Development of innovative magnetic field sensors with tuning features for a wide operative range

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RESEARCH TOPIC

The goal of this research activity consists in the development of integrated magnetic field sensors with a wide and "tunable" operating range and a constant resolution throughout the whole operating range. Two applications are planned for the sensors to be developed:

- detection of parking slot occupancy through the sensing of the alterations induced to the local strength of the geomagnetic field due to the presence of metallic targets such as cars or trucks.
- mapping of the magnetic field dispersed in a particle accelerator.

The detection range is the following:

[1µT-2T]

This Ph.D. project is focused BOTH toward industrial and scientific applications, it is expected to develop and test the sensor prototypes both at the research company and research entity involved, each for its own context.

weak magnetic field → PARADOX ENGINEERING

high magnetic field → CERN

THE LORENTZ FORCE MAGNETOMETER: WORKING PRINCIPLE AND PiezoMUMPs TECHNOLOGY

This typology of sensor is based on the interaction between an unknown external magnetic field to be estimated and a known current generated into an U-shaped cantilever beam. If the current I is driven into the cantilever, the interaction between this current and the magnetic field B produces the Lorentz force, F, whose amplitude is:

$$F = I \cdot B \cdot L$$

where L quantity is the length of cantilever subjected to perpendicular B. The measurand to be evaluated is converted in a voltage through the use of a piezo-electric material composing the MEMS device.

Indeed for fabricating the sensor prototype the PiezoMUMPs technology has been selected where an AlN (Aluminum Nitride) piezoelectric layer is used to generate an electric output: : this aspect represents the most important advantage in this process, because an electric signal is directly available in the output of the sensor.

