

Improving Kick Sensor Gesture Recognition with 79GHz mmWave Radar Technology



Introduced in 2011, capacitive kick sensors enhanced vehicle convenience by allowing a simple foot motion under the rear bumper to [open the trunk hands-free](#). Huf pioneered this technology and continues to make kick sensor detection more accurate and reliable, expanding beyond capacitive sensors, which require a different position in the vehicle that is more complex to manufacture and mount compared to Texas Instruments' 79GHz millimeter wave (mmWave) technology.

The Capacitive Technology Approach

One engineering challenge has been to make kick sensors more accurate by distinguishing intentional user gestures (valid use cases) from inadvertent gestures or unassociated movement (misuse cases): examples include pedestrians, children playing, or weather conditions such as rain or snow. While detecting kick motion requires little technical effort, preventing the vehicle trunk from accidentally opening is of paramount importance.

Huf addresses this challenge using capacitive sensor technology with two electrodes (see [Figure 1](#)) on the vehicle bumper, to detect movement behind and below the vehicle. The two electrodes define the width of the detection area. The system evaluates gestures using the measured signals and Huf's intelligent algorithm, determining whether the motion is a valid use case or a misuse case.



Figure 1. A Capacitive Sensor with Two Electrodes

How Huf and TI are Redefining Gesture Recognition

Precise gesture recognition and reliable differentiation between valid use cases and misuse cases present distinct challenges. Both depend on how the sensor is integrated into the vehicle. For example, the exact installation position of the sensor within the rear bumper can restrict the field of view, limiting users to kick only in specific areas when parked close to another vehicle or next to a curb.

For these reasons, Huf developed a [new design based on TI's mmWave radar](#) system-on-chip. The Huf kick sensor (see [Figure 2](#)) uses TI's [79GHz mmWave radar technology](#) to create a large field of view with more precise and reliable gesture recognition, while simplifying the vehicle integration. The 79GHz bandwidth provides wider range and velocity resolution compared to shorter bandwidth radar alternatives.

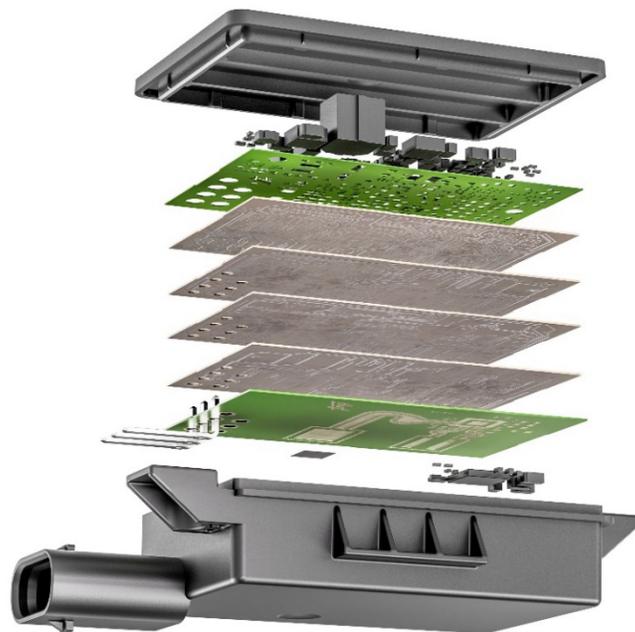


Figure 2. Component Layers of a Huf Kick Sensor Module with TI's mmWave Radar System-on-Chip

Huf's system uses adjustable kick range parameters, a novel feature that senses gestures even when made further away from the bumper. The mmWave radar-based approach also provides seamless plug-and-play implementation at almost any part of the vehicle, enabling car manufacturers to design more gesture-based access features such as opening a side door (as shown in [Figure 3](#)) or waving a foot or hand to open the trunk.



Figure 3. Opening a Side Door by Waving a Hand

How MIMO Antenna Arrays Enhance Performance

The expanded vehicle access uses virtual multiple-input multiple-output (MIMO) antenna arrays optimized for kick sensor applications to improve angular resolution, which is critical for precise position and gesture recognition.

MIMO systems receive and process signals from different directions through spatial diversity, which minimizes interference and multipath effects while isolating the intended motion for detection. The sensor's field of view enables natural operation across the wider width of the bumper, even if a trailer hitch affects the sensor from being centrally positioned at the rear of the vehicle. The algorithm uses information provided by the mmWave radar system-on-chip to differentiate valid use cases from misuse cases.

Development Expertise Meets Advanced Hardware

Huf's hardware and software development expertise, when combined with TI's high-performance mmWave radar IC, addresses a specific misuse case challenge. Valid kick gestures require continuous foot movement toward the vehicle, regardless of the user's position in the kick area. The system must distinguish these gestures from other movements, such as a cat passing by, to prevent the trunk from opening or closing unintentionally.

TI's mmWave radar system-on-chip uses Frequency Modulated Continuous Wave (FMCW) signaling and capture high-resolution range-Doppler maps for comprehensive analysis. Huf's algorithms analyze these to optimize the user's experience and enables reliable operation across all types of vehicles, from sports cars and sedans to SUVs, with varying geometries of bumpers, as well as under difficult external conditions such as heavy rain.

