Smart entrance counter solution

using XENSIV™ KIT_CSK_BGT60TR13C 60 GHz radar

About this document

Scope and purpose

This document serves as an application note for the smart entrance counter solution (SECS) using XENSIV™ KIT_CSK_BGT60TR13C, provided as part of the connected sensor kit (CSK) offering. It also describes the required software and hardware, as well as how to set up and get started with Infineon SECS using XENSIV™ KIT_CSK_BGT60TR13C.

Intended audience

This document is intended for design engineers, technicians, and developers of electronic systems interested in building their own smart entrance counter solution for various consumer applications using the CYSBSYSKIT-DEV-01 and XENSIV™ BGT60TR13C radar sensor.

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1 Smart entrance counter solution

A smart entrance counter solution (SECS) counts the number of people entering and exiting premises such as supermarkets, pharmacies, and office buildings. It helps business owners to determine the occupancy of their premises, enabling solutions such as maintaining social distancing, emergency evacuations, and energy-saving based on occupancy. The entrance counting data can be sent to a centralized server, allowing for interconnectivity among many sensors. Additionally, the statistics collected by the central server can be remotely displayed on a laptop or mobile device to understand the facility's occupancy level.

Infineon's SECS counts the real-time number of people entering/exiting. Enabled by Infineon's XENSIV™ BGT60TR13C radar sensor and its sophisticated radar entrance counting algorithm, this solution provides highly accurate counting without delay. The current solution has been developed for people entering/exiting one at a time.

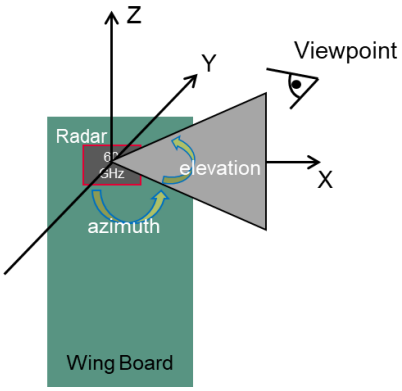
Figure 1 Radar mounted on the side of the door (left) and at the top of the door (right)

1.1 Key features

- Ready-to-use radar solution with adjustable detection range for entrance counting.
- Bidirectional counting with one sensor per entrance.
- Dashboard indicating a stop sign to the second person for maintaining social distancing.
- Radar sensor's immunity to environmental factors including temperature, wind, sunlight, and dust/debris.
- Full compliance with the General Data Protection Regulation (GDPR).
- A reliable and tested solution for entrance counting, suitable for retail, office, and commercial buildings.
- High accuracy and low latency counting.
- Real-time count of the number of people entering or exiting the premises.

1.2 Solution specifications

Table 1 Solution specifications

Specification	Description
Moving object size	Detect moving objects with a minimum height of 1 m
Field of view and radar orientation	• Detection range: Up to 3 m • Azimuth: ± 45 degrees, elevation: ± 40 degrees • Radar chip mounted in front-facing orientation at 1 to 1.5 m height from the ground *Note: Front-facing orientation example – radar wing board mounted on a wall with radar chip on the top side of the board as shown below).* 
Walking speed	Maximum supported moving object speed: 2 m/s
Detection timings	Can detect people going in or out (one person at a time) of the entrance area in real time (≤ 1 s)
Configurability	Easy configuration options using radar entrance counter code example using UART port to change various parameters (detection range, sensitivity, etc.)
Target platform	CSK comprising: • Rapid IoT Connect Developer Kit (CYSBSYSKIT-01): Based on PSoC™ 6 MCU (Arm® Cortex®-M4F) • XENSIV™ BGT60TR13C radar wing
CPU and memory consumption	CPU: ~25 percent (target platform), SRAM usage: < 125 KB, FLASH: < 256 KB
HW interface	Count data is available via UART or GPIO with optional provision for SPI/I2C interface as well using radar entrance counter code example
Certifications	SECS is FCC-certifiable. Recommended radar settings and test report on using an embedded reference form factor board can be provided on request.
Test conditions	Radar chip mounted above the door at the entrance or mounted on the side of the entrance passage. Test subject height: ~1.7 m Ambient temperature: 18 to 24°C Relative humidity (RH): 35 to 70 percent

Specification	Description
Target applications	Homes, offices, and commercial buildings

1.3 Known limitations

Addressing the limitations of the developed application, Table 2 summarizes the constraints with additional information on how they may impact the functionality of the application.

Table 2 Known limitations

Limitation	Scenario	Description	Considerations
Two persons walks behind each other through the entrance area		If the targets are too close to the radar, cannot identify the targets separately as it senses as a single entity.	The minimum distance between the targets must be at least 50 cm to 150 cm if two persons are moving into the fields simultaneously.
Two persons walk side by side through the entrance area		If the targets are too close to each other, radar cannot identify the targets simultaneously as it might be seen only as a single entity.	The minimum distance between the targets must be at least 50 cm to 150 cm if two persons are moving through the filed simultaneously.
Three persons walking through the entrance		Here too the distance between the individual targets is of almost importance as there must be enough space between the targets to get it identified properly.	The minimum distance between the targets must be of minimum of 50 cm to 150 cm to get them identified as three different targets by the radar.

2 Hardware and software requirements

2.1 Hardware requirements

The SECS is implemented and tested on boards shown in Figure 2. However, the code can be migrated to use other combinations.

- Rapid IoT Connect Developer (CYSBSYSKIT-DEV-01) V3.0
- XENSIV™ BGT60TR13C Wing (EVAL_BGT60TR13C_Wing) V1.0

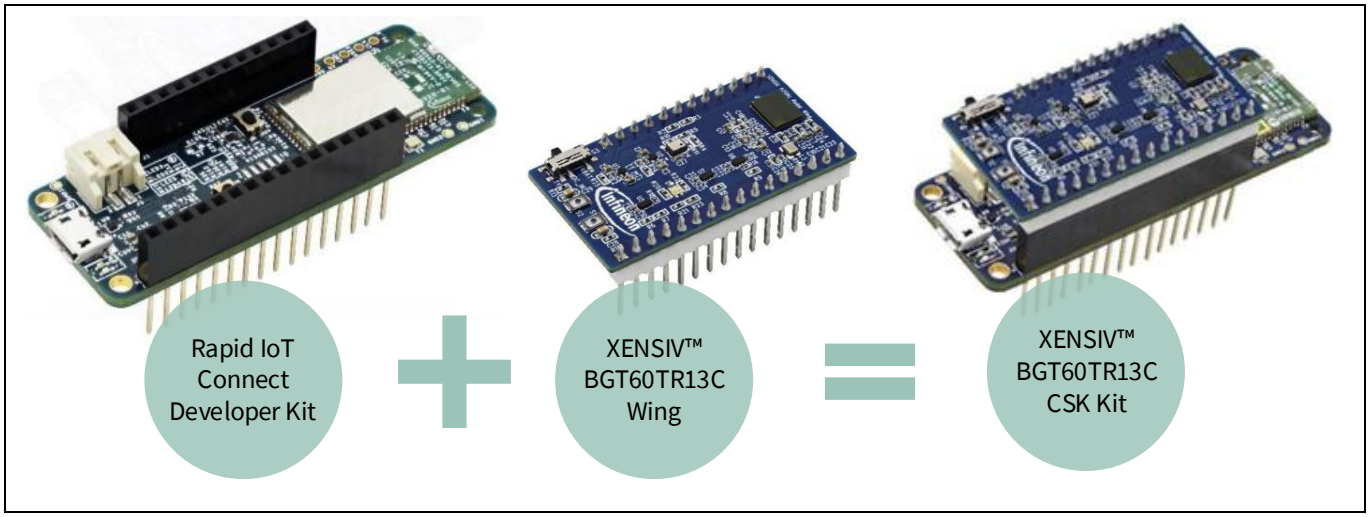


Figure 2 XENSIV™ KIT CSK BGT60TR13C

Note: For more detailed description of the hardware components, see the KIT_CSK_BGT60TR13C user guide [1].

