

# Battery-Powered mmWave Radar Sensor With Sub-1 GHz and Bluetooth® 5.2 Reference Design



## Description

This industrial reference design demonstrates the use of a battery-powered IWRL6432, 60-GHz mmWave radar with a sub-1 GHz or Bluetooth® 5.2 wireless communication. This design was demonstrated with people-counting, people-tracking, and motion-tracking applications from a Li battery. The results of the demonstration are sent to a remote host by sub-1G or Bluetooth, although the design is compatible with any existing IWRL6432 software. This design uses a LAUNCHXLCC1352R1 wireless microcontroller (MCU) LaunchPad™ Development Kit with a graphical user interface (GUI) to visually show radar sensing data and the detecting results.

## Resources

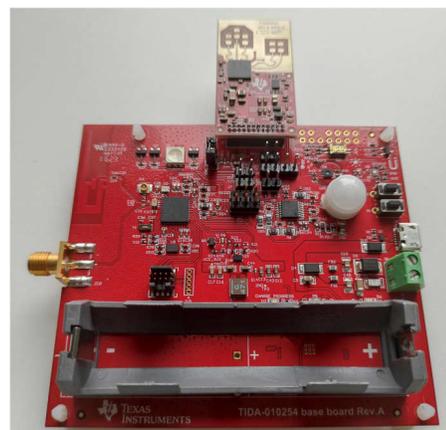
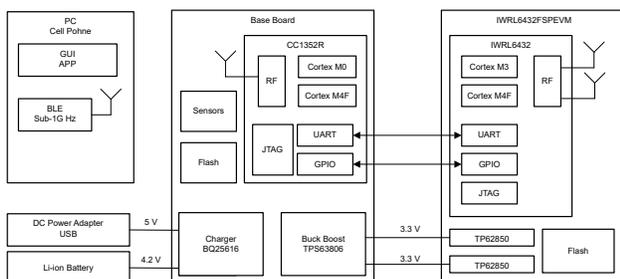
<a href="#">TIDA-010254</a>	Design Folder
<a href="#">IWRL6432, CC1352R</a>	Product Folder
<a href="#">TPS628502, BQ25616</a>	Product Folder
<a href="#">LAUNCHXL-CC1352R1</a>	Tool Folder

## Features

- Low-power, low-cost, 57-GHz to 64-GHz mmWave radar using the IWRL6432
- Long-range, low-power, sub-1 GHz or BLE wireless connectivity using the CC1352R
- Battery powered for high efficiency and small form factor
- Offers power-optimized test results
- Demonstrates people counting and people tracking software

## Applications

- [Occupancy detection \(people tracking, people counting\)](#)
- [Motion detector](#)
- [Video doorbell](#)
- [Automated door and gate](#)
- [IP network camera](#)



## 1 System Description

In building security systems and fire safety systems, people tracking and counting are often required. Additionally, human gesture recognition can also be used in smart home and video surveillance systems. The mmWave radar technology provides range, velocity, and angle of reflection data of a person or object, which can be processed in different application-specific ways. This reference design demonstrates these applications by utilizing the IWRL6432 low-power, 57- to 64-GHz mmWave radar sensor. The mmWave radar module of this design utilizes a 22-mm × 42-mm printed-circuit-board (PCB) etched antenna with 2 transmit elements and 3 receive elements.

The wireless radio communication section of this design utilizes a CC1352R microcontroller, which provides long-range connection and ultra-low power consumption. The CC1352R is a multiprotocol sub-1 GHz and 2.4-GHz wireless microcontroller (MCU) supporting Bluetooth® 5.2 Low Energy, IEEE 802.15.4, Zigbee®, and so on.

This reference design utilizes a Li-ion battery as the main power source, which connects to the 3.0-V to 4.2-V input terminal. The TPS63806 wide  $V_{IN}$  buck-boost converter, is utilized to convert this battery input to a 3.3-V output to power the system. Additionally, the board can also be powered via USB or an external DC input, which can also be used to charge the Li-ion battery.

This design guide addresses design theory, and the testing results of this reference design.

### 1.1 Key System Specifications

**Table 1-1. Key System Specifications**

PARAMETER	SPECIFICATIONS
Input power source	18650 Li-ion Battery
Power capacity	2000 mAh at 3.7 V
Radar type	IWRL6432 mmWave Radar
System power consumption	180 mW maximum
Radar field of view <b>azimuth</b>	±60°
Radar field of view <b>elevation</b>	±40°
Radar maximum range	10 m for person (limited to test environment)
Radar range resolution	0.18 m
Radar maximum velocity	36 m/s
Radar velocity resolution	About 0.08 m/s (minor motion detection mode)
People tracking (# ppl)	3 to 5
Radio Protocol	Bluetooth Low Energy (BLE), Sub-1 GHz
Radio transmitter frequency	2440 MHz, 915 MHz
Radio transmit power	5 dBm, 12 dBm

## 2 System Overview

This system design contains two modules: a radar module and the wireless radio communication module. These two modules are designated as the IWRL6432FSPEVM for the radar module, and Base Board for the wireless communication module.

