BGT60ATR24AIP shield

XENSIV™ 60 GHz radar system platform

About this document

Scope and purpose

This user guide describes the function, circuitry, and performance of the BGT60ATR24AIP shield, which is part of Infineon's XENSIV™ 60 GHz radar system platform. The shield provides the supporting circuitry to the onboard BGT60ATR24AIP monolithic microwave integrated circuit (MMIC) 60 GHz radar chipset with Antenna in Package (AIP). The shield offers a digital interface for configuration and transfer of the acquired radar data to a microcontroller board, e.g., "Radar Baseboard MCU7 Plus".

Intended audience

The intended audience for this document are design engineers, technicians, and developers of electronic systems, working with Infineon's XENSIV™ 60 GHz radar sensors especially in automotive scenarios called in-cabin monitoring systems (ICMS).

About this product group

Target applications

- In-cabin monitoring system (ICMS)

Product family

XENSIV™ 60 GHz radar sensors for automotive are highly integrated devices that deliver advanced sensing capabilities with high precision and low power consumption. Their compact form factor enables contactless sensing features for in-cabin monitoring systems (ICMS), providing exceptional accuracy, ease of integration, and cost-effective system implementation.

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.

Safety precautions

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

Table 1 **Safety precautions**

	**Caution:** *The 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

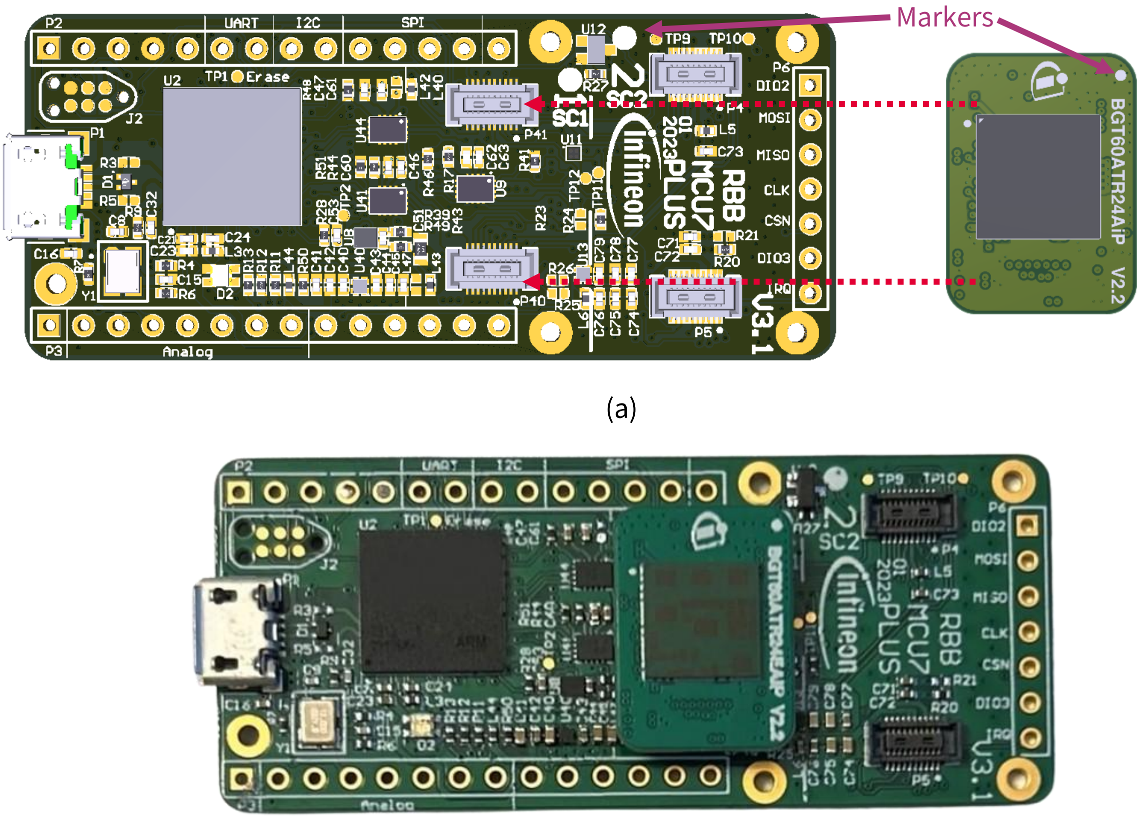
1 The board at a glance

1.1 Radar system platform

The 60 GHz radar system platform is the demo platform for 60 GHz radar solutions from Infineon. It consists of the “Radar Baseboard MCU7 Plus” as the microcontroller board and a radar sensor board, like the BGT60ATR24AIP shield.

This user guide focuses on the BGT60ATR24AIP shield. For detailed documentation on the radar baseboard, see UG155750 - Radar Baseboard MCU7 Plus user guide [1].

Figure 1 shows the “Radar Baseboard MCU7 Plus” with the BGT60ATR24AIP shield. Both boards have markers. Align these markers correctly while plugging the shield into the baseboard.



(a)

(b)

Figure 1 Radar Baseboard MCU7 Plus with the BGT60ATR24AIP shield: (a) unplugged or (b) plugged in

1.2 Key features

The BGT60ATR24AIP shield is optimized for fast prototyping designs and system integration as well as initial product feature evaluations. The board offers developers the flexibility to choose their own platform depending on their preferred use cases. The sensor supports various use cases, serving a broad spectrum of automotive and consumer applications such as child presence detection, seat occupancy detection, proximity and intrusion alert, obstacle detection systems, smart trunk opener systems, vital sign monitoring, and gesture recognition.

Some key features of the BGT60ATR24AIP shield are as follows:

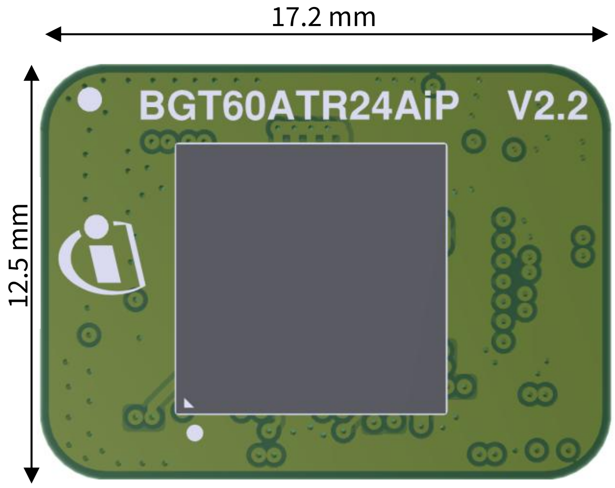
- Minimized form factor of 17.2 mm x 12.5 mm shield board with Antenna in Package (AIP) of 8 mm x 8 mm x 0.86 mm
- Flexible platform selection
- Highly flexible configuration on frequency-modulated continuous wave (FMCW) modulation
- Power consumption can be optimized according to the use case

2 Hardware description

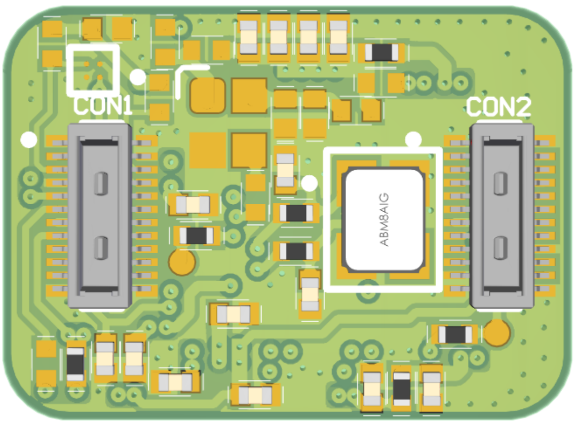
This section of the document provides an overview of the BGT60ATR24AIP shield hardware details, such as BGT60ATR24AIP considerations, power supply, clock generation, and board interfaces.

2.1 Overview

The dimensions of the BGT60ATR24AIP shield printed circuit board (PCB) are 17.2 mm x 12.5 mm. The radar sensor BGT60ATR24AIP is the central component on the top side of the PCB (Figure 2a). Because the antennas are integrated into the BGT60ATR24AIP chip package, the PCB can be manufactured using a standard FR4 laminate. The bottom side of the PCB features the main interfaces to the “Radar Baseboard MCU7 Plus” (CON1 and CON2 in Figure 2b).



