

BGT60CUTR13AIP connected sensor kit user guide

XENSIV™ radar sensors

About this document

Scope and purpose

This user guide describes the function, circuitry, and performance of the XENSIV™ BGT60CUTR13AIP Wing board, part of Infineon's XENSIV™ BGT60CUTR13AIP Connected Sensor Kit ([KIT_CSK_BGT60CUTR13](#)).

Intended audience

The intended audience for this document is design engineers, technicians, and developers of electronic systems, working with Infineon's XENSIV™ 60 GHz CMOS radar sensors.

About this product group

Target applications

- Motion detection: [Lighting](#), [HVAC](#) control, and [security](#) systems and intruder detection
- Gesture sensing: [Smart speakers](#), [TVs](#), and [wearables](#)
- Fall detection: For elderly care and privacy-focused monitoring (no camera image captured)
- Industrial automation: Level sensing and collision detection for [robotics](#)
- [Presence sensing](#): Smart entrance counting and tracking
- [Smart home and building](#): Thermostats, smoke detectors, occupancy, and proximity sensors
- [Home appliances](#): Washing machine and kitchen appliances

Product family

Infineon's [XENSIV™ 60 GHz CMOS radar sensors](#) with Antenna-in-Package (AiP) provide compact, high-precision, and low-power sensing solutions for IoT, smart home, and consumer applications.

Reference board/kit

Product(s) embedded on a PCB with a focus on specific applications and defined use cases that may include software. PCB and auxiliary circuits are optimized for the requirements of the target application.

Boards do not necessarily meet safety, EMI, quality standards (for example UL, CE) requirements.

Safety precautions

Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	Caution: <i>The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing, or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.</i>
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The board at a glance

1 The board at a glance

The XENSIV™ BGT60CUTR13AIP Connected Sensor Kit supports customers in testing sensor-driven IoT products and radar use cases as well as in prototyping. The KIT_CSK_BGT60CUTR13 (Figure 1) includes:

- Rapid IoT Connect Developer Kit (CYSBSYSKIT-DEV-01)
- XENSIV™ BGT60CUTR13AIP Wing (EVAL_60CUTR13_WING)

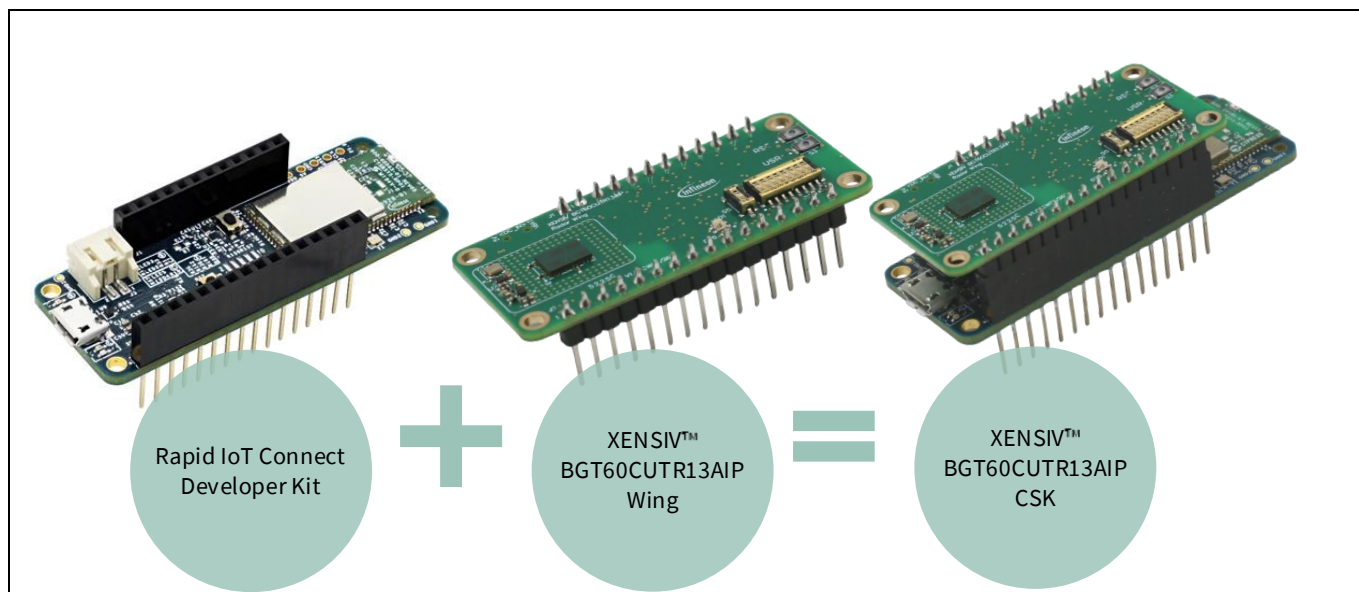


Figure 1 XENSIV™ BGT60CUTR13AIP Connected Sensor Kit

The Rapid IoT Connect Developer Kit (CYSBSYSKIT-DEV-01) shown in Figure 2 allows the evaluation of the Rapid IoT Connect module (CYSBSYS-RP01) on a standard Feather form-factor. The CYSBSYS-RP01 Rapid IoT Connect module is a turnkey module that enables secure, scalable, and reliable compute and connect.

The Rapid IoT Connect Developer Kit consists of a CYSBSYS-RP01 Rapid IoT connect system-on-module (SoM), which includes a PSOC™ 6 MCU, an AIROC™ CYW43012 single-chip radio, onboard crystals, oscillators, chip antenna, and passive components.



Figure 2 Rapid IoT Connect Developer Kit

The XENSIV™ BGT60CUTR13AIP Wing board shown in Figure 3 is based on the XENSIV™ BGT60CUTR13AIP 60 GHz radar sensor MMIC with one transmitting and three receiving antennas integrated. The XENSIV™ BGT60CUTR13AIP MMIC enables ultra-wide bandwidth frequency modulated continuous wave (FMCW) operation. To offload the microcontroller or application processor, the XENSIV™ BGT60CUTR13AIP features a

The board at a glance

fully embedded stand-alone motion/presence detection (MD) processing module that notifies the host via an interrupt once a target is moving within its field of view (FoV).

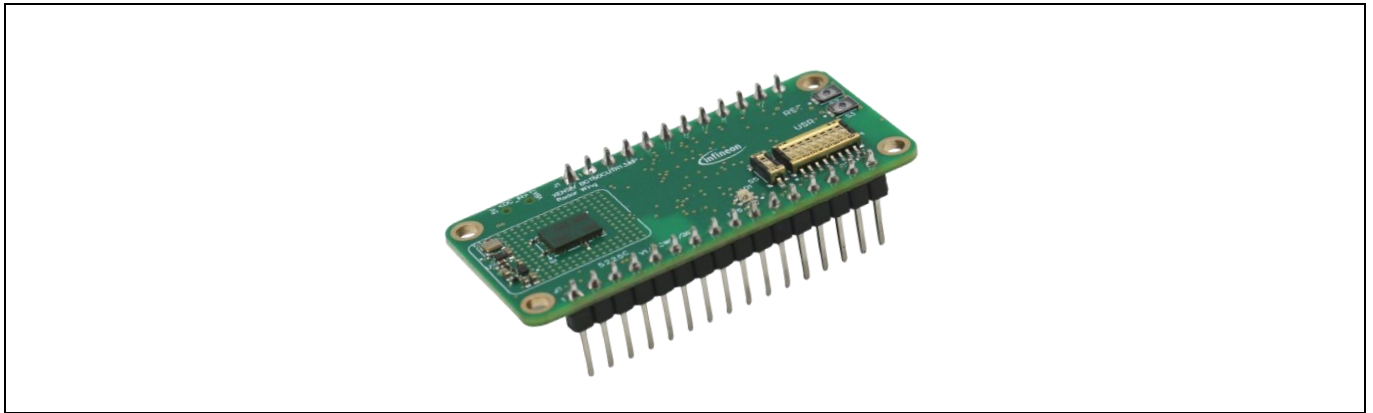


Figure 3 XENSIV™ BGT60CUTR13AIP Wing board

1.1 Scope of supply

The kit can be powered from a 3.7 V lithium-polymer (LiPo) battery or via a USB cable from an external 5 V power supply. The battery is automatically charged when the system is connected to an external power supply.

Note: The radar Wing board must be manually switched to either battery or external 5 V supply (switch S3 in [Figure 19](#)).

BGT60CUTR13AIP connected sensor kit user guide

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The board at a glance

1.2 Block diagram

A block diagram of the Wing board is shown in Figure 4. The Wing board includes the XENSIV™ BGT60CUTR13AIP surface-mounted device (SMD) module and the required power supply components. Power lines are highlighted in red. It is also equipped with push buttons and LEDs.

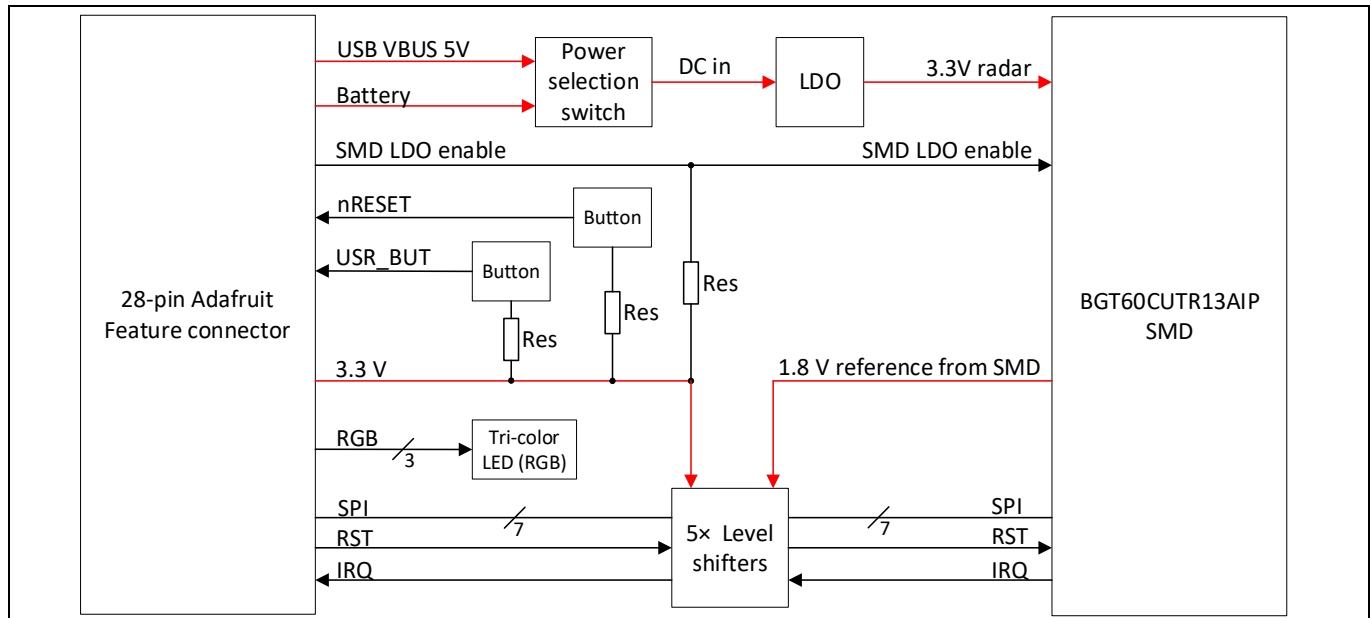


Figure 4 XENSIV™ BGT60CUTR13AIP Wing board block diagram

A system block diagram showing the shield connected to the CSK Rapid IoT baseboard is shown in Figure 5. The interface from the shield to the Rapid IoT baseboard includes digital signals, analog signals, and power lines. The baseboard can interact with the outside world using Wi-Fi, Bluetooth®, USB, or a combination of them depending on the firmware/software (FW/SW) installed on the baseboard. The kit can be powered from an external power supply or from a LiPo battery.

