XENSIV™ BGT60LTR11AIP shield

60 GHz radar system platform

Board version 2.0

About this document

Scope and purpose

This application note describes the function, circuitry, and performance of the 60 GHz radar BGT60LTR11AIP shield. The shield provides the supporting circuitry to the on-board BGT60LTR11AIP MMIC, Infineon's 60 GHz radar chipset with Antenna in Package (AIP). In addition to the autonomous mode configuration, the shield offers a digital interface for configuration and transfer of the acquired radar data to a microcontroller board, e.g. Radar Baseboard MCU7.

Intended audience

This document is intended for anyone working with Infineon's XENSIV™ 60 GHz radar system platform.

Disclaimer

The platform serves as a demonstrator to perform simple motion sensing. The test data in this document shows typical performance of demonstrator. However, board performance may vary depending on the PCB manufacturer, specific design rules they may impose and components they may use.

Table of contents

1 Introduction

1.1 Overview

The BGT60LTR11AIP MMIC is a fully integrated microwave motion sensor including Antennas in Package (AIP) as well as built-in motion and direction of motion detectors. A state machine enables operation of the MMIC without any external microcontroller. In its autonomous mode, it detects a human target up to 7 m with a low-power consumption. These features make the small-sized radar solution a compelling smart and cost-effective replacement for conventional PIR sensors in low-power or battery-powered applications.

The BGT60LTR11AIP shield demonstrates the features of the BGT60LTR11AIP MMIC and gives the user a “plug and play” radar solution. The MMIC is designed to operate as a Doppler motion sensor in the 60 GHz ISM-band. Two integrated detectors provide two digital output signals – one indicating motion and the other indicating the direction of motion (approaching or departing) of a human target.

The MMIC has four quad-state (QS1-4) input pins that give the performance parameters flexibility even when it is running in autonomous mode. These pins are used for configuration of the chip as explained in section 4.9. In autonomous mode, detection threshold or sensitivity (set via QS2) has 16 different levels to fulfill a configurable detection range from 0.5 m up to 7 m with a typical human target Radar Cross Section (RCS). Hold time is also configurable in 16 levels in autonomous mode via QS3, which allows detection status to be held up to 30 minutes (see Table 7). Duty-cycle settings are also configurable to allow a lower power consumption.

The MMIC also supports an SPI mode by changing the operation mode with QS1 pin (see Table 4). In this mode, the radar raw data can be extracted from BGT60LTR11AIP for signal processing on PC or an external microcontroller unit (MCU) using SPI. This sampled radar data can be used for developing customized algorithms. The shield can also be attached to an Arduino MKR board or an Infineon Radar Baseboard MCU7. Infineon’s Toolbox supports this platform with a demonstration software and a Radar Graphical User Interface (Radar GUI) to display and analyze acquired data in time and frequency domain.

This application note focuses on the BGT60LTR11AIP shield. Detailed documentation on the Radar Baseboard MCU7 can be found in corresponding application note.

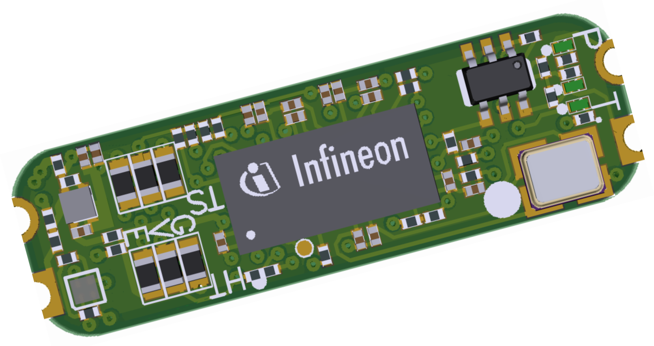


Figure 1 BGT60LTR11AIP shield using BGT60LTR11AIP MMIC

1.2 Key features and system benefits

The BGT60LTR11AIP MMIC is a fully integrated microwave motion sensor including antenna elements, configurable built-in detectors and a state machine allowing fully autonomous operation of the device. The chip is designed to operate as a Doppler motion sensor. In the fully autonomous mode, the integrated detectors deliver digital outputs indicating motion and direction of motion. An integrated frequency divider with a Phase-Locked Loop (PLL) provides VCO frequency stabilization. The MMIC supports multiple operation modes: autonomous, SPI mode and SPI mode with external clock. The different modes can be selected via QS1 pin (Section 4.9).

The BGT60LTR11AIP shield is optimized for fast prototyping designs and system integrations as well as initial product feature evaluations. In addition, the sensor can be integrated into systems like laptops, tablets, TVs, speakers etc. to ‘wake’ them up based on motion (or rather direction of motion) detection, 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 key-word based activation of systems. Radar sensors offer the possibility to hide them inside the end product since they operate through non-metallic materials. Therefore, it enables a seamless integration of technology in our day-to-day lives.

Some key features of the BGT60LTR11AIP shield are as follows:

- Form factor of 20 mm x 6.25 mm for the BGT60LTR11AIP shield
- Features an AIP (Antenna-In-Package) 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 retreating) for a human target
- Works standalone (autonomous mode) or also with SPI mode to interface with an external microcontroller
- Configurable settings like operation mode, detector threshold, hold time, operating frequency
- Low-power consumption
- Option to solder onto other PCBs such as Arduino MKR for extra flexibility

2 Getting started

This section provides a quick step-by-step process to get started with the BGT60LTR11AIP demo board.

STEP 1

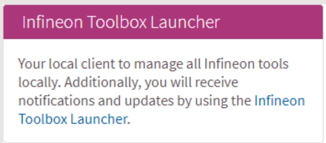
Box content

- BGT60LTR11AIP Shield
- Radar Baseboard MCU7

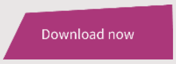
STEP 2

Infineon Toolbox

- Go to: [Infineon Products and Tools - Infineon Toolbox]()
- Click on "**Infineon Toolbox Launcher**" link.



- Scroll down and click on the "**Download now**" button.



- Run the "**infineon-toolbox-setup.exe**" file.

- Finish installation. Create a desktop shortcut.

STEP 3

Install BGT60LTR11AIP kit

- Open "**Infineon Toolbox**".
- Click on the "**Manage tools**" tab.
- Search for "Radar BGT60LTR11AIP".

- Click on "**Install**".
- Accept agreement and finish installation.

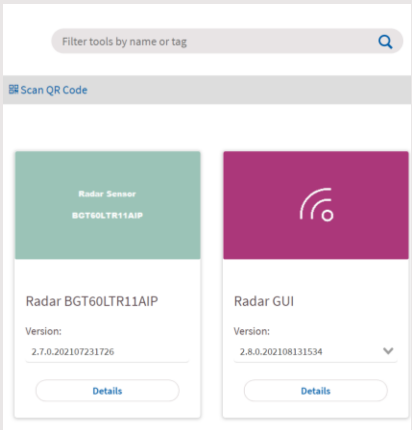


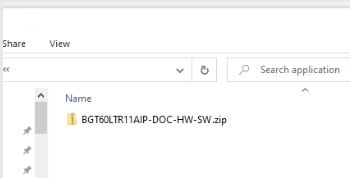
Figure 2 Steps 1 to 3 to get started with the BGT60LTR11AIP demo board

STEP 4

Optional

Download HW/SW package

- Open "**Infineon Toolbox**".
- Click on "**Radar BGT60LTR11AIP**".
- Follow the instructions mentioned on the left tab "**Getting Started**".
- Browse to the preferred location to store the files.



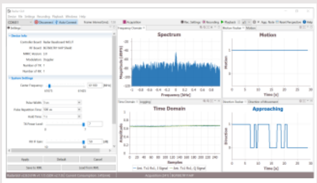
STEP 5

Connect board

- Insert the micro-USB cable into the Radar Baseboard MCU7 board

- Insert the USB connector into the PC's USB port.

- Open "**Radar GUI**"

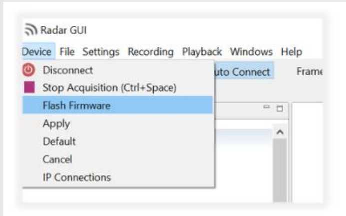


STEP 6

Optional

Firmware update

- Connect board as **STEP 5**
- Open **Infineon Toolbox ▶ Radar GUI ▶ Device ▶ Flash Firmware**.



- Select Device "**BGT60LTR11AIP**" from the dropdown list and select the "**.bin**" Firmware.
- Click on "**Flash Firmware**".

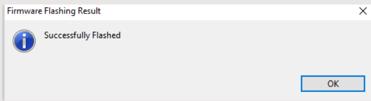


Figure 3 **Steps 4 to 6 to get started with the BGT60LTR11AIP demo board**

3 System specifications

3.1 BGT60LTR11AIP shield parameters

Table 1 lists the various parameters of the BGT60LTR11AIP shield.

Table 1 BGT60LTR11AIP shield specifications

Parameter	Unit	Min.	Typ.	Max.	Comments
System performance					
Maximum detection range	m	–	5	7	Typ. motion detection range for human target at high sensitivity (in both E and H plane orientation)
Power supply					
Supply voltage	V	1.5	3.3	5.0	
Current consumption	mA		3.48		@3.3V supplied via castellated holes PRT = 500µs, pulse width = 5µs (LEDs off)
Antenna characteristics (measured)					
Antenna type			1 x 1		Antenna in Package (AIP)
Horizontal – 3 dB beam width	Degrees		80		At frequency = 61.25 GHz
Elevation – 3 dB beam width	Degrees		80		At frequency = 61.25 GHz

4 Hardware description

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

4.1 Overview

The BGT60LTR11AIP shield is a very small PCB of 20 x 6.25 mm size. Mounted on top of the PCB is a BGT60LTR11AIP (U1 in Figure 2), Infineon's 60 GHz radar sensor with integrated antennas. The antennas are integrated into the chip package; therefore, the PCB can be manufactured using a standard FR4 laminate. The bottom side of the shield has the connectors to the Radar Baseboard MCU7 [1] (P1 and P2 in Figure 2). The castellated holes on the edges of the PCB provide additional access to the detector outputs and power supply signals of the shield. By using these castellated holes and removing P1 and P2, the BGT60LTR11AIP shield can be soldered onto other PCBs. On the top side of the shield is a marker that must be aligned with the marker on the radar baseboard MCU7 for correct alignment, as shown in Figure 5.