(a) Top view



(b) Bottom view

Figure 2 Top and bottom views of the BGT60ATR24AIP shield

2.2 Description of the functional blocks

The block diagram in Figure 3 depicts the concept behind the board. Radar sensors are very sensitive to noise and crosstalk on the supply domains. Therefore, the different supply domains must be decoupled. On the BGT60ATR24AIP shield, this is realized by capacitors on each supply domain. Communication with the radar sensor is mainly performed via a Serial Peripheral Interface (SPI) bus. Additionally, two more digital lines are required for operation. One line (IRQ) signals the MCU when new data needs to be fetched. The other (RST) allows the MCU to perform a hardware reset of the sensor.

For BGT60ATR24AIP, it is possible to use either an external oscillator clock or an internal oscillator clock with an external crystal. By default, the internal oscillator clock with the external crystal (XTAL) is used and the external oscillator (OSC) circuit is not populated. The details of the clock circuits will be explained in the sections below.

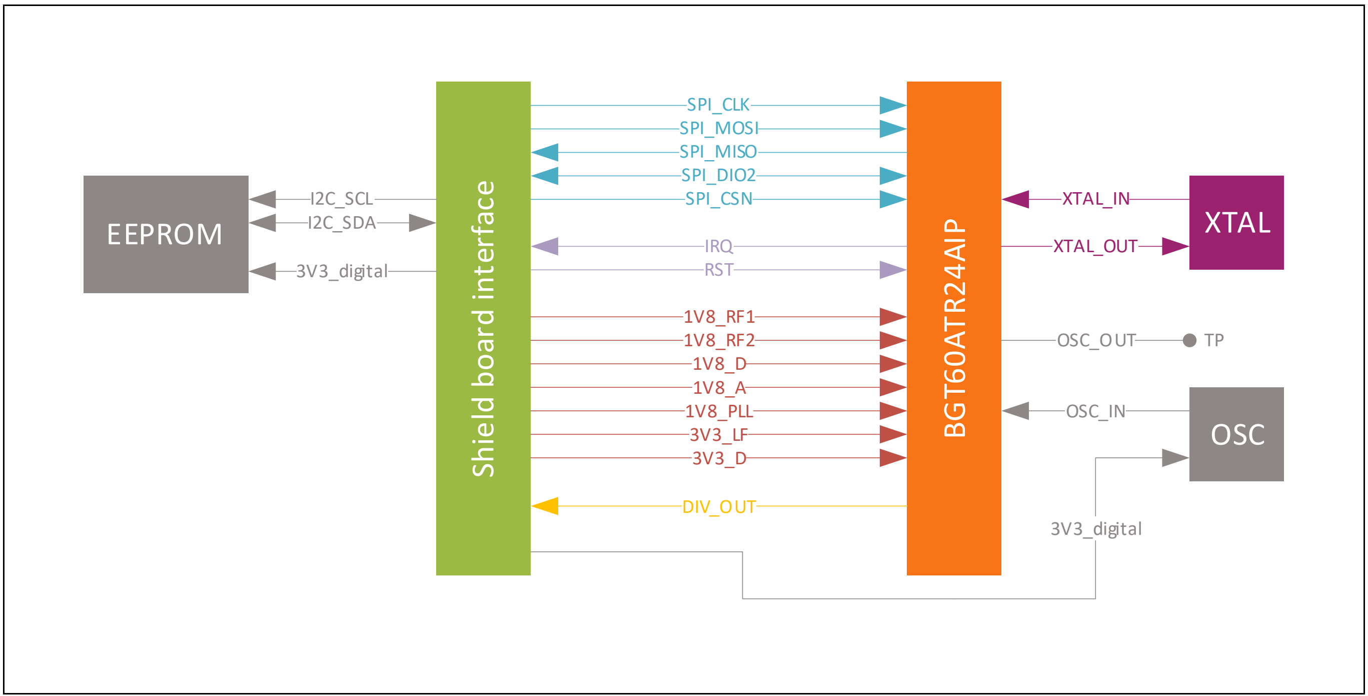


Figure 3 **Block diagram of the BGT60ATR24AIP shield**

2.2.1 BGT60ATR24AIP MMIC

BGT60ATR24AIP is a 60 GHz radar sensor with two transmitting and four receiving patch antennas in the package. The 4.7 GHz ultra-wide bandwidth allows frequency-modulated continuous wave (FMCW) operations with extremely high resolution. This enables precise range measurements of vital signs such as breathing rate or heart rate. The two transmitting and four receiving antennas form an 8-channel virtual array. This antenna configuration enables angle measurements and resolution of multiple targets for both azimuth and elevation planes.

BGT60ATR24AIP provides the following digital signal lines: oscillator input and output, 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.

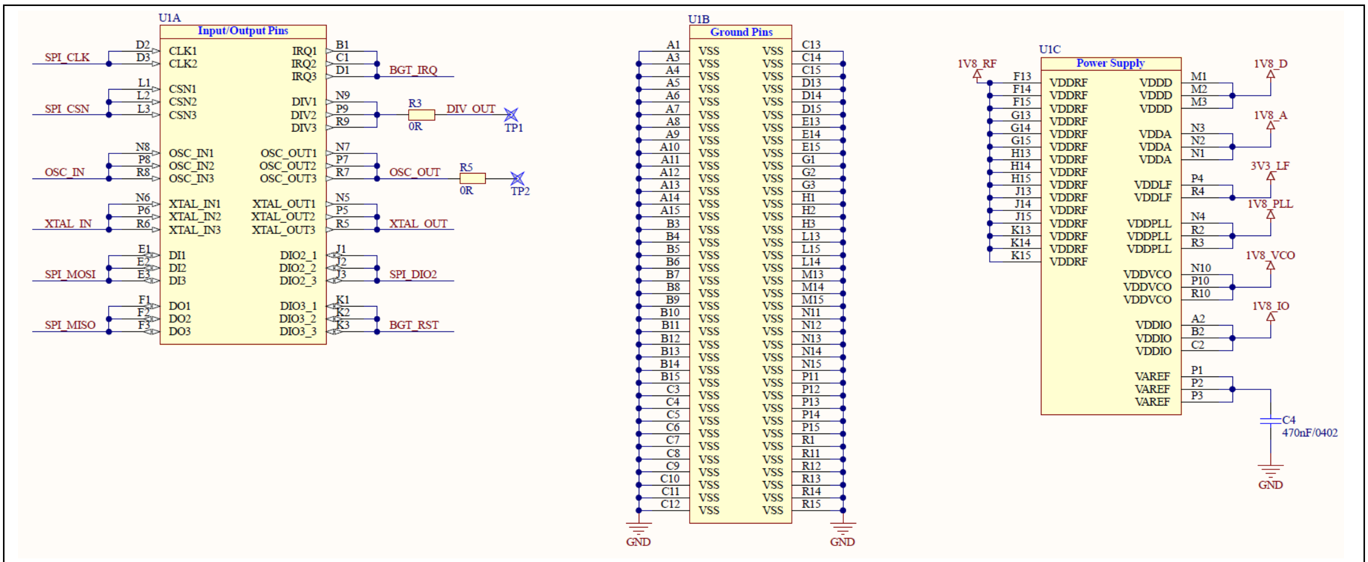


Figure 4 **BGT60ATR24AIP circuit diagram**

2.2.2 Sensor power supply

Since radar sensors are very sensitive to supply voltage fluctuations or cross-talk between different supply domains, a low-noise power supply with properly decoupled supply rails will prove vital. The Radar Baseboard MCU7 Plus provides a low-noise supply (for further details, see Section 2.2 of UG155750 - Radar Baseboard MCU7 Plus user guide [1]). Figure 5 depicts the schematics of the low-pass filters employed to decouple the supplies of the different power rails in the chip. For example, the SPI (which runs at up to 50 MHz) induces voltage fluctuations in the digital domain. These fluctuations would then transfer into the analog domain if not for the decoupling filters incorporated.

BGT60ATR24AIP has five 1.8 V power domains: analog, digital, Radio Frequency (RF), Phase-Locked Loop (PLL), and the voltage-controlled oscillator (VCO) circuitry. Additionally, there is a 3.3 V domain for the Loop Filter (LF). The digital domain (VDD_IO) is compatible with both 1.8 V and 3.3 V power supplies. By default, it is connected to the 1.8 V domain.