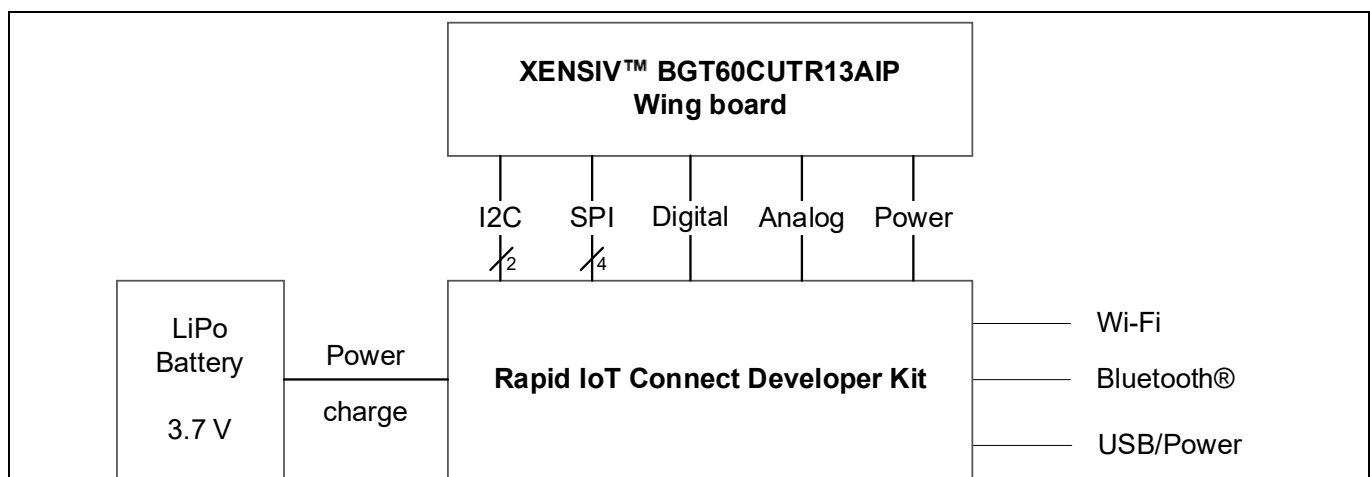


Figure 5 CSK system block diagram

The board at a glance**1.3 Main features**

- XENSIV™ BGT60CUTR13AIP MMIC
 - $6.05 \times 4.30 \times 0.9 \text{ mm}^3$ package size
 - 1Tx/3Rx Antenna-in-Package (AiP) with $90^\circ \times 120^\circ$ field of view (FoV)
 - Real-time data acquisition without interaction with the processor
 - Integrated state machine for low-power and real-time operation
- XENSIV™ BGT60CUTR13AIP Wing board
 - $50.9 \text{ mm} \times 23.0 \text{ mm}$ size on standard FR4 laminate
 - 1 RGB LED and 2 configurable user buttons
 - Form-factor compatibility with Adafruit
 - Electromagnetic band-gap (EBG) structure [4], to reduce the impact of neighboring components, resulting in a homogeneous FoV
- CYSBSYSKIT-DEV-01 Rapid IoT Connect Developer Kit (MCU board)
 - Operates with ModusToolbox™ and Infineon Rapid IoT Connect cloud platform

1.4 Board parameters and technical data**Table 2 Parameters**

Parameter	Symbol	Conditions	Value	Unit
Supply voltage	–	–	5 (Wing board) 3.3 (SMD module)	V
Operating frequency	–	–	57 to 63.36	GHz
EIRP	–	–	+15	dBm
Antenna-in-Package FoV	–	–	$90^\circ \times 120^\circ$	degree

2 CMOS radar-based system solutions overview

2.1 Introduction

XENSIV™ BGT60CUTR13AIP 60 GHz CMOS radar can enable a variety of use cases, such as motion detection, presence detection, localization, tracking, people counting, vital sensing, etc.

This document provides an overview of two main system solutions beyond motion/presence detection:

- Presence detection and localization (PDL) solution using on-chip detection outputs
- Presence detection and tracking (PDT) solution using a high-performance tracker

With both PDL and PDT solutions, the Infineon radar presence detection can detect and localize multiple people in both dynamic (motion) and static scenarios in a defined field of view (FoV), as described in [Section 2.5](#) on key specifications, using the XENSIV™ 60 GHz radar (BGT60CUTR13AIP) sensor. The PDT solution can track three to four people in the FoV.

While the PDL solution supports both indoor and outdoor applications, the PDT solution is designed for indoor applications and can track up to three people in the FoV, adding great value to a variety of applications (e.g., HVAC, Smart TV, security camera, etc.) enhancing application performance.

2.2 Radar for presence detection

Infineon radar system solutions utilize ultra-low-power (ULP) XENSIV™ 60 GHz CMOS radar, a sensor with Antenna-in-Package that provide ultra-wide bandwidth frequency-modulated continuous wave (FMCW) operation with a single-chip solution inside a small package. Sensor configuration, data acquisition trigger, and data transfer are enabled by a digital Serial Peripheral Interface (SPI). An integrated hardware sequencer together with a finite state machine (FSM) offers full flexibility to the user defining configurable chirps and timing parameters while ensuring cycle-accurate data acquisition with the minimal power consumption.

A basic depiction of the FMCW working principle for presence detection is shown in [Figure 6](#).

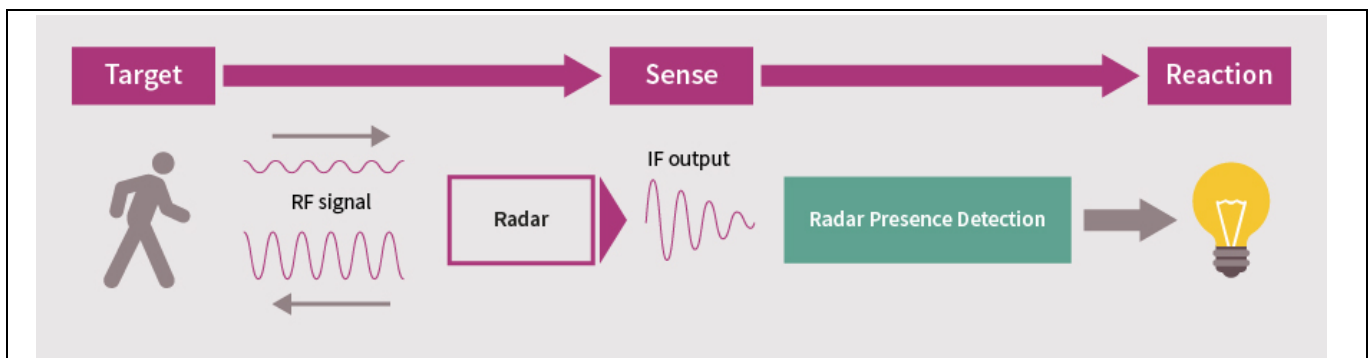


Figure 6 Motion and presence detection using 60 GHz radar sensor

2.3 Presence detection, localization, and tracking solutions

[Figure 7](#) describes three different system solution architectures which are available with CMOS radar:

- **On-chip autonomous:** There is no need for an external MCU for this system solution. Radar configurations are applied from internal ROM masks during power-up and motion/presence status is provided via a generic pin to the host/application processor

CMOS radar-based system solutions overview

- **PDL solution with on-chip detections:** This architecture is deployed for presence detection and localization (PDL) solution. Either an external MCU or a host/application processor writes the desired radar configurations via the SPI interface and receives on-chip detections via SPI (e.g., range doppler – RD, angle of arrival – AoA, etc.). Furthermore, a light-weight (<10 KB) clustering algorithm is applied to get localization information for multiple people in the FoV. This solution also provides features of clutter rejection (e.g., removing detections from a fan) and zone masking to remove detections from other disturbers (e.g., plant, curtain, etc.)
- **PDT solution with “off-chip” algorithms:** The PDT solution deploys advanced algorithms (use case optimized detection chain and tracker as described in [Section 2.3.2](#)) achieving high performance and accuracy in multi-person scenarios

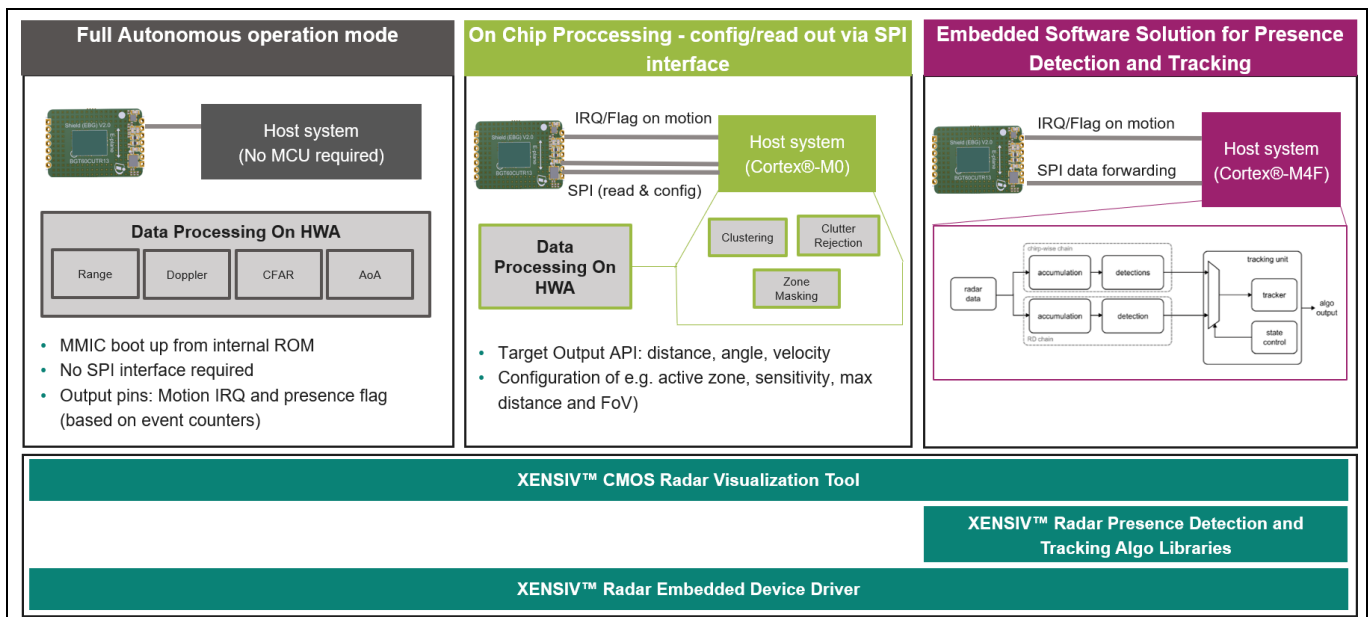


Figure 7 CMOS radar-based system solutions

While the PDL solution makes use of on-chip detections eliminating or minimizing the need for an external MCU, the PDT solution is heavily optimized to achieve the best performance using classical detection and tracking algorithms. While the PDT solution achieves the best performance in the market, the PDL solution optimizes the cost. Therefore, these solutions enable the right cost/performance ratios needed for the application use cases.

[Figure 8](#) provides a comparative overview of these system solutions. The PDL solution has been described in two different columns to show the use of either the host processor or the Arm® Cortex®-M0 core and the associated benefits.

	TR13 On-chip Autonomous (Arch 1)	TR13 On-chip Semi-Autonomous (Arch 2)	TR13 On-Chip Enhanced (Arch 3)	TR13 Premium Turnkey SW Solution (Arch 4)
Best-fitting Application	Motion/PIR replacement	Security Camera	Low/medium end Aircon, Smart TV	High-end aircons, Smart TV
Detection Processing	On-chip	On-chip	On-Chip	Use case optimized
MMIC	BGT60CUTR13AIP	BGT60CUTR13AIP	BGT60CUTR13AIP	BGT60CUTR13AIP
MCU/ Host	n/a – HW Accelerator only	n/a – HW Accelerator only	Cortex®-M0 (or accommodate in Host)	Cortex®-M4
Memory (SRAM)	n/a	n/a	<16 kB	256 kB
Processing Cost	+ 0\$	+ 0\$	+0 - 0.5\$	+1\$*
Motion/Presence FoV	Up to 8 m, ±60 deg, up to 8 moving targets (outdoor - up to 20m)			
Localization (incl. static)	No	wo/ Clustering	w/ Clustering (3-4 persons)	w/ Clustering (3-4 persons)
Tracking	No	No	No	3-4 persons
Chip Level Masking	Range masking (Chip)	Zone masking (Chip)		Zone Masking (Chip or App)

*autonomous mode for TR13 is supported for outdoor

Figure 8 A comparative overview of CMOS radar based system solutions

2.3.1 Radar configuration for PDL solution

The PDL solution makes use of on-chip detections from the hardware accelerator for presence detection including range doppler (RD), angle computations. Table 3 shows five indoor and two outdoor radar configuration settings which are pre-optimized for various application needs (e.g. power consumption vs. use-case performance incl. false alarm rates) to support motion, presence, and localization.

Table 3 Pre-optimized radar configurations for indoor and outdoor applications

Mode or attributes	Use case	Application	Battery or mains	Power consumption	Max. range at 0°	Range zone
Indoor low power (ULP)	Motion	Security or IP camera, doorbell, thermostat etc.	Battery	174 µW at 1 Hz 762 µW at 10 Hz	9 m	0.7 m
Indoor medium power (RD)	Motion		Battery	879 µW at 1 Hz 7.3 mW at 10 Hz	9 m	0.7 m
Outdoor low power (ULP)	Motion		Battery	375 µW at 1 Hz 2.736 mW at 10 Hz	20 m	1.4 m
Outdoor medium power (RD)	Motion		Battery	1.6 mW at 1 Hz 15 mW at 10 Hz	20 m	1.4 m
Indoor regular power (RD)	Motion	Smart TV, aircon, smart display, home appliances etc.	Mains	32 mW at 10 Hz	9 m	0.7 m
Indoor motion (RD) + Static (ULP) Binary	Presence		Mains	32 mW at 4 Hz	9 m	~0.7 m
Indoor Motion (RD) + Static (ULP)	Presence + localization		Mains	32 mW at 4 Hz	9 m	~0.7 m

2.3.2 Radar configuration for PDT solution

Table 4 provides the radar configuration used by the PDT solution optimized for localization and tracking performance needed in high-end applications such as residential aircon, smart TV etc. The default configuration used by the application and the embedded example is provided as part of the SW package in the **/application/configs/radar/** folder.

