Capacitive technology in wearable devices

Low-power, high-accuracy pressure sensing for battery operated wearable devices

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With more and more applications requiring high-accuracy atmospheric pressure data, engineers are seeking ever-more sensitive pressure sensing methods. New sensor technologies that are based on capacitive sensing enable engineers to create miniaturized and very accurate devices while satisfying demanding energy constraints and addressing reliability challenges.

Fitness monitoring wearables are a large part of a growing variety of products and applications require the high-accuracy sensing of static and dynamic air pressure. As these applications are typically found in battery-operated devices, it is also essential to combine the high accuracy with optimized low-power operation and reliability across a broad range of operating conditions.

Many existing small form-factor MEMS (Micro Electro-Mechanical System) pressure sensors are built around piezo-resistive measurement techniques. In these cases, the flexing of a diaphragm in relation to changes in pressure is sensed via a strain sensor. However, piezo-resistive sensing elements are particularly susceptible to variation with temperature changes and they do not respond linearly to temperature. For this reason, piezo-resistive sensors have a need for more complex calibration compared to a capacitive element. In addition, resistive measurement can represent a significant drain on power – a particularly important consideration when the target application is battery-powered and operating lifetime is critical.

Capacitive pressure sensing

Because of the limitations of piezo-resistive technology, engineers are turning to other techniques, one of which is capacitive MEMS technology. A structure for a capacitive cell configuration developed by Infineon is illustrated in Figure 1.

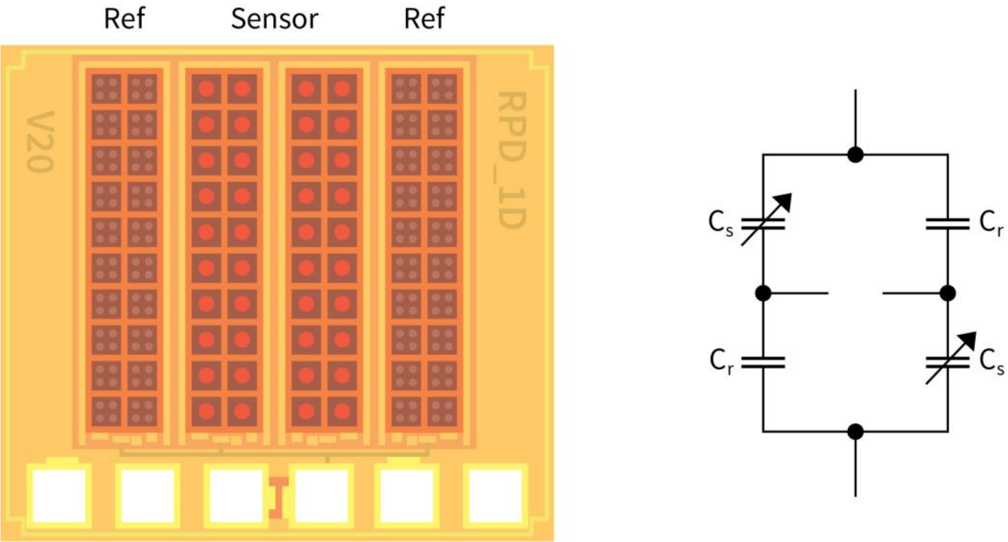


Figure 1. Capacitive pressure sensing cell structure and bridge configuration

Infineon’s capacitive barometric pressure sensor consists of four arrays of sensing and reference cells. The sensing cells have a flexible membrane which reacts to pressure changes and provides the air pressure measurement. The reference cells have a stiff membrane which does not react to pressure changes and provide a stable measurement reference. The benefit of this type of structure is that the pressure measurement can be differential and both sensing and reference cells are exposed to the same temperature changes, negating temperature drift effects. Key benefits include very good temperature stability over wide temperature and pressure ranges, low noise, and simple calibration. This combination of benefits makes capacitive technology particularly attractive in battery-powered applications where sensing of very small pressure changes is needed (for example when detecting body movements such as climbing stairs).

This capacitive barometric pressure sensor technology can be found in the DPS310 – a sensor developed specifically for mobile and wearable devices. The DPS310 integrates both barometric pressure and temperature sensing into a single, ultra-compact 8-pin LGA form factor package that measures just 2.0 mm x 2.5 mm x 1.0 mm. Average current consumption is just 1.7 µA for pressure measurement (falling to only 0.5 µA in standby mode).

Figure 2 outlines the functional block diagram of the device.