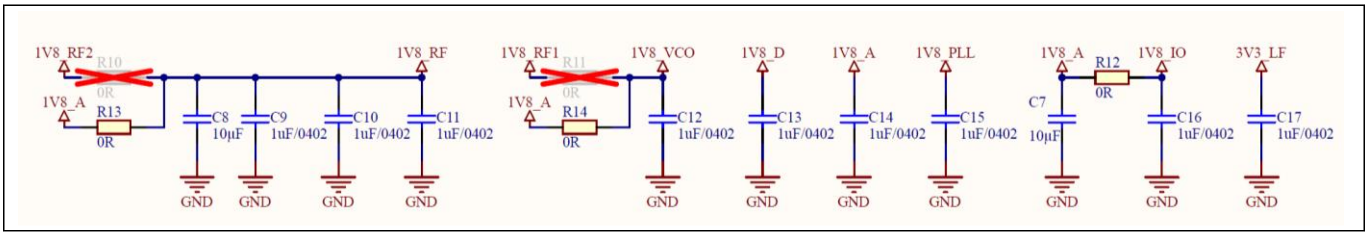


Figure 5 Power supply circuitry

- Use R10 and R11 for "Radar Baseboard MCU7 Plus"
- Use R13 and R14 for "Radar Baseboard MCU7"

2.2.3 External crystal oscillator clock (XOSC)

Infineon's BGT60ATR24AIP radar sensor requires an oscillator source with a stable reference clock providing low phase jitter and low phase noise. BGT60ATR24AIP comes with a built-in crystal oscillator to generate the operation clock for the overall system. For use cases with an externally available oscillator clock, the integrated XOSC can be fully disabled and bypassed to operate the chip via an external clock (OSC_IN). In all cases, the clock is forwarded to the frequency doubler inside the PLL to provide the option to double the clock frequency. There are four options for the external oscillator frequency: 38.4 MHz and 40 MHz with an internal doubler option and 76.8 MHz and 80 MHz without an internal doubler. For details of the oscillator options, see XTAL Oscillator section of the BGT60ATR24AIP datasheet [2].

The shield employs an NDK's automotive grade NZ2520SHA 80 MHz crystal oscillator, which is supplied with 1.8 V as depicted in Figure 6. By default, the components for the external crystal oscillator circuit are not populated. This oscillator source will output a stable 1.8 V digital signal. The most important parameters for choosing an oscillator are phase jitter and phase noise. Other oscillators should have similar phase jitter and phase noise as the NDK NZ2520SHA. Furthermore, the radar sensor will work most efficiently if the reference oscillator signal is neither too strong nor too weak. The series resistor (R4) reduces the RF level at the sensor so that it is at the ideal range for BGT60ATR24AIP. If a redesign of the board contains a different signal source or a vastly different layout is designed, the value of R4 (150 Ω) may have to be adjusted. A higher resistance results in a lower signal at the radar sensor. If the signal level is too low, the phase noise of the sensor will deteriorate. With a low resistance, the signal level at the sensor will be high and in the Range-Doppler illustration of the radar data, a peak (or ghost target) will appear for low distances. For this reason, the phase noise needs to be measured as well as the radar data need to be illustrated with a Range-Doppler plot to optimize the series resistance of the layout. The series resistance can be varied by soldering different resistors into the circuit. An optimized series resistance will show the ideal phase noise behavior of the sensor, paired with a clean Range-Doppler plot. If the phase noise behavior is non-ideal, the resistance value must be lower. If a peak appears in the Range-Doppler plot, the resistance must be higher.

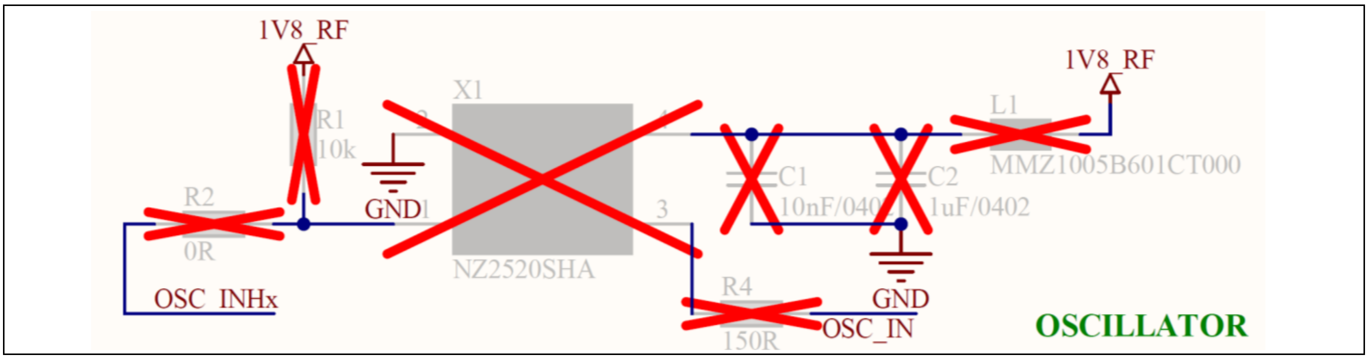


Figure 6 80 MHz crystal oscillator circuitry (The components are not populated)

2.2.4 Crystal clock (XTAL)

If the internal crystal oscillator is used, BGT60ATR24AIP requires an external crystal clock (38.4 MHz or 40 MHz). The shield uses an Abracon automotive-grade 40 MHz crystal clock (ABM8AIG-40.000MHZ-12-2Z-T3) with 10 pF bypass capacitors as shown in Figure 7. There is also the option to forward the internally generated clock to external devices via the buffered OSC_OUT pad (see Figure 3 and Figure 4).

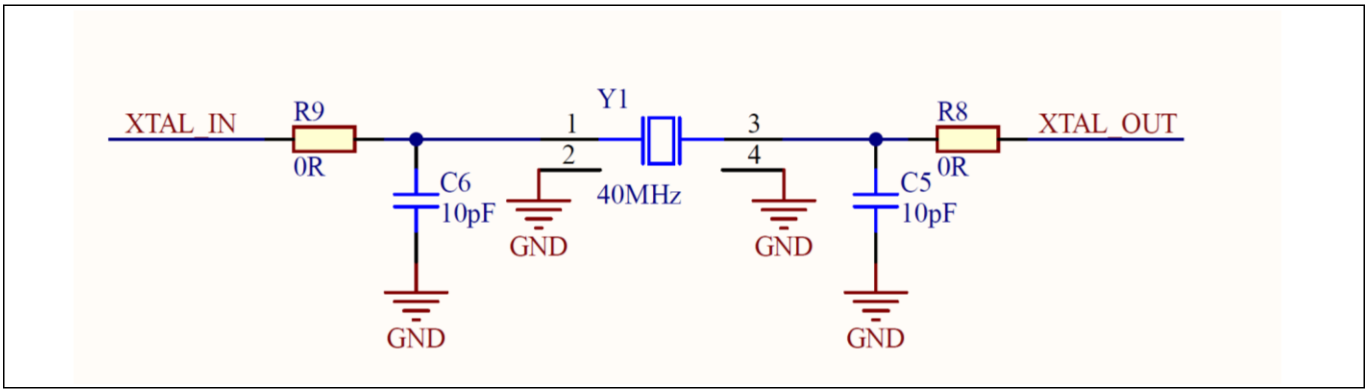


Figure 7 40 MHz crystal clock circuitry

2.2.5 Connectors

The BGT60ATR24AIP shield is an extension board of Infineon's 60 GHz radar system platform without a microcontroller. Connect the shield to an MCU board, such as the "Radar Baseboard MCU7 Plus".

The main connector interface of the BGT60ATR24AIP shield contains two Hirose DF40C-20DP-0.4V connectors. On the MCU side, the "Radar Baseboard MCU7 Plus" contains the corresponding DF40C-20DS-0.4V connectors. Figure 8 shows the pin map of the Hirose connectors of the BGT60ATR24AIP shield. On the top side of the shield, there is a marker that must be aligned with the marker on the MCU board for correct shield alignment, as depicted in Figure 1.

