KIT_CSK_BGT60CUTR13

XENSIV™ BGT60CUTR13AIP Connected Sensor Kit

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.

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.

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

About this product group

Target applications

HVAC, smart home and building, smart TV, smart displays, security camera, lighting, security devices, wearables, robotics, healthcare devices, etc.

Product family

XENSIV™ 60 GHz CMOS radar sensors for IoT.

Safety precautions

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

Table 1   Safety precautions

⚠️	**Caution:** *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.*

Table of contents

1 The board at a glance

The XENSIV™ BGT60CUTR13AIP Connected Sensor Kit (CSK) supports testing sensor-driven IoT products and radar use cases as well as in prototyping. It offers a real-time sensor evaluation with custom configurations, and cloud- and radar-based solution output visualization. The KIT_CSK_BGT60CUTR13 (Figure 1) includes:

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

Rapid IoT Connect Developer Kit

XENSIV™ BGT60CUTR13AIP Wing

XENSIV™ BGT60CUTR13AIP CSK
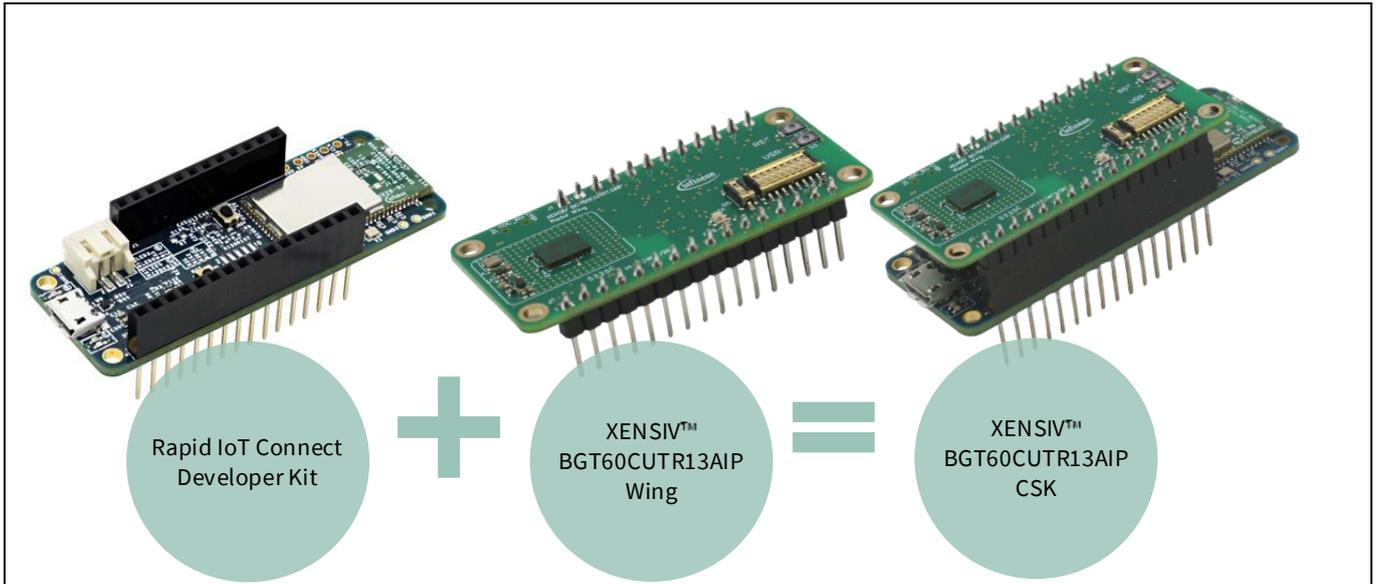
Figure 1   XENSIV™ BGT60CUTR13AIP Connected Sensor Kit

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

1 The board at a glance
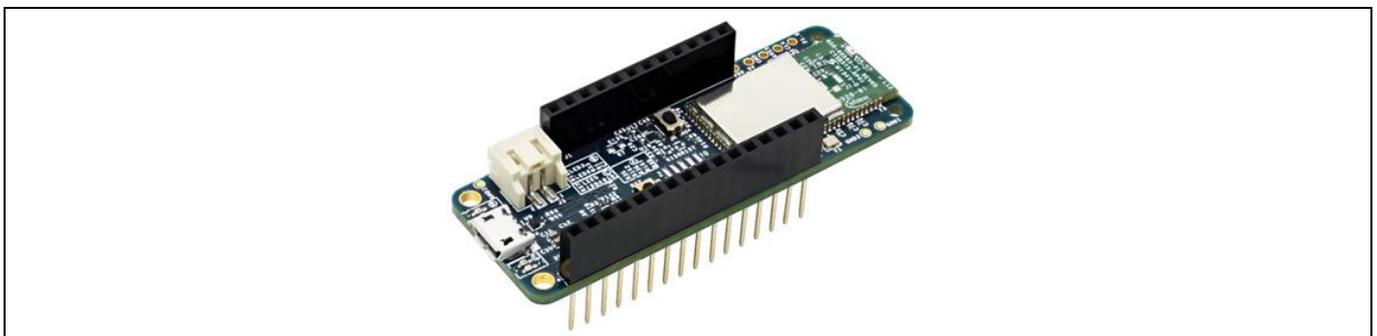
The XENSIV™ BGT60CUTR13AIP Wing board shown in Figure 3 is based on the XENSIV™ BGT60CUTR13AIP 60 GHz radar sensor MMIC with one transmitting and three receiving antennas integrated. The XENSIV™ BGT60CUTR13AIP MMIC enables ultra-wide bandwidth frequency modulated continuous wave (FMCW) operation.

To offload the microcontroller or application processor, BGT60CUTR13AIP CSK features a 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**
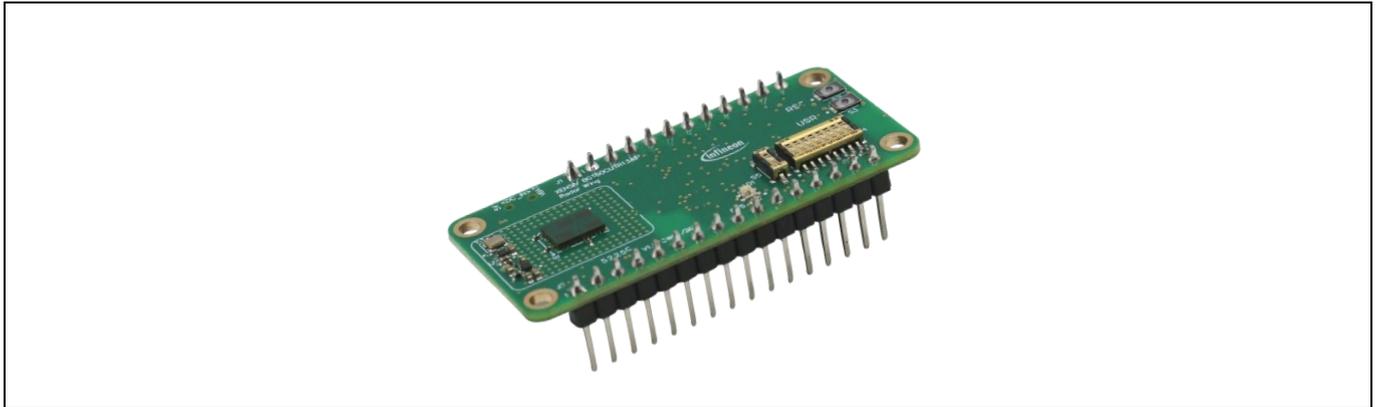
1.1   Scope of supply

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).*

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.
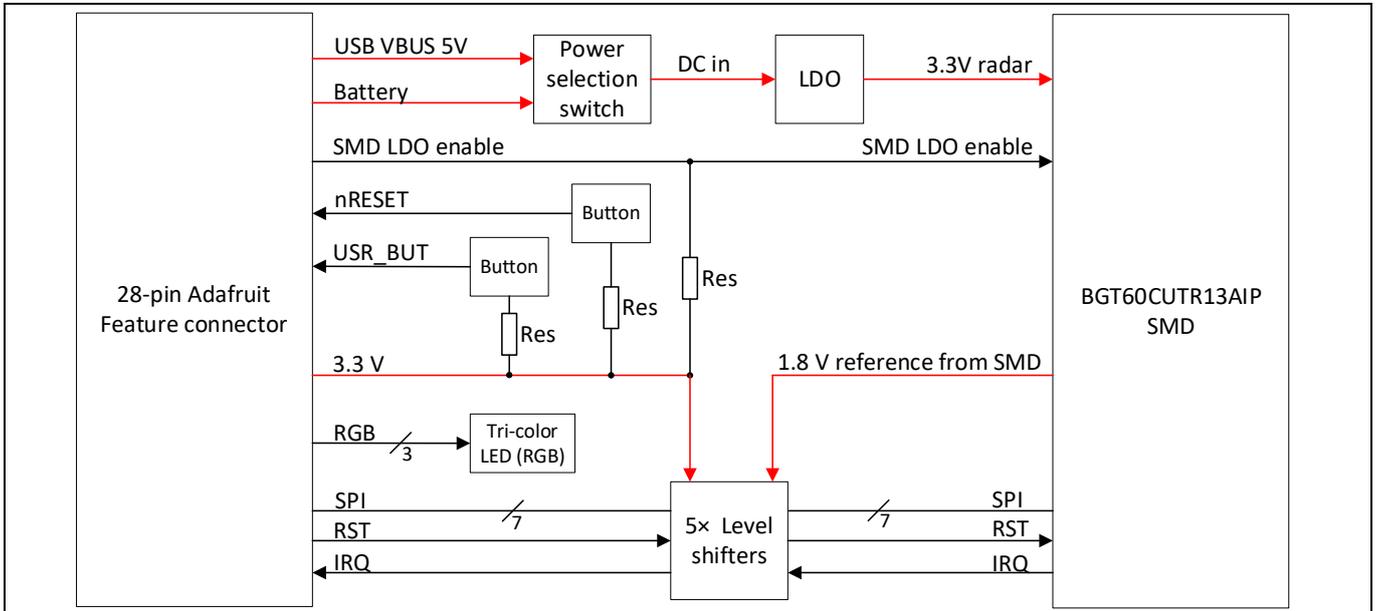
Figure 4   **XENSIV™ BGT60CUTR13AIP Wing board block diagram**

A system block diagram showing the shield connected to the CSK rapid IoT CSK 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**

