

BGT60LTR11AIP Radar Shield2Go

XENSIV™ 60 GHz radar

Board version V1.2

About this document

Scope and purpose

This application note describes the BGT60LTR11AIP Radar Shield2Go (S2GO RADAR BGT60LTR11) and gives an overview of its functions. The Shield2Go is an ultra-small Infineon Technologies PCB standard, which comes with different ICs on it intended for different use cases.

Intended audience

The intended audience for this document are engineers, prototype creators, hobbyists and makers – basically, anyone who wants to work hands-on with radar, but without the need to deal too much with the development process, focusing more on the application outcome.

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1 Introduction

1 Introduction

1.1 Overview

The Radar Shield2Go can be used independently as a “plug-in” radar sensor (e.g., with Arduino form factor boards or another microcontroller) to detect motion and direction of motion by using only two GPIOs (TD and PD) in autonomous mode (default). The board comes with two potentiometers and switches, making it easy to adjust the four QS signals of the radar mechanically. The switches can be used to switch between autonomous and SPI modes.

The Shield2Go comes with castellated holes to ensure several connection styles.

The Shield2Go family is recommended to be used with either Infineon’s XMC™ maker board series (e.g., [XMC1100 Boot Kit](#)/[XMC1400 Arduino](#)/[XMC 2Go](#)/[XMC4700 Relax Kit](#)) or Arduino boards (e.g., Rev3/MKR1000).

The BGT60LTR11AIP Shield2Go demonstrates the features of the BGT60LTR11AIP MMIC and gives the user a “plug and play” radar solution.

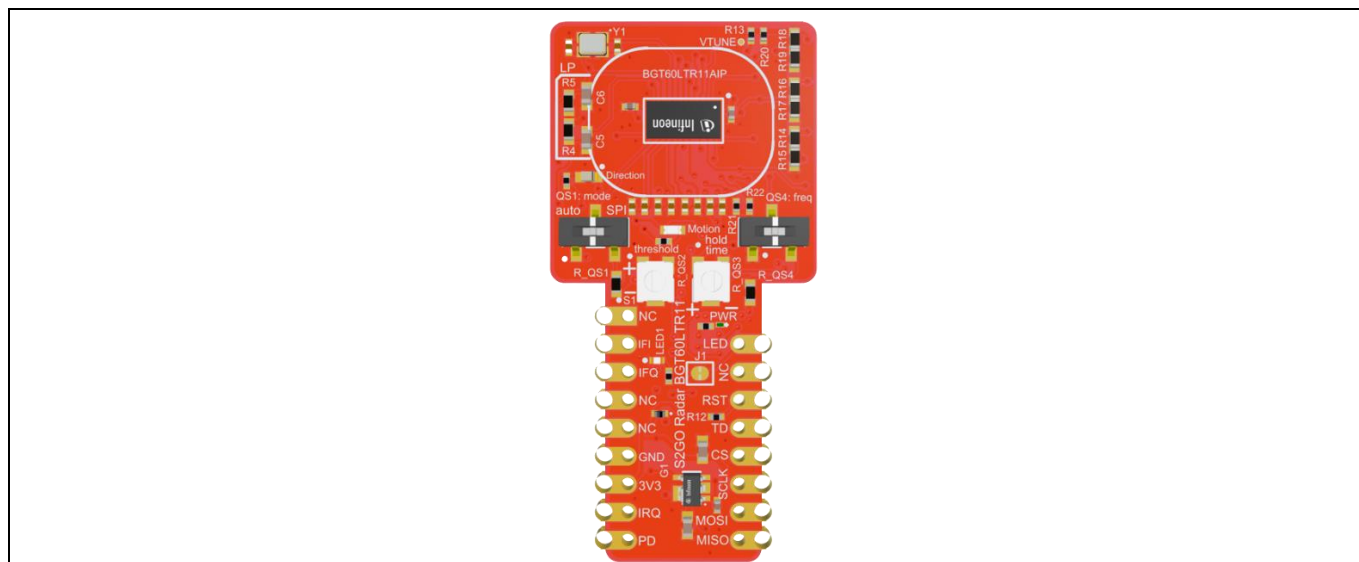


Figure 1 Radar Shield2Go with BGT60LTR11AIP

1.1.1 Hardware and third-party software

The Radar Shield2Go is compatible with the [Arduino IDE](#), [Platform.IO](#) with Arduino extension, and Infineon’s [ModusToolbox™](#) (formerly Cypress) SDK. You can find a detailed user guide to integrate the BGT60LTR11AIP library on the free and open-source repository [GitHub](#) [5].

Note: To use the existing library in Infineon’s ModusToolbox™ SDK, the integration is done manually with customized manifests, described on Infineon’s [GitHub](#).

The Shield2Go concept can also be attached to any board with an **Arduino Uno form factor**, by using an [Infineon MyIoT adapter](#).

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1.1.2 Quad-state input pins

The MMIC has four quad-state input pins (QS1 to QS4) that give the performance parameters flexibility when it is running in autonomous mode. These pins are used to configure the chip, as explained in section 4.2.2.

QS1 sets up the three modes of the MMIC (autonomous by default), QS2 controls the detector comparator threshold, QS3 sets up the hold time of the “target detect” output, and QS4 is used to select the device operating frequency by configuring the phase-locked loop (PLL).

QS1 is controlled by a dual-state switch and QS4 by a tri-state switch. QS2 and QS3 can be adjusted by two rotatable potentiometers.

In autonomous mode, the detection threshold (set via potentiometer R_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). The hold time is also configurable as 16 levels in autonomous mode via the potentiometer that controls QS3, which allows detection status to be held for up to 30 minutes (see section 4.2.5).

1.1.3 SPI communication

The MMIC also supports SPI mode by changing the operation mode with the QS1 pin (see section 4.2.3). In this mode, the raw radar data can be extracted from BGT60LTR11AIP for signal processing on a PC or an external MCU using SPI. This sampled radar data can be used to develop customized algorithms. The SPI mode offers the possibility to control the MMIC radar completely via SPI.

1.2 Key features

- Easy motion and direction of motion detection of an object with only two GPIOs
- Programmable in Arduino IDE and Platform.IO (VS Code extension)
- Configurable detection range from 0.5 m to 7 m
- LEDs that blink when presence or movement direction is detected
- Potentiometers and switches to adjust the settings of the radar (QS)
- Super-small (48.80 mm x 23.90 mm) board design with Infineon’s Shield2Go format
- 60 GHz transceiver BGT60LTR11AIP MMIC with one transmitter and one receiver unit

1.3 Potential applications

- Prototyping smart home appliances
- Security applications

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2 Board and pin-out overview

2 Board and pin-out overview

This section gives an overview of Infineon’s standardized Shield2Go pin-out.

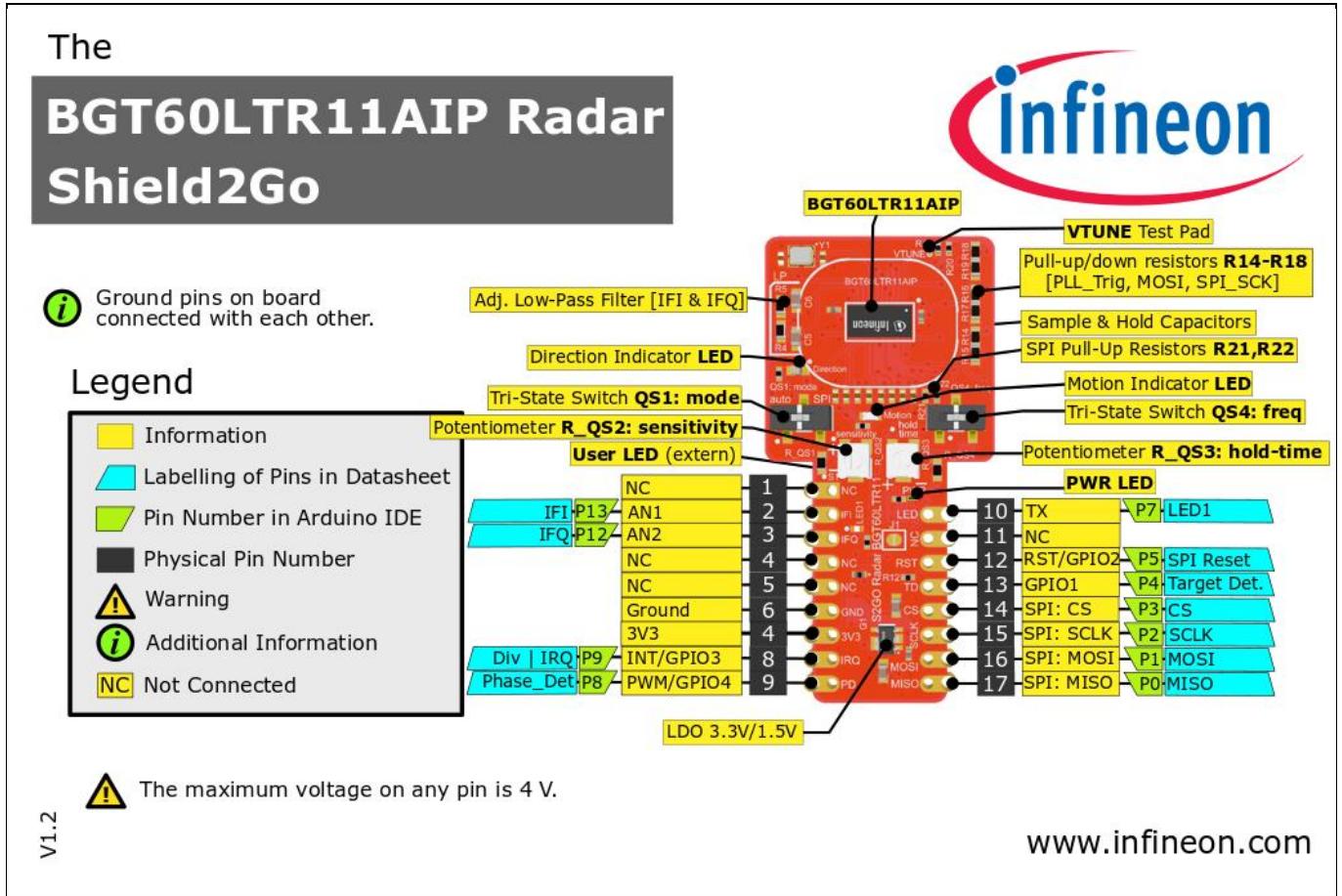


Figure 2 The BGT60LTR11AIP Radar Shield2Go (top view)

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2 Board and pin-out overview