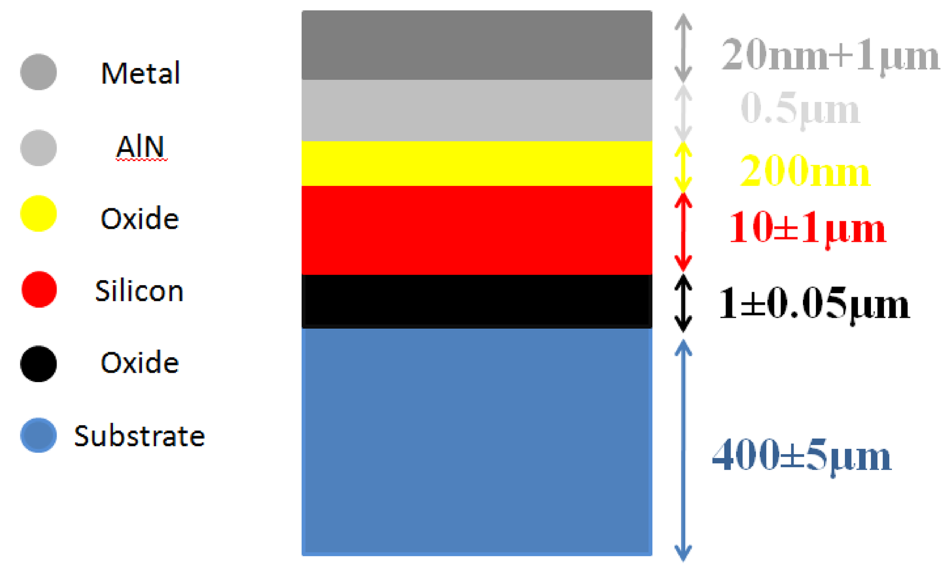


Fig. 2 : PiezoMUMPs Technology

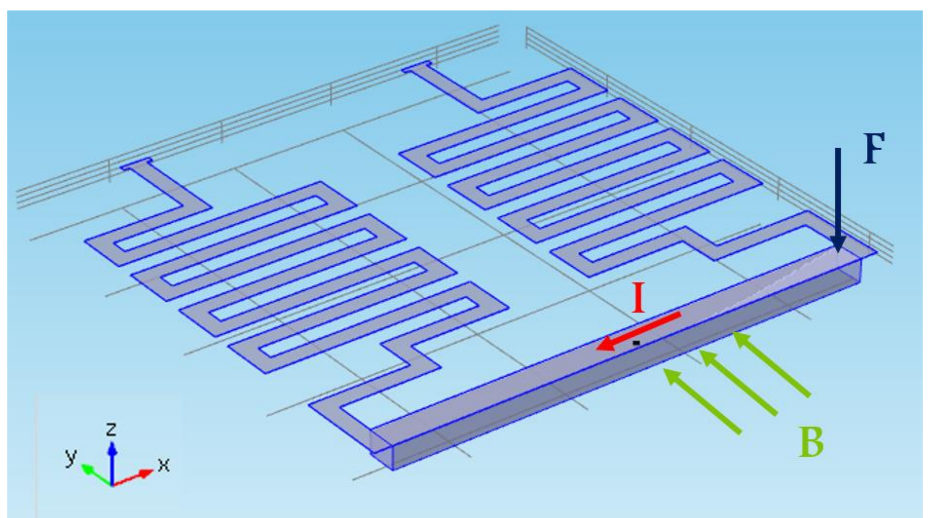
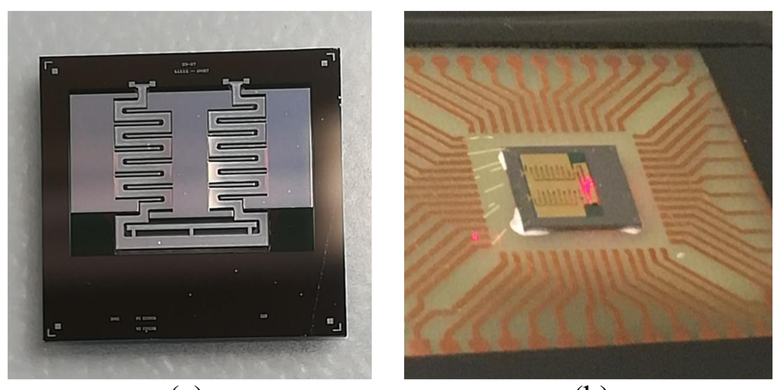


Fig. 1 : Architecture

MECHANICAL CHARACTERIZATION AS ACCELEROMETER

The fabrication of the device has been pursued with MEMSCAP and the die is shown in Fig. 3a; in order to characterize the MEMS accelerometer the die has been packaged and bonded on a PCB board (Fig. 3b) and afterwards an appropriate experimental setup has been realized in Fig. 4a.



(a) (b)

Fig. 3 : (a). Die; (b) Packaging and bonding

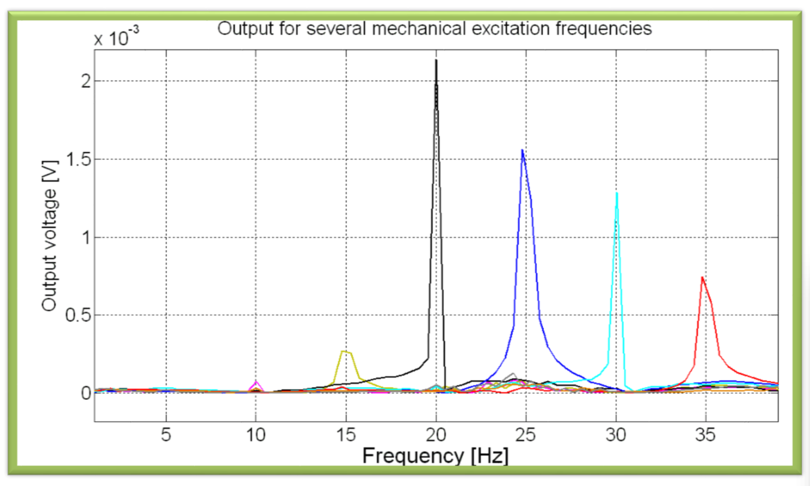


Fig. 5 : Topology 5

A resonance frequency of ~**20 Hz** has been experimentally estimated through the analysis of the output voltage for several mechanical frequencies, as illustrated in Fig. 5.

