Exclusive: Proximity Sensing in Mobile Phones

Sivaguru Noopuran, Product Marketing Engineer and Priyadeep Kaur, Application Engineer, Cypress Semiconductor

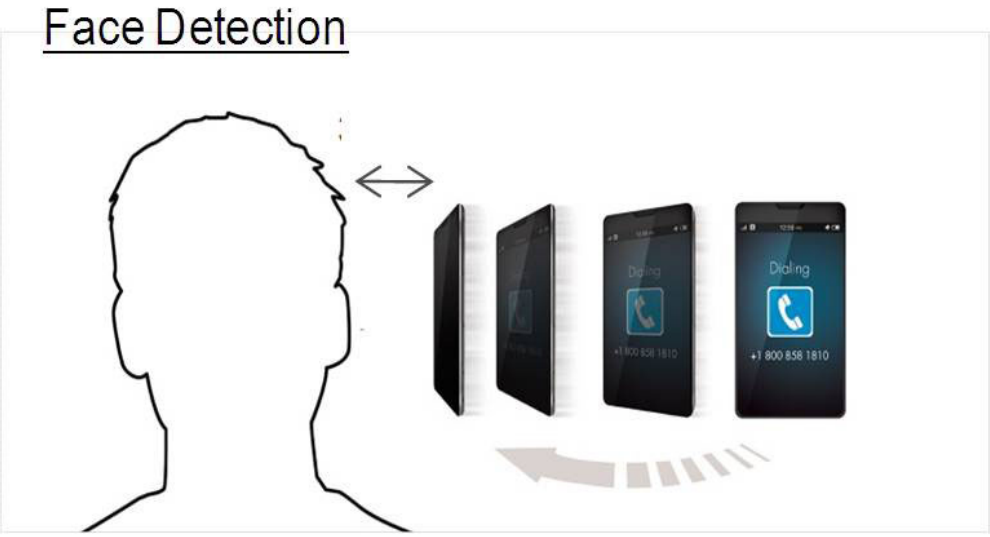
Proximity sensing technology is becoming popular across a wide range of industries, especially in consumer electronics, because OEMs introduce new products to market every year. The largest application within consumer electronics is the mobile phone. Given the competition in this particular market, it is important for OEMs to adopt the latest technology and offer unique features to differentiate their products.

Today, mobile phones use IR-based proximity sensors to detect the presence of a human ear. This sensing is done for two purposes: Reduce display power consumption by turning off the LCD backlight and to disable the touch screen to avoid inadvertent touches by the cheek. IR sensors have a number of disadvantages, including high power consumption, high cost, blind zones, and accumulation of dirt, as well as unreliable performance over temperature, hair, and skin color variations. Recent advances in capacitive proximity sensing technology address these designs disadvantages and could potentially replace every IR sensor in the mobile phone market.

Proximity Sensing-Cased Applications

Capacitive proximity sensing has enabled several features in mobile phones. While these features may not be evident to end users, they provide many important capabilities, including optimized power consumption, integrated functionality, and cost reduction. It is essential that product designers understand the different features that can be implemented through capacitive proximity sensing.Some of the features include:

- ***Face detection***: Face detection has existed in mobile phones (both smartphones and feature phones) for over a decade. Face detection prevents false touches when the phone is close to the ear and reduces power consumption by dimming/shutting off the display. Mobile phones are battery-operated, which is the most useful and frequently implemented feature.



SAR (Specific Absorption Rate) regulation: This feature is commonly implemented in tablets, but it can also be applicable to mobiles in certain cases. Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field. The FCC (Federal Communications Commission) requires devices to limit the absorption of RF energy by reducing the RF transmit power of the tablet when in close proximity to the human body.

Wake-on approach feature: This feature makes the user interface (i.e., buttons/touchscreen) visible on a proximity detect event. This enables the device to operate in a low power, standby state when not in use and then wake-up into an active state when a user's hand approaches. This helps reduce system wake-up time, improve device responsiveness and overall design aesthetics, and optimize average power consumption.