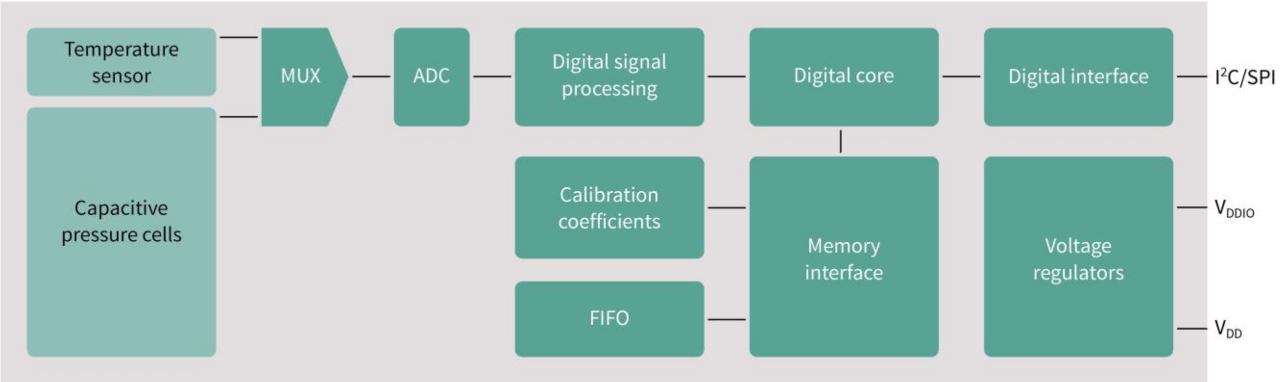
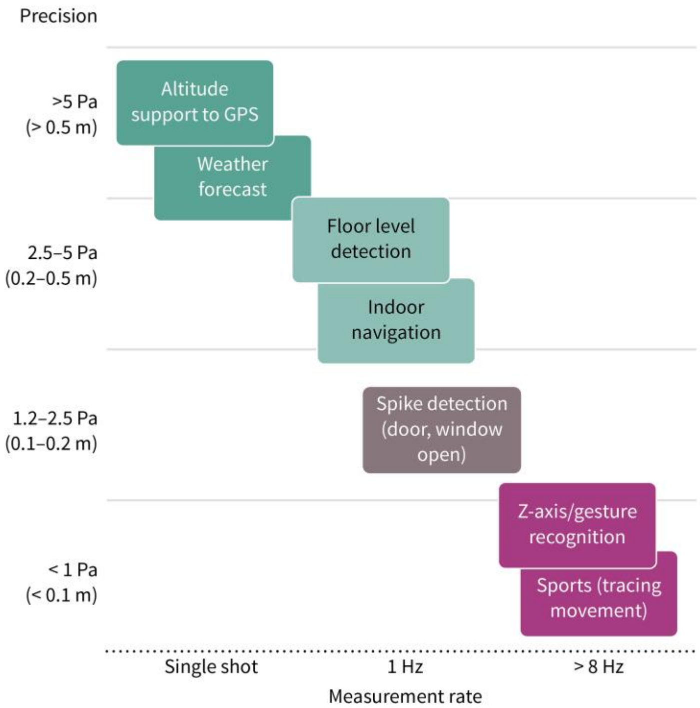


Figure 2. DPS310 functional block diagram

Capable of precision to +/-0.005 hPa (equating to +/-5 cm), the device can measure air pressure between 300 hPa and 1200 hPA and has a pressure temperature sensitivity of less than 0.5 Pa/K. Every sensor is individually calibrated during production with the calibration coefficients stored in one-time programmable (OTP) memory.

Raw data can be transferred using an I^2C or SPI interface, with compensated pressure values being calculated in the host device. An integrated FIFO that can store the last 32 measurements facilitates further system power savings by allowing the host processor to remain in sleep mode for long periods between readouts.



Typical 1.8 V @ 25°C	Precision mode			
	Ultra low power	Low power	Standard	High precision
Current @ 1 measurement per sec. [µA][1]	1.7	3.4	11	38
Precision [Pa]	5.0	2.5	1.2	0.5
Precision [m]	0.5	0.2	0.1	0.05
Measurement time [ms]	3.6	8.4	28	105
Measurement rate[1]				
1 Hz	OK	OK	OK	OK
8 Hz	OK	OK	OK	OK
32 Hz	OK	OK	OK	–
64 Hz	OK	OK	–	–
128 Hz	OK	–	–	–

1) The current consumption is directly proportional to the measurement rate.

Figure 3. Trade-off between energy consumption and precision

The DPS310 has been designed to give end users significant flexibility in determining the balance between energy consumption, measurement rate, and precision. For example, smart phone and smart watch applications can select the optimum configuration to save energy. Figure 3 shows the precision requirements of various applications and the operation modes that can be configured to match those requirements.

Applications

Wearable devices that require sensors for monitoring fitness activities and body motion are one of the key target applications for the DPS310 pressure sensor. Most wearable fitness devices available on the market today use accelerometers to count steps. In such applications sensor current consumption can be as much as 1.5 mA which places a high demand on the battery in the wearable device. By replacing an accelerometer with the DPS310 it is possible to provide the same functionality by measuring the air pressure difference when the body moves. The DPS310 can easily detect actions such as walking or climbing, transient states, single steps, and even gestures. It can distinguish between stepping and climbing up and down by measuring and monitoring dynamic and static pressure changes. In such a case all of the sensing activity can be achieved for a current consumption of 176 µA. (Measurement rate: 16 Hz and Precision 1.2 Pa). Due to its high precision, DPS310 is capable of accurately detecting a wide range of body movements.