2.1 Board dimensions

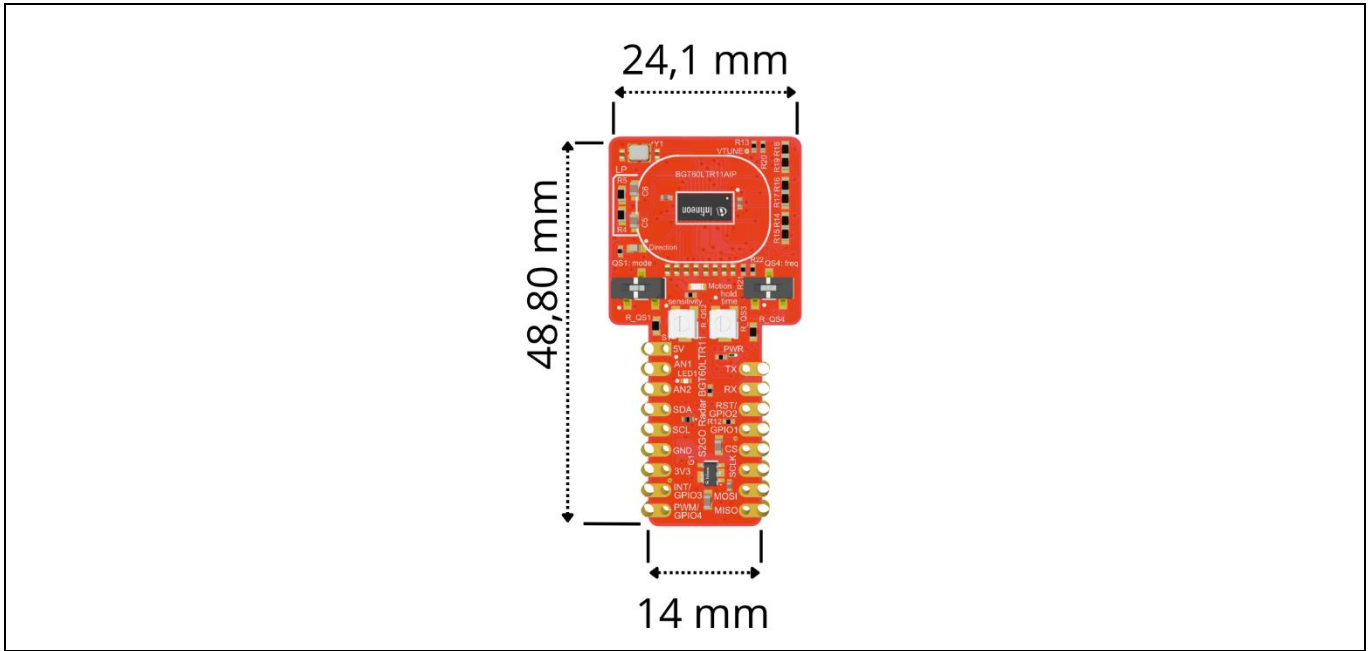


Figure 3 Layer stack-up of the BGT60LTR11AIP Radar Shield2Go

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3 Getting started

3 Getting started

3.1 Overview

The Radar Shield2Go needs an MCU to communicate and run custom code. However, if connected to a power source, the direction and motion LEDs blink in the presence of an object even without an MCU connected. The target detect (TD) pin is an active low pin. Hence, when no target is detected, the voltage level appears to be 3.3 V on this pin. The phase detect (PD) pin voltage varies, depending on the direction of the moving object. While the target is approaching, the pin puts out 3.3 V, and when the target is departing from the radar, it puts out close to 0 V. These pins can be read from analog pins or digital pins TD and PD.

Move the switch lever “QS1: mode” to the left position to set up the radar in autonomous mode, and apply 3.3 V (pin 7) and GND (pin 6) to the corresponding power pins of the Shield2Go. Note that the power source offers a minimum of 150 mA. If power is supplied, the PWR LED turns on. Now, the radar can recognize any movement or direction of an approaching or departing object. The blue LED lights up when object movement is detected, and the red LED lights up when the target is approaching or departing. See section 5.3 for more information about LED behavior.

The radar now works on its own, without any other MCU needed. However, for reading/writing the radar MMIC, connect one of the recommended MCUs mentioned in section 1.1.1. Note that any MCU will work if the voltage levels are the same (3.3 V), otherwise level shifting is mandatory. Because Infineon offers software libraries compatible with Arduino and Infineon XMC™ boards, software setup for other MCU platforms might be more difficult.

Infineon’s software libraries and installation guides are open-source and available on Infineon’s [GitHub channel](#) [5]. The Radar Shield2Go needs to be connected with the pin headers of the MCU board either with wires or via stacking onto an adapter (e.g., Infineon’s MyIoT adapter for Arduino).

3.2 Hardware setup

Connect the Radar Shield2Go to any microcontroller and supply the board with a 3.3 V DC (150 mA) power source (which can usually be driven by the MCU board).

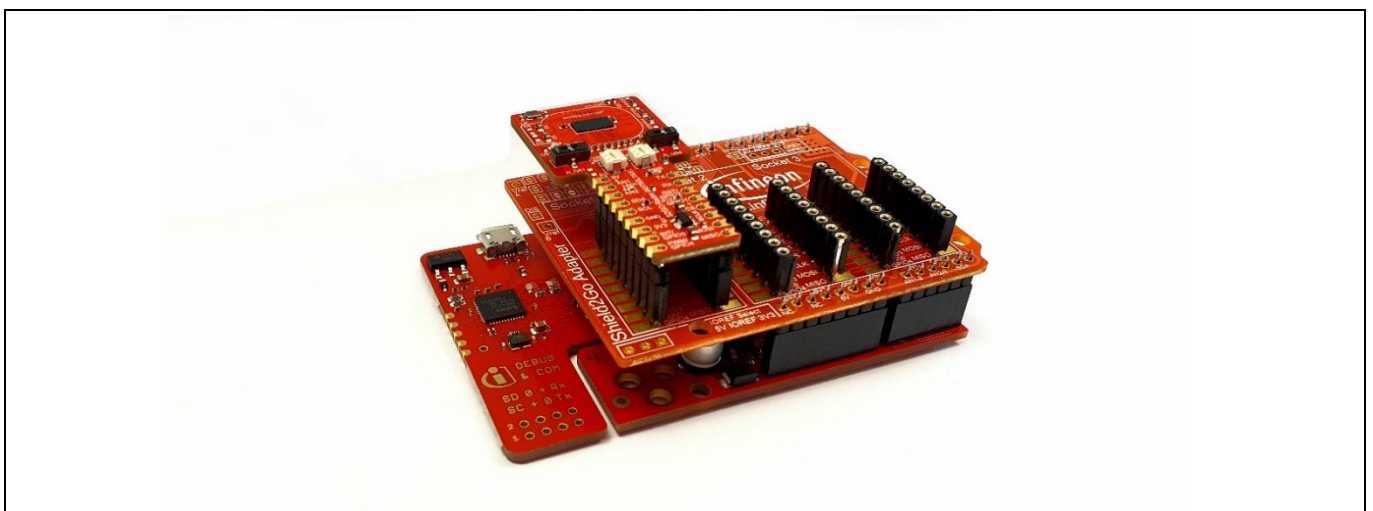


Figure 4 Radar Shield2Go on top of Infineon’s MyIoT adapter and Arduino-compatible XMC1100 Boot Kit (very bottom)

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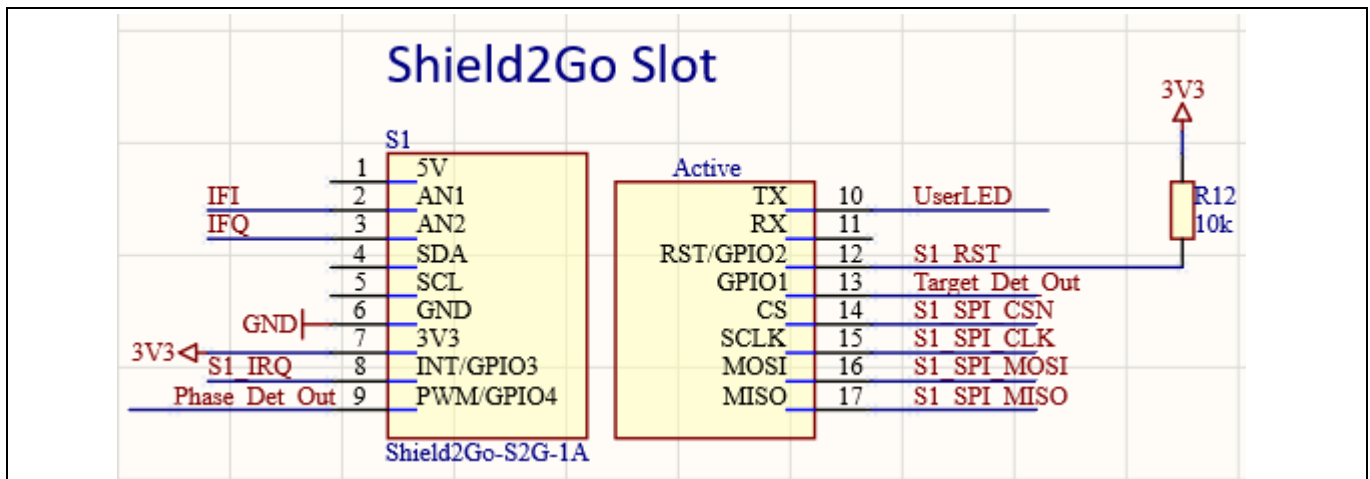


Figure 5 Shield2Go connector S1 schematics

After that, connect the microcontroller board via USB to your computer and continue with the software setup as described in section 4.

Note: By using Infineon’s *MyloT adapter*, you can easily plug up to three Shield2Gos on an Arduino Uno Rev3 form factor due to the integrated level shifter on the adapter. The adapter works with 5 V (e.g., Arduino Uno Rev3) and 3.3 V shields (e.g., XMC1100 Boot Kit/XMC4700 Relax Kit). Please read the *MyloT adapter manual* for more details on how to configure the voltage shifting.

The following boards are recommended for use and are compatible with the Arduino IDE and Platform.IO