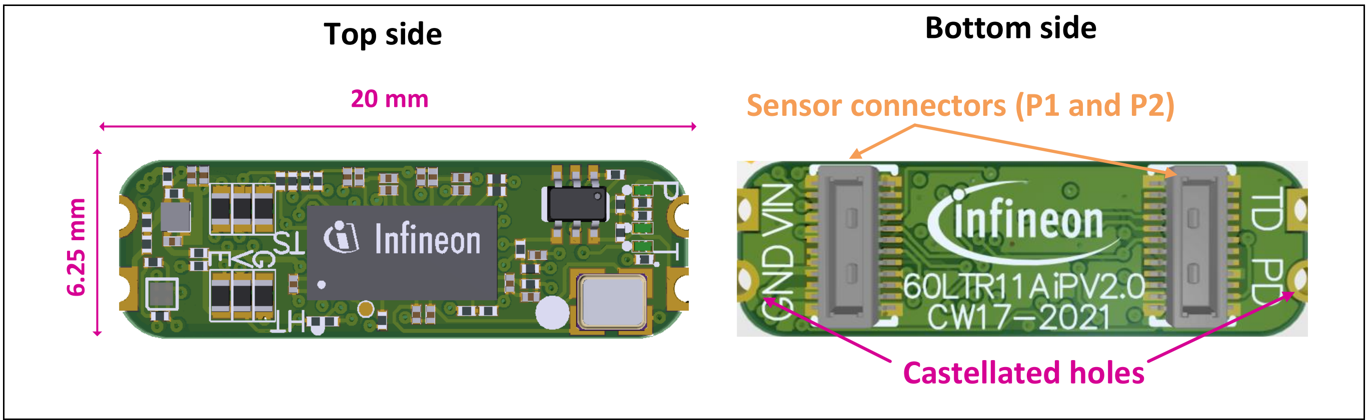


Figure 4 **Top and bottom view of BGT60LTR11AIP shield**

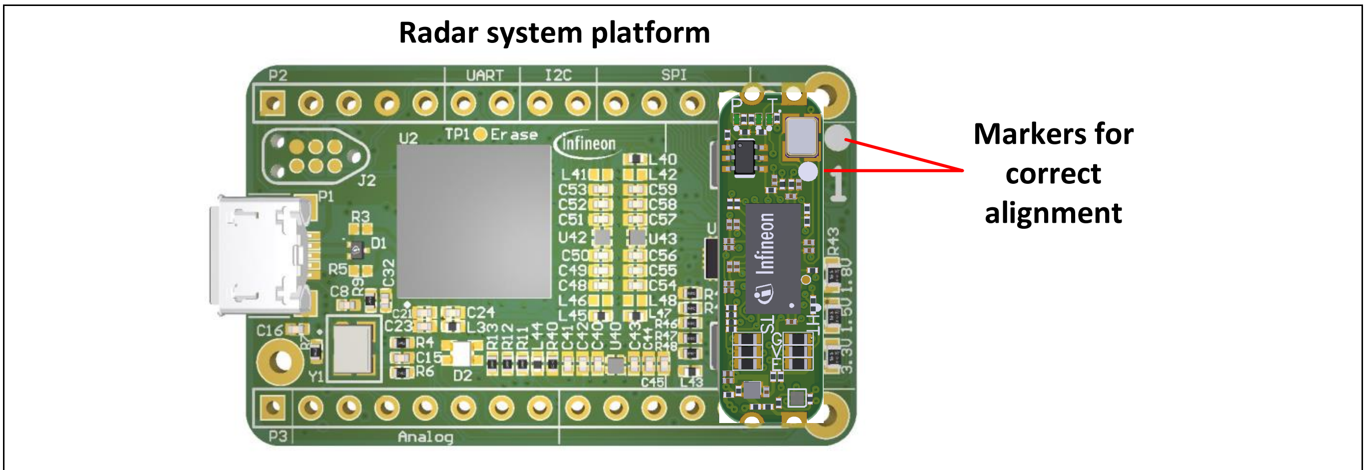


Figure 5 **Markers on Radar Baseboard MCU7 and BGT60LTR11AIP shield for alignment**

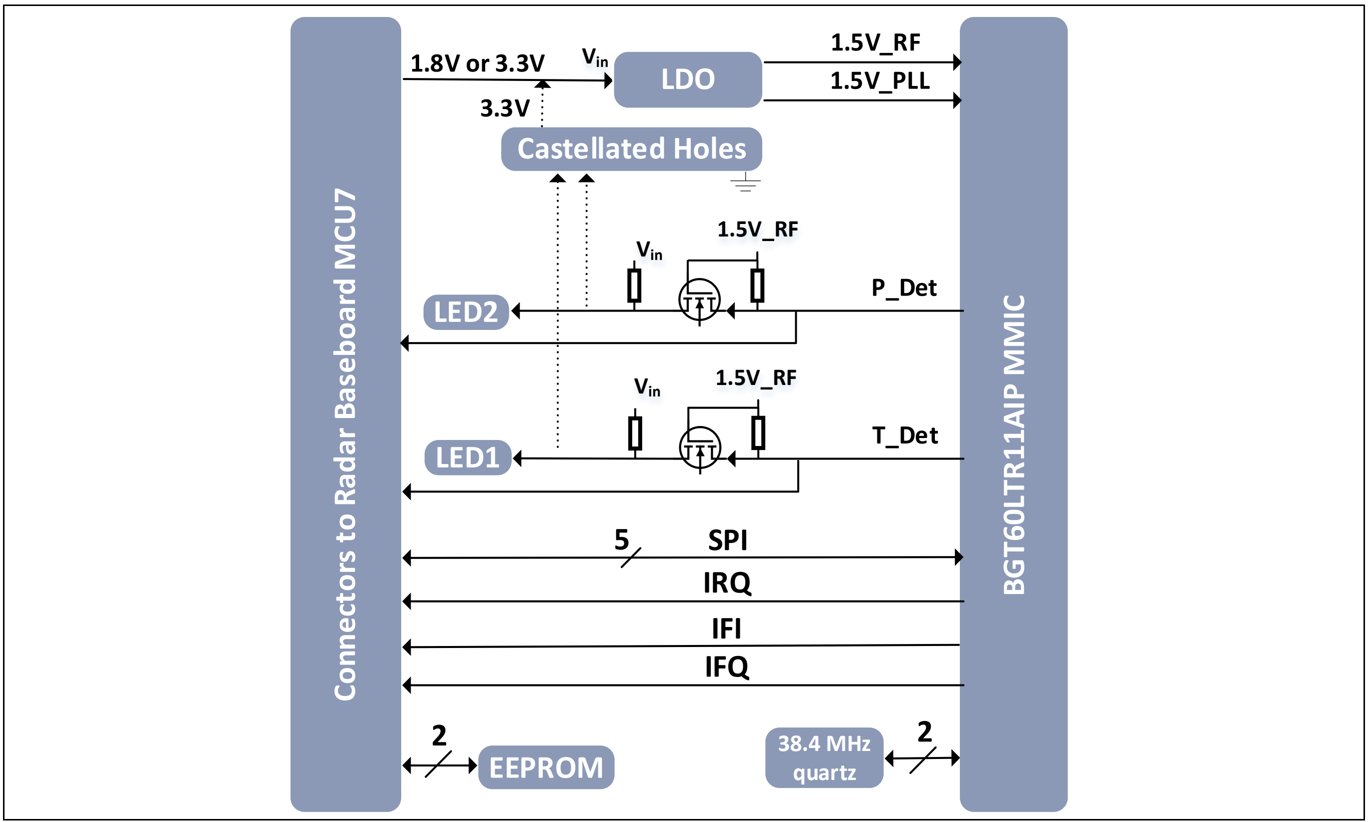


Figure 6 Block diagram of the BGT60LTR11AIP shield

The block diagram in Figure 6 depicts the configuration of the shield. When the shield is plugged into the Radar Baseboard MCU7, the MMIC's supplies are initially deactivated. Only the EEPROM is powered. The MCU reads the content of the EEPROM's memory to determine which shield is plugged into the connectors. Only when the shield has been correctly identified, are the MMIC's supplies activated.

Communication with the MMIC is mainly performed via a Serial Peripheral Interface (SPI). The BGT_RTSN allows the MCU to perform a hardware reset of the MMIC. The BGT_SELECT and BGT_RTSN lines of the SPI are also pulled up with 10 kΩ resistors. The interrupt request (IRQ) line can be used to signal the MCU when new data needs to be fetched.

4.2 BGT60LTR11AIP MMIC

The BGT60LTR11AIP MMIC (Figure 8) serves as the main element on the BGT60LTR11AIP shield. The MMIC has one transmit antenna and one receive antenna integrated into the package. The package dimensions are 6.7 mm (± 0.1 mm) x 3.3 mm (± 0.1 mm) x 0.56 mm (± 0.05 mm), as illustrated in Figure 8 and Figure 9.

The MMIC has an integrated Voltage Controlled Oscillator (VCO) for high-frequency signal generation. The transmit section consists of a Medium Power Amplifier (MPA) with configurable output power, which can be controlled via the SPI.

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 in order 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 Base Band (ABB) unit consists of an integrated sample and hold circuit for low-power duty-cycled operation 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 indicate the detection of movement in front of the radar and the direction of movement with two digital signals (BGT_TARGET_DET and BGT_PHASE_DET). See section 4.8 for more details. The detector circuit offers a user-configurable hold-time for maximum flexibility.

