Air pressure sensors in smartphones: Transforming navigation and fitness tracking

Dr. Thomas Block, Product Management Environmental Sensors, Bosch Sensortec - September 13, 2016

Today's smartphones utilize a wide array of accelerometers, gyroscopes and various other sensors in their designs. Relatively unknown is the barometric pressure sensor, which measures air pressure. These sensors are currently being integrated into premium-grade smartphones, but are also becoming more common in mainstream phones or wearables such as fitness trackers and Internet of Things (IoT) applications.

Why measure air pressure?

A barometric pressure sensor measures air pressure and can, therefore, play a key role in weather forecasting - lower pressure indicates that poor, rainy weather is more likely. Also, air pressure is affected by altitude changes, which means that such a sensor can provide highly accurate information about vertical elevation.

Let's take a look at some of the most significant applications and the role that barometric pressure sensors perform in consumer equipment.

Indoor navigation

Indoor navigation is one of the more interesting applications for this technology, where air pressure data is interpreted to determine the user's current floor level in a building - this is useful for finding one's way through shopping malls or underground parking lots.

GPS-based systems do not generally function inside large modern buildings, which tend to block out satellite signals. To enable navigation in such shielded environments, altitude detection with the help of the pressure sensor can be combined with step counting data from an accelerometer to
establish a three-dimensional matrix, otherwise commonly known as 3D navigation.

Indoor localization is essential for accurately identifying a caller’s location when they call emergency services. In the USA, the FCC (Federal Communication Commission) has recently updated their E911 rules, mandating that the location of a 911 caller indoors be automatically transmitted to emergency responders. It is expected that all smartphones will require a pressure sensor for the purpose of accurately pinpointing a caller’s location inside a large building.

An example of this trend is Bosch Sensortec’s cooperation with NextNav in the development of accurate floor level detection solutions. NextNav has demonstrated its ability to provide precise altitude information by implementing Bosch Sensortec’s BMP280 pressure sensor within the scope of its wide-area Metropolitan Beacon System (MBS) network. To improve data accuracy for a given metropolitan area, sensor readings are used to compensate for changing weather conditions and the effects of local microclimates. **Figure 1** shows a measurement with a smartphone, available on the market, in which Bosch pressure sensor technology is integrated. The graph demonstrates how the Bosch sensor provides data which matches that of high accuracy reference devices.
Figure 1 Bosch sensors are as accurate as reference devices for air pressure tracking (source: NextNav)

GPS enhancement

Even in an outdoor environment, GPS technology has its limitations. Its level of accuracy can be considerably compromised by obstacles such as trees or nearby skyscrapers, by poor weather conditions or by an insufficient number of available satellites. Adding measurements from an air pressure sensor enables smartphones to compare these altitude points with known terrain elevations sourced from a database, and then apply this data to compensate for GPS positioning errors.
While GPS can perform certain altitude measurements itself, it is only complete and reliable under optimal signal transmission conditions, which means outdoors under a clear sky. In other scenarios, the coordinates may be off by ten meters or even more. Figure 2 shows an altitude measurement for a person walking down a hill and out the rooftop of a four-story parking lot – the inaccuracy of the GPS reading compared to the barometric pressure sensor is evident.

Figure 2 GPS versus barometric pressure sensor altitude raw signal measurements (source: Bosch Sensortec)

Fitness and calorie tracking

Air pressure sensors also help improve the accuracy of fitness trackers, particularly in calorie counting applications. Typically, calorie consumption is calculated by combining step count data from an accelerometer with user specific data such as their age, weight and height. Depending on the sensors inside the device, heart rate data or the recorded speed, distance and altitude of GPS can also be included in the calculations.

While an accelerometer can tell when a person is using stairs, it is not able to determine whether that person is going up or down. By establishing the direction of vertical travel, the pressure sensor
enables the calorie tracking software to correctly calculate the energy expended by the user. And there’s simply no way of cheating! The pressure sensor is sensitive enough to tell whether the user has taken the elevator instead of the stairs.

Outdoors, elevation data helps improve calorie tracking accuracy, for example when the user is walking up a hill. GPS data or elevation figures retrieved from a database can be used, but they are relatively inaccurate – for example, databases struggle with being able to accurately represent altitude changes while crossing bridges (Figure 3).

*USGS: United States Geological Survey

Figure 3 is an example for accurate distance tracking. The air pressure stays stable while crossing a bridge. In comparison to the Google elevation service and USGS (United States Geological Survey) the pressure sensor is detecting that the pedestrian is crossing a bridge. Consequently the realistic calorie expenditure can be calculated.

As well as providing vertical position data, an air pressure sensor can be used with an accelerometer to improve the accuracy of movement classification. For example, accelerometers can provide inaccurate information when the user is moving their phone while playing a game or when they are making a call. Air pressure data can be utilized to verify and improve accelerometer readings.

Tests have repeatedly shown that air pressure sensors in combination with accelerometers improve the accuracy of calorie count tracking by an order of ten to fifteen percent (source: Energy Expenditure Estimation with Smartphone Body Sensors).

Weather forecasting
As air pressure is a key factor in weather forecasting, air pressure sensors play an important role in this application. With air pressure sensors available on iPhones and various Android devices, several weather apps, such as Dark Sky, Weather Signal and Sunshine, have started utilizing crowd-sourced air pressure readings to improve the accuracy of their predictions.

Of course, to provide accurate weather predictions, a smartphone needs to be able to factor in the effect of the user's current altitude on the measured air pressure readings. This is performed by comparing air pressure data from a local weather station with the phone’s own sensor readings or comparing these readings with map data from a database.

This form of highly localized weather information is also a promising innovation for various smart home and IoT applications.

**Drones: altitude detection**

Knowing the altitude of a drone helps the pilot to improve their landing. One air pressure sensor can be located on the drone and another on the user’s remote control. The difference between these two sensor readings gives the drone’s altitude. In addition, this information can be used for in-flight stabilization of the drone.

Despite this having cost implications, it is expected that air pressure sensors will soon be common in drones retailing at or above the 100 EUR price tag level.

**The sensors that make it all possible**

While certain applications are currently still in the development phase, air pressure sensors are already being integrated into many smartphones and similar devices. For example, Bosch Sensortec’s BMP280 is a barometric pressure sensor specifically designed for mobile applications. It is housed in a compact package and boasts low power consumption, making it ideal for battery powered devices. The BMP280 uses piezo-resistive pressure sensor technology to achieve high precision, whilst providing good linearity, long term stability and high EMC robustness.

Air pressure sensors can also be an integrated part of multi-measurement sensors. For example, Bosch Sensortec’s BME680 combines high linearity and accuracy sensors for gas, barometric pressure, humidity and temperature measurement into a single package with a footprint of 3 x 3 mm².
Summary

Air pressure sensors play a valuable role in smartphones, fitness trackers, smartwatches and other wearables - and in the new IoT world. Their utility is not limited to mobile weather apps, as they also provide accurate altitude measurements to transform indoor navigation, calorie counting and many other applications. With both standalone and integrated components now available on the market, air pressure sensors will have a growing presence in consumer products in the near future.

References

2. Amit Pande, Yunze Zeng, Aveek K. Das, and Prasant Mohapatra, Department of Computer Science, University of California, Davis; Sheridan Miyamoto, Betty Irine Moore School of Nursing, UC Davis School of Medicine; Edmund Seto, School of Public Health, University of California, Berkeley; Erik K. Henricson, and Jay J. Han, Dept. Physical Medicine and Rehabilitation, UC Davis School of Medicine, Energy Expenditure Estimation with Smartphone Body Sensors, Retrieved on 18th July 2016