Userguide for XENSIV™ BGT60UTR11AIP Radar Wing Board

About this document

Scope and purpose

This document is a user guide for the XENSIV™ BGT60UTR11AIP radar wing, provided as part of the connected sensor kit (CSK) offering.

Intended audience

Customers interested in using the XENSIV™ BGT60UTR11AIP radar sensor to build their own IoT solution for various consumer applications.

Table of contents

1 Important Notice

Infineon Technologies AG (Infineon) provides the evaluation unit (evaluation kit) titled "connected sensor kit" which is built to enable testing and evaluation of the XENSIV™ BGT60UTR11AIP radar wing under the following conditions:

- The evaluation unit is intended to be used for development, TESTING and EVALUATION PURPOSES ONLY and is not considered by Infineon to be a finished end product fit for general consumer use.

- The evaluation unit (not being an end product) is not intended to be complete in various product aspects such as required design, marketing, manufacturing, product safety, security and environmental measures.

- The evaluation unit (evaluation kit) does not fall within the scope of the European Union directives and FCC regulation, and therefore may not meet the technical requirements of these directives or other related directives and regulations.

- The evaluation unit is provided for test and evaluation purposes only to evaluate the XENSIV™ BGT60UTR11AIP radar. The evaluation unit is provided "as is" without any warranty or liability of any kind.

- The user assumes all responsibility and liability for proper and safe handling of the goods, including following ESD precautions. Further, the user indemnifies Infineon from all claims arising from the handling or use of the goods.

- NEITHER PARTY SHALL BE LIABLE TO THE OTHER PARTY FOR ANY DAMAGES INCLUDING (BUT NOT LIMITED TO) INDIRECT, SPECIAL, INCIDENTAL AND CONSEQUENTIAL DAMAGES.

For additional information, please contact an Infineon application engineer or visit www.infineon.com.

2 Introduction

The key component on the wing board is Infineon's XENSIV™ BGT60UTR11AIP radar sensor. It enables ultra-wide bandwidth frequency-modulated continuous-wave (FMCW) operation in antenna-in-package(AIP). Sensor configuration and data acquisition are enabled with a digital interface, and the integrated state machine enables real time data acquisition with power mode optimization and flexibility to optimize the performance as well.

The BGT60UTR11AIP is optimized for low power consumption and system cost optimization. With its compact size of only 16 mm^2, it is suitable for integration into the smallest devices. The MMIC is manufactured using Infineon's B11 SiGe BiCMOS technology, ensuring excellent RF performance.

The sensor supports various use cases, serving a broad application spectrum such as presence detection, range zone segmentation, levelsensing, 1D gesture, proximity sensing or distance measurement. These use cases target applications such as notebooks, TVs, smart speakers, wearables, smart home and automations for comfort, energy savings and security/safety functions

2.1 XENSIV™ BGT60UTR11AIP radar

The BGT60UTR11AIP is a 60 GHz radar sensor with one transmitting and one receiving U-slotted patch antennas in package. The 5.5 GHz ultra-wide bandwidth allows Frequency-Modulated Continuous Wave (FMCW) operations with extremely high resolution. This enables precise range measurements, 1D gestures and also the measurement of vital signs such as breathing rate or heart rate.

The BGT60UTR11AIP provides the following digital signal lines: oscillator input, four SPI signals, hardware reset line (RST) and interrupt request output (IRQ) to the MCU. Furthermore, there is a divider output signal. It must be enabled in the chip and outputs a 1:16 fraction of the RF generated by the radar sensor

Sensor configuration and data transfer are enabled with a single digital interface. Multiple devices connected to the same bus can be configured and triggered together by using the implemented broadcast mode. Device specific programmable wake-up times allow time domain multiplexed radar frames. The integrated state machine enables independent and real time data acquisition without interaction to the processor. Three possible power mode options give the user full flexibility between performance and power consumption optimizations.

New smart sensors for gesture recognition can be based on radar systems – in special cases, FMCW radars. Those systems can comprise several blocks: radio frequency (RF) front end, analog baseband (ABB), analog-to-digital converter (ADC), phase-locked loop (PLL), memory (e.g., FIFO), serial peripheral interface (SPI) and antennas. Smart sensors require a high level of integration, so the components listed above should be integrated in a single-chip solution. BGT60UTR11AIP offers this level of integration in a single chip

The core functionality of Infineon's XENSIV™ BGT60UTR11AIP radar sensor is to transmit the FMCW signal via the transmitter channel (TX) and receive the echo signals from the target object on the receiving channel (RX). Each receiver path includes a baseband filtering, a VGA, as well as an ADC. The digitized output is stored in a FIFO. The data are transferred to an external host, microcontroller unit (MCU) or application processor (AP), to run radar signal processing.

2.1.1 Key benefits

- High sensitivity to detect sub-mm movements for human presence detection and vital sensing applications
- High bandwidth for precise distance measurements with mm accuracy

- Small size for integration into space-constrained environments
- Low power consumption for battery-driven applications

2.1.2 Key feature

- 6 GHz bandwidth and ramp speed of up to 400 MHz/µs
- Antenna in package (AIP) with **±60°** Field of View (**FoV)**
- Integrated finite **state machine** (FSM) for low power consumption and real-time operation
- Single **50 MHz SPI** for chip configuration and data transfer
- Digital interface for chip configuration and radar data acquistion
- Dedicated power modes for power reduction

2.2 Hardware prerequisites

The following boards are required from the CSK:

- Rapid IoT connect developer kit (CYSBSYSKIT-DEV-01) (see **Figure 1**)
- XENSIV™ BGT6UTR11AIP radar wing (EVAL_BGT60UTR11AIP_WING) (see **Figure 2**)

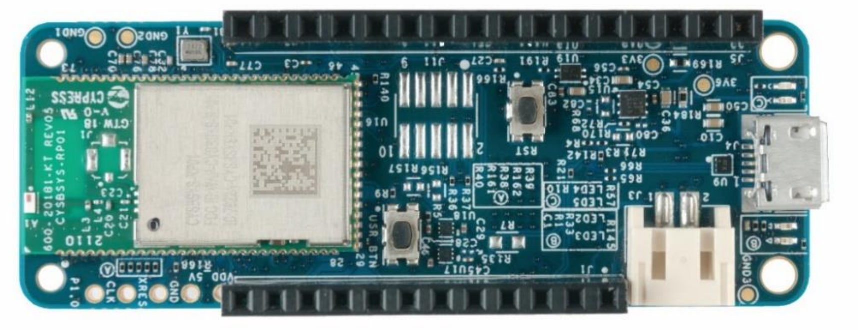


Figure 1: CYSBSYSKIT-DEV-01 rapid IoT connect developer kit

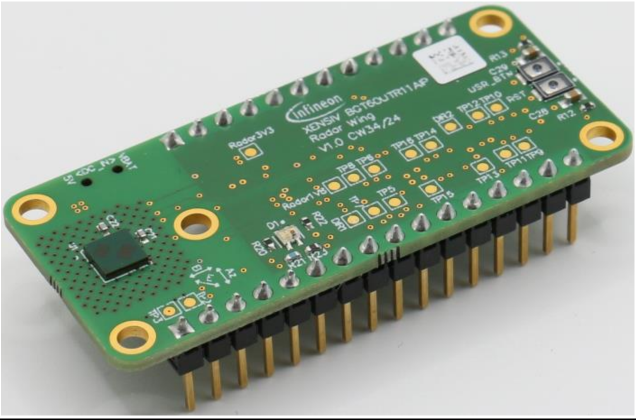


Figure 2: XENSIV™ BGT60TR13C radar wing

2.3 Board details

The CYSBSYSKIT-DEV-01 rapid IoT connect developer kit serves as the compute and connect part of the CSK. Infineon sensor wing boards, such as the XENSIV™ BGT60UTR11AIP radar wing, sense the environment. The wing board has Adafruit feather-compatible connectors to be stacked individually or combined with other CSK-compatible wing boards on the rapid IoT connect developer kit

2.4 Kit and system block diagram

A block diagram of the wing board is shown in ***Figure 3***. The wing board comprises the XENSIV™ BGT6UTR11AIP radar sensor, and the required power supply components. Power lines are highlighted in red. It is also equipped with push buttons and LEDs.