Table 4 Radar configuration used by PDT solution, optimized for high-end applications

Parameter	Value
Tx antennas [#]	[1]
Rx antennas [#]	[1]
Number of samples [#]	64
Number of chirps [#]	32
Start frequency [GHz]	61.00
End frequency [GHz]	61.50
Chirp repetition time [ms]	0.04
Frame repetition time [s]	0.10
Sampling rate [MHz]	2.00

2.4 Use case of PDT solution for HVAC application

Presence detection and tracking software takes the residential aircon application to the next level of technological advancement, where the solution provides not only motion and presence detection but also tracks up to three people (moving and/or stationary) in the FoV achieving better user comfort and overall energy efficiency. Infineon PDT solution provides exact location of users in the FoV, which is crucial to optimize the application performance, e.g., directing and regulating the airflow accordingly in the room to maximize the user comfort, controlling the airflow to reduce energy consumption in absence of people, etc.

Figure 9 to Figure 11 show a high-level representation of presence detection and tracking use case for indoor usage.

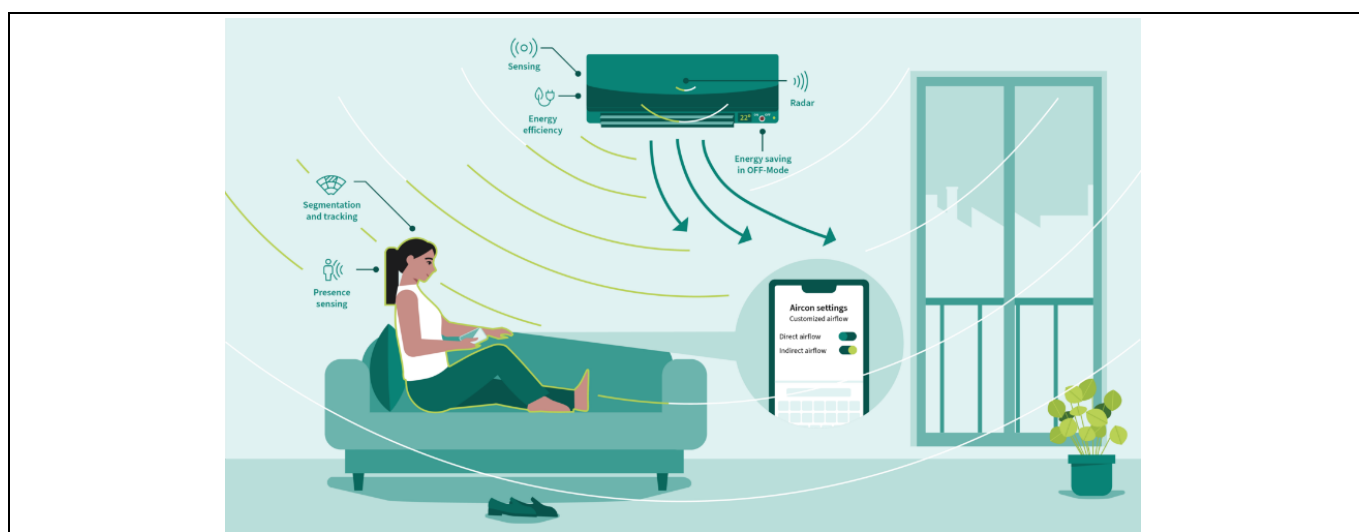


Figure 9 Use case illustration for HVAC (residential aircon application)

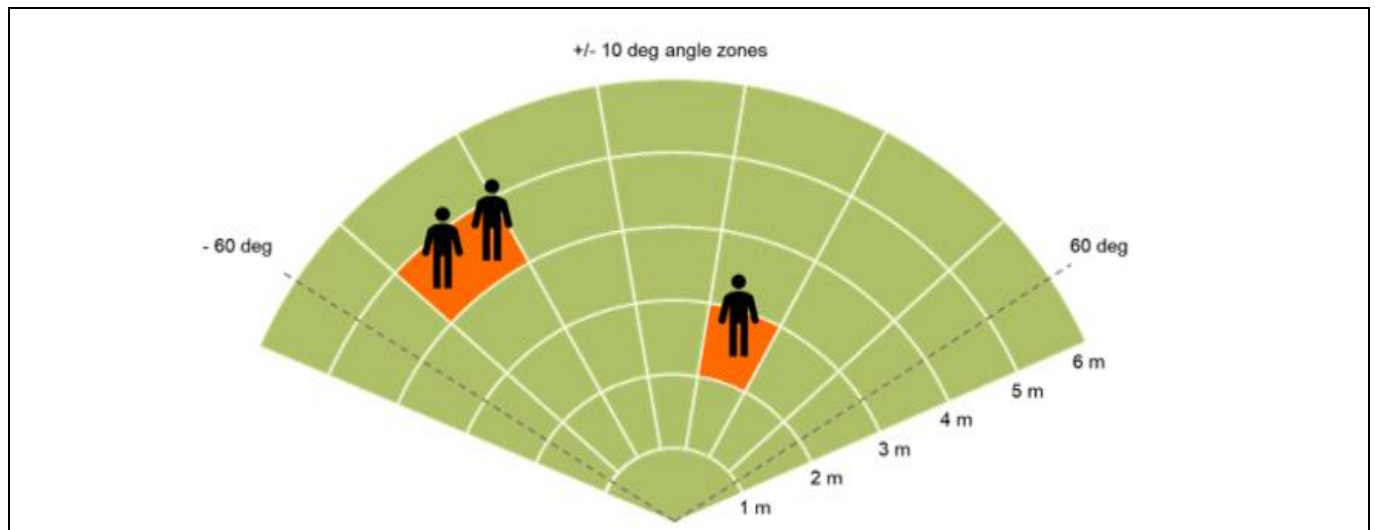


Figure 10 An example of multi-person detection and tracking in the defined field of view (FoV)

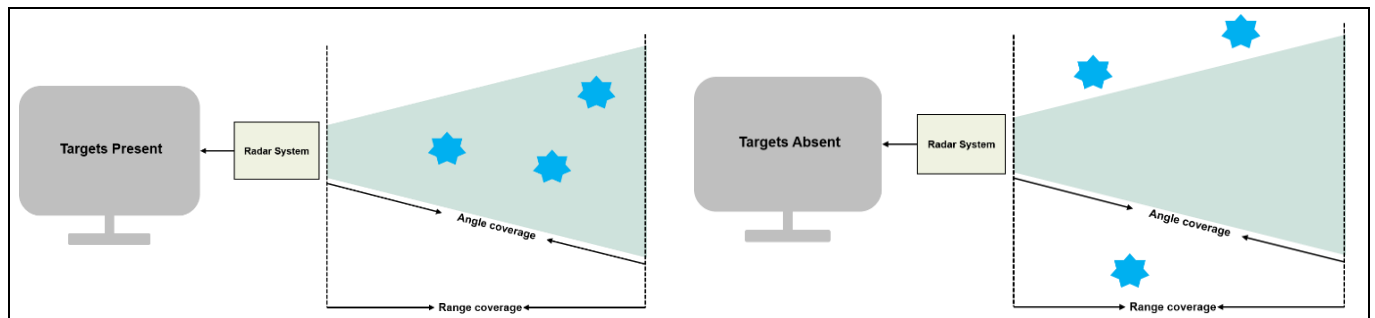


Figure 11 Presence (minimum one person in FoV) and absence states (no person in FoV) illustration

2.5 Key features and specifications for typical applications

The following table provides the key features and specifications concerning residential aircon, smart TV, etc.

Table 5 Key features and application specifications

Feature	Description
Energy saving	- Indicate a person walking or leaving the room based on macro motion - Detection for up to three targets sitting and standing in the FoV
Air flow management with multi-target tracking	- Localization of up to three people in FoV (both PDL and PDT) - Tracking up to three static and dynamic targets in the FoV (PDT only) - Output: Presence detection, target ID, range (m), azimuth angle (°), velocity (m/s)
Supported aircon types	Wall-mounted, standing and ceiling-mounted types
FoV (Range (m), Angle (°))	5 m to 6 m $\pm 60^\circ$
Mounting height	1.2 m to 2.5 m
Radar housing	ABS/2.5 mm
Platform	- PDT: - MCU: Arm® Cortex®-M4, 256 KB SRAM, 512 KB flash - PDL: - Optional MCU: Arm® Cortex®-M0, 16 KB SRAM, 32 KB flash
Certifications	FCC/CE certifiable

3 System and functional description

3.1 Getting started

The Connected Sensor Kit is a cutting-edge IoT development platform that empowers engineers to swiftly design, test, and refine innovative IoT devices. By providing pre-configured sensor scenarios and real-time data visualization, this kit enables developers to visualize the performance of the XENSIV™ BGT60CUTR13AIP CMOS radar with the hardware accelerator, using the XENSIV™ CMOS Radar Visualization Tool, allowing engineers to rapidly evaluate use cases and validate their ideas.

To further accelerate development, a comprehensive suite of code examples is available within ModusToolbox™, see [Section 3.3](#), offering a one-stop shop for developers to kick-start their IoT projects with ease.

3.2 XENSIV™ CMOS Radar Visualization Tool

The [XENSIV™ CMOS Radar Visualization Tool](#) is a Python-based GUI, which is used to configure the XENSIV™ Radar BGT60CUTR13AIP sensor (from pre-configured radar configuration files) and offers visualization of detected target data as well as recording and replaying this data. Radar data could be just pure detections or track output, which depends on the firmware flashed in the device. These firmware images are developed to address the following use cases.

- Indoor presence detection and tracking (off-chip)
 - Tracking up to 3 targets
- Indoor presence detection and localization (on-chip)
 - Only detections from clustering and clutter localization algorithm
- Evaluation Firmware
 - Use cases using only XENSIV™ BGT60CUTR13AIP Radar on-chip MD block

Key features

The XENSIV™ CMOS Radar Visualization Tool offers the following features:

- Firmware auto-update check on Rapid IoT Connect Developer Kit
- Pre-configured use cases for indoor and outdoor with different power settings (low, medium, high)
 - Load custom radar configurations
- Conversion of radar configuration from .txt to C header format
- Visualization of detection or tracking events (range, speed, azimuth angle, elevation angle)
 - Segment plot to display range and angle of each target, along with its own shape and color
 - Time series plot to show ULP and RD event triggers
 - Table view of targets or tracks
 - Logging view
- Event logging to a .txt file and playback from a file
- WebSocket interface to consume or forward radar events
- GUI usage help and hardware user guide in Help menu

System and functional description

3.2.1 Download and install

Install [XENSIV™ CMOS Radar Visualization Tool](#) from Infineon developer center (IDC) webpage for the desired OS, i.e. Versions for Windows (x64), macOS, and Linux (Debian and RPM) are available. Once the tool is installed, users can launch the tool from the desktop shortcut icon or from [IDC launcher app](#) or just search the tool from the respective OS program search.

3.2.2 Getting started

Once you have the kit ready as shown in [Figure 1](#), connect it to the laptop via Micro-USB to USB-A cable and follow these steps to get started:

1. Optionally, flash new firmware to the CSK via the **Device** menu in the menu bar if the firmware auto-detect dialog does not appear
2. Select the CSK in use on the **Event Source** dropdown menu on the left-side
3. Select the required **COM** port from the **Device** dropdown menu
4. Select one of the predefined use cases on the left-side. For example, **Presence Detection Localization**. Optionally, you can also provide your own configuration by selecting **Custom** in this tab and provide the configuration path in **Device Config**
- a) Optionally:
 - Override certain MD-related settings via the **Motion detector settings** panel
 - Activate data logging under the **Event Log Folder > Log directory** section
- b) Click the **Play** button from Terminal Input section to fetch data and see the visualization on the right-side
- c) Optionally, adapt visualization settings under the gear icon next to the plots (i.e., show the last 'n' detections)

[Figure 12](#) shows this workflow:

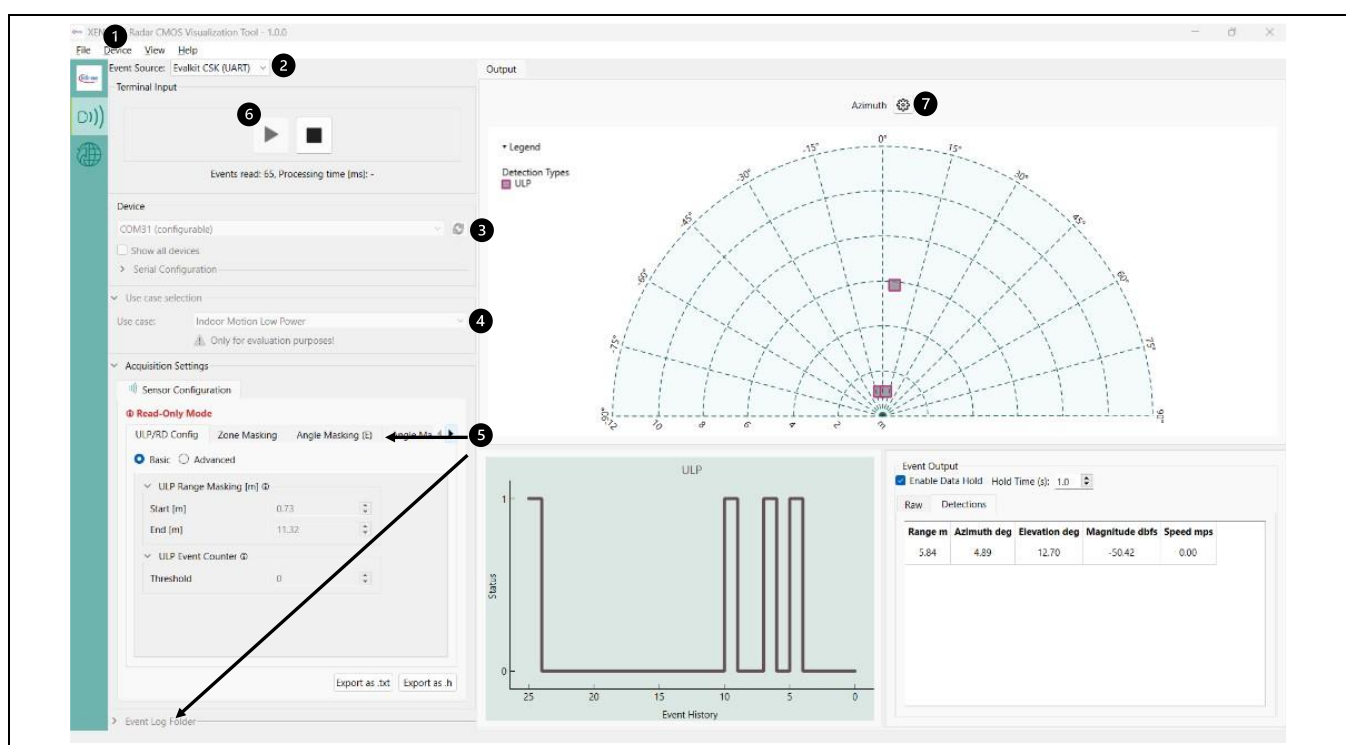


Figure 12 XENSIV™ CMOS Radar Visualization Tool

System and functional description

Figure 13 shows how to get the detailed documentation of the XENSIV™ CMOS Radar Visualization Tool, describing what each use case intended for.

