MEMS Digital Accelerometer, The New Sensor In Seismic Exploration

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Abstract. In this paper, we had presented the MEMS digital accelerometer, currently one of the most advanced sensors used in seismic exploration. We had presented the functioning of the LIS344 accelerometer model, recommended to be used within geophones or hydrophones, given its performance in the low acceleration sector. In the last figure of the paper is the authors proposal of a hydrophone.

Keywords: MEMS, hydrophone, seismic exploration.

1 Introduction

In the past years, the results obtained in the design of the high –sensitivity, resolution, stability and low noise digital accelerometers, with the following characteristics: high sensitivity have allowed for their widespread presence in seismic exploration. The MEMS (Micro Electro Mechanical Systems) accelerometers are miniature integrated (4x4x1,5mm), low-weight (40 grams) circuits, up to 3 times more sensitive than the conventional geophones, the noise level is of around 1µm/s and have a sensitivity for low frequencies of up to 1Hz. The frequency response is linear, both for direct and alternative current, up to around 500Hz.

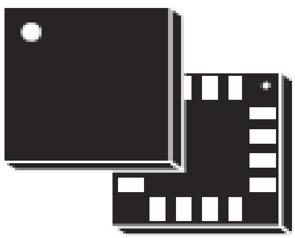

Fig. 1 The assembling layout of the MEMS accelerometer on 3 axes LIS344

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2 MEMS (Micro electro Mechanical Systems)

Generally, the MEMS accelerometers use the capacitive mode, in which the capacity depends on the ratio between the surface area of the plates A and the distance between them, d, being defined by the equation

$$C = f(A/d) \ . \qquad (1)$$

The accelerometer has two plates for each axis, a fixed and a mobile plate, as per the figure below.

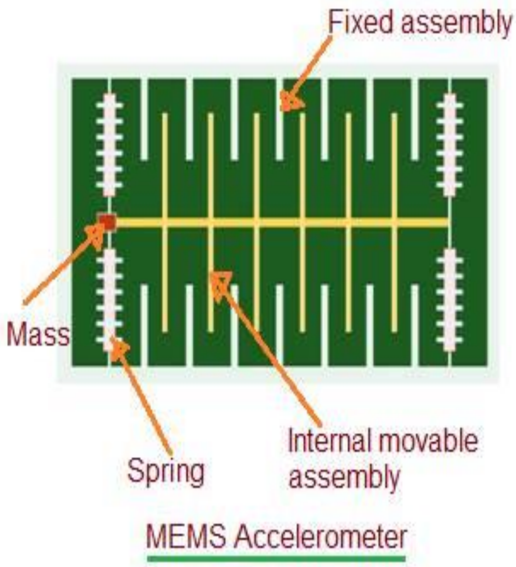

Fig. 2. MEMS accelerometer

The acceleration of the device's mass on the axis results in a capacity variation, which allows for the determination of the acceleration (a) from the equation, by measurement:

$$C = f(a/x), \text{ considering } \quad a = f(x) \ . \qquad (2)$$

The MEMS capacitive transducers can modulate their capacity, according to the relation

$$C = \frac{Q}{V} = k\frac{S}{d} \ . \qquad (3)$$

By varying the distance between the plates, having a fixed plate and a variable distance (d) between them, or by varying the surface of the capacity (s), maintaining a fixed distance between the plates and modulating the surface area by displacing the mobile plate in relation with the fixed plate. In order to maintain tuning linearity, in both methods a reaction force intervenes, having the role of maintain the value of the capacity as constant, by varying the charge in the first case, or by varying the tension in the second. This reaction force is in a direct relation with the capacity, and, as a consequence, with the acceleration.

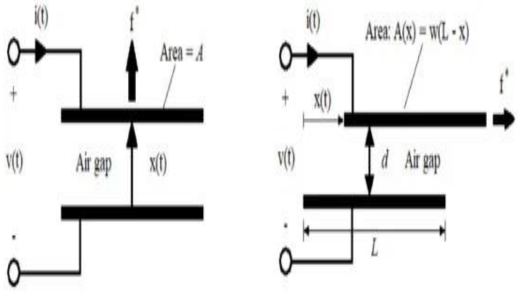

Fig. 3 Graphic rendering of the plates

In the case of varying the distance between the plates, to have a linear relation, the tension between the plates will need to be varied proportionally, in such a manner that the capacity be maintained constant; in the second case, a proportional charge (current) injection shall be made.