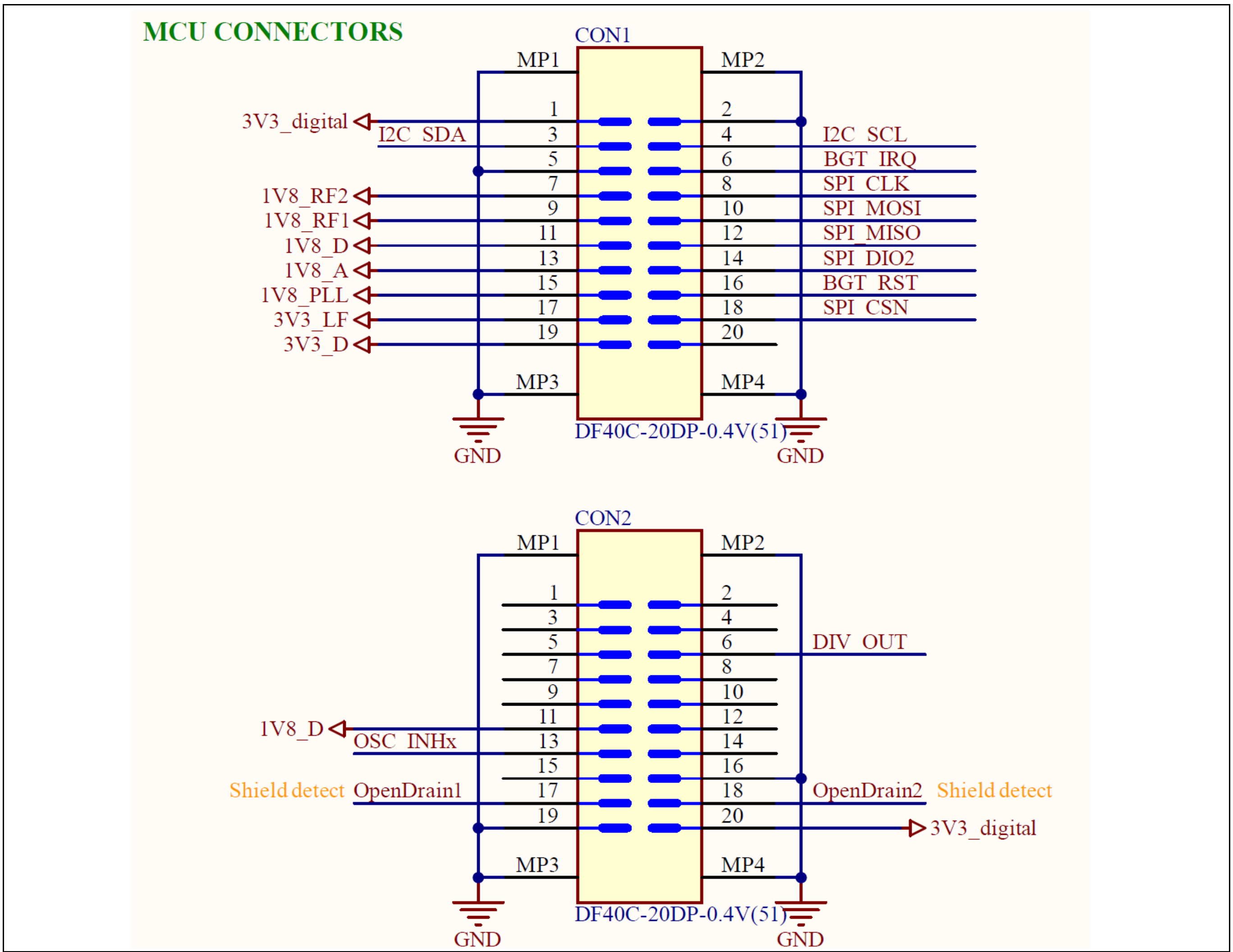


Figure 8 Pin map of the sensor connectors on the BGT60ATR24AIP shield

To provide the correct level shifter voltage for the MCU board, the 1.8 V (1V8_D) supply line is connected to pin 11 of CON2 (Vdigital, refer to "Level shifters" section of UG155750 - Radar Baseboard MCU7 Plus user guide [1]). If a sensor is plugged in incorrectly (rotated by 180 degrees), GND and 3V3_digital signals will still be matched between the MCU board and sensor board. Therefore, the sensor's I²C signal lines for the EEPROM will still be pulled up and the MCU will notice that OpenDrain1_1 and OpenDrain2_1 are pulled up instead of its I²C signals. This allows the MCU to detect whether the sensor is plugged in correctly (I²C signals pulled up) or incorrectly (OpenDrain1_1 and OpenDrain2_2 pulled up).

There is a risk of the Hirose connectors wearing out when regularly plugged into and unplugged from the shield. To prevent this, it is recommended not to lift the board out of the connector on the short side. Instead, simply pull on the long side of the board, thereby tilting the short side. This will significantly increase the operational lifetime of the connectors.

2.2.6 EEPROM

The BGT60ATR24AIP shield contains an EEPROM memory to store data such as the board identifier. Its connections can be seen in Figure 9. By default, the components for the EEPROM circuit are not populated. The microcontroller will read the content of the EEPROM's memory to determine which sensor is connected to the sensor interface. It is not mandatory to use this EEPROM with BGT60ATR24AIP, as it has an internal chip ID which can be read by SPI directly. The EEPROM is only for ensuring compatibility with other Infineon chips that do not have the chip ID feature.

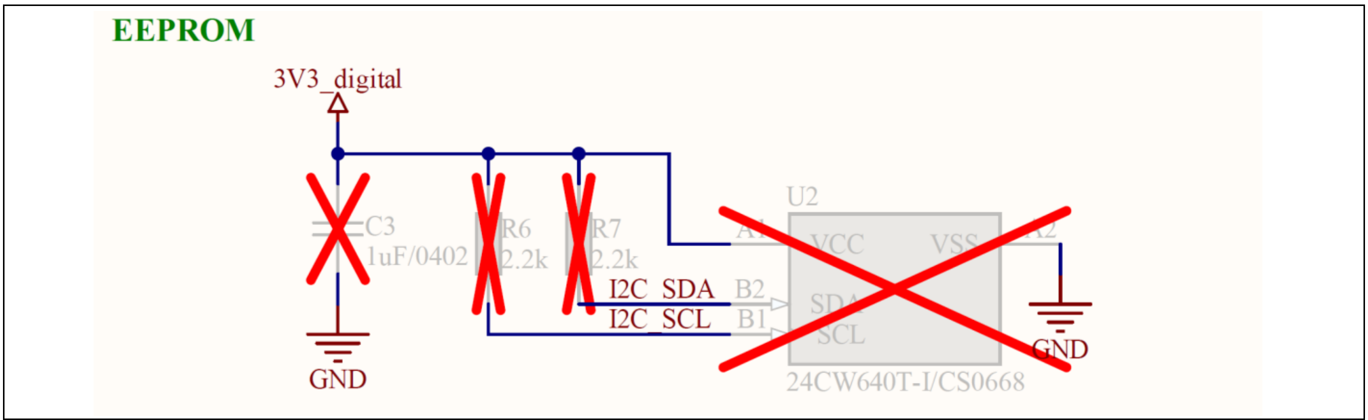


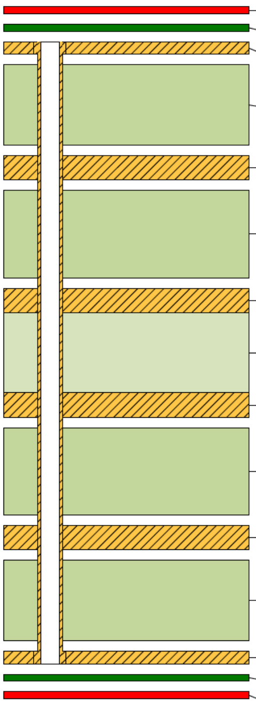
Figure 9 Schematic of EEPROM circuitry (the components are not populated)

2.3 PCB design recommendation

The size of the ground plane for the antennas-in-package is limited by the BGT60ATR24AIP chip dimension. As a result, there will always be a portion of the RF signal interacting with the PCB structures around the BGT60ATR24AIP chip. In some cases, this interaction will have an impact on the antenna radiation pattern. In cases where this interaction must be reduced, the antenna radiation pattern may be simulated on the PCB including the components close to the radar device and the PCB design may be optimized for the radiation pattern.

2.4 Layer stackup

Since the antennas are integrated on the BGT60ATR24AIP MMIC, the shield PCB does not require high performance RF material. As shown in Figure 10, FR4 material is used in the 6-layer stackup.



