BGT60LTR11AIP autonomous reference board user guide

XENSIV™ radar sensors

About this document

Scope and purpose

This document describes the function, circuitry, and performance of the XENSIV™ BGT60LTR11AIP autonomous 60 GHz radar reference board (REF_BGT60LTR11AIP_AUT) V1.0. The board provides the supporting circuitry to the XENSIV™ BGT60LTR11AIP monolithic microwave integrated circuit (MMIC) with Antenna in Package (AIP).

Intended audience

This document is intended for design engineers, technicians, and developers of electronic systems, working with Infineon's XENSIV™ 60 GHz 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 radar MMICs with Antenna in Package (AIP) provide compact, high-precision, and low-power sensing solutions for IoT, smart home, and consumer applications.

Reference Board

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.

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.*

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1 Introduction

1.1 Overview

The XENSIV™ BGT60LTR11AIP MMIC is a fully integrated Antenna in Package (AIP) microwave motion sensor with built-in motion and direction of motion detectors. This small-sized radar solution is a compelling, smart, and cost-effective replacement for conventional passive infrared (PIR) sensors in low-power or battery-powered applications. The MMIC is designed to operate as a Doppler motion sensor in the 60 GHz ISM band.

The MMIC supports multiple operation modes, including autonomous and SPI modes. The MMIC has four quad-state (QS1–4) input pins that provide flexibility in performance parameters even when it is running in autonomous mode. See Section 4.

The BGT60LTR11AIP autonomous reference board works in autonomous mode, which is set using the QS1 pin. Autonomous mode offers flexibility in the configuration of radar MMIC parameters, such as detection threshold, hold time, and operation frequency. In autonomous mode, the required configuration can be set into the MMIC registers using QS1-4 and the integrated detectors also deliver digital outputs indicating motion and direction of motion.

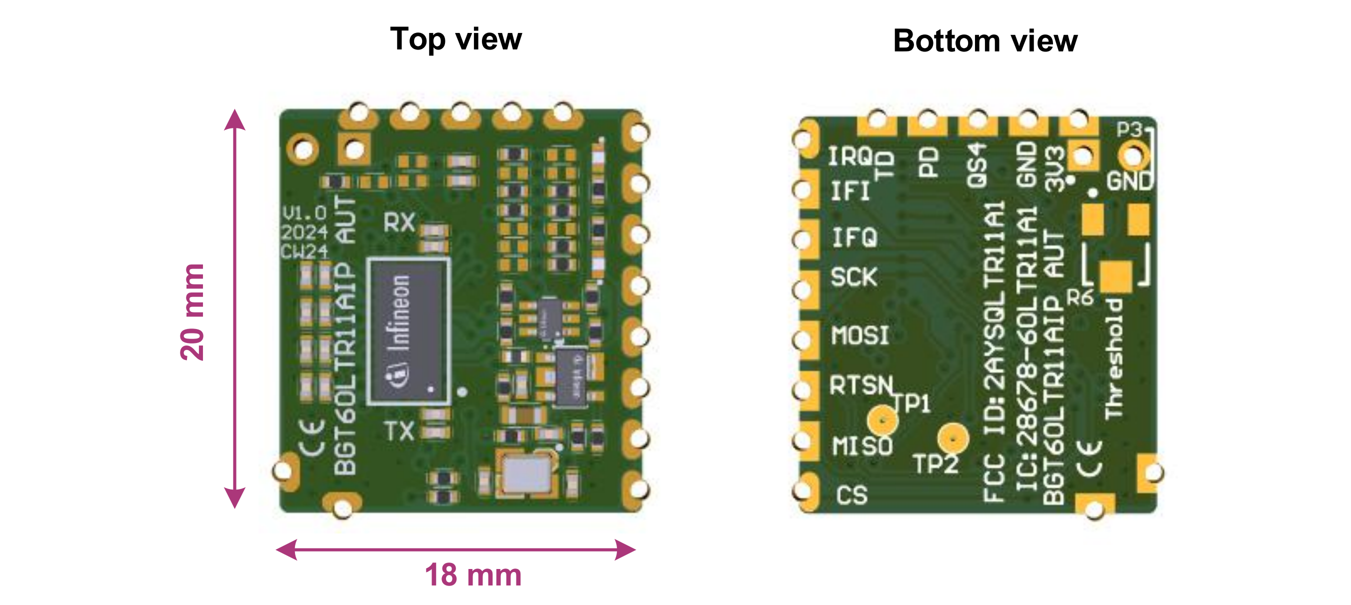


Figure 1 Top and bottom views of BGT60LTR11AIP autonomous reference board

1.2 Key features

The BGT60LTR11AIP autonomous reference board is optimized for initial product feature evaluation, fast prototyping design, and system integration. In addition, the sensor can be integrated into systems like laptops, tablets, TVs, and speakers to 'wake' them up based on motion (or direction of motion) detection, or to put them to sleep or auto-lock when no motion is detected for a defined amount of time. This way, it can be a smart power saving feature for these devices and might also eliminate the need for keyword-based activation of systems. Radar sensors can be concealed inside the end product because they operate through non-metallic materials.

A few key features of the BGT60LTR11AIP autonomous reference board are as follows:

- 20 mm x 18 mm form factor
- Features an AIP MMIC of small size (6.7 mm x 3.3 mm x 0.56 mm), thereby eliminating antenna design complexity at the user end
- Detects motion and direction of movement (approaching or departing) for a human target
- Works standalone (autonomous mode)
- Configurable settings like operation mode, detector threshold, hold time, and operating frequency via QS pins
- Quartz oscillator built on chip, only external quartz resonator required on the module. LDO on module (Vcc = VIN = 3V3)

2 System specifications

Table 2 BGT60LTR11AIP autonomous reference board specifications

Parameter	Unit	Min.	Typ.	Max.	Conditions/notes
System performance					
Maximum detection range	m	–	7	–	Typical motion detection range for human target at high sensitivity (in both E-plane and H-plane orientations)
Power supply					
Supply voltage	V	–	3.3	–	–
Current consumption	mA	–	5	–	At 5 V supplied via USB PRT = 500 µs, pulse width = 5 µs (LEDs off)
Antenna characteristics (measured)					
Antenna type	–	–	1 x 1	–	Antenna in Package (AIP)
Horizontal – 3 dB beam width (HPBW)	Degrees	–	80	–	At frequency = 61.25 GHz
Elevation – 3 dB beam width (HPBW)	Degrees	–	80	–	At frequency = 61.25 GHz

3 Hardware description

This section provides an overview of the board's hardware building blocks, such as BGT60LTR11AIP MMIC, microcontroller, power supply, crystal, and board interfaces.