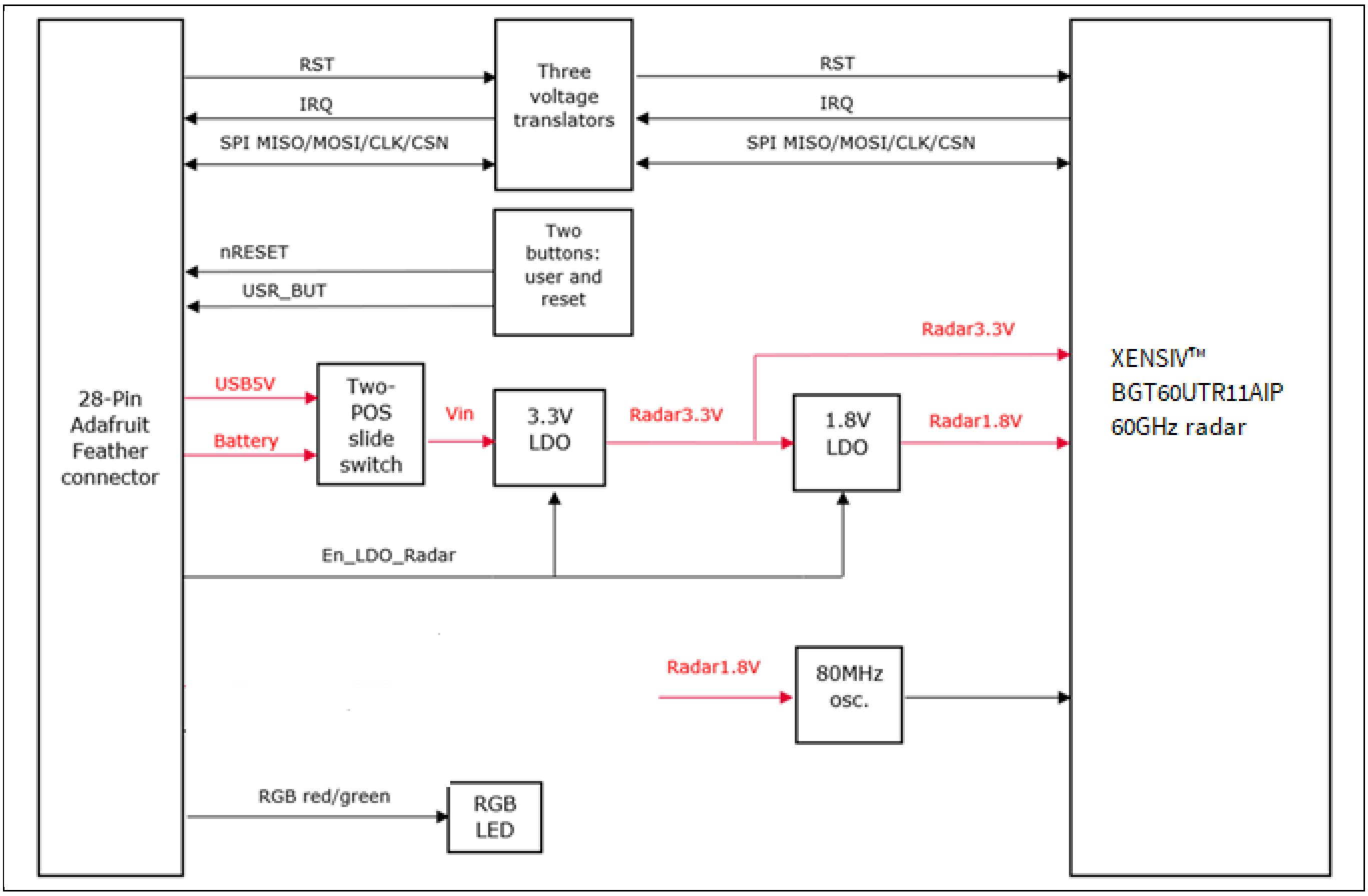


Figure 3: XENSIV™ BGT60UTR11AIP radar wing block diagram

A system block diagram showing the shield connected to the CSK rapid IoT baseboard is depicted in **Figure 4**. The interface from the shield to the rapid IoT baseboard includes I2C, 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.

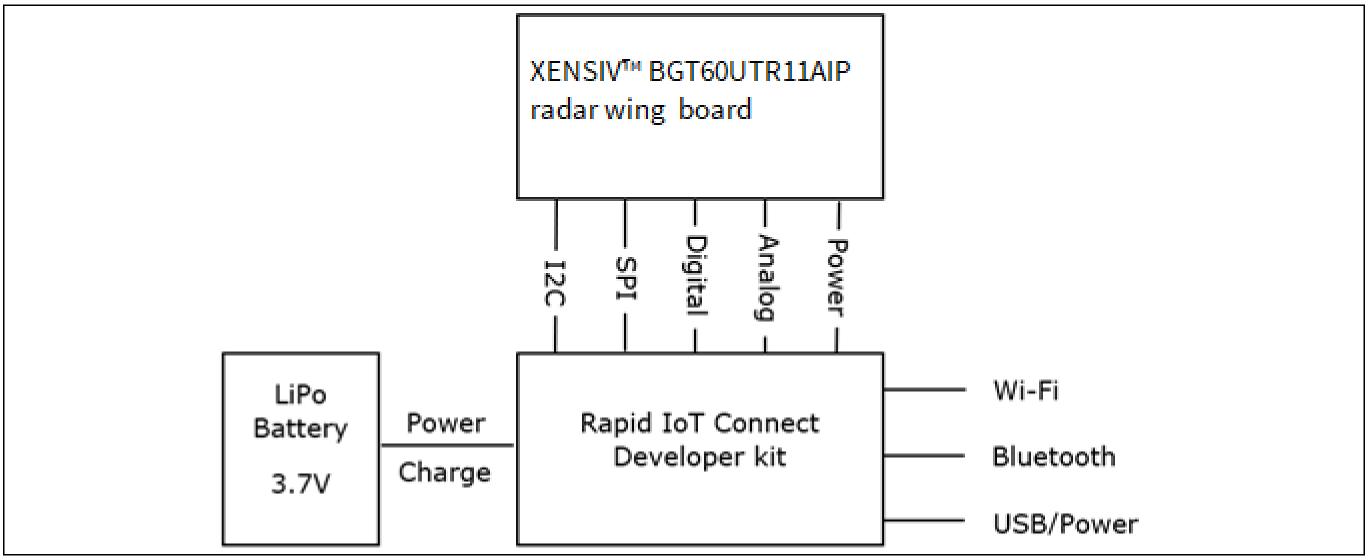


Figure 4: CSK system block diagram

2.5 Getting Started

This guide will help you to get acquainted with the XENSIV™ BGT60UTR11AIP radar wing:

- The CYSBSYSKIT-DEV-01 rapid IoT connect developer kit requires ModusToolbox™ 3.0 or higher to design and debug applications. Download and install ModusToolbox™ from https://www.infineon.com/cms/en/design-support/tools/sdk/modustoolbox-software . See the ModusToolbox™ Installation Guide and ModusToolbox™ IDE Quick Start Guide for additional information.
- The **Getting Started with ModusToolbox™** chapter describes example codes based on ModusToolbox™ to extract presence values readouts from the wing board.
- The **Hardware description** chapter describes the major hardware (HW) features of the XENSIV™ BGT60UTR11AIP radar wing.
- The Appendix provides a detailed HW description, and the bill of materials (BOM)

2.6 Abbreviations

Table 1:Abbreviation used in this document

Abbreviation	Description
BSP	Board support package
CSK	Connected sensor kit
GPIO	General-purpose input/output
HW	Hardware
I^2C	Inter-integrated circuit
IoT	Internet of Things
LED	Light-emitting diode

Abbreviation	Description
PAS	Photoacoustic spectroscopy
PCB	Printed circuit board
PSoC	Programmable system-on-chip
SPI	Serial peripheral interface
UART	Universal asynchronous receiver transmitter

3 Build your own application

The XENSIV™ BGT60UTR11AIP radar wing is supported by the xensiv-radar-sensing libraries. Code examples using these libraries are available in ModusToolbox™.

3.1 XENSIV™ BGT60UTR11AIP radar sensor library

This library provides APIs that enable the user to use existing radar applications such as presence detection, or build applications on top. The library uses the ModusToolbox™ HAL interface. Refer to the README.md file for more details.

https://github.com/Infineon/xensiv-radar-sensing

3.2 Code examples

The code examples demonstrate presence detection use cases implemented using the xensiv-radar-sensing library. Refer to the README.md file

https://gitlab.intra.infineon.com/wpp/ce/mtb/mtb-example-psoc6-radar-presence/-/tree/topic/SPEAR-914

3.2.1 Getting Started with ModusToolbox™

1. ModusToolbox™ software is a free development ecosystem that includes the ModusToolbox™ IDE. Using ModusToolbox™ IDE, you can enable and configure device resources, middleware libraries, and program and debug the device. You can download the software from the **ModusToolbox™ home page**. See the ModusToolbox™ user guide for additional information.
2. Open the **modushell** and use the following function git function to clone the project to the particular library(mtb-example-psoc6-radar-presence) to any desired folder

   git clone git@gitlab.intra.infineon.com:wpp/ce/mtb/mtb-example-psoc6-radar-presence.git
3. After cloning the project to a folder use the cd(change directory) to move into the clone repo

   cd mtb-example-psoc6-radar-presence
4. Use the following function to check the current state of your repository including the tracked and untracked files, modified files and branch information

   git status

   Note: by default, the repository will be pointing out to the default develop branch
5. Then check out to the particular branch where the repo is located

   git checkout topic/SPEAR-914
6. Use the pull command to update the repo with the necessary folders

   git pull

   N.S: To crosscheck whether you are in the specified branch use the git status function as explained in step 4

