Simplify smart speaker human machine interface with capacitive-touch technology

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Overview

Smart speakers and home assistants will soon be ubiquitous. According to Juniper Research, more than 70 million households in the U.S. will have at least one smart speaker installed by 2022.

Smart speaker functionality has grown significantly since their launch in 2015. The original purpose of delivering a user's audio content is still one of the main reasons consumers buy one (or more) for use throughout their home. These speakers feature a voice-activated digital assistant that maintains "communication" with the user. Other physical controls on the speaker must be simple and unobtrusive, while still enabling the required functionality. These controls could be a simple power ON/OFF button, a volume-control slider or wheel, buttons to skip or repeat audio tracks, a button to mute the microphone, etc.

Voice as a means to interact with devices has become popular, thanks to "Alexa", "Hey Siri" and "OK Google." One of the main reasons that smart speakers have caught on so quickly with consumers is the inherent simplicity of their interactions. There are very few buttons for basic functionality, with most of the interaction occurring via voice commands.

Leonardo Da Vinci once said, "Simplicity is the ultimate sophistication." When applied in the 21st century, this design philosophy means that the human-machine interface (HMI) should be as simple as possible, and the design of the interface needs to be intuitive. Furthermore, designers must create a noticeable difference in the interface design, due to the fact that voice is the preferred interface. **Figure 1** shows the typical HMI of a smart speaker.

Capacitive touch functionality enables designers to implement unique features and differentiate their product in a crowded marketplace. In this paper, I'll show some of the differentiating features that you can implement using Texas Instruments (TI) MSP430™ microcontrollers (MCUs) with CapTIvate™ touch technology.

***Figure 1**. Typical smart speaker with basic HMI.*

MSP430™ capacitive-touch-sensing MCUs with CapTIvate technology

TI MSP430 MCUs featuring CapTIvate technology enable touch-control designs with an integrated feature-rich capacitive-sensing peripheral. This peripheral enables highly reliable, ultra-low-energy designs without compromising touch performance, making it ideal for battery-powered applications with sleek HMIs. The configurable CapTIvate peripheral also supports self- and mutual-capacitance measurement topologies, allowing designers to leverage the benefits of each topology in the same unique interface design with a single MCU. High-level noise tolerance, a full-featured and programmable MCU, and a comprehensive ecosystem distinguish MSP430 MCUs with CapTIvate technology from other capacitive-touch controllers.

The MSP430 CapTIvate MCUs can significantly enhance the potential functionality implemented in smart speakers through:

- **Mechanical button replacements.** As consumers become more comfortable with capacitive-touch buttons on their products, embedded system designers are beginning to appreciate the benefits of replacing mechanical buttons with capacitive-touch buttons. For example, you could replace each of the four push buttons on smart speakers with capacitive-touch buttons, each sensed using a single MSP430 CapTIvate MCU. This would yield significant savings in the cost of the buttons, the cost of manufacturing the top surface with button cutouts, and the savings from a simplified assembly process.
- **Advanced inputs such as sliders and wheels.** MSP430 CapTIvate MCUs enable system designers to implement advanced input mechanisms such as sliders and wheels to control different functions on the device. For example, a tap could turn the microphone on and off, a swipe on the slider sensor could skip or rewind an audio track, or a rotary-touch motion on the wheel sensor could increase or decrease the volume. These gesturing mechanisms could not be supported without capacitive-sensing controllers. Check out a cool training video that describes some of the 3-D gestures possible on MSP430 CapTIvate MCUs.
- **Proximity detection.** MSP430 CapTIvate MCUs can also implement proximity detection, such that the LED ring could turn on and/or greet users whenever they bring their hand near the device. This is an easy enhancement and provides a wow factor to a smart speaker design.
- **Improved aesthetics.** Removing the need to cut out the button holes in the top surface provides one other significant benefit: designers have the flexibility to make the surface more aesthetically pleasing. It does not even need to be a completely flat surface; creative designers can experiment with different shapes and materials to come up with a design that is both functional and attractive in order to maximize market acceptance. MSP430 CapTIvate MCUs can implement touch through metal, touch through glass, touch through wood and touch through plastic.
- **Increased reliability.** Reliability in touch and proximity detection is a critical element