2.1.1 Rapid IoT Connect Developer Kit

Rapid IoT Connect Developer Kit (CYSBSYSKIT-DEV-01) shown in Figure 3 allows for evaluation of the Rapid IoT Connect module (CYSBSYS-RP01) on a standard Feather form factor. CYSBSYS-RP01 Rapid IoT Connect module is a turnkey module that enables secure, scalable, and reliable compute and connect.

Rapid IoT Connect Developer Kit carries a CYSBSYS-RP01 Rapid IoT connect system-on-module (SoM). The Rapid IoT Connect SoM includes a PSoC™ 6 MCU, a CYW43012 single-chip radio, onboard crystals, oscillators, chip antenna, and passive components.

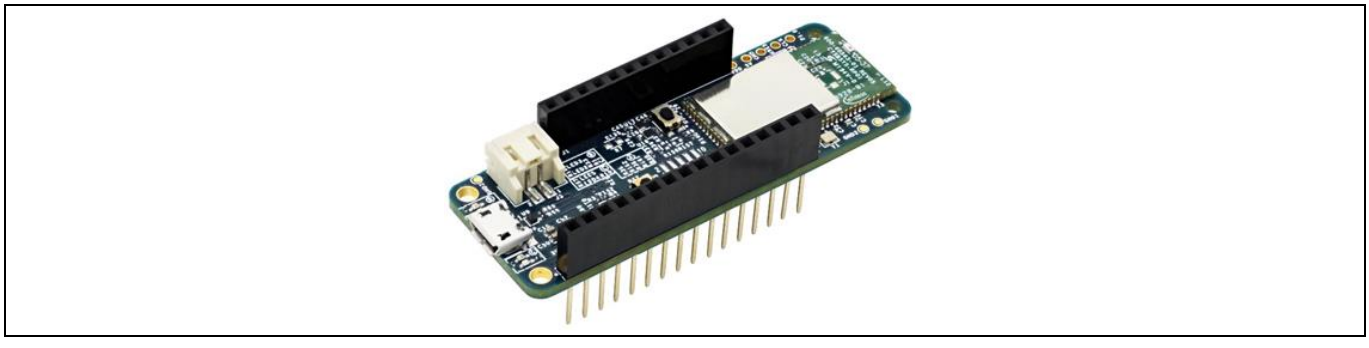


Figure 3 CYSBSYSKIT-DEV-01

Key features:

- CYSBSYS-RP01 module.
- Supports up to 2 MB FLASH and 1 MB SRAM.
- 512 Mbit external Quad SPI NOR FLASH that provides a fast, expandable memory for data and code.
- KitProg3 onboard SWD programmer/debugger, USB-to-UART, and USB-I2C bridge functionality.
- Battery connector, charging IC, and charging indicator LED.
- KitProg3 mode button, KitProg3 status LED, and KitProg3 power LED.
- 16 KB of emulated EEPROM.
- Feather-compatible pin header.
- Delivers dual-cores with a 150 MHz Arm® Cortex®-M4 as the primary application processor and a 100 MHz Arm® Cortex®-M0+ as the secondary processor for low-power operations.
- Supports Full-Speed USB, a Quad-SPI interface, 13 Serial Communication Blocks, 7 programmable analog blocks, and 56 programmable digital blocks.

2.1.2 XENSIV™ BGT60TR13C Wing

XENSIV™ BGT60TR13C Wing shown in Figure 4 is based on the BGT60TR13C MMIC 60 GHz radar sensor with integrated one transmitting and three receiving antennas. BGT60TR13C MMIC enables ultra-wide bandwidth frequency modulated continuous waves (FMCW) operation. It is equipped with an integrated finite-state machine (FSM). With the aid of the FSM, BGT60TR13C can perform FMCW frequency sweeps (so-called chirps), data acquisition as well as storing of samples into the internal FIFO memory autonomously.

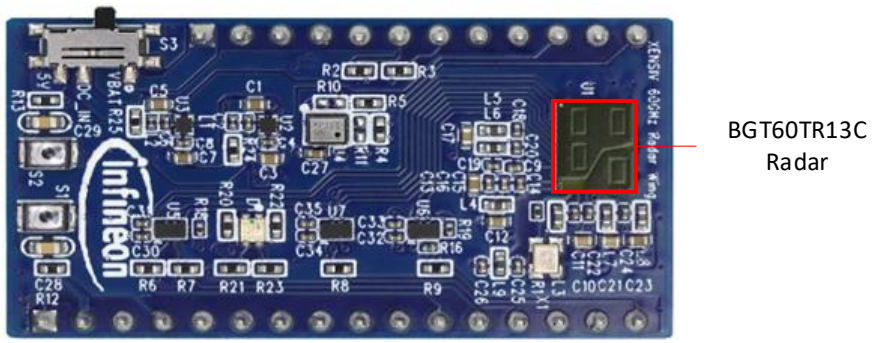


Figure 4 XENSIV™ BGT60TR13C Wing (top view)

BGT60TR13C features:

- It has an ultra-wide bandwidth of 5.5 GHz and a very low range resolution down to ~3 cm.
- Higher Doppler velocity is achieved with a ramp-up speed of 400 MHz/µs.
- High signal-to-noise ratio (SNR) ensures detection of people up to 10 m distance, front facing towards the sensor, while high sensitivity allows detection of movements down to sub-millimeter. Via the very commonly used Serial Peripheral Interface (SPI).
- 60 GHz radar sensor for FMCW operation.
- Antenna-in-package.
- Optimized power modes for low-power operation.

2.2 Software requirements

- ModusToolbox™ software v2.4 or later (tested with v2.4)
- Board support package (BSP) minimum required version: 3.0.0
- Programming language: C
- Serial terminal (Tera Term, ModusToolbox™ IDE terminal, etc.)

3 Mounting guidelines and coverage

To properly mount the hardware unit of the CSK, which includes the radar wing board and rapid IoT baseboard, it is recommended to follow these guidelines.

Attention: ***Ensure that there are no moving objects or swinging doors in the radar's field of view (FoV).***

3.1.1 Top/ceiling mount

- To top/ceiling mount the sensor, position at a height up to 3 m from the ground with the longer edge of the sensor board perpendicular to the passage.
- It is recommended to limit the maximum range of the solution to the height of the sensor board from the ground for optimal performance.