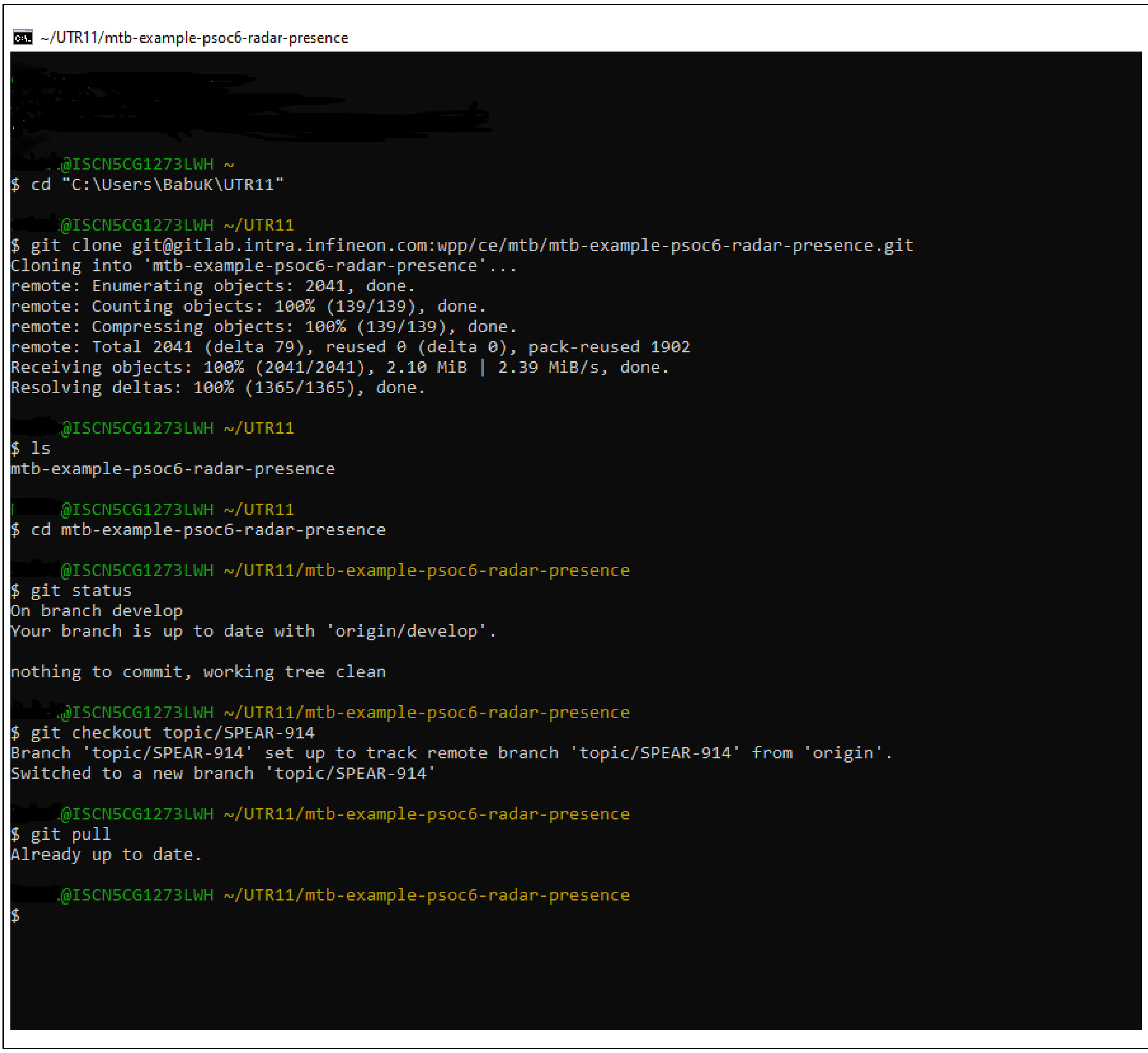


Figure 5: Modus Shell Functions

To get started:

1. In the ModusToolbox™ IDE, import the desired code example (application) into a new workspace.
   - Click on New application from quick panel

Figure 6 :ModusToolbox™ – new application

– Select CYSBSYSKIT-DEV-01 in the choose Board Support Package (BSP) window and click Next, as shown in below figure.

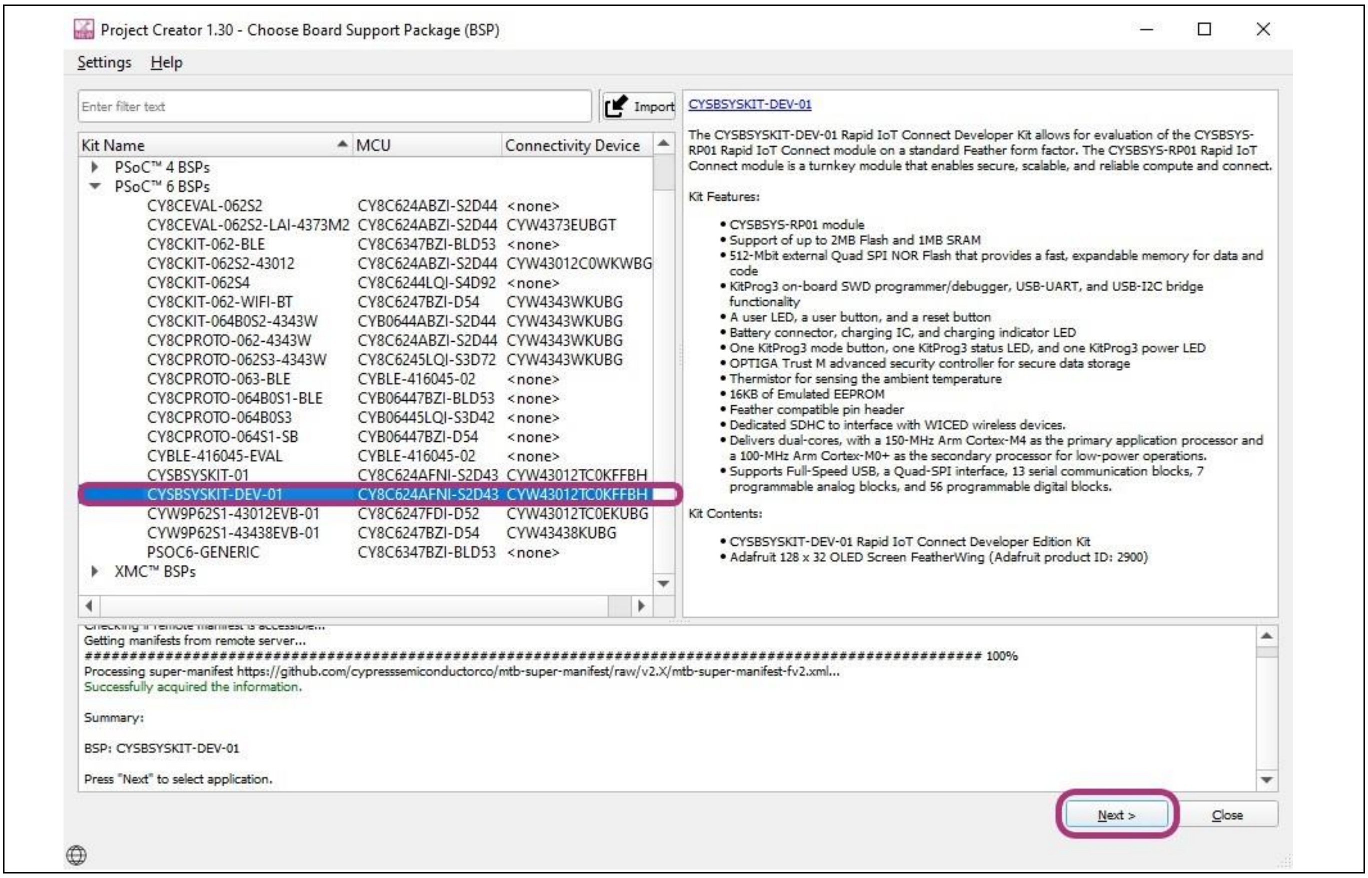


Figure 7: Select development kit

- Import the application to the modus toolbox IDE from the cloned repo as mentioned in step 6