1 The board at a glance

1.3 Main features

- XENSIV™ BGT60CUTR13AIP MMIC
  - 6.05 x 4.30 x 0.9 mm³ package size
  - 1Tx/3Rx Antennas-in-Package (AIP) with 90° x 120° field of view (FoV)
  - Real time data acquisition without interaction with the processor
  - Integrated state machine for low-power and real time operation
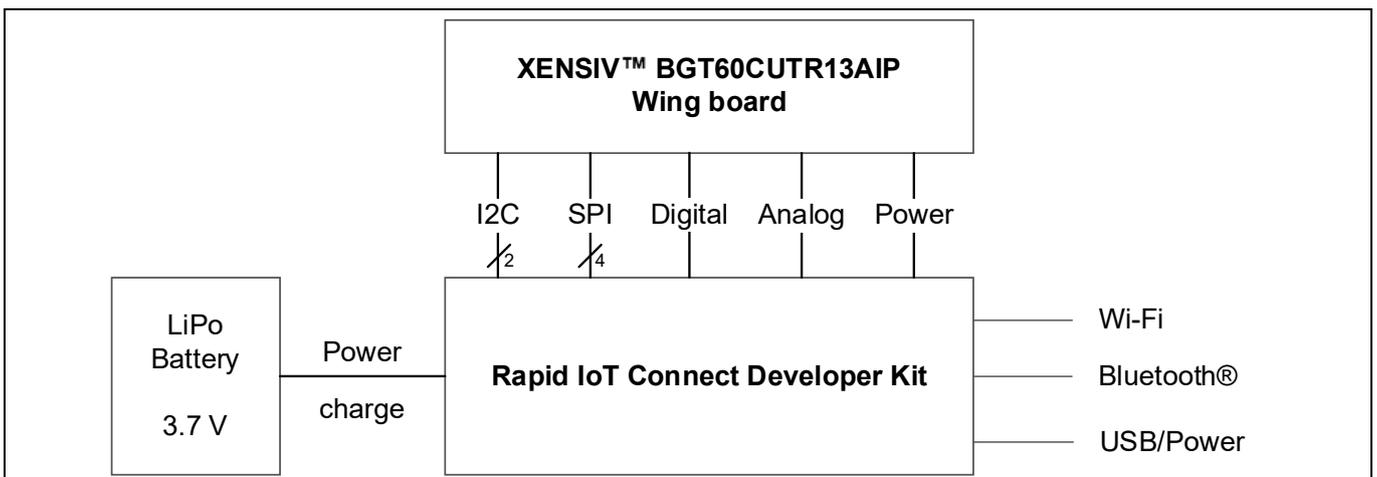- XENSIV™ BGT60CUTR13AIP Wing board
  - 50.9 mm x 23.0 mm size on standard FR4 laminate
  - 1 RGB LED and 2 configurable user buttons
  - Form-factor compatibility with Adafruit
  - Electromagnetic band-gap (EBG) structure [4], to reduce the impact of neighboring components, resulting in a homogeneous 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° x 120°	degree

2 CMOS radar-based system solutions overview

2.1 Introduction

XENSIV™ 60 GHz CMOS radar BGT60CUTR13AIP can enable varieties 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. 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 varieties 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 providing 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 timings while ensuring cycle accurate data acquisition with the lowest power consumption.

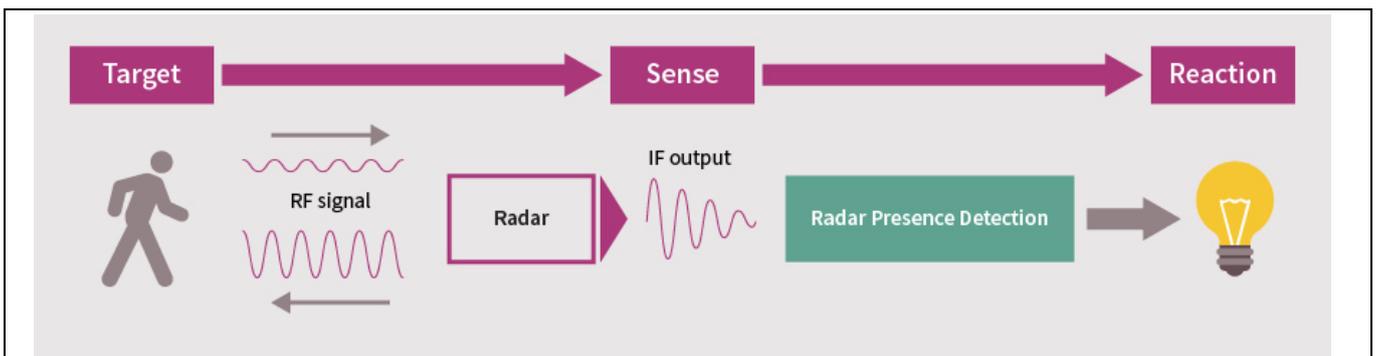A basic depiction of FMCW working principle for presence detection is shown in Figure 6.

Figure 6 **Motion and presence detection using 60 GHz radar sensor**

2.3   Presence detection, localization, and tracking solutions

Figure 7 representation 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 host/application processor

- **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 SPI interface and receives on-chip detections via SPI (e.g., range, doppler, angle of arrival – AoA, etc.). Further 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:** PDT solution deploys advanced algorithms (use case optimized detection chain and tracker as described in Section 2.4) achieving high performance and accuracy on multi-person scenarios
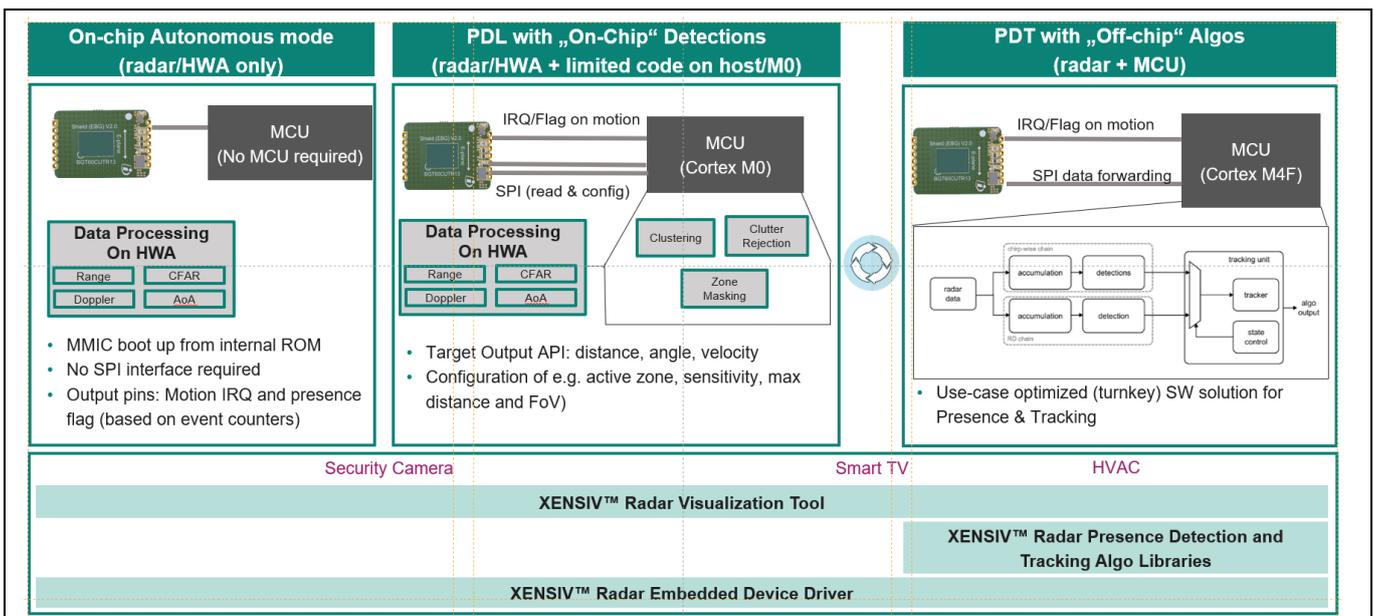

Figure 7   CMOS radar-based system solutions

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

Figure 8 provides a comparative overview of these system solutions. PDL solution has been described in two different columns to show the usage of either host processor or M0 and the associated benefits with it.

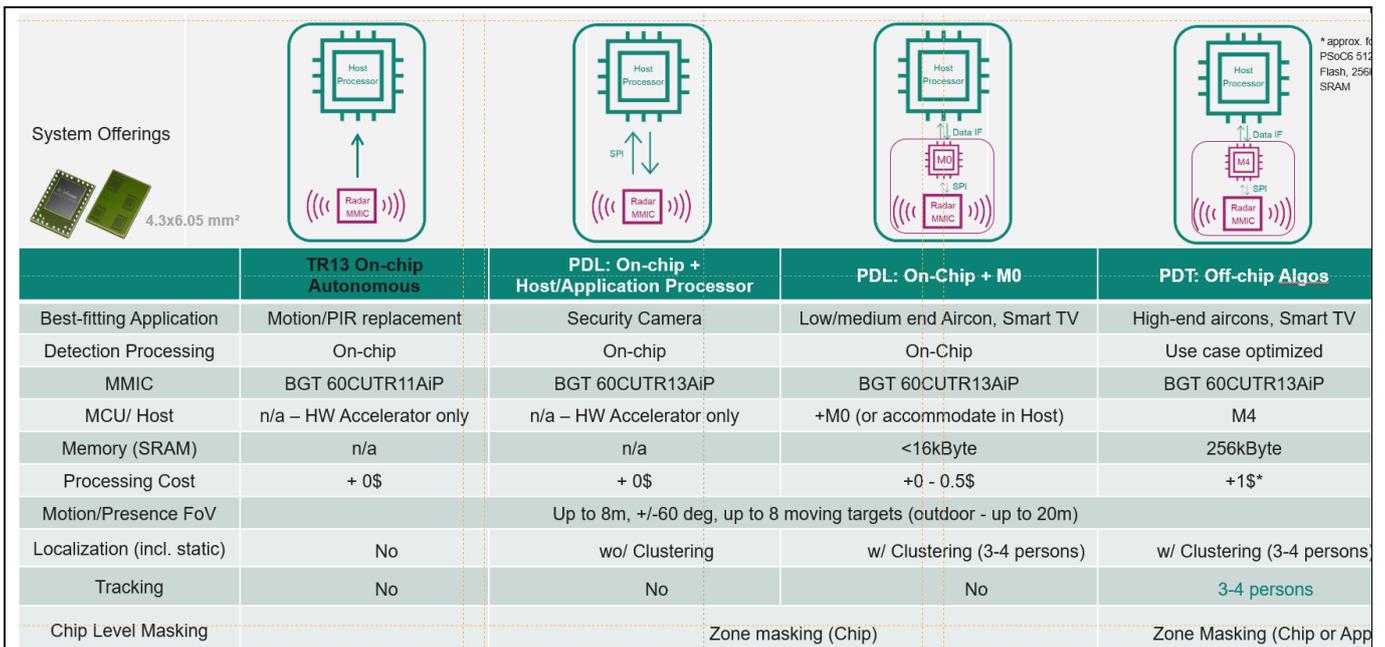| System Offerings 4.3x6.05 mm²	TR13 On-chip Autonomous	PDL: On-chip + Host/Application Processor	PDL: On-Chip + M0	PDT: Off-chip Algos
Best-fitting Application	Motion/PIR replacement	Security Camera	Low/medium end Aircon, Smart TV	High-end aircons, Smart TV
Detection Processing	On-chip	On-chip	On-Chip	Use case optimized
MMIC	BGT 60CUTR11AiP	BGT 60CUTR13AiP	BGT 60CUTR13AiP	BGT 60CUTR13AiP
MCU/ Host	n/a – HW Accelerator only	n/a – HW Accelerator only	+M0 (or accommodate in Host)	M4
Memory (SRAM)	n/a	n/a	<16kByte	256kByte
Processing Cost	+ 0$	+ 0$	+0 - 0.5$	+1$*
Motion/Presence FoV		Up to 8m, +/-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		Zone masking (Chip)		Zone Masking (Chip or App