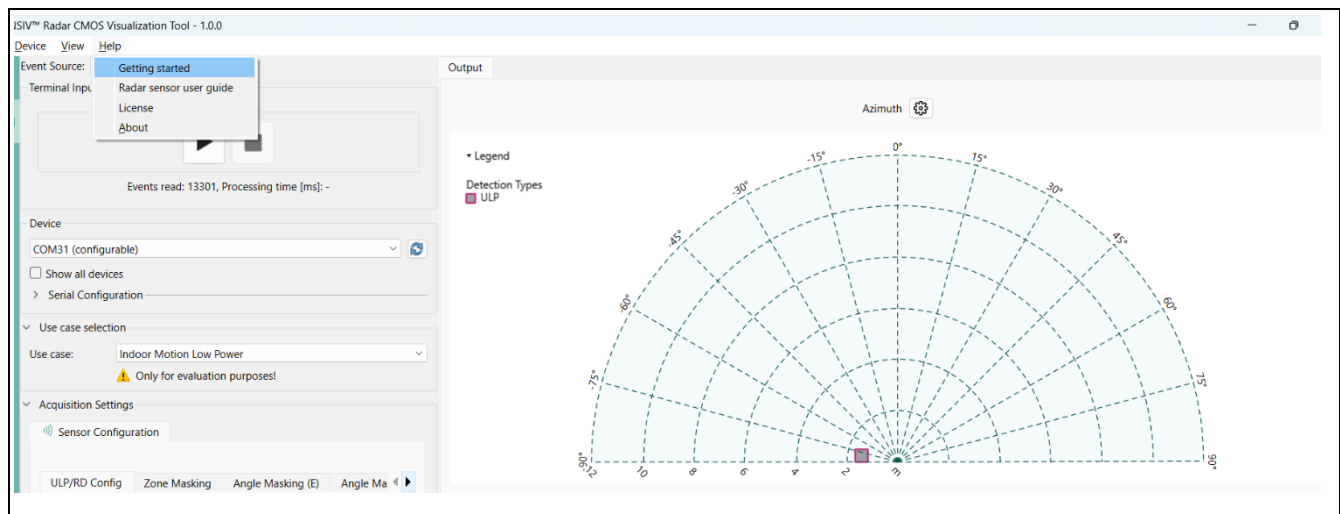


Figure 13 XENSIV™ CMOS Radar Visualization Tool Help

Furthermore, the tool comes with a few pre-built firmware images for on-chip and off-chip use cases:

- **Evaluation for on-chip signal processing:**

This is a base firmware (*evaluation_on_chip_csk.hex*), which expects a radar configuration from the PC, to configure the sensor and then forward the detected radar events to the PC. Here, the user has full flexibility to evaluate either provided use case configurations or load any custom radar configuration for the on-chip motion detection use case

- **Presence detection localization:**

This firmware (*presence_detection_localization_csk.hex*) adds additional signal processing like clustering and clutter localization on top of raw detection events from on-chip processing module. Outputs are still detections, i.e. no tracking but more reliable detections. The complete solution still fits on a low-cost Arm® Cortex®-M0 MCU

- **Presence detection and tracking:**

This is a premium firmware (*presence_detection_and_tracking_csk.hex*) from Infineon, to offer the indoor presence detection and tracking use case. Up to three human targets can be tracked reliably within the field of view. The off-chip algorithm only utilizes raw AC data from the XENSIV™ BGT60CUTR13AIP CMOS radar and offers a sophisticated detection chain and tracker, which requires a microcontroller Cortex®-M4 with 128 KB SRAM and floating-point unit (FPU)

3.3 Code examples in ModusToolbox™

The XENSIV™ BGT60CUTR13AIP CSK offers seamless integration with ModusToolbox™, with complete application code examples for on-chip and off-chip software solutions, and sensor driver for faster go-to-market for on-chip and off-chip software solutions. The following code examples are also publicly available at [Infineon's GitHub account](#). Simply search for "CMOS" there.

3.3.1 PSOC™ 6 MCU: XENSIV™ 60 GHz CMOS radar indoor presence detection and localization with clutter localization and clustering

This code example ([mtb-example-psoc6-cmos-radar-clutter-clustering](#)) demonstrates Infineon's radar presence/motion detection application for detecting human presence within a configurable distance. Powered by the XENSIV™ 60 GHz radar, this application provides extremely high accuracy in detecting both micro and macro motions. The ability to detect micro motion offers unique benefits over conventional technologies deployed to detect human presence, making it ideal for user interaction with devices. Furthermore, the code example also demonstrates XENSIV™ 60 GHz radar capabilities by implementing a combination of the clutter-localization and clustering algorithm on the XENSIV™ BGT60CUTR13AIP Connected Sensor Kit hardware platform.

This code example uses the [sensor-xensiv-bgt60cutrxx](#) driver library to interface with the XENSIV™ BGT60TRxx 60 GHz FMCW radar sensors. This library can be set up to use the ModusToolbox™ HAL interface or user-provided communication functions.

3.3.2 PSOC™ 6 MCU: XENSIV™ 60 GHz CMOS radar indoor people presence detection and tracking

This code example ([mtb-example-psoc6-cmos-radar-people-tracking](#)) provides a ModusToolbox™ application for detecting and tracking people in an indoor environment up to ~8 meters using Infineon's XENSIV™ 60 GHz radar. The application processes radar raw data in various sophisticated signal processing chains, resulting in different kinds of detections. These detections are then fed to a custom-made tracker that decides to assign/reassign/delete tracks to actual targets. The algorithm returns distance and angle data of up to 3 to 5 targets within the set range and field of view (FoV).

3.3.3 PSOC™ 6 MCU: Motion detection using XENSIV™ BGT60CUTR13AIP CMOS radar sensor

This code example ([mtb-example-psoc6-cmos-radar-motion-detection](#)) demonstrates XENSIV™ BGT60CUTR13AIP CMOS 60 GHz radar sensor capabilities by implementing the on-chip feature for motion detection on the connected sensor kit (CSK) hardware platform.

System design

4 System design

This section introduces the various features of the XENSIV™ BGT60CUTR13AIP radar Wing board. The male Adafruit headers face downwards to either plug the board directly into the Rapid IoT baseboard or on top of another Wing board, such as the Infineon XENSIV™ BGT60CUTR13AIP Wing board. Figure 14 and Table 6 provide a description of the components mounted on the XENSIV™ BGT60CUTR13AIP radar Wing board. The white block of the silk print is a replica of the SMD module layout.

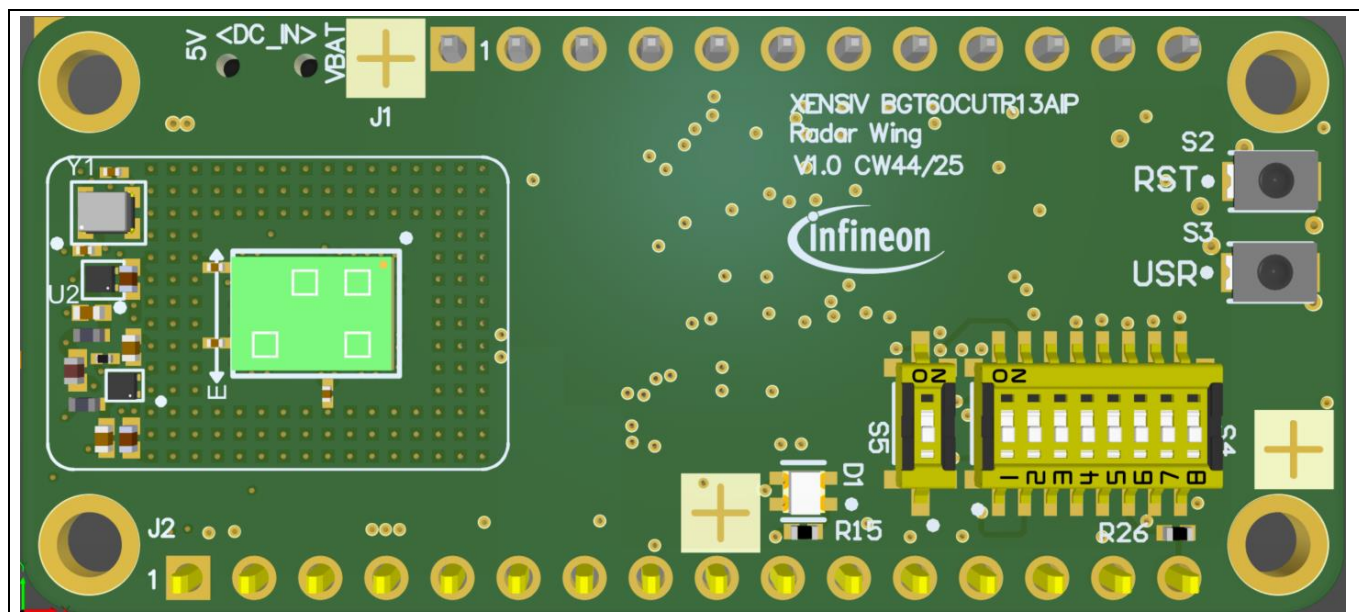


Figure 14 Front view of the XENSIV™ BGT60CUTR13AIP radar Wing board

Table 6 Onboard hardware

Ref designator	Function
U1	XENSIV™ BGT60CUTR13AIP device
Y1	80 MHz crystal resonator
D1	Tri-color LED
S1	To select the board power supply from CYSBSYSKIT-DEV-01 Rapid IoT baseboard: USB5V or from LiPo battery supply of the kit
S2	System reset button; active LOW
S3	User button; active LOW
J1, J2	Adafruit headers

System design

4.1 Schematics

The XENSIV™ BGT60CUTR13AIP Wing board contains the direct copy of the BGT60CUTR13AIP SMD module.

Figure 15, Figure 16, and Figure 17 show the SMD schematics.