3.1 Key features

The BGT60LTR11AIP autonomous reference board is a 20 mm x 18 mm PCB as shown in Figure 2. Mounted on top of the PCB is an Infineon XENSIV™ BGT60LTR11AIP 60 GHz radar sensor. The antennas are integrated into the chip package; therefore, the PCB can be manufactured using a standard FR4 laminate.

The board can be powered up by using the 3.3 V pins. One LDO is used for providing a clean supply to the components on the board. The MMIC uses a 38.4 MHz crystal (Y1) as an oscillator source with a stable reference clock. The connectors provide access to other important signals of the board. The board has two LEDs (D1 and D2) to output the results from the internal detectors. The block diagram of the board is shown in Figure 2.

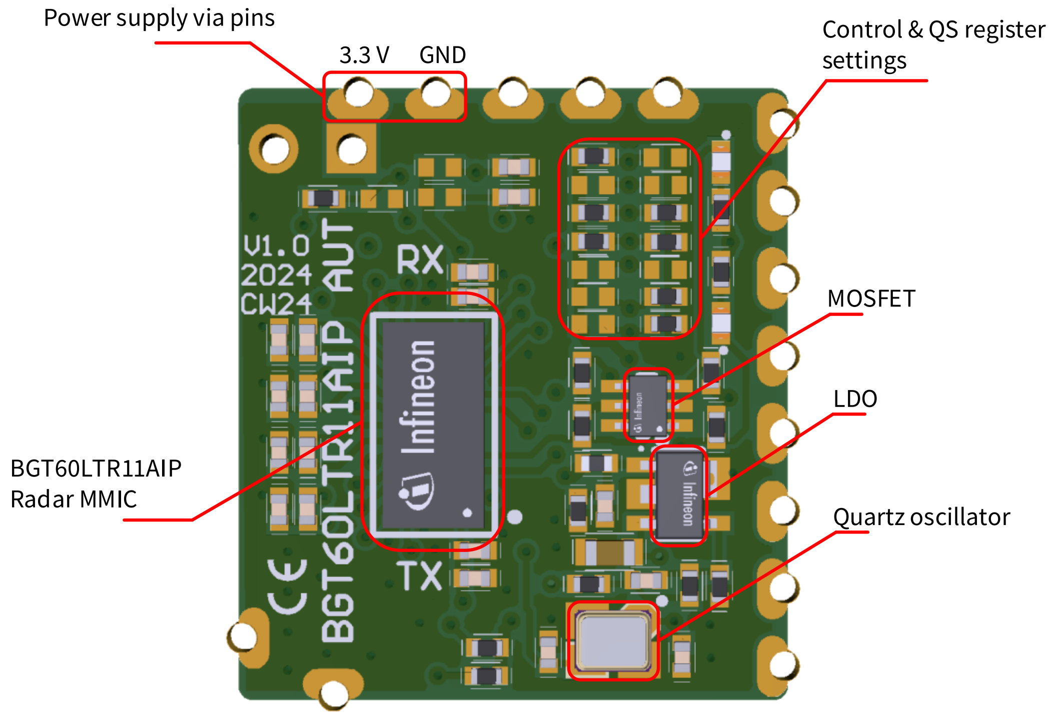


Figure 2 Components on BGT60LTR11AIP autonomous reference board

3.2 BGT60LTR11AIP MMIC

The BGT60LTR11AIP MMIC (Figure 3) is the main element on the BGT60LTR11AIP autonomous reference board. The MMIC has one transmit antenna and one receive antenna integrated into the package, as shown in Figure 4. The package dimensions are 6.7 mm x 3.3 mm x 0.56 mm, as shown in Figure 5.

The MMIC has an integrated voltage-controlled oscillator (VCO) and PLL for high-frequency signal generation. The transmit section consists of a medium power amplifier (MPA) with configurable output power, which can be controlled via SPI [3].

The chip features a low-noise quadrature receiver stage. The receiver uses a low-noise amplifier (LNA) in front of a quadrature homodyne down-conversion mixer to provide excellent receiver sensitivity. Derived from the internal VCO signal, an RC poly-phase filter (PPF) generates quadrature LO signals for the quadrature mixer.

The analog baseband (ABB) unit consists of an integrated sample-and-hold circuit for low-power duty-cycled operation. This is followed by an externally configurable high-pass filter, a variable gain amplifier (VGA) stage, and a low-pass filter.

The integrated target detector circuits in the MMIC use two digital signals (TDet and PDet) to indicate the detection of movement in front of the radar and the direction of movement. See Section 3.7 for more details. The detector circuit offers a user-configurable hold-time for maximum flexibility.

