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Project PIM

a low-cost mobile seismo-acoustic sensor for geophysical deployments

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In this work, we present the "Pressure and Initial Measurement" (PIM) measurement board. The goal of project PIM is to develop a low-cost measurement board with multiple seismo-acoustic digital sensor and to compare them with existing high-fidelity equipment. PIM is designed using Micro-electromechanical Systems (MEMS) sensors. The sensors on the measurement board are an absolute pressure sensor, differential pressure sensor and an accelerometer. The board can be placed on top of a Raspberry Pi which serves as a datalogger. Printed circuit boards (PCB) have been designed to connect MEMS to the Raspberry Pi. All components of PIM are cheap, have a low energy consumption and have a small dimension. This allows for a versatile sensor that can be used for geophysical field studies, i.e. as mobile sensor arrays or in areas where the security of a deployed sensor is less guaranteed. Besides introducing a low-cost seismo-acoustic mobile sensor, we present the outcome of several calibration tests. The calibration protocol for PIM is based on the calibration protocol of the Royal Netherlands Meteorological Institute.

1 Raspberry Pi

The Raspberry Pi, RPi, is a small low-cost computer and in this project used as datalogger. It runs a Linux environment, and has compatible geophysical software installed. It can communicate with external devices by use of known ports, as well by GPIO header. This is a 40-pin header, each pin representing a single port.

2 PCB

The GPIO header enables communication between a RPi and a printed circuit board (PCB). Sensors are mounted on this PCB, each having its own electrical and data circuit with the RPi. If the circuit is not accomplished, the sensor can not be switched on or communicate with the RPi.

3 Data communication

Communication between the RPi and the sensors is by I2C or SPI. Both are bus protocols that allow serial data transfer. The general difference between both is that I2C allows multiple masters and slaves, is half-duplex and holds the clock down so the data can be transferred.

4 Weather proof, Gore Tex, casing

A weather proof casing is developed to protect the sensor board. Gore Tex air-vent stickers, which resist water, are used to contain air-flow inside the casing.

5 Sensors

Absolute pressure

LPS33HW (a) - I2C communication
is an ultra-compact piezo-resistive pressure sensor with build-in 24-bit ADC. Operating between -40 °C to +85 °C, with a max resolution of 1 hPa.
MS5837 (b) - I2C communication
is also a piezo-resistive sensor with build-in 24-bit ADC. Operating between -20 °C to +85 °C and having a max resolution of 2 hPa.

Differential pressure

SDP31 (c) - I2C communication
is a differential pressure sensor. Operating between -40 °C to +85 °C. Measuring pressure differences of -500 Pa till 500 Pa with a max resolution of 0.1Pa.

Temperature/Humidity

SHT35 (d) - I2C communication
is a humidity and temperature sensor. Measuring between -40 °C to +90 °C with an max accuracy of 0,2°C and a relative humidity with ±2% accuracy.

IMU

MPU-9250 (e) - SPI communication
is a 9-axis motion devices (3-axis gyroscope, 3-axis accelerometer, 3-axis magnetometer) with build-in 16-bit ADC. The measurement ranges are for the gyroscope; ±250 to ±2000 dgr/sec, accelerometer; ±2 to ±16 g, and the magnetometer; ±4800μT.

Analog Digital Converter

ADS-1262 (f) - SPI communication
The ADS-1262 is a 32-bit ADC of Texas Instruments. The ADC makes it possible to connect "off-the-shelf" analog seismo-acoustic sensors to compare those with the sensors listed above.
Raspberry Shake
The Raspberry Shake is a 24-bit ADC, mounted on a separate PCB. The Shake has a shortened GPIO header and can be placed on top of our PCB.

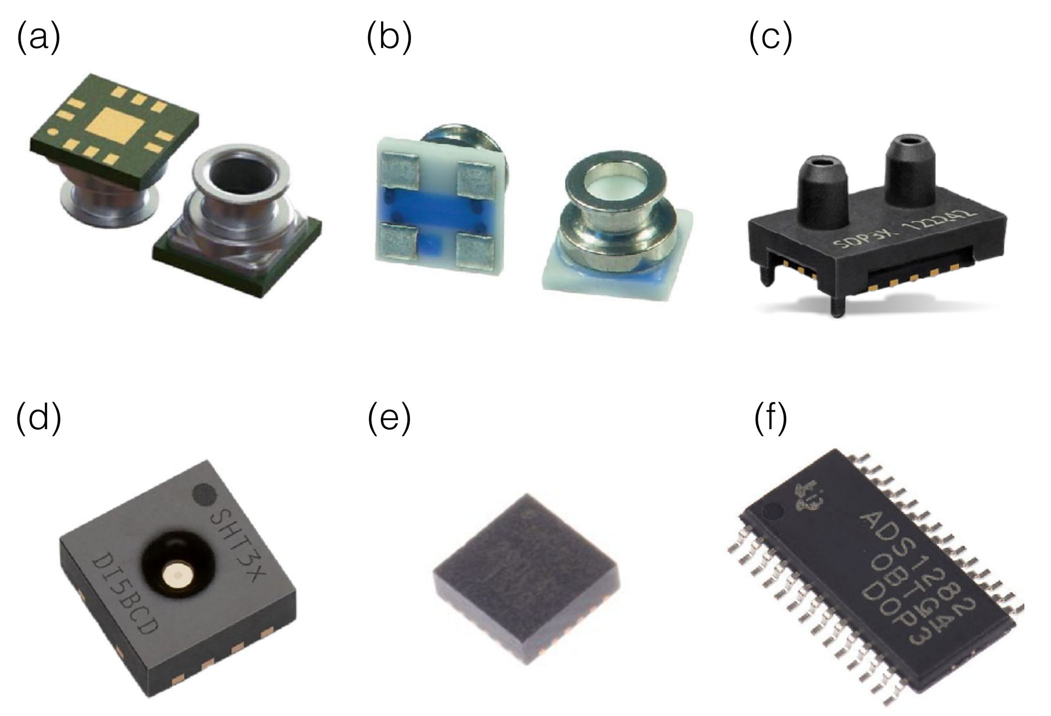

Figure 1: Sensors on the PCB.

