QPF5100Q

Kick Sensor for Hands-free Car Trunk

Abstract

This application note provides design guidance for implementing a hands-free automotive trunk kick sensor using the Qorvo® QPF5100Q Ultra-Wideband (UWB) System-on-Chip (SoC). It describes the system architecture and operating principles, details UWB transceiver performance, and explains the use of the integrated microcontroller and peripheral interfaces. Additional sections cover power management design including DC-DC converter considerations, antenna placement strategies, and PCB layout guidelines. The goal is to help engineers develop a reliable, secure, and low-power UWB kick sensor module that meets automotive performance and qualification standards.

1. Introduction

Ultra-Wideband (UWB) technology provides a secure and precise foundation for hands-free vehicle functions such as trunk kick sensors. UWB operates by transmitting short, low-power pulses across a wide frequency spectrum to measure distance with centimeter-level accuracy. For a kick sensor, this precision enables reliable detection of a user's foot motion beneath the rear bumper, while UWB's inherent resistance to relay and spoofing attacks ensures secure operation. Due to the module remaining powered even when the vehicle is off, minimizing idle current drawing is critical to avoid draining the car battery. The design goal is to manage power intelligently, activating the UWB transceiver only when a valid event or proximity trigger is detected.

Modern UWB kick sensor systems use a tiered activation approach to balance responsiveness with power efficiency. A low-power channel, such as Bluetooth® Low Energy (BLE) or a low-frequency RF field, can detect an approaching key fob and wake the UWB sensor only when detailed ranging and gesture detection are required. Once active, the UWB system performs a quick range verification followed by radar-based motion sensing to confirm a kick gesture, and then immediately returns to standby.

Please refer to Figure 2-1 for details description of authentication in Tiered Activation and Gesture Detection Sequence below.

1. BLE Wake-Up: The vehicle's BLE beacon periodically scans for an authorized key fob within approximately 10–30 m. After successful authentication, the kick sensor module powers its UWB circuitry for fine-range detection.

2. UWB Ranging Burst: The QPF5100Q UWB SoC activates when the key is within close range (typically under 5 m). It performs two-way ranging to confirm proximity and determine that the user is located behind the vehicle.

3. Foot Detection Radar: With the key validated and the user in position, the QPF5100Q transmits a short UWB radar burst beneath the bumper and listens for reflections from a moving foot. A valid kick motion is identified by a distinct change in measured distance within approximately 0.2 to 0.5 m of the sensor. Detection is based on comparing the pre-scan static condition with the subsequent foot movement.

4. Trunk Release: Once the gesture is confirmed, the QPF5100Q's embedded microcontroller—or the vehicle's body control module via CAN—initiates trunk opening. The system then re-enters a low-power sleep state.

This tiered activation method minimizes energy consumption by keeping the high-power UWB radio active only for brief intervals. Even if the transceiver current consumption is high during a ranging or radar burst lasting 100 ms the duty-cycle-averaged current remains low in the tens of microamps—insignificant compared to the vehicle's overall standby load. By controlling activation timing through the QPF5100Q's integrated processing and power-management features, designers can achieve a secure, responsive, and battery-efficient hands-free trunk sensor system.

2. Functional System Overview

The proposed system uses the Qorvo® QPF5100Q automotive UWB SoC as the core of a secure, low-power hands-free trunk sensor. The QPF5100Q integrates a UWB transceiver, Arm® Cortex®-M33 MCU with TrustZone®, and CAN-FD controller in a compact, automotive-grade package.

UWB technology delivers superior precision and reliability over infrared or capacitive sensors while reducing system cost and complexity. It's inherent resistance to relay attacks and security enhancement.

In operation, multiple QPF5100Q anchors in the bumper and cabin perform precise ranging and key localization, guided by BLE-based wake-up and authentication. This multi-anchor design achieves sub–10 cm accuracy, enabling trunk release only when an authorized user stands directly behind the vehicle.