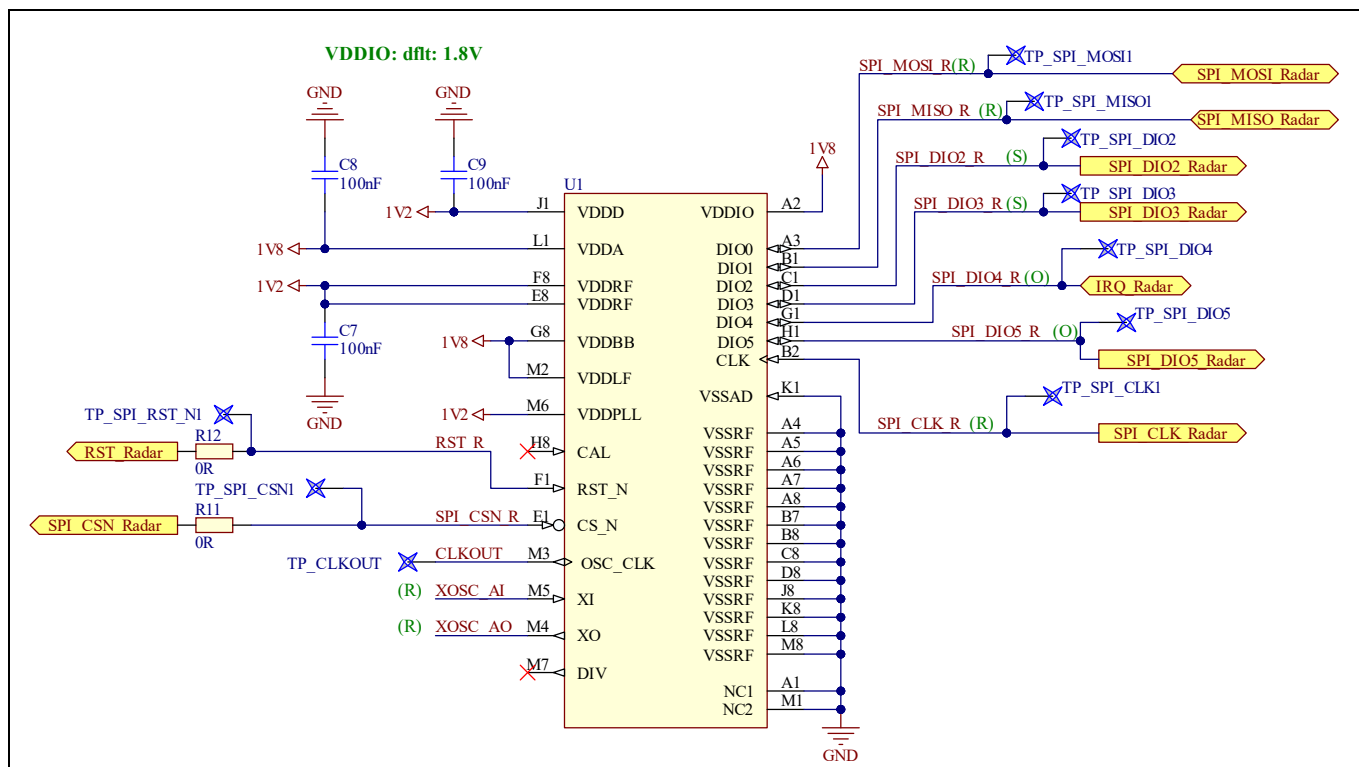


Figure 15 XENSIV™ BGT60CUTR13AIP radar MMIC schematic (direct copy of SMD)

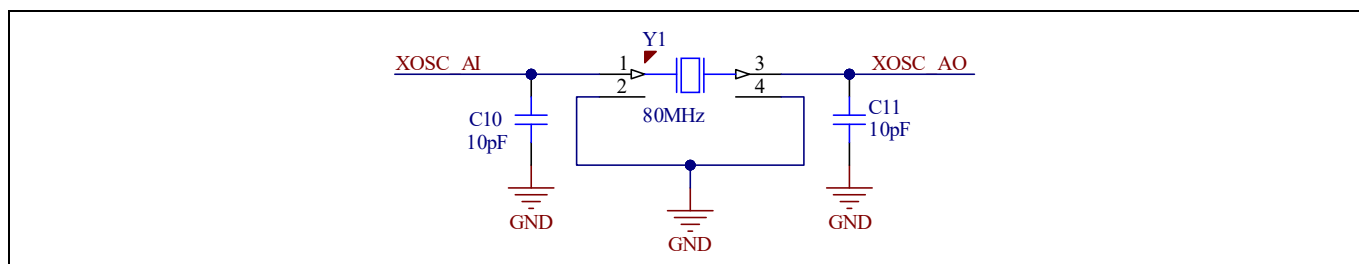


Figure 16 Crystal oscillator circuit on the XENSIV™ BGT60CUTR13AIP Wing board (direct copy of SMD)

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XENSIV™ radar sensors

System design

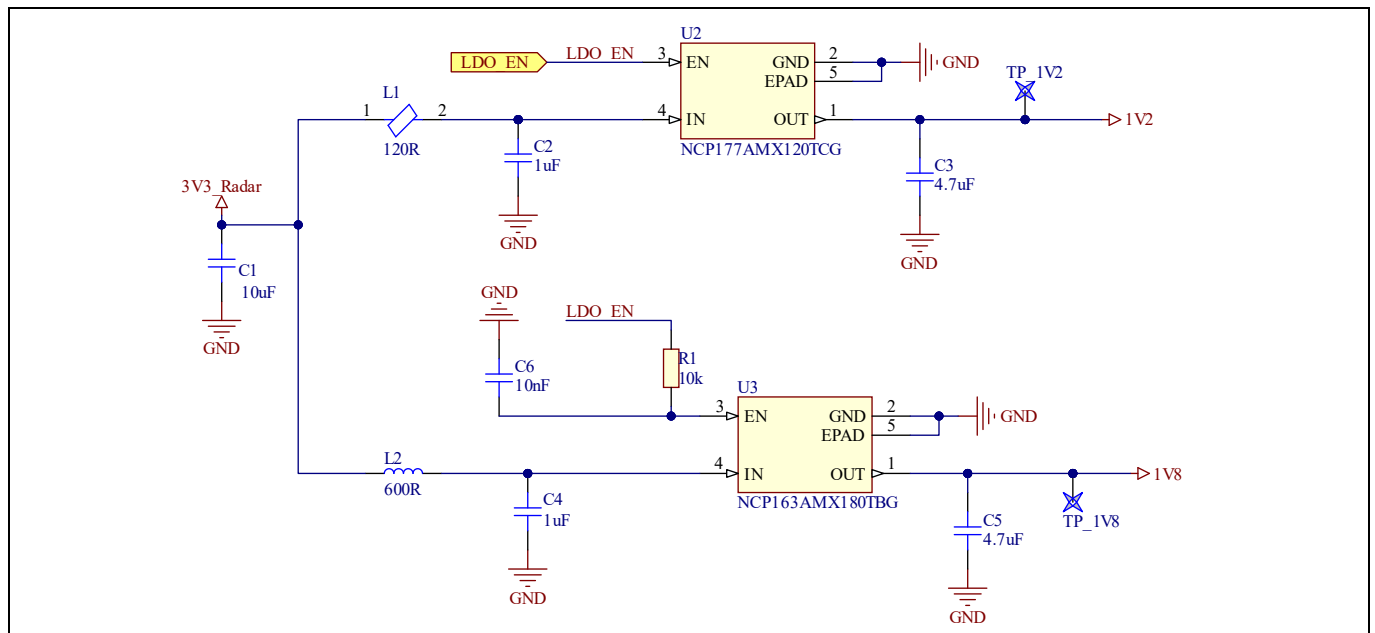


Figure 17 Voltage supply for radar sensor (direct copy of SMD)

The XENSIV™ BGT60CUTR13AIP SMD module has a nominal input voltage of 3.3 V. Therefore, a 3.3 V LDO is applied to transfer input voltage to 3.3 V, as shown in [Figure 18](#).

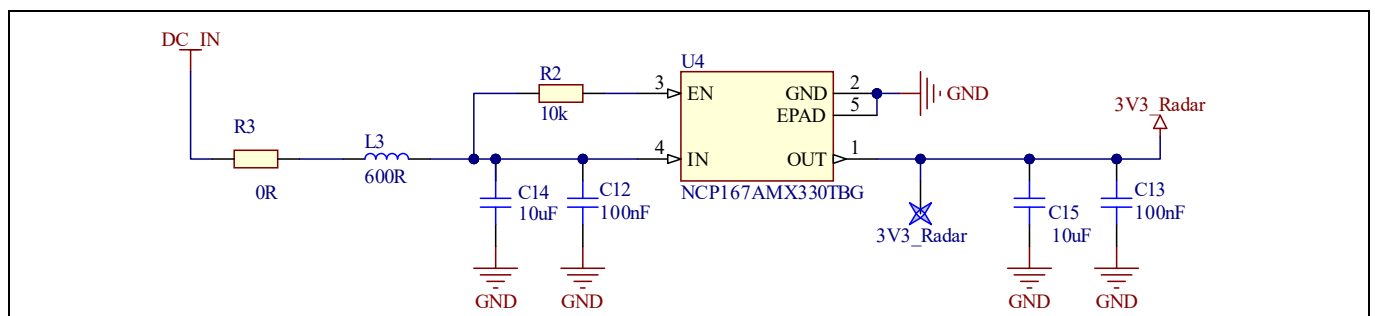


Figure 18 Voltage supply to SMD module schematic

[Figure 19](#) shows the board power selection schematic.

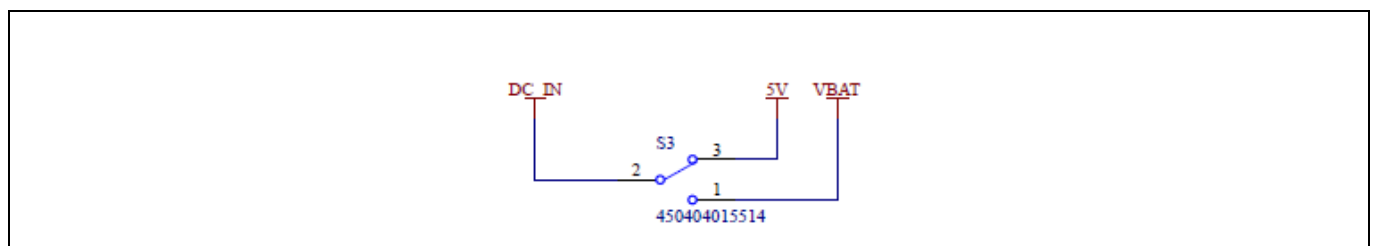


Figure 19 Board power selection (S3) schematic

System design

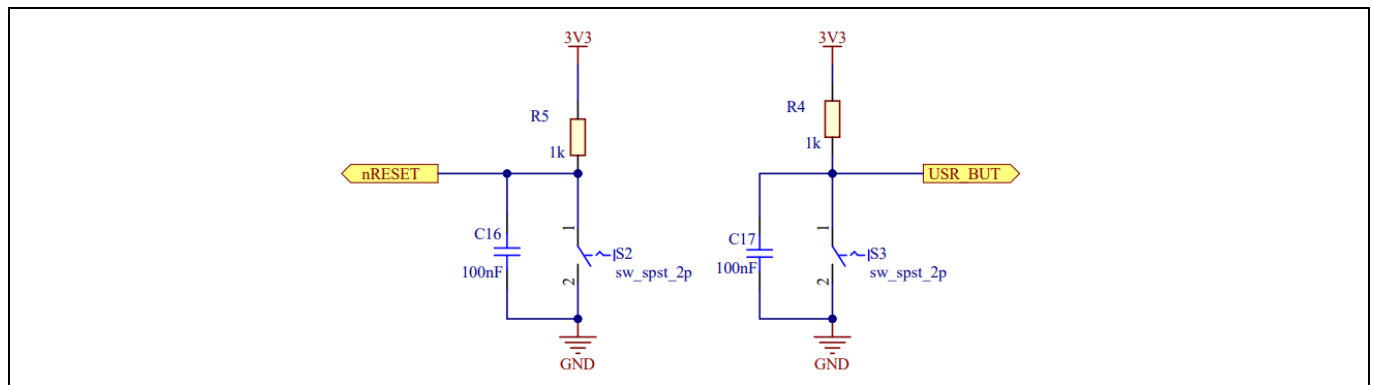


Figure 20 Reset (S2) and user button (S3) schematic

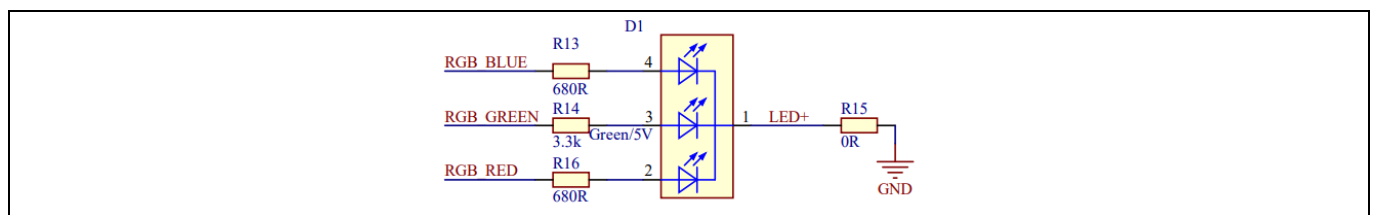


Figure 21 LED schematic

The SPI bus of XENSIV™ BGT60CUTR13AIP radar MMIC has a signal voltage of 1.8 V. XENSIV™ BGT60CUTR13AIP Wing board contains the level shifter group to transfer the signals to 3.3 V, as shown in [Figure 22](#).