Material	Layer	Thickness	Dielectric Material	Type	Gerber
	Top Overlay			Legend	GTO
Surface Material	Top Solder	0.010mm	Solder Resist	Solder Mask	GTS
Copper	Top Layer	0.018mm		Signal	GTL
Prepreg		*0.115mm*	*FR4*	*Dielectric*	
Copper	GND1	0.035mm		Signal	G1
Prepreg		*0.125mm*	*FR4*	*Dielectric*	
Copper	Signal	0.035mm		Signal	G2
Core		*0.115mm*	*FR4*	*Dielectric*	
Copper	Power	0.035mm		Signal	G3
Prepreg		*0.125mm*	*FR4*	*Dielectric*	
Copper	GND2	0.035mm		Signal	G4
Prepreg		*0.115mm*	*FR4*	*Dielectric*	
Copper	Bottom Layer	0.018mm		Signal	GBL
Surface Material	Bottom Solder	0.010mm	Solder Resist	Solder Mask	GBS
	Bottom Overlay			Legend	GBO

Total thickness: 0.791mm

Figure 10 Layer stackup of the BGT60ATR24AIP shield

2.5 Metal layers overview

Figure 11 through Figure 16 show the different metal layers of the PCB. Layer 1 comprises only BGT60ATR24AIP MMIC. Layers 2 and 5 consist of the ground plane for isolation. Layers 3 and 4 consist of signal and power lines, respectively. Layer 6 comprises the SMD components.