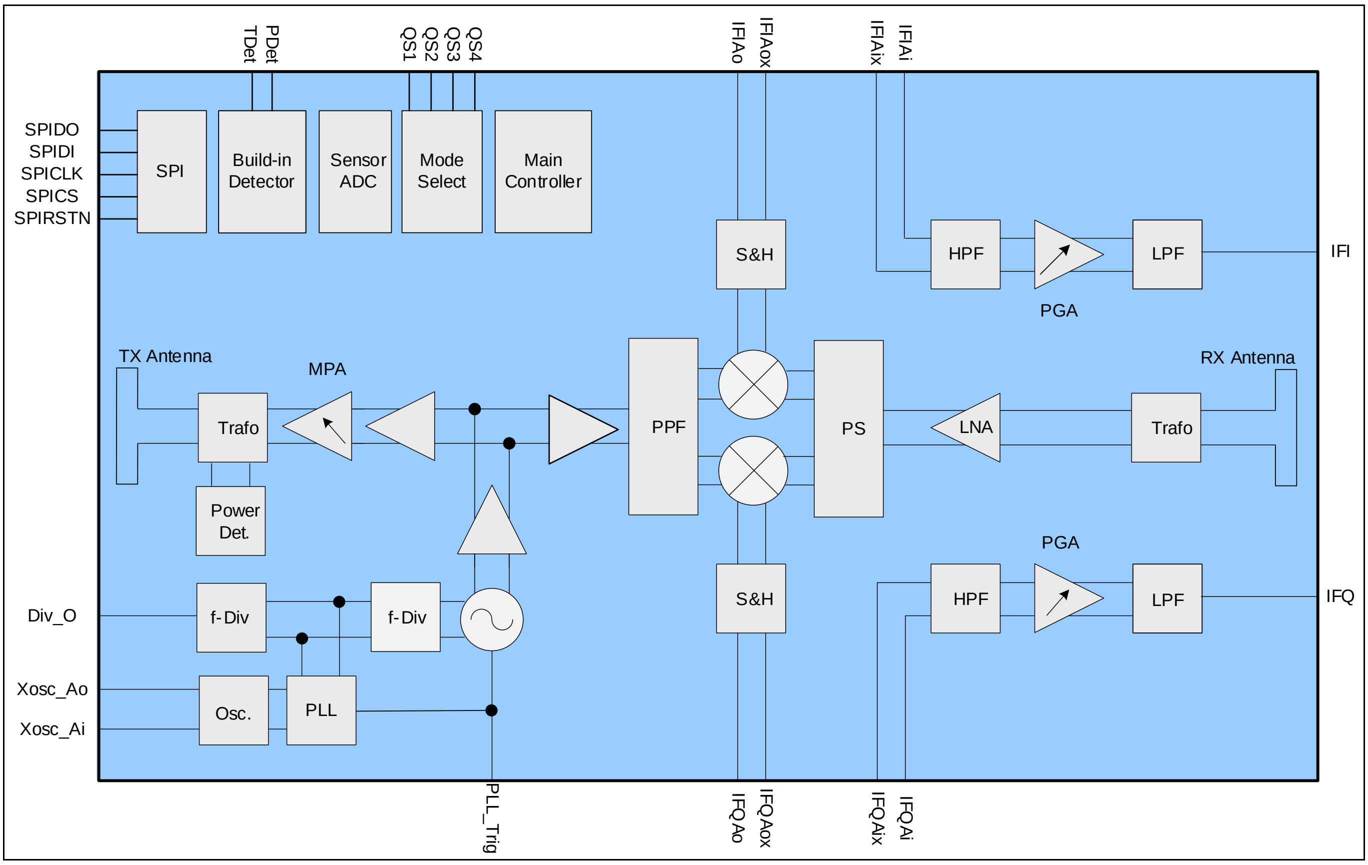


Figure 7 **BGT60LTR11AIP MMIC block diagram**

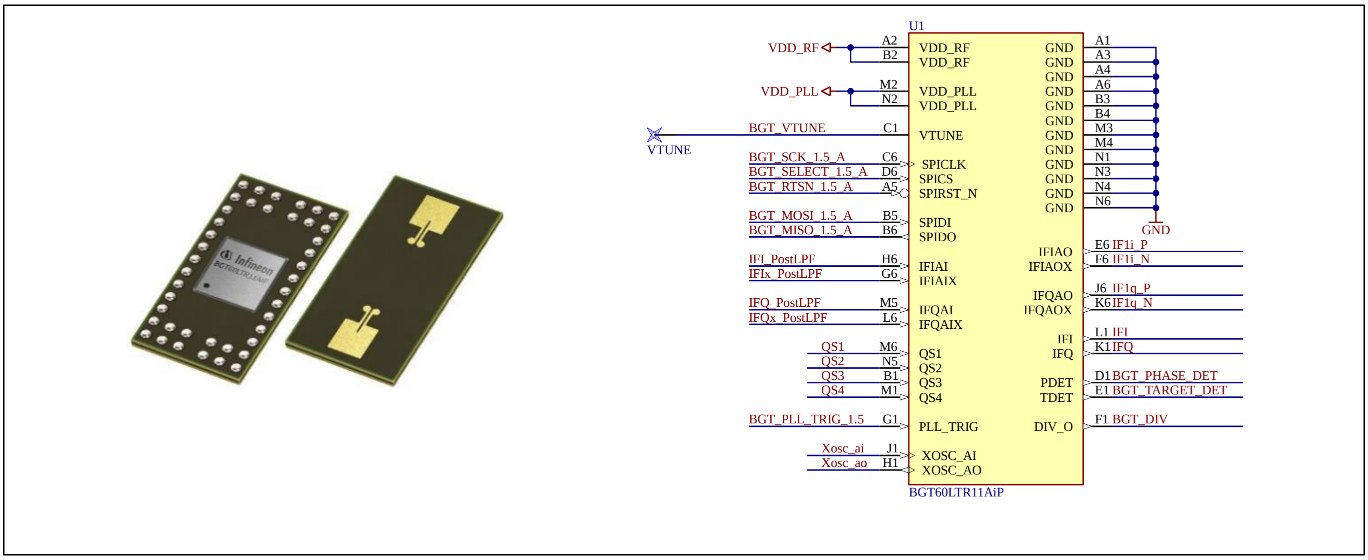


Figure 8 **Package and pin-signal assignment of the BGT60LTR11AIP MMIC**

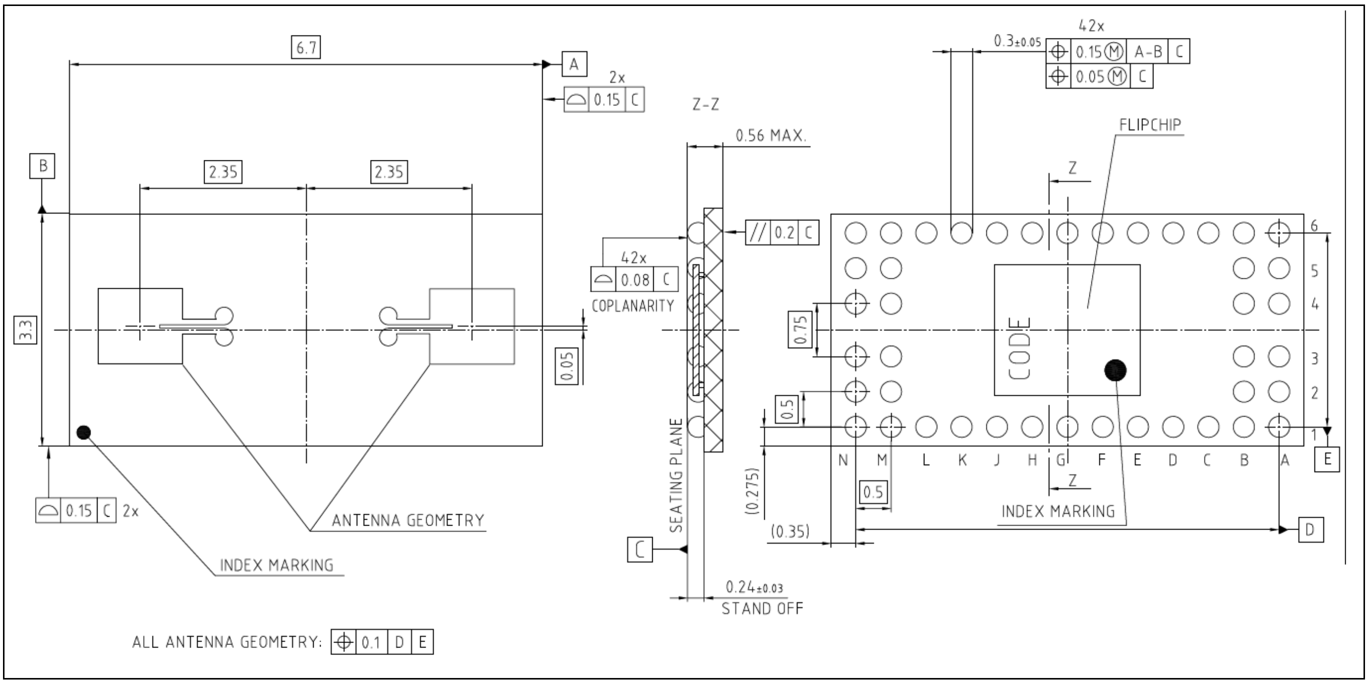


Figure 9 Top and side view of the BGT60LTR11AIP MMIC package – all dimensions in mm

4.3 Sensor supply

Since radar sensors are very sensitive to supply voltage fluctuations or cross-talk between different supply domains, a low-noise power supply as well as properly decoupled supply rails are vital. The Radar Baseboard MCU7 provides a low-noise supply. Figure 10 depicts the schematics of the low-pass filters employed to decouple the supplies of the different power rails in the BGT60LTR11AIP shield. High attenuation of voltage fluctuations in the MHz regime is provided by ferrite beads (L1, L3 and L5). For example, the SPI which runs up to 50 MHz, induces voltage fluctuations on the digital domain, which would then couple into and interfere with the analog domain without the decoupling filters. The ferrite beads are chosen such that they can handle the maximum current of the sensor with a low DC resistance (below 0.25 Ω) and an inductance as high as possible. The high inductance will reduce the cut-off frequency of the low-pass filter, which provides better decoupling for lower frequencies.