3.1.2 Side mount

- To side mount the sensor, position in a portrait orientation at a height between 1.1 to 1.5 m on a wall, door, or pillar. Face the radar sensor towards the entry/exit passage from the side to allow for people counting.
- When side mounting the sensor, it is recommended to set the maximum range parameter based on the width of the entrance. This value should be less than the sensor-to-wall distance, if applicable.

3.1.3 Field of view

Figure 5 shows the field of view.

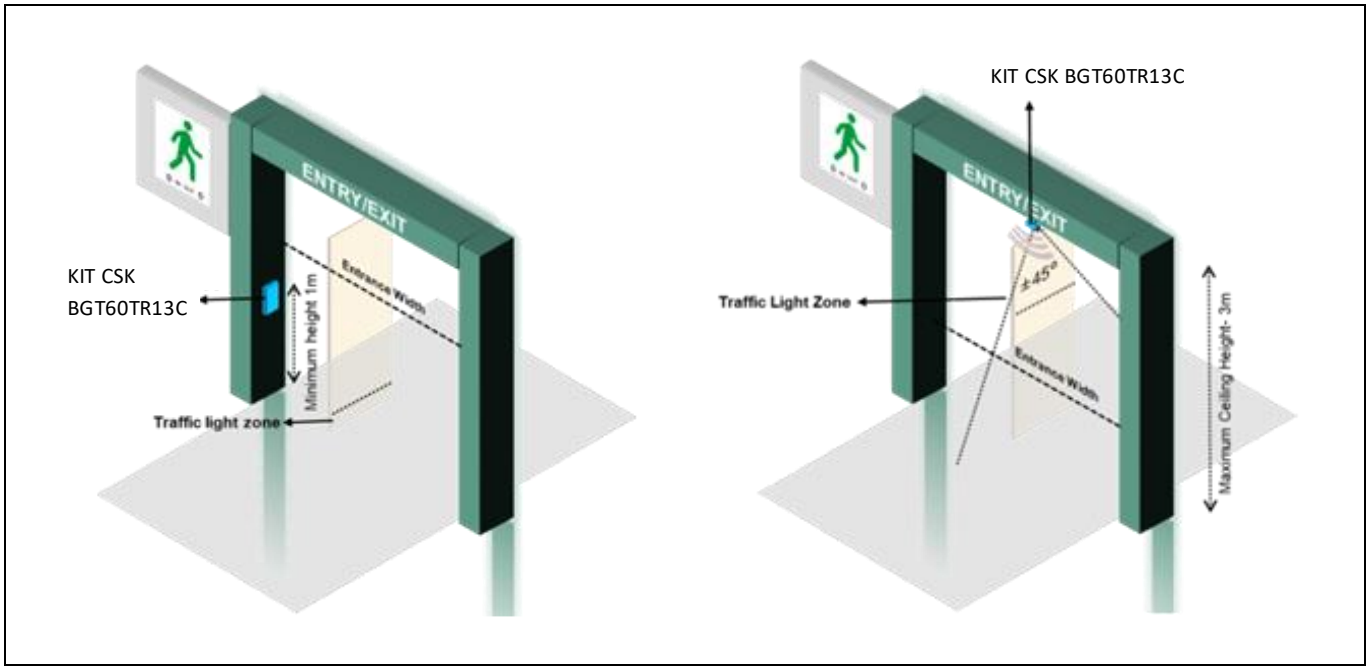


Figure 5 Radar mounted on the side of the door (left) and at the top of the door with the longer edge perpendicular to the passage (right)

4 Quick IoT Experience

4.1 Signup and login

Create an account with the Infineon Rapid IoT Connect Cloud Platform by signing up with your email address. You will receive a password via email, which you will be prompted to change upon your first login to one of your choosing.