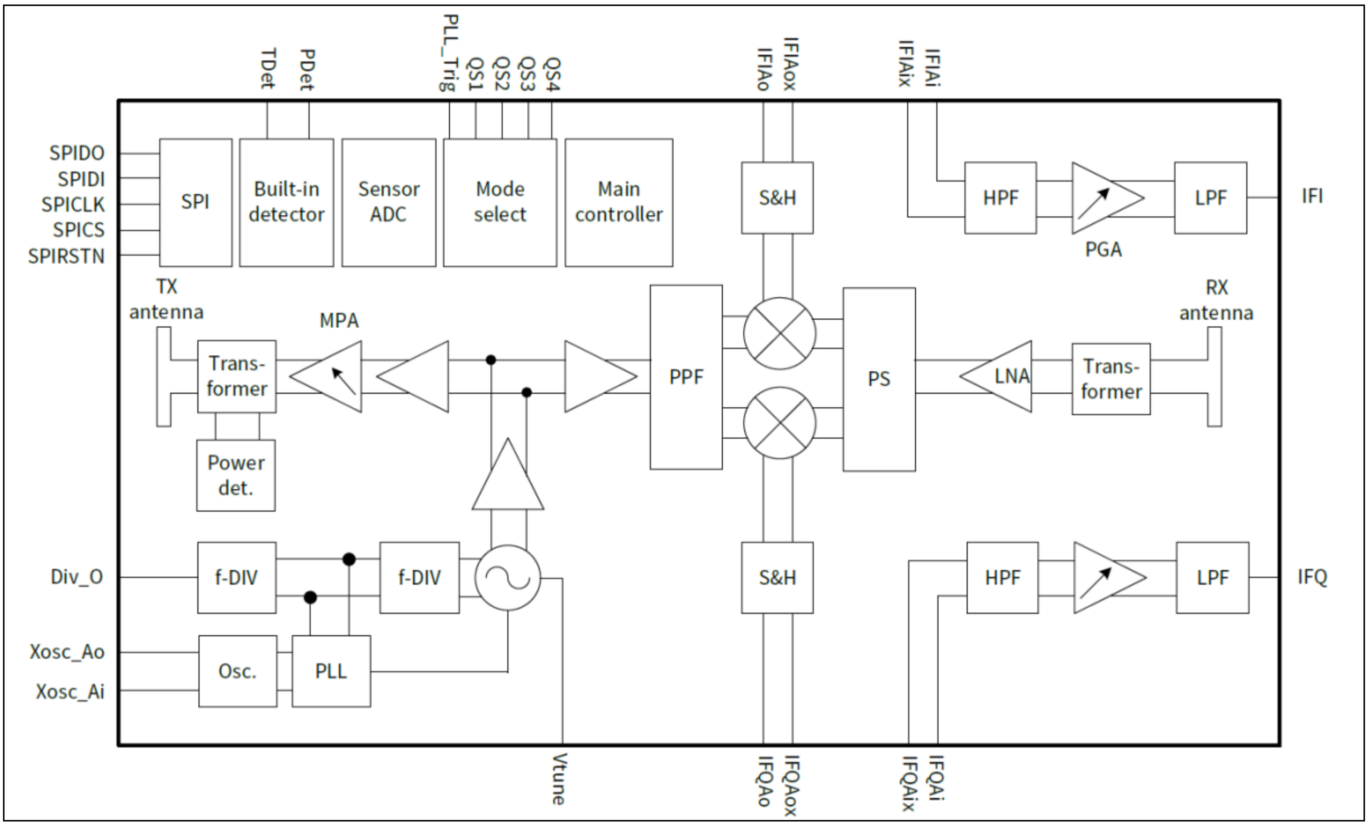


Figure 3 **BGT60LTR11AIP MMIC block diagram**

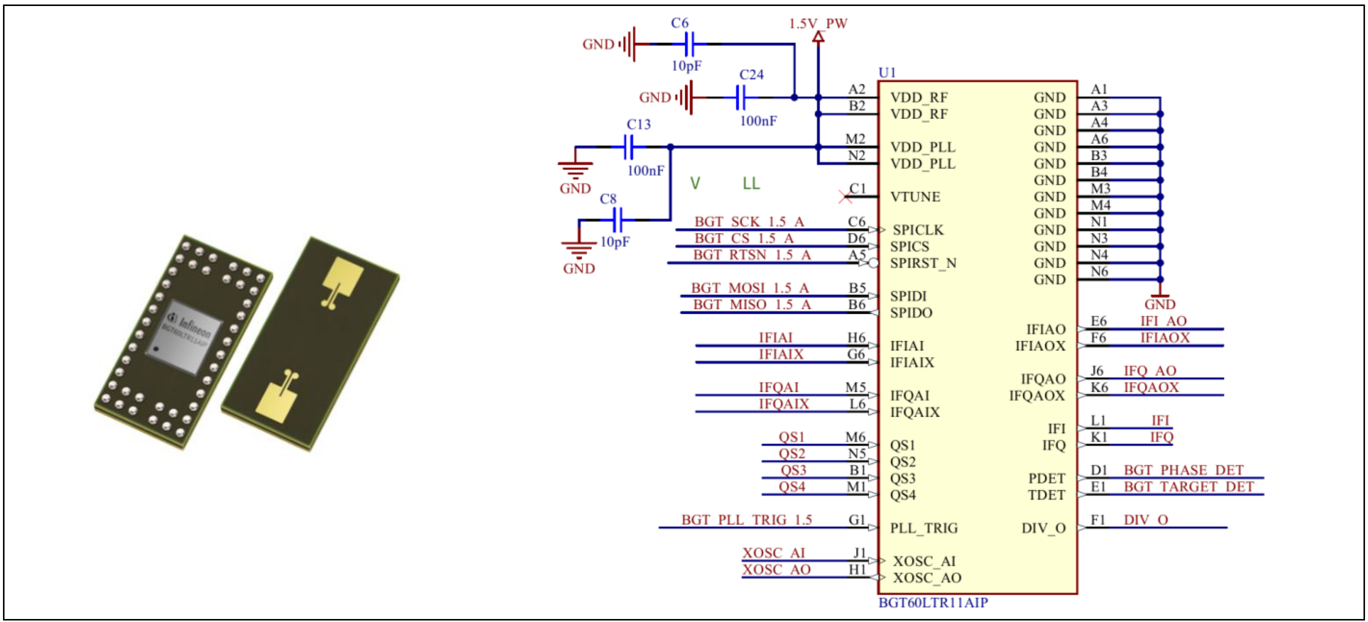


Figure 4 Package and pin-signal assignment of BGT60LTR11AIP MMIC

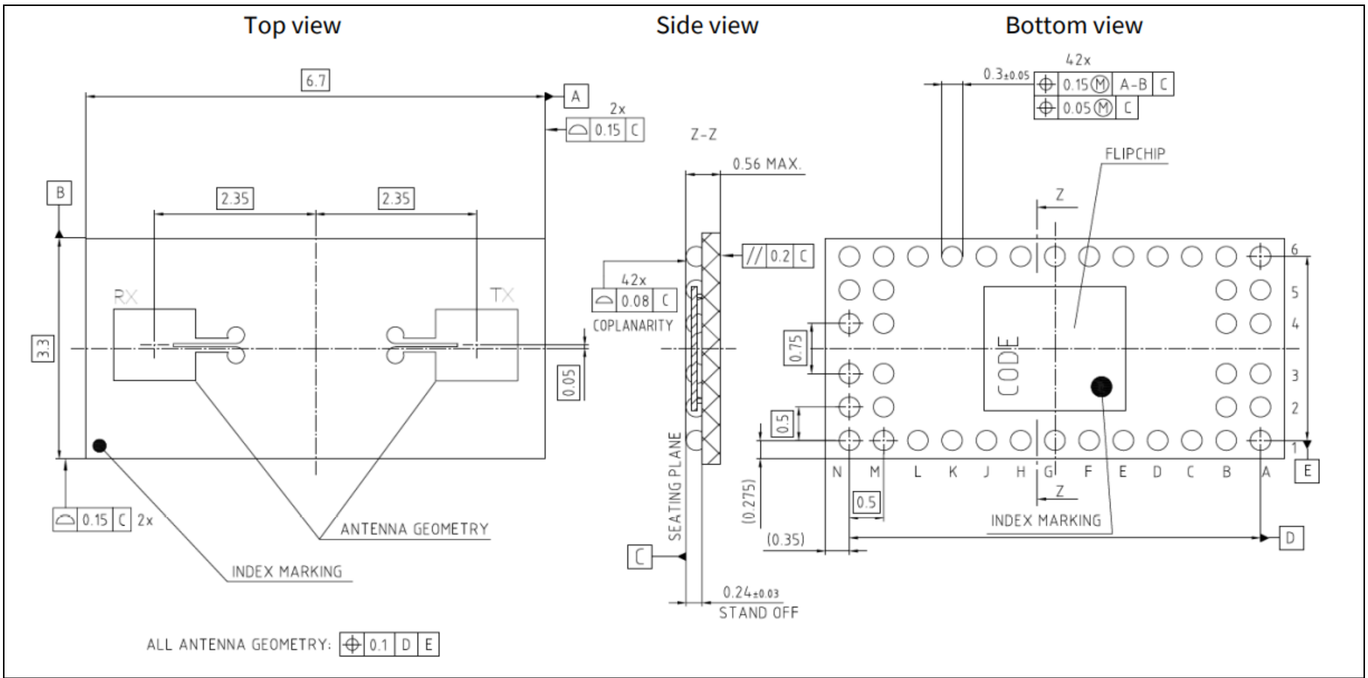


Figure 5 Top, side, and bottom views of BGT60LTR11AIP MMIC package (dimensions in mm)