Figure 8   A comparative overview of CMOS radar based system solutions

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.
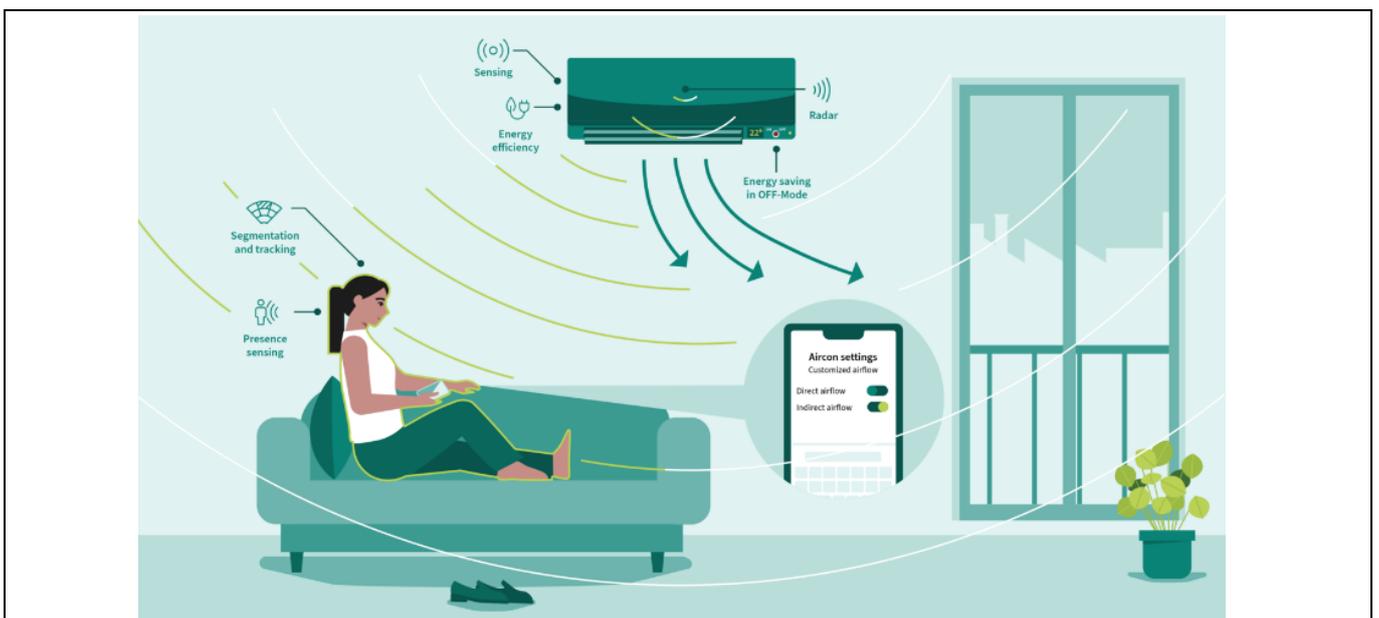

Figure 9   Use case illustration for HVAC (residential aircon application)
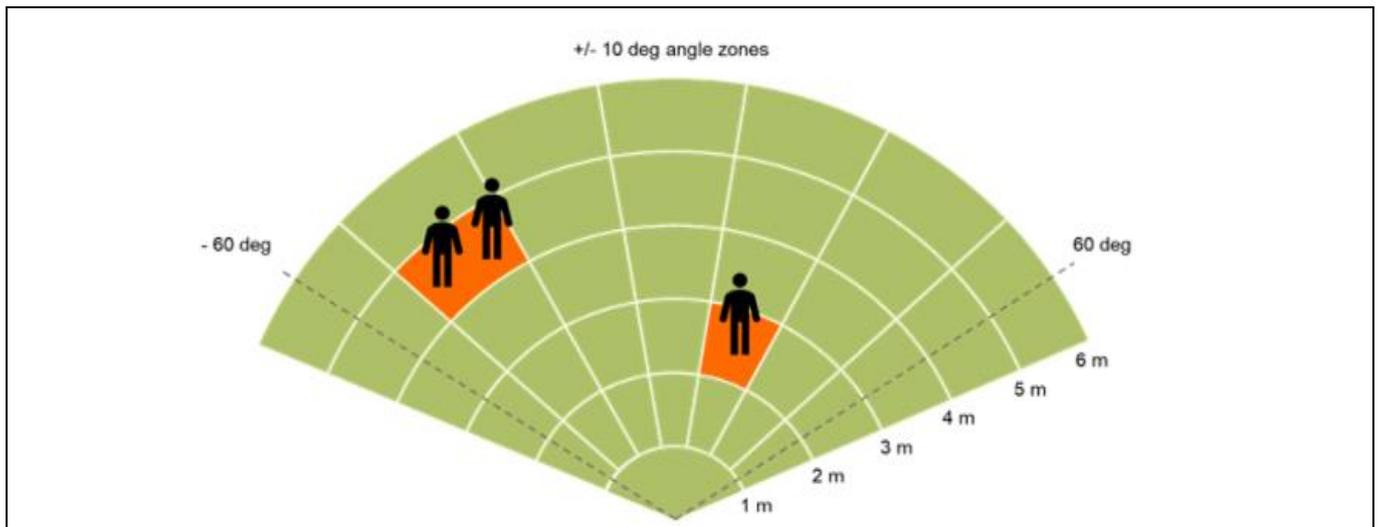
Figure 10   An example of multi-people detection and tracking in the defined field of view (FoV)
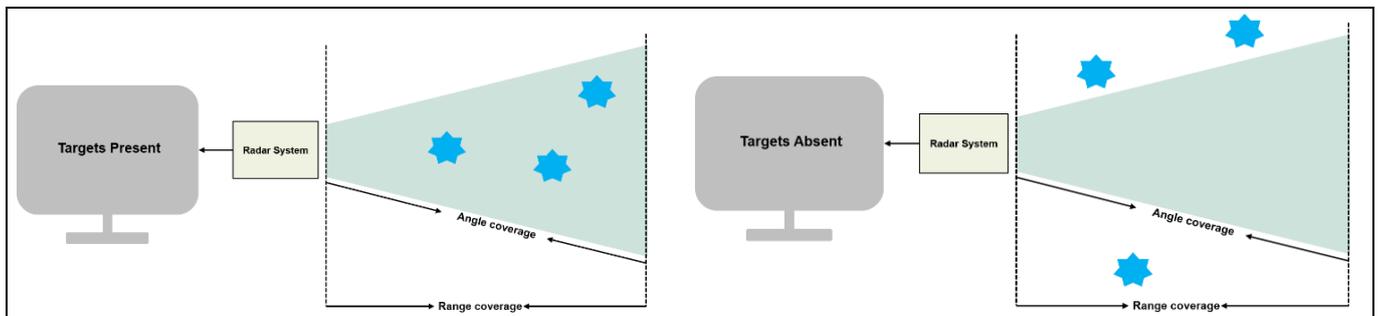

Figure 11   Presence (minimum one person in FoV) and absence states (no person in FoV) illustration

2.5   Key features and specifications for typical applications

The following table provides the key features and specification considering residential air conditioning, smart TV, etc.

Table 3   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 mount, standing type, ceiling mount
FoV (Range (m), Angle (°))	• 5 m to 6 m ±60°
Mounting height	• 1.2 m to 2.5 m
Radar housing	• ABS/2.5 mm

Feature	Description

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™ Radar CMOS 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™ Radar CMOS Visualization Tool

The XENSIV™ Radar CMOS Visualization Tool visualizes, records, and replays data from the XENSIV™ Radar BGT60CUTR13AIP on-chip motion detector (MD). The data represents sensor information, which is stored in target registers, such as range, azimuth, elevation, magnitude, and speed. This is a real-time view of the sensor data, i.e., targets show up and disappear very quickly. Optionally, the detections (from the ULP sequence) can be clustered using a DBSCAN algorithm and clutter can be detected (i.e., targets with a certain Doppler velocity or signature).

The tool includes the following features:

- The GUI comes with different pre-defined indoor and outdoor use cases. Some use cases have the optional clustering and clutter detection enabled
- Raw (unprocessed) data from the sensor can be logged into JSON text files. Also, the clustering and clutter information are logged to this file
- Logged data can also be replayed in the GUI

3.2.1 Download and install

Install Infineon Developer Center (IDC) Launcher and search for the XENSIV™ Radar CMOS Visualization Tool and install it. Once the tool is installed, go to the extracted folder and start the *Xensiv_Radar_CMOS_Visualization_GUI* executable to run the tool.

3.2.2 Select desired use case

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
2. Select the used CSK on the left-side **Event Source** dropdown menu
3. Select the required **COM** port from the **Device** dropdown menu
4. Select one of the pre-defined use cases on the left-side. For example, **Indoor Presence Localization**. Optionally, you can also provide your own configuration by selecting **Custom** in this tab and provide the path to the configuration in **Device Config**
a) Optionally:
   - Override certain MD-related settings via the **Motion detector settings** panel
   - Activate data logging under the **Data fetching** > **Data logging** section

b) Hit the **Play** button 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)
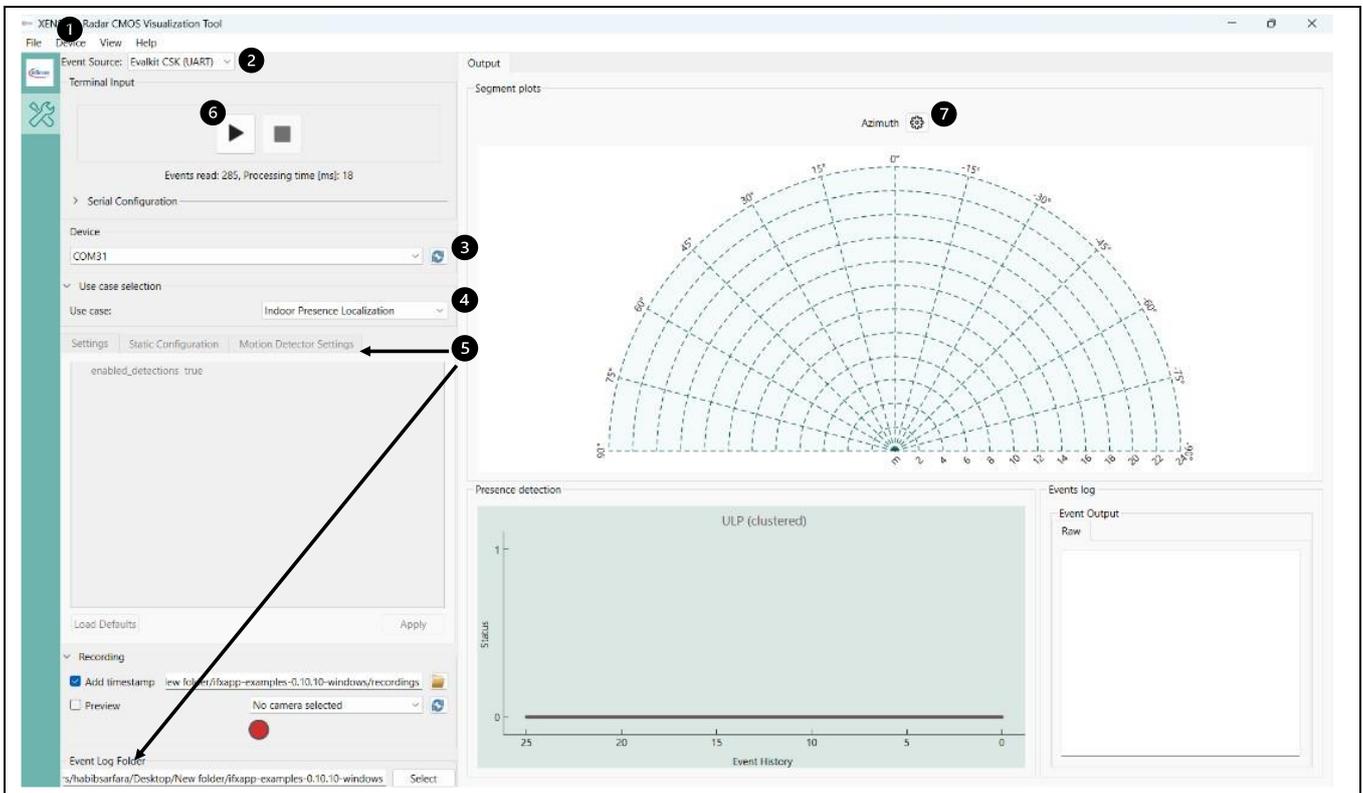
Figure 12 shows this workflow:

Figure 12   XENSIV™ Radar CMOS Visualization Tool

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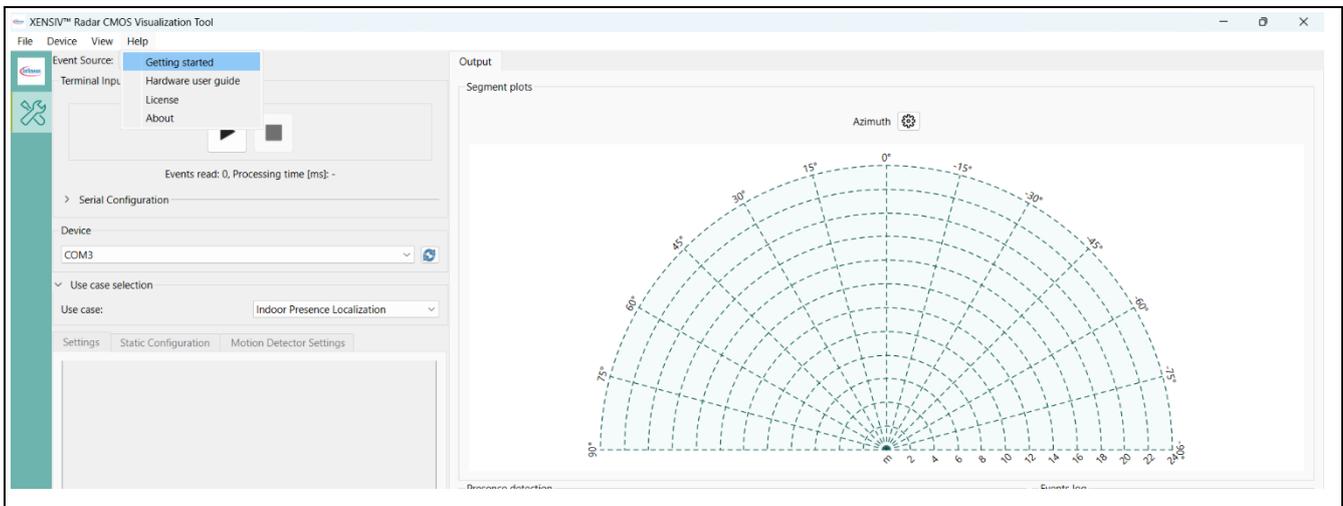

Figure 13   XENSIV™ Radar CMOS Visualization Tool Help

Furthermore, the tool comes with two firmware instances:

- **people-localization-onchip-0.4.0:** The firmware for on-chip processing, which utilizes the signal processing capabilities of the chip and outputs the target list
- **people-localization-offchip-0.4.0:** Performs the off-chip algorithm for indoor people localization utilizing a tracker. The off-chip algorithm only utilizes raw data from the XENSIV™ BGT60CUTR13AIP CMOS radar and comes with a sophisticated tracker on top which requires a microcontroller

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 solution, and sensor drivers for faster go-to-market. For on-chip and off-chip software solution.

3.3.1 PSOC™ 6 MCU: XENSIV™ 60 GHz radar on-chip motion detection with clutter localization and clustering

This code example demonstrates Infineon's radar presence/motion detection application to detect 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 using user-provided communication functions.

3.3.2 PSOC™ 6 MCU: XENSIV™ 60 GHz radar off-chip indoor people detection and tracking

This code example 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 3-5 targets within the set range and field of view (FoV).

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 on the Rapid IoT baseboard or on top of another Wing board, such as the Infineon XENSIV™ BGT60UTR11AiP Wing board. Figure 14 and Table 4 provide a description of the components mounted on the XENSIV™ BGT60CUTR13AIP radar Wing board. The white block of the silk print is a direct copy of the SMD module.
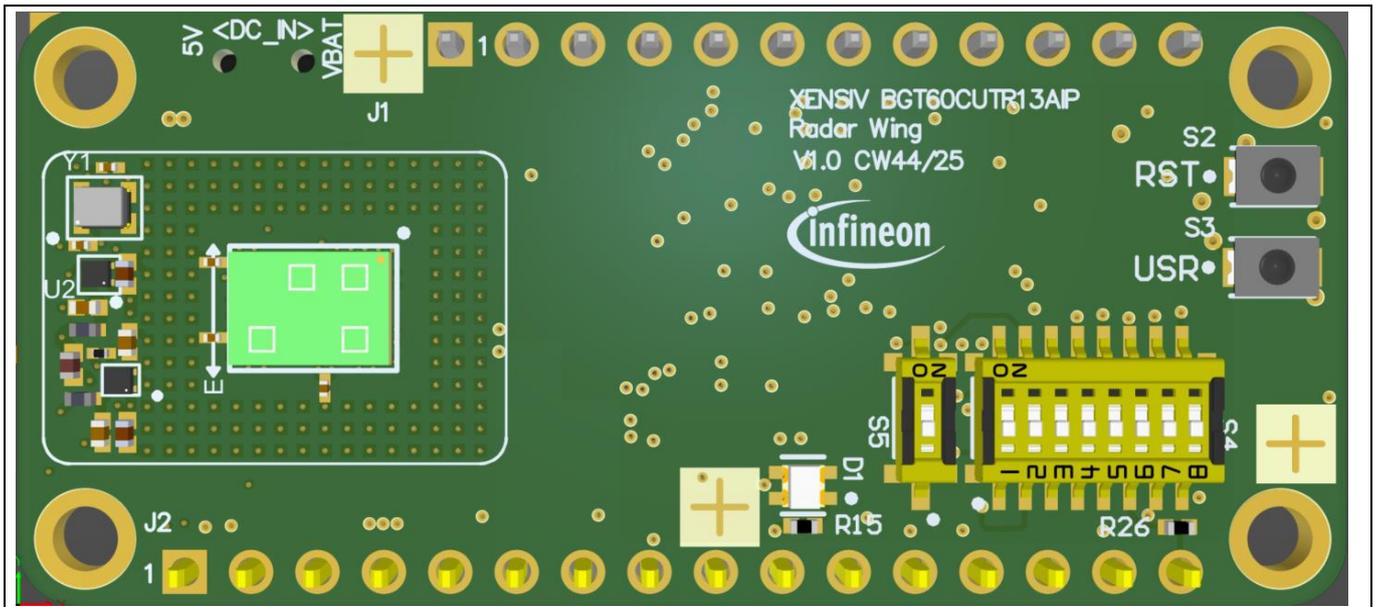

Figure 14   Front view of the XENSIV™ BGT60CUTR13AIP radar Wing board

Table 4   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 CYCBSYSKIT-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

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.
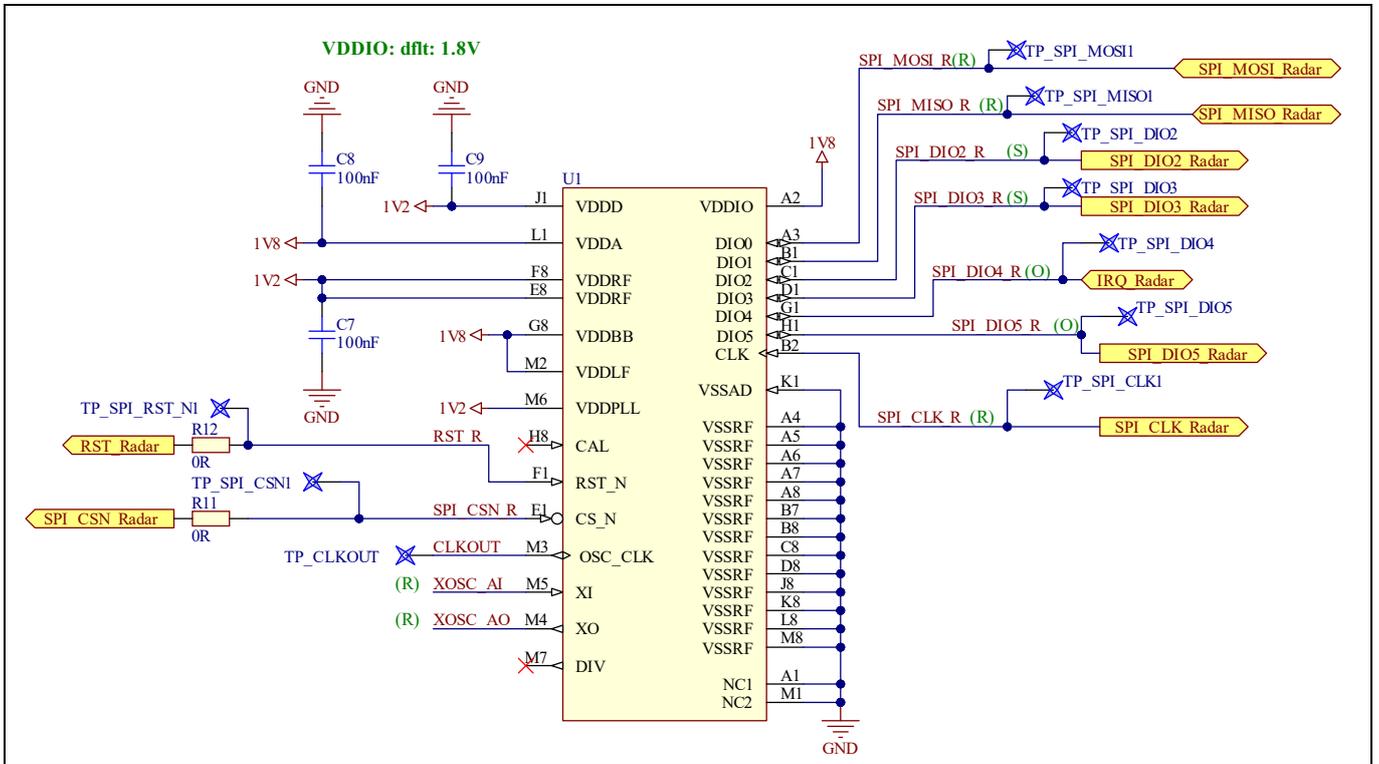

