Enhancing Touchscreen Experience by Adding Proximity Detection and Haptics Feedback

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Abstract: This paper is intended to help design engineers understand the technology behind the proximity detection with standard 4-wire analog resistive touchscreens and illustrate the potential uses in automotive applications that could benefit from this technology.

Keywords: resistive touchscreen; proximity detection; haptics feedback; capacitive sensing; display legibility, radio console, navigation systems.

Introduction
Today, touchscreens have become widespread and are progressively replacing mechanical buttons in applications where an interactive, easy-to-use interface is desirable. In the automotive sector, these applications include center stack radio consoles, navigation systems and backseat entertainment units.

While it is becoming increasingly natural for people to interact with a system via touch screen, there is still considerable advancements that can be made to make touch interfaces even more intuitive, comfortable and safe in an automotive environment. This application requires that the driver’s attention be focused on the road with minimal interaction and distraction. With that in mind, Semtech recently announced the newest members of their 4D-Touch™ family; the SX8654/55/56/57/58 are ultra low power 4/5-wire resistive touchscreen controllers with integrated proximity sensing and haptics for an enhanced user experience.

Proximity detection allows the system to know when the user wants (or doesn’t want) to interact with the screen. This information can then be used to control LCD backlight intensity, system wake-up, and button/menu visibility thereby improving display legibility, ease-of-use, and safety.

Haptics feedback can be used together with audio (i.e. audible feedback via buzzer) to enhance the touch acknowledgement or to simulate mechanical button tactile feedback.

Self-Capacitance Sensing
Capacitive sensing is the art of measuring a small variation of capacitance in a noisy environment. Variations in design can enable not only touch sensing but also proximity sensing.

To illustrate the principle of capacitive sensing we will use the simplest implementation where the sensor is a copper plate on a PCB but the exact same principles apply when any other conductive material/object is used for the sensor.

The figure below shows a cross-section and top view of a typical capacitive sensing implementation. The sensor connected to the chip is a simple copper area on the top layer of the PCB. It is usually surrounded (shielded) by ground for noise immunity (shield function) but also indirectly couples via the grounds areas of the rest of the system (PCB ground traces/planes, housing, etc). For obvious reasons (design, isolation, robustness …) the sensor is stacked behind an overlay which is usually integrated in the housing of the complete system.

![Figure 2. Typical Capacitive Sensing Implementation](image_url)
When no conductive object (finger/palm/face, etc) is present, the sensor only sees an inherent capacitance value $C_{\text{Env}}$ created by its electrical field's interaction with the environment, in particular with ground areas.

When a conductive object (finger/palm/face, etc) approaches, the electrical field around the sensor will be modified and the total capacitance seen by the sensor increases by the user capacitance $C_{\text{User}}$. This phenomenon is illustrated in the figure below.

![Figure 3. Proximity Effect on Electrical Field and Sensor Capacitance](image)

The challenge of capacitive sensing is to detect this relatively small variation of $C_{\text{Sensor}}$ ($C_{\text{User}}$ usually contributes only a few percents) and differentiate it from environmental noise ($C_{\text{Env}}$ also slowly varies together with environmental characteristics such as temperature, etc). For this purpose, the controller integrates an auto offset compensation mechanism which dynamically monitors and removes $C_{\text{Env}}$ to extract and process $C_{\text{User}}$ only.

In first order, $C_{\text{User}}$ can be estimated by the formula below:

$$C_{\text{User}} = \varepsilon_0 \cdot \varepsilon_r \cdot \frac{A}{d}$$

- $A$ is the common area between the two electrodes (in this case the common area between the user’s finger/palm/face and the sensor).
- $d$ is the distance between the two electrodes (in this case the proximity distance between the user and the system).
- $\varepsilon_0$ is the free space permittivity and is equal to 8.85 $10^{-12}$ F/m (constant)
- $\varepsilon_r$ is the dielectric relative permittivity.

When performing proximity sensing the dielectric relative permittivity is roughly equal to that of the air as the overlay is relatively thin compared to the detection distance targeted. Typical permittivity of some common materials is given in the table below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Typical $\varepsilon_r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>8</td>
</tr>
<tr>
<td>FR4</td>
<td>5</td>
</tr>
<tr>
<td>Acrylic Glass</td>
<td>3</td>
</tr>
<tr>
<td>Wood</td>
<td>2</td>
</tr>
<tr>
<td>Air</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1. Common Materials Permittivity

From the discussions above we can conclude that the most robust and efficient design will be the one that minimizes $C_{\text{Env}}$ value and variations while improving $C_{\text{User}}$.

Adding Capacitive to Resistive Technology

A 4-wire resistive touch screen consists in two (resistive) conductive sheets separated by an insulator when not pressed. Each sheet is connected through 2 electrodes at the border of the sheet. When pressure is applied on the top sheet, a connection with the lower sheet is established. All four electrodes are connected to the touchscreen controller which performs an ADC-based measurement to determine touch location.

![Figure 4. 4-wire Touchscreen](image)

Capacitive sensing is performed using nothing more than what’s already there for the standard resistive operation. As illustrated in figure below, no specific touchscreen or additional component/connection is required.

![Figure 5. Proximity Sensing Interface Overview](image)
• The sensor is the top layer of the touchscreen. Its capacitance (to ground) will vary when a conductive object is moving in its proximity.

• The optional shield is the bottom layer of the touchscreen. It is used to protect the sensor against potential surrounding noise sources and improve its global performance. It also brings directivity allowing the sensor to detect objects approaching from the top only.

• The analog front-end (AFE) performs the raw sensor’s capacitance measurement and converts it into a 12-bit digital code. It also controls the shield.

• The digital processing block computes the raw capacitance measurement from the AFE and extracts the binary information (PROXSTAT) corresponding to the proximity status, i.e. object is “Far” or “Close”.

For obvious cost and power consumption optimization reasons the touchscreen controller embeds a unique ADC which automatically switches between resistive and capacitive measurements depending on the detected touchscreen status.

<table>
<thead>
<tr>
<th>Touchscreen Status</th>
<th>ADC Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touched</td>
<td>Resistive</td>
</tr>
<tr>
<td>Not-touched</td>
<td>Capacitive</td>
</tr>
</tbody>
</table>

**Table 2. Resistive vs Capacitive ADC Usage**

**Examples of Automotive Applications**
The presence of user’s hand can be used to adapt/optimize LCD backlight intensity. It can usually be set low when the user doesn’t need to interact and set higher when finger proximity is detected; resulting in a more comfortable and hence safer environment.

Proximity detection can also be used to bring up special/hidden menu when the user’s hand approaches the panel. Typical applications include navigation and video players where the screen’s area can be used more efficiently (no permanent “Menu” button needed anymore) and the interaction from the user is reduced (no first touch required anymore to open the “Menu”).

**Figure 6. LCD Backlight Intensity Control**

Of course proximity sensing in an automotive environment is not limited to these two usages. Its innovative technology can open paths to new concept ideas only limited by designers’ creativity.

**Figure 7. Button/menu Visibility Control**

**Conclusion**
Capacitive proximity sensing using the touchscreen can significantly contribute in making touch interfaces even more intuitive, comfortable and safe in an automotive environment.

By enabling built-in proximity sensing using ANY resistive panel, Semtech has added an especially expensive high-end feature at the fraction of the cost of traditional IR proximity sensing. Proximity and haptics feedback will enable the OEM to upgrade a generally lower cost resistive touchscreen panel with high-end features.

**References**