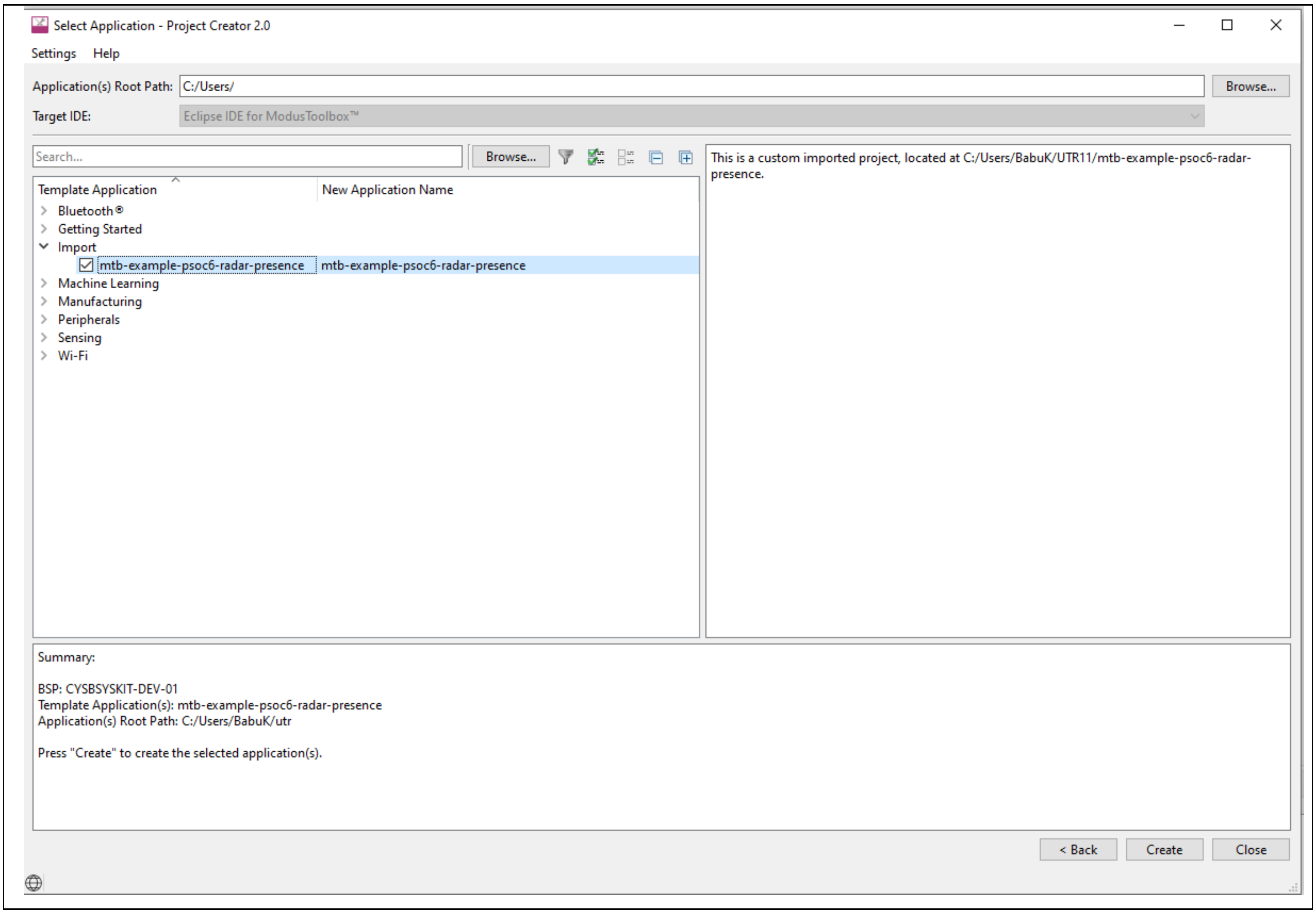


Figure 8: Importing the application

2. To build and program the application, in the Project Explorer, select project. In the quick panel, scroll to the launches section and click the Program (KitProg3_MiniProg4) configuration.
3. ModusToolbox™ has an integrated debugger. To debug a PSoC™ 6 MCU application, in the Project Explorer, select project. In the quick panel, scroll to the launches section and click the Debug (KitProg3_MiniProg4) configuration.

4 Presence detection solution

The Infineon radar presence detection solution detects both macro- and micro-motions in a configurable range using the XENSIV™ BGT60UTR11AIP radar sensor. This user guide describes the required SW and HW, including how to set up and get started with the Infineon radar presence detection solution using the CSK. Please refer to the CSK user manual for more details on the CSK. Additional documents are available and these are listed at the end of this document.

4.1 Radar for presence detection

What if there was a solution that could detect the tiniest movements without requiring an opening in the product housing?

Infineon's radar presence detection solution enables the detection of human presence within a configured range. Enabled by Infineon XENSIV™ BGT60UTR11AIP radar (60 GHz radar, antenna-in-package) with its sophisticated radar presence detection algorithms, this solution provides extremely high accuracy in detecting both macro- and micro-movements.

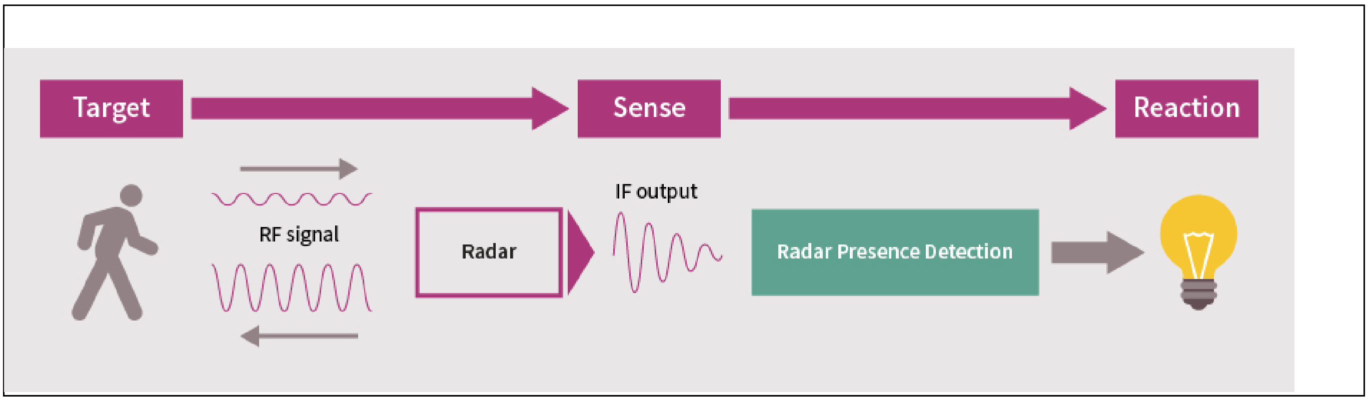


Figure 9: CSK motion detection using 60GHz radar sensor

4.2 Presence detection application

Presence detection is an application of a radar system, where the radar can detect targets in a specified vicinity. Specifically, the radar detects targets within an angle coverage up to a certain distance. Parameters such as maximum distance can be configured through the radar settings. Presence detection can be further utilized for applications such as keywordless authentication or automatic interaction of smart devices with the user. **Figure 10** shows a high-level representation of presence detection.

Infineon's presence detection algorithm consists of a state machine comprising the following two states:

- Absence state
- Presence state

A state machine is a mathematical model of computation and can be in exactly one of the finite number of states at a given time.

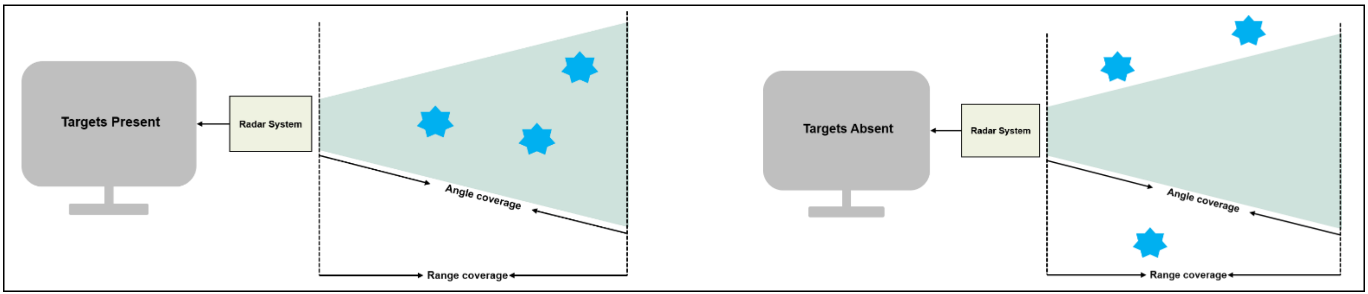


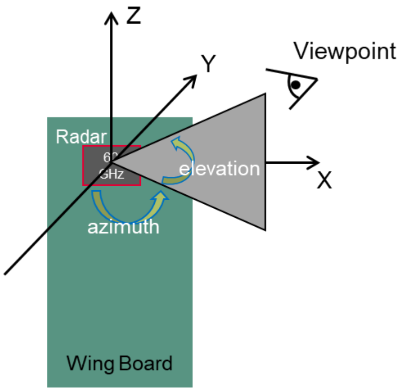
Figure 10:Presence detection principle

4.3 Key benefits

- Ready-to-use radar solution for presence sensing with adjustable detection range and sensitivity
- Ability to detect micro-movements
- Radar sensor immune to environmental factors such as temperature, wind, sunlight and dust/debris
- A fully tested and verified solution for presence sensing for home, office and commercial buildings

4.4 Key specification-presense detection solution

Table 2:Key specification-presense detection solution

Moving object size	Detect moving objects with a minimum height of 1 m
Field of view and radar orientation	• Azimuth: ± 60 degrees, elevation: ± 60 degrees • Radar chip mounted in front-facing orientation at 1 to 1.5 m height from the floor *Note: Front-facing orientation example – radar wing board mounted on a wall with radar chip on the top side of the board as shown below.* 
Movement detection range	• Maximum supported moving object speed (m/s): 2 m/s • Macro-motion range (regular human movements): minimum: 0.5 m, maximum: less than or equal to 10 m Micro-motion* detection range: minimum: 0.5 m, maximum: less than or equal to 5 m • Static objects (non-living) are not detected 1. **Micro-motions:* *Stationary human (normally breathing and blinking eyes) in sitting or*

Moving object size	Detect moving objects with a minimum height of 1 m
	standing positions (in line of sight) with no active movements for at least 30 s – working on laptop/keyboard, reading book, etc.
Detection timings	• Able to detect presence and absence (less than or equal to 1 s for presence) when at least one moving object is present in the field of view 1. Declaration of presence/absence states is configurable (time) along with the ability to introduce constant delays (1 to 30 s) before absence state is activated
Configurability	Easy configuration options via radar presence code example using UART port to change various parameters (detection range, sensitivity).
Target platform	CSK comprising: • Rapid IoT connect developer kit (CYSBSYSKIT-01): based on PSoC® 6 (ARM® Cortex®-M4F) • XENSIV™ BGT60UTR11AIP radar wing
CPU and memory consumption	CPU: less than 10 percent (target platform), RAM usage: less than 100 kB, Flash: less than 256 kB
HW interface	Presence information is available via UART or GPIO, with optional provision for SPI/I²C as well using radar presence code example
Certifications	Presence solution is FCC certifiable. Recommended radar settings and test report using an embedded reference form factor board could be provided on request.
Test conditions	• Radar board mounted at height of 1 to 1.5 m from the ground in front-facing orientation (radar sensor on the top side) • Test subject height ~1.7 m • Ambient temperature: 18 to 24°C RH: 35 to 70 percent
Target applications	Homes, offices, commercial buildings

4.5 Mounting guidelines and coverage

The following mounting guidelines are recommended for the HW unit (radar wing board and rapid IoT connect developer kit) of the CSK:

- Mount it on a wall or tabletop at 1 to 1.5 m height from the ground.
- Unit should be mounted in such a way that the radar wing board is in front-facing orientation (radar chip on top side).
- Ensure that the maximum range parameter is set properly (e.g., set the value lower than the distance to the opposite wall in order to avoid reflection).
- With the above conditions met, below is a representative coverage map created in open space based on around 1.7 m test subject at standard room temperature and humidity conditions.