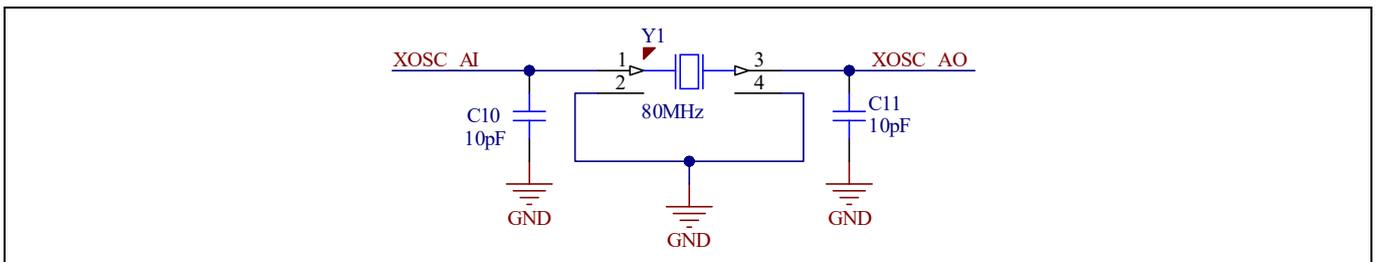**Figure 15   XENSIV™ BGT60CUTR13AIP radar MMIC schematic (direct copy of SMD)**

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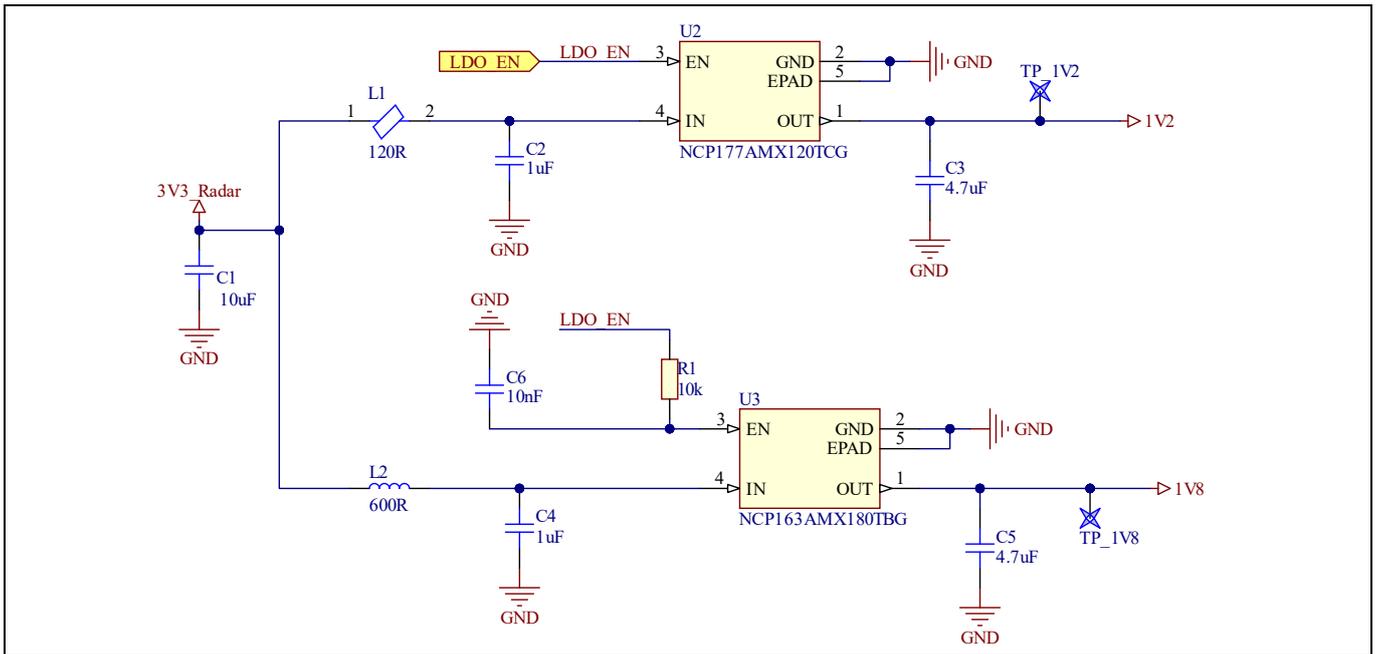
4 System design

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

The 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.
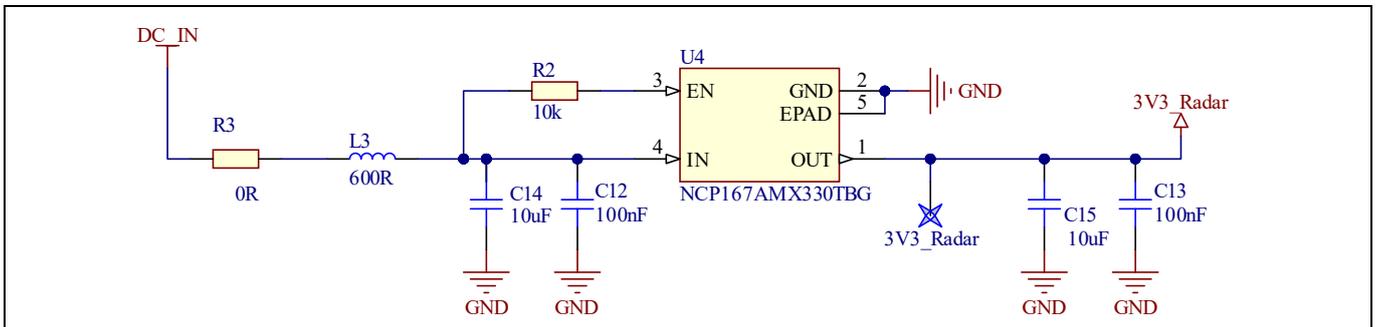

Figure 18   Voltage supply to SMD module schematic

Figure 19 shows the board power selection schematic.
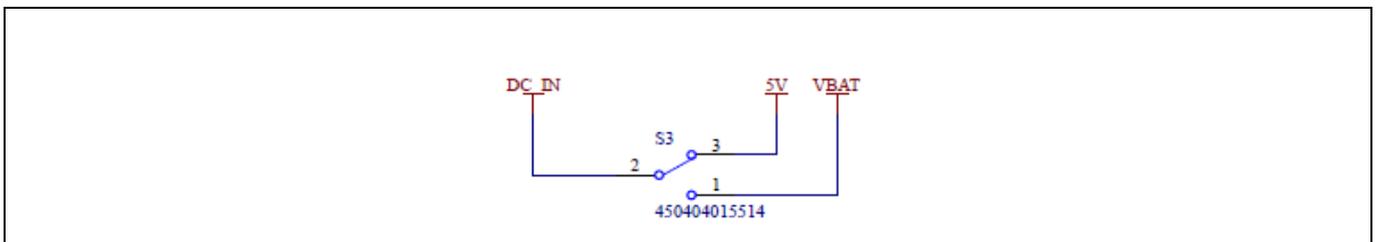

Figure 19   Board power selection (S3) schematic

4 System design
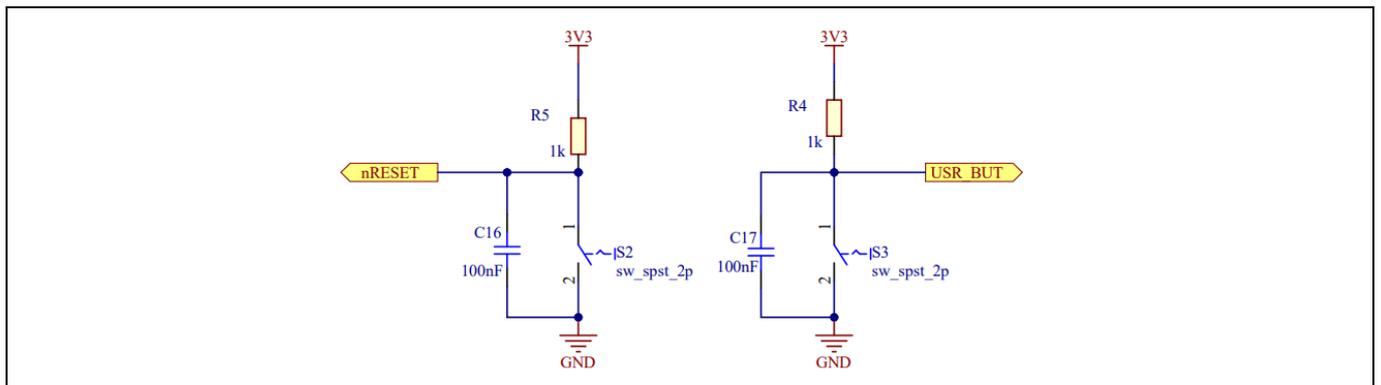
Figure 20   Reset (S2) and user button (S3) schematic
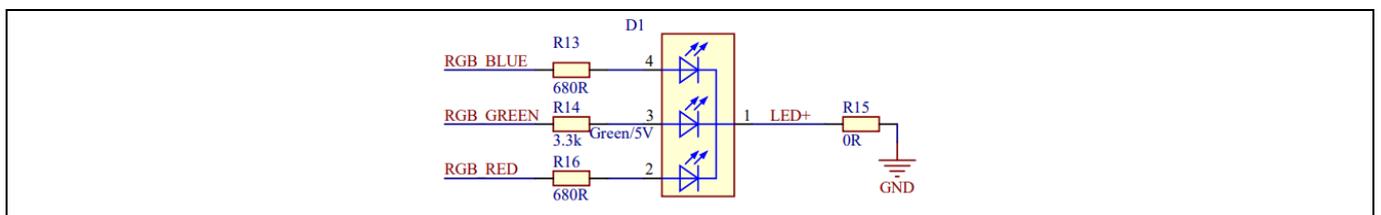
Figure 21   LED schematic