3.3 Sensor supply

Because radar sensors are sensitive to supply voltage fluctuations or crosstalk between different supply domains, a low-noise power supply and properly decoupled supply rails are vital. Figure 6 shows the schematics of the low-pass filters employed to decouple the supplies of the different power rails in the BGT60LTR11AIP autonomous reference board. One LDO is used to create a stable and clean supply voltage of 1.5 V (for the MMIC).

R11 along with test point (TP2) can be used to make accurate current consumption measurements at the output of both the LDOs. You can choose between two different LDO packages; in this board, G1 and G2 do not populate (DNP).

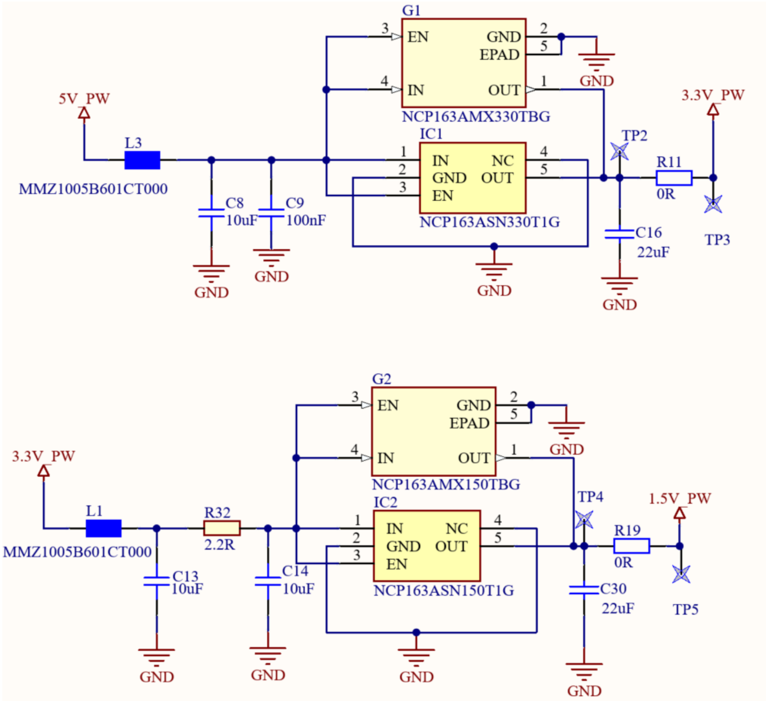


Figure 6 Schematics of sensor supply and low-pass filters

3.4 Oscillator

The MMIC requires an oscillator source with a stable reference clock providing low phase jitter and phase noise. The oscillator is integrated inside the MMIC. This saves current consumption because the crystal oscillator consumes only a few milliamperes (mA) and runs continuously. The BGT60LTR11AIP autonomous reference board uses a 38.4 MHz crystal oscillator, as shown in Figure 7.

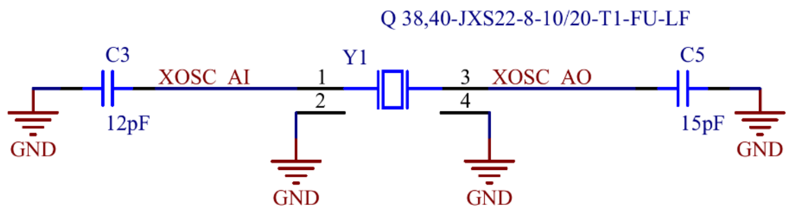


Figure 7 Crystal circuit on BGT60LTR11AIP autonomous reference board

3.5 External capacitors

The BGT60LTR11AIP MMIC is duty-cycled and performs a sample-and-hold (S/H) operation for lower power consumption. The S/H switches are integrated in the chip at each differential IQ mixer output port. They are controlled synchronously via the internal state machine. The capacitors between the S/H and the high-pass filter (HPF) are external (Figure 8). C14, C20, C15, and C21 are 5.6 nF capacitors used as “hold” capacitors for the S/H circuit. They can be configured for different pulse width settings, as shown in Table 3. C16, C22, C17, and C23 are the DC blocking (or high-pass) capacitors. They are 10 nF to get a high pass of 4 Hz (if internal high pass resistor, R_{HP} = 4 MΩ).

Do not use higher values because it affects the analog base band (ABB) settling time. The DC blocking capacitors are important because the mixer output has a different DC voltage than the internal ABB. In Figure 8, the external hold (C_{hold}) and high-pass capacitors (C_{HP}) are shown for all four branches in the differential IQ configuration.

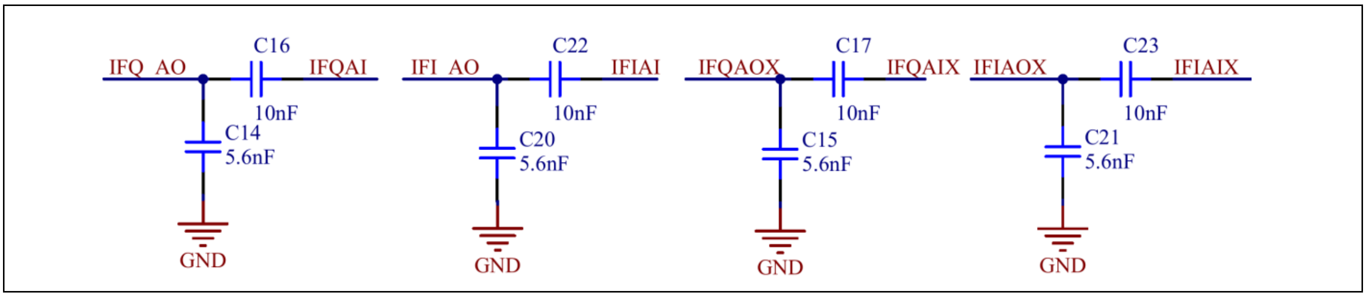


Figure 8 External capacitors

Table 3 Recommended hold capacitors (C14, C20, C15, and C21) for different pulse widths

Pulse width (µs)	Hold capacitor value (nF)
3	4.7
4	5.6
5 (default)	5.6 (default)
10	15

The charging time of the hold capacitor (C_{hold}) is limited to the selected pulse width. Shorter pulse widths require smaller C_{hold} to get it ~ 90% charged during one pulse. The rise time is controlled by C_{hold} itself and the internal mixer output resistance (R_{mixer_out}) of 300 Ω in each branch.