The reaction force that shall maintain the capacity constant is produced by means of a Sigma Delta modulator introduced in the compensation circuit by a negative reaction, as per the figure below

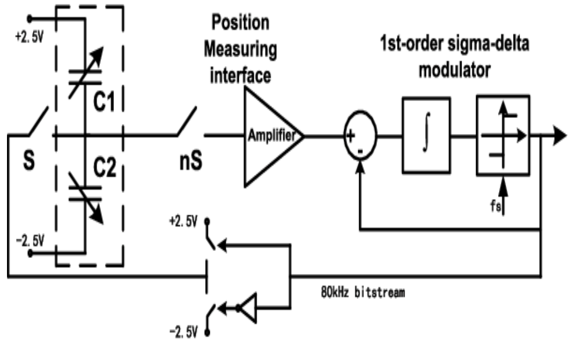

Fig.4 Reaction loop

The maintaining of the capacity constant, by means of the reaction loop including the Sigma Delta modulator, ensures the linearity and stability of the measurement, whose result is expressed directly in the digital format at the modulator's output. Negative reaction is frequently used to linearize the output signal, irrespective of the fact that it is analogic, digital or any type of modulated impulse.

The MEMS seismometer is characterized by:

-Low noise, from a few to some tens of ng/√Hz (nano acceleration per square root of frequency),

-Approximately 1g domain measurement

-High sensitivity

-Modelled as an arch – mass system

-The system’s mass is as low as a few milligrams

-The frequency band is smaller than the resonance frequency of the arch – mass system

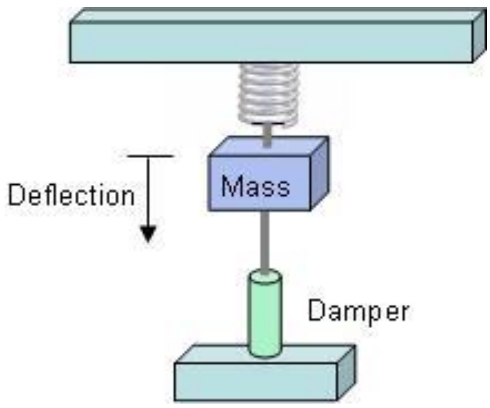

Fig.5 MEMS seismometer

Choosing the MEMS accelerometric sensor on three axes, type LIS344ALH has been determined by its performances in the field of low accelerations of ±2g, specific to seismic explorations. The operating frequency band is of 1.8kHz, adjustable by including external capacitors on its analog outputs.

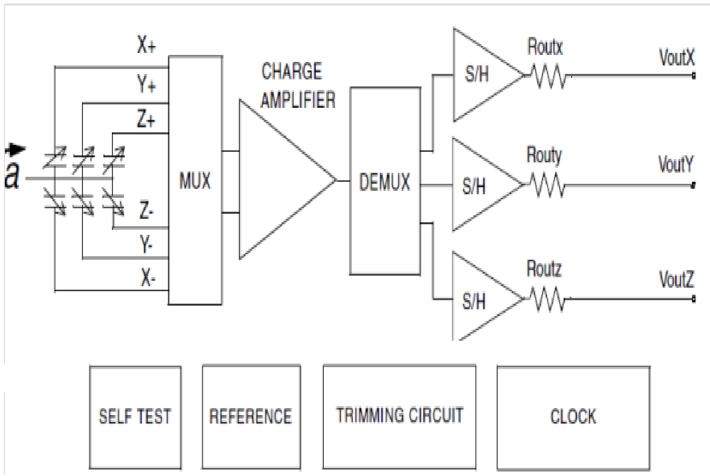

Fig. 6 Block diagram of the MEMS LIS344ALH accelerometer

The accelerometer is made up of three capacitive half-bridges, a common charge amplifier framed by groups of three multiplexers, demultiplexers, and by sampling circuits.

The analog output ensures a reduced noise, of 50ug//√Hz, in relation with the digital MEMS accelerometers. By a patented process, silica structures are created, suspended by anchors, displacing freely in the direction of the movement. When the sensor is moving, the mass is displaced into a new position, generating a lack of balance in the half-bridge, which is measured by integrating the charge as a response for the tension impulse applied to the capacitive sensor. In a state of balance, the value of the capacitors is of a few pF and the variation in the acceleration is by the fF (femtofarad). The output of the half-bridges is asymmetrically obtained by double correlation, method which allows for the measurement of the output tension, eliminating the offset, after the execution of two measurements, one under known conditions and the other in actual conditions, and then by subtracting the results, and which has as an additional effect the noise reduction. The measurement of the output parameters is done by the proportional method, in order to eliminate the influence of the variations of the voltage supply.
The system proposed by the authors in figure 7 is equipped with a MEMS-type three-axes acceleration sensor (micro-electromechanical system) LIS344 type, with analog outputs in voltage on three axes, followed by digitization on 24-bit and three-axes ADS1247 with outputs directly digitised on 20-bit. The calculation unit and interface consisting of a Raspberry Pi zero W module equipped with Bluetooth wireless communication interfaces and WiFi, has the possibility of storing the acquired data on the SD card, uses Python as its operation system. The power supply is made from a long-lasting Li-Ion battery, included in the hub.

