QPF5100Q

In Car Cabin Child Presence Detection (CPD)

Abstract

This application note provides design guidance for implementing an in-car cabin child presence detection sensor (CPD) 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 in-car cabin CPD sensor module that meets automotive performance and qualification standards.

1. Introduction

Euro NCAP defines direct sensing as detecting the "absolute presence" of a human inside the vehicle by tracking heartbeat, respiration, movement, or other signs of life, and it explicitly contrasts this with indirect logic-based approaches (doors, pressure/capacitance) that cannot distinguish live persons from objects. UWB radar is well aligned to that definition because it can detect micro-motions without needing cameras or wearables, and Qorvo explicitly cites CPD and physiological monitoring as radar-enabled UWB capabilities. This also highlights the urgency of implementing direct sensing in automotive applications, as starting in 2025, Euro NCAP will no longer award the highest 5-star rating to vehicles that do not incorporate a direct sensing feature.

Euro NCAP stands for the European New Car Assessment Program. It is an independent organization that evaluates the safety of new vehicles sold in Europe and publishes safety ratings to help consumers compare cars.

Modern UWB CPD 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 a leaving key fob and send notification or alarm the driver through their mobile phone that a live occupant is being locked inside the car.

Please refer to Figure 2-1 for details description of CPD warning Sequence below.

1. **Vehicle Shutdown & Locking:** The process begins when the engine is turned off and the driver locks the vehicle.
2. **BLE Proximity Monitoring:** The car's BLE radio enters a "listening" mode. It monitors the digital key-fob or smartphone's signal strength to determine when the driver has moved away from the vehicle.
3. **UWB Radar Activation:** Once the BLE connection indicates the driver is out of range, the vehicle activates its internal UWB anchors in reflective (radar) mode.
4. **In-Cabin Scanning:** The UWB system transmits nanosecond pulses that reflect off objects in the cabin. It specifically looks for micro-motions, such as the rise and fall of a chest while breathing, to identify life.
5. **Signal Analysis:** The system's algorithms process the Channel Impulse Response (CIR) to distinguish between a living child and static objects like gym bags or blankets.
6. Multi-Stage Warning Sequence as follows:
    a. **Initial Warning:** If life is detected, the vehicle may first trigger local alerts like horn honks or flashing lights within 10 seconds.
    b. **Remote Alert (BLE/Cellular):** The vehicle sends a push notification to the driver's smartphone or digital key-fob via BLE (if still in range) or cellular data, warning them that a child remains in the car.

c. **Escalation:** If the driver does not respond, some systems are designed to contact emergency services or third-party intervention partners.

2. Functional System Overview

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

In operation, one or more in-cabin QPF5100Q sensors acquire repeated channel impulse response (CIR) measurements after the vehicle is switched off and locked. The CPD algorithm evaluates small, periodic changes in the CIR that are consistent with respiration and distinguishes them from static cabin reflections. BLE, a digital key, or another vehicle-presence mechanism may be used to trigger the sensing sequence and support the subsequent driver-warning workflow.

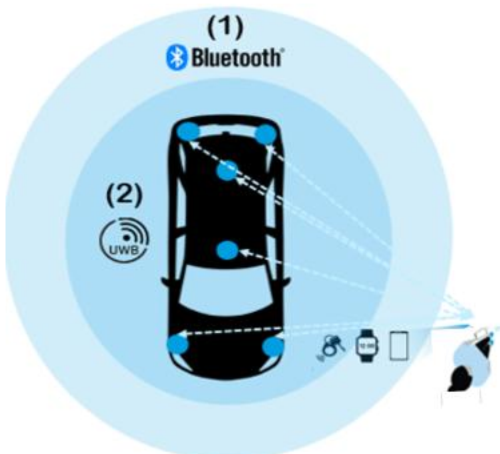

Figure 2-1. Multi Anchor UWB Automotive System

3. High Level Solution Block Diagram

Figure 3-1 below illustrates the main components and connections of a QPF5100Q-based UWB Child Presence Detection 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 external UWB antennas positioned inside the cabin to detect chest displacement motions.

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.