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

4 System design
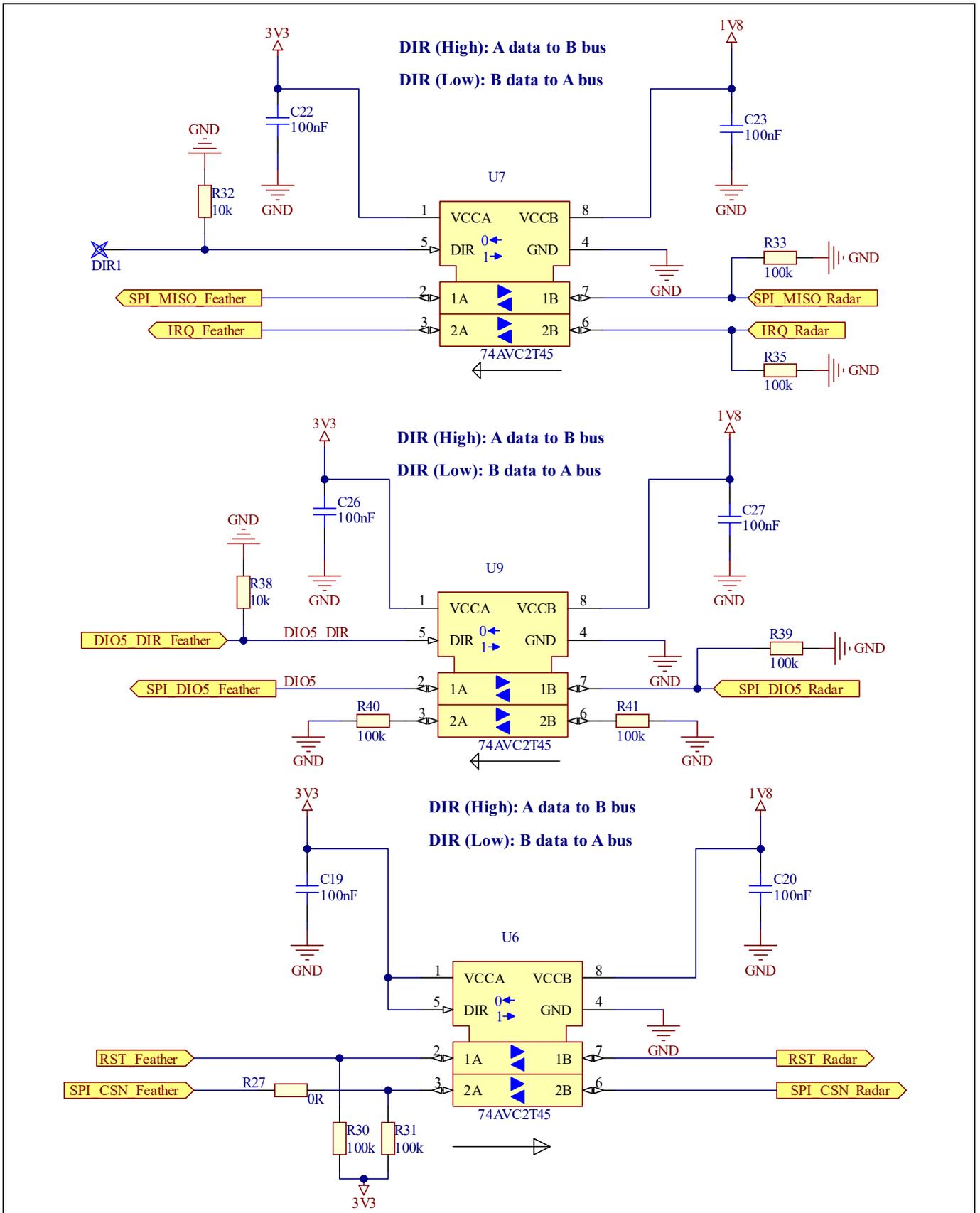
4 System design
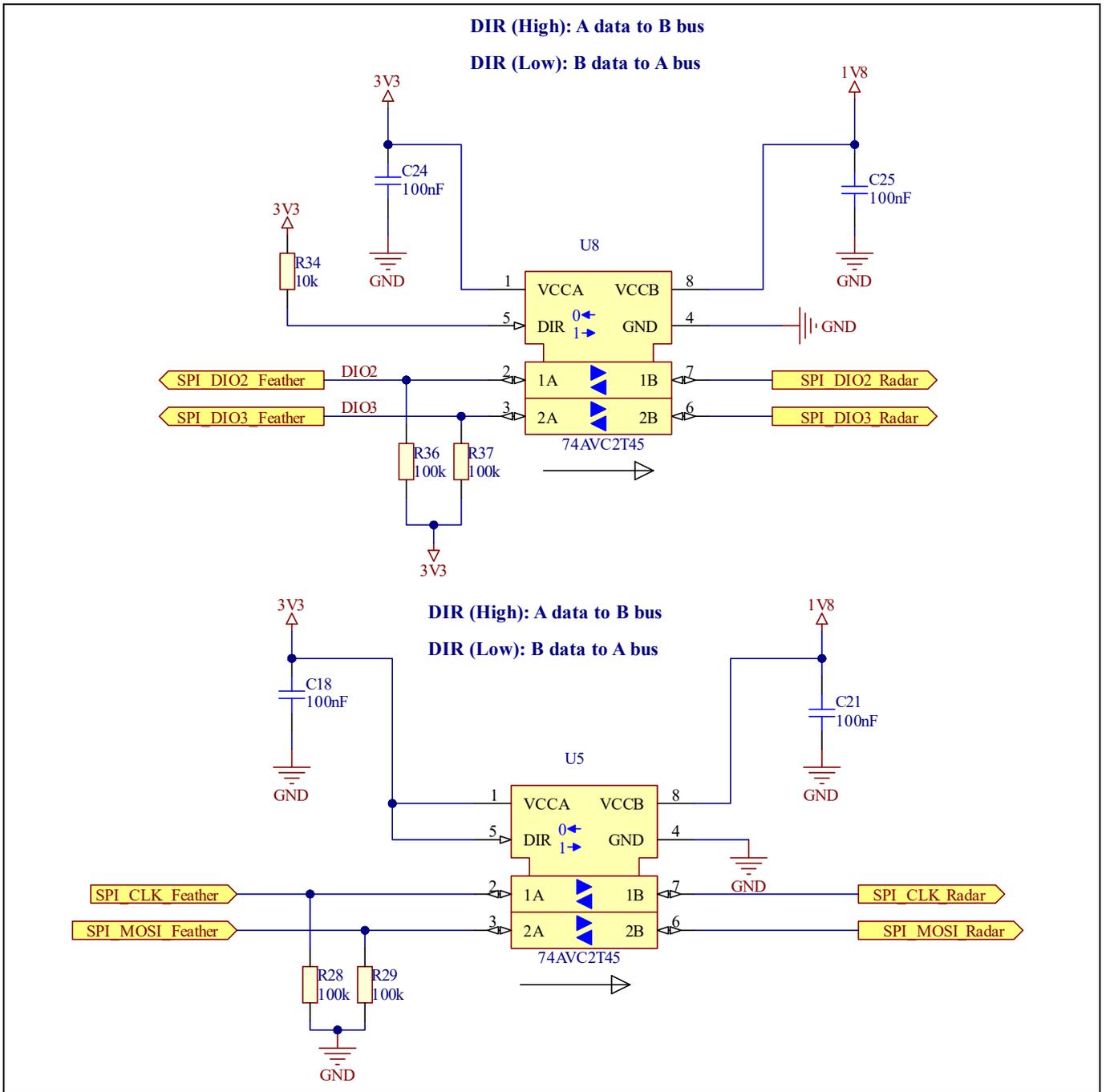
Figure 22   Level shifter schematic

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.

4 System design
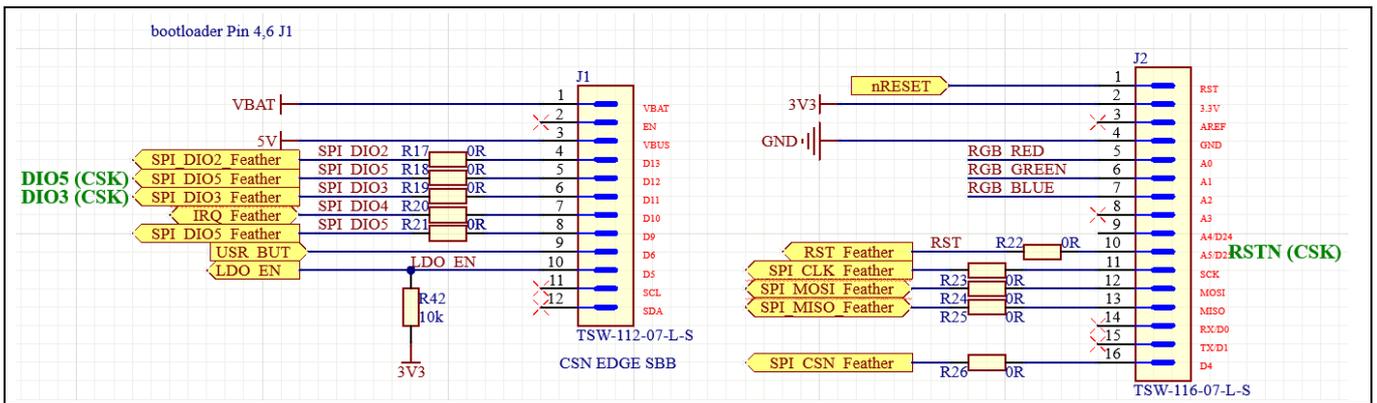
Figure 23   Adafruit headers schematic

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.
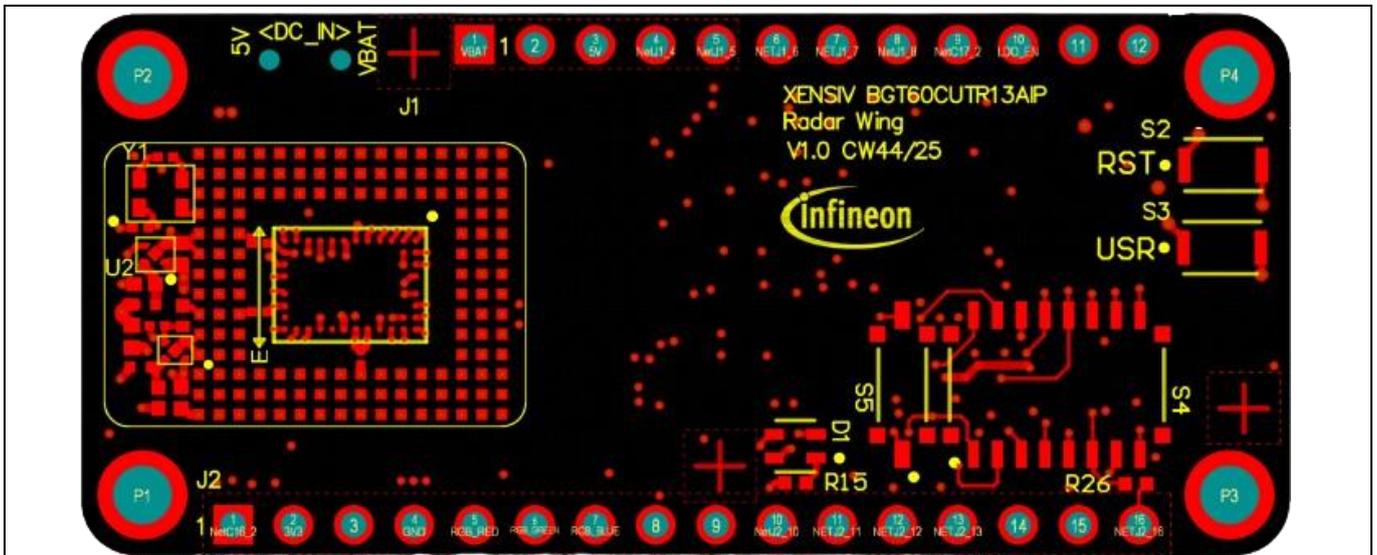
Figure 24   PCB layout of XENSIV™ BGT60CUTR13AIP radar Wing board

4.3   Bill of materials

Table 5 lists the bill of materials (BOM) of the XENSIV™ BGT60CUTR13AIP radar Wing board.