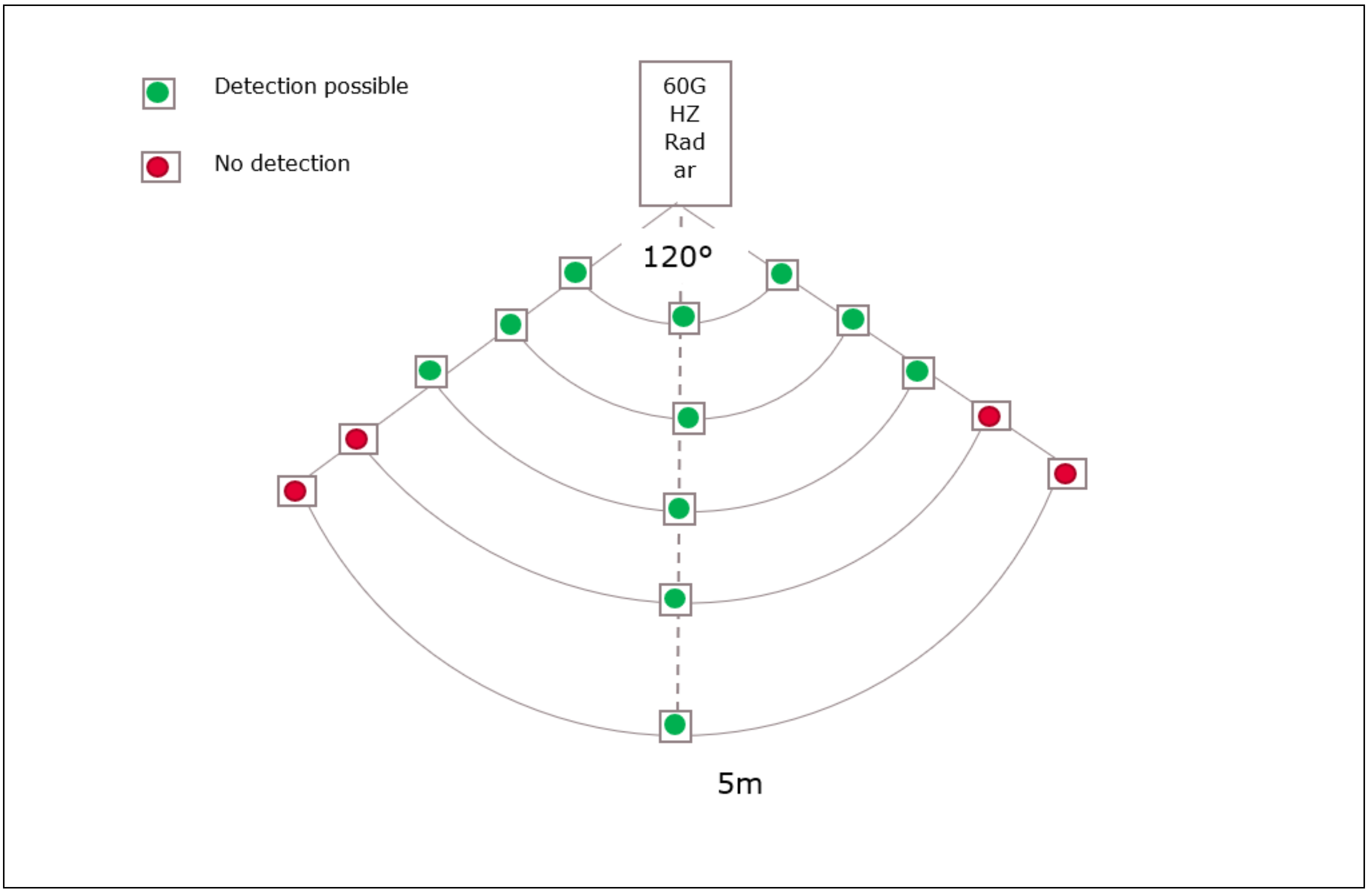


Figure 11: Representative coverage map of radar sensor for certain Known limitation and recommendation

4.5.1 Known limitation

- The presence detection solution is verified using CSK HW as a reference platform. It is provided as part of the CSK offering primarily for evaluation purposes on an "as is" basis (no liability/warranty). The user is responsible for evaluating, adapting and qualifying it as part of their products for their intended applications.
- CSK HW (rapid IoT baseboard, sensor wing boards) is provided as a reference platform (functionally verified but not qualified), enabling functional tests only for development purposes. It is not aimed at supporting qualification tests and reliability assessments.
- The current verification is done for front-facing wall-mount configuration, HW mounted (vertical orientation with radar sensor on top side) at a height so that it covers the torso area of most adults. It is recommended to mount the radar board at a height of 1.1 to 1.4 m for the best results.
- The presence detection application provides primarily "presence" or "absence" outputs when at least one person is there within the active zone (+/- 60-degree azimuth, +/- 60-degree elevation, up to configured range) for front-facing radar orientation. It doesn't yet support segmentation, angle data, people counting and positioning information.
- The current solution detects presence in case of motion irrespective of the type of moving objects (e.g., humans, pets, service robots, etc.).
- The maximum range parameter can be set up to 10 m. However, verification testing has been done primarily for a maximum range of 5 m.

- The detection range might reduce at angles depending on the sensitivity setting being used. For example, with the default settings using medium sensitivity at [+60 degrees, -60 degrees], macro-movement detection range might reduce to 3.5 to 4 m, whereas micro-movement detection range might reduce to 3.3 to 3.8 m. Higher-sensitivity settings help in achieving longer ranges at angles.
- Elimination of target detection through the wall is not supported in this release.
- The solution is not designed/optimized for presence detection through glass walls.

4.6 Recommendations

- It is recommended to set the maximum range parameter based on the room size. The user should avoid setting longer ranges for smaller rooms (e.g., 5 m maximum range for a room length of 3 m), as it might result in false presence detection caused by multiple reflections.
- The solution might react to certain moving conditions (e.g., moving curtains, plant movements, facing a wall within its active zone, etc.) so, for the time being, the user is recommended to either install it in a location where such conditions can be avoided, or adapt the maximum range accordingly.
- For optimal results, the user is recommended not to install a reference HW board in corners where the radar chip is facing a side wall, to avoid multiple reflections.

5 Hardware description

This chapter introduces you to various features of the XENSIV™ BGT60UTR11AIP radar wing. Apart from the headers, all components are mounted on the top side of the wing board. The wing board has male headers facing downward to either plug the wing board directly into the rapid IoT baseboard or on top of another wing board such as the Infineon XENSIV™ PAS CO_2 wing board.

5.1 Wing board components

Figure 12 and **Figure 13** describe the components mounted on the XENSIV™ BGT60UTR11AIP radar wing.