Benefits of Capacitive Proximity Sensing

- ***Improved industrial design***
  - Offers sleek and clean aesthetics.
  - Replaces mechanical buttons, switches, and sliders.
  - Enhances reliability by eliminating mechanical wear and tear.
  - Reduces overall system cost.
- ***Increased functionality***
  - Offers lower power consumption than other proximity methods, such as infrared detection.
  - Provides greater user interface design flexibility for product designers, such as Wake on Approach.
- ***Increased usability***
  - Simplifies machine control interfaces.

One of the biggest competitors to this technology is IR (Infra-red) based proximity sensing. As mentioned earlier, face detection is the most popular feature that is implemented in mobiles using proximity sensing. Capacitive proximity sensing has its own advantages over IR and can be summarized as in the table below with face detection feature as an example:

Capacitive Proximity Sensing Feature	Advantage over IR Proximity Sensing
Lower power consumption	10-50 mA lower current consumption than IR-based sensors.
Higher reliability	Capacitive proximity sensing is immune to ambient light, whereas it has been observed that IR based sensing can have performance issues based on ambient light frequency.
Better industrial design	Flush bezel with no additional holes, capacitive proximity sensing is often implemented as an integrated solution with other UI features such as buttons/sliders.
Lowest cost	Eliminates the extra IR sensor and LED, capacitive proximity sensor is implemented on a PCB.
Equivalent or better performance	Capacitive proximity sensing can offer up to 30 mm detection range in mobile phones .

Capacitive Proximity Sensor Implementation

Capacitive proximity sensors are based on the same principle as self capacitance-based capacitive touch sensing.

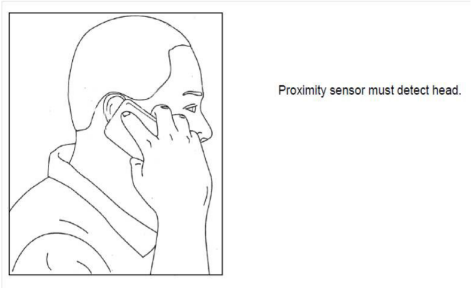
Here, the sensor is a conductive pad or a loop laid on a non-conductive substrate. This conductive pad has a self capacitance Cp. When another conductive material (i.e., a human face in this application) comes close to the conductive pad, the capacitance of the sensor increases (by an amount = Cf). A microcontroller continuously measures the capacitance of the sensor(s) and looks for a sudden jump in capacitance to determine the presence of a conductive object near the sensor.

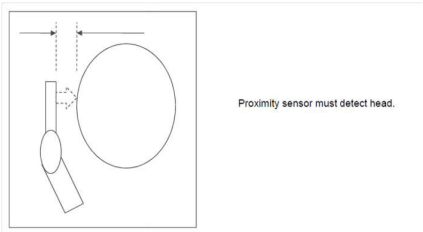
Proximity sensors are designed to maximize the ratio Cf/Cp for a given sensor to be able to reliably detect proximity.
A capacitive proximity sensor-based implementation for face detection involves the following aspects:

1. Sensor placement.
2. Sensor design.
3. Sensor material and stack-up.
4. Firmware techniques for enhanced proximity.
5. Firmware techniques for use case handling.