Table 5   BOM of the most important/critical parts of the evaluation

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

4 System design

Ref designator	Description	Manufacturer	Manufacturer P/N	Footprint	Qty
C3, C5	4.7 µF ±10% 6.3 V ceramic capacitor X5R 0402 (1005 metric)	Murata	GRM155R61A475 MEAAD	CAPC1005X65 N-1	2
C6	10 nF ±10% 16 V ceramic capacitor X7R 0402 (1005 metric)	Murata	GRM155R71C103 KA01	CAPC1005X55 N-0	1
C7, C8, C9	0.1 µF ±20% 10 V ceramic capacitor X5R 0201 (0603 metric)	Murata	GRM033C71C104 KE14D	CAPC0603X33 N	3
C10, C11	10 pF ±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 ±10% 16 V ceramic capacitor X5R 0402 (1005 metric)	Murata	GRM155R61C104 KA88	CAPC1005X55 N-0	12
C16, C17	100 nF ±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 MΩ	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 MΩ	TDK	INDC1005X55N_ MMZ1005	MMZ1005B601 CT000	2
R1	Resistor SMD 10 kΩ 1/16 W 0201	MULTICOMP PRO	MCRE000164	RESC0603X26 N	1
R2, R32, R34, R38, R42	Resistor SMD 10 kΩ 1/16 W 0402	Panasonic Electronic Components	ERJ2RKF1002X	RESC1005X40 N	5

4 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	RESC1005X03 N	15
R4, R5	Resistor SMD 1 kΩ 5% 1/10 W 0402	Panasonic Electronic Components	ERJ-2GEJ102X	RESC1005X40 N	2
R13, R16	Resistor SMD 680 Ω 5% 1/16 W 0402	Yageo	CRCW0402680RF K	RESC1005X40 N	2
R14	Resistor SMD 3.3 kΩ 1% 1/20 W 0201	Panasonic Electronic Components	ERJ-2RKF3301X	RESC0603X26 N	1
R28, R29, R30, R31, R33, R35, R36, R37, R39, R40, R41	Resistor SMD 100 kΩ 1% 1/16 W 0402	Yageo	RC0402FR-07100KL	RESC1005X40 N-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	BGT60CUTR13AI PXUMA1	BGT60CUTR13 AIP	1
U2	LDO regulator, ultra-low noise, high PSRR, RF, and analog circuits	ON Semi	NCP177AMX120T CG	ONSEMI-SMD-CASE 711AJ	1
U2	LDO regulator, ultra-low noise, high PSRR, RF, and analog circuits	ON Semi	NCP177AMX120T CG	ONSEMI-SMD-CASE 711AJ	1
U3	LDO regulator ultra-low noise, high PSRR, RF, and analog circuits	ON Semi	NCP163AMX180T BG	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

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 6. Figure 25 also shows the test points which were used for testing the boards in the lab or production.
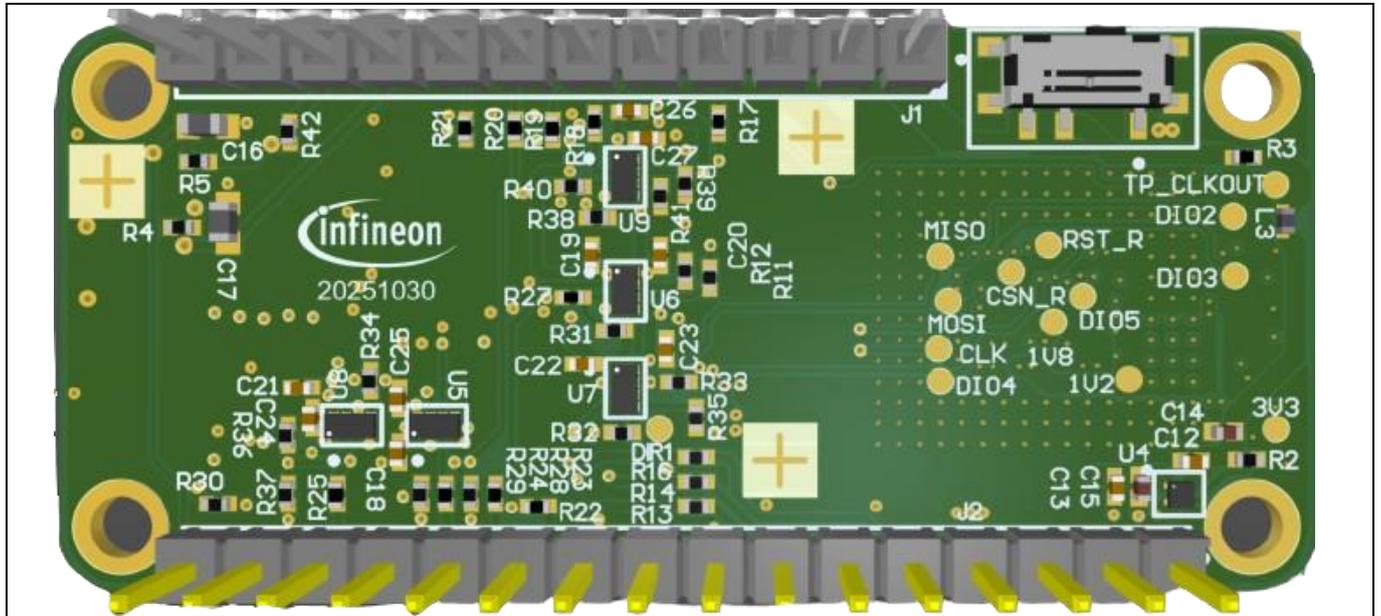

Figure 25   Adafruit headers and test points on the bottom of the XENSIV™ BGT60CUTR13AIP radar Wing board

Table 6   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	I²C SCL	P6_0	SCL	–	Not connected

4 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	I²C 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.
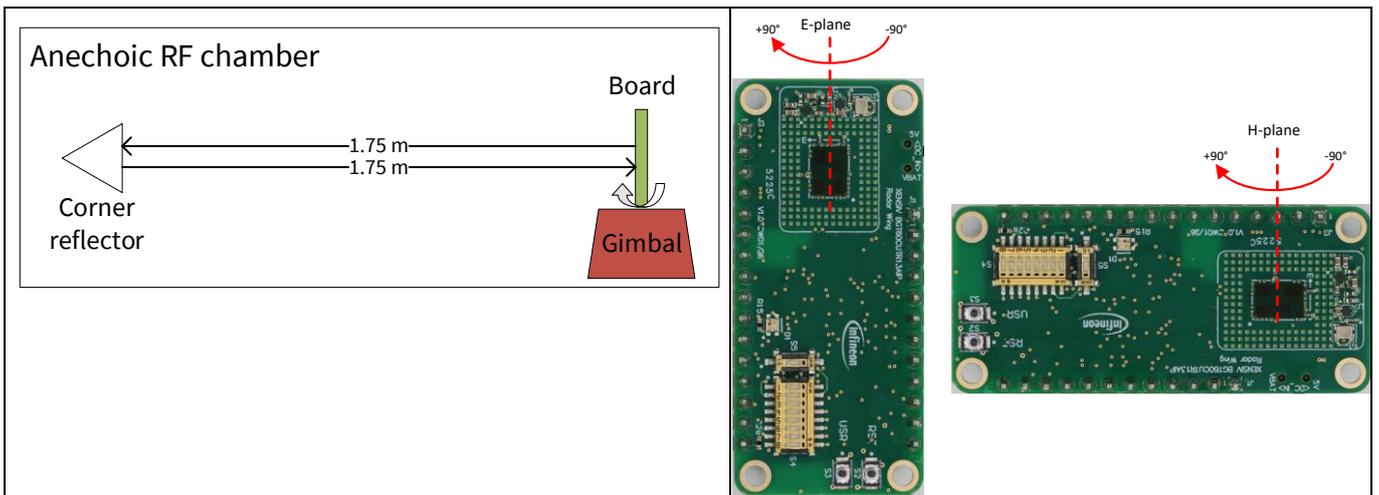

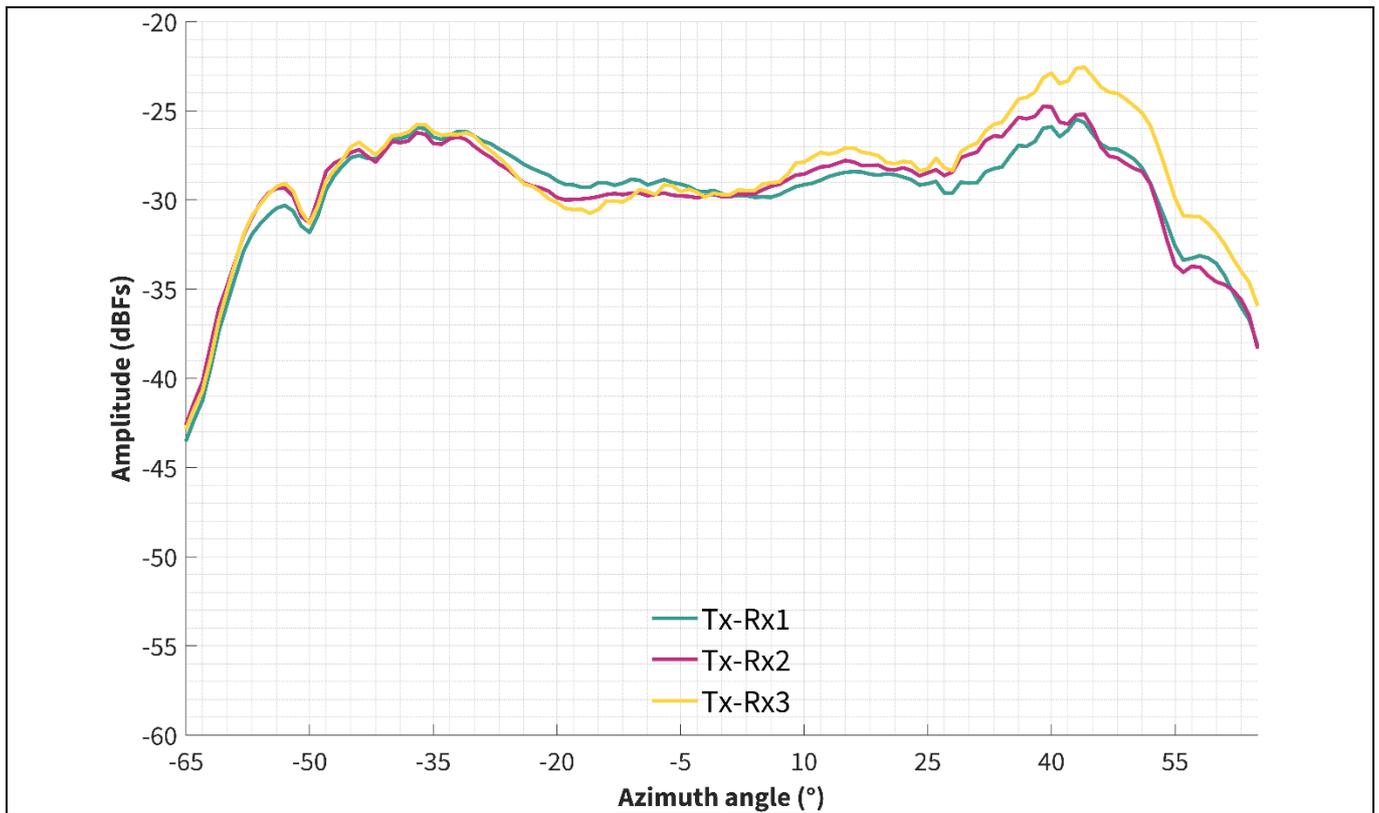**Figure 26** **Anechoic chamber setup for radar mode measurements**