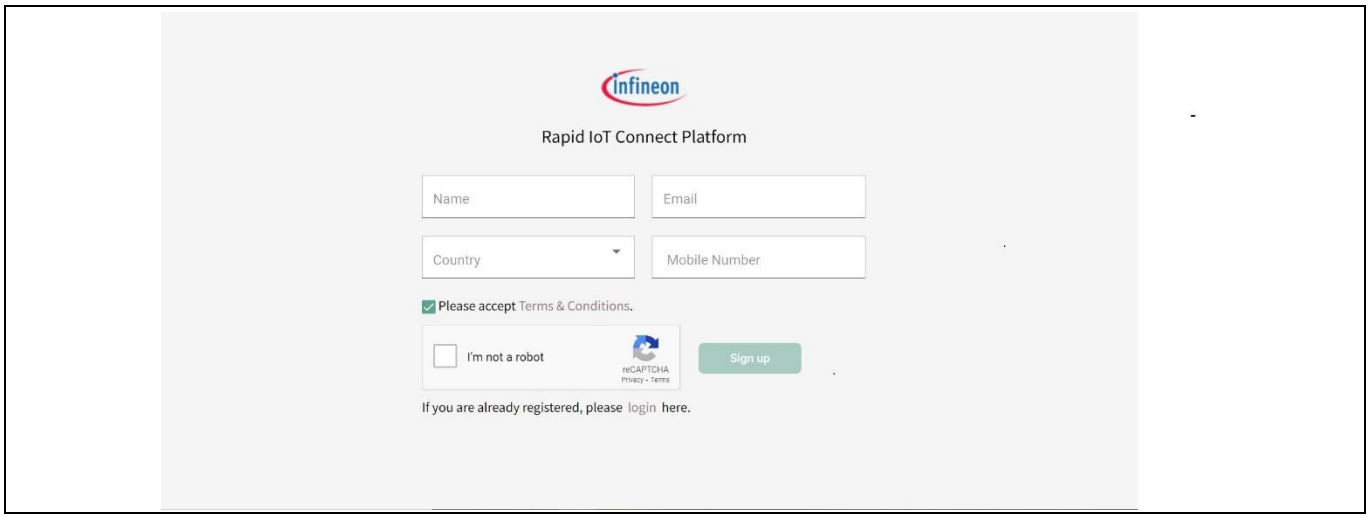


Figure 6 Rapid IoT Connect Cloud Platform signup view

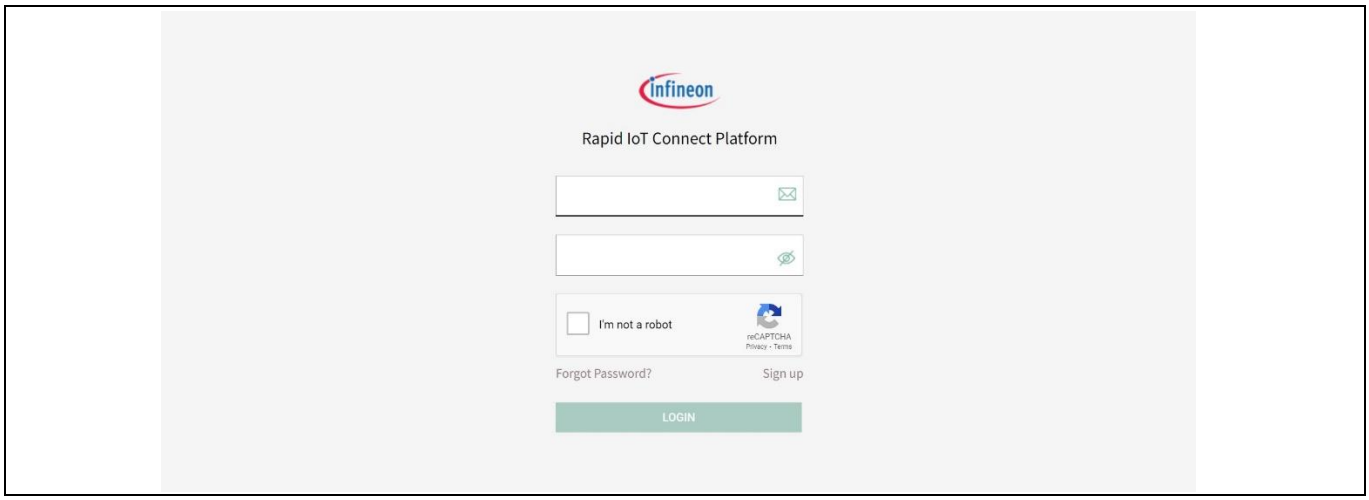


Figure 7 Rapid IoT Connect Cloud Platform login view

4.2 Add your device

Click on the **Add device** button to start the process of adding your new KIT CSK BGT60TR13C device. A pop-up wizard appears to guide you through the process. On the initial screen, provide a name for your device, and enter the development kit serial number as shown in Figure 9. Finally, click the **Next** button to proceed to the next screen.

Figure 8 Add your device

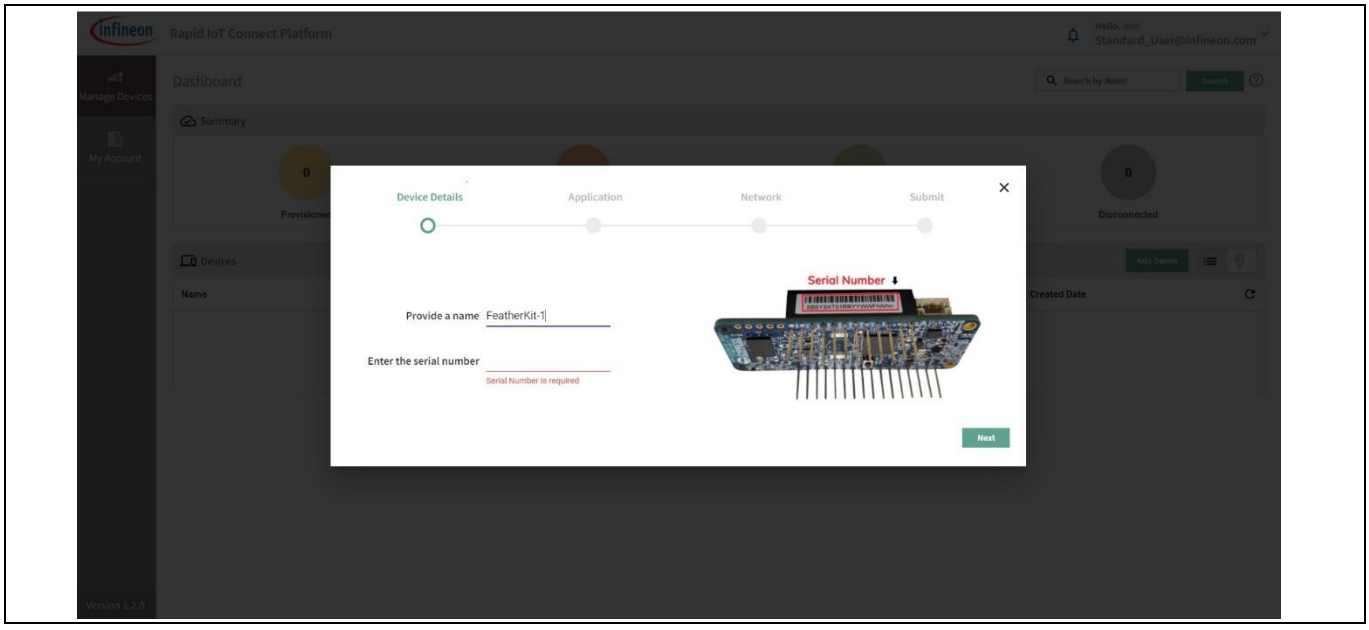


Figure 9 Add device wizard

4.3 Application

With the Quick IoT Experience, you can complete an IoT sensor experience that includes telemetry and fleet monitoring, all in 10 minutes or less.

After you complete the setup wizard, you can download and program your development kit with a pre-built hex file. This hex file prepares and configures your development kit with the latest Wi-Fi firmware, an example application, and all the credentials required to securely connect to the cloud.

Note that the example application automatically uses the integrated temperature sensor. Ensure to select your desired application based on the XENSIV™ wing board you have, in this case the XENSIV™ BGT60TR13C wing.

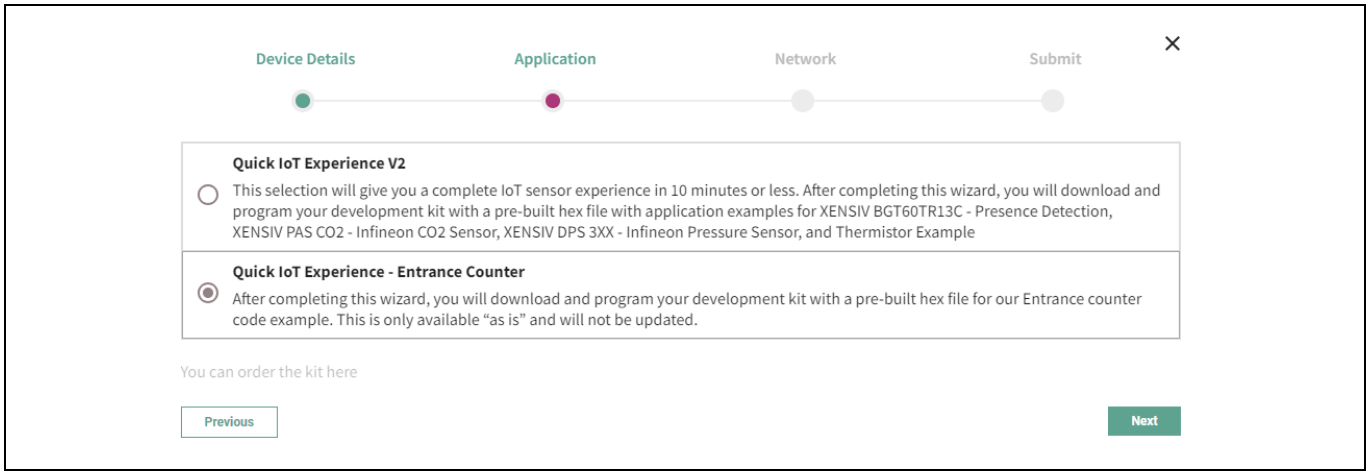


Figure 10 Select application

4.4 Configure Wi-Fi network

You can connect to your preferred WPA2 network by providing the Wi-Fi SSID and password by selecting **Create New Network**, or set up an access point/hotspot with WPA2-PSK security by using the following credentials:

- SSID: IFX_Sensor
- Security: WPA2-PSK
- Password: S66M14022021

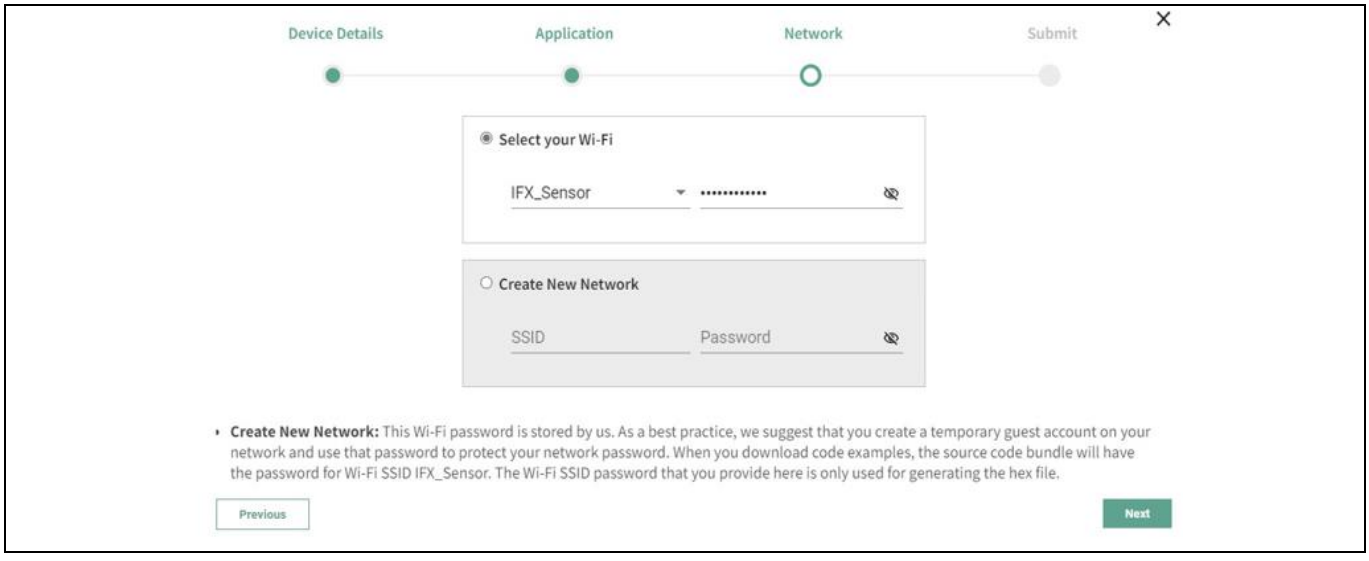


Figure 11 Configure and select network

4.5 Submit your device configurations

Ensure all the information that you have entered is accurate before clicking the **Submit** button. If you need to make changes, you can go back to earlier screens by pressing the **Previous** button. After you click **Submit**, a custom hex file will be built for your device, and a software bundle will be generated for programming your development kit, as shown in Figure 12.

Note: You can add/register a maximum of five devices with the Rapid IoT Connect Cloud Platform account.

4.6 Download the zip package

Depending on your laptop or PC's operating system (Windows/Linux/Mac), you will receive a downloadable package that includes a hex file firmware image and a programming tool for your KIT_CSK_BGT60TR13C. The package will be in the form of a zip file. To view the detailed device status, click on the ⊕ (expand) button. To download the zip package, click (download) next to **Success** on the application as shown in Figure 12.

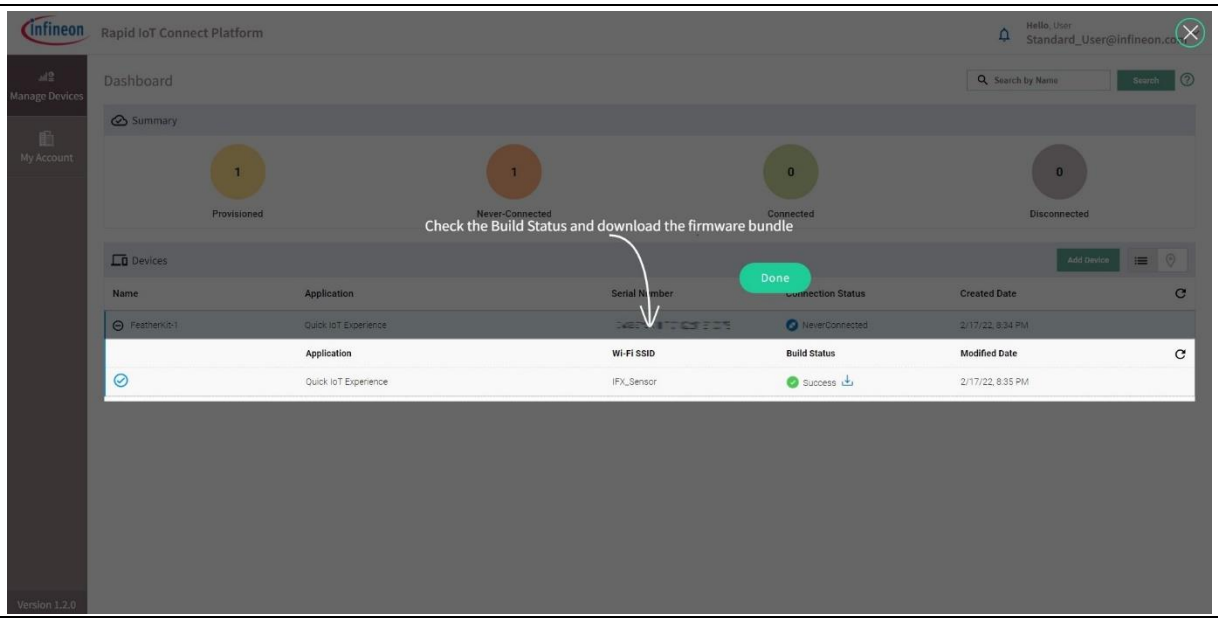


Figure 12 Device management dashboard

4.7 Program the KIT_CSK_BGT60TR13C

Use a Micro-USB cable to connect your development kit to your PC or laptop. Then, extract the zip file and run the program_kit script. For Windows users, the script will be a .cmd file, while Linux and Mac users will see a .sh and .command files, respectively. If you are using Linux or Mac, ensure to run the script from a terminal with the necessary permissions. For detailed instructions, see the README.md file as shown in Figure 13.