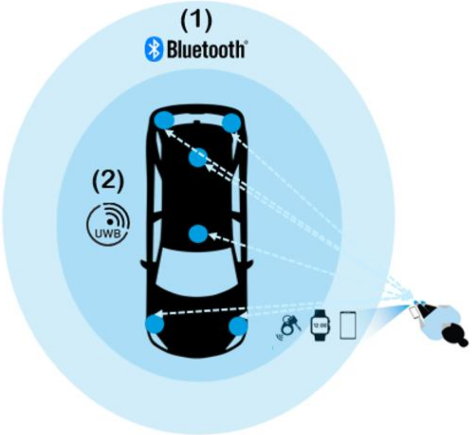

Figure 2-1. Multi Anchor UWB Automotive System

3. High Level Solution Block Diagram

Figure 3-1 below illustrates the main components and connections of a QPF5100Q-based UWB kick sensor system. The Qorvo® QPF5100Q Ultra-Wideband (UWB) System-on-Chip (SoC) functions as the complete UWB module, integrating the impulse radio transceiver, Arm® Cortex®-M33 microcontroller with TrustZone® security, and CAN-FD controller in a compact, automotive-qualified package. The SoC is mounted on the vehicle's sensor PCB, which includes supporting circuitry and an external UWB antenna positioned to monitor the foot-detection zone beneath the rear bumper.

Power is supplied from the vehicle's 12-volt battery and converted to 3.3 V by an off-chip DC-DC buck converter that powers the QPF5100Q and its peripherals. An external CAN-FD transceiver connects the SoC to the vehicle's CAN bus for communication with the body control module (BCM). The PCB also includes connectors for power, ground, and network signals, as well as optional SPI or I²C headers for programming and diagnostics.

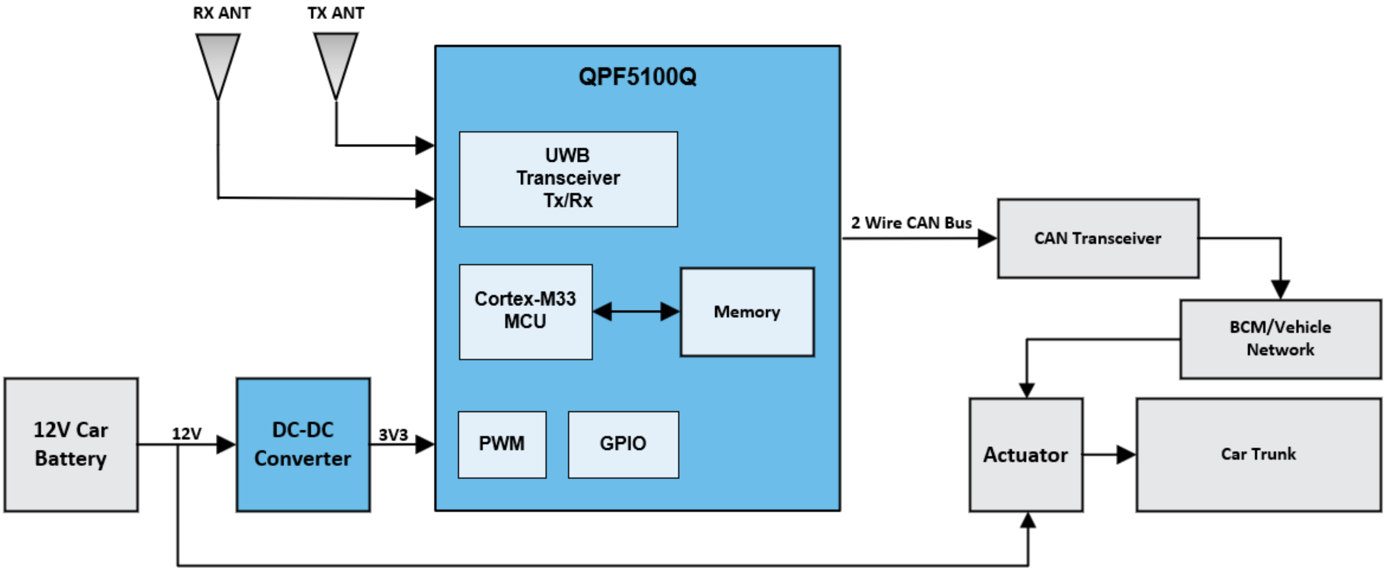

Figure 3-1. Implementation of QPF5100Q for Hands-Free Kick Sensor System Components

This block diagram represents a typical configuration. The QPF5100Q's high level of integration minimizes the external bill of materials: its dual receivers remove the need for an external RF switch, and the built-in AES-256 encryption engine provides secure ranging and data protection without additional hardware.