5 System performance

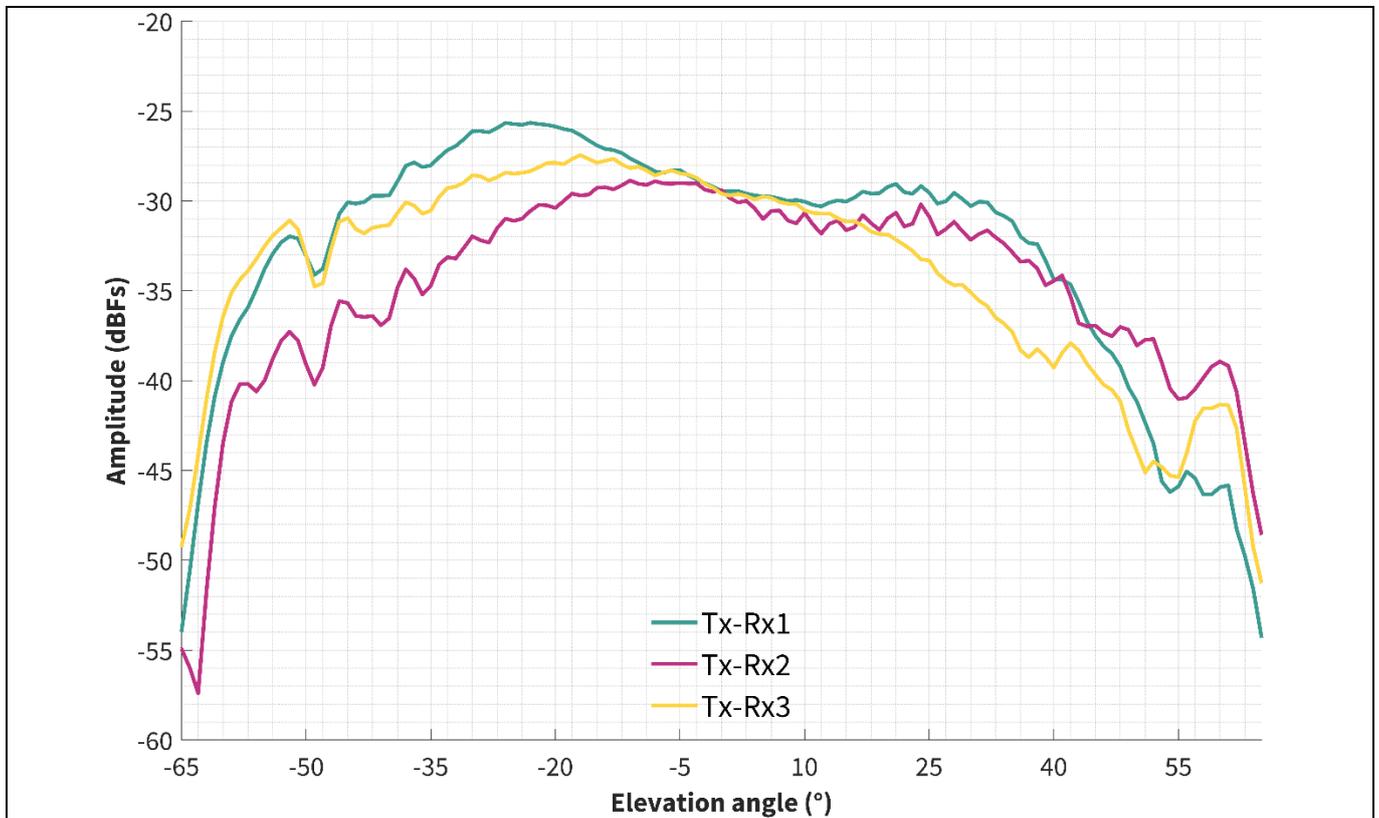**Figure 27   Received amplitude, azimuth, E-plane, ±60° FoV**

Figure 28   Received amplitude, elevation, H-plane, ±45° FoV

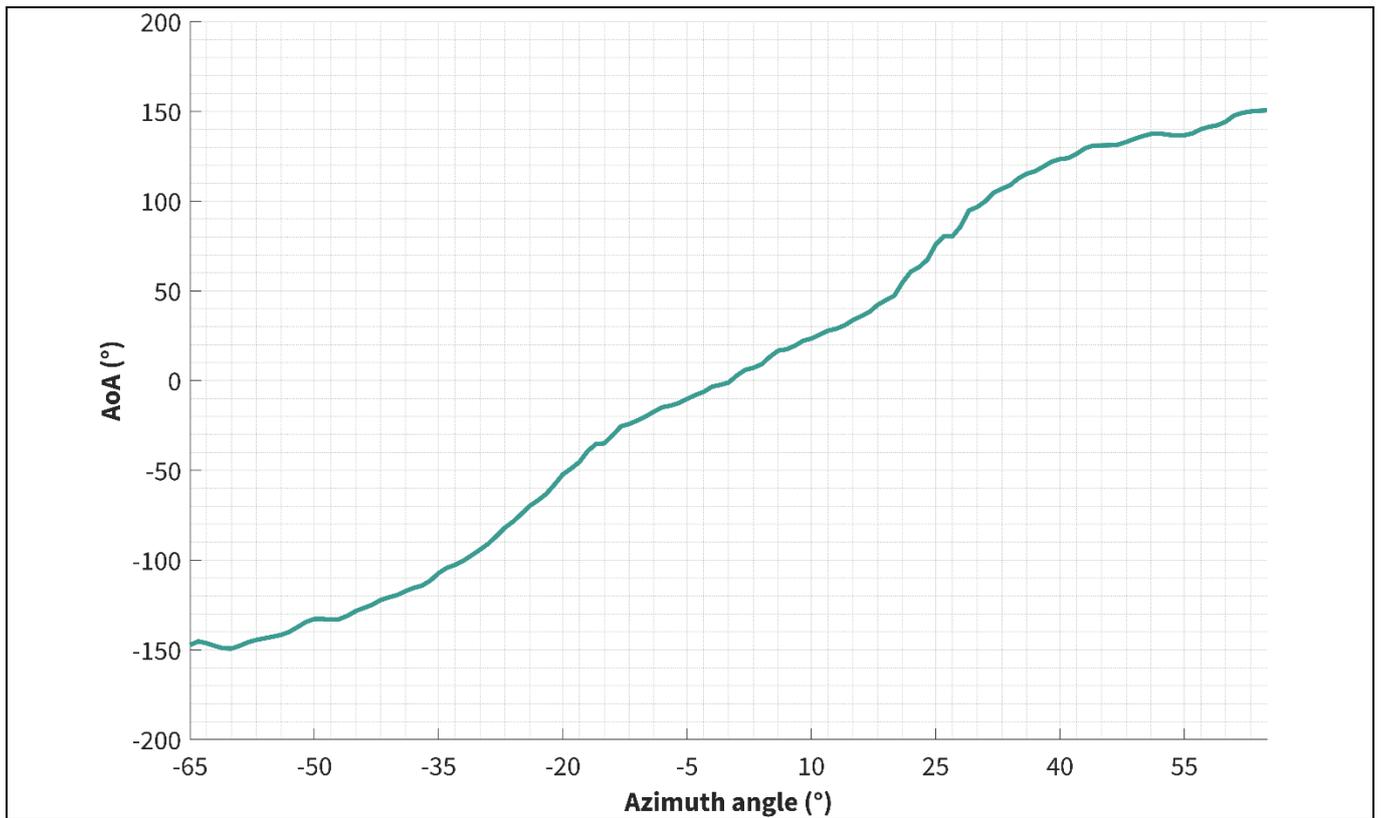**5 System performance**

Figure 29   **Phase difference plots: azimuth (RX3-RX1)**

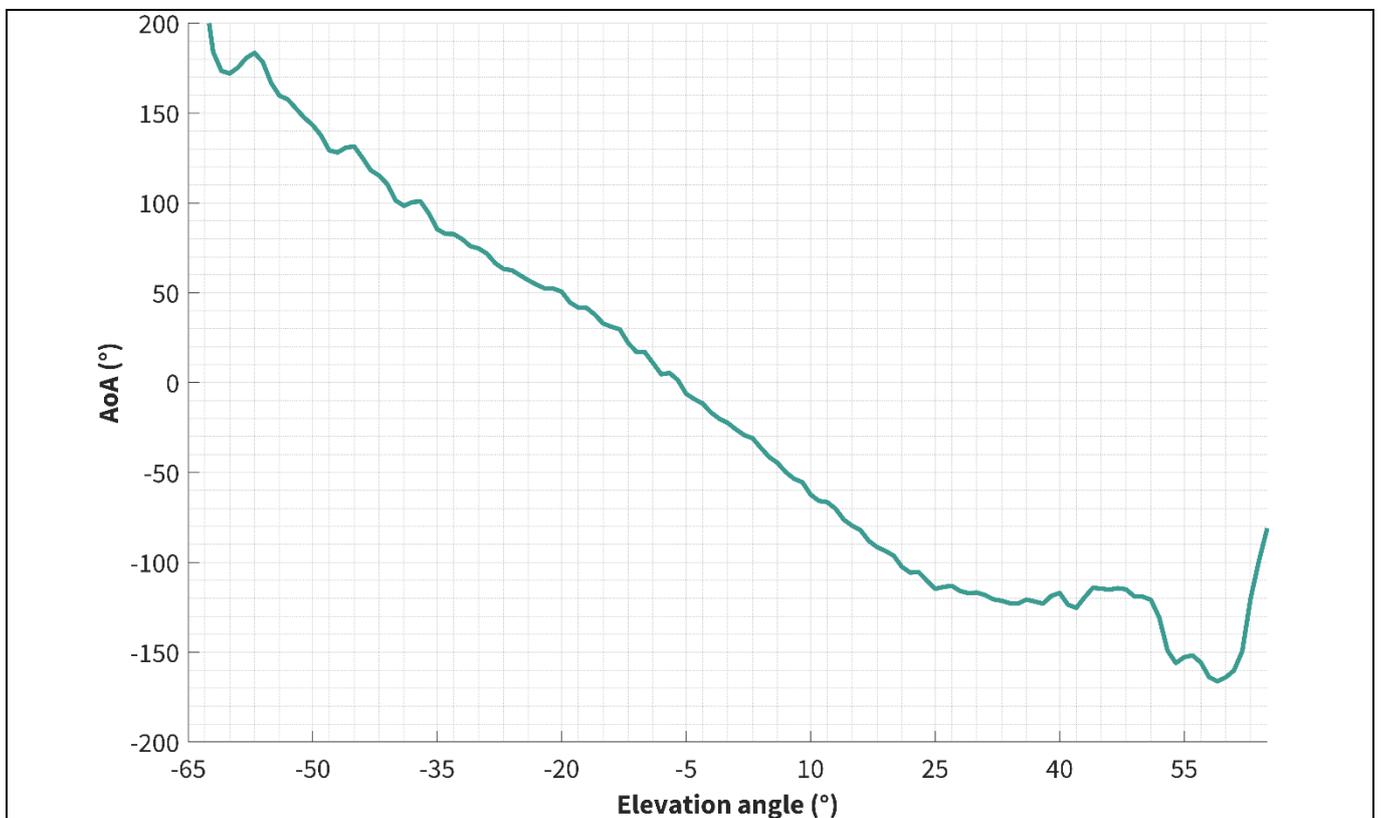**Figure 30**   **Phase difference plots: elevation (RX2-RX1)**

References

[1]   Infineon Technologies AG. *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

BSP
board support package (BSP)

CSK
connected sensor kit (CSK)

FMCW
frequency modulated continuous wave (FMCW)

FSM
finite state machine (FSM)

GPIO
general-purpose input/output (GPIO)

HW
hardware (HW)

I²C
inter-integrated circuit (I^{2}C)

IoT
Internet of Things (IoT)

LED
light-emitting diode (LED)

LiPo
lithium-polymer(LiPo)

PCB
printed circuit board (PCB)

SPI
Serial Peripheral Interface (SPI)

UART
Universal Asynchronous Receiver Transmitter (UART)

Revision history

Document revision	Date	Description of changes
1.00	2026-02-11	Initial release

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