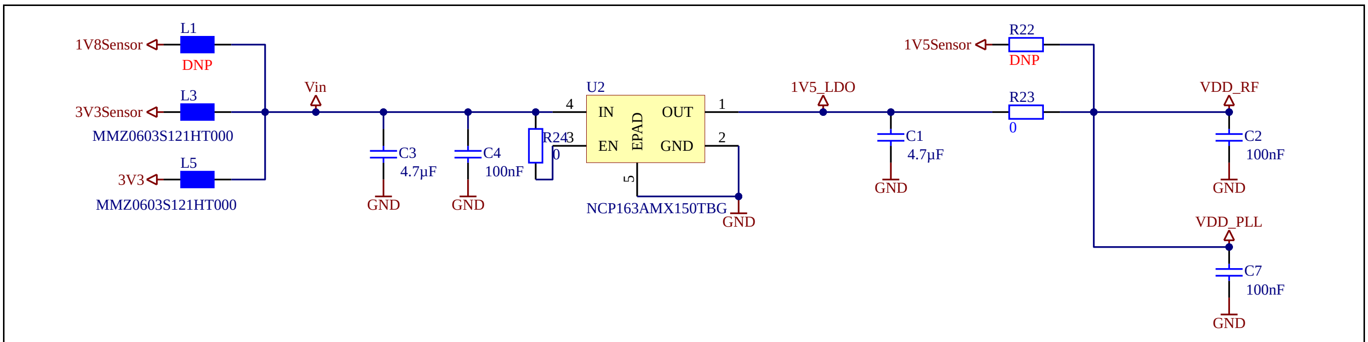


Figure 10 Schematics of the sensor supply and low-pass filters

4.4 Crystal

The MMIC requires an oscillator source with a stable reference clock providing low phase jitter and low phase noise. The oscillator is integrated inside the MMIC. This saves current consumption, as crystal oscillators consume only a few milliamperes and run continuously. The BGT60LTR11AIP shield uses a 38.4 MHz crystal oscillator, as shown in Figure 11.

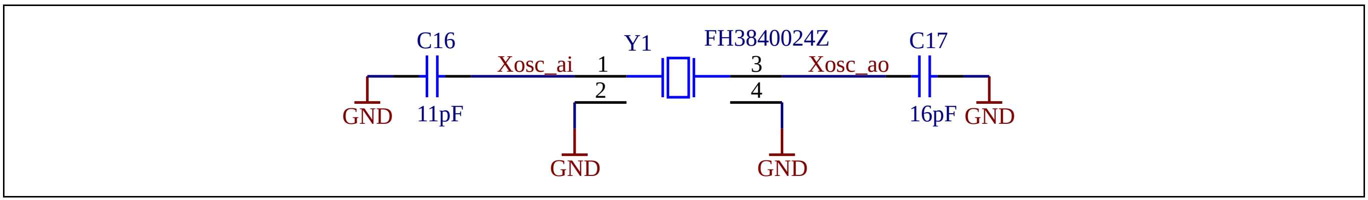


Figure 11 The crystal circuit on the BGT60LTR11AIP shield

4.5 External capacitors

The BGT60LTR11AIP MMIC is highly duty-cycled and performs a sample and hold (S&H) operation for lower power consumption. The S&H switches are integrated in chip at each differential IQ mixer output ports. They are controlled synchronously via the internal state machine. The capacitors between S&H and the high-pass filter (HPF) are external. C10, C11, C14 and C15 are 5.6 nF capacitors used as “hold” capacitors for the S&H circuitry. They can be configured for different pulse width settings, as shown in Table 2. C8, C9, C12 and C13 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). It is not recommended to use higher values as it will affect 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 12 the external hold (C_{hold}) and high-pass capacitors (C_{HP}) are shown for all four branches in the differential IQ configuration.

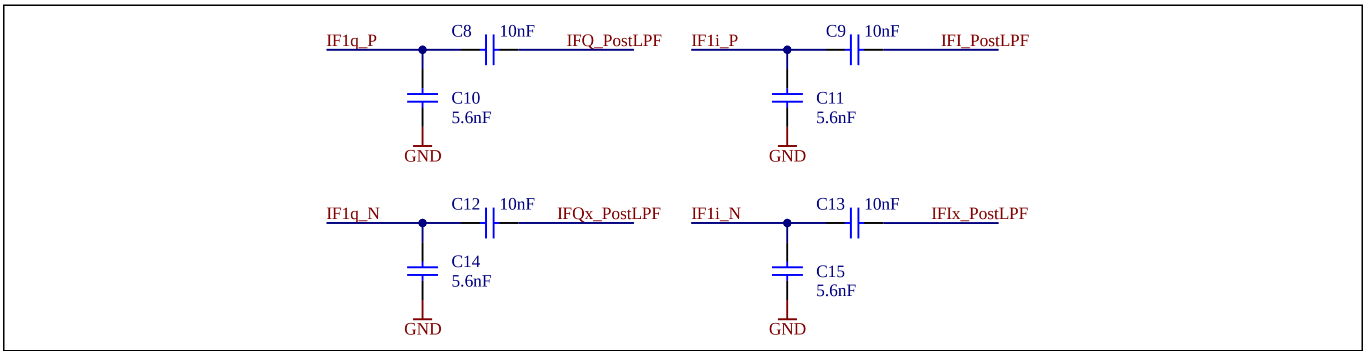


Figure 12 External capacitors

Table 2 Recommended hold capacitors (C10, C11, C14 and C15) for different pulse width

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

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. Rise-time is controlled by the C_{hold} itself and the internal mixer output resistance of 300Ω in each branch.

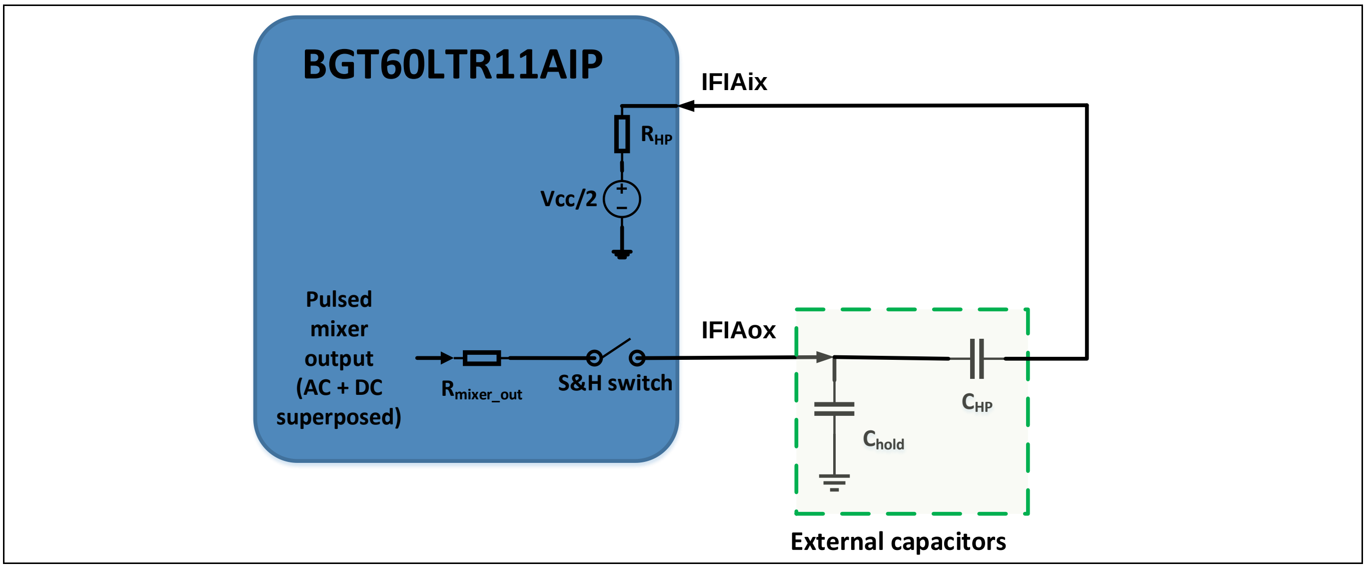


Figure 13 External capacitors for BGT60LTR11AIP

Longer pulse width can have a higher C_{hold} value. This leads to a reduced bandwidth (BW) of the RC fiter ($R_{mixer\text{-}out}$ & C_{hold}). Consequently, there will be lower baseband noise because of reduced noise folding bandwidth.

For this RC structure (R_{mixer_out} and C_{hold}) 10%/90% rise-time and 3-dB cut off low-pass frequency can be calculated under following conditions:

t_{rise}=10% / 90% = S&H ON time = 4µs, Pulse width = 5µs, R_{mixer_out} = 300 Ω

$$f_{LP_{3dB}} = \frac{0.35}{t_{rise}}$$

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

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

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

High-Pass 3dB cut off frequency ($f_{HP_{3dB}}$) for C_{HP} (= 10nF) and R_{HP} (= 4MΩ) is:

$$f_{HP_{3dB}} = \frac{1}{2\pi R_{HP} C_{HP}}$$

$$f_{HP_{3dB}} = \frac{1}{2\pi * 4M\Omega * 10nF} = 4\ Hz$$

4.6 Connectors

The BGT60LTR11AIP shield can be connected to an MCU board, like the Radar Baseboard MCU7 with the P1 and P2 connectors. Visible on the top and bottom side of the PCB are the castellated holes (P3 and P4). TD and PD pins of the castellated holes correspond to the internal detector outputs of the MMIC.

The shield contains two Hirose DF40C-20DP-0.4V connectors, P1 and P2. The corresponding DF40C-20DS-0.4V connectors are on the Radar Baseboard MCU7. Figure 14 illustrates the pin-out of the Hirose connectors of the BGT60LTR11AIP shield.

The Hirose connectors can wear out when regularly plugged into and unplugged from the shield. To prevent this, do not lift the board on the short side out of the connector. Instead, simply pull on the long side of the board, thereby tilting the short side. This will significantly increase the lifetime of the connectors.

The signal IRQ is connected with a R5 resistor (0 Ω) to the divider output (BGT_DIV) of the MMIC. In pulse mode, BGT_DIV generates a signal that acts as an interrupt signal for the MCU to start ADC acquisition. BGT_DIV could also be used to measure divider frequency.