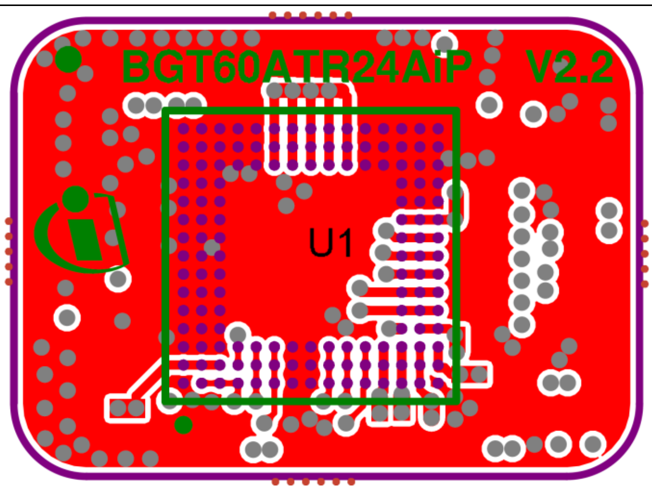


Figure 11 Layer 1 – Top layer

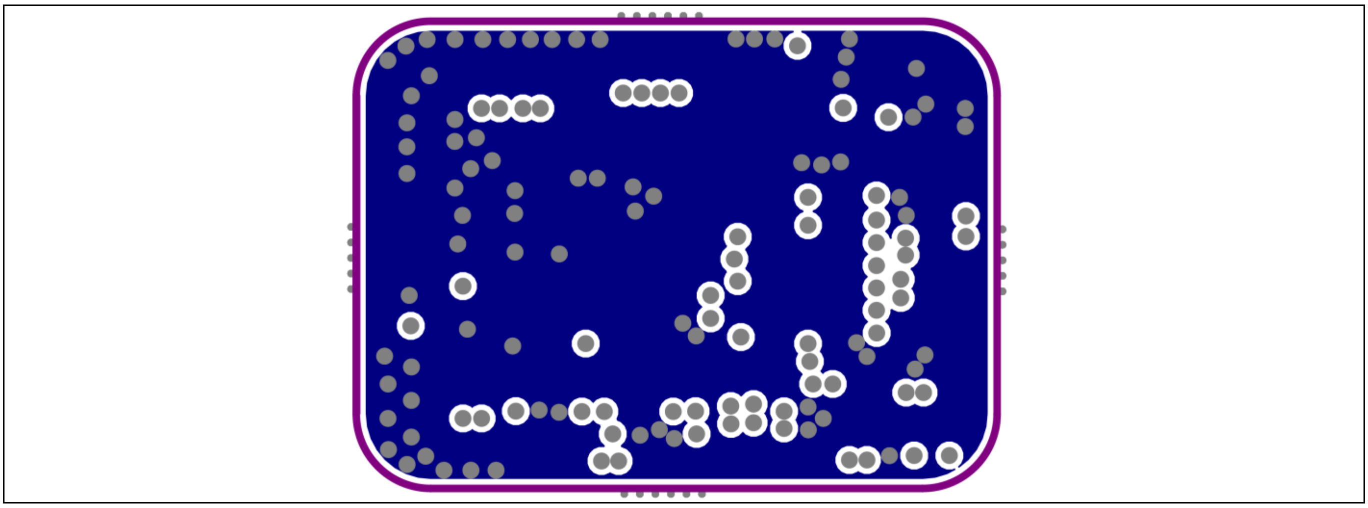


Figure 12 **Layer 2 – GND1 layer**

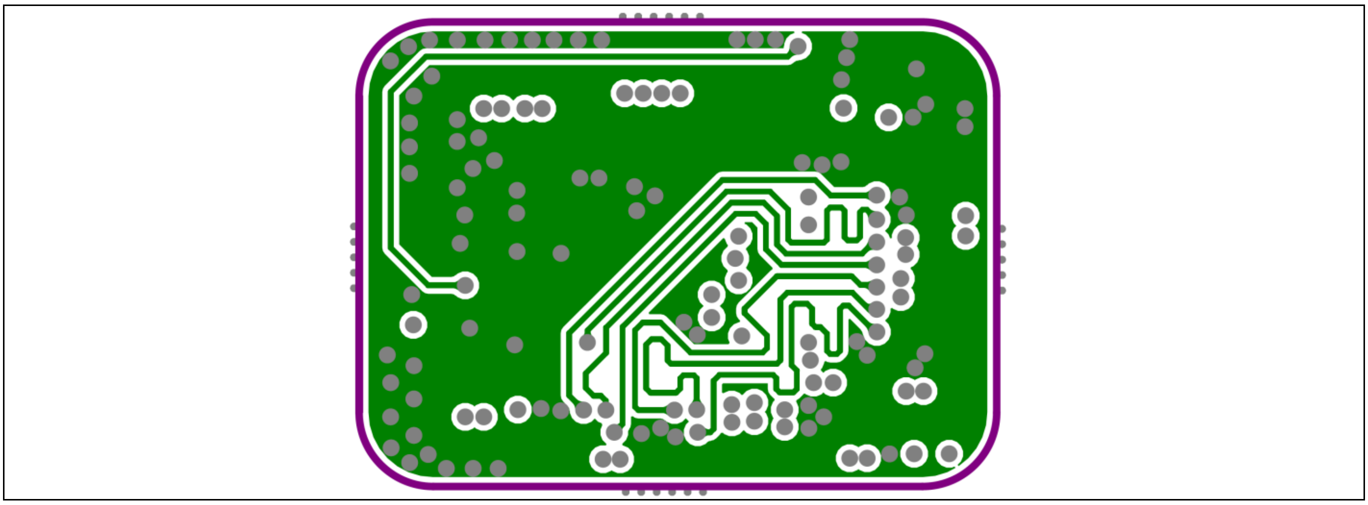


Figure 13 **Layer 3 – Signal layer**

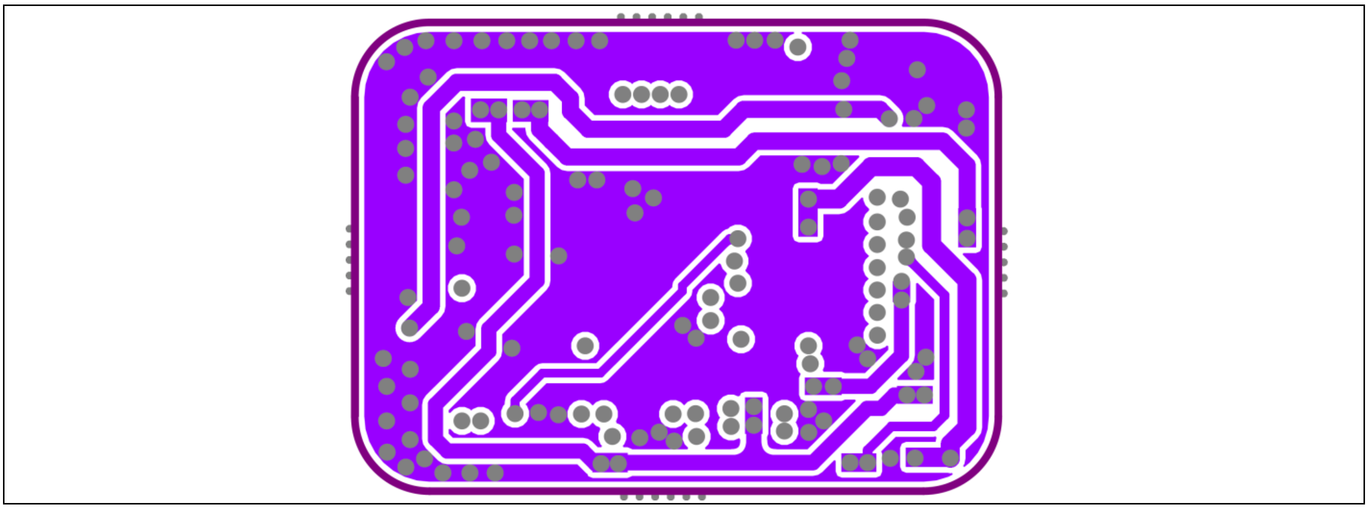


Figure 14 **Layer 4 – Power layer**

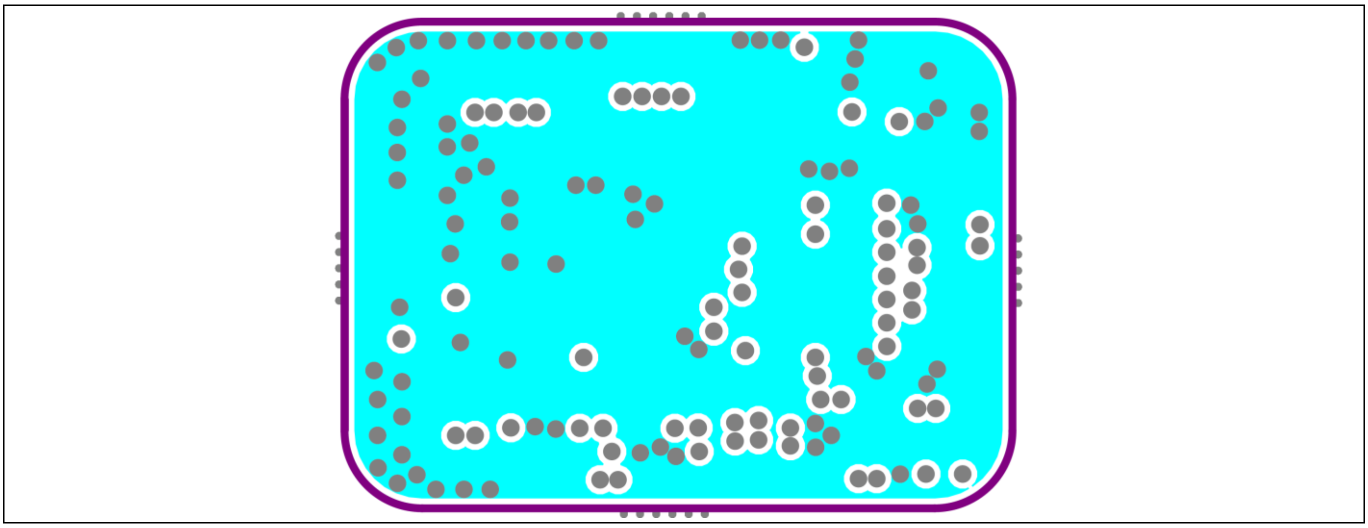


Figure 15 Layer 5 – GND2 layer

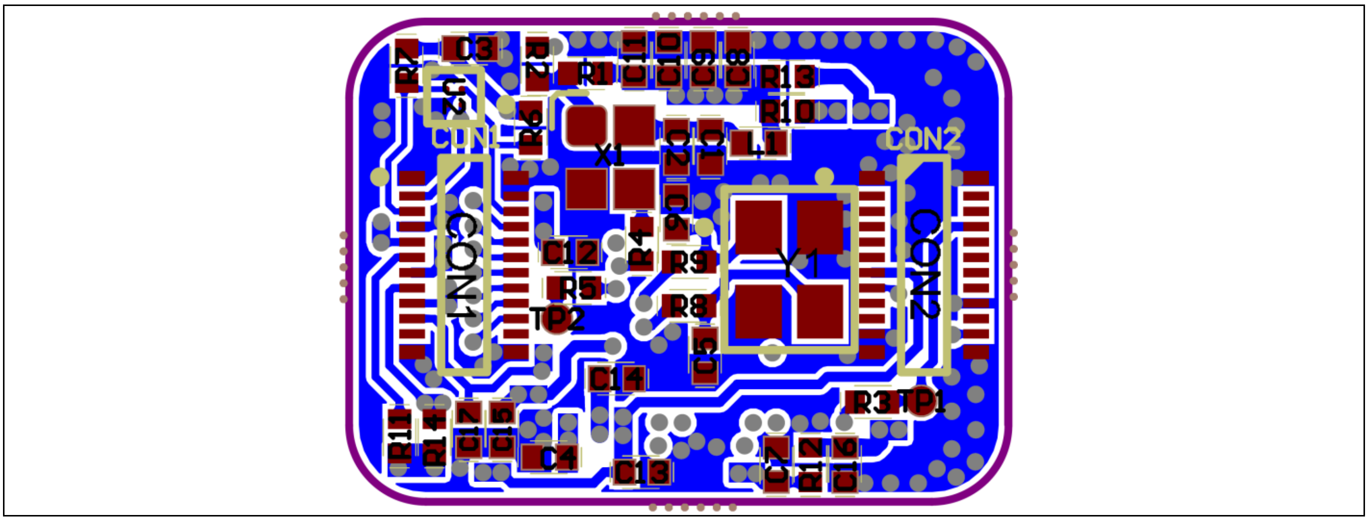


Figure 16 Layer 6 – Bottom layer (bottom view)

2.6 Antenna structure

BGT60ATR24AIP consists of two transmit and four receive antennas as shown in Figure 17. Using the two Tx channels in MIMO mode, the 8-channel virtual antenna array is obtained as shown in Figure 18.