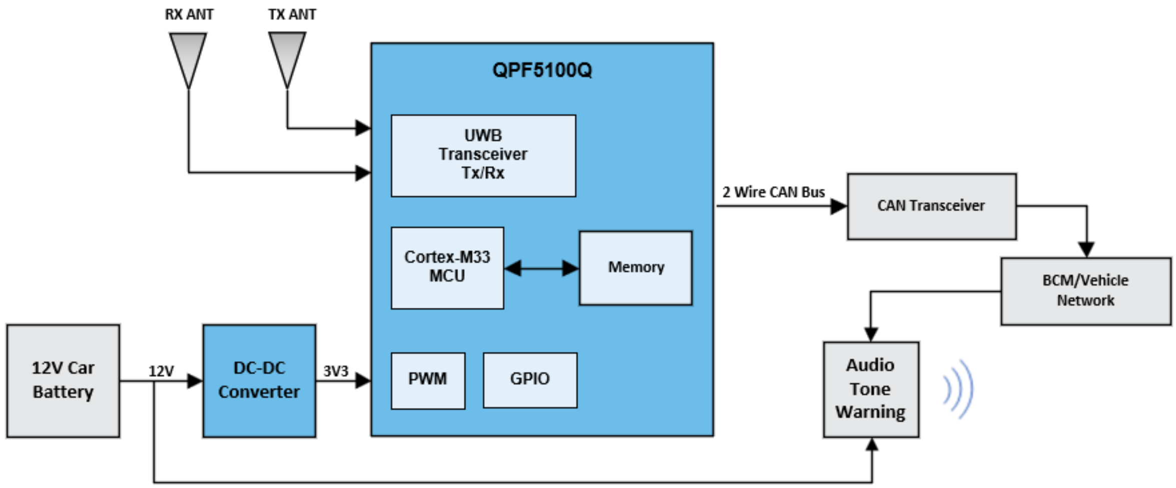

Figure 3-1. Implementation of QPF5100Q for Child Presence Detection System Components

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 6.25–8.25 GHz range, each occupying 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 memory.

4. Design Considerations & Benchmarks

This application note focuses on requirements that are specific to in-cabin child presence detection. For QPF5100Q electrical specifications, supported UWB channels, transmitter and receiver performance, reference-clock requirements, interfaces, power-supply design, and general PCB implementation, refer to the latest QPF5100Q Data Sheet and QPF5100Q Hardware Design Guide. Keeping those platform-level requirements in the controlled product documents avoids duplicating information that may change as device recommendations are updated.

4.1.1. Antenna Design and Placement

The UWB antennas are a critical element of a child presence detection (CPD) system because they directly determine sensing coverage, detection reliability, and robustness to in-cabin multipath. For Euro NCAP-aligned CPD, the system must rely on direct sensing (detecting signs of life such as movement and/or respiration), which places a premium on stable antenna performance across the full operating band and across all required cabin coverage zones.

In an automotive design, the antenna must balance compact size, wide bandwidth, and a radiation pattern that reliably covers the occupant compartment. In Europe, UWB operation in vehicles is commonly associated with the 6.0–8.5 GHz range, and many UWB implementations emphasize operation around the globally adopted high-band channels (for example, Channel 5 near 6.49 GHz and Channel 9 near 8.0 GHz). The antenna should therefore maintain good impedance matching across the selected operational bandwidth (often specified as VSWR ≤ 2:1, or an equivalent S11/return-loss target of -10dB) to ensure stable sensitivity and repeatable sensing performance.

The TX-RX isolation is critical to reduce the TX power leakage into the receiver as it saturates the LNA in the receiver path and de-sensitizes the receiver. To achieve a robust CPD detection rate, TX–RX isolation should be at least 30 dB or better. Achieving this typically requires careful antenna placement/separation.

Linear-polarized antennas are generally preferred for UWB in-cabin Child Presence Detection (CPD) because they produce more predictable propagation and more stable radar signatures inside the highly reflective, metal-dominant car cabin. Circular-polarized (CP) antennas can be used for CPD as long as Tx/Rx antennas propagation direction is opposite (RHCP/LHCP) as reflections undergo a change of CP handedness. UWB radar relies on tiny chest micro-motions for respiration detection — so unwanted polarization flips can decrease detection rates.

The radiation pattern should be chosen to match the CPD sensing volume. A broad, cabin-facing beam helps ensure coverage across seating positions and, where required, footwell areas; moderate directivity can further improve signal-to-clutter performance by concentrating energy into the monitored volume. Depending on packaging and coverage needs, suitable antenna implementations include wideband printed/planar antennas (for broad coverage and easier placement) or moderate-gain patch-style antennas (for more controlled field-of-view). Qorvo uses antenna arrays with a field of view of 40 degrees for single RX radar. For dual RX radar directive, single patch antennas can also be used.

Because the antenna is integrated into a complex vehicle environment, nearby structures and materials (trim plastics, housings, brackets, wiring, and adjacent metal) can detune the antenna or distort the radiation pattern. Antenna performance should therefore be verified in the final installation state—using VNA matching checks and vehicle-level RF validation—and tuned as necessary to compensate for dielectric loading and packaging effects.

Support for antenna selection, integration, and validation is available through Qorvo engineering support channels.

The diagram below provides a side and top view for the radiation pattern coverage of a two-element patch antenna array (This configuration gives ~8dB directional antenna gain) used in the Qorvo demo for child presence detection inside the car. The diagram shows the two-element patch antenna array mounted under the rear-view mirror the TX/RX antenna facing toward the back of the vehicle. The antenna beam is tilted downwards to cover front and rear seats.