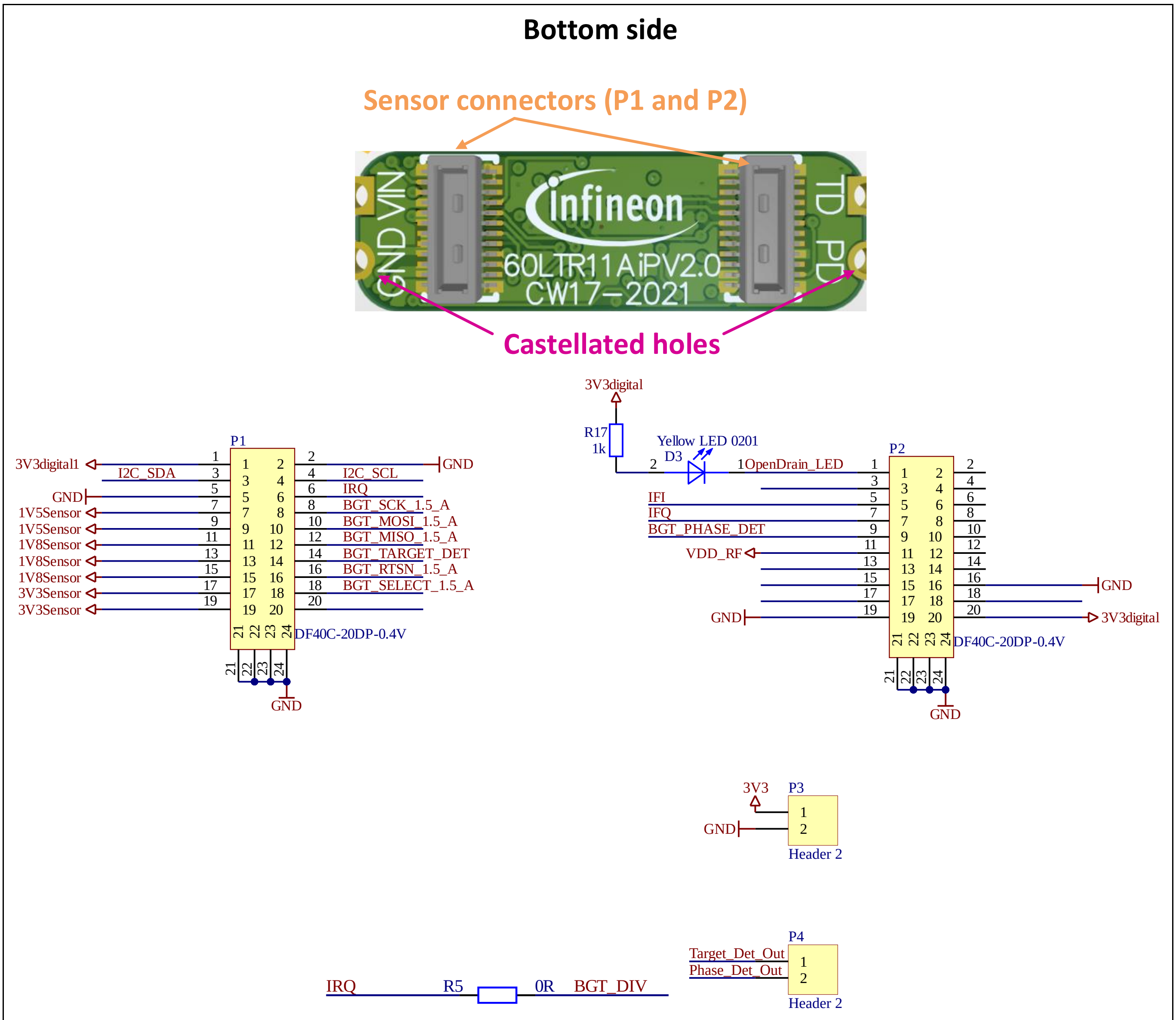


Figure 14 Connectors on the BGT60LTR11AIP shield, and their pin-outs

4.7 EEPROM

The BGT60LTR11AIP shield contains an EEPROM connected via an I²C interface to store data like a board identifier. Its connections can be seen in Figure 15. This EEPROM contains a descriptor indicating the type of the shield board and MMIC. This is used by the firmware to communicate properly with the shield. The EEPROM can be removed when the shield is intended to be used independently in the autonomous mode.

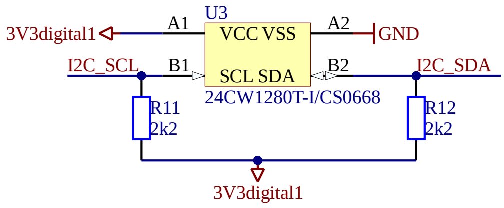


Figure 15 Connections of the EEPROM

4.8 LEDs and level shifting

The shield has two LEDs to indicate the motion detection (green) and target's direction of motion (red), as shown in Figure 16. R1 and R2 are limiting resistors. The digital block within the detector in the MMIC evaluates and sets the Target_detect/Phase_detect outputs of the BGT60LTR11AIP MMIC. Target detected (T_{det}) output is active low. Phase detected (P_{det}) output is used to show the direction of the detected target. It is set to high for approaching targets, otherwise low. The default state for P_{det} is low.

The outputs from MMIC are at the voltage level of 1.5 V. They are level-shifted to the voltage level of V_{in} by using the circuit shown in Figure 16. In the circuit, BGT_TARGET_DET and BGT_PHASE_DET are outputs of MMIC (1.5 V voltage level). V_{DD_RF} is 1.5 V and V_{in} is 3.3 V (when connected with Radar Baseboard MCU7).

- When BGT_TARGET_DET is high (1.5 V), NMOS is off (V_{gs} = 0 V), and Target_Det_Out is 3.3V through the R14 pull-up resistor.
- When BGT_TARGET_DET is low (0 V), NMOS is on (V_{gs} = 1.5 V), and Target_Det_Out is pulled down to 0 V.

The same applies to the BGT_PHASE_DET signal.

Table 3 LED detection

LED	Mode	Comments
Green	On – target detected Off – target not detected	Target_Det_Out is an active low signal
Red	On – depart departing Off – target approaching	Phase_Det_Out is an active low signal

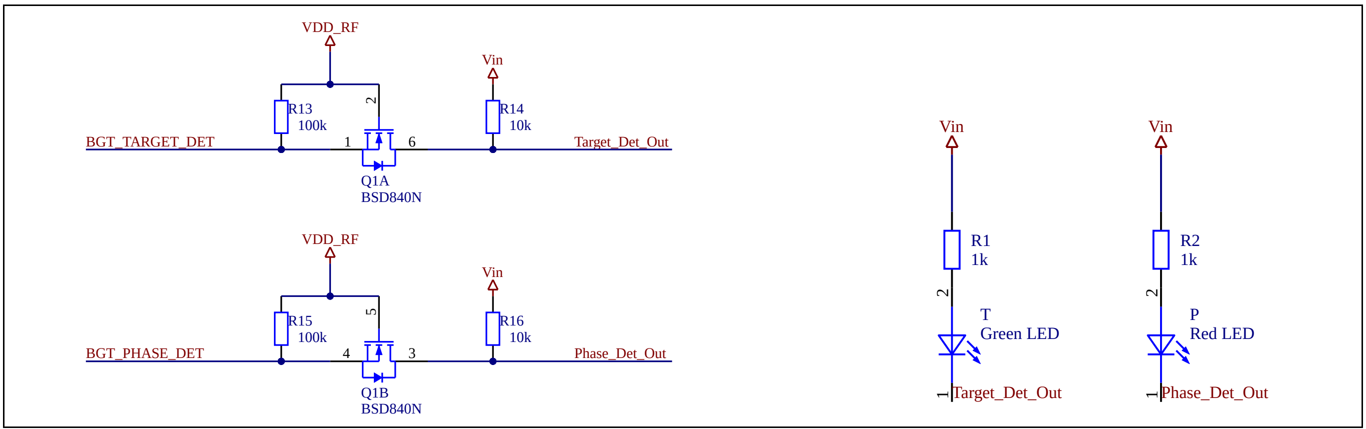


Figure 16 Connections of the LEDs and level shifter

4.9 MMIC operation modes and settings

The BGT60LTR11AIP MMIC has four quad-state inputs (QS1 to QS4). These can be configured in different ways to change the settings of the MMIC, as shown in Figure 17, Table 4, and Table 5.

When the pin PLL_TRIG is kept 1 during chip boot and QS1 is either GND or OPEN (i.e., in autonomous mode), pins SPI_SCK and SPI_MOSI are also sampled to determine the Pulse Repetition Time (dc_rep_rate). In addition, pins QS2 and QS3 are evaluated by the ADC and converted in 4-bit values each after each "mean window". The settings for autonomous mode are mentioned in Section 5.

