Capacitive Sensing – Ushering in a revolution in Automotive HMI design
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Executive Summary
With greater emphasis and the increase in the amount of information interchange between a human being and various systems in a car, Human Machine Interface (HMI) technologies have gone through a paradigm shift and have taken user experience to a whole new platform.

This article attempts to highlight the importance of capacitive sensing in the evolution of Human Machine Interface from simple mechanical buttons to present day advanced systems. Topics covered in this article include introduction to capacitive HMI technology, change in design methodologies and some of the applications which have evolved because of capacitive touch sensing.

Introduction
The increasing numbers of electronic systems in a car have ushered in a revolution which has transformed the car into a safe, luxurious and intelligent machine. One thing that has not changed however is the importance of human interaction with the car. This interaction defines the user experience and is a key marketing differentiator between different vehicles.

The systems measuring and tracking interactions of the user as well as providing feedback are collectively known as Automotive Human Machine Interface (HMI) systems. From the user’s perspective, this interaction maybe conscious - when he deliberately provides input to a system, or subconscious – when the system measures his intent without his knowledge.

Capacitive Sensing – Ushering in a revolution in Automotive HMI
Even with the inherent barriers in the adoption of new HMI technologies in the automotive environment, engineers are constantly trying to improve HMI systems to make them more intuitive, look cooler, and be more accurate. At the heart of this change are innovative human interaction sensing technologies which are enabling this evolution. One such technology is capacitive sensing which has revolutionized the design and implementation of HMI applications.

Very simply, a capacitive sensor is composed of a pair of adjacent electrodes.

When a human being (or any other conductive object) comes in proximity to these electrodes, there is additional capacitance between the electrodes and the object which can be measured to detect the object’s presence.
Capacitive Sensing Ushers in a Revolution in Automotive HMI Design

Using this technology, it is easy to build touch sensors acting as buttons, sliders, trackpads etc.

Alternately capacitive sensing can also be used for proximity sensing where no contact is required between the sensor and the user's body. This can be achieved by increasing the sensitivity of the sensors. Further, such sensors are non-line of sight, therefore, a single sensor is enough to detect approach in 3 dimensions.

Such a technology becomes even more powerful in conjunction with programmable mixed signal controllers. Such devices enable the measurement of capacitance intelligently enabling the detection of human proximity in terms of range, direction of approach, gesture recognition etc. They also enable the possibility of integrating other functions like controlling motors and LEDs to provide feedback to the user based on touch/proximity.

A fully programmable device also adds significant value by improving performance with programmable sensitivity thresholds, variable scan speeds to reduce current consumptions and offer improved noise immunity.

**Capacitive sensing in Infotainment HMI enhancement**

Capacitive sensing is being increasingly used to replace mechanical buttons with touch sensitive buttons for infotainment systems.

The diagram below illustrates the use of a programmable mixed signal controller to achieve intelligent capacitive sensing.

![Figure 2.](image_url)

Some applications which use capacitive sensing on the center console are illustrated below.
Figure 3. Capacitive Touch Implementation for a Navigation System
Figure 4. Capacitive Touch Button Implementation for Car Audio
Capacitive Touch Buttons for HVAC

Capacitive touch sensing can also be used in conjunction with mechanical buttons to provide enhanced, hybrid buttons responding differently to touch (may be a preview function) and to a mechanical button press (maybe activation of the function), as illustrated below.
These applications can be further enhanced by the use of capacitive sensing based proximity sensors, wherein, depending upon proximity of user, additional features can be activated such as backlight control.

Capacitive Touch Screens – Touch screens are a great value add to the center console of the car. Not only do they provide an excellent enhancement to the user interface but also act as natural integrators of multiple controls onto one system. Traditional touch screens have been dependent upon mechanical pressure from the user to change resistance levels to enable detection.
of touches. Such touch screens, called resistive touch screens, had limitations in the fact that they could only recognize a single finger touch and deteriorated over time. Capacitive touch screens enable multiple finger recognition along with gesture decoding, as well as superior light transparency and increased sensitivity and are now fast becoming the touch screen technology of choice. Adopting such touch screens into the car enables further design differentiation and improved UI. An example of a multipurpose touch screen controlling HVAC, Audio/Video and Navigation is shown below.

![Touch Screen Example](https://example.com/touch_screen.png)

**Figure 9**

**Center console design models:**

**The Brick Design Model**

Center consoles have been traditionally designed using the brick design model. In this model, each center console component is a complete unit comprising of controls/switch panel as well as the actual electro mechanical box.

For example a center console is composed of a number of independent components comprising the HVAC, Audio, and Navigation units. Each individual component is a complete system comprising the controls, electronic components and mechanical actuators etc.