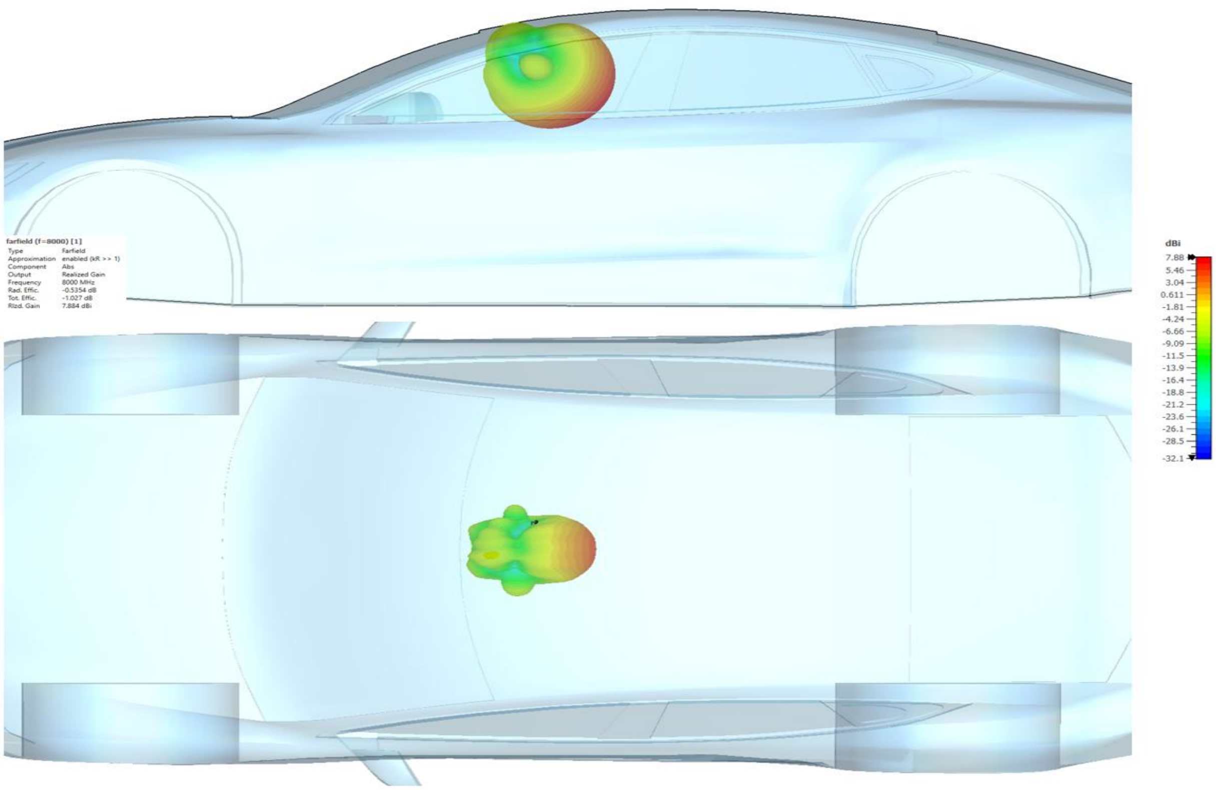

Figure 4-1. Radiation pattern of a two-element patch antenna array used in Qorvo QPF5100Q CPD demo.

5. Utilize CIR Radar for Chest Motion Sensor Overview

UWB radar transmits very short pulses over a wide bandwidth. The receiver records the channel impulse response (CIR), which represents received energy as a function of propagation delay and captures reflections from the cabin environment. Static structures such as seats, pillars, the dashboard, and glazing produce largely stable CIR components. Respiration causes small periodic changes in reflections from the occupant, which can be observed over successive CIR measurements. The CPD algorithm tracks these slow-time variations in selected delay regions and applies filtering, clutter suppression, and decision logic to determine whether signs of life are present. For breathing-rate ranges, warning timing, and assessment conditions, refer to the current Euro NCAP Child Presence Detection Test and Assessment Protocol listed in the references.

Please follow the link given in Section 7 for Euro NCAP requirements.

Figure 5-1. In-car cabin UWB CPD

6. Summary

Ultra-Wideband (UWB) Child Presence Detection uses repeated CIR measurements to detect small occupant motions, including respiration-related motion, within the vehicle cabin. The approach can operate in darkness and does not require image capture or direct line of sight, supporting privacy-conscious sensing when a child is sleeping, covered by a blanket, or seated in a rear-facing child seat.

After the vehicle is switched off and locked, the sensing sequence can be activated by the vehicle system and used to trigger local, mobile, or telematics-based warnings when signs of life are detected. System performance must be validated across the intended cabin configurations, occupant positions, environmental conditions, and applicable safety-assessment scenarios.

A QPF5100Q-based implementation combines UWB sensing, embedded processing, and vehicle-network connectivity in a compact platform. The final CPD solution, including algorithms and warning logic, remains subject to vehicle-level validation and the applicable Euro NCAP or regional requirements.

7. References/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.
- Euro NCAP CPD Test and Assessment Protocol v1.2

Revision History

Revision	AUTHOR	Date	Description
Draft A	Thanh Luu	11 Sept. 2026	In-car Cabin Child Presence Detection

Contact Information

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Important Notices