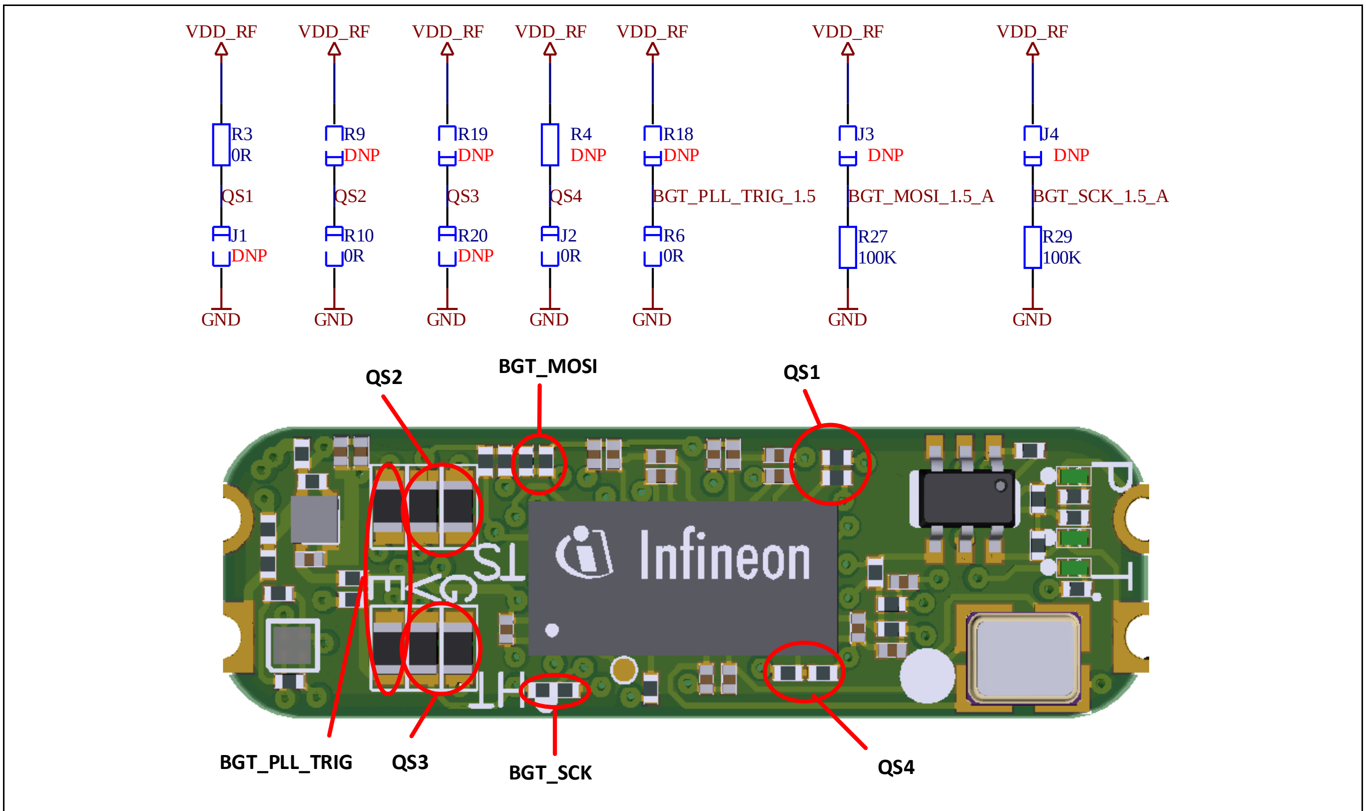


Figure 17 QS1 to QS4 schematic and layout connections

Table 4 QS1 settings: operation modes of the MMIC

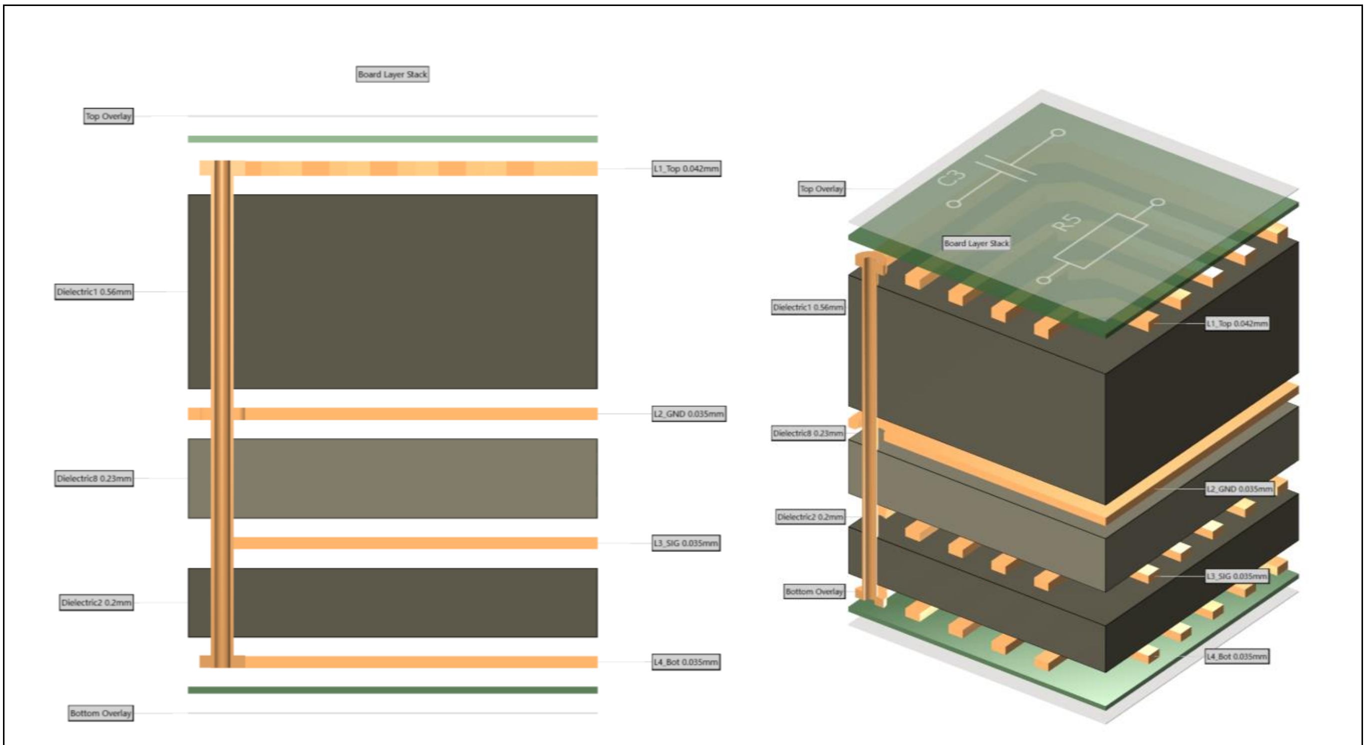
QS1	Mode	PCB configuration
GND	Autonomous (Continuous Wave) mode	J1 = 0 Ω; R3 = DNP
OPEN	Autonomous (pulse mode) operation	J1 = DNP; R3 = DNP
100 kΩ to V_{DD}	SPI mode with external 9.6 MHz clock enabled	J1 = DNP; R3 = 100 kΩ
V_{DD} (default)	SPI mode	J1 = DNP; R3 = 0 Ω

Table 5 QS4 settings: device operating frequency

QS4	Japan e-fuse	Mode	PCB configuration
GND (default)	1	61.1 GHz	J2 = 0 Ω; R4 = DNP
OPEN	1	61.2 GHz	J2 = DNP; R4 = DNP
100 kΩ to V_{DD}	1	61.3 GHz	J2 = DNP; R4 = 100 kΩ
V_{DD}	1	61.4 GHz	J2 = DNP; R4 = 0 Ω
GND (default)	0	60.6 GHz	J2 = 0 Ω; R4 = DNP
OPEN	0	60.7 GHz	J2 = DNP; R4 = DNP
100 kΩ to V_{DD}	0	60.8 GHz	J2 = DNP; R4 = 100 kΩ
V_{DD}	0	60.9 GHz	J2 = DNP; R4 = 0 Ω

4.10 Layer-stack up and routing

The PCB is designed with a 4-layer stack up with standard FR4 material. Figure 18 shows the different layers and their thicknesses.



#	Name	Material	Type	Thickness	Dk
	Top Overlay		Overlay		
	Top Solder	Solder Resist	Solder Mask	0.02mm	3.5
1	L1_Top		Signal	0.042mm	
	Dielectric1	FR-4	Core	0.56mm	4.2
2	L2_GND		Plane	0.035mm	
	Dielectric8	FR-4	Prepreg	0.23mm	4.2
3	L3_SIG		Signal	0.035mm	
	Dielectric2	FR-4	Core	0.2mm	4.3
4	L4_Bot		Signal	0.035mm	
	Bottom Solder	Solder Resist	Solder Mask	0.02mm	3.5
	Bottom Overlay		Overlay		

Figure 18 PCB layer stack-up in 2D and 3D views

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.

5 Autonomous (pulse mode) operation

In the autonomous mode operation, the MMIC uses internal detectors for motion and direction of motion indication. The detector output signals are connected to LEDs, which glow according to target movement.

A shield working in autonomous mode can be used as a plug-on radar module. To make the shield work in autonomous mode, refer to Table 4. Remove R3 resistor to make it work in autonomous pulse mode as shown in Figure 19.

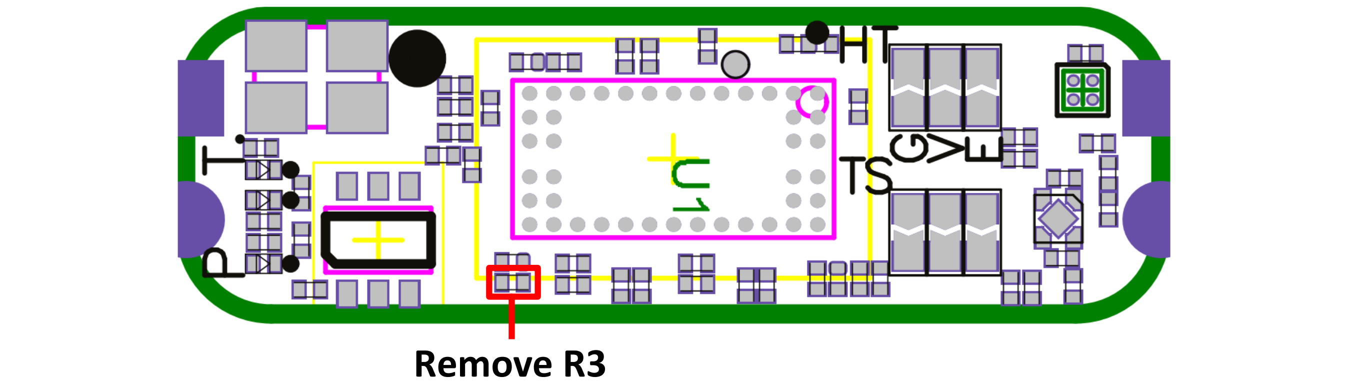


Figure 19 Converting the shield to autonomous (pulse mode) operation

The MMIC only needs power supply with the castellated holes and generates outputs on TD and PD castellated holes depending on the movement of the target. In Figure 20 a shield is shown working independently with a battery that supplies to the VIN, GND pins of the castellated holes.

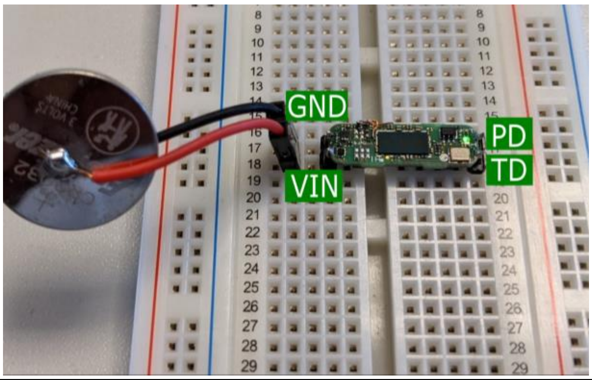


Figure 20 Shield working independently with a battery power supply

Table 6 Performance of BGT60LTR11AIP shield in autonomous mode

Detection information	Typical range	Comment
Motion	5 m	At sensitivity 13 (default setting in shield)
Direction of motion	3 m	At sensitivity 13 (default setting in shield)

Note: *Once a BGT60LTR11AIP shield is converted to autonomous mode, it should NOT be connected to Radar GUI via Radar Baseboard MCU7 to change the settings. The resistor values mentioned in Table 7 and Table 8 are recommended to be soldered on the shield in order to achieve the desired settings.*

5.1 Configuring sensitivity and hold time

In order to have up to 16 settings for QS2 (Sensitivity) and QS3 (Hold time), the PLL_TRIG should be connected to VDD by removing R6 and placing R18 = 0 Ω. This will put the MMIC into 'Advanced-mode'.