The IWRL6432FSPEVM is powered from a 3.3-V supply from the base board. The IRWL6432FSPEVM communicates with the wireless radio microcontroller CC1352R over serial-peripheral interface (SPI) and universal asynchronous receiver, transmitter (UART). The IRWL6432FSPEVM utilizes UART as an mmWave firmware programmable interface.

The base board also contains an optical sensor, temperature sensor, Hall-effect sensor, and a passive infrared (PIR) sensor for environmental circumstance and noise optimization.

### 2.1 Block Diagram

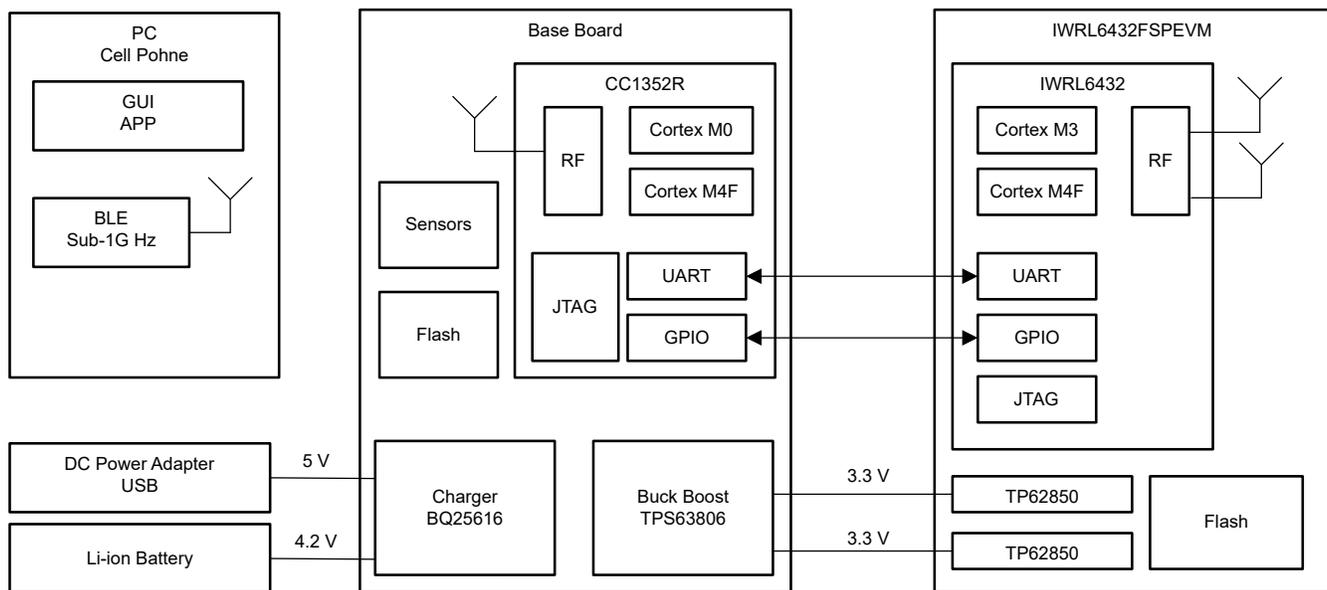


Figure 2-1. TIDA-010254 Block Diagram

### 2.2 Design Considerations

In this design, the mmWave radar result data is sent over the UART ports, and then the CC1352R sends the resulting data to a wireless client (personal computer (PC) or cell phone) via BLE or sub-1 GHz.

#### 2.2.1 mmWave Sensor Application

The mmWave people tracking and counting application examples are both demonstrated in this design. These examples are from the mmWave SDK demonstration `motion_and_presence_detection` project. The UART baud rate is set to "1250000", for better GUI tracking frame rate and simplification of the CC1352R coding. The example configuration is the same as IWRL6432EVM.

For more detailed information on the mmWave people tracking and people-counting examples, see [IWRL6432 People Tracking](#).