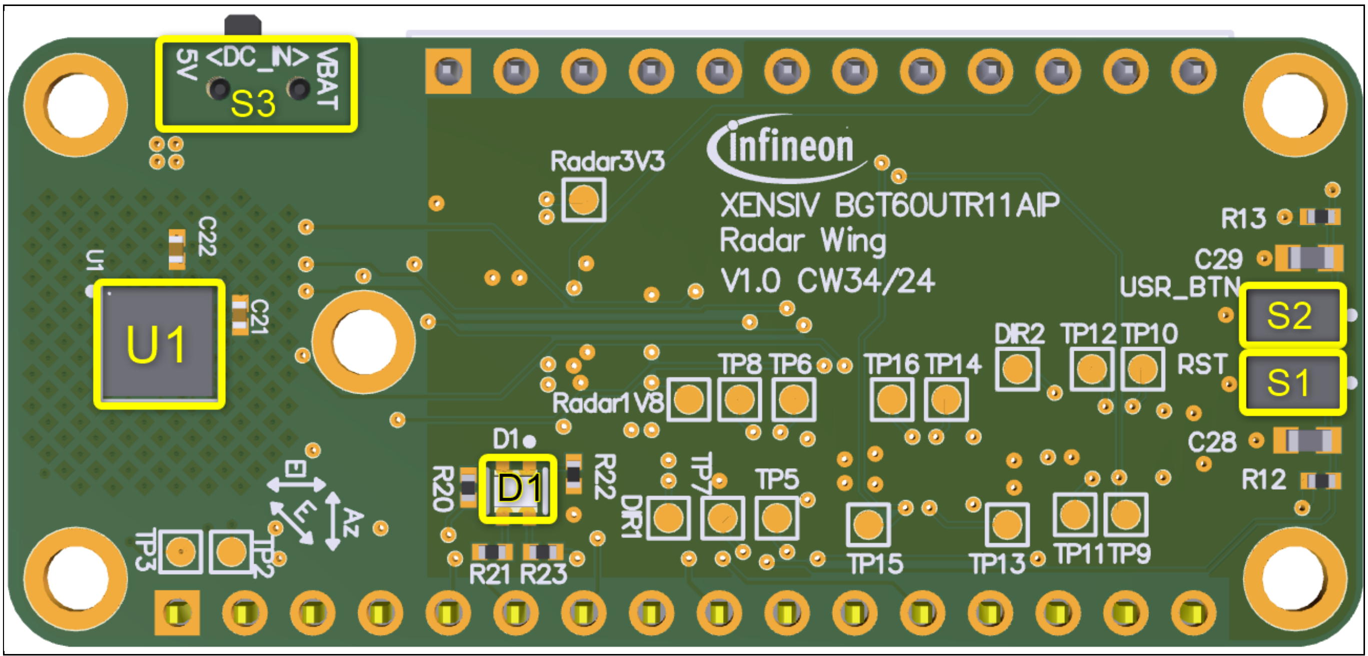


Figure 12: Front view of the BGT60UTR11 radar wing

Table 3:Onboard HW description

Designator	Function
U1	XENSIV™ BGT6UTR11AIP
X1	80.0000 MHz CMOS oscillator
D1	Tri-colored LED
S1	System reset button, active low
S2	User button, active low
S3	To select the board power supply from CYCBSYSKIT-DEV-01 rapid IoT baseboard: USB5V or from lithium battery supply of the kit
J1 J2	Adafruit headers

5.2 Adafruit feather-compatible connectors

Figure 6 highlights the 28-pin Adafruit feather-compatible adaptor headers. The function of the respective header pins is described in Table 3. The image also shows the test points which were used for testing the boards in the lab or production.

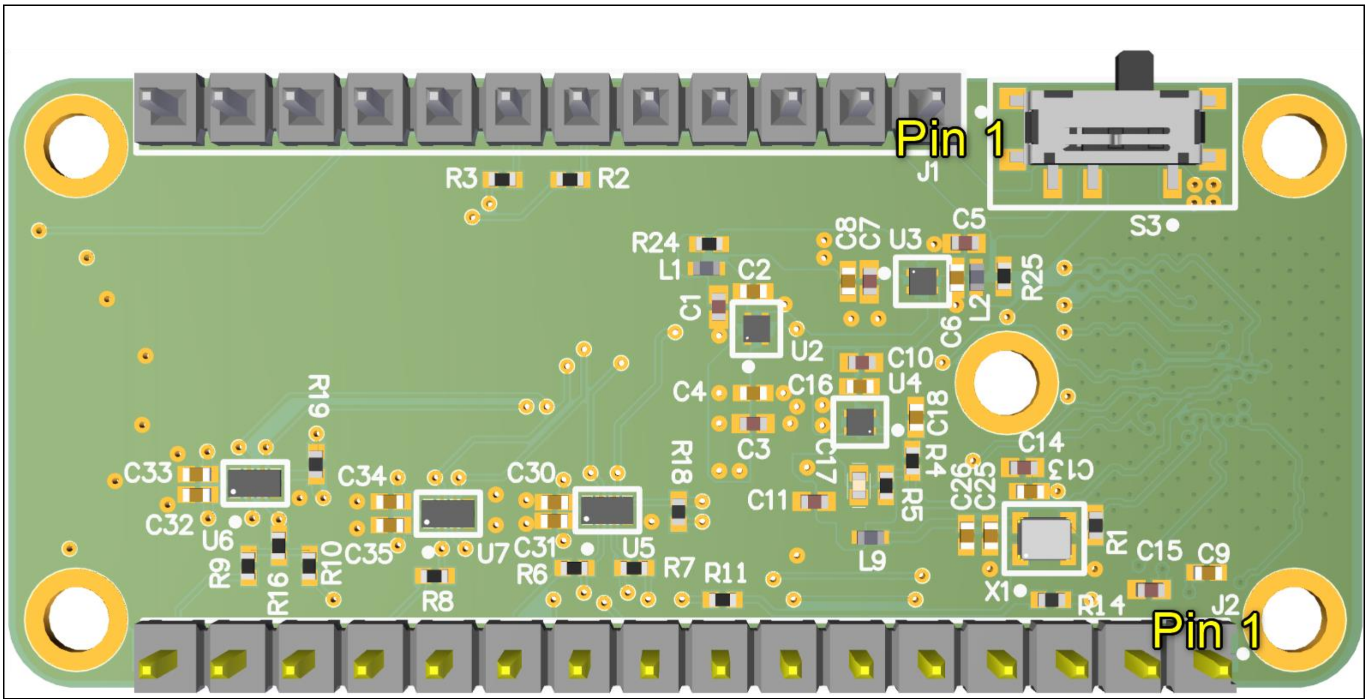


Figure 13:Adafruit headers and test points on the back view of the XENSIV™ BGT6UTR11AIP radar wing

Table 4: Adafruit feather-compatible pin-out

Header mapping	Primary onboard function	PSoC 6 MCU pin (rapid IoT baseboard)	Adafruit feather-compatible mapping (rapid IoT baseboard)	Adafruit feather-compatible mapping (radar wing board)	Details
J1.1	V_{BAT}	–	–	VBAT	LiPo battery voltage
J1.2	EN	–	–	–	Not connected
J1.3	V_{BUS}	–	–	5 V	USB power
J1.4	GPIO	P9_0	GPIO13	–	Not connected
J1.5	GPIO	P9_1	GPIO12	–	Not connected
J1.6	GPIO	P9_2	GPIO11	RST_Feather	RST
J1.7	GPIO	P9_3	GPIO10	IRQ_Feather	IRQ
J1.8	GPIO	P9_4	GPIO9	–	Not connected
J1.9	GPIO	P9_7	GPIO6	USR_BUT	User button
J1.10	GPIO	P8_4	GPIO5	en_LDO_Radar	Enable the LDOs (3.3 V and 1.8 V) on radar wing board for radar sensor

Header mapping	Primary onboard function	PSoC 6 MCU pin (rapid IoT baseboard)	Adafruit feather-compatible mapping (rapid IoT baseboard)	Adafruit feather-compatible mapping (radar wing board)	Details
J1.11	I^2C SCL	P6_0	SCL	I2C_SCL_Feather	Connected to KitProg3. Note that this pin has a 4.7k pull-up for I^2C communication.
J1.12	I^2C SDA	P6_1	SDA	I2C_SDA_Feather	Connected to KitProg3. Note that this pin has a 4.7k pull-up for I^2C communication.
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	SPI_CSN_Feather	SPI chip select
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		Not connected

5.2.1 Power supply

The kit can be powered from a 3.7 V 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 18:Board power selection (S3)Figure 18**).

5.2.2 Mechanical buttons

Table 5:Mechanical Buttons

Abbreviation	Description
S1	System reset
S2	User button – executed function can be individually programmed by user

Appendix A: Hardware design

The design of the shield was realized using the Altium PCB design tool. The Altium design files are available on request.