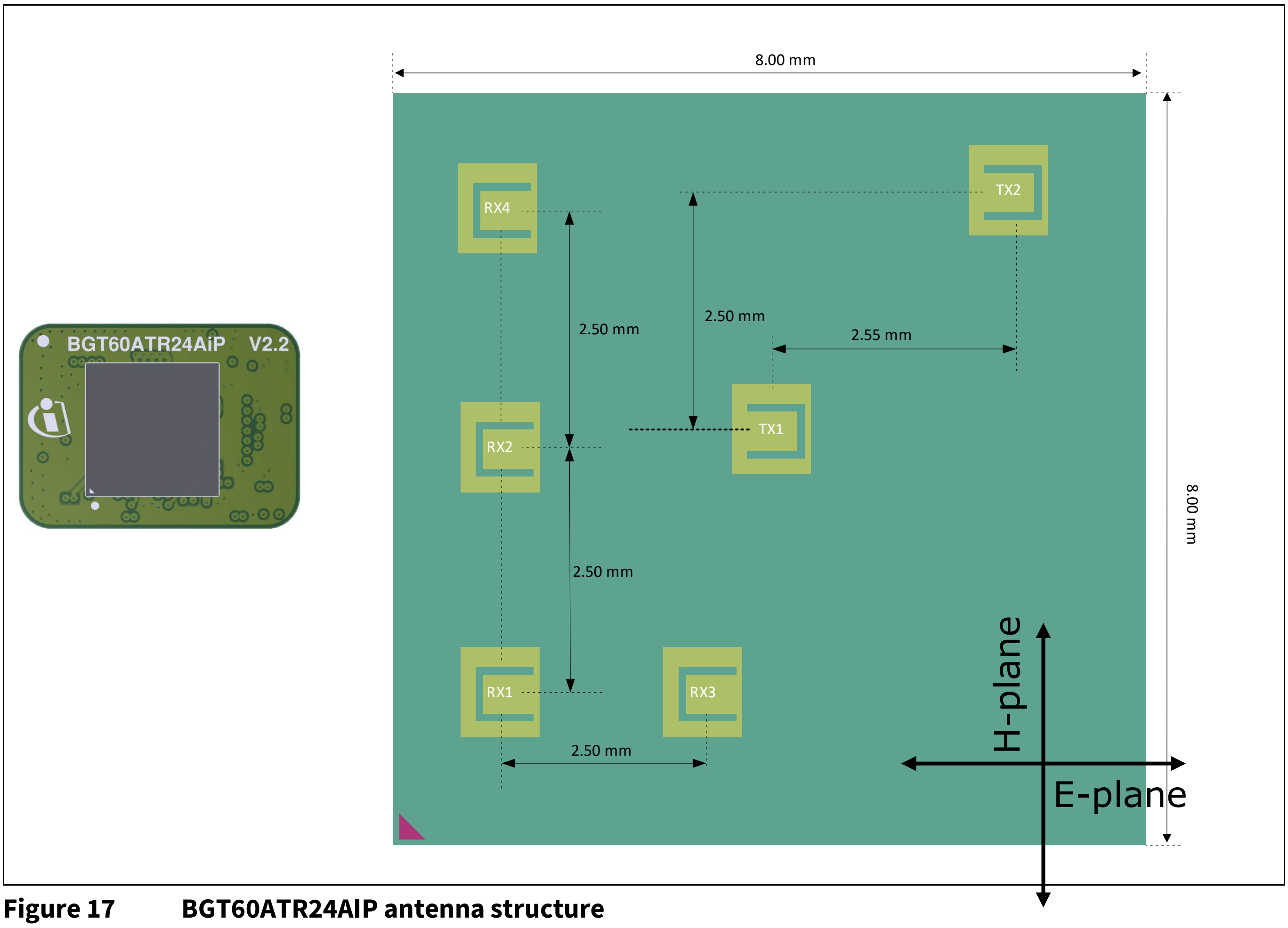


Figure 17 BGT60ATR24AIP antenna structure

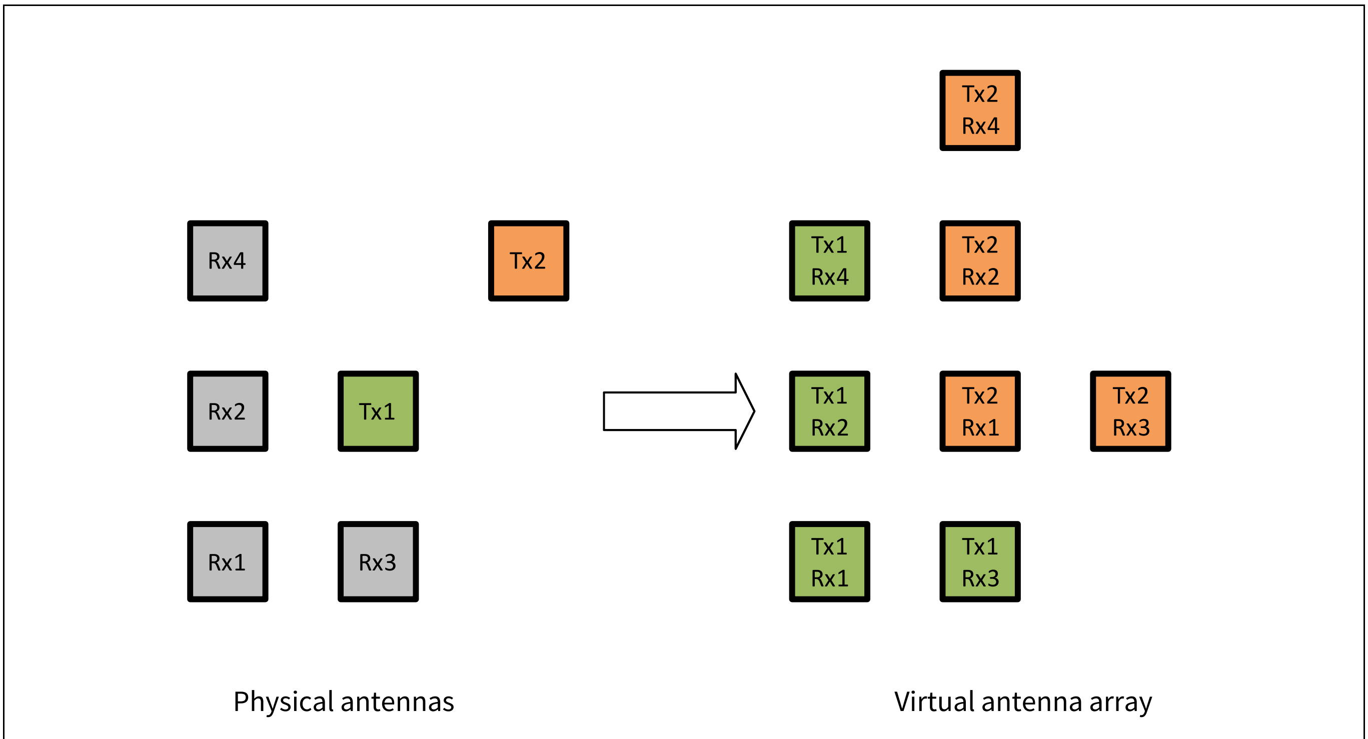


Figure 18 Physical antennas and corresponding MIMO mode virtual antenna array

3 Measurement results

3.1 Field of view (FoV) measurements

To analyze the radar FoV, the BGT60ATR24AIP shield is characterized along the azimuth plane and elevation plane of the shield board. A corner reflector is placed opposite to the radar board. The radiation emitted by the radar sensor is reflected by the corner reflector and measured with the receiver antennas of the radar board. In order to avoid clutter, the measurement is typically performed in an anechoic RF chamber. The measurement characterizes the chip in radar operation. Thus, both transmit and receive antennas are part of the measurement. For the measurement, the standard FMCW radar scheme is followed and the signals at the receive antennas are recorded. The gimbal sweeps the predefined angles in the azimuth plane and elevation plane and generates the 2D radiation pattern.

3.2 Test results

Figure 19 shows the measurement setup that is used. The corner reflector is placed at a distance of 1.4 m from the BGT60ATR24AIP shield in an anechoic chamber. The radar board is mounted on the gimbal, which can rotate by ±60 degrees along the azimuth plane and elevation plane, respectively. The measurements are performed using a Radar Baseboard MCU7 Plus with a chirp frequency range of 58-62 GHz and repeated with five different boards. The H-plane and E-plane plots for Tx1 and Tx2 channels are presented in Figure 20 and Figure 21, respectively.