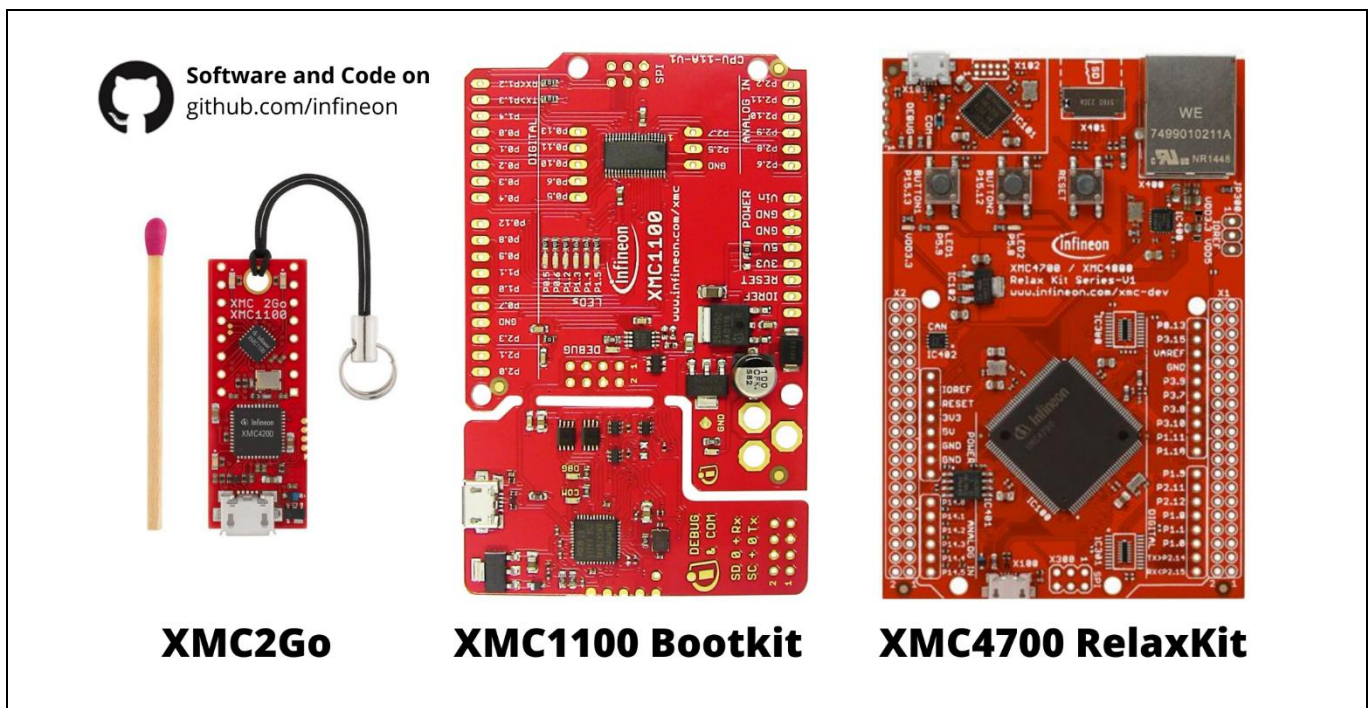


Figure 6 Recommended boards

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- [XMC2Go](#) is equipped with Infineon's powerful Arm® Cortex®-M0 based microcontroller XMC1100 and is the ideal board in Shield2Go form factor for tiny applications.
- [XMC1100 Boot Kit](#) or [XMC1400 Arduino](#) are powerful microcontroller boards with Arduino Uno Rev3 form factor that offer the user more performance and GPIOs, including multiple buses (I2C, SPI), pulse-width modulation (PWM) signals, ADC, DAC, LEDs, and a breakable and reusable debugger for multiple purposes.
- [XMC4700 Relax Kit](#) is an extremely powerful microcontroller board with Infineon's Arm® Cortex®-M4 based microcontroller XMC4700. It also comes in an Arduino Uno Rev3 form factor, with an additional 80 GPIOs to use, and Ethernet.



You can also use Arduino's boards, such as the popular Arduino Uno Rev3 or the MKR1000 Wi-Fi board. We have prepared examples of applications on the do-it-yourself website Hackster.IO for you – check out the [Infineon_Team Channel](#) for more information.



Find all libraries and instructions to get started on Infineon's [GitHub](#) repository.

3.3 Software setup

3.3.1 Required software for Infineon's XMC™ boards

- [SEGGER J-Link](#), either for Windows or Linux (for XMC™)
- [Arduino IDE](#), either for Windows or Linux
- XMC-for-Arduino (installed with Arduino IDE)
- [Radar BGT60LTR11 Library](#) for Arduino on Infineon's GitHub repository (installed with Arduino IDE, v2.0.0 or higher)
- Follow these installation steps:
 - **Install Arduino IDE.** If you are new to Arduino, please [download](#) the program and install it first.
 - **Install XMC™ board.** The official Arduino boards are already available in the Arduino software, but other third-party boards such as the Infineon XMC™ MCU-based board need to be explicitly included. Follow the instructions in the [link](#) to add the XMC™ board family to Arduino.
 - **Install the library.** In the Arduino IDE, go to the menu Sketch > Include library > Library Manager. Type BGT60LTR11 and install the library.
 - **Additionally,** install SEGGER J-Link if you are using an Infineon XMC1100 Boot Kit or XMC4700 Relax Kit. Continue with the section below if you are using Infineon's XMC™ microcontroller for Arduino

3.3.2 Required software for Arduino

- [Arduino IDE](#), either for Windows or Linux
- [Radar BGT60LTR11 Library](#) for Arduino on Infineon's GitHub repository (installed with Arduino IDE, v2.0.0 or higher)
- Follow these installation steps:
 - **Install Arduino IDE.** If you are new to Arduino, please [download](#) the program and install it first.
 - **Install the library.** In the Arduino IDE, go to the menu Sketch > Include library > Library Manager. Type BGT60LTR11 and install the library.

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- **Additionally**, install SEGGER J-Link if you are using an Infineon XMC1100 Boot Kit or XMC4700 Relax Kit. Continue with the section below if you are using Infineon’s XMC™ microcontroller for Arduino

3.3.3 Installation instructions for XMC™ microcontrollers

You can also find the whole XMC-for-Arduino installation guide for Infineon’s XMC™ repository on [GitHub](#).

3.3.3.1 Prework for SEGGER J-Link

In order to use and program the Infineon XMC™ microcontrollers in the Arduino IDE, SEGGER J-Link must be installed on your PC. Please follow this link to [SEGGER J-Link](#) and install the J-Link software and documentation pack for your operating system. If you have already installed [DAVE™ – Development Platform for XMC™ Microcontrollers](#) you can skip this step, as the respective drivers/programs are already installed on your system.

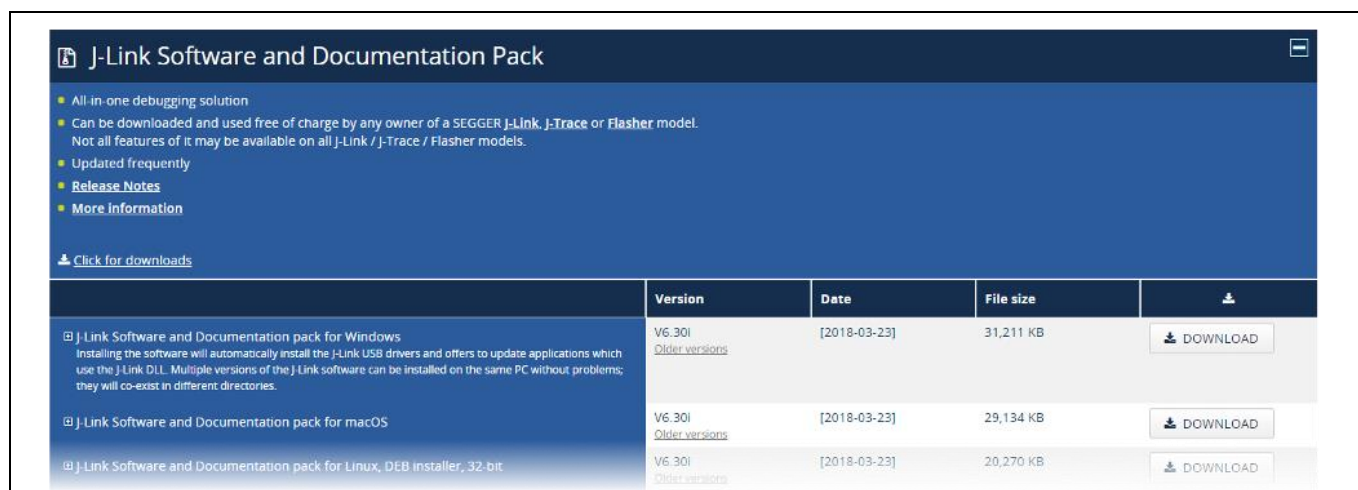


Figure 7 Arduino configuration – installing J-Link software for XMC™ microcontrollers (not needed for Arduino)

3.3.3.2 Using Arduino IDE with XMC™ microcontroller

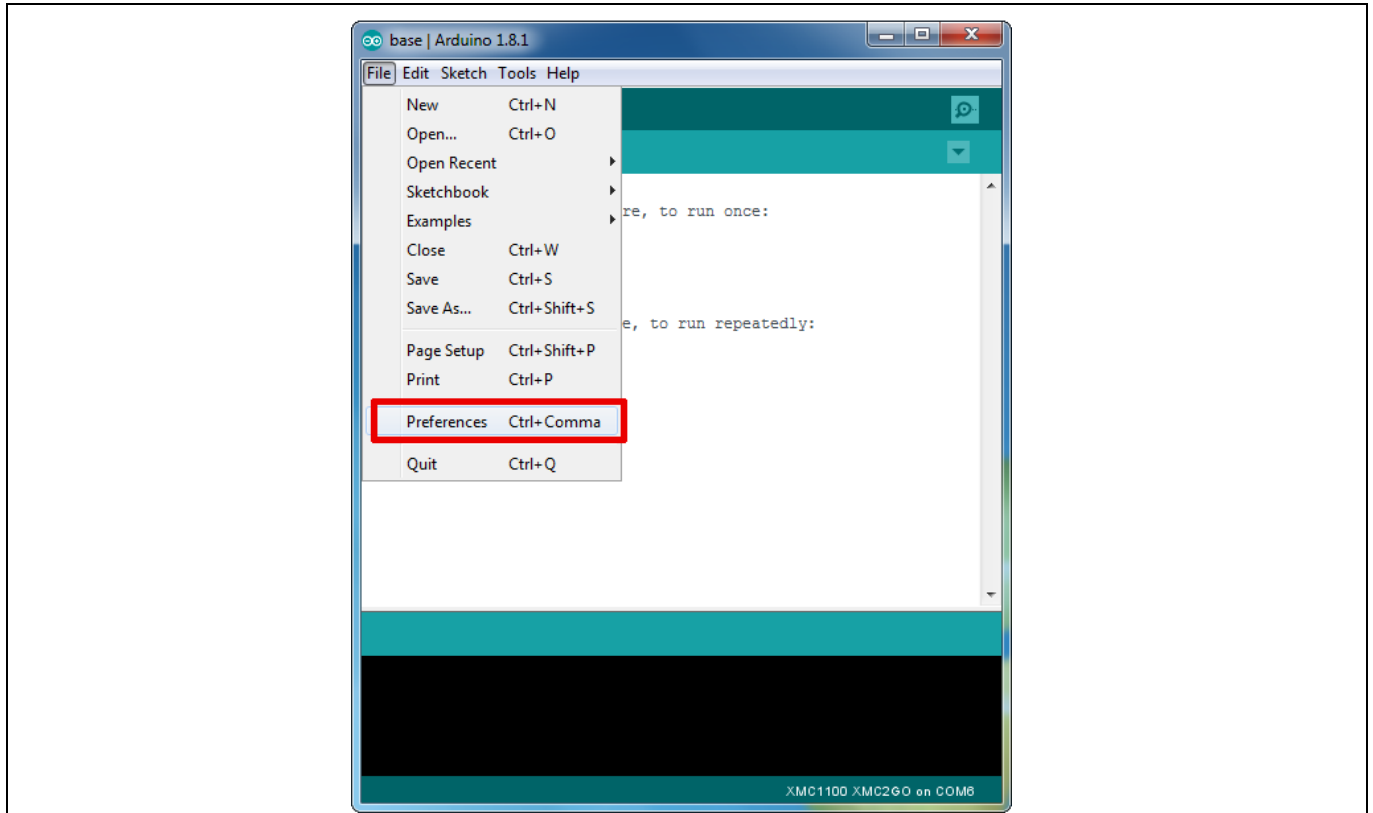


Figure 8 Arduino IDE configuration – Preferences

Paste the following URL into the “Additional Boards Manager URLs” input field under File > Preferences to add Infineon’s microcontroller boards to the Arduino IDE. (It is easier to copy – there is no clickable link.)

https://github.com/Infineon/XMC-for-Arduino/releases/latest/download/package_infineon_index.json