The limitations of such a design is that each system is developed in a silo, and the car manufacturer has only limited control in being able to provide a uniform look and feel. The designers also have limited freedom to design center consoles with restrictions on styling. There is also an increased cost adder to allow for tooling costs associated with additional grooves and harnesses. Due to an increased number of mechanical components, there is also an increased chance of failure.

**The integrated design model**

In the integrated design model, the control for all elements of the center console are unified into a single front panel with the actual electro-mechanical systems connected through a data bus. The distribution and integration of the control panel enables HMI designers with greater flexibility in styling as well as greater control over uniform look and feel. Such a design also reduces tooling charges and increases reliability. Because of integration and reduction of controls, such designs also reduce the total cost of systems.

The integrated design model is largely made possible because of capacitive touch sensing. Designers can integrate a flat panel with capacitive sensors, and have greater freedom to play around with curves thereby provide a better overall styling of front panels. Due to the reduced number of mechanical components and less grooves (which trap dust etc), such designs also enhance reliability and reduce system costs.
The proliferation continues….

As capacitive touch sensing technology matures, electronic design engineers are finding interesting new applications for it within the automotive environment.

Two factors are contributing to the proliferation of this technology into automotive environments,
1. Touch sensing controllers have now started to support automotive specific communication protocols like LIN and CAN. This trend enables many other applications, which have traditionally been on one of these network busses to be easily migrated to touch sensing based sensors.

2. Capacitive sensing is being increasingly accepted in tough environments like automobiles and industrial control panels. This has been made possible by mature, robust ICs, with semi companies beginning to manufacture new devices enabling faster scan rates, better noise immunity, and low power consumption. This coupled with an increasingly experienced application engineering community is proving as a strong catalyst in the expansion of this technology into newer application areas.

Some of these innovative applications are detailed below:

**Human Interaction Sensors:**

- Capacitive sensing based Passive Keyless Entry System:
  Passive Keyless Entry Systems have been around for some time, however recently capacitive sensing is beginning to be used for the detection of approach of the driver’s hand. This sets up the trigger for encrypted communication between the keyfob located in the driver’s pocket and the immobilizer in the car. Once authenticated, the driver is granted access to enter the car and drive away, without ever needing to take his key out of his pocket.
1. User Detection By Capacitive Touch Or Proximity

2. Comm with Immobilizer

3. User authentication for car access

Figure 12. Capacitive touch sensors in Passive Keyless Entry Systems

- Proximity based detection of direction of approach to center console
  Capacitive proximity sensors in the centre console of a car can be used to implement multiple customizable features depending upon the direction and distance of approach of hand. This enables the centre console to adapt to or change its response depending on whether the driver or the passenger is approaching the centre console.
Function Set 1 Activated With Approach Of Passenger Hand

Function Set 2 Activated With Approach Of Driver Hand

Figure 13. Centre Stack Function Control Based On Direction Of Approach

- Indoor Illumination Control:
  Capacitive proximity sensing provides an efficient means for implementing ‘range’ sensitive illumination control for various indoor and outdoor car systems. ICs are available which combine, capacitive touch sensing, LIN communication support and LED dimming capability which provide a single chip solution for such applications.

  Some examples are:
  - Proximity based backlight for door handle with intensity control based on range of hand
  - Proximity based compartment lighting
  - Touch and proximity based dome light with LIN
Backlight Turns On With The Approach Of Hand

Capacitive touch sensor based switches

- Switches:

  Touch buttons are gradually getting more popular and are replacing mechanical switches & buttons due to their superior aesthetics, flexibility and reliability.

  Some examples are mentioned below. Some of these applications are further being proliferated because of availability of LIN/CAN communication protocols
Capacitive Sensing Ushers in a Revolution in Automotive HMI Design

Figure 15. Capacitive Touch Implementation for Switches

Figure 16. Capacitive Touch Trunk Release Switch
Capacitive touch buttons can also provide an efficient, waterproof implementation of a number lock based car entry system. Given below is an illustration:

**Capacitive Touch Button Number Keypad**

![Capacitive Touch Based Number Lock System](image)

**Figure 17. Capacitive Touch Based Number Lock System**

- **Liquid Level Sensors:**

  Apart from human presence sensing, capacitive sensing can also be used to measure presence of liquids. This property finds applications in liquid level sensing and can be used for fuel level, brake fluid level, coolant level detection. Ability to control LCDs and LIN & CAN support, which enable communication with body control or other system modules, provide a single chip solution for such systems.
Conclusion
From making infotainment systems cooler to providing a reliable methodology for measuring liquid levels, capacitive sensing is proving to be an immensely popular and useful sensing technology for use in the automotive applications. Its potential is just beginning to be tapped with next generation mixed signal controllers which are designed for the automotive industry. As systems get more demanding, designers will find that this technology provides an effective sensing technology for a wide gamut of applications.

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