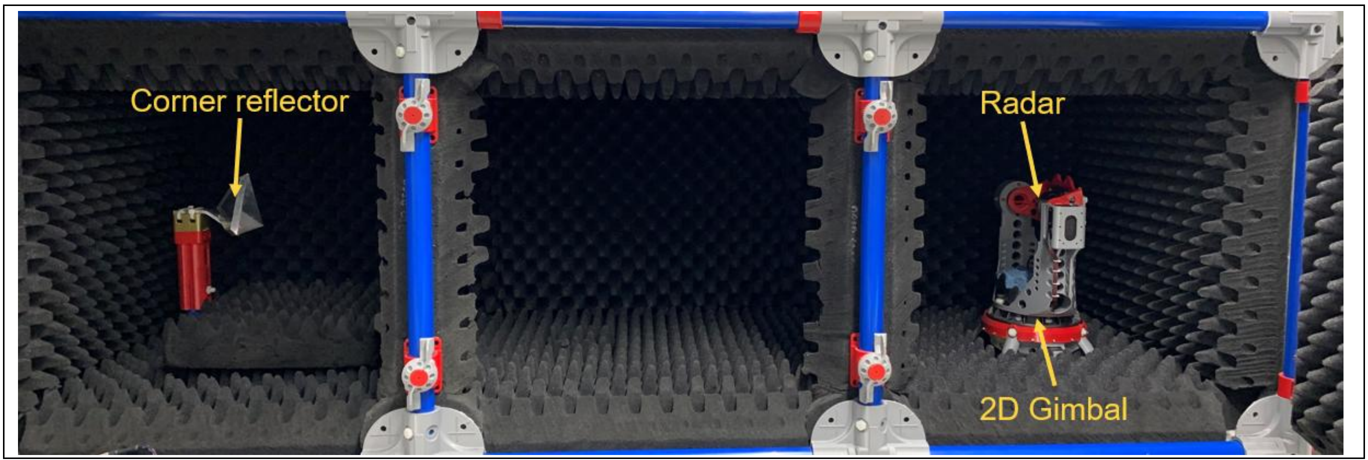


Figure 19 Measurement setup in anechoic chamber

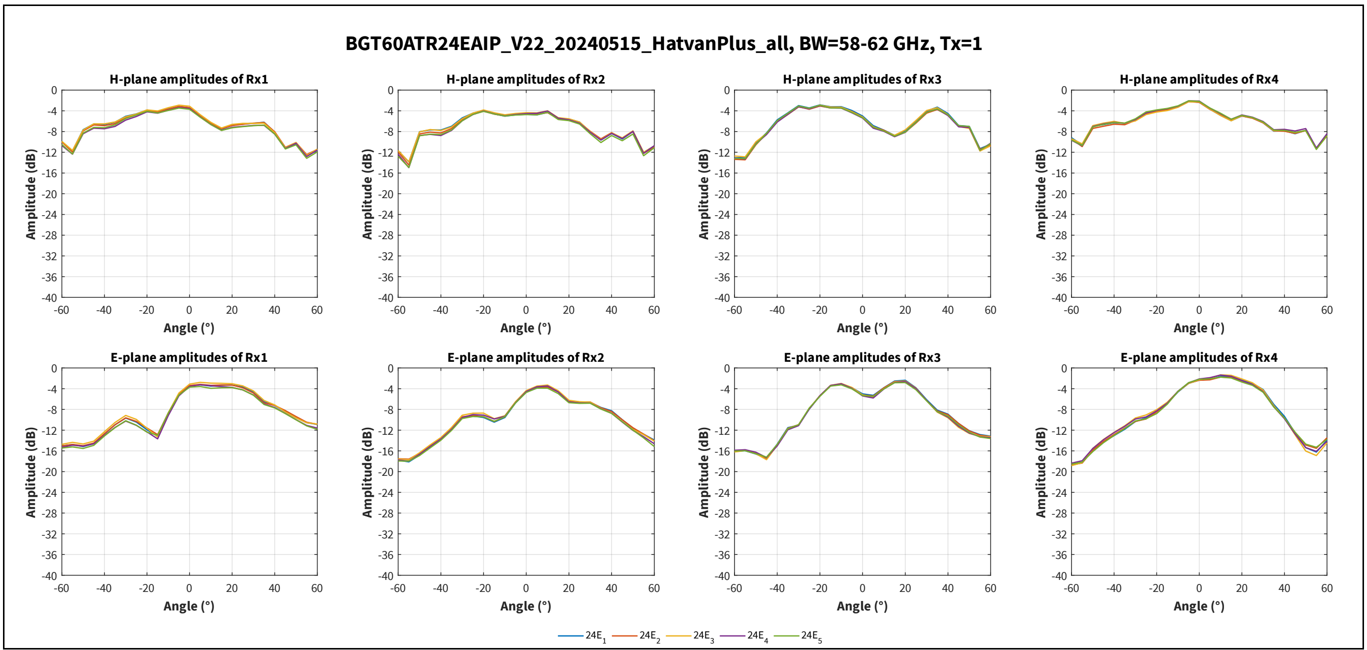


Figure 20 1D radiation patterns on H-plane and E-plane for Tx1 channel with 58-62 GHz bandwidth (five boards)

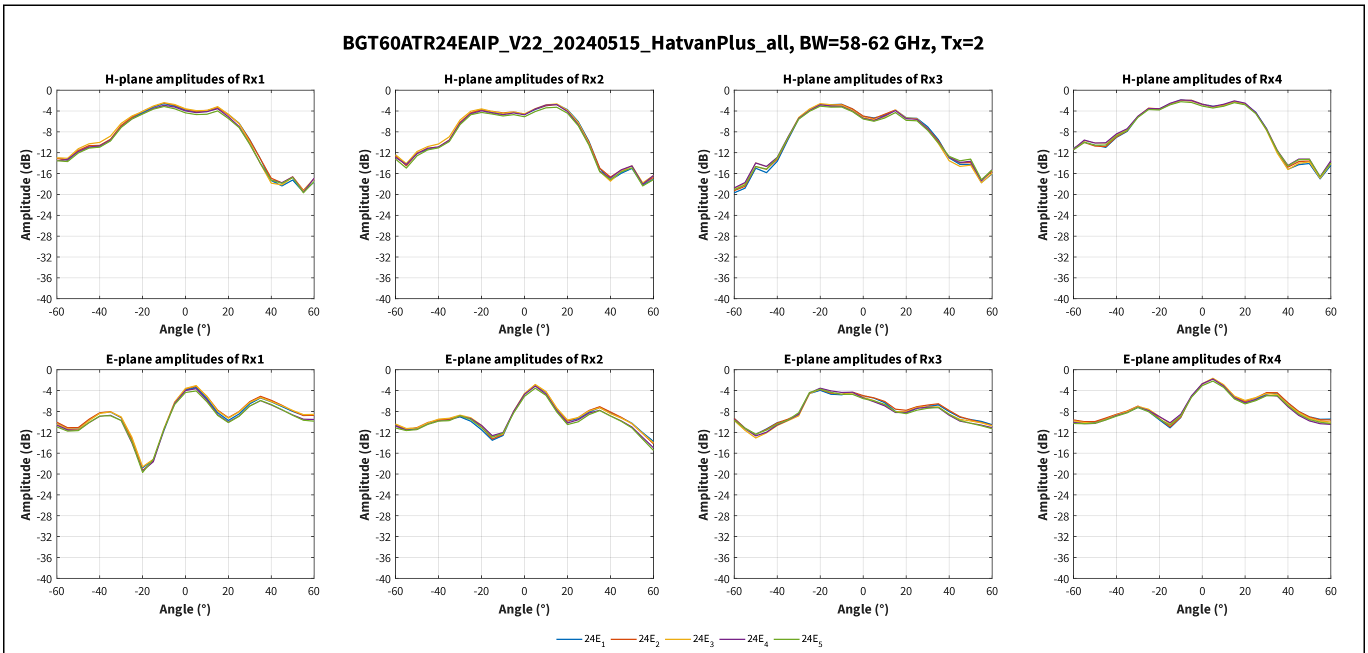


Figure 21 1D radiation patterns on H-plane and E-plane for Tx2 channel with 58-62 GHz bandwidth (five boards)

4 Related resources

- Webpage: 60 GHz radar sensors for automotive
- Webpage: XENSIV™ 60 GHz BGT60ATR24AIP radar sensor
- Infineon Developer Community: Radar sensors forum

References

[1] Infineon Technologies AG: *UG155750: Radar Baseboard MCU7 Plus user guide*; Available online

[2] Infineon Technologies AG: *XENSIV™ BGT60ATR24AIP MMIC datasheet;* Available online

Glossary

AIP
Antenna in Package (AIP)

EEPROM
electrically erasable programmable read-only memory (EEPROM)

EMI
electromagnetic interference (EMI)

ESD
electrostatic discharge (ESD)

FMCW
frequency-modulated continuous wave (FMCW)

FoV
field of view (FoV)

GND
ground (GND)

I²C
Inter-Integrated Circuit (I²C)

ICMS
in-cabin monitoring system (ICMS)

IRQ
interrupt request (IRQ)

LF
loop filter (LF)

MCU
microcontroller unit (MCU)

MIMO
multiple-input multiple-output (MIMO)

MMIC
monolithic microwave integrated circuit (MMIC)

OSC
oscillator (OSC)

PCB
printed circuit board (PCB)

PLL
phase-locked loop (PLL)

RF
radio frequency (RF)

RST
reset (RST)

SMD
surface-mounted device (SMD)

SPI
Serial Peripheral Interface (SPI)

Tx
transmit channel (Tx)

VCO
voltage-controlled oscillator (VCO)

XOSC
crystal oscillator circuit (XOSC)

XTAL

crystal oscillator (XTAL)

Revision history

Document revision	Date	Description of changes
1.00	2024-10-17	Initial release
1.10	2026-07-31	Editorial updates Updated References section

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Customer shall check the Evaluation Board for any physical damage which may have occurred during transport. If customer detects any damages or defects in the Evaluation Board, customer shall not connect the Evaluation Board to a power source. Customer shall contact Infineon for further support. If customer observes unusual operating behavior during the evaluation process, customer shall immediately shut off the power supply to the Evaluation Board and consult Infineon for support.
Customer shall not touch the Evaluation Board during operation and keep a safe distance.
Customer shall not touch the Evaluation Board after disconnecting the power supply, several components may still store electrical voltage and can discharge through physical contact. Several parts, like heat sinks and transformers, may still be very hot. Allow the components to cool before touching or servicing.
The electrical installation must be completed in accordance with the appropriate safety requirements.