Advanced Signal Processing and Analysis

Huf's software uses range-Doppler information to identify individual gestures. A kick gesture must occur in a certain time period and within a specified maximum distance from the sensor. A specific minimum signal strength facilitates accurate analysis.

However, a range-Doppler heat map alone cannot distinguish between valid use cases and misuse cases. Huf's software uses additional variables, such as the calculation of the angle of arrival (AoA) to the selected target, for example to the person being detected by the radar sensor.

AoA signal curves for the use cases shown (see [Figure 4](#) and [Figure 5](#)) differ between scenarios. Valid use cases show an AoA measurement that always returns to the starting point when completing a kick gesture (see [Figure 4](#)), while the start and end points differ when, for example, a person walks by the vehicle ([Figure 5](#)). This is due to the fact that the user does not move along the vehicle when making an intended gesture. In addition, when the kick is triggered, the user's foot is constantly in one place.

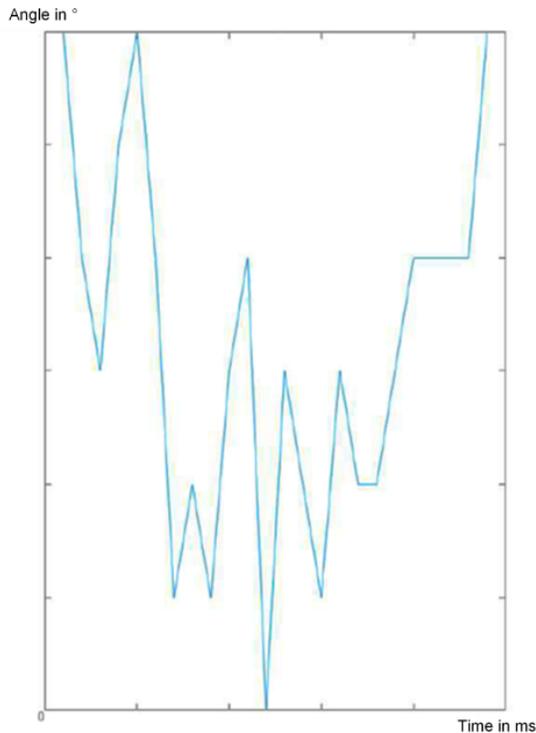


Figure 4. Angle of arrival: Kick gesture (valid use case)

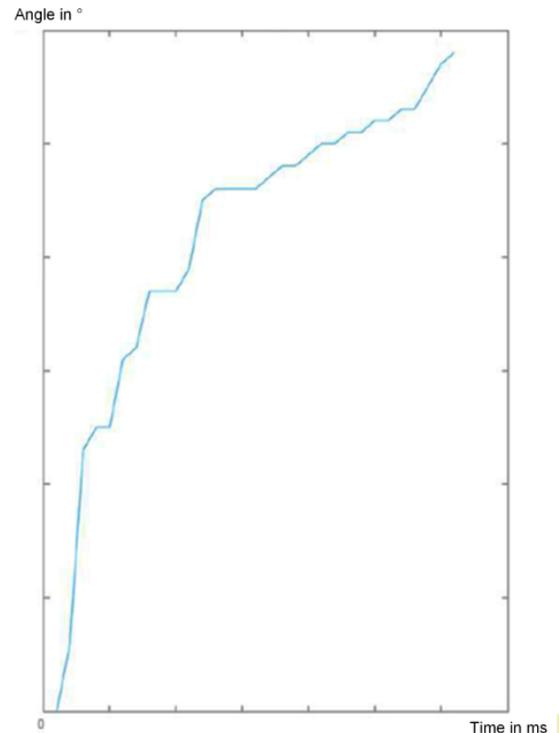


Figure 5. Angle of arrival: Pass by (misuse case, for example cat crossing or ball rolling by)

An AoA calculation can be based on two approaches: trigonometry-based time-of-flight procedures or frequency-offset evaluation between two nearby antennas.

Algorithms such as the multiple signal classification (MUSIC) or the Capon method, also known as minimum variance distortion less response (MVDR) typically handle angle calculations. These methods do require relatively high computational effort.

TI's mmWave radar system-on-chip supports AoA calculations by providing hardware accelerators for Fast Fourier Transformations (FFTs) as well as Cortex-M4F application processors. This approach enables fast and efficient angle calculation.

The hardware accelerators operate independently from the main processor, which analyzes the measured and processed data, calculates the range Doppler heat map, and enables gesture evaluation with calculations through the algorithms.

Conclusion

The shift from capacitive to 79GHz mmWave radar sensor technology is improving kick sensor accuracy and provides an opportunity to expand gesture control features in more places around a vehicle. Future applications can include climate-control systems, infotainment and audio control.

Automakers are beginning to realize the true potential of innovation, such as what Huf developed with TI, to push the boundaries of precision, ultimately giving drivers and passengers a more convenient experience.

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