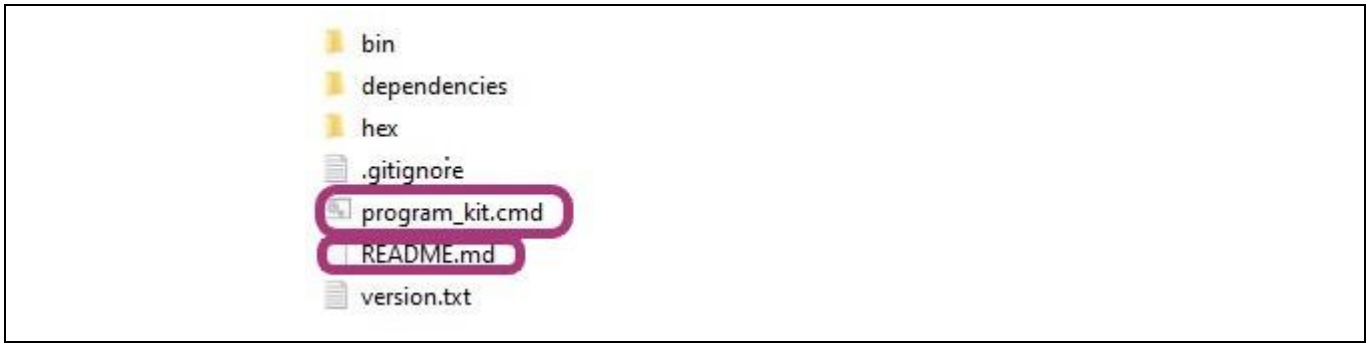


Figure 13 Package content

4.8 Device management

Manage your device or devices and their configurations in the device management tab. To view the details of a particular device, click on the expand icon next to its **Created Date** entry.

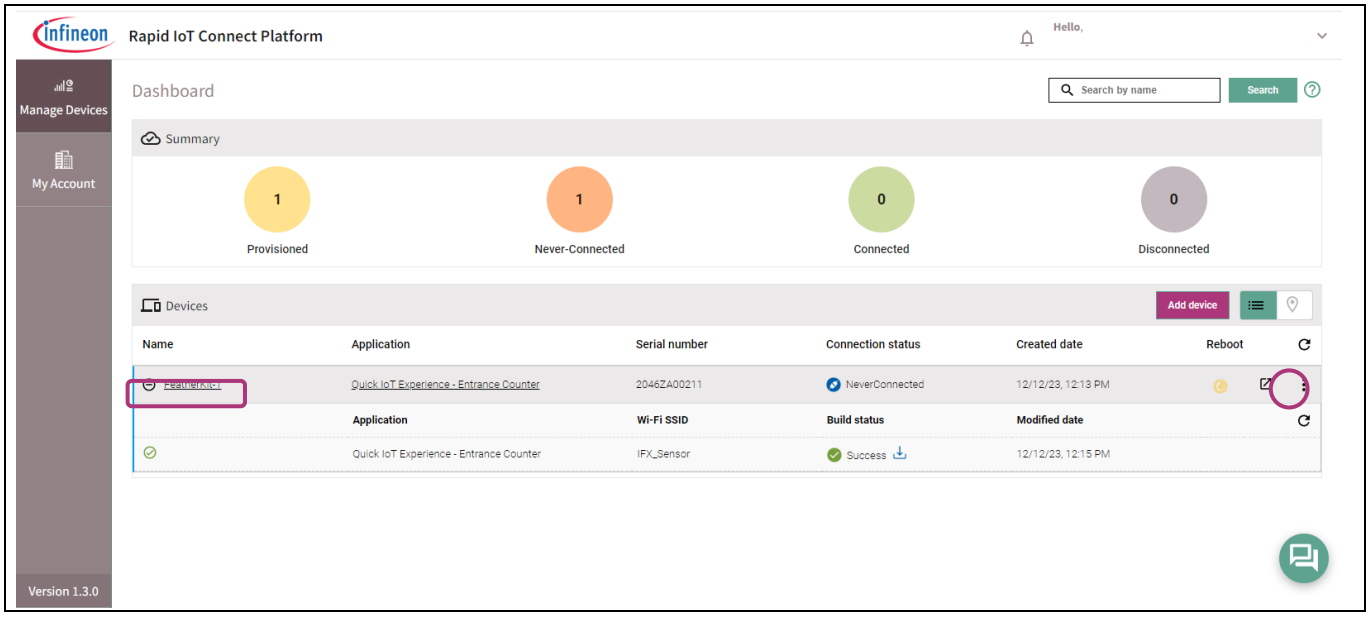


Figure 14 Device connection status

4.9 Select desired application

To select the desired application for your connected Infineon sensor wing board (in this case, XENSIV™ BGT60TR13C wing), go to the **Attributes** tab in the device details. Click on the dropdown menu for Sensor_Solution and select the desired value. By default, the application will be set to **Thermistor** because the only sensing element available on the CYSBSYSKIT-DEV-01 is a thermistor. After you select the application, the attributes will be pushed to the device, and it will reboot to the desired application.

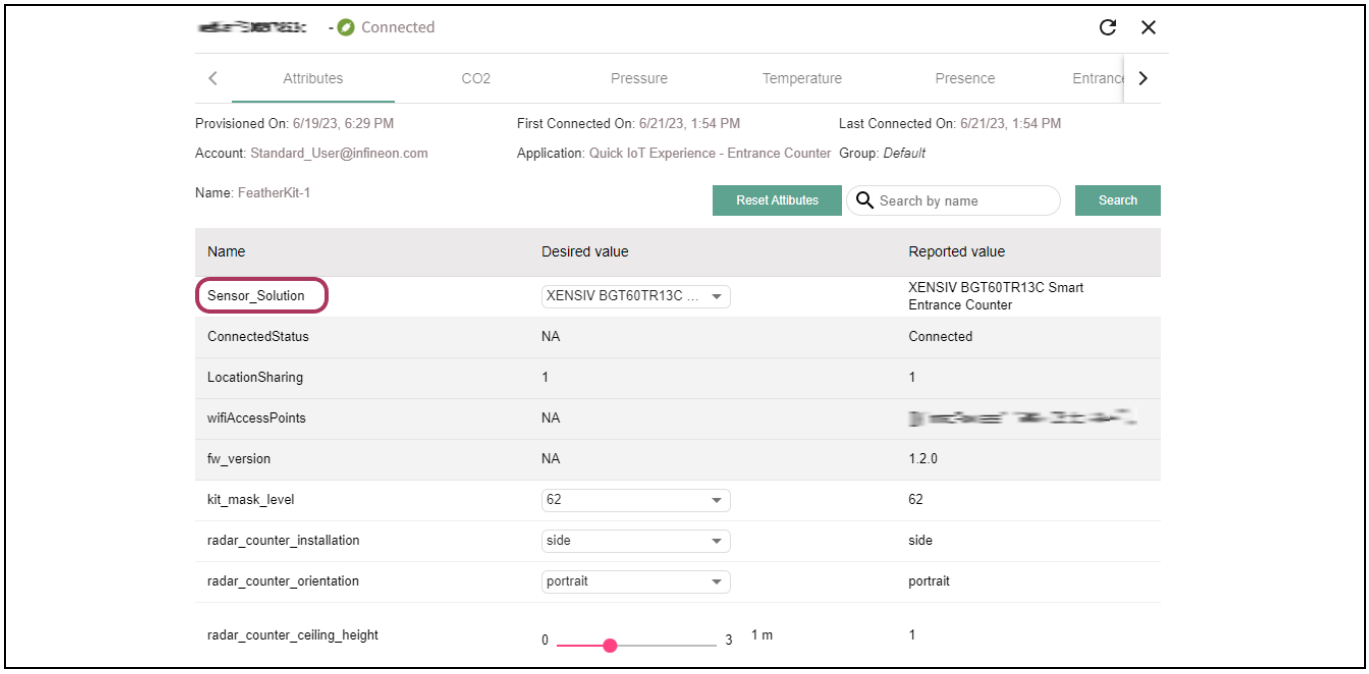


Figure 15 Attributes tab for connected device

Note: Selecting a new application may cause the connectivity to temporarily disconnect and reconnect from the Rapid IoT Connect Cloud platform.