6 KNMI calibration

All sensors and ADC are following the KNMI calibration protocols. Three types of calibration protocols are followed. Lab calibrations are done to detect the systematic bias and to expose the sensors too extreme conditions. Field calibrations are done to test the sensors in the field. ADC calibrations are done to measure the frequency stability and estimate the sensor stability due to internal noise processes.

Upcoming:

- Improvement differential pressure measurements
- MPU test on shaker-table
- Development of a RPi noise reduction casing
- Internal self noise detection of all sensors and ADC
- Comparison between PIM and the Raspberry Shake

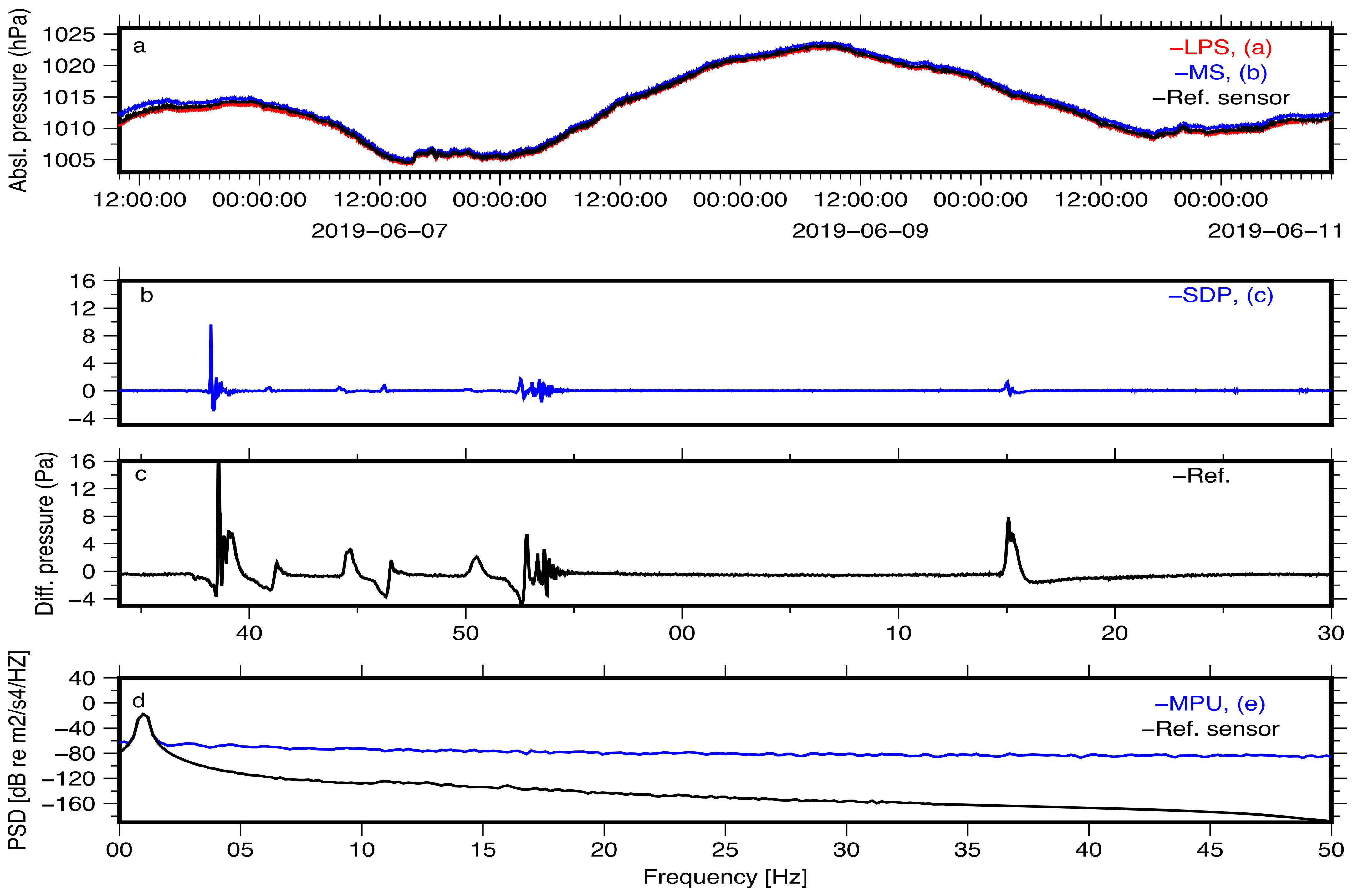

Figure 2: *Outcome of field and lab measurements. a.) shows the outcome of a field test from 06-06-2019 till 11-06-2019 of the absolute pressure sensors (a) and (b) compared with a KNMI reference sensor. b.) shows a minute of a lab test of the dfferential pressure sensor compared with a Hyperion IFS-5000 reference sensor c.) on 18-06-2019. d.) shows a PSD of the Z component of the accelerometer (e) compared with a reference geophone.*

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