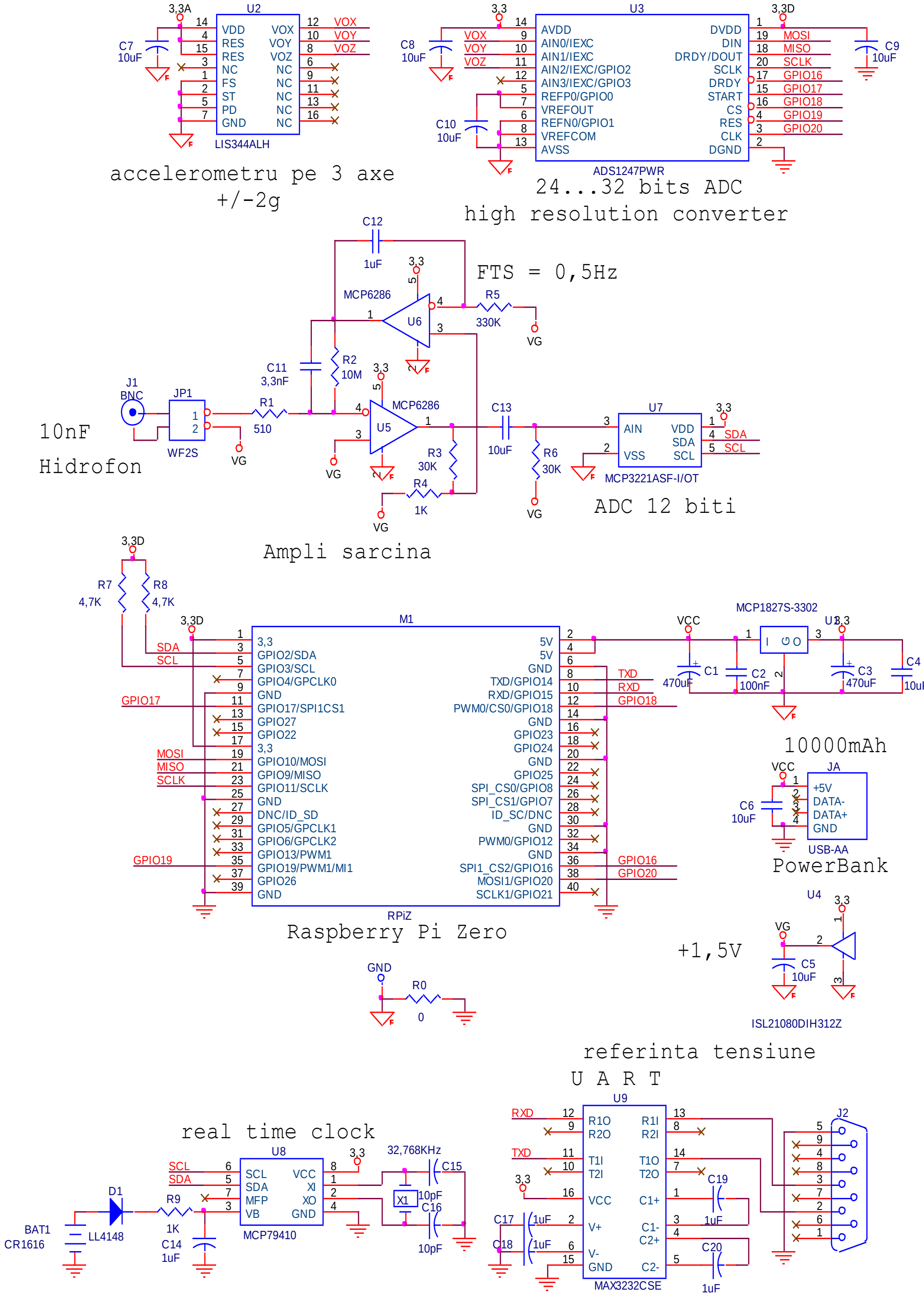

Fig. 7 Authors proposed hydrophone

3. Conclusions

From the analysis carried out, it is derived that the MEMS digital output accelerometer is high-performance and demonstrates benefits for its use in new geophone and hydrophone models, rendering the use of signal converters with geophones and hydrophones redundant, thus obtaining robust acquisition systems. The proposal of the paper's authors is of using the MEMS accelerometers in developing a new long-term seismic acquisition hub, with a low energy consumption, as per the scheme above.

References

[1] Mark Farine et al, General application of MEMS sensors for Land seismic Data acqusition – Is it time?

[2] C. P. Singh (2006), MEMS Based Digital Geophones with Onboard Sigma Delta Modulator, *6th Exploration Conference & Exposition on Petroleum Geophysics "Kolkata 2006"*

[3] A. D'Alessandro , S. Scudero and G. Vitale (2019), A Review of the Capacitive MEMS for Seismology, *Sensors,July 2019*

[4] L. Guerineau (208) An Ultra-low noise MEMS accelerometer for Seismology, *Sercel presentation*

[5] Kandekar et al (2018), Anatomy of MEMS Capacitive Accelerometer, International Journal for Research in Applied Science & Engineering Technology (IJRASET

[6] C. Nur'aidha1 et al (2018), Development of Seismic Data Acquisition Based on MEMS Accelerometer MMA7361L, *International Journal of Applied Engineering Research Vol 13, Nr 10*