A1. Schematics

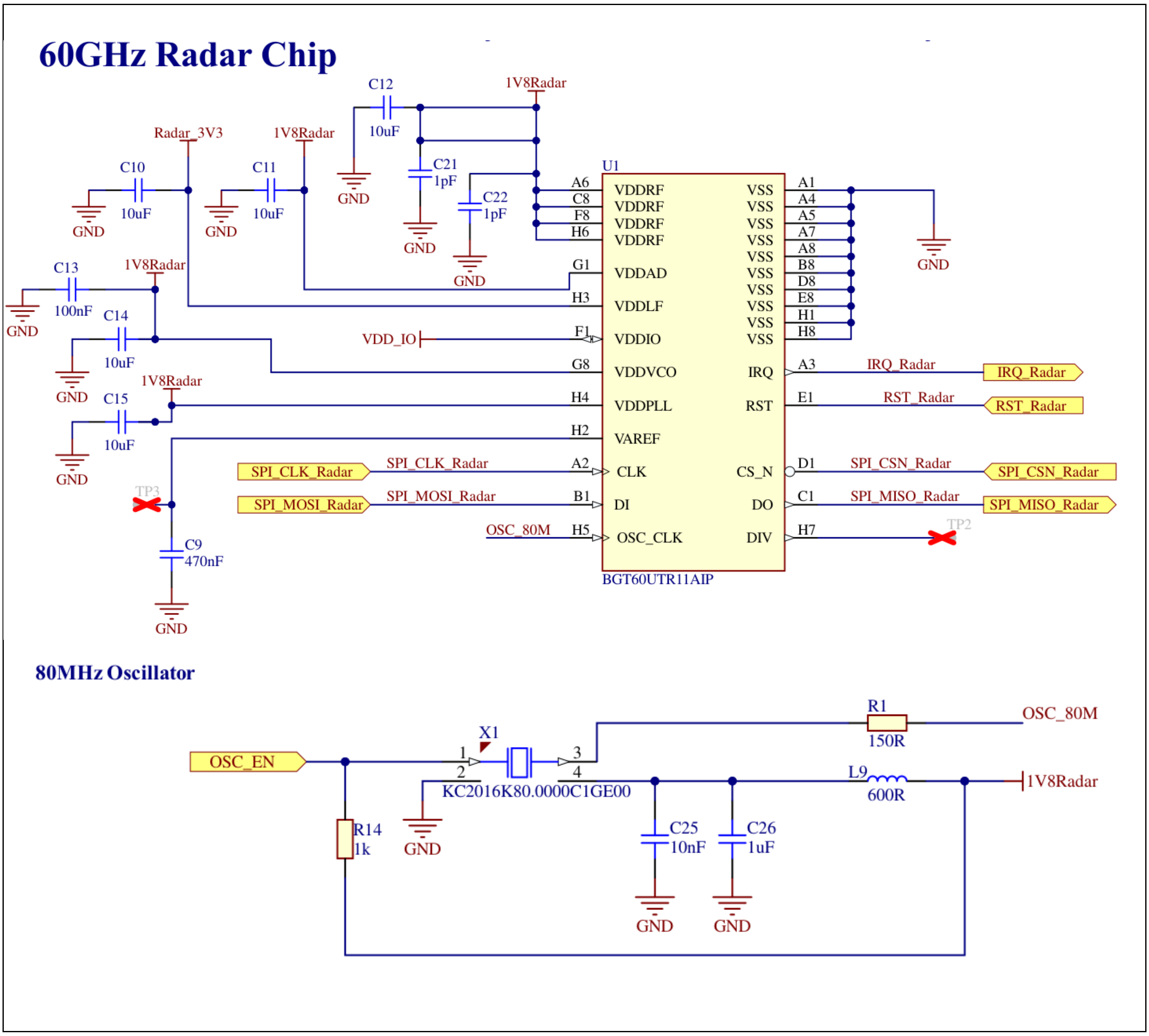


Figure 14:Schematic of XENSIV™ BGT60UTR11AIP radar with 80 MHz oscillator

A1.1 Adafruit feather-compatible headers

Figure 15 shows the pin assignment of J1 and J2 on the XENSIV™ BGT60TR13C radar wing. The Adafruit feather-compatible header is used to plug into the CYCBSYSKIT-DEV-01 rapid IoT connect developer kit.

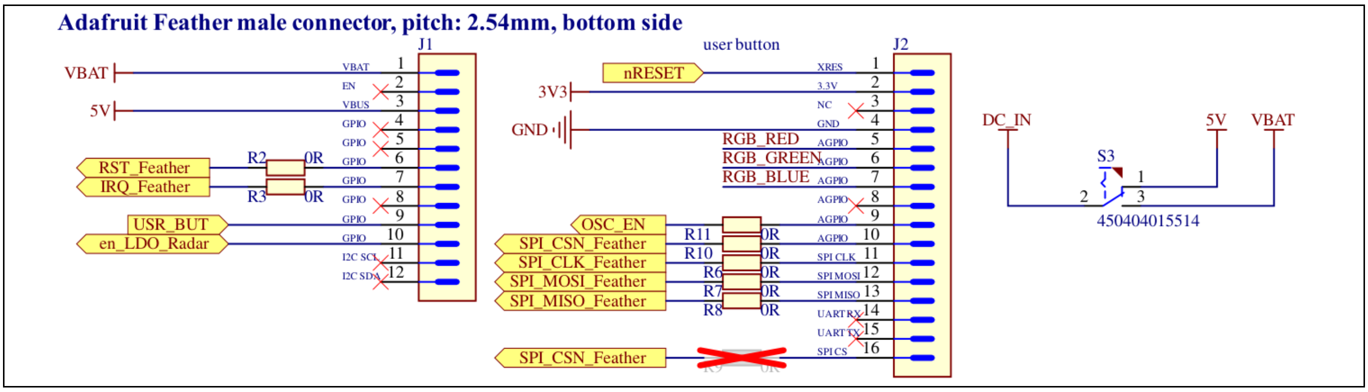


Figure 15:Schematic of Adafruit headers

A1.2 User interface (buttons, LEDs)

The user interface on the wing board consists of two mechanical buttons and three LEDs.

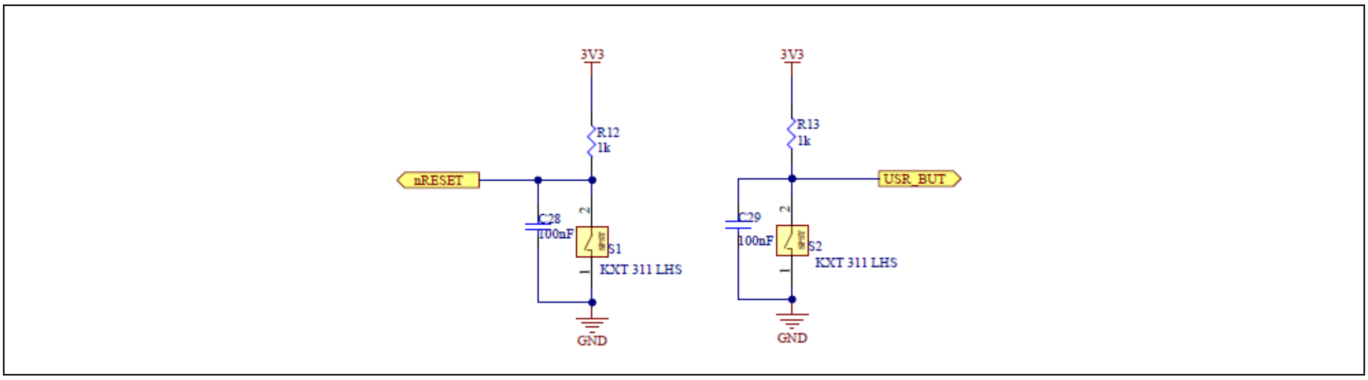


Figure 16:Schematic of reset (S1) and user button (S2)

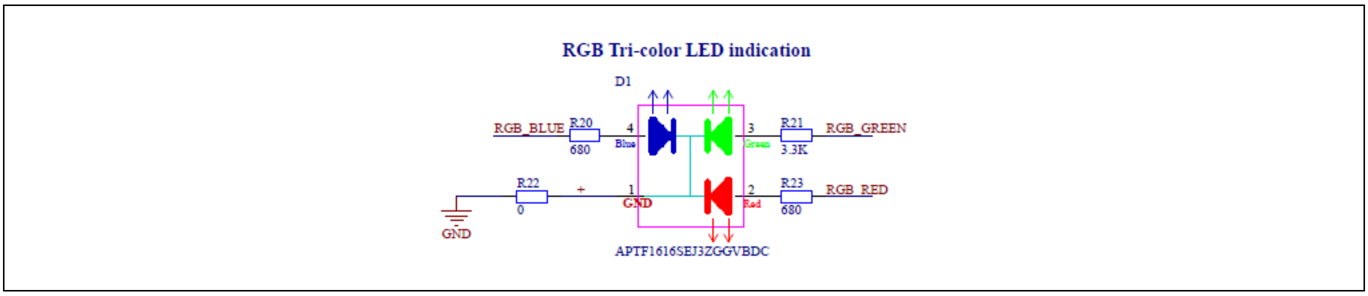


Figure 17:Schematic of LEDs

A1.3 Others

shows the board power selection.

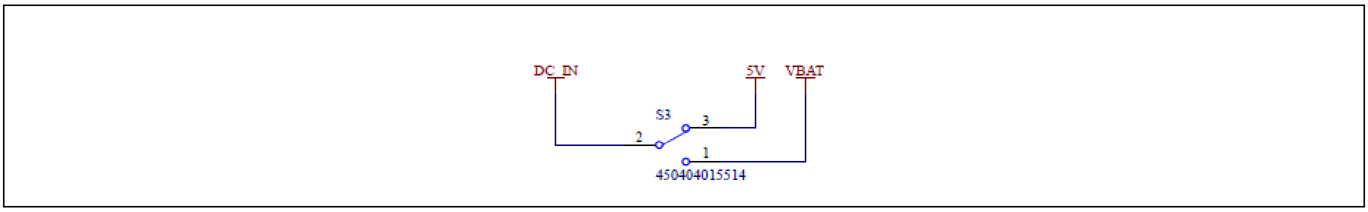


Figure 18:Board power selection (S3)

shows the voltage regulator circuit to provide stable power supply to the radar sensor.