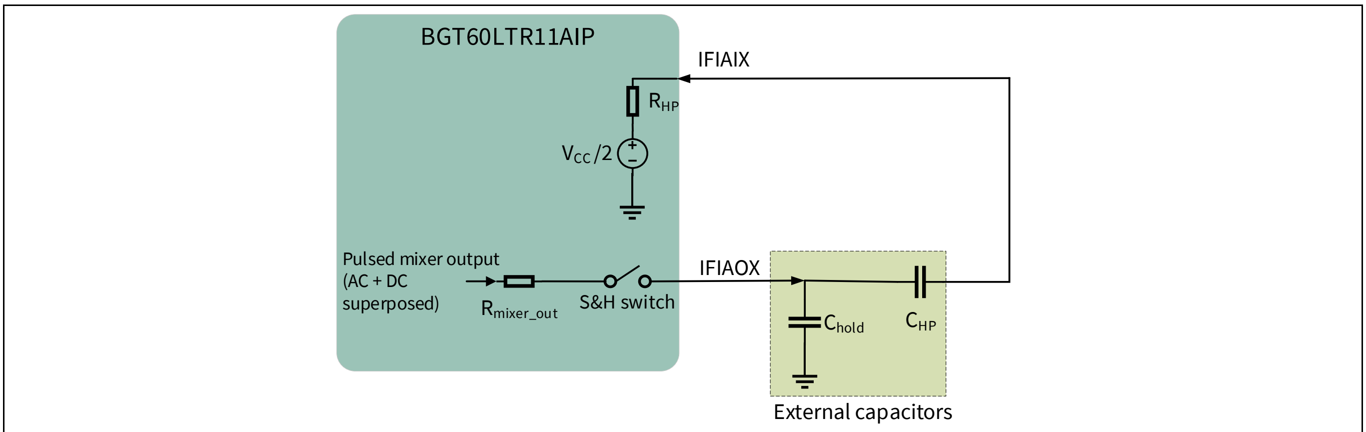


Figure 9 External capacitors for BGT60LTR11AIP

A longer pulse width can have a higher C_{hold} value. This leads to a reduced bandwidth (BW) of the RC filter (R_{mixer_out} and C_{hold}). Consequently, there will be lower baseband noise because of reduced noise folding bandwidth.

For this RC structure, the low-pass 3 dB cutoff frequency ($f_{LP_{3dB}}$) can be calculated under the following conditions:

$$t_{rise} = \frac{10\%}{90\%} = \text{S/H } ON\ time = 4\ \mu\text{s}$$

$$Pulse\ width = 5\ \mu\text{s}$$

$$R_{mixer\_out} = 300\ \Omega$$

$$f_{LP_{3dB}} = \frac{0.35}{t_{rise}} = \frac{0.35}{4\mu s} = 87.5\ kHz$$

Equation 1

This can also be calculated based on the following formula:

$$f_{LP_{3dB}} = \frac{1}{2\pi \times R_{mixer\_out} \times C_{hold}}$$

$$C_{hold} = 6.1\ nF \rightarrow 5.6\ nF\ \text{(closest E12 series value)}$$

Equation 2

The high-pass 3 dB cutoff frequency ($f_{HP_{3dB}}$) can be calculated under the following conditions:

$$C_{HP} = 10\ \text{nF}$$

$$R_{HP} = 4\text{M}\Omega$$

$$f_{HP_{3dB}} = \frac{1}{2\pi \times R_{HP} \times C_{HP}} = \frac{1}{2\pi \times 4M\Omega \times 10nF} = 4\ Hz$$

Equation 3

3.6 LEDs

The board also has two LEDs (D1 and D2) as shown in Table 4 and Figure 10.

Table 4 LEDs on BGT60LTR11AIP autonomous reference board

LED	Purpose
D1	Green LED connected to TDet output pin of the BGT60LTR11AIP radar MMIC to indicate the detection of movement in front of the radar
D2	Red LED connected to PDET output pin of the BGT60LTR11AIP radar MMIC to indicate the direction of movement

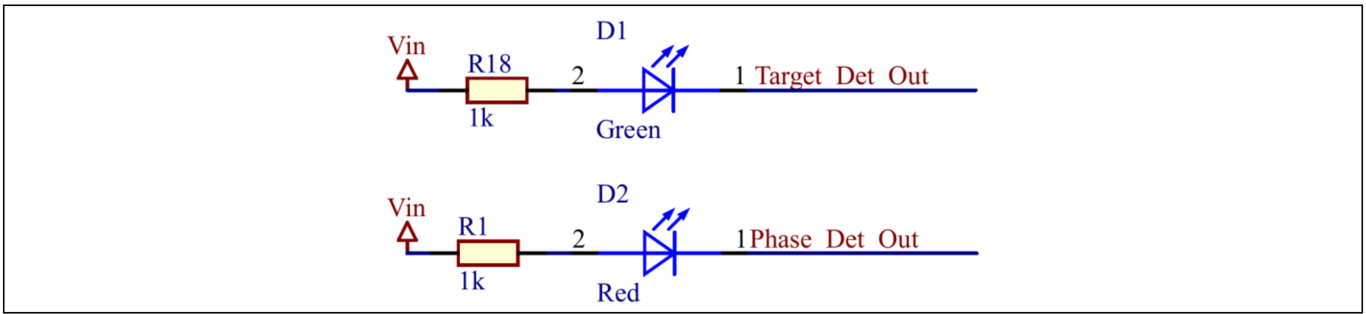


Figure 10 LED connections

3.7 MMIC quad state inputs

The radar MMIC can be configured in both operation modes. In autonomous mode, the sensor configuration parameters are set via QS pins and external resistors. In SPI mode, the connection to a microcontroller allows setting the sensor configuration parameters by writing in the internal registers through SPI.

The BGT60LTR11AIP MMIC has four quad-state inputs QS1-4. Figure 11 shows the default settings of these QS pins on the board; these can be used as a reference to configure the board with different settings. By default, the board is configured in autonomous mode (QS1).

