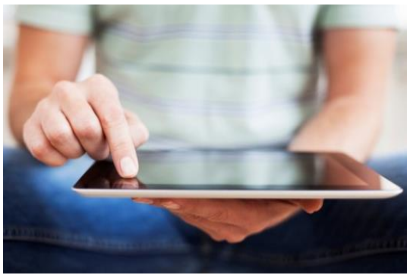
AZD081 – Advanced capacitive proximity sensing techniques to meet FCC SAR regulations in mobile device



The use of wireless mobile devices has increased rapidly in the last few years, with high demands on wireless connection performance. The regulations for human exposure to electromagnetic radiation have become a limiting factor in the performance of wireless communication. FCC SAR regulations dictate reduced output power levels in the presence of a human body. The effect of reduced power levels may lead to a connection interrupt, therefore the accurate detection of a human body is critical.

The limitations are explored through the use of specific examples where sensors are triggered falsely by non-human objects, hence limiting the output power of the device when that is not required. Capacitive sensing techniques are proposed to distinguish between human and non-human sensor activation. Further design criteria for the sensor location, sensor performance and software detection algorithms are discussed. The examples include most common triggers, such as mobile device covers, glass and metal. The ability of the sensor to adapt to the environment is a key aspect in accurate sensing when in proximity to human and non-human objects.

1 Introduction

The regulations imposed by the FCC (Federal Communications Commission) define a specific absorption rate (SAR), which is a safe measure of the rate at which RF signals are absorbed by the human body. Designers of wireless mobile devices tend to prefer higher output power levels for optimal performance of their product. By adhering to the FCC SAR regulations, output power is reduced in cases where it is required, although also due to a variety of false triggers. Dropped connections and degraded upload performance are more likely to occur as a result of lowered wireless signal output power. The rejection of false triggers is a key aspect of optimizing the performance of a wireless connection.

Solutions are required to distinguish between relevant activations and false activations. Offered in this article are techniques dependent on human behaviour and human capability. Proposed is the use of multiple capacitive sensors with advanced adaptive characteristics, strategically placed in order to effectively solve the problem at hand.

2 Capacitive sensing

As opposed to IR solutions, capacitive sensing technology is preferred because of lower power consumption, the fact that an aperture is not essential and that it is not sensitive to ambient light conditions. Additional advantages include the small real estate required for the sensor and the low cost of such a solution.

Capacitive sensing can be done between a single electrode and the circuit common ground (self-capacitance), or between two electrodes (mutual capacitance). Each method has its advantages, but because of the largely variable parasitic capacitance between the circuit common ground and earth in mobile devices, mutual capacitance techniques are preferred.

The sensitivity of capacitive sensors is highly adjustable. This allows for a large variety of electrode sizes and overlay materials. Conductive overlays have a degrading effect on the operation of the sensors and may cause loss of sensitivity or even unstable operation. As with RF antennas, capacitor sensors should not be covered with a conductive overlay.

Mobile device covers are commonly used and may be regarded as an undetermined additional overlay. With capacitive sensing, calibration could be critical to the accurate triggering of proximity sensors. Detection of the cover becomes possibly by pre-fitting the cover with a metal strip. This would enable an automatic variable calibration for accurate sensing, whether or not the cover is fitted. Such implementation also allows for detecting the changes caused by opening and closing a screen cover.

3 Distinguishing between human and non-human objects

It is relatively simple to prove that it is impossible to distinguish between human and non-human triggers by observing capacitance in one dimension only. Figure 1 shows an example where a sensor is placed on a human lap and then on an earthed metal sheet. The difference in capacitive effect is much too small to distinguish, especially with the variance in proximity and human body characteristics.

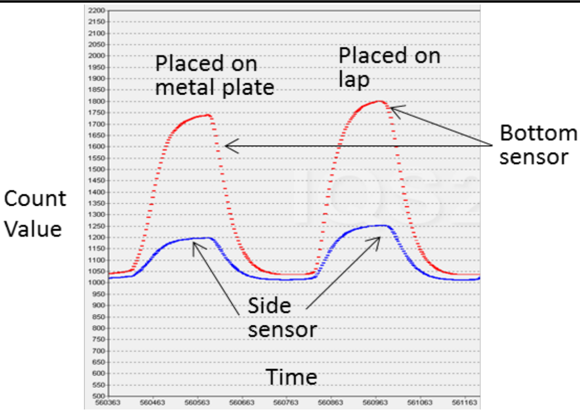


Figure 1: Capacitive sensor counts for human and non-human interaction

By placing multiple sensors in a manner that would reflect user behavior and capability, one is able to distinguish between human and non-human proximity triggers. For example, as shown in Figure 2, it would be very unlikely for the user of a tablet computer to cover four sensors at the same time for a few minutes, keeping in mind that FCC regulations dictate a 6-minute SAR average value. On the other hand, it would be easy to trigger all four sensors by placing the tablet computer on a metal or glass table. On this basis, multiple sensors are proposed to solve issues of false triggers with proximity sensors. A three-sensor solution is also shown in Figure 3. Such solution is aimed at a single IC sensor implementation using three channels.