Note: The former “package_infineon_index.json” URL will no longer be maintained after version 1.4.0. Upcoming versions will not be shown as available in the board manager

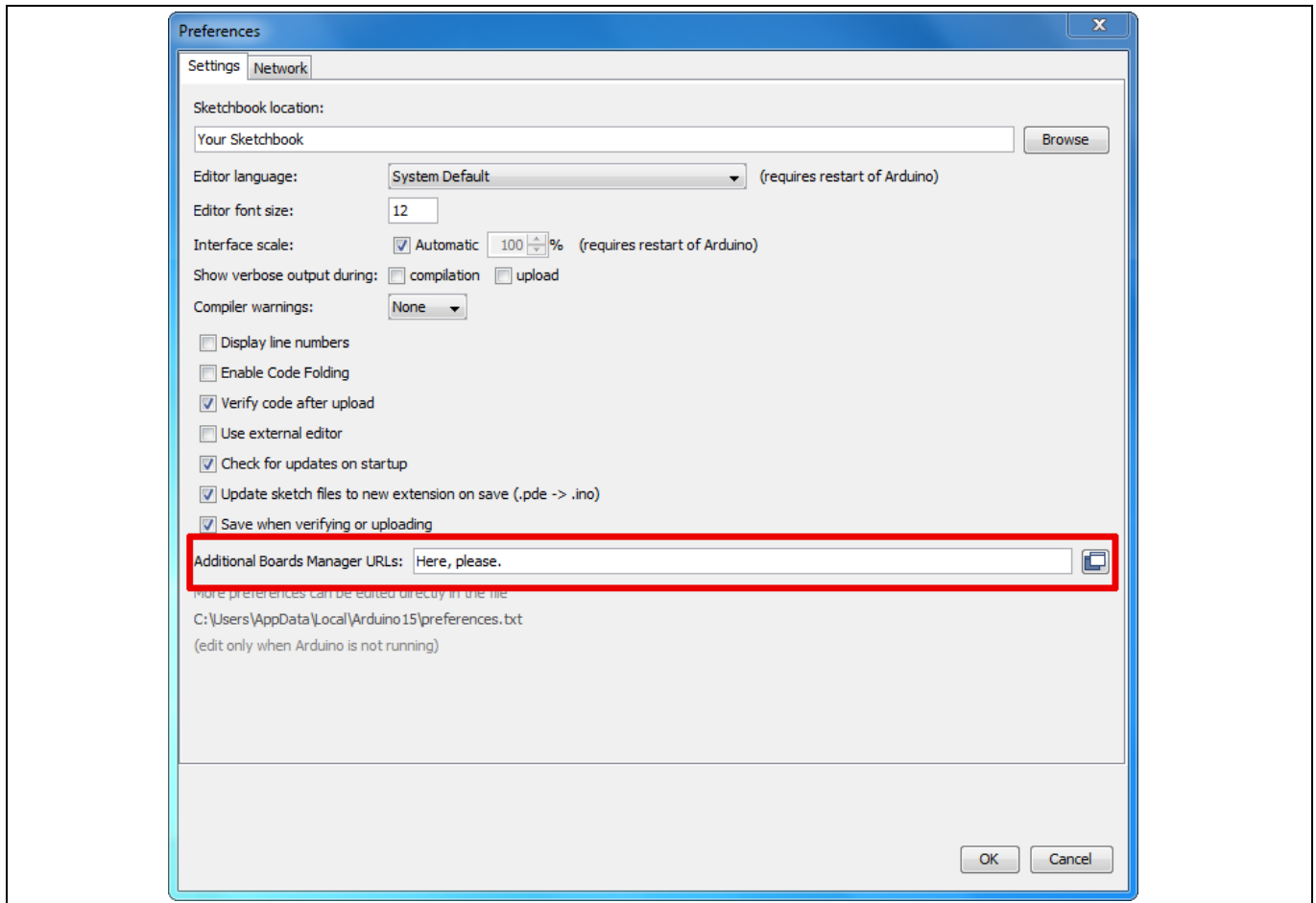


Figure 9 Arduino IDE configuration – Additional Boards Manager URLs

To install the boards, please navigate to **Tools > Board > Boards Manager...** and search for “XMC”. You will find options to install the board files for the microcontrollers. Click “Install” to add the boards to your Arduino IDE.

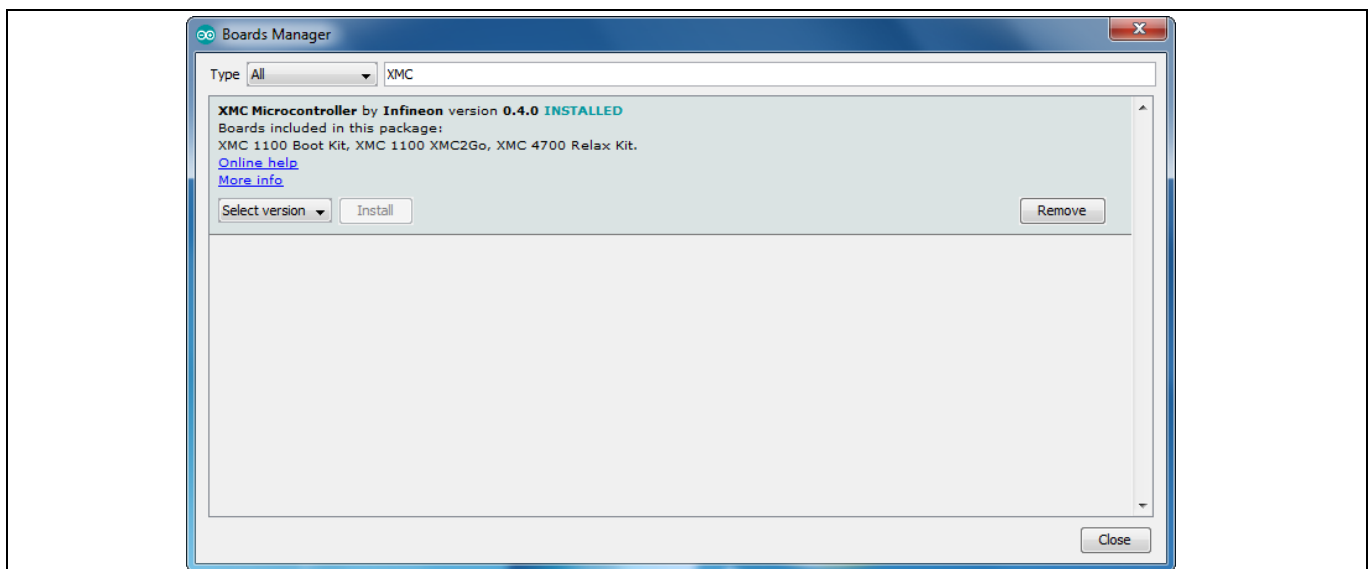


Figure 10 Arduino configuration – installing XMC™ library

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In the boards listed under **Tools > Board**, the XMC™ microcontroller boards are added and can be used from now on.

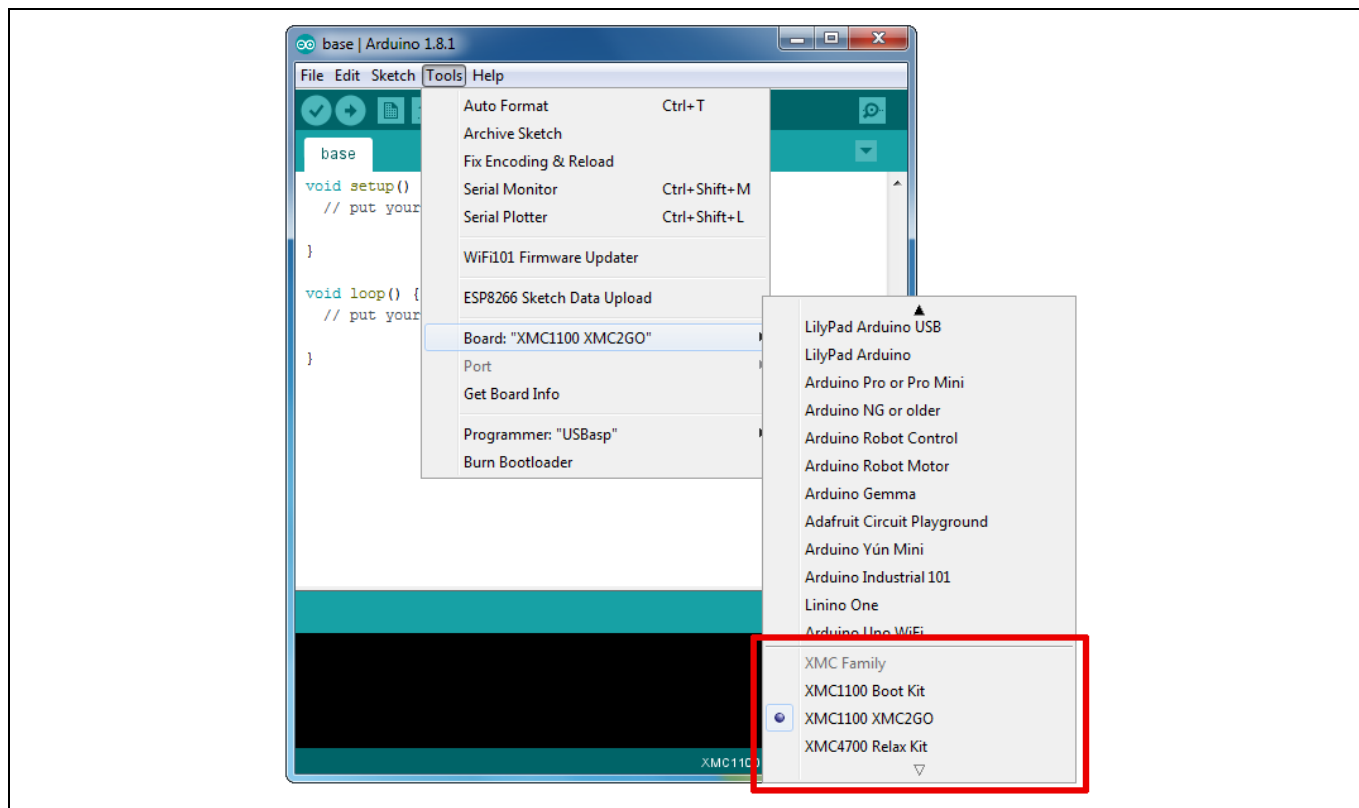


Figure 11 Arduino configuration – choose your XMC™ board

Note: This integration will only work for Arduino IDE 1.5 or above.
The XMC1100 Boot Kit has limitations compared to the official Arduino boards (consult the [XMC-for-Arduino Wiki](#) for more information).
Refer also to the LICENSE.md/txt file for further information.
Arduino 1.8.0 IDE might have problems with the XMC-for-Arduino releases. XMC-for-Arduino support for “arm-linux-gnueabi” is only up to version 1.1.

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4 Radar modes setup

4 Radar modes setup

4.1 TD and PD signals

With the Shield2Go you can adjust all four quad-state signals (QS1 to QS4) mechanically rather than via software. Use the potentiometers and switches to adjust all quad states in autonomous mode. In SPI mode, you can adjust all QS signals by changing the BGT60LTR11AIP registers.

The default direction information is set to “approaching”. The truth table for the output pad voltage is shown in Table 1.