The QPF5100Q supports UWB channels 5, 6, 8, and 9 in the 6.5–8 GHz range, each offering up to 500 MHz of bandwidth per IEEE 802.15.4z HRP-UWB. The device combines a complete RF front end with transmitter and dual receivers, a digital baseband processor, and a 32-bit Arm® Cortex®-M33 MCU, along with integrated interfaces including CAN-FD, GPIO, PWM, and secure memory.

To maintain long-term system accuracy and alignment with the vehicle's UWB anchors, the reference clock must use a high-quality and highly stable timing element, ideally a 38.4 MHz crystal or resonator with tight stability, low drift dielectric, and minimal ageing effects. Designers must also maintain low supply noise and decoupling to prevent clock jitter that degrades ranging accuracy. Given the vehicle battery environment and long idle periods, the reference clock must reliably launch and stabilize quickly during each wake cycle, enabling rapid ranging and gesture detection without sacrificing battery life.

3.1.1. Digital Baseband Processor Microcontroller & Interfaces

QPF5100Q UWB module integrates a digital baseband processor (DBP) for PHY-layer control and precise timing, offloading real-time functions from the MCU. Driven by the 38.4 MHz reference clock and internal PLLs, it achieves sub-nanosecond scheduling accuracy. The DBP handles BPSK/BPM-BPSK modulation, correlation, decoding, and timestamping, with MAC-level address filtering and autoreply to reduce MCU load. It features AGC/DGC for adaptive gain, AES-128/256 for IEEE 802.15.4z STS security, and OTP-based calibration for TX power and DC offset. External RF control via u-Bus or RFFE is supported, enabling secure, precise UWB operation with minimal MCU intervention. The QPF5100Q features a 32-bit Arm® Cortex®-M33 MCU that controls UWB transceiver functions, system management, and vehicle communication. Running up to 100 MHz, it supports DSP, FPU, and TrustZone® security for efficient and secure processing. The MCU handles real-time UWB events via low-latency interruptions and manages deep-sleep modes for ultra-low power operation. Integrated interfaces include SPI, I²C, UART, CAN-FD, and configurable GPIOs. On-chip flash and SRAM enable standalone operation and custom algorithm execution within an automotive-qualified package.

3.1.2. Antenna Design and Placement

The UWB antenna is a critical element of the kick sensor system, directly determining range, field of view, and detection reliability. Designing and integrating an antenna for an automotive environment requires balancing size, bandwidth, and radiation pattern while ensuring compatibility with the vehicle's materials and installation constraints.

Because the antenna is mounted inside the rear bumper, space is limited and form factor is important. At approximately 8 GHz, a quarter wavelength is only about 9 mm, enabling the use of compact antennas such as chip, patch, or printed designs. The kick sensor antenna operates on a single channel requires to cover 500MHz bandwidth that supports one of the UWB Channels 5, 6, 8, or 9. Maintaining good impedance matching across 500MHz bandwidth (for example, VSWR < 2:1) ensures stable operation and consistent ranging performance. Qorvo is using directional antenna with dual Rx radar to determine the target AoA (Angle of Arrival)

The antenna's radiation pattern must reliably cover the target area beneath the bumper where a foot movement occurs. A horizontally broad beam between 60° and 120° allows adequate lateral coverage, while a narrower vertical beam focused downward helps reduce unwanted reflections. A directional patch antenna with a higher-gain, narrower field of view is well suited for this purpose. Compact chip or flexible printed-circuit (FPC) antennas can also be used; their wider patterns simplify placement but may increase the need for signal processing to reject background reflections.

Linear-polarized antennas are generally preferred for UWB kick sensors because they produce more predictable propagation and more stable radar signatures outside the highly reflective, metal-dominant car body. More important is the physical orientation of the antenna: it should face the region under the bumper and may be angled slightly downward using an integrated bracket or angled PCB section. Bumper plastics such as ABS or PP are largely transparent to UWB signals, but metallic paint or nearby structural metal can detune the antenna. Designers should verify antenna performance in situations—either through simulation or vehicle testing—and adjust tuning as needed to compensate for dielectric loading.

Because foot detection occurs at a short range (typically 0.2–0.5 m), even low-gain antennas provide sufficient signal strength. Higher-gain, narrower field of view antennas can improve signal-to-noise ratio and reduce false triggers, but UWB's range-gating and Doppler processing already mitigate distant reflections effectively. A human leg has a radar cross-section of roughly 0.1–0.2 m² at these frequencies, producing a strong return at close distances.