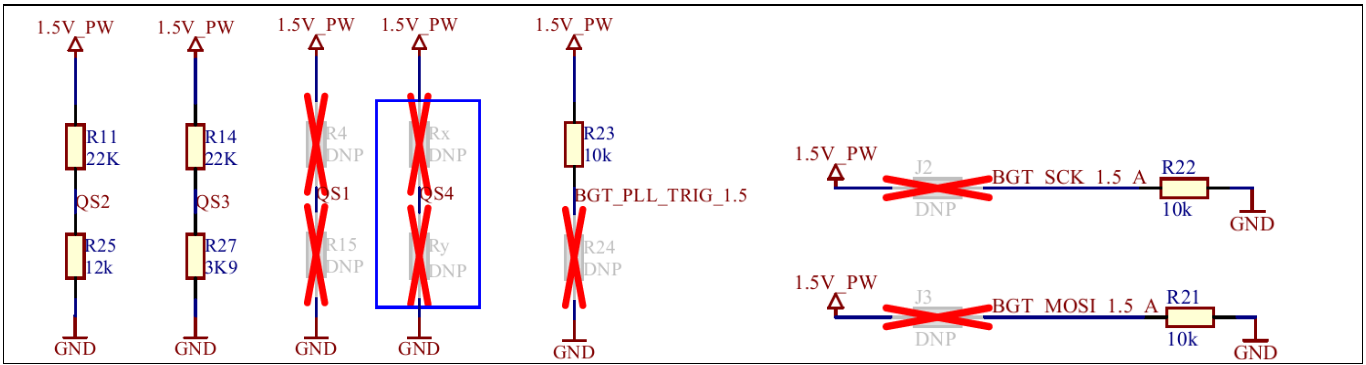
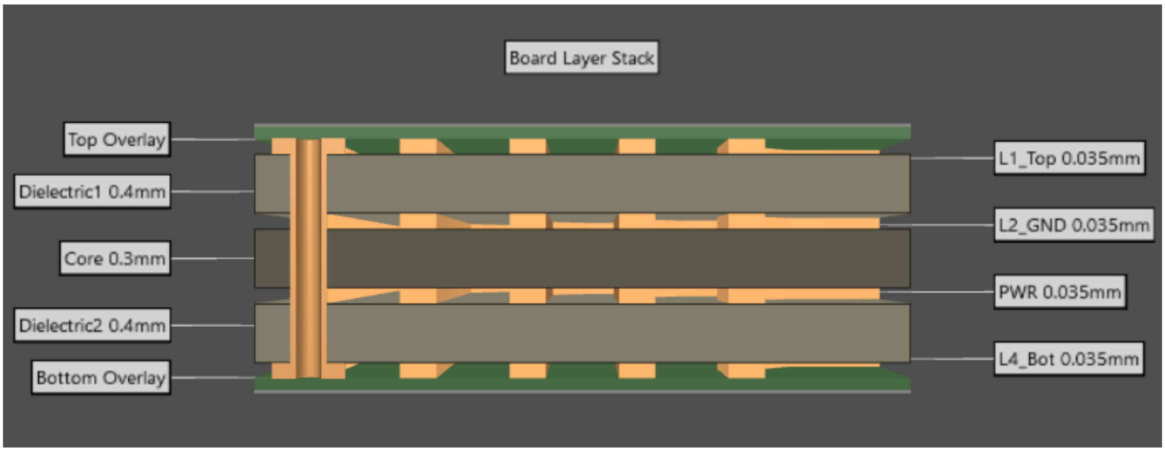


Figure 11 QS1 to QS4 schematic and layout connections

Note: The BGT60LTR11AIP autonomous reference board works only in autonomous mode. For SPI mode, see the BGT60LTR11AIP SPI reference board (REF_BGT60LTR11AIP_M0) [3].

3.8 Layer stackup and routing

The PCB is designed with a 4-layer stack up with standard FR4 material. Figure 12 shows the different layers and their respective thicknesses.



#	Name	Material	Type	Weight	Thickness	Dk
	Top Overlay		Overlay			
	Top Solder	Solder Resist	Solder Mask		0.02mm	3.5
1	L1_Top		Signal	1oz	0.035mm	
	Dielectric1	PP-006	Prepreg		0.4mm	4.1
2	L2_GND	CF-004	Signal	1oz	0.035mm	
	Core	FR-4	Core		0.3mm	4.2
3	PWR	CF-004	Signal	1oz	0.035mm	
	Dielectric2	PP-006	Prepreg		0.4mm	4.1
4	L4_Bot		Signal	1oz	0.035mm	
	Bottom Solder	Solder Resist	Solder Mask		0.02mm	3.5
	Bottom Overlay		Overlay			

Figure 12 QS1 to QS4 schematic and layout connections

In the routing on the PCB, the VTUNE pin on BGT60LTR11AIP MMIC should be left floating. Any components added to the line, or a long wire connected can result in spurs.

4 Radar MMIC settings

In autonomous mode, the radar sensor MMIC configuration parameters are only set via the QS pins and external resistors.

4.1 Operation mode

The QS1 pin allows choosing the operation mode of the radar MMIC, as shown in Table 5.

Table 5 QS1 settings

QS1	Operation mode of the MMIC	PCB configuration	
Ground	Autonomous continuous wave (CW) mode	R4 = 0 Ω	R15 = DNP*
Open	Autonomous pulsed mode (default)	R4 = DNP*	R15 = DNP*
100 kΩ to V_{DD}	SPI mode with external 9.6 MHz clock enabled	R4 = DNP*	R15 = 100 kΩ
V_{DD} (default)	SPI mode	R4 = DNP*	R15 = 0 Ω

*DNP: Do Not Populate/Do Not Place.

4.2 Detector threshold

The internal detector threshold is the minimum signal strength that must be reached to trigger a detection event. The lower the threshold set, the higher the sensitivity and therefore the higher the detection range.

QS2 is used to select the detector threshold value for autonomous mode. To have up to 16 threshold values, connect PLL_TRIG to V_{DD} by removing R24 and placing R23 = 0 Ω. This will put the MMIC into "Advance mode".

See Table 6 for recommended resistor values for changing the QS2 on the autonomous reference board.

Table 6 QS2 settings

Resistor settings		Detector threshold
R11	R25	
DNP*	DNP*	61
22 kΩ	2.2 kΩ	66
22 kΩ	3.9 kΩ	80
22 kΩ	5.6 kΩ	90
22 kΩ	8.2 kΩ	112
22 kΩ	12 kΩ	136 (default)
22 kΩ	15 kΩ	192
22 kΩ	18 kΩ	248
22 kΩ	27 kΩ	320
10 kΩ	15 kΩ	284
10 kΩ	18 kΩ	480
10 kΩ	27 kΩ	640
10 kΩ	39 kΩ	896

Resistor settings		Detector threshold
R11	R25	
10 kΩ	47 kΩ	1344
10 kΩ	100 kΩ	1920
10 kΩ	270 kΩ	2560

*DNP: Do Not Populate/Do Not Place.