### 2.2.2 IWR6432 UART Communication

The CC1352R communicates with and configures the IWR6432 device via UART commands with a baud rate of 1250000.

```

sensorStop 0
channelCfg 7 3 0
chirpComnCfg 16 0 0 128 4 28 0
chirpTimingCfg 6 32 0 40 60.5
frameCfg 2 0 200 64 100 0
antGeometryCfg 0 0 1 1 0 2 0 1 1 2 0 3 2.418 2.418
guiMonitor 2 0 0 0 0 1 0 0 1 0 0
sigProcChainCfg 32 2 3 2 8 8 1 0.3
cfarCfg 2 8 4 3 0 11.0 0 0.5 0 1 1 1
aoaFovCfg -70 70 -40 40
rangeSelCfg 0.1 10.0
clutterRemoval 1
compRangeBiasAndRxChanPhase 0.0 1.00000 0.00000 -1.00000 0.00000 1.00000 0.00000 -1.00000 0.00000
1.00000 0.00000 -1.00000 0.00000
adcDataSource 0 adc_data_0001_CtestAdc6Ant.bin
    
```

After the configuration is completed, the IWR6432 starts sending out radar result data continuously back to the CC1352R through this UART port. Then, the CC1352R sends the data directly over the air to a PC or cell phone via BLE or sub-1 GHz.

### 2.2.3 LAUNCHLCC1352R1 Communication

A LAUNCHLCC1352R1 wireless MCU LaunchPad™ Development Kit is used as BLE or sub-1 GHz client, to receive the radar result data from the CC1352R device on the base board. Then, the LAUNCHLCC1352R1 sends the data to a PC or cell phone GUI by using a virtual UART port (the user UART COM port number can be different on a different PC).



**Figure 2-2. Virtual UART Port on PC or Phone GUI**

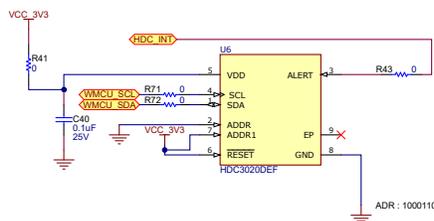
The virtual UART port baud rate is set to "1250000".

This virtual UART port is also used to send the configurations to the IWR6432 device on the base board.

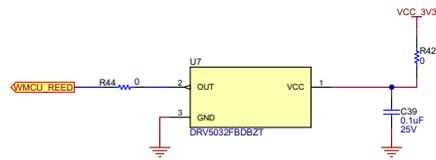
In this design, a simple serial socket client BLE application example is implemented in the LAUNCHLCC1352R1.

### 2.2.4 Sensors Application

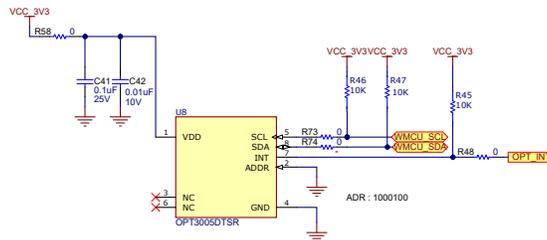
This system design contains four different sensors on the base board.



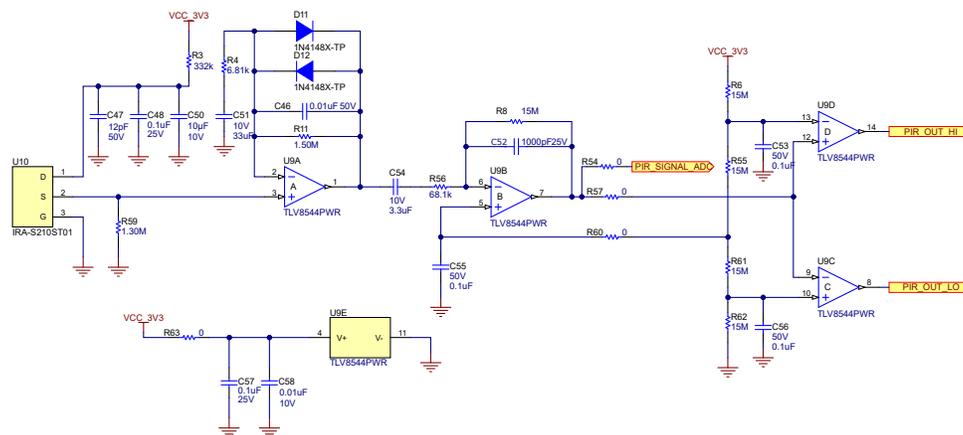
**Figure 2-3. Humidity and Temperature Sensor**