***Figure 2**. An elegant HMI provides differentiation in the market.*

of the simplicity and unobtrusiveness of a smart speaker's HMI. Many noise sources create serious challenges for reliably detecting capacitive touch. Smart speakers typically have Wi-Fi® and/or *Bluetooth*® connectivity, which increase the amount of electromagnetic noise. MSP430 CapTIvate MCUs ensure excellent noise immunity through a combination of signal-processing algorithms, low-noise hardware design and noise-avoidance techniques. CapTIvate technology uses an integrator-based charge-transfer engine with a frequency-hopping oscillator, as well as parasitic capacitance correction and spread-spectrum clock modulation to improve noise immunity. The CapTIvate software library provides several signal-processing algorithms that you can use to increase the robustness of touch or proximity detection. These include multi-frequency algorithms, infinite-impulse-response (IIR) filters, de-bounce mechanisms and dynamic threshold adjustments. This reference design demonstrates a noise-tolerant capacitive-touch HMI design, while this video explains all of the noise-immunity features of CapTIvate MCUs.

- **Moisture-tolerant capability.** People have used traditional Bluetooth speakers in their bathrooms, kitchens and pool-side for a while. We can expect smart speakers to follow suit, but that means adding moisture tolerance to smart speakers. Having a completely sealed top surface with capacitive-touch controls really helps because a device with mechanical buttons requires cost-prohibitive measures to make it moisture-tolerant. MSP430 CapTIvate MCUs can reliably detect touch or proximity in the presence of moisture. This cool video demonstrates the moisture-tolerant capabilities of MSP430 CapTIvate MCUs.
- **Lower power consumption.** Smart speakers with Wi-Fi connectivity are usually wall-plug powered, so they do not typically have low-power requirements. This is, however, a limitation from the user's point of view, as it limits the speaker's portability. Making a smart speaker battery-powered would require redesigning the device architecture as well as a more complex power-management scheme to extend the battery life. In fact, some manufacturers make portable smart speakers with rechargeable batteries that have a run time of around 10 to 12 hours.

  Capacitive-touch controllers in these devices need to achieve the lowest power consumption possible while still detecting touch or proximity. MSP430 MCUs with CapTIvate Technology are the lowest power capacitive-touch-sensing solution with < 2 µA/avg per button. These MCUs also support a wake-on-touch or wake-on-proximity detection, so that you can place most of the power-consuming processors in a deep low-power mode until activated by a touch or proximity event. Check out this reference design, which demonstrates low-power touch through glass.

Additionally, our new line of CapTIvate MCUs is bringing capacitive-sensing capabilities to cost-sensitive applications. The new MSP430FR2522 and MSP430FR2512 MCUs with integrated capacitive touch can add up to 16 buttons and proximity sensing to voice-activated home automation systems, audio applications and more. These devices are designed for cost-sensitive applications.

Key features and benefits of the new CapTIvate touch MCUs

- **Low-cost capacitive touch MCUs:** Designers can now use the MSP430FR2522/ MSP430FR2512 MCUs to add the benefits of capacitive touch and proximity sensing to their cost-sensitive application.
- **Speed time to market:** Developers can quickly evaluate capacitive sensing for their application with a portfolio of MCUs, easy-to-use tools, software, reference designs and documentation through online CapTIvate technology guide as well as TI E2E™ community support. Brainstorm your own applications and with only 5 minutes and some creativity, you can create your own masterpiece using CapTIvate Design Center. For fast evaluation, a CAPKEYPAD BoosterPack™ plug-in module is now available. The BoosterPack module can be used with LaunchPad™ development kits, the CapTIvate development kit (MSP-CAPT-FR2633) or the CapTIvate programmer board (CAPTIVATE-PGMR) for maximum flexibility.

The integrated capacitive-sensing technology is part of a full MCU with on-chip 10-bit SAR ADC, GPIOs, timers, multiple serial interfaces (I^2C, SPI, UART) and is available in TSSOP and QFN packages.

Conclusion

TI MSP430 MCUs with CapTIvate technology feature one of the most noise-immune capacitive-sensing technologies available. The MCUs' configurable combination of button-, slider-, wheel- and proximity-sensing interfaces and ultra-low-power consumption enable you to create eye-catching yet simple interfaces. Creative designers can use this technology to enhance their upcoming smart speaker designs to further increase their worldwide reach and the tremendous success that these devices have already enjoyed.

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