System design

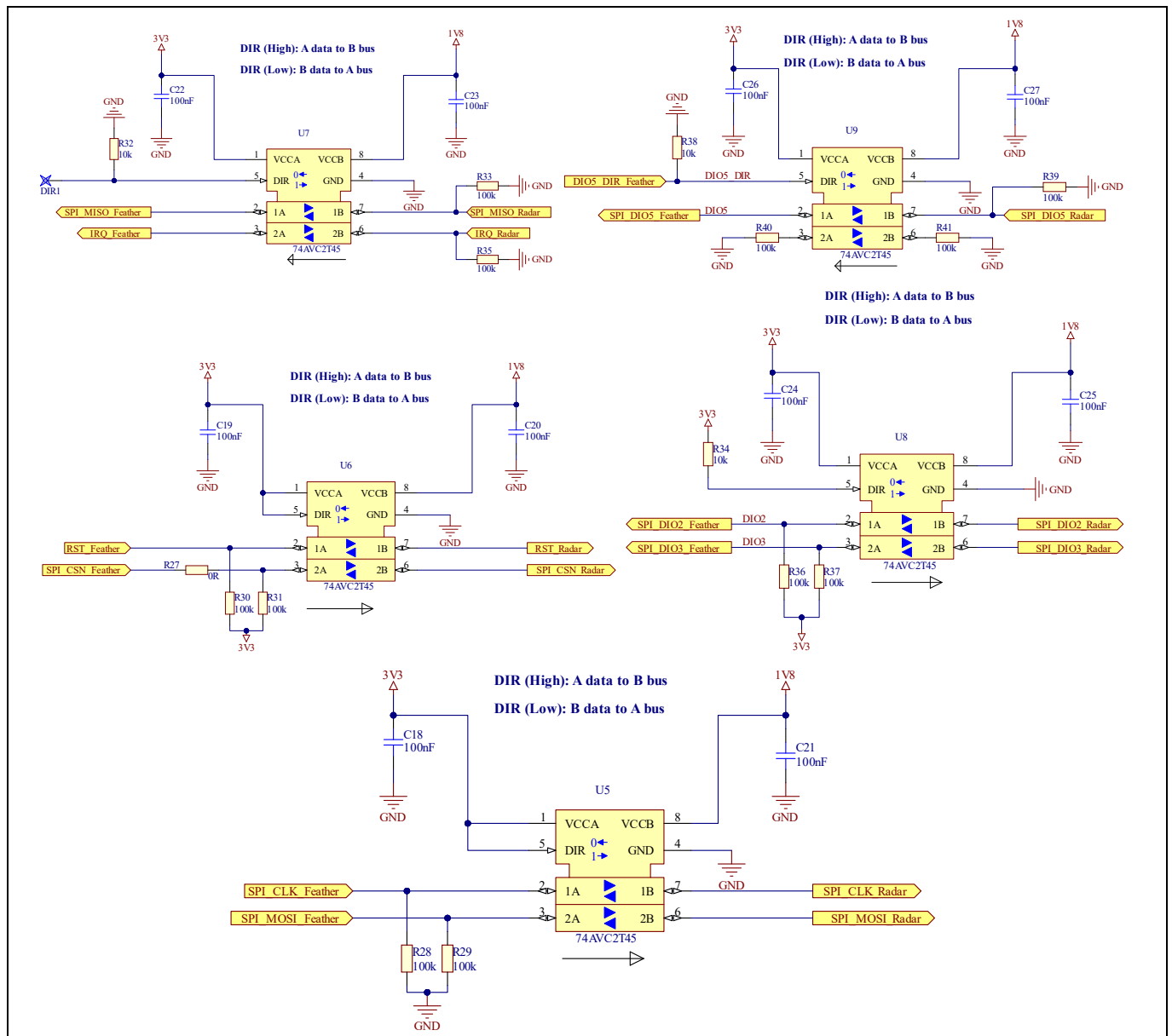


Figure 22 Level shifter schematic

Figure 23 shows the pin assignment of J1 and J2 on the XENSIV™ BGT60CUTR13AIP radar Wing board. The Adafruit Feather-compatible header is used to plug into the CYCBSYSKIT-DEV-01 Rapid IoT Connect Developer Kit.

System design

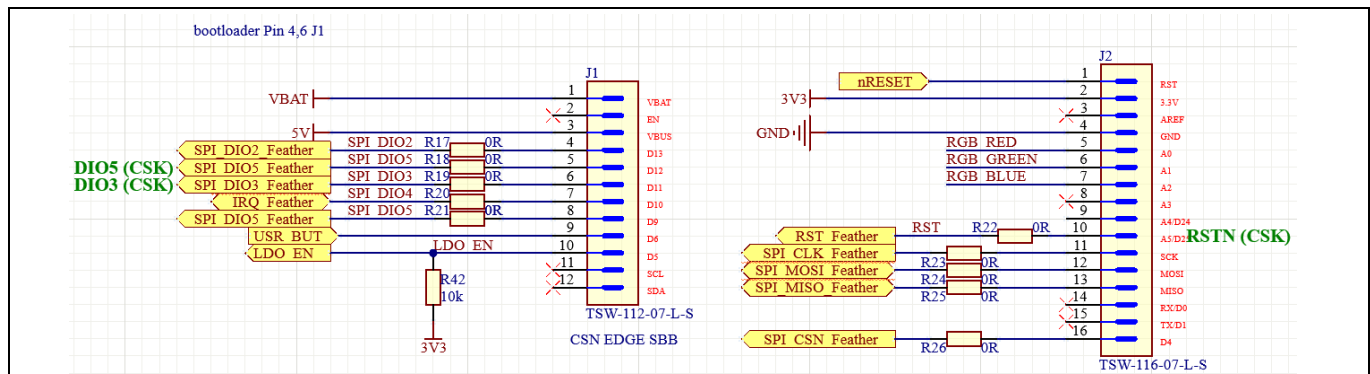


Figure 23 Adafruit headers schematic

4.2 Layout

The size of the XENSIV™ BGT60CUTR13AIP radar Wing board is 50.9 mm (L) x 23 mm (W), as shown in Figure 24.

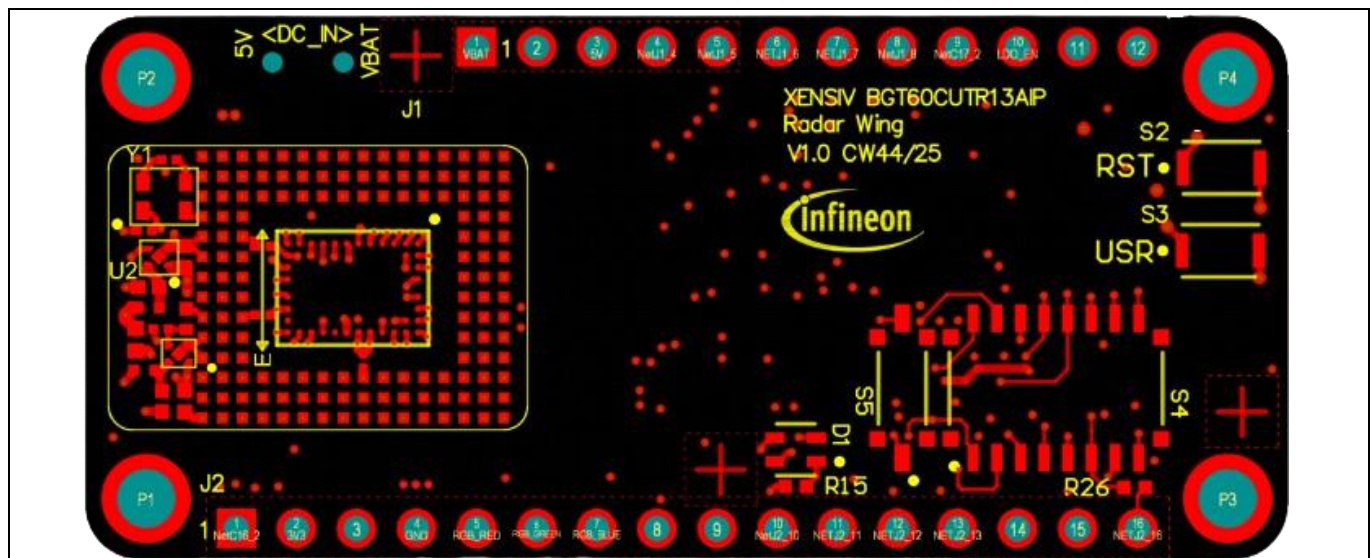


Figure 24 PCB layout of XENSIV™ BGT60CUTR13AIP radar Wing board

4.3 Bill of materials

Table 7 lists the bill of materials (BOM) of the XENSIV™ BGT60CUTR13AIP radar Wing board.

Table 7 BOM of the most important/critical parts of the evaluation

Ref designator	Description	Manufacturer	Manufacturer P/N	Footprint	Qty
C1, C14, C15	10 μ F $\pm$ 20% 6.3 V ceramic capacitor X6S 0402 (1005 metric)	Murata	GRM155C80J106 ME11D	CAPC1005X70 N	3
C2, C4	1.0 μ F $\pm$ 10% 6.3 V ceramic capacitor X5R 0402 (1005 metric)	Murata	GRM155R61C105 KA12	CAPC1005X55 N-0	2

System design

Ref designator	Description	Manufacturer	Manufacturer P/N	Footprint	Qty
C3, C5	4.7 μ F $\pm$ 10% 6.3 V ceramic capacitor X5R 0402 (1005 metric)	Murata	GRM155R61A475 MEAAD	CAPC1005X65 N-1	2
C6	10 nF $\pm$ 10% 16 V ceramic capacitor X7R 0402 (1005 metric)	Murata	GRM155R71C103 KA01	CAPC1005X55 N-0	1
C7, C8, C9	0.1 μ F $\pm$ 20% 10 V ceramic capacitor X5R 0201 (0603 metric)	Murata	GRM033C71C104 KE14D	CAPC0603X33 N	3
C10, C11	10 pF $\pm$ 10% 10 V ceramic capacitor X5R 0201 (0603 metric)	Murata	GCM0335C1E100 FD03	CAPC0603X33 N	2
C12, C13, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27	100 nF $\pm$ 10% 16 V ceramic capacitor X5R 0402 (1005 metric)	Murata	GRM155R61C104 KA88	CAPC1005X55 N-0	12
C16, C17	100 nF $\pm$ 10% 50 V ceramic capacitor X7R 0603 (1608 metric)	KEMET	C0603C104K5RA CTU	CAPC1608X87 N	2
D1	Full-color surface mount LED, 520 nm, green, low-power consumption	KINGBRIGHT	LED-SMD-APTf1616SEJ3Z GGVBDC	APTf1616SEJ3 ZGGVBDC	1
J1	Header, 12-pin, pitch 2.54 mm, vertical, single row	Molex	HDRV12W64P25 4_1X12_3048X25 4X898B	TSW-112-07-L-S	1
J2	Header, 16-pin, pitch 2.54 mm, vertical, single row	Molex	HDRV16W64P25 4_1X16_4070X25 4X838B	TSW-116-07-L-S	1
L1	Ferrite bead 120 Ω at 100 MHz ferrite bead 0402 (1005 metric) 350 mA 220 M Ω	TDK	MMZ1005B121C T000	INDC1005X55N_MMZ1005	1
L2, L3	Ferrite bead 600 Ω at 100 MHz signal line ferrite bead 0402 (1005 metric) 200 mA 850 M Ω	TDK	INDC1005X55N_MMZ1005	MMZ1005B601 CT000	2
R1	Resistor SMD 10 k Ω 1/16 W 0201	MULTICOMP PRO	MCRE000164	RESC0603X26 N	1
R2, R32, R34, R38, R42	Resistor SMD 10 k Ω 1/16 W 0402	Panasonic Electronic Components	ERJ2RKF1002X	RESC1005X40 N	5

System design

Ref designator	Description	Manufacturer	Manufacturer P/N	Footprint	Qty
R3, R11, R12, R15, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27	Resistor SMD 0 Ω jumper 1/16 W 0402	TE Connectivity Passive Product	CRG0402ZR	RESC1005X03N	15
R4, R5	Resistor SMD 1 k Ω 5% 1/10 W 0402	Panasonic Electronic Components	ERJ-2GEJ102X	RESC1005X40N	2
R13, R16	Resistor SMD 680 Ω 5% 1/16 W 0402	Yageo	CRCW0402680RFK	RESC1005X40N	2
R14	Resistor SMD 3.3 k Ω 1% 1/20 W 0201	Panasonic Electronic Components	ERJ-2RKF3301X	RESC0603X26N	1
R28, R29, R30, R31, R33, R35, R36, R37, R39, R40, R41	Resistor SMD 100 k Ω 1% 1/16 W 0402	Yageo	RC0402FR-07100KL	RESC1005X40N-1	11
S1	Slide switch SPDT surface mount	Würth Elektronik	SW-SMD-450404015514	450404015514	1
S2, S3	KXT 311 LHS, tactile switch SPST-NO 0.02 A 15 V, KXT3 Series ultra-low profile top actuated, 100 g, SPST	C&K	SW-SMD-KXT311LHS	KXT311LHS	2
S4	DIP switch 8 positions, 16 pins, 4 mounting pads	Nidec	CVS-08B	SW-SMD-CVS-08B	1
S5	DIP switch 1 positions, 2 pins, 4 mounting pads	Nidec	CVS-01B	SW-SMD-CVS-01B	1
U1	60 GHz radar sensor with Antenna-in-Package	Infineon	BGT60CUTR13AIPXUMA1	BGT60CUTR13AIP	1
U2	LDO regulator, ultra-low noise, high PSRR, RF, and analog circuits	ON Semi	NCP177AMX120TCG	ONSEMI-SMD-CASE 711AJ	1
U3	LDO regulator ultra-low noise, high PSRR, RF, and analog circuits	ON Semi	NCP163AMX180TBG	ONSEMI-SMD-CASE 711AJ	1
U5, U6, U7, U8, U9	Dual bit, dual supply voltage level translator and transceiver	Nexperia USA Inc.	74AVCH2T45GT	NXP-SMD-SOT833-1-1-V	5
Y1	Crystal resonator, 80 MHz	TXC.	TXC 8Y80062002	XTAL-SMD-KC2016K	1

System design

4.4 Connector details

Figure 25 highlights the 28-pin Adafruit Feather-compatible headers. The function of the respective header pins is described in Table 8. Figure 25 also shows the test points which were used for testing the boards in the lab or production.