Table 1 Truth table for the output pad voltage

Output pad voltage		Motion	Approaching/Departing
TD	PD		
high	high	No	N.A.
low	low	Yes	Departing
low	high	Yes	Approaching

The BGT60LTR11AIP provides four quad-state inputs, QS1 to QS4. With one quad-state input, it is possible to get four states from one input pin. These pins are used to configure the chip.

4.2 “Advance mode” and quad-state inputs

On reset of the digital main controller and during the init sequence some chip input pins are sampled to determine the configuration the chip should start with. Figure 12 shows the schematics of the default configuration for the MMIC operation modes and settings.

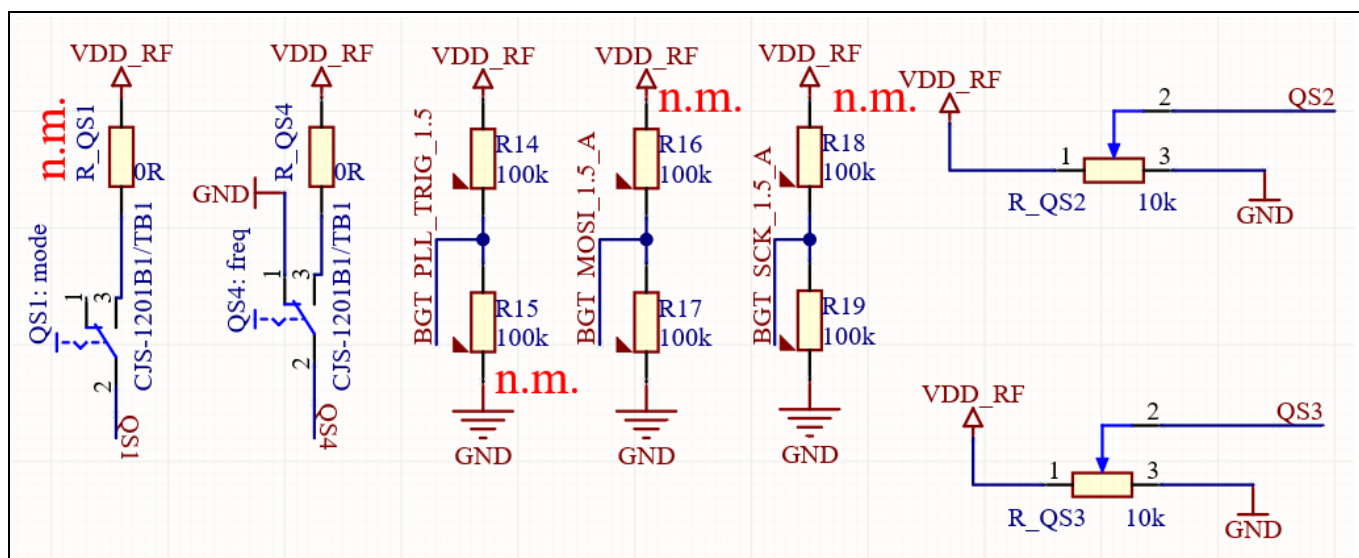


Figure 12 MMIC operation modes and settings (n.m. = not mounted)

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4 Radar modes setup

4.2.1 “Advance mode”

When the **PLL_Trig** pin is “0” as the digital main controller wakes up from reset, the chip boots in basic mode (not advance mode). When the pin is kept at “1” during chip boot and QS1 is either GND or OPEN, pins SPIDI and SPICLK are also sampled to determine the **PRT: dc_rep_rate (Reg7[11:10])**. In addition, pins QS2 and QS3 are evaluated by the ADC and converted into 4-bit values before each “mean window”.

By default, the Radar Shield2Go is pulled to VDD_RF (1.5 V) with a 100 kΩ resistor R14; hence, **“autonomous mode” is activated**. Additionally, “advance mode” is activated.

When this pin is 0, when the digital main controller wakes up from reset, the chip boots like earlier versions, only considering the four quad-state inputs below with their 2-bit information per pin.

Table 2 PRT in “advance mode”

PLL_Trig	SPI_MOSI	SPI_CLK	dc_rep_rate
0	*	*	1/2 (fuse dependent)
1	0	0	1
1	0	1	3
1	1	0	0
1	1	1	2

4.2.2 Quad-state basics for adjustable QS1 to QS4 signals

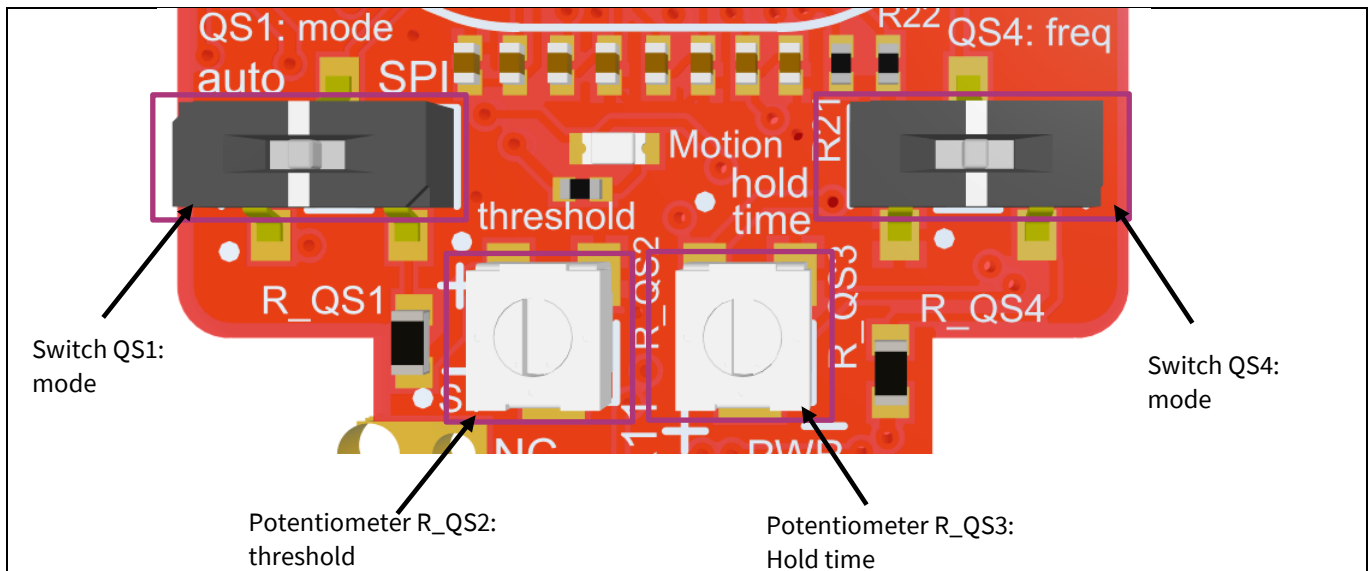


Figure 13 Overview of QS1 to QS4 signals on the BGT60LTR11AIP Radar Shield2Go from the top

The quad-state inputs QS1 to QS4 enable configuration of four different states with one input pin. Figure 13 shows the two switches QS1/QS4 and two potentiometers for the detector threshold (QS2) and hold time (QS3). Table 3 shows possible input states and the resulting internal signals in the binary description. Quad-state inputs are sampled at the start of the init sequence by the internal main controller at power-up. A change after this sampling has no effect. Resampling can be triggered by setting the reset pin or activating the soft reset by writing the corresponding bit in Reg15. The reset pin is by default pulled to V_{DD} (3.3 V) via the 10 kΩ resistor R12.

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In order to have up to 16 settings for QS2 (threshold) and QS3 (hold time), the PLL_TRIG should be connected to V_{DD} by removing R15 and placing R14 = 100 k Ω . This will put the MMIC into “advance mode”. Note that advance mode is set by default.

4.2.3 QS1 – MMIC operation modes

QS1 is used to select the mode of the chip. By default, it is recommended to use either (advance) autonomous mode or SPI mode. Advance mode allows the use of 15 instead of four threshold values for QS2 (threshold) and QS3 (hold time). By default, this board comes with autonomous (advance) and SPI mode settings. Change resistor R_QS1 to enable/disable the other modes, by soldering it, accordingly, as described in Table 3.

Table 3 QS1 settings

Switch position – QS1 mode	QS1	Operation mode of the MMIC	PCB configuration
Left position (floating)	Open (default)	Autonomous pulsed mode	Not important (default)
Right position	100 k Ω to V_{DD}	SPI mode with external 9.6 MHz clock enabled (FH3840024Z)	R_QS1* = 100 k Ω
Right position	V_{DD}	SPI mode	R_QS1* = 0 Ω (default)

* R_QS1 is assembled with 0 Ω , 0603 (imp.)

4.2.4 QS2 – detector threshold

QS2 is used to select the detector threshold value; with the same radar cross-section as a target, a lower detector threshold value corresponds to a higher detection range, which is written into Reg2 as described in the user's guide to BGT60LTR11AIP [3].

Additionally, QS2 can be controlled by the 10 k Ω potentiometer R_QS2 to adjust the detector threshold. To increase the voltage, turn the knob counterclockwise; to reduce the voltage, turn the knob clockwise.

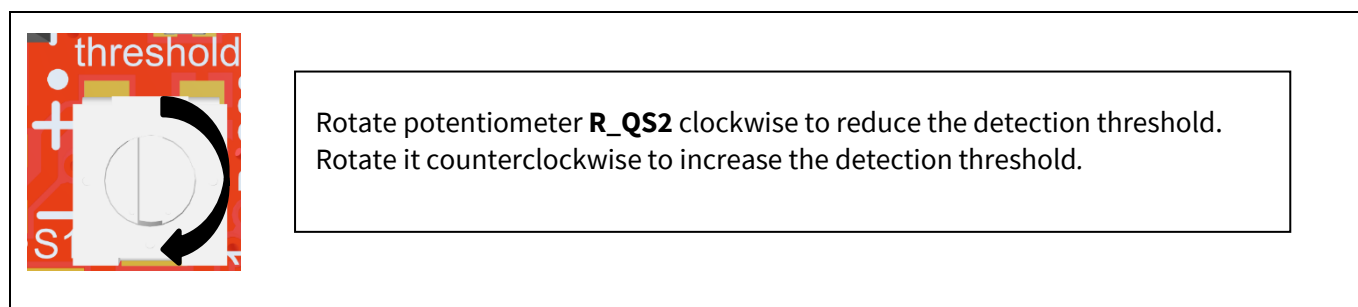


Figure 14 Rotation direction of R_QS2 potentiometer – detector threshold

Note: A low detection threshold results to a higher detection range, and vice-versa.