4.3 Detector hold time

The internal detector hold time is the time for which the internal detector outputs remain active after target detection.

QS3 is used to select the detector hold time value for autonomous mode. To have up to 16 hold time values, set "Advance mode", as explained in Detector threshold. The default QS3 setting on the shield for the hold time is 1 second. See Table 7 for recommended resistor values for changing the QS3 on the autonomous reference board.

Table 7 QS3 settings

Resistor settings		Detector hold time
R14	R27	
22 kΩ	680 Ω	128 ms
22 kΩ	2.2 kΩ	500 ms
22 kΩ	3.9 kΩ	1 s (default)
22 kΩ	5.6 kΩ	2 s
22 kΩ	8.2 kΩ	3 s
22 kΩ	12 kΩ	5 s
22 kΩ	15 kΩ	10 s
22 kΩ	18 kΩ	30 s
10 kΩ	27 kΩ	45 s
10 kΩ	15 kΩ	1 min.
10 kΩ	18 kΩ	90 s
10 kΩ	27 kΩ	2 min.
10 kΩ	39 kΩ	5 min.
10 kΩ	47 kΩ	10 min.
10 kΩ	100 kΩ	15 min.
10 kΩ	270 kΩ	30 min.

4.4 Operating frequency

The QS4 pin allows choosing the operating frequency of the radar MMIC, as shown in Table 8.

Table 8 QS4 settings

QS4	Device operation frequency	PCB configuration	
Ground	61.1 GHz	Rx = 0 Ω	Ry = DNP*
Open	61.2 GHz	Rx = DNP*	Ry = DNP*
100 kΩ to V_{DD}	61.3 GHz	Rx = DNP*	Ry = 100 kΩ
V_{DD} (default)	61.4 GHz	Rx = DNP*	Ry = 0 Ω

*DNP: Do Not Populate/Do Not Place

4.5 Pulse repetition time (PRT)

PRT is the duty cycle repetition rate, which means the time until the next pulsing sequence starts in pulsed mode.

The PRT can be configured in autonomous pulsed mode (QS1 is either GND or OPEN, as shown in Table 5) only if "Advance mode" is enabled by keeping the PLL_Trig pin to "1". The SPI pins BGT_MOSI and BGT_SCK are sampled during chip boot-up and determine the PRT setting, as shown in Table 9.

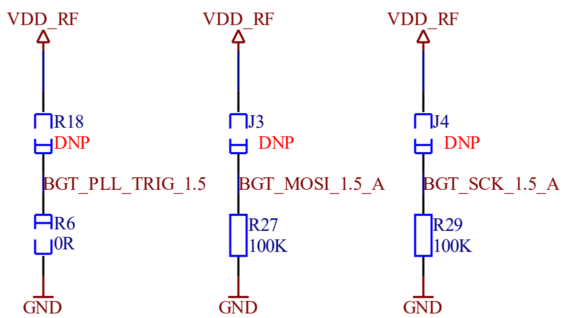


Figure 13 Configuring PRT

Table 9 PRT configuration in (pulsed) autonomous mode

BGT_PLL_TRIG*	BGT_MOSI	BGT_SCK	PRT	PCB components			
1	0	0	500 µs	J3 = DNP*	R27 = 100 kΩ	J4 = DNP*	R29 = 100 kΩ
1	0	1	2000 µs	J3 = DNP*	R27 = 100 kΩ	J4 = 100 kΩ	R29 = DNP*
1	1	0	250 µs	J3 = 100 kΩ	R27 = DNP*	J4 = DNP*	R29 = 100 kΩ
1	1	1	1000 µs	J3 = 100 kΩ	R27 = DNP*	J4 = 100 kΩ	R29 = DNP*

*R6 = DNP, R18 = 0 Ω, DNP = Do Not Populate/Do Not Place.

5 Simulation results

To analyze the sensor radiation characteristics, the radiation pattern of the BGT60LTR11AIP autonomous reference board is simulated along the H-plane and E-plane of the sensor.

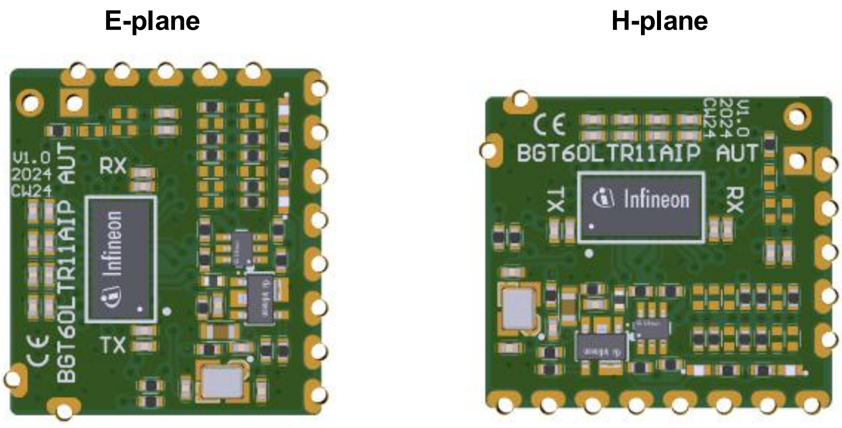
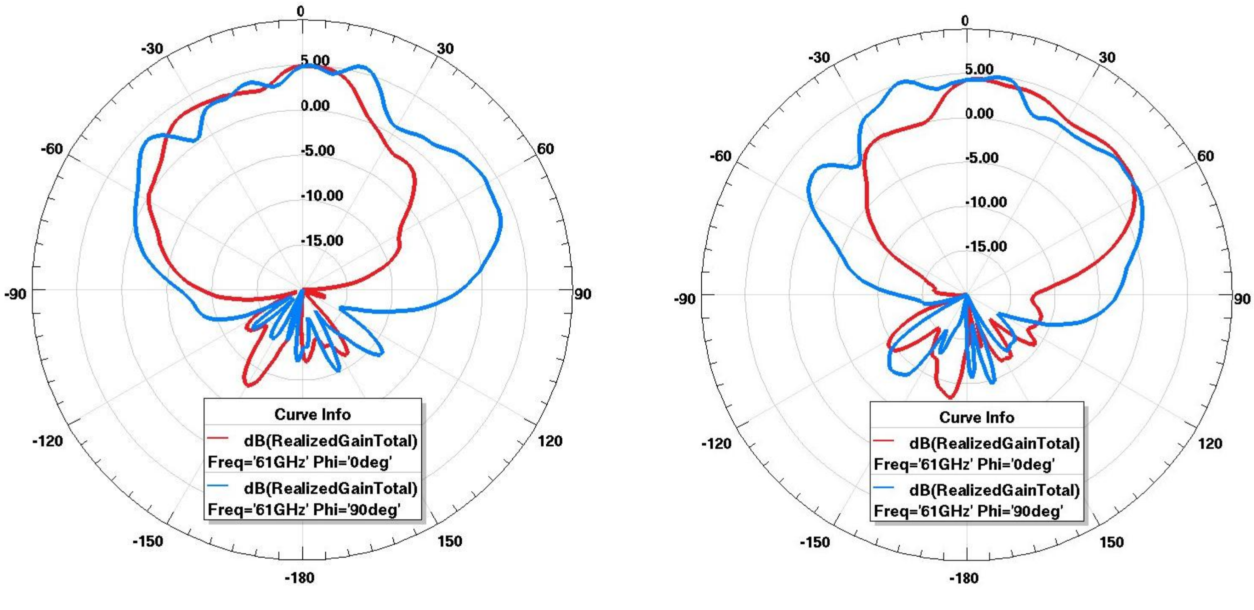