Environmental factors such as dirt, water, or ice may slightly attenuate signals, but UWB operation is robust to these effects. Locating the antenna behind an RF-transparent enclosure provides additional protection without degrading performance.

4. CIR Radar Technology Overview

4.1. Explain CIR Radar Technology in the Application

A wideband radar (such as UWB) uses very short-duration pulses (in the order of nanoseconds) or an extremely large bandwidth signal greater or equal to 500MHz. This yields very high range resolution, meaning the radar can distinguish multiple objects that are only a few centimeters apart in distance. In the context of gesture recognition such as foot movement, the radar is usually configured for short-range sensing with directional antenna (preferably in the kick sensor application, limit surrounding environment improves gesture detection) cover the confined areas in approximately 0.5m under the bumper.

In signal processing terms, the channel impulse response represents how a transmitted “impulse” is transformed by the propagation channel (the environment between transmitter and receiver). For a kick sensor radar, the channel includes the open air of the car’s bumper and all objects within it that can reflect the signal. If one could send a very short impulse (short pulse) and record the returning signal vs. time, the received waveform would *literally* be the impulse response of the channel – a series of pulses or peaks at different time delays. Each peak corresponds to a reflection from the leg/foot in the detection zone. In practice, UWB radar approximates this by sending nanosecond-scale pulses and sampling the echoes. The output of a UWB radar is essentially an estimated CIR: a time-domain waveform with amplitudes at discrete delay bins, often visualized as a sequence of amplitude values versus delay. Figure 4-1 and Figure 4-2 illustrate an example of a CIR sample of UWB radar in 2 scenarios that aid explanation in detecting the leg/foot movement. The orange trace represents the direct path free of object in the propagation channel and the blue trace represents an object detected as there are 2nd and 3rd peaks due to reflection from the leg/foot. This is just a simple explanation of CIR radar works in theory; it is lot more complex in implementation as it involves samples capture, signal processing and possible FFT to look for a unique pattern of the kick signal that is beyond this application note.

Figure 4-1. Foot movement under car trunk

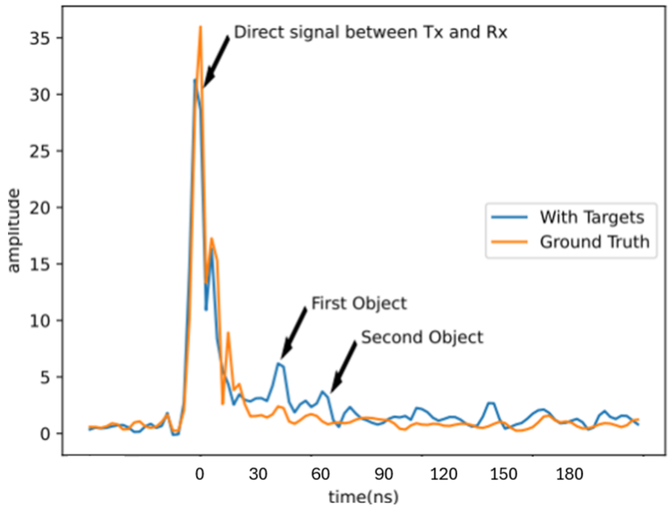

Figure 4-2. CIR illustrate foot movement (Blue trace)

5. Summary

Using a UWB CIR radar as a kick sensor provides a technically elegant and robust solution for hands-free trunk opening. It leverages precise distance sensing and motion detection to reliably recognize a foot gesture, offering improved user experience over older sensors. By carefully considering placement, calibration, and algorithms – and addressing practical challenges like environmental effects and false trigger prevention (kick movement must match and presence of key-fob to minimize false triggering) – automotive engineers can integrate UWB radar kick sensors to create a convenient and secure trunk access system for modern vehicles.

6. Links to Design information

Interested parties may contact the Qorvo Customer Support Team to obtain a Non-Disclosure Agreement (NDA) and gain access to the QPF5100Q data sheet and hardware design guide.

Revision History

Revision	AUTHOR	Date	Description
A	Thanh Luu	11 Sept. 2026	Initial draft

Contact Information

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Important Notices