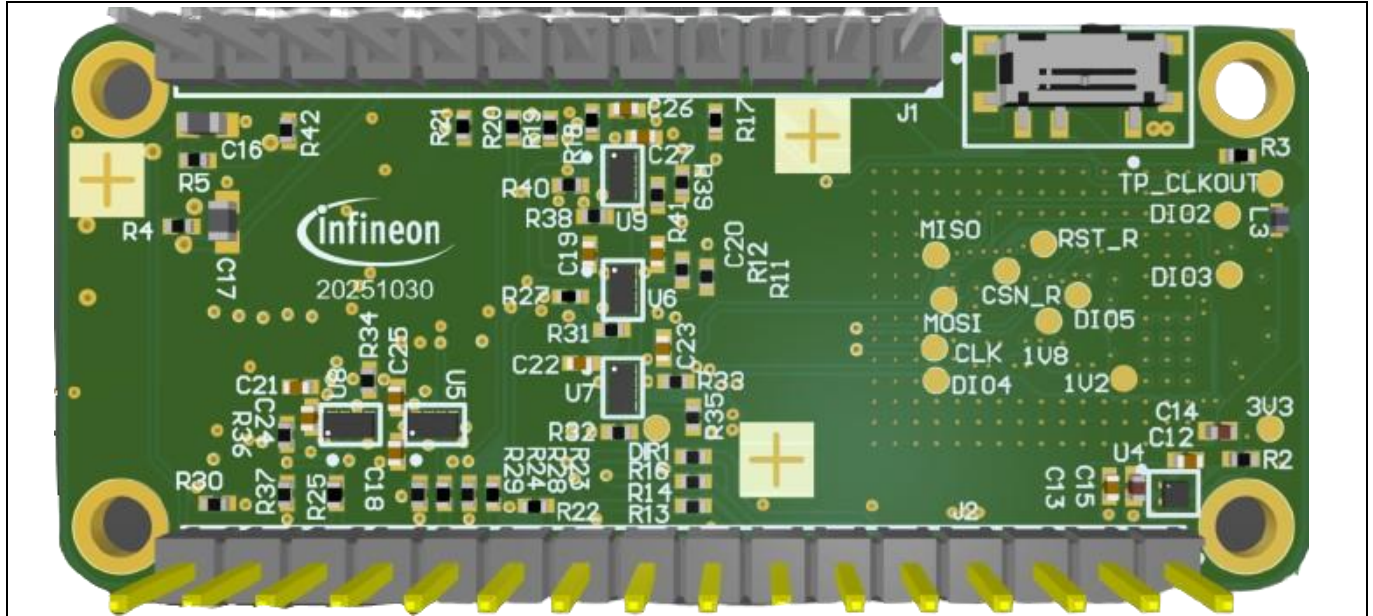


Figure 25 Adafruit headers and test points on the bottom of the XENSIV™ BGT60CUTR13AIP radar Wing board

Table 8 Adafruit Feather-compatible pinout

Header mapping	Primary onboard function	PSOC™ 6 MCU pin (Rapid IoT baseboard)	Adafruit Feather-compatible mapping (Rapid IoT baseboard)	Adafruit Feather-compatible mapping (BGT60CUTR13AIP radar Wing board)	Details
J1.1	VBAT	–	–	VBAT	LiPo battery voltage
J1.2	EN	–	–	–	Not connected
J1.3	VBUS	–	–	5 V	USB power
J1.4	GPIO	P9_0	GPIO13	SPI_DIO2_Feather	DIO or SPI IO2
J1.5	GPIO	P9_1	GPIO12	SPI_DIO5_Feather	DIO or SPI IO5
J1.6	GPIO	P9_2	GPIO11	SPI_DIO3_Feather	DIO or SPI IO3
J1.7	GPIO	P9_3	GPIO10	SPI_DIO4_Feather	IRQ
J1.8	GPIO	P9_4	GPIO9	SPI_DIO5_Feather	–
J1.9	GPIO	P9_7	GPIO6	USR_BUT	User button
J1.10	GPIO	P8_4	GPIO5	LDO_EN	Enable the LDOs (1.8 V and 1.2 V) on radar Wing board for radar sensor. The default is enabled
J1.11	I ² C SCL	P6_0	SCL	–	Not connected

System design

Header mapping	Primary onboard function	PSOC™ 6 MCU pin (Rapid IoT baseboard)	Adafruit Feather-compatible mapping (Rapid IoT baseboard)	Adafruit Feather-compatible mapping (BGT60CUTR13AIP radar Wing board)	Details
J1.12	I ² C SDA	P6_1	SDA	–	Not connected
J2.1	XRES	XRES	XRES	nRESET	Reset button
J2.2	3.3 V	VDDA, VDDIO	VCC	3V3	Analog voltage for PSOC™ 6 MCU
J2.3	NC	–	NC	–	Not connected
J2.4	GND	–	GND	GND	Ground
J2.5	Analog GPIO	P10_0	A0	RGB_RED	RGB red color
J2.6	Analog GPIO	P10_1	A1	RGB_GREEN	RGB green color
J2.7	Analog GPIO	P10_2	A2	RGB_BLUE	RGB blue color
J2.8	Analog GPIO	P10_3	A3	–	Not connected
J2.9	Analog GPIO	P10_4	A4	–	Not connected
J2.10	Analog GPIO	P10_5	A5	RST_Feather	RST
J2.11	SPI Clock	P5_2	SCK	SPI_CLK_Feather	SPI clock
J2.12	SPI MOSI	P5_0	MOSI	SPI_MOSI_Feather	SPI Master Out/Slave IN (MOSI)
J2.13	SPI MISO	P5_1	MISO	SPI_MISO_Feather	SPI Master In/Slave OUT (MISO)
J2.14	UART RX	P6_4	RX	–	Not connected
J2.15	UART TX	P6_5	TX	–	Not connected
J2.16	SPI CS	P5_3	GPIO	SPI_CSN_Feather	SPI Chip Select

5 System performance

Measurements can be performed in either an open-air measurement setup (OAMS) or an anechoic chamber. The latter is preferred for documenting and comparing the performances of various radar system designs due to its advantages. The anechoic chamber provides a controlled environment and precise measurement setup enabling repeatable and efficient measurements that minimize the impact of external electromagnetic waves and reflective surfaces. It ensures that the measurements are not influenced by external factors.

In the anechoic chamber, a corner reflector is placed opposite the carrier board. In the measurement of this document, the corner reflector has an equivalent RCS of 6 m^2 at 60 GHz. The radiation emitted by the radar transmitter is reflected by the corner reflector and measured with the receiver antennas of the radar. Therefore, both transmitter and receiver antennas are part of the measurement. The radar is mounted on a gimbal, which has a distance to the corner reflector of 1.75 m in this chamber measurement setup.

To analyze the antenna radiation pattern, the module is characterized along the E-plane and H-plane of the radar SoC. The measurement setup diagram is shown in [Figure 26](#). The carrier board is mounted on a gimbal in an anechoic chamber. The gimbal sweeps the predefined angles and for each angle step, the radar SoC performs a radar measurement in application-mode.

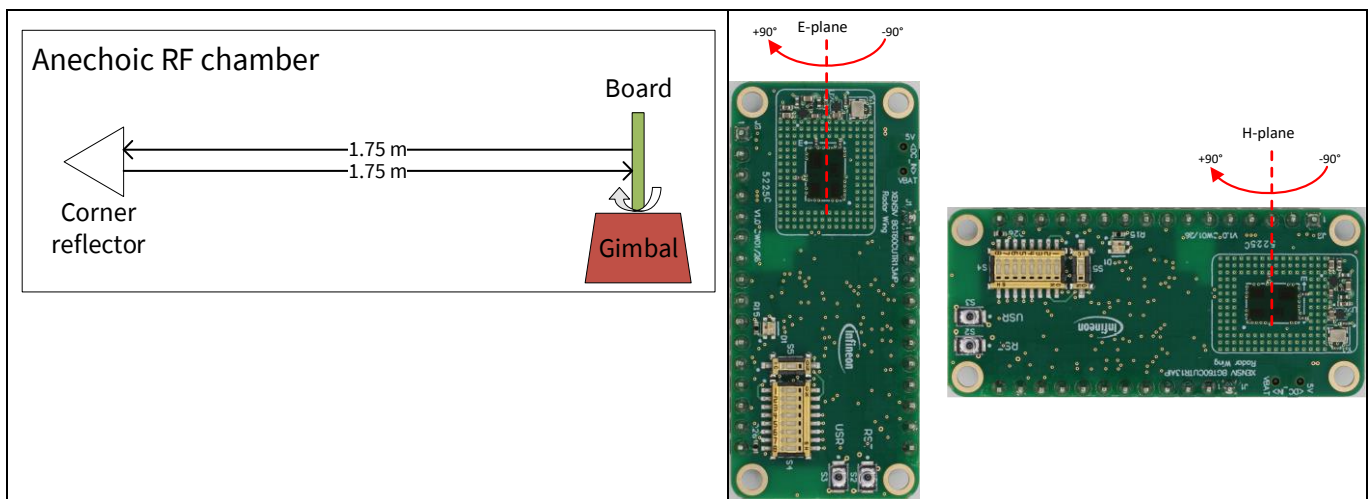
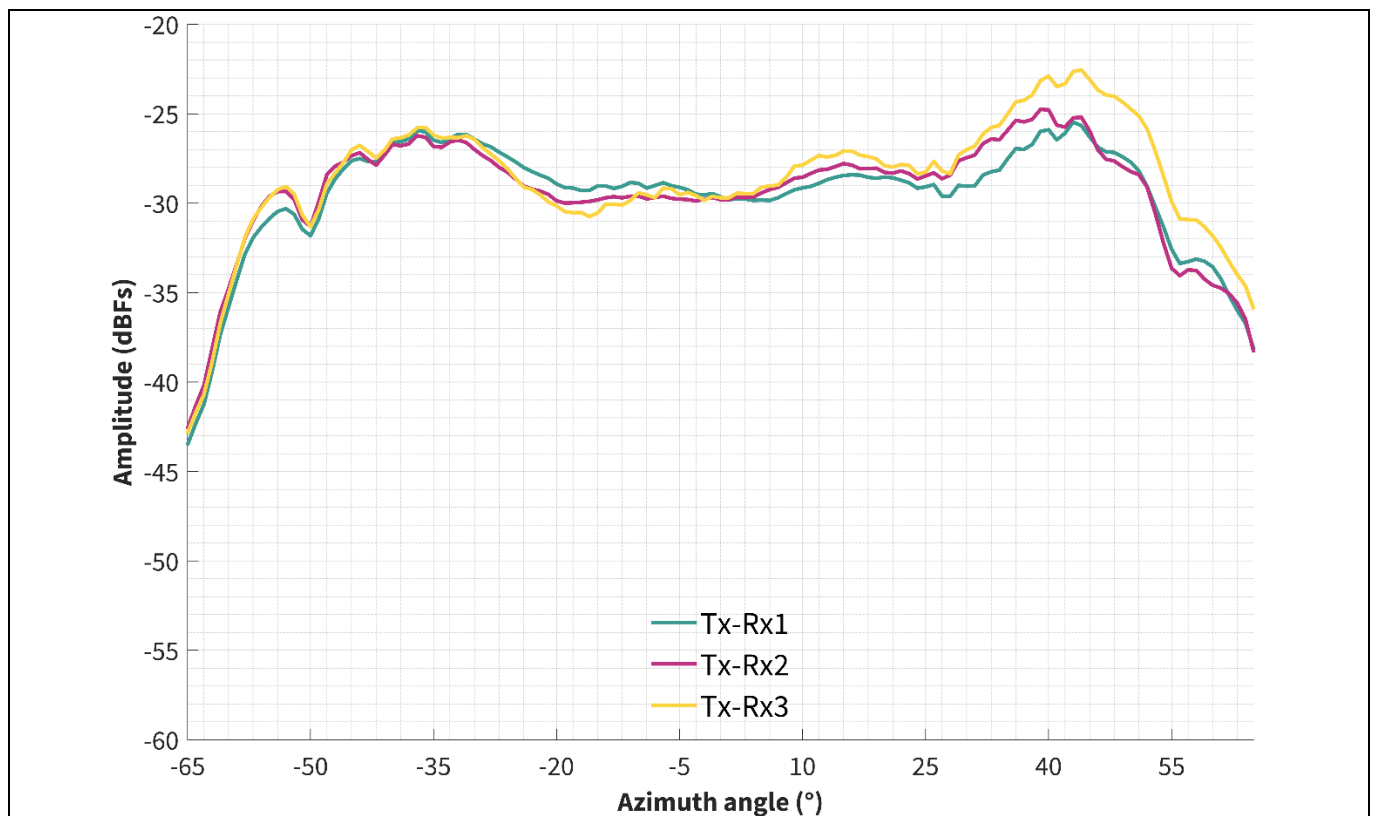
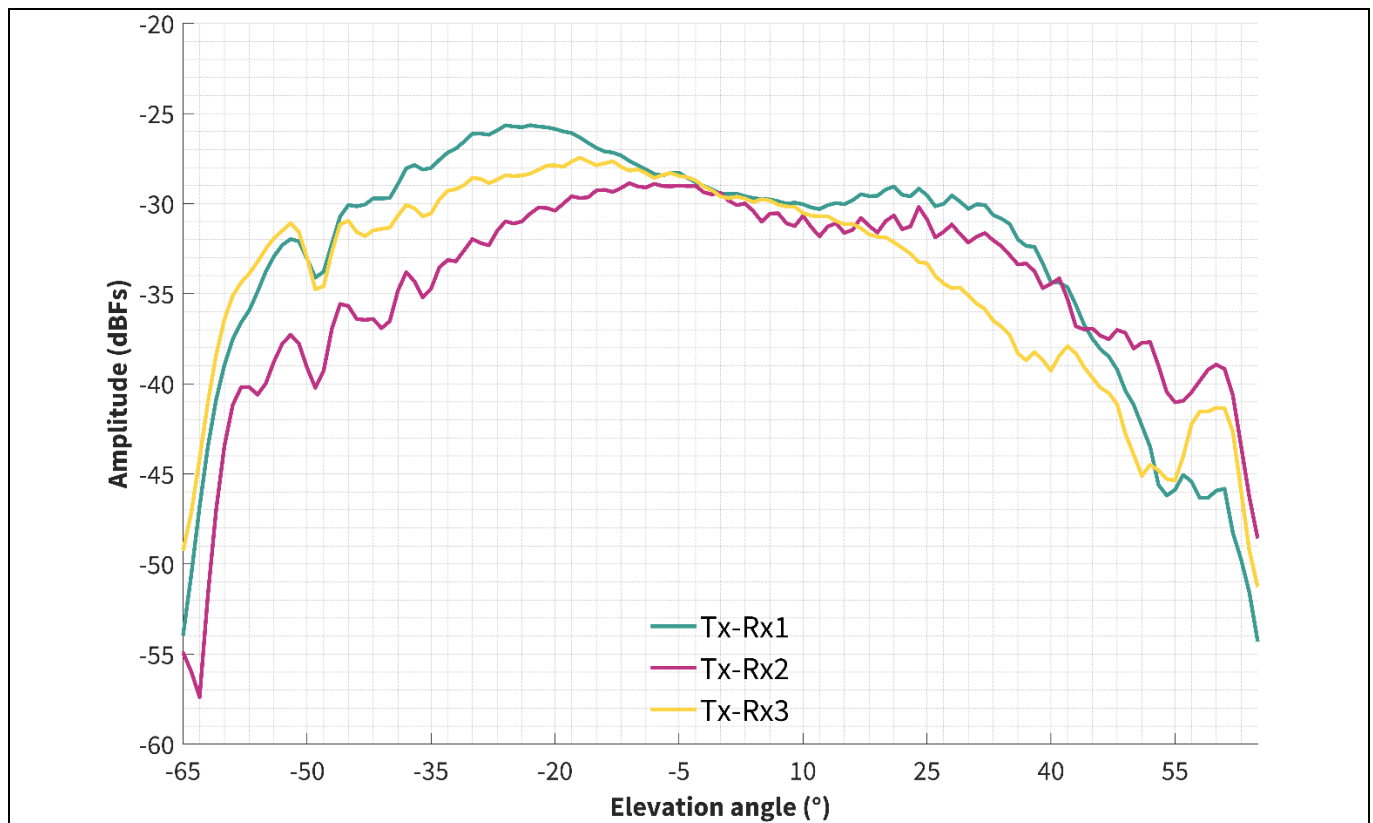