Figure 14 E-plane and H-plane orientations of BGT60LTR11AIP autonomous reference board

The realized gain of the transmitting antenna in H-plane and E-plane at a frequency of 61 GHz is shown in Figure 15a. The antenna characteristics of the receiving antenna in H-plane and E-plane at a frequency of 61 GHz is shown in Figure 15b.



(a) TX – H/E plane at f = 61 GHz (b) RX – H/E plane at f = 61 GHz

Figure 15 Radiation pattern simulations of BGT60LTR11AIP autonomous reference board

6 Measurement results

The measurements are conducted for the autonomous MMIC operation mode with different settings.

- **Scenario**
  Measure the maximum detection range of a human target along the H/E plane of the sensor for different angles
- **Firmware**:
  No FW is required for the autonomous board
- **Height**:
  Board is placed at 1.2 m
- **Detection status**
  Driven from the internal detector output (TDet). Figure 16 shows the measurement results in the H-plane and E-plane and the correct shield orientation

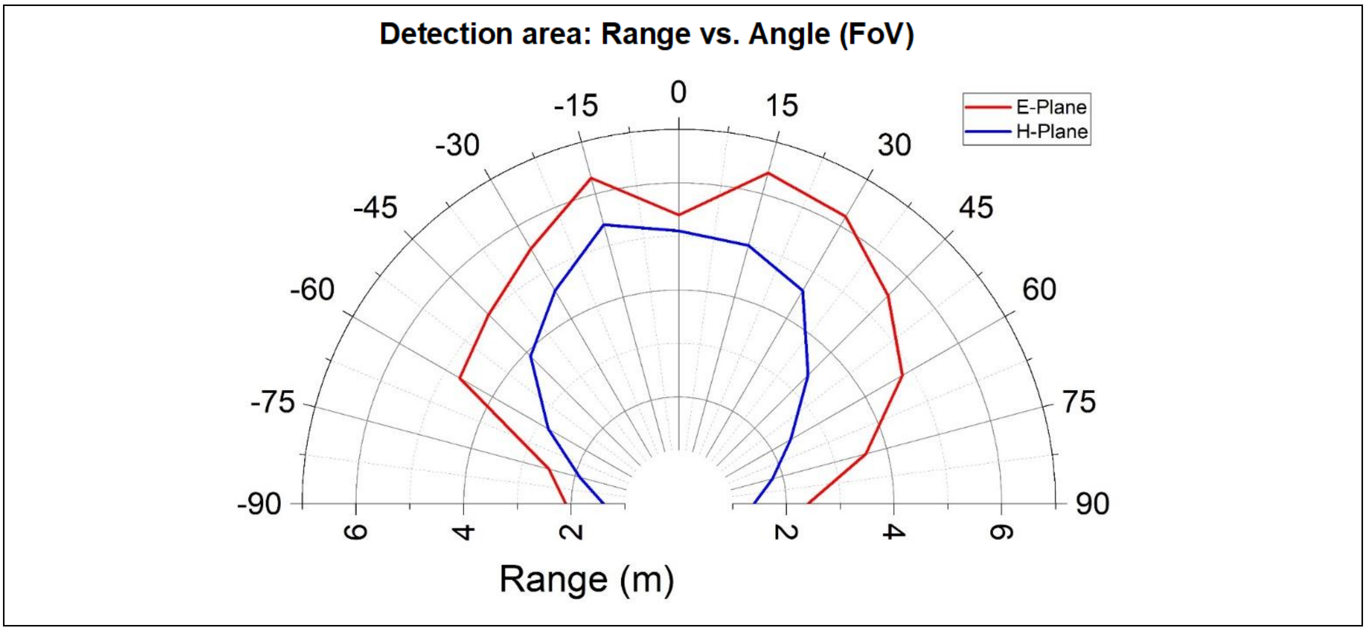


Figure 16 Detection area of the internal detectors

7 Related resources

- Webpage: XENSIV™ 60 GHz radar sensors
- Infineon Developer Community: XENSIV™ radar sensors forum

References

[1] Infineon Technologies AG: *BGT60LTR11AIP MMIC datasheet*; Available online

[2] Infineon Technologies AG: *UG124434 : User's guide to BGT60LTR11AIP*; Available online

[3] Infineon Technologies AG: *REF_BGT60LTR11AIP_M0;* Available online

Glossary

ABB
analog baseband (ABB)

AIP
antenna in package (AIP)

BW
bandwidth (BW)

CW
continuous wave (CW)

DC
direct current (DC)

DNP
do not populate/do not place (DNP)

EMC
electromagnetic compatibility (EMC)

ESD
electrostatic discharge (ESD)

GND
ground (GND)

HPF
high-pass filter (HPF)

HVAC
heating, ventilation and air conditioning (HVAC)

LDO
low-dropout regulator (LDO)

LNA
low-noise amplifier (LNA)

LO
local oscillator (LO)

MMIC
monolithic microwave integrated circuit (MMIC)

MPA
medium power amplifier (MPA)

PCB
printed circuit board (PCB)

PIR
passive infrared (PIR)

PLL
phase-locked loop (PLL)

PPF
poly-phase filter (PPF)

PRT
pulse repetition time (PRT)

QS
quad-state (QS)

RC
resistor-capacitor (RC)

S/H
sample-and-hold (S/H)

SPI
serial peripheral interface (SPI)

TP
test point (TP)

VCO
voltage-controlled oscillator (VCO)

VGA
variable gain amplifier (VGA)

Revision history

Document revision	Date	Description of changes
1.00	2026-08-11	Initial release

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