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4 Radar modes setup

Table 4 QS2 settings – detector threshold

Pad	Detector threshold
$0 \cdot V_{DD}/16 - 1 \cdot V_{DD}/16$	61 (right endpoint of potentiometer)
$1 \cdot V_{DD}/16 - 2 \cdot V_{DD}/16$	66
$2 \cdot V_{DD}/16 - 3 \cdot V_{DD}/16$	80
$3 \cdot V_{DD}/16 - 4 \cdot V_{DD}/16$	90
$4 \cdot V_{DD}/16 - 5 \cdot V_{DD}/16$	112
$5 \cdot V_{DD}/16 - 6 \cdot V_{DD}/16$	136
$6 \cdot V_{DD}/16 - 7 \cdot V_{DD}/16$	192
$7 \cdot V_{DD}/16 - 8 \cdot V_{DD}/16$	248
$8 \cdot V_{DD}/16 - 9 \cdot V_{DD}/16$	320
$9 \cdot V_{DD}/16 - 10 \cdot V_{DD}/16$	384
$10 \cdot V_{DD}/16 - 11 \cdot V_{DD}/16$	480
$11 \cdot V_{DD}/16 - 12 \cdot V_{DD}/16$	640
$12 \cdot V_{DD}/16 - 13 \cdot V_{DD}/16$	896
$13 \cdot V_{DD}/16 - 14 \cdot V_{DD}/16$	1344
$14 \cdot V_{DD}/16 - 15 \cdot V_{DD}/16$	1920
$15 \cdot V_{DD}/16 - 16 \cdot V_{DD}/16$	2560 (left endpoint of potentiometer)

Due to mechanical tolerances and manufacturing differences in the potentiometer, it is difficult to predict the degree of rotation of the potentiometer. Table 5 gives an orientation for the configuration of the threshold, hence the radar detection range. Please note that your values may differ slightly from the values below.

Table 5 Measured threshold vs. range of Radar Shield2Go in autonomous (advance) mode (for reference only)

Measured potentiometer voltage “VDD_RF-QS2” (V1)	Measured potentiometer voltage “GND-QS2” (V2)	Expected detection range	Comment
1.412 V	0.173 V	7.66 m	Rightmost position
1.378 V	0.207 V	6.9 m	
1.296 V	0.289 V	5.8 m	
1.144 V	0.441 V	5.4 m	
0.929 V	0.656 V	4.76 m	
0.794 V	0.791 V	4.1 m	
0.665 V	0.92 V	2.48 m	
0.577 V	1.008 V	2.1 m	
0.388 V	1.197 V	1.7 m	
0.229 V	1.357 V	1.2 m	
0.108 V	1.477 V	0.93 m	
0 V	1.585 V	0.45 m	Leftmost position

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4 Radar modes setup

4.2.5 QS3 – detector hold time

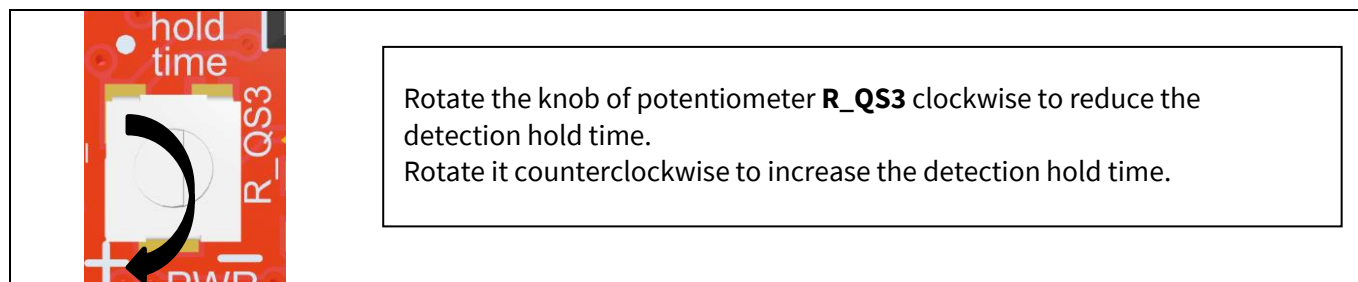


Figure 15 Rotation direction of R_QS3 potentiometer – detector hold time

QS3 is used to select the hold time of the TDet output, and it is written into Reg10 as described in the user's guide to BGT60LTR11AIP [3].

Table 6 QS3 settings – detector hold time

Pad	Detector hold time
$0 \cdot V_{DD}/16 - 1 \cdot V_{DD}/16$	100 ms (right endpoint of potentiometer)
$1 \cdot V_{DD}/16 - 2 \cdot V_{DD}/16$	500 ms
$2 \cdot V_{DD}/16 - 3 \cdot V_{DD}/16$	1 s
$3 \cdot V_{DD}/16 - 4 \cdot V_{DD}/16$	2 s
$4 \cdot V_{DD}/16 - 5 \cdot V_{DD}/16$	3 s
$5 \cdot V_{DD}/16 - 6 \cdot V_{DD}/16$	5 s
$6 \cdot V_{DD}/16 - 7 \cdot V_{DD}/16$	10 s
$7 \cdot V_{DD}/16 - 8 \cdot V_{DD}/16$	30 s
$8 \cdot V_{DD}/16 - 9 \cdot V_{DD}/16$	45 s
$9 \cdot V_{DD}/16 - 10 \cdot V_{DD}/16$	1 min.
$10 \cdot V_{DD}/16 - 11 \cdot V_{DD}/16$	90 s
$11 \cdot V_{DD}/16 - 12 \cdot V_{DD}/16$	2 min.
$12 \cdot V_{DD}/16 - 13 \cdot V_{DD}/16$	5 min.
$13 \cdot V_{DD}/16 - 14 \cdot V_{DD}/16$	10 min.
$14 \cdot V_{DD}/16 - 15 \cdot V_{DD}/16$	15 min.
$15 \cdot V_{DD}/16 - 16 \cdot V_{DD}/16$	30 min. (left endpoint of potentiometer)

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4 Radar modes setup

Due to mechanical tolerances and manufacturing differences in the potentiometer, it is difficult to predict the degree of rotation of the potentiometer. Table 7 gives an orientation for the configuration of the QS3 voltage, hence the radar's hold time. Please note that your values may differ slightly from the values below.

Table 7 Measured voltage vs. hold time of QS3 potentiometer in autonomous mode (for reference only)

Measured potentiometer voltage QS3	Expected detector hold time	Measured detector hold time	Comment
0 V	100 ms	Less than 1 s	Rightmost position
0.112 V	500 ms	Less than 1 s	
0.279 V	1 s	1.37 s	
0.355 V	2 s	2.21s	
0.493 V	5 s	5.54 s	
0.713 V	30 s	30 s	
0.898 V	60s	60s	
1.06 V	90 s	90 s	
1.134 V	2 min.	2 min.	
1.248 V	5 min.	5 min.	
1.452 V	15 min.	15 min.	Leftmost position

4.2.6 QS4 – operating frequency

QS4 is used to select the device operating frequency by configuring the PLL. Frequency is also dependent on the Japan e-fuse. The QS4 signal can be adjusted by using the tri-state switch “QS4: freq” on the Radar Shield2Go.

Table 8 QS4 settings – operating frequency

Switch position – QS4 mode	QS4	Operating frequency	PCB configuration
Left position	Ground	61.1 GHz	Not important
Middle position (floating)	Open (default)	61.2 GHz	Not important
Right position	100 kΩ to V _{DD}	61.3 GHz	R_QS4 = 100 kΩ
Right position	V _{DD}	61.4 GHz	R_QS4 = 0 Ω (default)

*DNP = R_QS4 is assembled by default with a 0 Ω resistor. Exchange for a 100 kΩ [0603 size imp.] resistor.

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5 Hardware circuits

5 Hardware circuits

5.1 Power supply

This Shield2Go needs to be connected to a 3.3 V DC power supply that provides at least 150 mA. **Connect +3.3 V to pin 7 and ground to pin 6 (GND).**

The BGT60LTR11AIP Shield2Go is equipped with a 150 mA Infineon LDO TLS202A1 that provides the necessary 1.5 V for the radar IC, as seen in Figure 16.

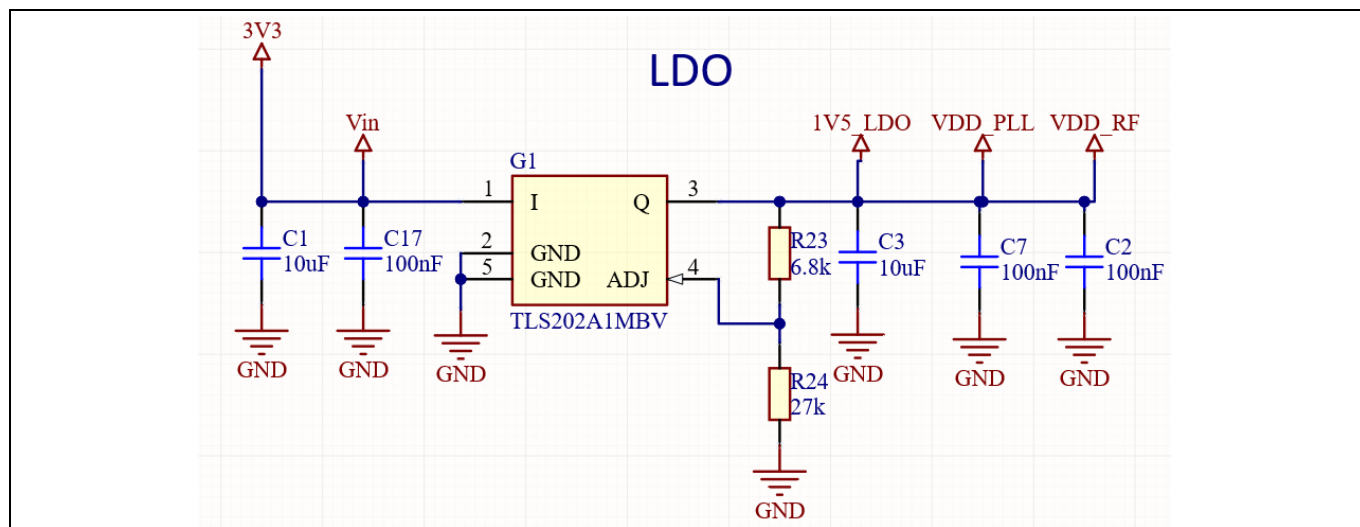


Figure 16 Power supply circuit

5.2 Level shifters

The Radar Shield2Go is equipped with 3.3 V to 1.5 V level shifters. The level shifters are responsible for transforming the voltage signals to 3.3 V. Hence, all inputs/outputs of the Radar Shield2Go work only with 3.3 V voltage levels. For use with, e.g., 5 V levels, further level shifting is required. The level shifting on the BGT60LTR11AIP Shield2Go is shown in Figure 17.

Infineon's [MyloT adapter](#) offers the perfect solution for such a purpose, and is capable of transforming 3.3 V to 5 V, making the Shield2Go usable with 5 V boards. See the [MyloT adapter manual](#) for more information.