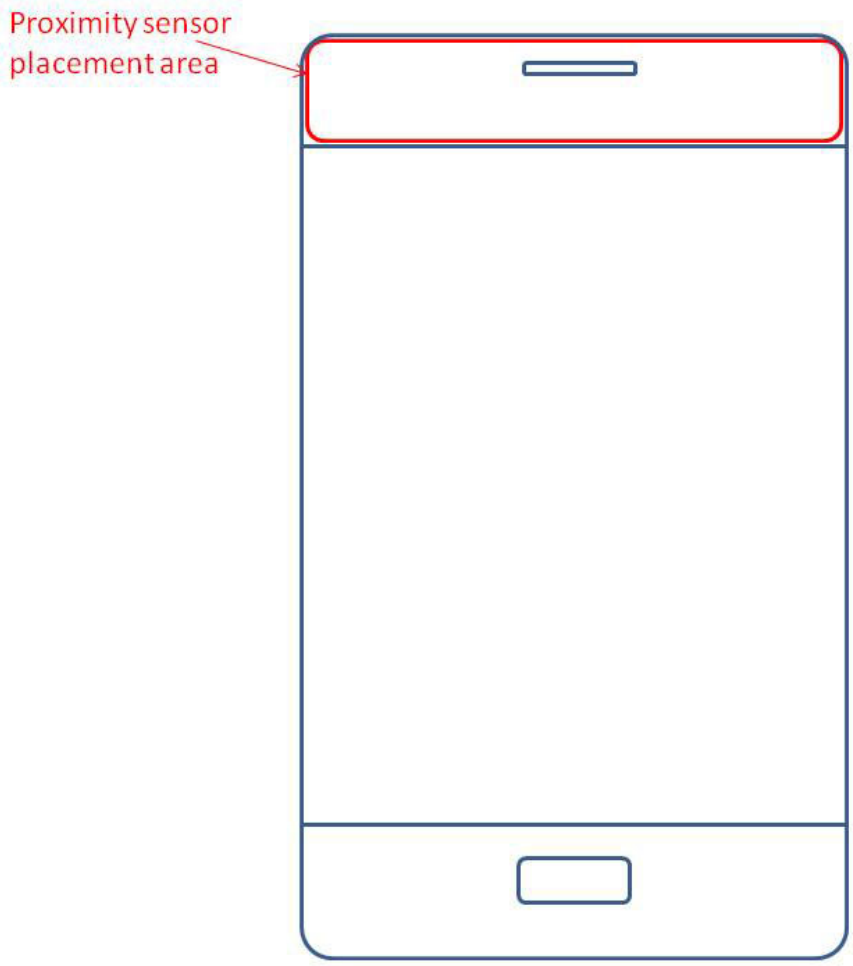
Sensor Placement

When a user picks a mobile phone to attend a call, the top are of the phone comes closest to the face, as shown below:





Note that the hand of the user covers the screen area and back side of phone, thus the sensor placement should be such that it detects the face but is not affected by the hand. For this reason, it is best to place the proximity sensor near the top area of the front side of the phone, as shown below:



Sensor Design and Layout

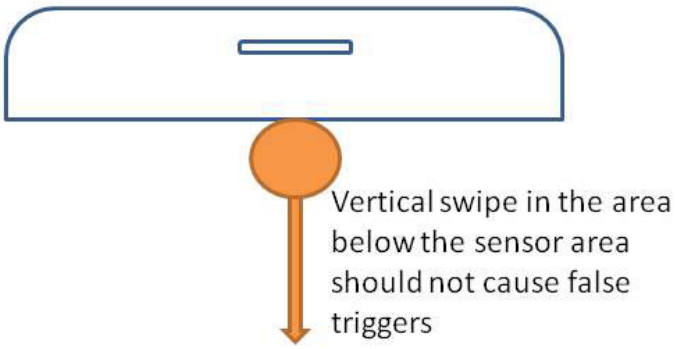
Sensors have to be carefully laid out in the available area in order to achieve the highest detectable proximity distance. At the same, designers must minimize capacitance changes due to unintended detections like hand, swipe gestures near the sensor area, etc. Also, it is important to ensure the least EMI/EMC or ESD noise coupling to the sensor.

A sensor pattern showb below, helps to achieve these requirements. A loop design ensures high Cf/Cp value, while the ground trace surrounding the loop ensures minimum detection from sides. This surrounding ground also helps in reducing the effects of ESD and other EMI noise coupling on the sensor.

The proximity sensor trace width is 1 to 2 mm, while the ground trace width can be 0.5 to 2 mm, depending on the available area.

Though the above sensor pattern prevents detection from the sides and only detects proximity of conductive objects from top plane of the phone, it has the disadvantage of being uniformly sensitive across the sensor spread area.