The default QS2 and QS3 setting on the shield are for sensitivity level 13 and 1 second hold time, respectively. Table 7 shows the recommended resistor values for changing the QS2 and QS3 on the autonomous shield.

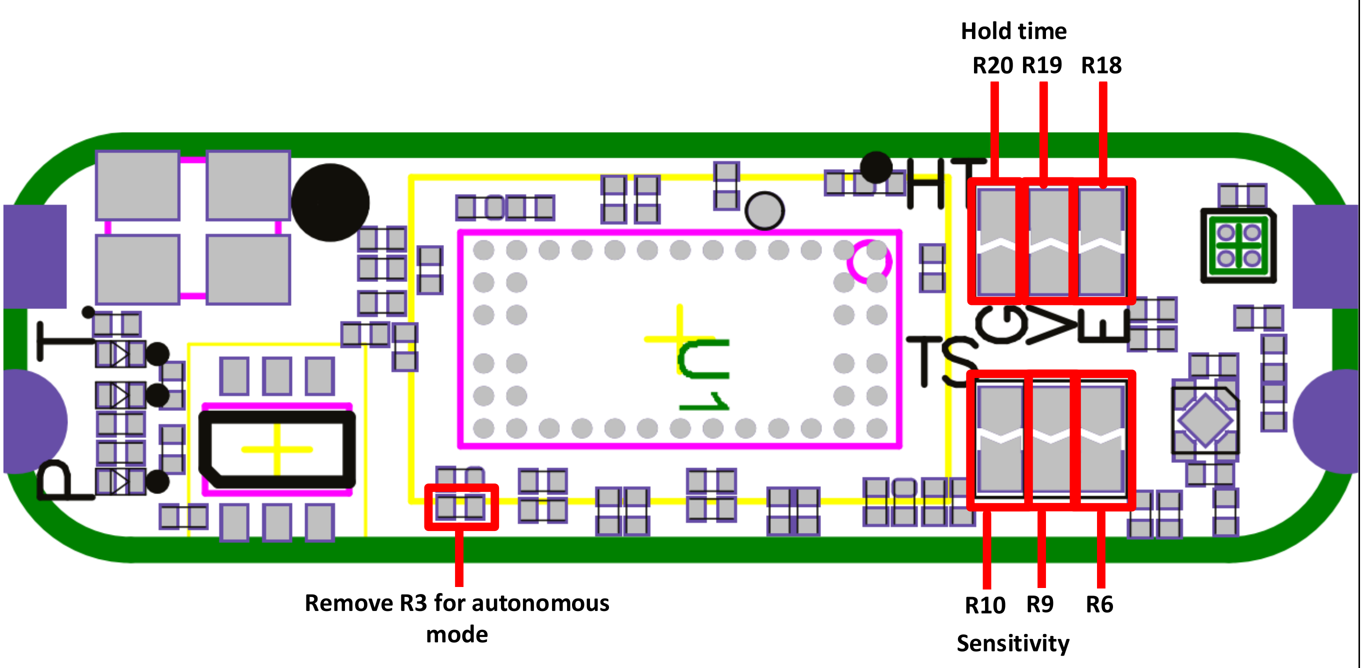


Figure 21 Changing sensitivity and hold time in autonomous (pulse mode) operation

Table 7 Recommended resistor settings for the QS2 (R9, R10) and QS3 (R19, R20)

Sensitivity level (QS2)	Resistor setting		Hold time (QS3)	Resistor setting	
	R10	R9		R20	R19
14 (highest)	1.1 kΩ	10 kΩ	500 ms	1.1 kΩ	10 kΩ
13 (default)	1.8 kΩ	10 kΩ	1 s (default)	1.8 kΩ	10 kΩ
12	2.8 kΩ	10 kΩ	2 s	2.8 kΩ	10 kΩ
11	3.9 kΩ	10 kΩ	3 s	3.9 kΩ	10 kΩ
10	5.1 kΩ	10 kΩ	5 s	5.1 kΩ	10 kΩ
9	6.8 kΩ	10 kΩ	10 s	6.8 kΩ	10 kΩ
8	9.1 kΩ	10 kΩ	30 s	9.1 kΩ	10 kΩ
7	11 kΩ	10 kΩ	45 s	11 kΩ	10 kΩ
6	15 kΩ	10 kΩ	1 min	15 kΩ	10 kΩ
5	20 kΩ	10 kΩ	90 s	20 kΩ	10 kΩ
4	24 kΩ	10 kΩ	2 min	24 kΩ	10 kΩ
3	39 kΩ	10 kΩ	5 min	39 kΩ	10 kΩ
2	51 kΩ	10 kΩ	10 min	51 kΩ	10 kΩ
1	91 kΩ	10 kΩ	15 min	91 kΩ	10 kΩ
0 (lowest)	270 kΩ	10 kΩ	30 min	270 kΩ	10 kΩ

5.2 Configuring Pulse Repetition Time (PRT)

To configure the Pulse Repetition Time (PRT) for the autonomous mode (QS1 is either GND or OPEN as shown in Table 4), pins SPI_MOSI and SPI_CLK are used. They are sampled during chip boot up.

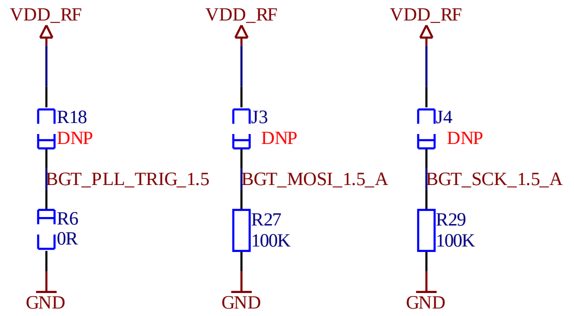


Figure 22 Configuring Pulse Repetition Time (PRT)

Table 8 PRT configuration in autonomous mode

SPI_MOSI	SPI_CLK	PLL_TRIG*	PRT (µs)	PCB components
0	0	1	500	J3 = DNP, R27 = 100kΩ , J4 = DNP, R29 = 100kΩ
0	1	1	2000	J3 = DNP, R27 = 100kΩ, J4 = 100kΩ, R29 = DNP
1	0	1	250	J3 = 100kΩ, R27 = DNP, J4 = DNP, R29 = 100kΩ
1	1	1	1000	J3 = 100kΩ, R27 = DNP, J4 = 100kΩ, R29 = DNP

*R6 = DNP, R18 = 0Ω

5.3 Operation with Arduino MKR

The shield has dimensions such that it can be mounted onto an Arduino MKR series board as shown in Figure 23 as a plug-on motion sensor.

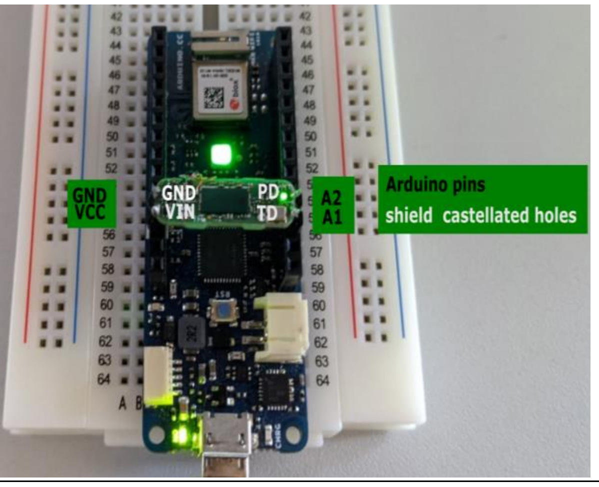


Figure 23 Shield mounted on an Arduino MKR Wifi1010 board

6 Current consumption

The shield can be powered directly through the castellated holes, VIN and GND (Figure 4 – autonomous mode) on the sides of the shield or through a baseboard platform like the Radar Baseboard MCU7 (Figure 5- SPI mode). The current consumption of the BGT60LTR11AIP MMIC can be optimized by configuring pulse width and Pulse Repetition Time (PRT).

Table 9 Typical current consumption of the BGT60LTR11AIP MMIC (pulse mode)

Pulse width (µs)	Pulse Repetition Time (PRT) (µs)	Current consumption (mA)
5	250	6.05
5	500 (default)	3.21
5	1000	1.76
5	2000	1.03