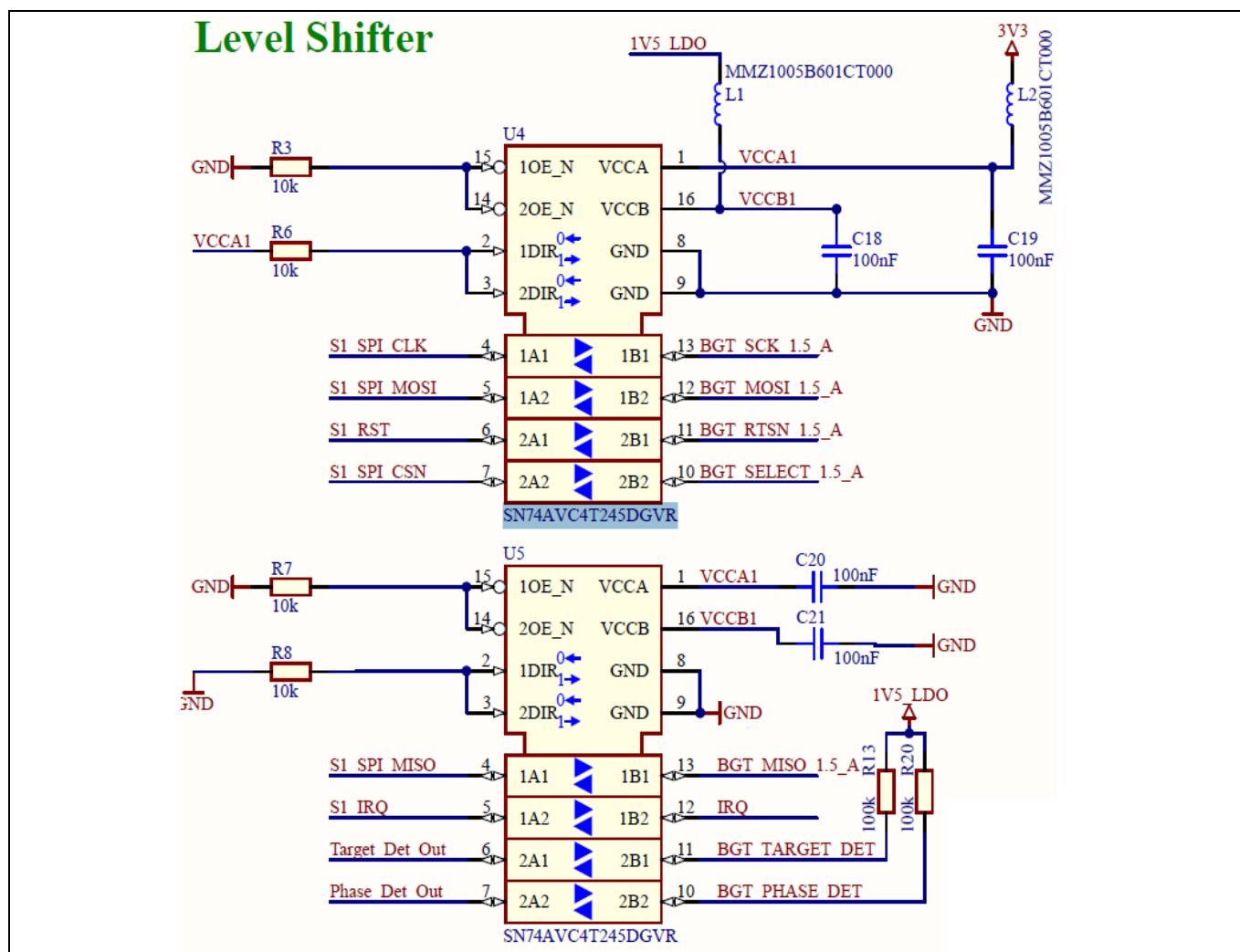


Figure 17 Level shifter circuit (3.3 V to 1.5 V, and vice versa)

5.3 LEDs

The Radar Shield2Go comes with four different LEDs:

- The green PWR LED indicates that the +3V3 pin is connected to a power supply.
- the blue motion LED indicates any movement detected by the radar,
- while the red direction LED indicates an approaching or departing object.

Table 9 shows the behavior of the motion (blue) and direction (red) LEDs, in case the MMIC radar detects an object's presence or its direction of movement.

Table 9 LED behavior when a movement or target is recognized by the BGT60LTR11AIP MMIC

LED	Mode	Comments
Blue – motion	On – target detected Off – target not detected	TD is an active low signal
Red – direction	On – depart departing Off – target approaching	PD is an active low signal

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5 Hardware circuits

The motion LED and direction LED are directly connected to target detection pin 13 (TD) and phase detection pin 9 (PD). The shield has two LEDs to indicate the motion detection (blue) and the target’s direction of motion (red), as shown in Table 9. R10 and R11 are current-limiting resistors. The digital block within the detector in the MMIC evaluates and sets the TD/PD outputs of the BGT60LTR11AIP MMIC. Target detected (TD) output is active low. It is set to low when enough events on the pulse train are counted. Phase detected (PD) output is used to show the direction of the detected target. It is only valid in the case of a detected target, and it is set to high for approaching targets and set to low for departing targets.

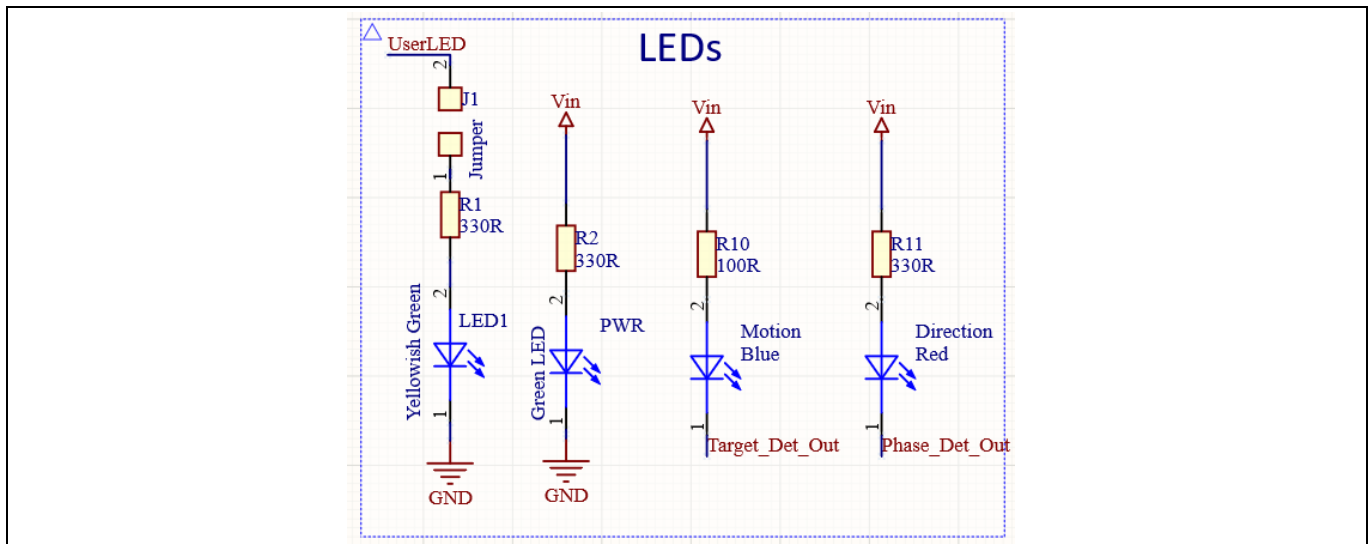


Figure 18 LED schematics

For the TD pin, when no target is detected, the voltage level appears to be 3.3 V on this pin. The PD pin voltage varies, depending on the direction of the moving object. While the target is approaching, the pin puts out 3.3 V, and when the target is departing from the radar it puts out close to 0 V. These pins can be read from analog pins or digital pins TD and PD.

Additionally, the yellow LED1 can be controlled with P10 via an external GPIO of a microcontroller and serves as a custom user LED. Unsolder jumper J1 if you want to disconnect LED1 from P10. Figure 18 shows the schematics of the four LEDs.

5.4 Crystal oscillator

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 milli-amperes and run continuously. The Radar Shield2Go uses a 38.4 MHz crystal oscillator, as seen in Figure 19.

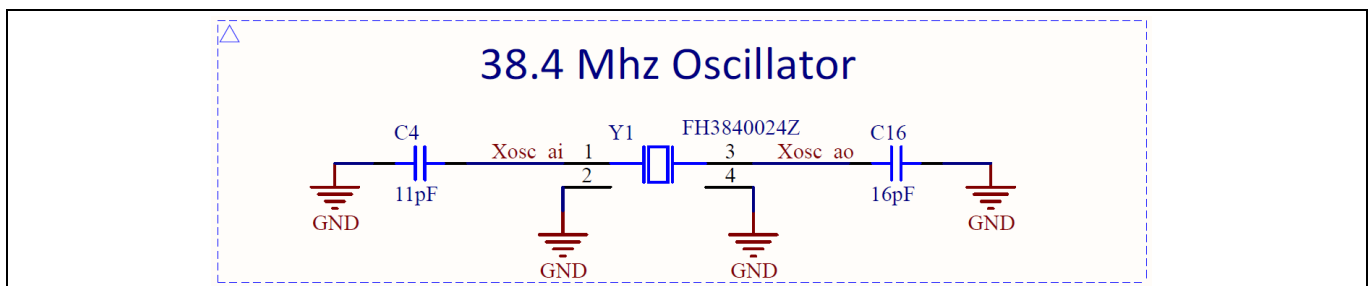


Figure 19 Oscillator circuit with 38.4 MHz crystal

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5 Hardware circuits

5.5 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 into the chip at each differential IQ mixer output port. 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 10. 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 RHP = 4 MΩ). It is not recommended to use higher values, as it will affect the analog baseband (ABB) settling time. The DC blocking capacitors are important because the mixer output has a different DC voltage than the internal ABB.

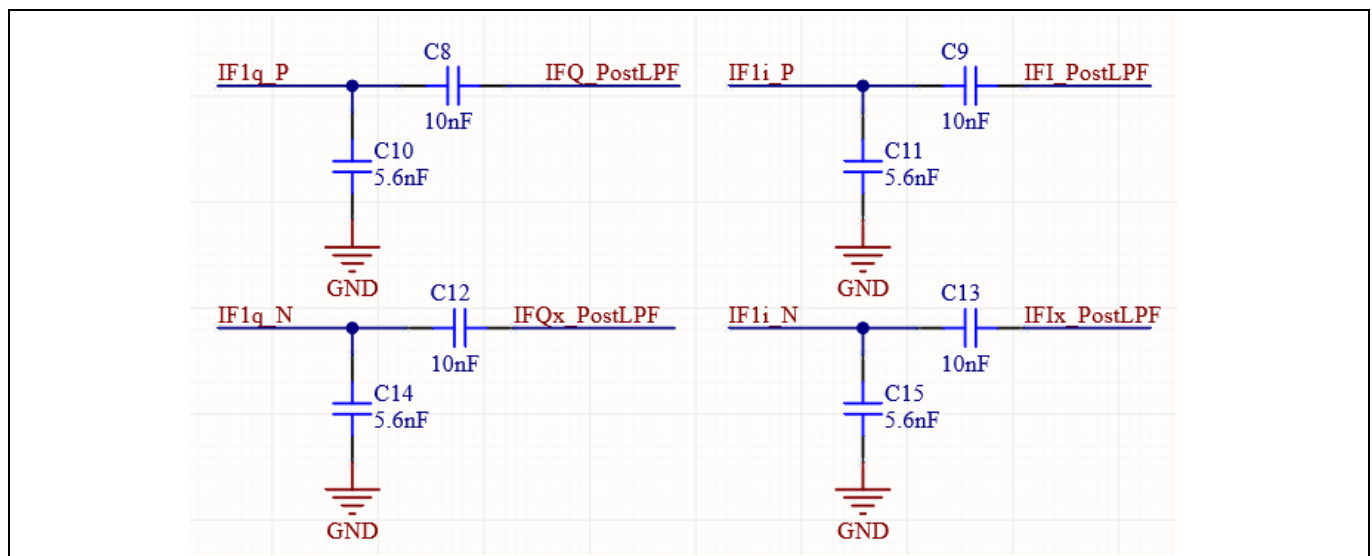


Figure 20 External capacitors on the BGT60LTR11AIP Radar Shield2Go

In Figure 20 the external hold (C_{hold}) and high-pass capacitors (C_{HP}) are shown for all four branches in the differential IQ configuration.

