping and seismic intensity measurements but also directly within large structures such as buildings, dams, bridges, nuclear plants etc. subject to sub-surface landslip or externally induced stress and vibrations to determine the structure integrity.

Strong motion seismic sensor technology is evolving in response to these emerging demands and traditional electromechanical solutions (Forced Balanced Accelerometers "FBA" or electromechanical solutions) are being increasingly displaced by more cost effective and more robust MEMS based solutions. The growth of SHM systems in many regions of the world is driven by both the preventive measurement and prediction of unquantifiable and subjective ageing of many large structures such as dams, bridges, high-rise building, etc. and the increasing pressure on many governments to provide effective civil protection, control and intervention solutions through comparative analysis of structures before, during and after major earthquake, as seen quite recently in Indonesia, Italy, Haiti, Chile, New Zealand, Spain or Japan. It has been reported that earthquakes are responsible for almost 60% of all deaths caused by natural disasters, this heightening governmental and public awareness of the devastating consequences of such events.

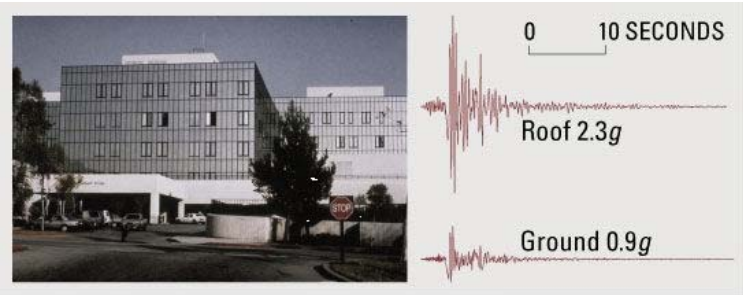
A relatively narrow family of sensors is currently deployed within SHM systems, which are namely velocity sensors (broadband and strong motion), tilt and strong motion accelerometers, strain gages, positional or displacement, curvature and corrosion sensors. These sensors must comply with a host of national and regional standards, often historically inherited from their wide adoption in Geotechnical and Geophysical research.

Strong motion accelerometers

Strong motion accelerometers are sub-classified into grades or classes (A, B, C and D) by the US Geological Survey institute (USGS) and this standard is widely used as reference. The key parameters differentiating performance in the various categories are full scale g range, dynamic range or noise levels across key frequency bands, linearity and power consumption.

Class C sensors requirements are most commonly fulfilled today by a range of open loop capacitive MEMS based sensors deriving their functional performance from developments in the automotive and more recently multi-media applications, benefiting in consequence from good reliability, low power consumption and lower cost. Noise performance limits and signal resolution anyway constrain their use to acting largely for applications where ambient noise levels are relatively high such as rapid earthquake event detection or early warning protection used to switch down infrastructures such as elevators, gas or electricity supply or to act as 'wake up' signal for power sensitive systems.

Class B sensors are today extensively used in Structural Health & Building Monitoring applications thanks to their high level (>18bit) signal resolution in frequency band 0.02 to 100Hz. High dynamic range is required to compare pre and post event data and to accurately and safely monitor relative changes or damage to the structure. Demand for full scale g ranges has progressively increased to ±5g reflecting actual recorded acceleration levels of 3 to 4g (+ 1g for gravity compensation), resulting from amplification throughout the building. Linearity levels are targeted at approximately 1% max. of full scale.



Amplification effect from ground to roof on a four floor building

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Traditionally Force Balance Accelerometers and large electromechanical structures combined with a servo loop electronic have traditionally been used as Class B sensors as they were the unique solutions available. These products were the best compromise in term of performance versus reliability under harsh environment, power consumption and size.

Many applications require more robust products, smaller and with much lower power consumption and this has been the driving force for the emergence of MEMS solution such as the SF2006SN.A from Colibrys.

Class A sensors are characterized in particular by their very high signal resolution (20 to 24 bit) and high dynamic range, especially at very low frequencies. They are most typically used throughout the Geo-scientific and Civil Protection applications but with relatively low uptake to date in SHM due to high power consumption, excessively low dynamic range and above all their significantly higher cost. Ongoing MEMS developments should here also offer interesting alternatives in the near future, enabling new great opportunities for the final users.

Colibrys accelerometers for Building & Structural Health monitoring systems

Colibrys is already an established leader in the world of seismic applications, offering Class C and Class B NENS sensors to this market. Colibrys proposes both the SF2006 and SF1500 class B sensors (Fig.2).

The SF2006SN still offers a very low noise performance (900ngrms/√Hz) for a larger full scale (± 5g). This makes it ideal for seismic sensing and structure monitoring where higher accelerations have to be measured.

The SF1500S and SF1500SN offer unmatched noise performances allied with robustness. This ± 3g MEMS sensor provides an extremely low noise of 300ngrms/√Hz and is ideal for strong motion measurements.

Principle of operation

The SF2006 and SF1500 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 ± 5g for the SF2006 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 +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 >1000Hz for the SF2006 and DC to >1500 Hz for the SF1500.

Fig 2: SF2006 accelerometer

Conclusion

Many established volume suppliers of MEMS capacitive sensors are exploring this market to expand or diversify their existing business base. Colibrys MEMS seismic products, with their extremely low noise and large dynamic range are the world's best-in-class and present the unique opportunity to replace traditional Force Balance Accelerometers (FBAs).

In the coming years it is hoped to launch new lower cost, lower power consumption Class A and Class B sensors based on latest MEMS sensor and closed loop electronics designs and start to establish market share for supply of Class A sensors also

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