Table 3 Entrance counter application attributes

Attribute	Description
radar_counter_installation	Side: Side mounting installation Ceiling: Ceiling mount installation Default is side.
radar_counter_orientation	Portrait: Radar board is installed at portrait orientation Landscape: Radar is installed at landscape orientation Default is portrait.
radar_counter_entrance_width	0.0 – 3.0 Entrance width in meters. Default is 1.0.
radar_counter_ceiling_height	0.0 – 3.0 Ceiling height in meters. This parameter is used in ceiling mount installation. Default is 1.0.
radar_counter_min_person_height	0.0 – 2.0 Minimum person height to count in meters. This parameter is used in ceiling mount installation. Default is 1.0.

Attribute	Description
radar_counter_traffic_light_zone	0.0 – 1.0 Area where traffic light is red in meters. This can be used for reminding social distancing purpose. Default is 1.0.
radar_counter_sensitivity	0.0 – 1.0 Sensitivity for presence detection. Step of 0.1. Default value is 0.5.
kit_mask_level	Disable logs, enable minimal logs or full logs to cloud 60: WARN, MINOR, MAJOR, FATAL all to UART terminal 62: INFO, WARN, MINOR, MAJOR, FATAL all to UART terminal 124: WARN, MINOR, MAJOR, FATAL all to Cloud UI as well as UART terminal
radar_counter_reverse	True: reverse IN/OUT count event False: IN/OUT count event as normal Default value is false.
room_capacity	Capacity of the room in terms of people. Default value is 100. Minimum value is 1.

4.10 Change application attributes

To view all attributes on one page, click on the **Items per page** dropdown menu at the bottom of the **Attributes** tab and adjust the number of items accordingly. For the Entrance Counter use case, see the list of attributes as shown in Figure 16.