**Figure 2-4. Hall-Effect Sensor**



**Figure 2-5. Ambient Light Sensor**



**Figure 2-6. PIR Sensor**

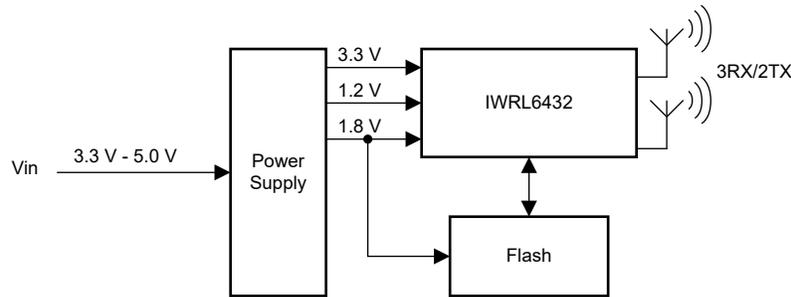
These sensors are controlled by the CC1352R on the base board. The sensor data is used to optimize the IWRL6432 device configuration, or wake the device up from a low-power mode for longer battery lifetime.

The sensor data can also be sent over the air to a PC or cell phone by BLE or sub-1 GHz and displayed in the GUI.

## 2.2.5 Power Supply Design

This system design considers the following power supply specifications:

- The IWR6432 radar requires multiple voltage rails. To get better power consumption, this design uses three power rails: 3.3 V, 1.8 V, and 1.2 V.



**Figure 2-7. IWR6432 3 Power Rails Structure**

- The CC1352R device requires a 3.3-V rail.
- The humidity and temperature sensor, Hall-effect sensor, ambient light sensor, and PIR sensor all require a 3.3-V rail.
- The main power supply is 3.0-V to 4.2-V Li-ion battery, with an option for 5-V USB or external DC power.

## 2.2.6 IWR6432 Power Supply Considerations

The IWR6432 device utilizes three power rails for operation: a 1.2-V digital, SRAM, and RF supply, 3.3-V IO supply, and 1.8-V analog supply. [Table 2-1](#) lists the peak currents on each of the rails. The typical power consumption depends on the chirp profile and frame configuration used.

**Table 2-1. Power Rail Current Requirements**

POWER RAIL	PEAK CURRENT
3.3 V	90 mA
1.8 V	270 mA
1.2 V	1100 mA

## 2.3 Highlighted Products

### 2.3.1 IWR6432

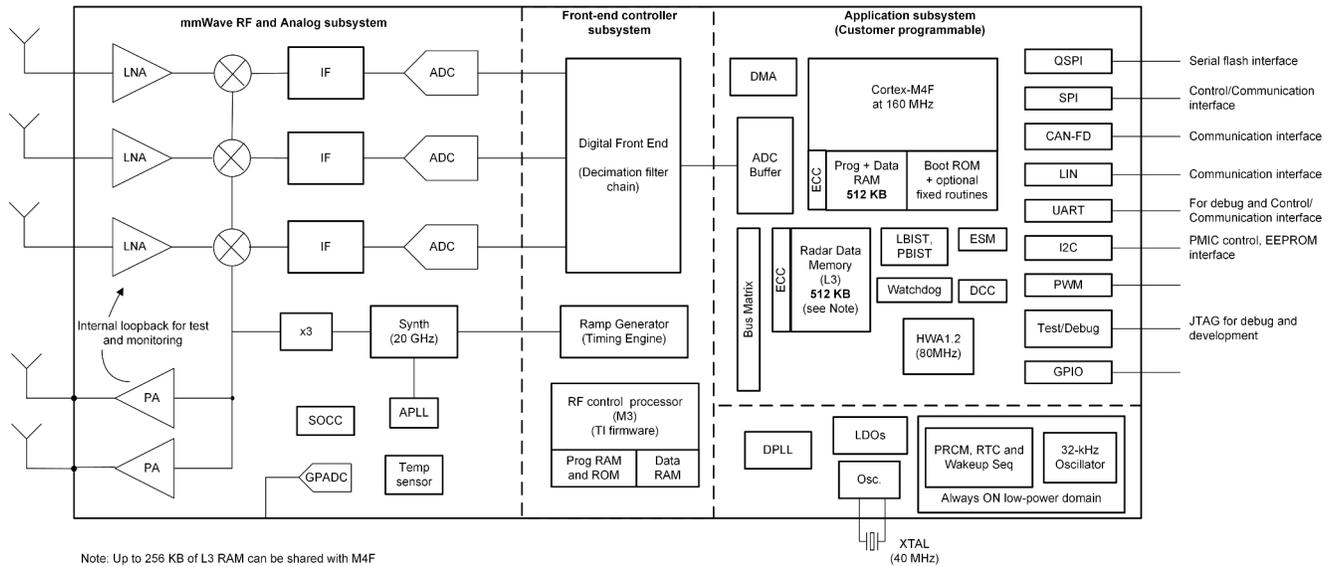
The IWR6432 mmWave sensor device is an integrated single-chip mmWave sensor based on Frequency Modulated Continuous Wave (FMCW) radar technology. The device is capable of operation in the 57-GHz to 64-GHz band and is partitioned into mainly four power domains:

**RF, Analog Sub-System:** This block includes all the RF and Analog components required to transmit and receive the RF signals.