Table 10 Recommended hold capacitors (C10, C11, C14 and C15) for different pulse widths (PW)

Pulse width (μ s)	Hold capacitor value (nF)
3	4.7
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 percent charged during one pulse. Rise-time is controlled by the C_{hold} itself, and the internal mixer output resistance of 300 Ω in each branch.

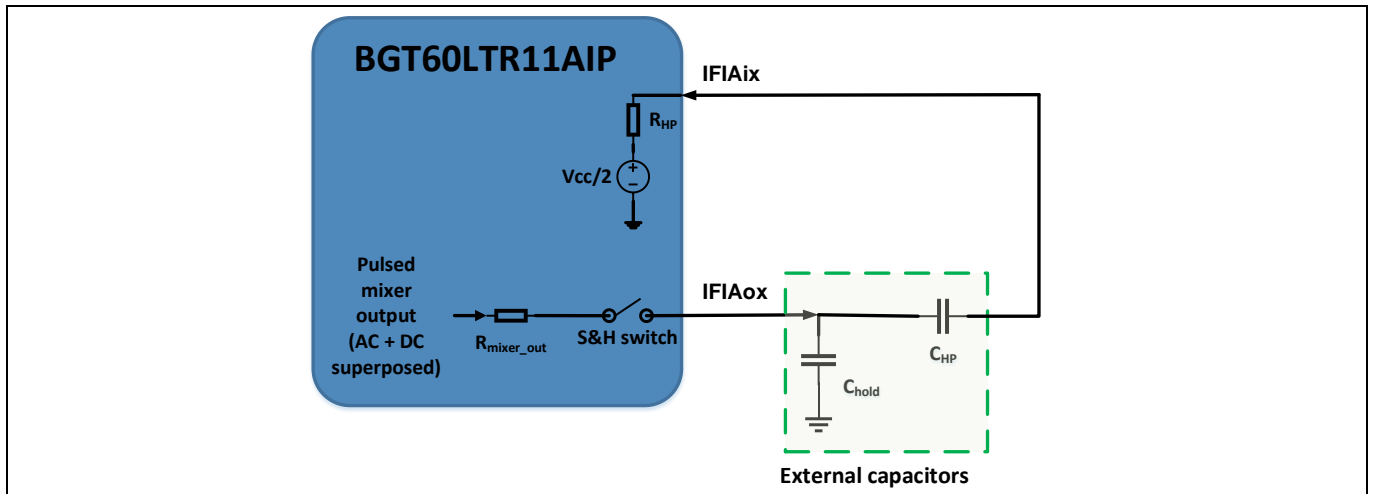


Figure 21 Internal circuit of the BGT60LTR11AIP connected with adjustable external capacitors

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

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6 PCB design

6 PCB design

6.1 Layer stack-up and routing

#	Name	Material	Type	Weight	Thickness	Dk	Df
	Top Overlay		Overlay				
	Top Solder	Solder Resist	Solder Mask		0.02mm	3.5	
1	L1_Top		Signal	1oz	0.035mm		
	Dielectric 3	FR-4	Core		0.56mm	4.2	0.02
2	L2_GND	CF-004	Signal	1oz	0.035mm		
	Dielectric1	FR-4	Prepreg		0.23mm	4.2	
3	L3_PWR	CF-004	Signal	1oz	0.035mm		
	Dielectric 4	FR-4	Core		0.56mm	4.3	0.02
4	L4_Bot		Signal	1oz	0.035mm		
	Bottom Solder	Solder Resist	Solder Mask		0.02mm	3.5	
	Bottom Overlay		Overlay				

Figure 22 Layer stack-up of the BGT60LTR11AIP Radar Shield2Go

The PCB is designed with a four-layer stack-up with standard FR4 material. Figure 22 shows the different layers and their thicknesses. In the routing on the PCB, the VTUNE pin on the BGT60LTR11AIP MMIC should be left floating. Any components added to the line, or a long wire connected can result in spurs.

The MMIC is very sensitive to noises and electrical influences; therefore, the GND and PWR layers were separated from the signal layers (top and bottom). Additionally, to guarantee best performance of the radar, an elliptical space of 4 to 5 cm around the MMIC was kept free from any PCB components (except the power capacitors).

6.2 Bill of materials

Table 11 Bill of materials

Qty	Designator	Package metric	Package imperial	Value	Manufacturer order number
1	C4	1005	0402	11 pF	GRM1535C1H110GDD5
1	C16	1005	0402	16 pF	GRM1535C1H160GDD5
1	Direction	1608	0603	Red	LSM0603412V
1	G1			TLS202A1MBV	TLS202A1MBV
1	LED1			Yellowish green	SML-P12MTT86R
1	Motion			Blue	LSM0603463V
1	PWR	Green	Green	XZBGR155W5MAV	XZBGR155W5MAV
1	R10		0402	100 R	CRCW0402100RFK
1	R23	1005	0402	6.8 k	CRCW04026K80FK
1	R24	1005	0402	27 k	CRCW040227K0FK
1	U1	BGA, 42 pins		BGT60LTR11AIP	BGT60LTR11AIP
1	Y1			FH3840024Z	FH3840024Z

6 PCB design

Qty	Designator	Package metric	Package imperial	Value	Manufacturer order number
2	C1, C3	1608	0603	10 μ F	GRM188R61E106MA73, GRM188R61A106KE69
2	C5, C6	1608	0603	150 nF	GRM188R61A154MA01
2	L1, L2	1005		600 R	MMZ1005B601CT000
1	QS1: mode			CJS-1200B1	CJS-1200B1
1	QS4: freq.			CJS-1201B1	CJS-1201B1
2	R13, R20		0402	100 k	CRCW0402100KFK
2	R_QS2, R_QS3			10 k	22AR10KLFTR
2	U4, U5			SN74AVC4T245DGVR	SN74AVC4T245DGVR
3	R1, R2, R11		0402	330 R	CRCW0402330RFK
4	C8, C9, C12, C13	1005	0402	10 nF	GRM155R60J103KA01
4	C10, C11, C14, C15	1005	0402	5.6 nF	GRM155R71E562JA01
7	C2, C7, C17, C18, C19, C20, C21	1005	0402	100 nF	C1005X7R1H104K050BB
7	R3, R6, R7, R8, R12, R21, R22			10 k	CRCW040210K0FK
3	R14, R17, R19	1608	0603	100 k	RC0603FR-07100KL
3	R_QS1, R_QS4, R9		0603	0 R	RC0603JR-070RL
4	R15, R16, R18	1608	0603	100 k	RC0603FR-07100KL
2	R4, R5		0603	0 R	RC0603JR-070RL
1	S1	8-pin		8-pin, 2.54 mm pitch, male	2211S-08G
1	S1	9-pin		9-pin, 2.54 mm pitch, male	2211S-09G


6.3 Schematics

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6 PCB design

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Radar BT60LTR11AIP Shield2Go



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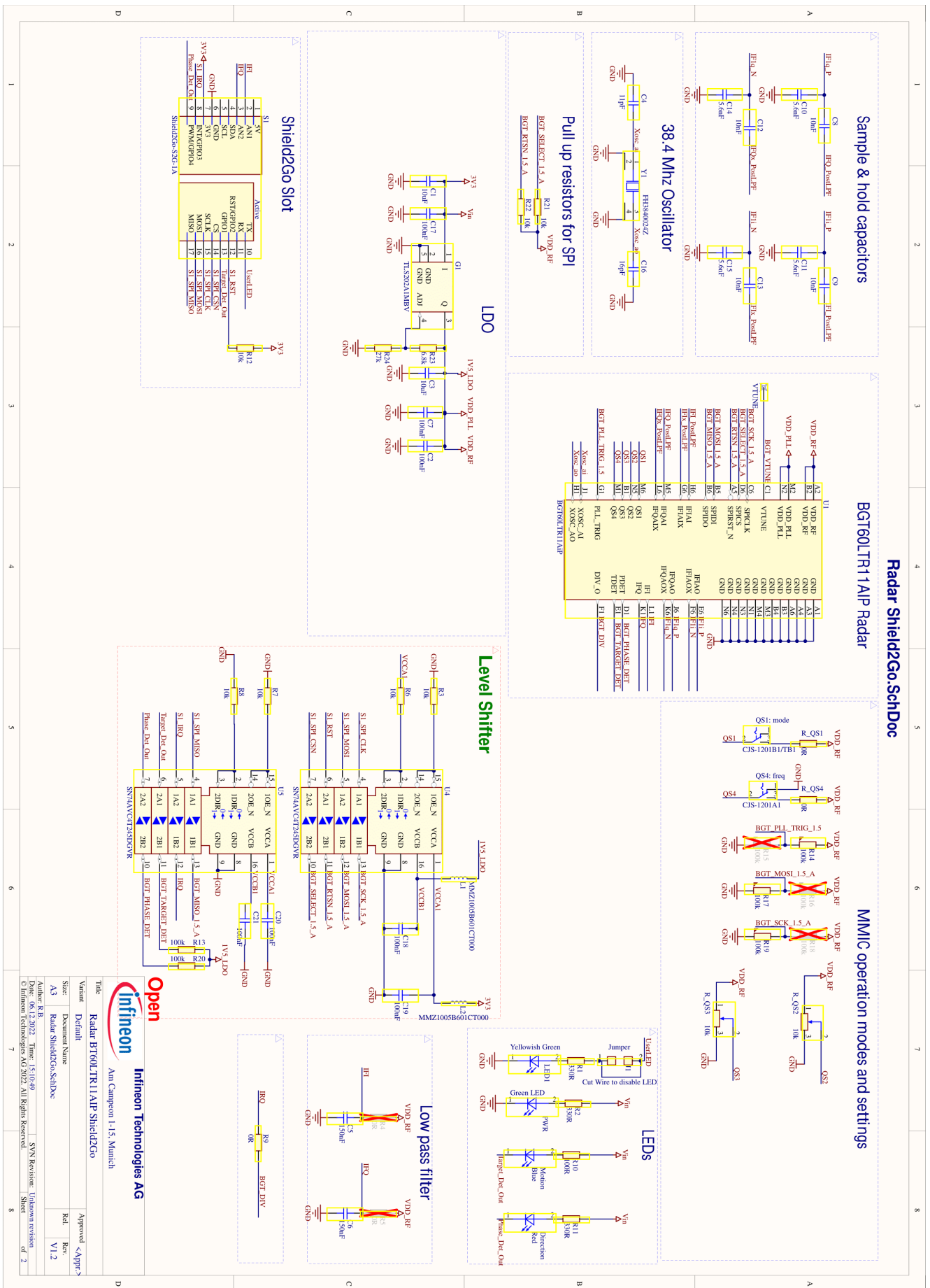
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Revision history

Revision history

Document revision	Date	Description of changes
1.00	2022-12-15	Initial version
1.10	2023-05-10	Updated Fig.14, Fig.15, Tab.4, Tab.5, and Tab.6 to fix the potentiometer related statement Miscellaneous document cleanup updates

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