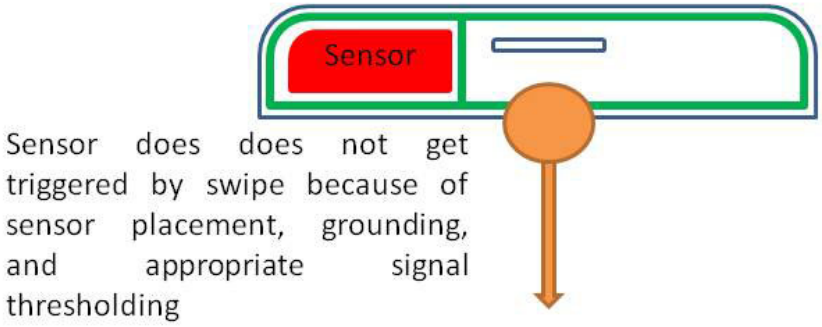
Certain phones allow swipe gestures (from top to bottom) to open some notification menu, as shown below:



In such cases, the above pattern inadvertently detects a swipe as a valid signal. This is because the sensor is very sensitive and a finger swipe close to the sensor sometimes triggers it on.

In such cases, designers can reduce the size of the sensor and place it in a position where swipes are not expected.

In order to make the sensor directional, it should be guarded by ground from all sides.



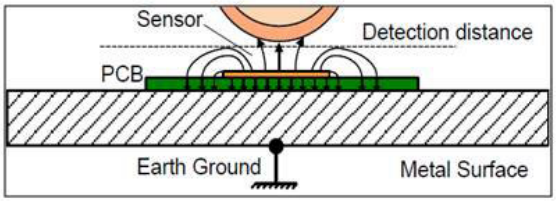
Note that the sensor signal may still increase because of swiping; however, this effect can be neglected by putting a higher threshold for proximity sensing. It is also implicit that this pattern will have a decreased proximity range compared to a loop sensor, because of a smaller sensor size and the increased threshold on signal change required to detect proximity but neglect swipes.

Sensor Material and Stack Up

Capacitive sensors can be printed on the top glass using ITO or metal ink, or they can be implemented on an FPC placed just below the top glass.

FPC is generally better because of their fast turn-around times for manufacturing. If changes are required during initial design changes, these would also be faster.

Generally below the FPC there could be a speaker, head phone jacks, or other interfaces that would induce noise to the proximity sensors. It is required to have some form of ground plane between the FPC and these devices. It is more effective to put this ground plane on a board other than the FPC where the sensor is placed, because FPCs are very thin (compared to FR4). Having a ground on the FPC increases the parasitic capacitance of the sensors (Cp) and decreases the capacitance coupling to a face (Cf).



The ground plane should be placed on the top side of the boards, just below the sensor FPC, or as a metal plane below the FPC. In this case, the air gap and additional adhesive between FPC and metal reduce the effect of capacitance coupling to the ground plane.

Firmware Techniques for Proximity Range Enhancement

Proximity sensors are highly sensitive and noisier than the touch sensors. By reducing the noise, a lower signal (i.e. higher proximity distance) can be sensed. High order, digital IIR filters are known to provide large noise reduction; however these compromise on response time. Adaptive filtering of the raw capacitance to digital conversion data proves very useful for applications restricted on response time.

Firmware Techniques for use Case Handling

High-level firmware algorithms in firmware could help in easily accommodating the following use cases:

a. Swipe rejection.
b. Touch rejection (in top area, near the sensors).
c. Holding the phone in hand.

These techniques could be as simple as implementing different levels of thresholds for different signals (as exemplified in sensors design section). Touch/ Proximity sensing microcontroller vendors offer proprietary algorithms that allow easy-to-use case handling.

For more information visit www.cypress.com [1].

Source URL (retrieved on *10/01/2014 - 3:29pm*):
http://www.wirelessdesignmag.com/articles/2014/01/exclusive-proximity-sensing-mobile-phones?cmpid=related_content

Links:
[1] http://www.cypress.com