Speeding development

Many of the target applications for the new sensor lie in the consumer electronics field, where minimizing time-to-market is essential. In recognition of this, Infineon has created support tools that will help engineers minimize the time they spend evaluating, prototyping, and designing in the new sensor to their products.

Among these tools are the company's sensor hub evaluation environments. Currently the platforms on offer comprise the Infineon Wireless Sensor Hub 2.0 and the Infineon Sensor Hub Nano boards shown in Figure 4.

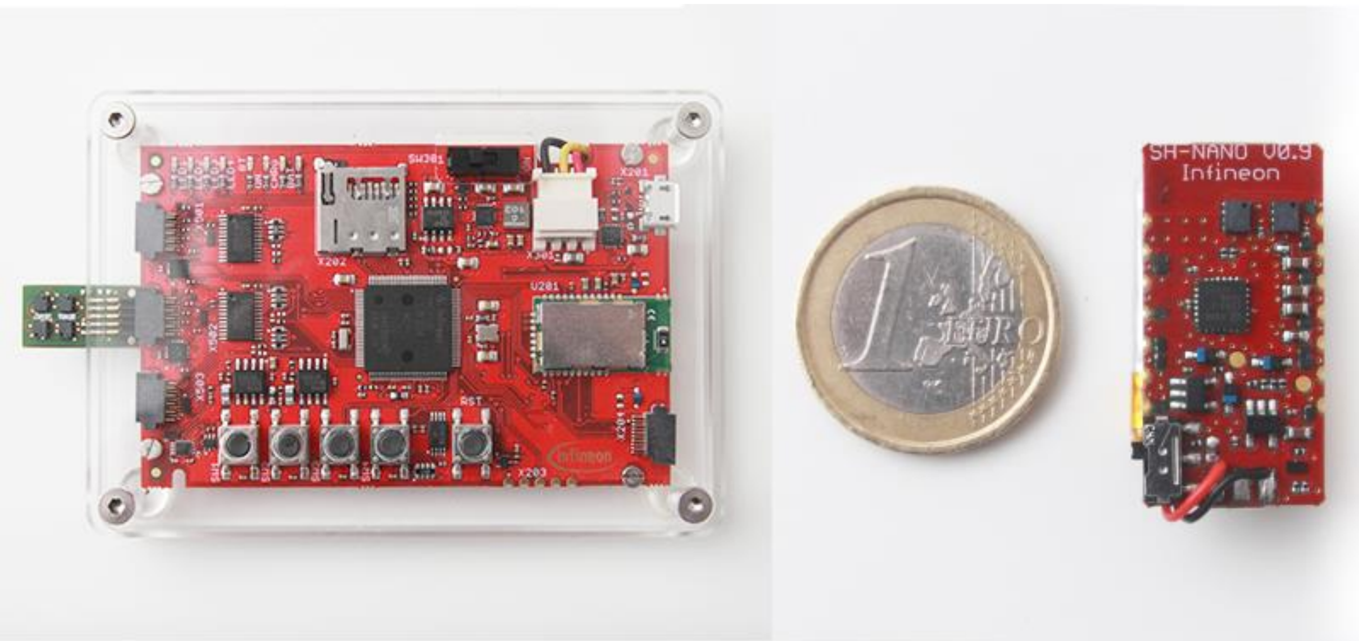


Figure 4. Sensor Hub evaluation environments support design-in of DPS310 pressure sensors

The Infineon Wireless Sensor Hub 2.0 supports the concurrent evaluation of up to 12 different DPS310 pressure sensors and provides two I^{2}C and one SPI interface, to which DPS310 shuttle boards can be connected. Each sensor shuttle board comprises up to four sensors. An SD card supports standalone operation while both Bluetooth and USB connectivity are available for the real-time transfer of data to the host computer.

Infineon's Sensor Hub Nano is a standalone board measuring just 30 mm x 15 mm x 10 mm (including battery) that accommodates one DPS310 sensor and allows developers to quickly test the DSP310 in various use cases. Data is transferred to the host PC via a Bluetooth connection.

Both of the sensor hub evaluation environments are designed for use with the Infineon SES2G Sensor Software Analyzer. This software allows the user to configure sensor and display settings, record real-time data received from the sensor hub board, and export that data in a variety of formats for further analysis.

Designers can use the evaluation environment to test, among other features, various IIR (infinite impulse response) filtering implementations for specific use cases. IIR filtering enables air pressure sensing applications to distinguish between different types of air turbulence, whether generated by atmospheric conditions or the type of user motion encountered during fitness activities. In effect, disturbances can be suppressed or triggered at the software driver or application level by implementing different filtering alternatives. Since the sensor provides raw data, the DPS310 architecture is flexible. The DPS310 software driver includes a filter bank and filtering operations are performed in a host device.

As an alternative to using the SES2G sensor evaluation software, the Infineon Pressure Sensor Android app is available free of charge. Compatible with both of the sensor hubs, this app connects via Bluetooth and provides access to key sensor functionality to speed the evaluation and testing of sensor performance in a target application.

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