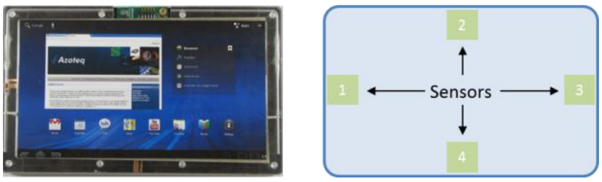


Figure 2: A mock-up tablet (left) with example sensor locations (right)

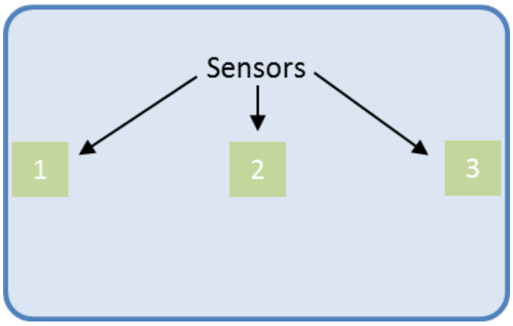


Figure 3: Example sensor placement for the use of a three-channel device

4 Capacitive sensor capabilities

A highly configurable device best addresses the important issue of calibration. With pre-loaded calibration data, the sensor could adapt for various protective covers and start-up conditions. Such conditions include the possibility of the user powering up the device while holding it.

Figure 4: Powering up the tablet while holding it should adhere to the regulations

A safe implementation would initialize the sensor with predetermined data that is based on the absence of human or object proximity. With such a configuration, proximity events will lead to the assumption of a fitted device cover (all sensors activated) or human proximity (only some sensors activated). The calibration values can be adapted for that which is common to all sensors (device covers), and proximity can be based on the differences (human proximity).

Capacitive sensors are subject to long-term environmental drift and sudden changes in environment. Automatic sensor calibration algorithms are essential for simple and accurate sensing under such conditions. These algorithms can be forced to start only from the first perceived release condition (the human proximity taken away). This allows for a safe start-up with predetermined values. Detection of the first release is made possible by dynamic threshold value adjustment and threshold-crossing direction adjustment.

SAR regulations could not be met when including the effect of human proximity as an environmental shift. For this reason it is important to know when proximity is registered (touch event), but also when it is cleared (release event). Hence, a need exists for knowing the direction of proximity threshold crossing. By adding hysteresis to this, the user may vary touch intensity without causing releases. Only a proper release will clear the touch event. This functionality is crucial to applications in which long-term constant proximity is mixed with the need for long-term environmental calibration.

5 Conclusion

Capacitive sensors in wireless mobile devices offer a cost-effective solution for enforcing FCC SAR regulations, with many possibilities for improving sensor activation accuracy. With the increase in wireless network connectivity and popularity of various protective covers for devices, accurate detection forms part of being ready for future and current demands in mobile devices.

Patented proximity sensing technology from Azoteq meets all the required sensor capabilities mentioned. The automatic tuning implementation (ATI) is intelligently used to adapt to environmental drift and to keep the sensor operation at an optimal level. DYCAL™ technology from Azoteq ensures that touch and release events are accurately detected without calibration during sensor activation events. With DYCAL™, environmental drift is continuously compensated for, while re-calibration is only done after release events.

Azoteq offers a comprehensive product line of single- or multi-channel devices using various sensing technologies. The IQS253 is a three-channel sensor that can be configured for self- or projected-capacitance. It offers I^2C-compatibility for run-time configurability along with DYCAL™ technology.

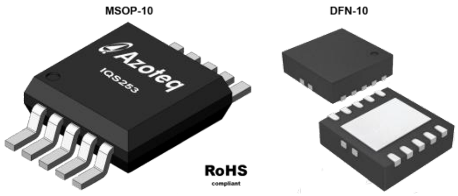


Figure 5: The IQS253, sold in two package types

In addition to the IQS253, the IQS128 is a standalone solution that is used in many tablet computers across the world. The IQS128 offers simplicity with direct outputs, along with DYCAL™ technology. The IQS252 offers a two-channel standalone solution using projected-capacitance and DYCAL™ technology.

For further information on Azoteq sensors, visit www.azoteq.com. The application note, AZD058, contains some test results and a discussion of a mock implementation of an IQS253 in a tablet computer.

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