Figure 26 Anechoic chamber setup for radar mode measurements

System performance

**Figure 27** Received amplitude, azimuth, E-plane, ±60° FoV**Figure 28** Received amplitude, elevation, H-plane, ±45° FoV

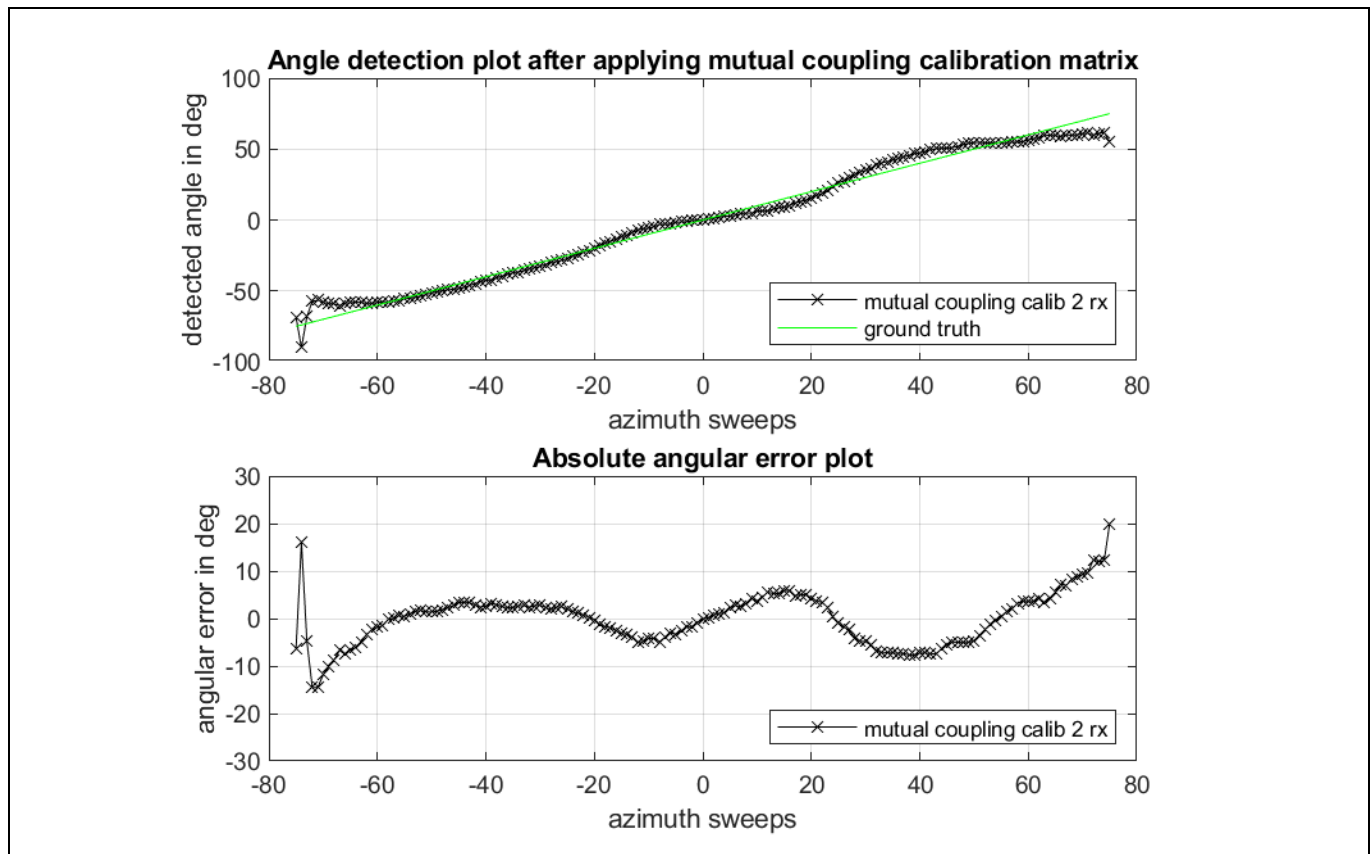


Figure 29 Angle detection and angular error after calibration: azimuth (RX3-RX1)

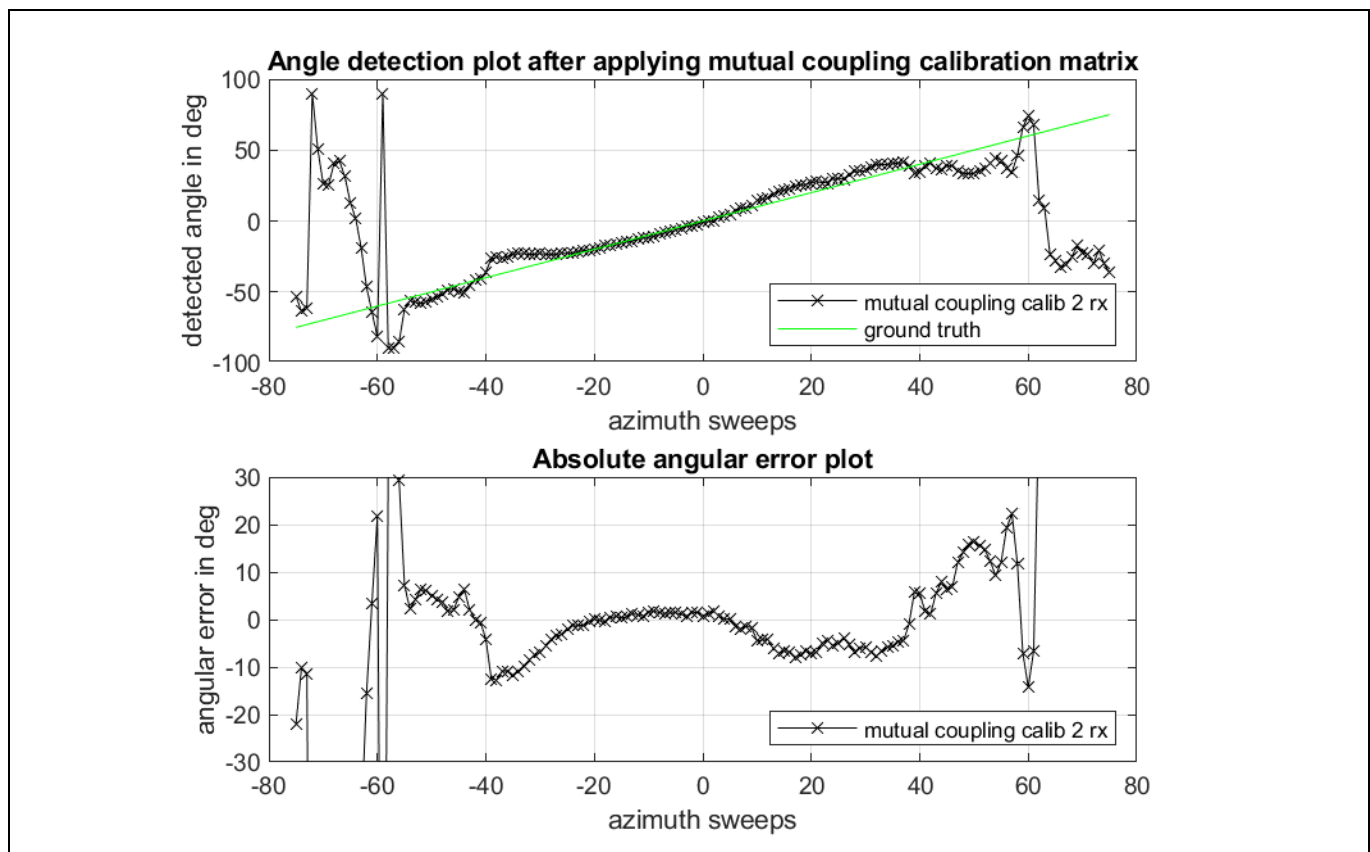


Figure 30 Angle detection and angular error after calibration: elevation (RX2-RX1)

References

References

- [1] Infineon Technologies AG: *XENSIV™ BGT60CUTR13AIP MMIC datasheet*; [Available online](#)
- [2] Infineon Technologies AG: *AN228571: Getting started with PSOC™ 6 MCU on ModusToolbox™ application note*; [Available online](#)
- [3] Infineon Technologies AG: *Code examples for ModusToolbox™*; [Available online](#)
- [4] Infineon Technologies AG: *AN155366: Electromagnetic band gap (EBG) structure application note*; [Available online](#)

Glossary

Glossary

AiP

antenna-in-package (AiP)

AoA

angle of arrival (AoA)

BSP

board support package (BSP)

CMOS

complementary metal-oxide-semiconductor (CMOS)

CSK

connected sensor kit (CSK)

DBSCAN

density-based spatial clustering of applications with noise (DBSCAN)

EBG

electromagnetic band gap (EBG)

EIRP

effective isotropic radiated power (EIRP)

ESD

electrostatic discharge (ESD)

FMCW

frequency modulated continuous wave (FMCW)

FoV

field of view (FoV)

FSM

finite state machine (FSM)

FW

firmware (FW)

GPIO

general-purpose input/output (GPIO)

GUI

graphical user interface (GUI)

HVAC

heating, ventilation, and air conditioning (HVAC)

HW

hardware (HW)

I²C

inter-integrated circuit (I²C)

Glossary

IoT

Internet of Things (IoT)

LDO

low-dropout regulator (LDO)

LED

light-emitting diode (LED)

LiPo

lithium-polymer (LiPo)

MCU

microcontroller unit (MCU)

MD

motion detection (MD)

MMIC

monolithic microwave integrated circuit (MMIC)

PCB

printed circuit board (PCB)

PDL

presence detection and localization (PDL)

PDT

presence detection and tracking (PDT)

PSRR

power supply rejection ratio (PSRR)

RD

range Doppler (RD)

RF

radio frequency (RF)

SMD

surface-mounted device (SMD)

SPI

Serial Peripheral Interface (SPI)

SW

software (SW)

UART

universal asynchronous receiver transmitter (UART)

ULP

ultra-low power (ULP)

Revision history

Revision history

Document revision	Date	Description of changes
1.00	2026-02-11	Initial release
1.10	2026-08-13	Added radar configuration guidelines for PDL and PDT solutions Updated XENSIV™ CMOS Radar Visualization Tool documentation and firmware descriptions

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