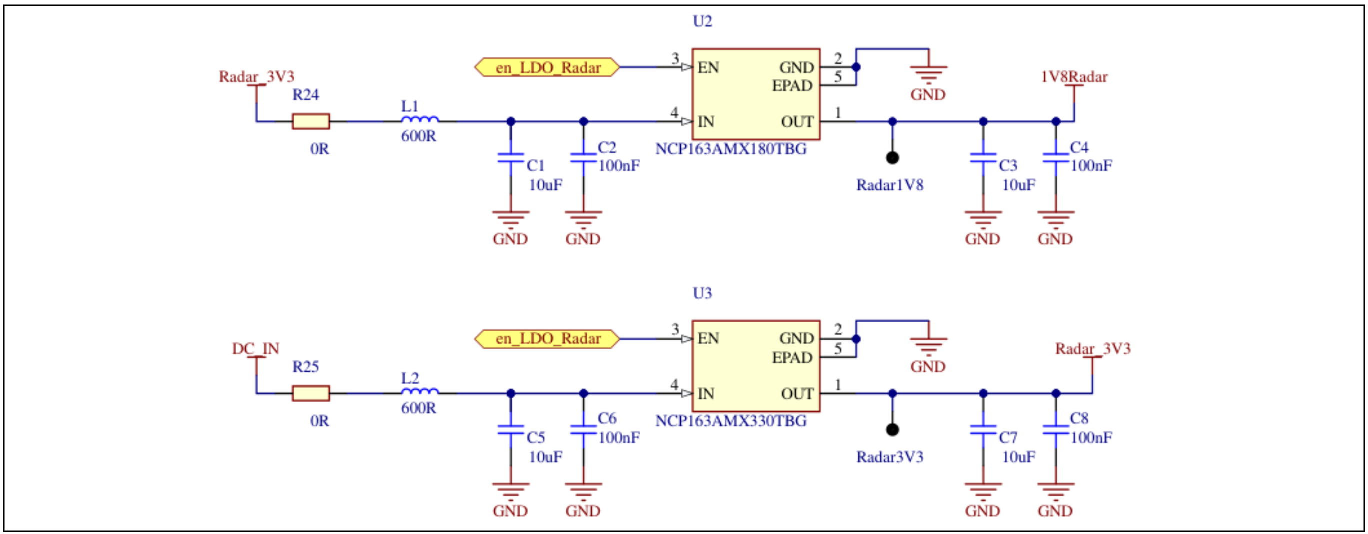


Figure 19:Voltage supply for radar sensor

shows the filter circuit to keep the radar power supply free from spurious emissions.

A1. PCB layout

The size of the XENSIV™ BGT60TR13C radar wing is 43 mm (L) x 23 mm (W).

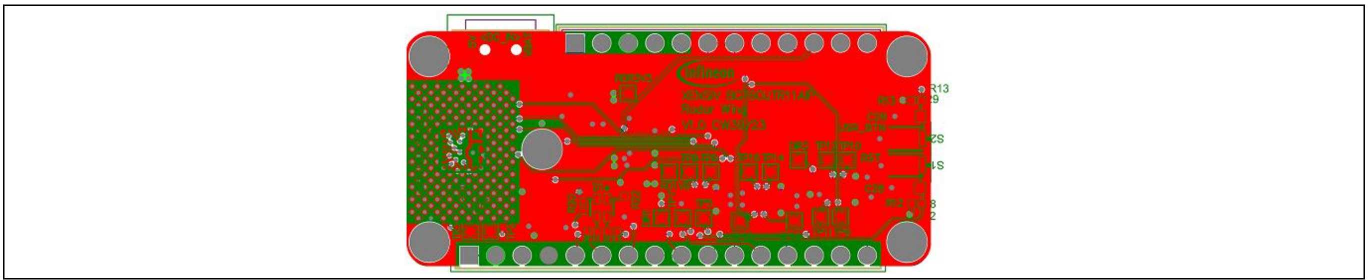


Figure 20:PCB layout of XENSIV™ BGT6UTR11AIP radar wing

B1. Bill of materials

Table 6: BOM

Value	Description	Designator	Manufacturer	Footprint	Part number	Quantity
10uF	10 µF ±20% 6.3V Ceramic Capacitor X6S 0402 (1005 Metric)	C1, C3, C5, C7, C10, C11, C12, C14, C15	Murata Electronics	CAPC1005 X70N	GRM155C80J106 ME11D	9
100nF	0.1 µF ±20% 10V Ceramic Capacitor X5R 0201 (0603 Metric) CAP CER 0.1UF 10V X7R 0201	C2, C4, C6, C8, C13, C30, C31, C32, C33, C34, C35	Murata Electronics	CAPC0603 X33N	GRM033R61A10 4ME15D, GRM033Z71A10 4KE14D	11
470nF	Ceramic capacitor 0.47 µF 10 V X6S 0201, LMK063BC6474KPLF	C9	Taiyo Yuden	CAPC0603 X39N	LMK063BC6474K PLF	1
1uF	1 µF ±20% 6.3V Ceramic Capacitor X7T **0201** **(0603** Metric)	C16, C18, C26	Murata Electronics	CAPC0603 X35N	GRM033D70J105 ME01D	3
10nF	10000 pF ±10% 10V Ceramic Capacitor X7R **0201** (0603 Metric)	C25	Murata Electronics	CAPC0603 X33N	GCM033R71A10 3KA03D	1
100nF	Ceramic capacitor 0.1 µF 6.3 V X7R 0603	C28, C29	KEMET	CAPC1608 X87N	C0603C104K5RA CTU	2
APTF16 16SEJ3 ZGGVB DC	Full-Color Surface Mount LED, 520nm, Green, Low power consumption	D1	KINGBRIGHT	LED-SMD-APTF1616 SEJ3ZGGV BDC	APTF1616SEJ3ZG GVBDC	1
Test points	Generic Surface Mount TP /w 1mm diameter	DIR1, DIR2, RD1V8, RDR3V3, TP2, TP3, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16	NA	TP	TP SMD	18
Header 12	Header, 12-pin, pitch 2.54 mm, vertical, single row	J1	Molex	HDRV12W 64P254_1 X12_3048 X254X898 B	TSW-112-07-L-S	1
Header 16	Header, 16-pin, pitch 2.54 mm, vertical, single row	J2	Molex	HDRV16W 64P254_1 X16_4070 X254X838 B	TSW-116-07-L-S	1
600 Ωs at 100 MHz ferrite bead	Ferrite bead 600 Ω at 100 MHz ferrite bead 0201 (0603 metric) 250 mA	L1, L2	Murata Electronics	INDC0603 X33N	BLM03AX601SN1 D	2

	850 mΩ					
600 Ω at 100 MHz ferrite bead	Ferrite bead 600 Ω at 100 MHz signal line ferrite bead 0402 (1005 metric) 200 mA 850 mΩ	L9	TDK Cooperation	INDC1005 X55N_MM Z1005	MMZ1005B601C T000	1
150R	Resistor SMD 150 Ω 1% 1/20 W 0201, AC0201FR-07150RL	R1	Yageo	RESC0603 X26N	AC0201FR-07150RL	1
0R	Resistor SMD 0 Ω jumper 1/16 W 0402 CRG0402ZR	R2, R3, R4, R6, R7, R8, R10, R11, R22, R24, R25	TE Connectivity Passive Product	RESC1005 X03N	CRG0402ZR	11
1k	Resistor SMD 1k Ω 5 percent 1/10 W 0402	R12, R13	Panasonic Electronic Components	RESC1005 X40N	ERJ-2GEJ102X	2
1k	ERJ-1GNF1001C, resistor SMD 1k Ω 1 percent 1/20 W 0201	R14, R18, R19	Panasonic Electronic Components	RESC0603 X26N	ERJ-1GNF1001C	3
0R	Resistor SMD 0 Ω jumper 1/20 W 0201, CRCW02010000Z0ED	R16	Vishay Dale	RESC1005 X03N	CRCW02010000Z 0ED	1
680R	RC0402JR-07680RL, resistor SMD 680 Ω 5 percent 1/16 W 0402	R20, R23	Yageo	RESC1005 X40N	CRCW0402680RF K	2
3.3K	3.3 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric)	R21	Panasonic Electronic Components	RESC1005 X40N	ERJ-2RKF3301X	1
KXT 311 LHS	KXT 311 LHS, tactile switch SPST-NO 0.02 A 15 V, KXT3 Series ultra low profile top actuated, 100 g, SPST	S1, S2	C&K	SW-SMD-KXT311LH S	KXT311LHS	2
Slide switch	Slide switch SPDT surface mount, 450404015514	S3	Würth Elektronik	SW-SMD-45040401 5514	450404015514	1
BGT60 UTR11 AIP	60 GHz Radar Sensor with Antennas in Package	U1	Infineon Technologies	BGT60UTR 11AIP	BGT60UTR11AIP	1
NCP16 3AMX1 80TBG	LDO Regulator, Ultra-Low Noise, High PSRR, RF and Analog Circuits	U2	ON Semiconducto r	ONSEMI-SMD-CASE 711AJ	NCP163AMX180 TBG	1

NCP163AMX330TBG	LDO Regulator Ultra-Low Noise, High PSRR, RF and Analog Circuits	U3	ON Semiconductor	ONSEMI-SMD-CASE 711AJ	NCP163AMX330TBG	1
NCP163AMX120TBG	LDO Regulator, Ultra Low Noise, High PSRR, RF and Analog Circuits	U4	ON Semiconductor	ONSEMI-SMD-CASE 711AJ	NCP163AMX120TBG	1
74AVC2T45	Dual Bit, Dual Supply Voltage Level Translator and Transceiver	U5, U6, U7	Nexperia USA Inc.	NXP-SMD-SOT833-1-1-V	74AVCH2T45GT	3
80MHz	Clock Oscillator, 80MHz	X1	Kyocera International Inc.	XTAL-SMD-KC2016K	KC2016K80.0000C1GE00	1

Revision history

Document revision	Date	Description of changes
V 1.0	17-02-2025	Initial Version

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