APPLICATION NOTE

Seismic Prevention

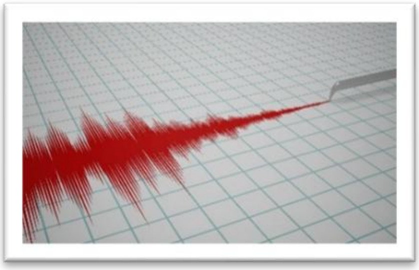

Figure 1: A seismograph

Improvement in accelerometer performance opens the possibility of competing with standard seismometers. In some cases, preliminary shocks generated by tectonic plates make it possible to predict the imminence of a seismic disaster. This application note highlights the role of accelerometers for seismic prevention. The concept is to install high precision accelerometers near seismic zones. Seismic zones typically occur at the borders of two tectonic plates. Of all the different types of seismic disturbances, subduction creates the most powerful and frequent earthquakes. The number of units deployed in the field is related to the desired precision in locating the source of the disaster.

The interval of time between an earthquake and a local alert can be very small, from one minute to a few seconds. Two types of waves are emitted from the epicenter: the P-waves are the first to propagate, followed by the S-waves, which are slower but have a much larger amplitude. The waves travel through the ground at 1 to 5 kilometers per second, whereas the signals emitted by the sensors reach the urban areas almost instantly. This allows the population that are not into the blind zone to execute the security procedures in time.

Architecture of the System

In order to optimize the chance of detecting an earthquake, the accelerometers are generally installed at a constant distance from one another. The MCU operates in an idle mode as long as the measurements don't exceed a threshold. If vibrations are detected, the system switches to an awake state and sends the data to the closest seismic observation center. The use of relays can be a good solution to reduce radio consumption.

Two vibration sensors installed on the x and y axes are required for P-wave detection, as they propagate parallel to the ground. On the other hand, three accelerometers are needed for S-wave detection, as they propagate perpendicular to the surface.

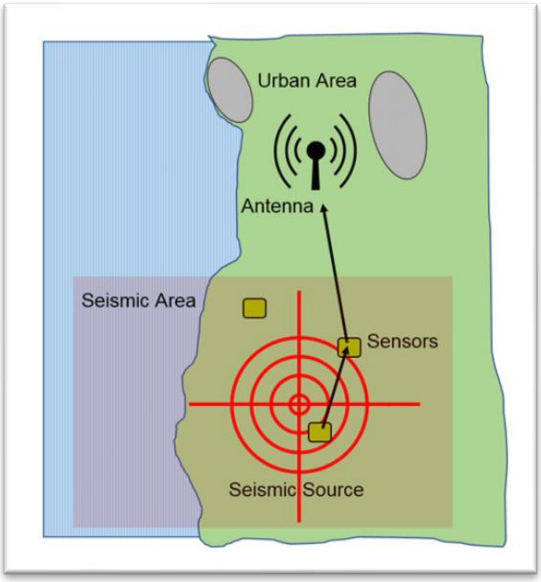

Figure 2: The principle of seismic prevention

A Strict Environment

The sensors are installed in high-level controlled rooms in order to measure the earth vibrations. Therefore, the temperature, parasite vibrations, power consumption and size of the sensors are not considered as the main factors in selecting the right sensor.

A seismic wave propagates between 0-10 Hz, depending on its type, soil composition and distance to the epicenter. Its amplitude on the ground, also known as the Peak Ground Acceleration (PGA), doesn't exceed 1g.

Performance Required

The most important point is to read the low amplitude, low frequency vibrations with net accuracy. The Advanced National Seismic Systems (ANSS) are divided into 3 classes. The least demanding class is the Class C, accepting all sensors with a 90 dB ratio between the lowest noise and the maximum value read. Class B includes all sensors with 110-120 dB in accuracy. The most effective accelerometers are found in Class A (or strong motion): they assure an excellent precision of 134-140 dB. The formula for the seismic classes is developed as follows:

$$\text{Dynamic Range} = 20 \times \log\left(\frac{0.707 \times \text{Max. Value}}{3 \times \text{Resolution}}\right) \text{[dB]}$$

where *Max. Value* and *Resolution* are, respectively, the highest and lowest values read by the sensor. The sensors chosen for this application must respect the requirements of Class B and Class C. In addition, the sensors must be stable and reliable over long periods of time.

The MEMS Accelerometers

A MEMS accelerometer functions through the displacement of electrostatic charges on the surface of electrodes. A proof mass suspended by a spring bends towards one of two fixed electrodes. The variation in capacitance - therefore in voltage - is directly related to the acceleration. MEMS accelerometers read excitations at low frequencies, typically from DC 0 Hz to 1000 Hz.

Piezo ceramic accelerometers, including piezo electric (PE) and piezo resistive (PR) sensors, have a very large bandwidth. However, they cannot measure very low frequencies, generally those below 0.5-1 Hz.

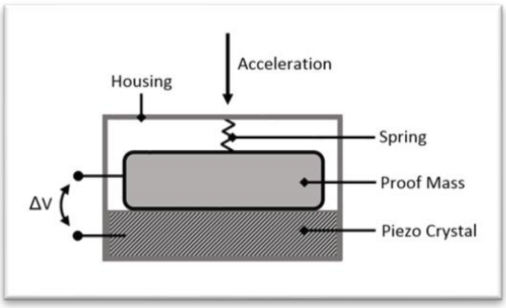

Figure 3: The principle of piezo accelerometers

Safran Timing Technologies SA
Av. des Sciences 13
1400 Yverdon-les-Bains - Switzerland

T +41 58 100 5000
F +41 58 100 5001
ww.safran-navigation-timing.com

Servo-accelerometers are direct competitors in portable seismic prevention. The servo balanced accelerometers are high performance, yet expensive sensors. Their uses are mostly reserved for Class A and Class B applications, as they function in a closed loop configuration.

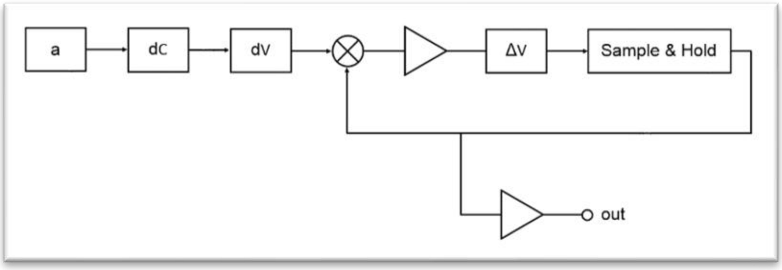

Figure 4: A possible configuration for closed loop accelerometers

Safran SI1000 Series

With a noise density down to 0.7 µg/√Hz for a recommended range of ±3g, the SI1000 sensor respects the requirements for seismic detection. By applying the formula found on the previous page, the dynamic range reaches 110 dB for a bandwidth of 100 Hz, hence approved for class B applications.

The sensor functions in an open loop and is very stable: it has a non-linearity coefficient of 0.1% FS. Lastly, the sensor withstands shocks up to 1500g, making it extremely resistant.

Glossary:

- ANSS: Advanced national seismic system
- dB: Decibel
- DC: Direct current
- FS: Full scale
- Hz: Hertz
- MEMS: Microelectromechanical systems
- PE: Piezoelectric
- PGA: Peak ground acceleration
- PR: Piezoresistive