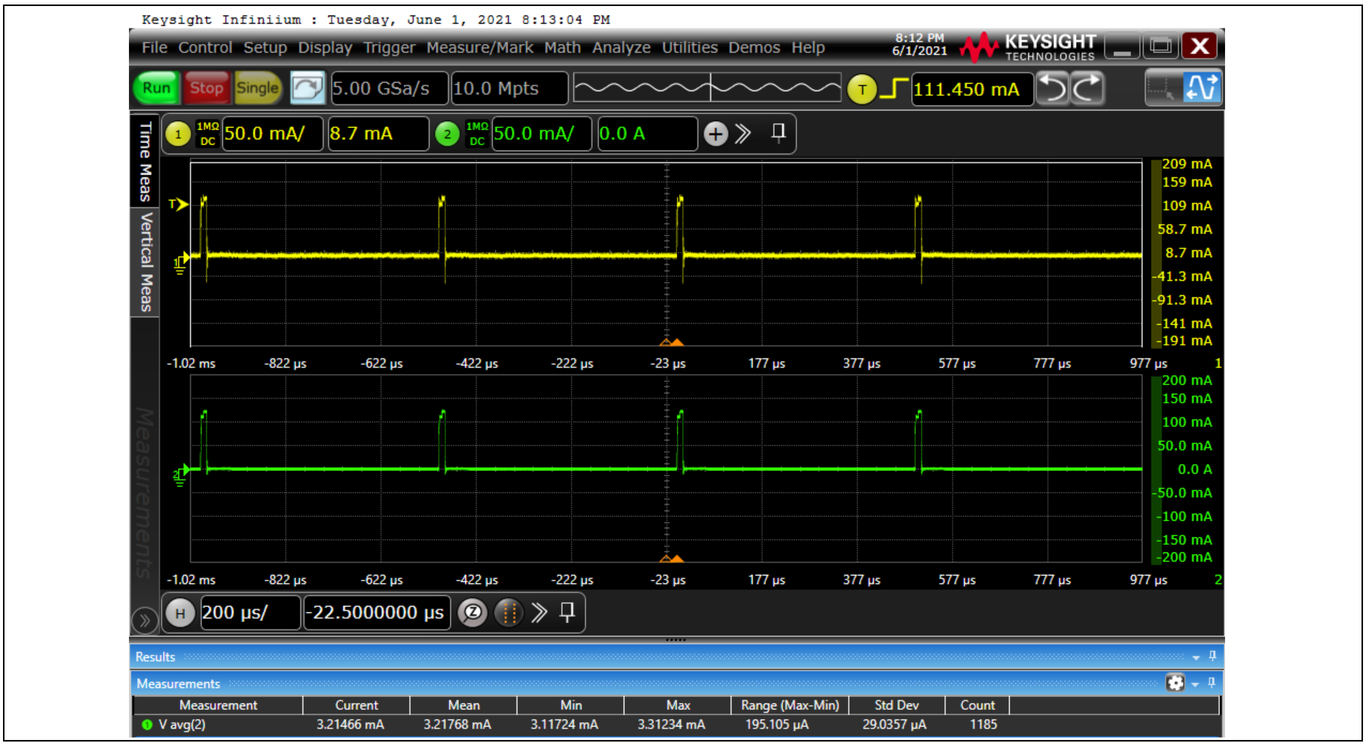


Figure 24 Current consumption of shield with pulse width = 5 µs and PRT = 500 µs

6.1 Adaptive Pulse Repetition Time (APRT)

The APRT is a power-saving option when the MMIC is used in SPI mode. When enabled (set in Reg2), it multiplies the PRT by a factor of 2, 4, 8 or 16 (set in reg13: prt_mult) when no target is detected (Figure 26 and Figure 27). When a target is detected, the PRT returns to the default value to ensure reliable detection (Figure 28).

This effectively reduces the ON-time of the MMIC since the default PRT is only used when a target is detected, hence reducing the overall power consumption. Depending on the use-case and the multiplier value selected, the power consumption of the shield can be reduced significantly.

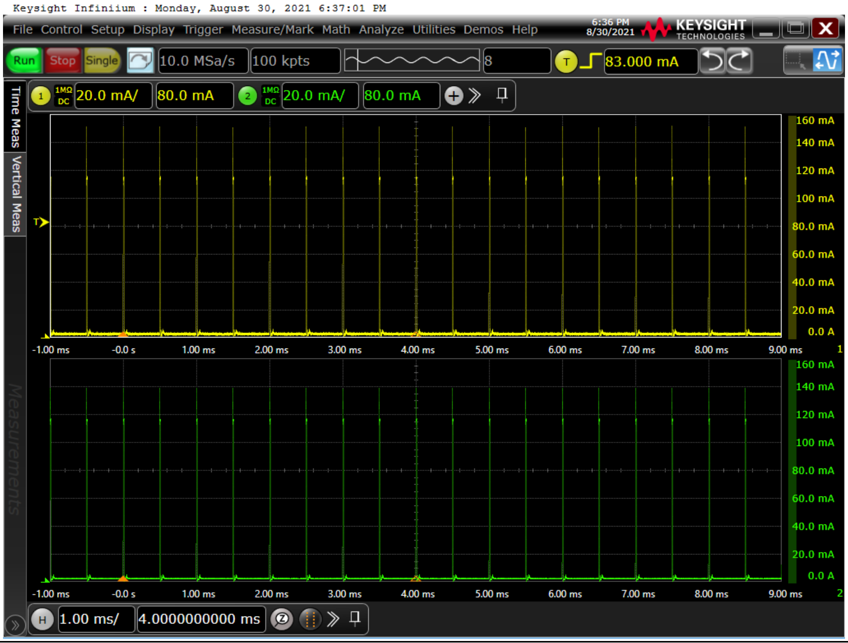


Figure 25 APRT disabled with PRT = 500µs (target detected/not detected: PRT = 500µs)

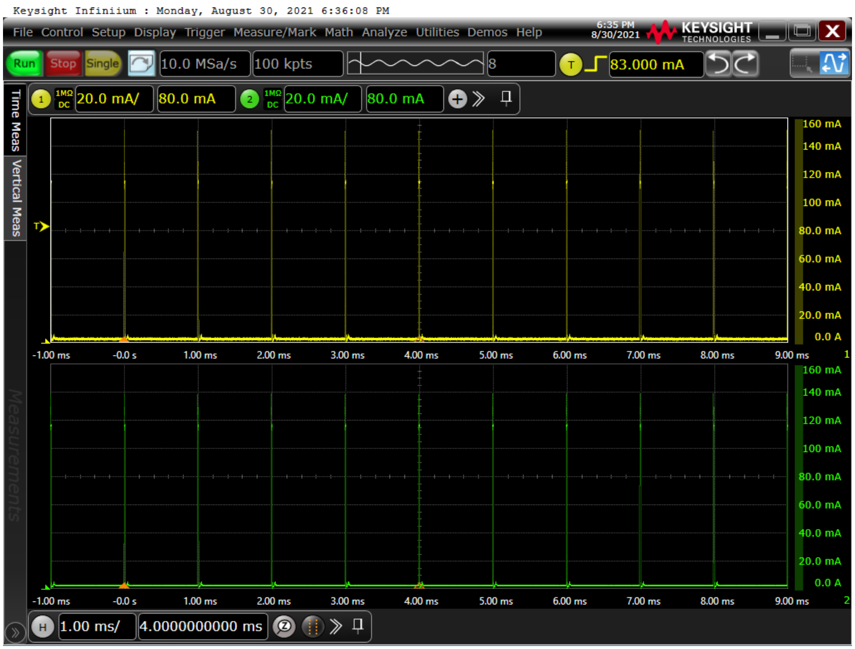


Figure 26 APRT enabled with multiplier = 2 (no target detected: PRT = 1ms)

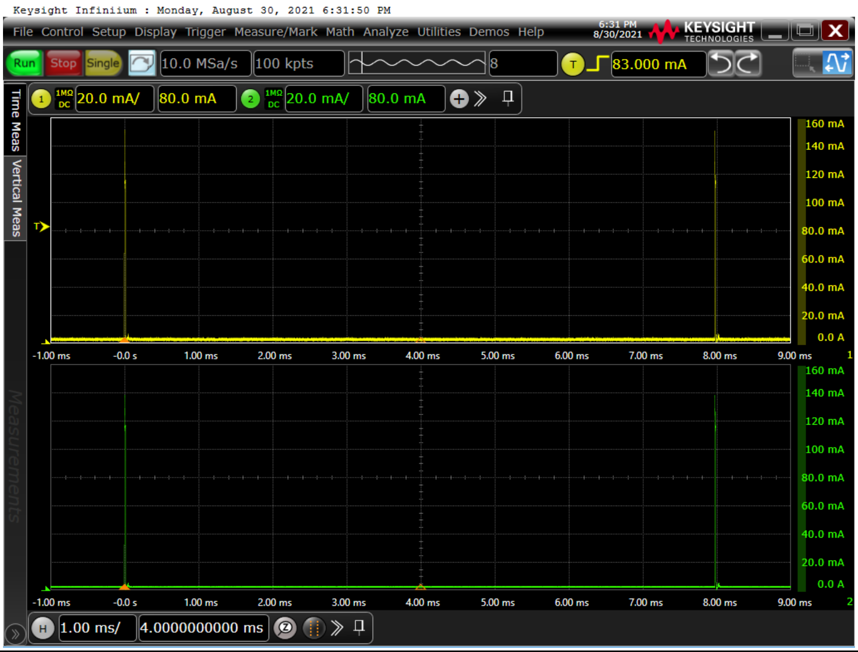


Figure 27 APRT enabled with multiplier = 16 (no target detected: PRT = 8ms)

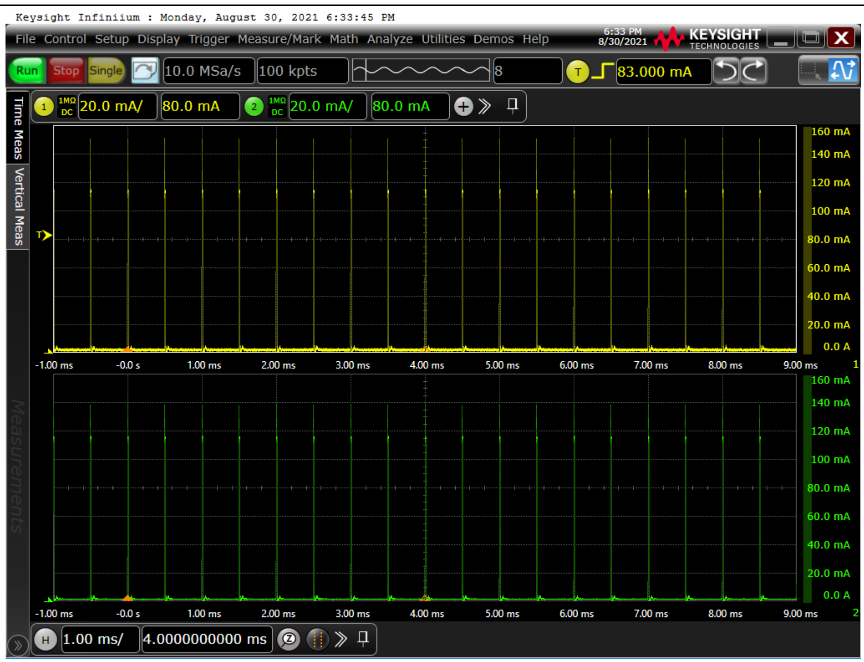


Figure 28 APRT enabled with multiplier = 16 (target detected: PRT switches back to 500µs)

7 References

[1] Infineon application note – AN599 – "*Radar Baseboard MCU7*"

Revision history

Document version	Date of release	Description of changes
V1.0	2020-06-03	First version – preliminary
V1.1	2020-10-20	Mass market version
V1.2	2020-11-17	Updated autonomous mode info
V1.3	2021-03-16	Updated Figure 14
V1.4	2021-07-15	Major document updates to support shield V2.0
V1.5	2021-07-29	Updated Table 8
V1.6	2021-10-11	Added "2. Getting Started" section Updated section 5 content Added "6. Current consumption" section

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