A sensitivity of ~**0.0038 V/(m/s2)**, a noise level of ~3.37e-05 V and a resolution of ~0.0089 m/s2 have been estimated.

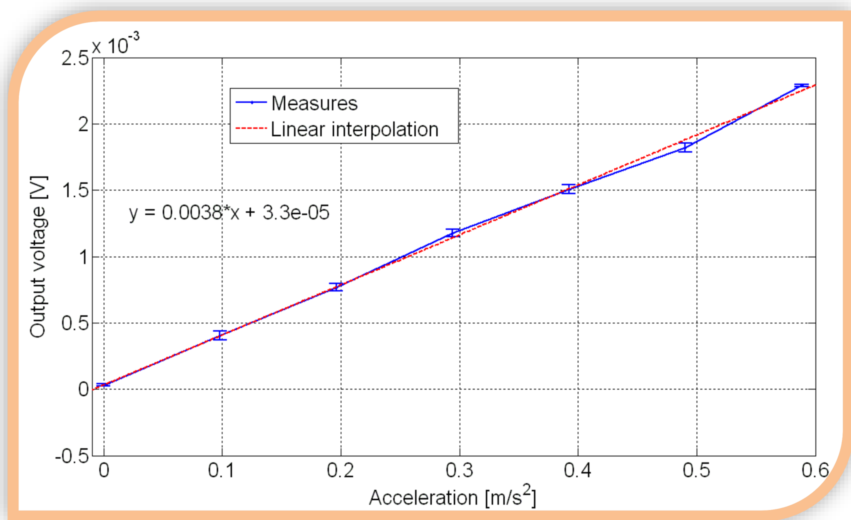


Fig. 6 : Topology 5

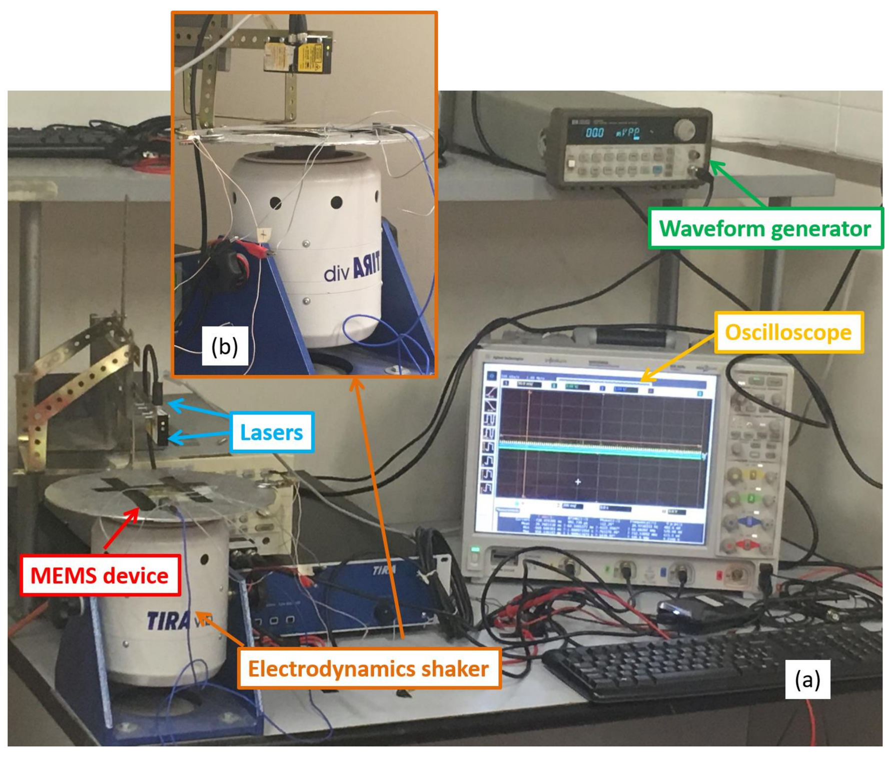


Fig. 4 : Meander architecture

PRELIMINARY MEASUREMENTS AT CERN

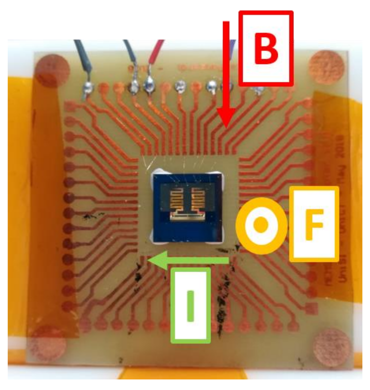


Fig. 7 : Operative condition

In order to actuate the MEMS device through the Lorentz force and to characterize it as magnetic field sensor some preliminary measurements have been carried out in the *Batiment 311 of MM (Magnetic Measurements) group*, at CERN, in Geneva. It is interesting to note that a **normal conductive dipole**, in yellow, is able to create an uniform magnetic field until 0.8 T (nominally).

Two different sensitivity have been estimated:

- **S=12e-5 V/T** for I =10 mA
- **S= 28e-5 V/T** for I =40 mA

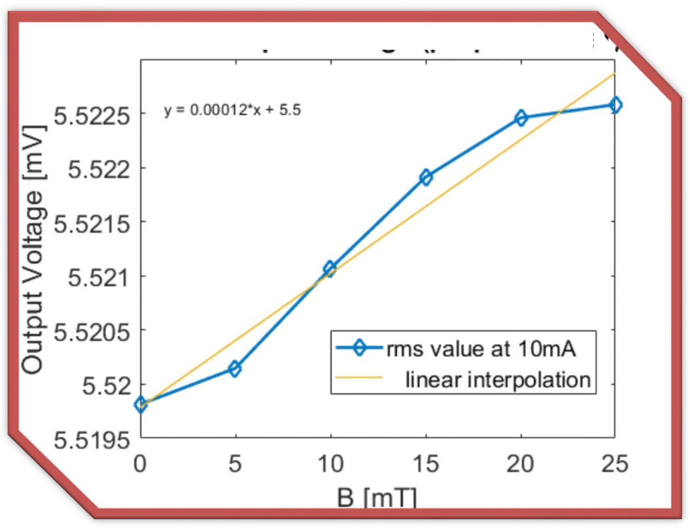


Fig. 9: Output voltage VS magnetic field at 10 mA

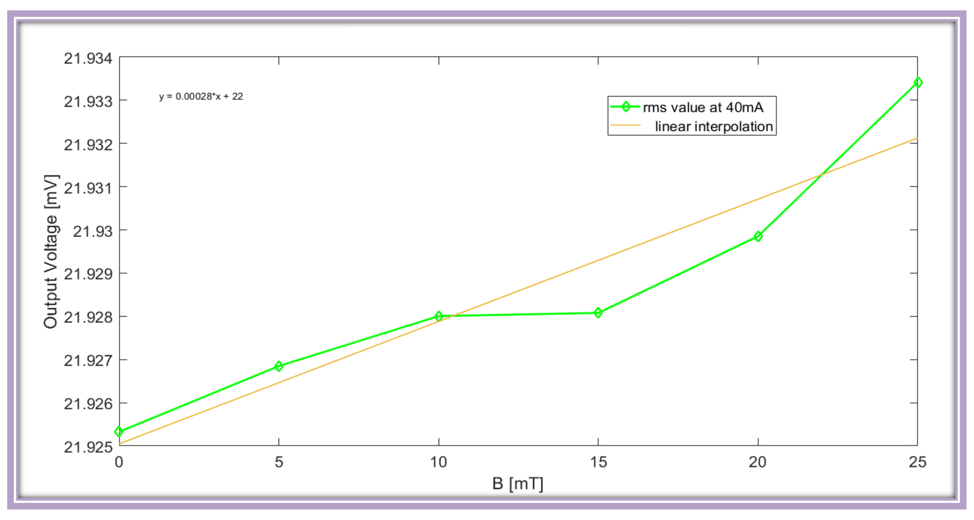


Fig. 10: Output voltage VS magnetic field at 40 mA

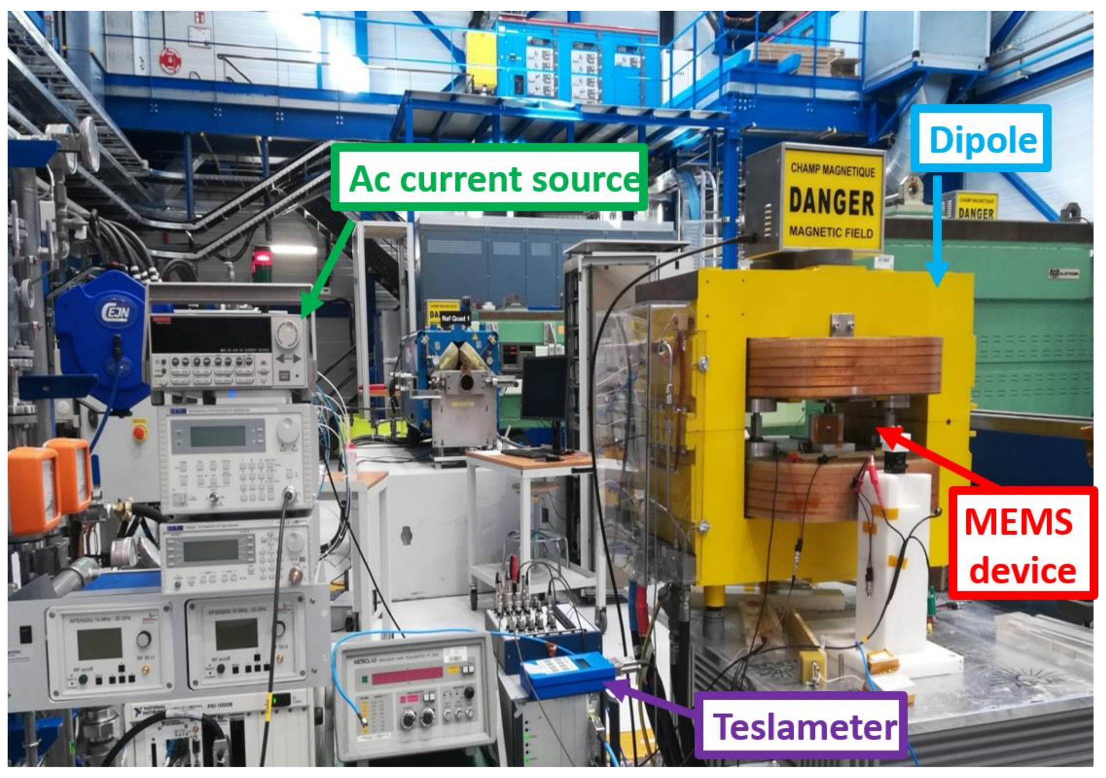


Fig. 8: Experimental setup at CERN

LAYOUT THROUGH THE MEMSPRO CAD

Other two layouts have been implemented using the MEMSPro CAD to reproduce the PiezoMUMPs technology. They have been realized in order to have two different readout strategies: piezoelectric and capacitive. They have been sent to the MEMSCAP foundry.

The idea is to compare the performance of the new architecture with the U-shaped beam cantilever, having the same dimensions.

In Fig. 11 a differential configuration has been implemented in order to obtain better performance. It is interesting to underline that the differential configuration is particularly indicated to measure weak magnetic fields, in preparation of the next characterization in Paradox Engineering.