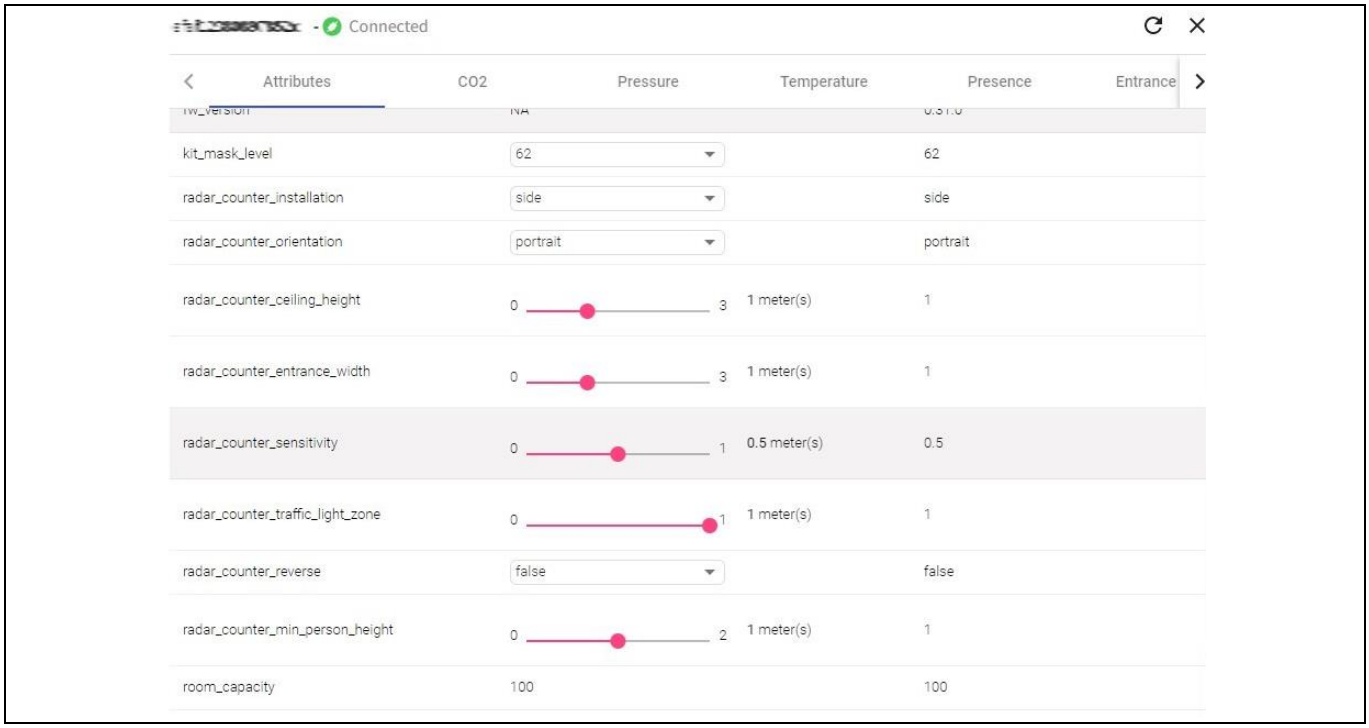


Figure 16 Entrance counter attributes

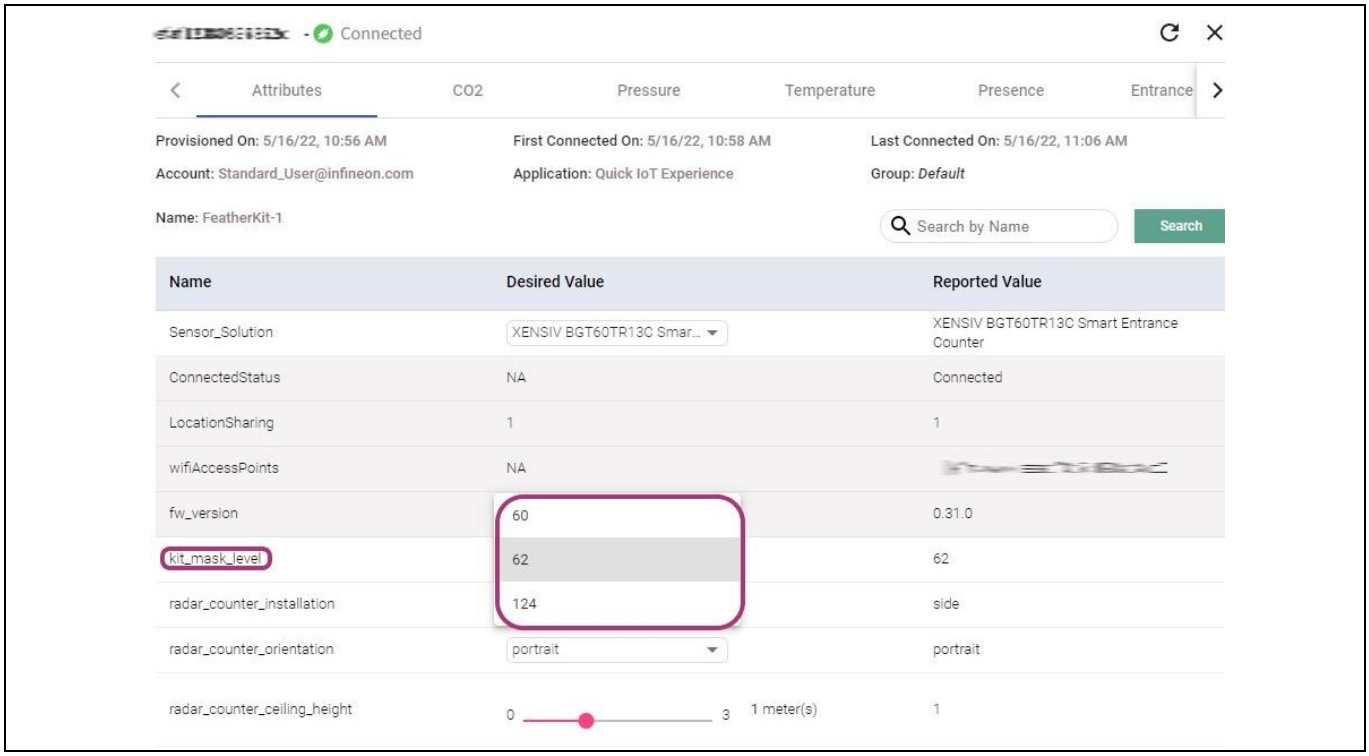


Figure 17 Device log level configuration

4.11 View sensor data

To view your sensor data on the cloud, click on the desired tab at the top of the device details window. If you have the XENSIV™ BGT60TR13C wing board, select the **Smart Entrance Counter** tab.

By default, your application will be set to Thermistor. Click on the Presence or Entrance Counter tab to view the data represented as a graph for easy viewing. You can also download the raw data in .CSV format by clicking the **Download** button in the top-right corner.

Note that the data retention period for a Standard User is 14 days, meaning that data recorded more than 14 days ago cannot be retrieved. If you require a longer retention period, please contact Infineon Support to upgrade your account.

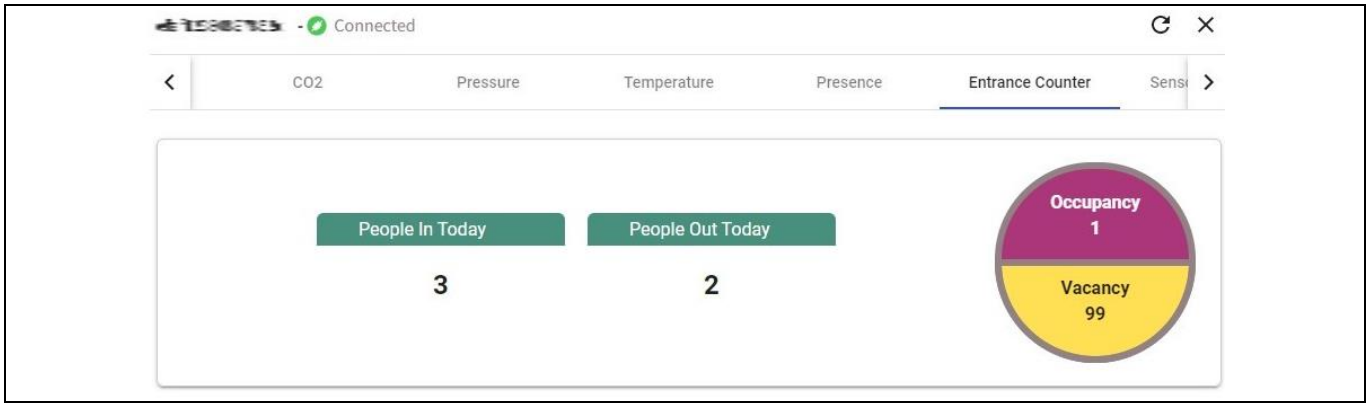


Figure 18 Entrance counter data visualization

5 Build your own application

5.1 Overview

XENSIV™ KIT BGT60TR13C is compatible with the xensiv-radar-sensing library. ModusToolbox™ offers sample code examples that utilize these libraries. See the README.md file for more details.

The xensiv-radar-sensing library provides APIs that allow the user to utilize existing radar applications such as presence detection, entrance counter, or develop new applications on top of it. The library implements the ModusToolbox™ Hardware Abstraction Library (HAL) interface.

If you need to use or customize the SECS source code, you can see the related code example based on the xensiv-radar-sensing library available on Infineon's GitHub and supported through ModusToolbox™, see Connected sensor kit: Radar entrance counter application.

5.2 Firmware design and implementation

The SECS application runs on FreeRTOS where a scheduler defines and manages different tasks. The application source files included in the firmware of the radar entrance counter application are listed in Table 4.

Table 4 Application source files

Source file name	Description
main.c	Contains the application entry point. It initializes the UART for debugging and then initializes the controller tasks.
radar_counter_task.c	Contains the task function for the entrance counter application, as well as the callback function.
radar_counter_terminal_ui.c	Contains the task function of the terminal UI.
radar_led_task.c	Contains the task function that handles the LEDs.

For each source file in the SECS application, Table 5 provides a list of functions along with their corresponding descriptions.

Table 5 Application functions

Function name	Description
main.c	
main	Main function for the CM4 CPU. It does the following: • Initializes the BSP • Enables global interrupt • Initializes Retarget-IO • Creates the radar entrance counter, terminal, and LED tasks • Starts the scheduler
radar_counter_task.c	
radar_counter_callback	Updates the LEDs and handles the radar events
radar_counter_task	Initializes the radar sensing module and starts the processing loop
radar_counter_task_set_mute	Enables/disables terminal output from the radar counter task
radar_counter_terminal_ui.c	

Function name	Description
terminal_ui_menu	Prints the configuration menu
terminal_ui_info	Prints the help info
terminal_ui_readline	Gets the user input from the terminal
terminal_ui_print_result	Prints the return value of a parameter configuration function call
radar_counter_terminal_ui	Starts the terminal UI task loop
radar_led_task.c	
gpio_led_set	Uses the GPIO pins to activate the LEDs by the user
radar_led_set_pattern	Sets the LED blinking pattern for the entrance counter events
radar_led_task	Initializes the parameters for the LED blinking pattern

Table 6 lists the BGT60TR13C radar device configuration that the current firmware uses which has been optimized for the SECS.

Table 6 BGT60TR13C radar configuration for SECS

Parameter	Value
Chirps per frame	4
Samples per chirp	128
ADC sample rate [Hz]	2352940
Frame period [us]	5000
Lower frequency [MHz]	61020
Upper frequency [MHz]	61480
Tx power level	31
RX antenna mask (binary)	7
IF gain [dB]	48

If you want to learn more about the implementation details or contribute to the project, the GitHub repository [4] is the place to start.

References

[1] Infineon Technologies AG: *XENSIV™ KIT CSK BGT60TR13C User Guide*; Available online

[2] Infineon Technologies AG: *AN228571 – Getting started with PSoC™ 6 MCU on ModusToolbox™ software*; Available online

[3] Infineon Technologies AG: *Using ModusToolbox™ software*; Available online

[4] Infineon Technologies AG: *Connected sensor kit: Radar entrance counter application*; Available online

Revision history

Document revision	Date	Description of changes
1.00	2023-12-20	Initial release

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