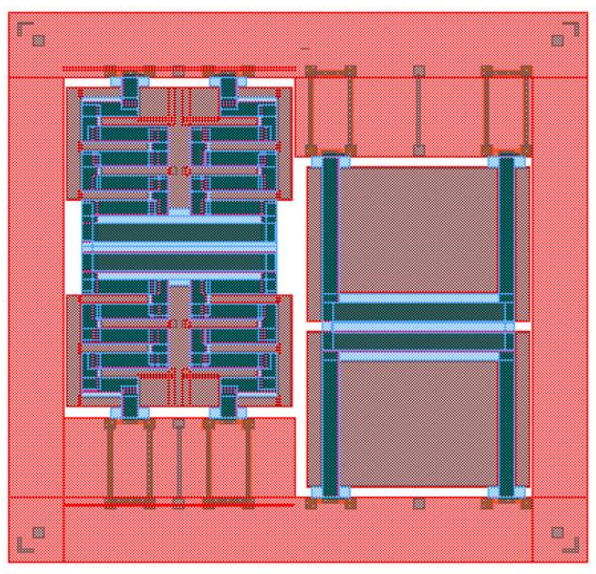


Fig. 11 : Differential Architectures

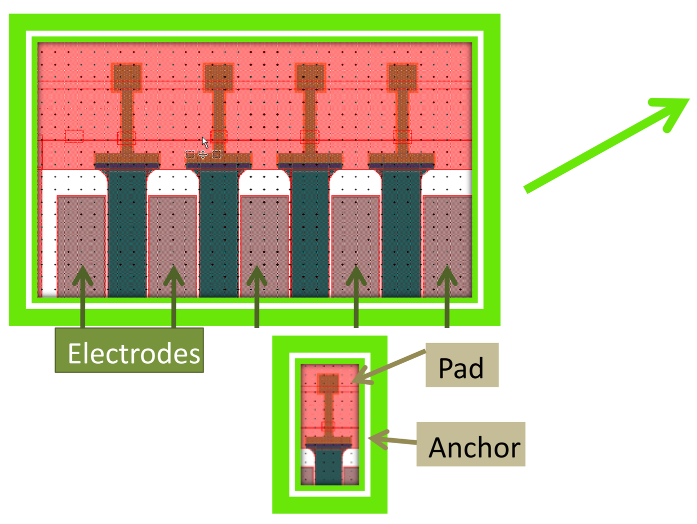


Fig. 12 : Details

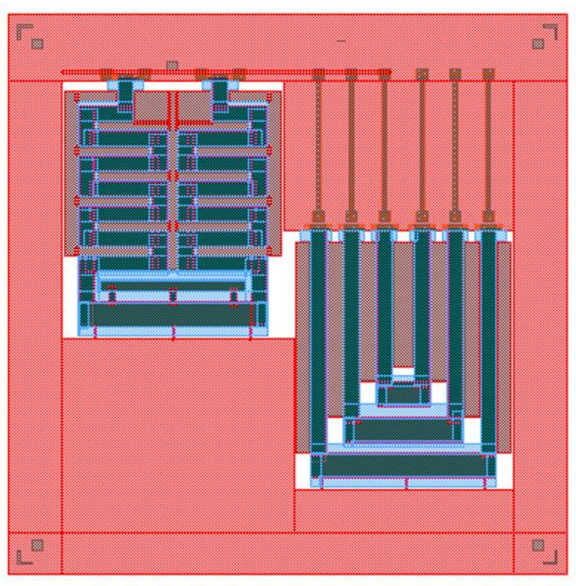


Fig. 13 : Single structures

FURTHER ACTIVITIES

At the moment the research activity is engaged in the study of circuit conditioning for both readout strategies and for both architectures. The following steps will be focused on the characterization of new MEMS devices and on the preparation for sensor applications, in details at Paradox Engineering, where the sensor will be tested to detect the parking slot occupancy.