**Front-End Controller Sub-System (FECSS):** FECSS contains the processor responsible for radar front-end configuration, control, and calibration.

**Application Sub-System (APPSS):** APPSS is where the device implements a user-programmable Arm® Cortex® M4 allowing for custom control and automotive interface applications. Top Sub-System (TOPSS) is part of the APPSS power domain and contains the clocking and power management subblocks.

**Hardware Accelerator (HWA):** HWA block supplements the APPSS by offloading common radar processing such as fast Fourier transform (FFT), Constant False Alarm rate (CFAR), scaling, and compression.



**Figure 2-8. IWRL6432 Block Diagram**

The IWRL6432 device is specifically designed to have separate knobs for each of the above-mentioned power domains to control their states (power ON or OFF) based on use-case requirements. The device also features the capability to exercise various low-power states like sleep and deep sleep, where low-power sleep mode is achieved by clock gating and by turning off the internal IP blocks of the device. The device also provides the option of keeping some contents of the device, like the application image or RF profile retained in such scenarios.

Additionally, the device is built with TI's low-power, 45-nm radio-frequency (RF) complementary MOS (CMOS) process and enables unprecedented levels of integration in an extremely small form factor. IWRL6432 is designed for low-power, self-monitored, ultra-accurate radar systems in the industrial (and personal electronics) space for applications such as building and factory automation, commercial and residential security, personal electronics, presence and motion detection, and gesture detection and recognition for human machine interfaces.

### 2.3.2 CC1352R

The SimpleLink™ MCU CC1352R device is a multiprotocol and multiband Sub-1 GHz and 2.4-GHz wireless MCU supporting Thread, Zigbee, Bluetooth 5.2 Low Energy, IEEE 802.15.4g, IPv6-enabled smart objects (6LoWPAN), MIOTY, Wi-SUN®, proprietary systems, including the TI 15.4-Stack (Sub-1 GHz and 2.4 GHz), and concurrent multiprotocol through a Dynamic Multiprotocol Manager (DMM) driver. The device is optimized for low-power wireless communication and advanced sensing in building security systems, HVAC, smart meters, medical, wired networking, portable electronics, home theater and entertainment, and connected peripherals markets. The highlighted features of this device include:

- Multiband device supporting concurrent multiprotocol for both Sub-1 GHz and 2.4 GHz through a DMM driver
- Wide flexibility of protocol stack support in the [SimpleLink™ CC13x2 and CC26x2 Software Development Kit \(SDK\)](#)
- Maximum transmit power of +14 dBm at Sub-1 GHz with 24.9 mA and +5 dBm at 2.4 GHz with 9.6 mA current consumption
- Longer battery life wireless applications with low standby current of 0.85 µA and full RAM retention
- Industrial temperature ready with lowest standby current of 5 µA at 85°C
- Advanced sensing with a programmable, autonomous ultra-low power [Sensor Controller CPU](#) with fast wake-up capability. As an example, the sensor controller is capable of 1-Hz ADC sampling at 1-µA system current.
- Low [SER \(Soft Error Rate\)](#) failure-in-time (FIT) for long operation lifetime with no disruption for industrial markets with always-on SRAM parity against corruption due to potential radiation events
- Dedicated software controlled radio controller (Arm® Cortex®-M0) providing flexible low-power RF transceiver capability to support multiple physical layers and RF standards

- Excellent radio sensitivity (−121 dBm) and robustness (selectivity and blocking) performance for SimpleLink long-range mode

The CC1352R device is part of the SimpleLink MCU platform, which consists of Wi-Fi®, Bluetooth Low Energy, Thread, Zigbee, Sub-1 GHz MCUs, and host MCUs that all share a common, easy-to-use development environment with a single-core software development kit (SDK) and rich tool set. A one-time integration of the SimpleLink platform enables the addition of any combination of the devices in the portfolio into your design, allowing 100 percent code reuse when your design requirements change. For more information, see [SimpleLink™ MCU platform](#).

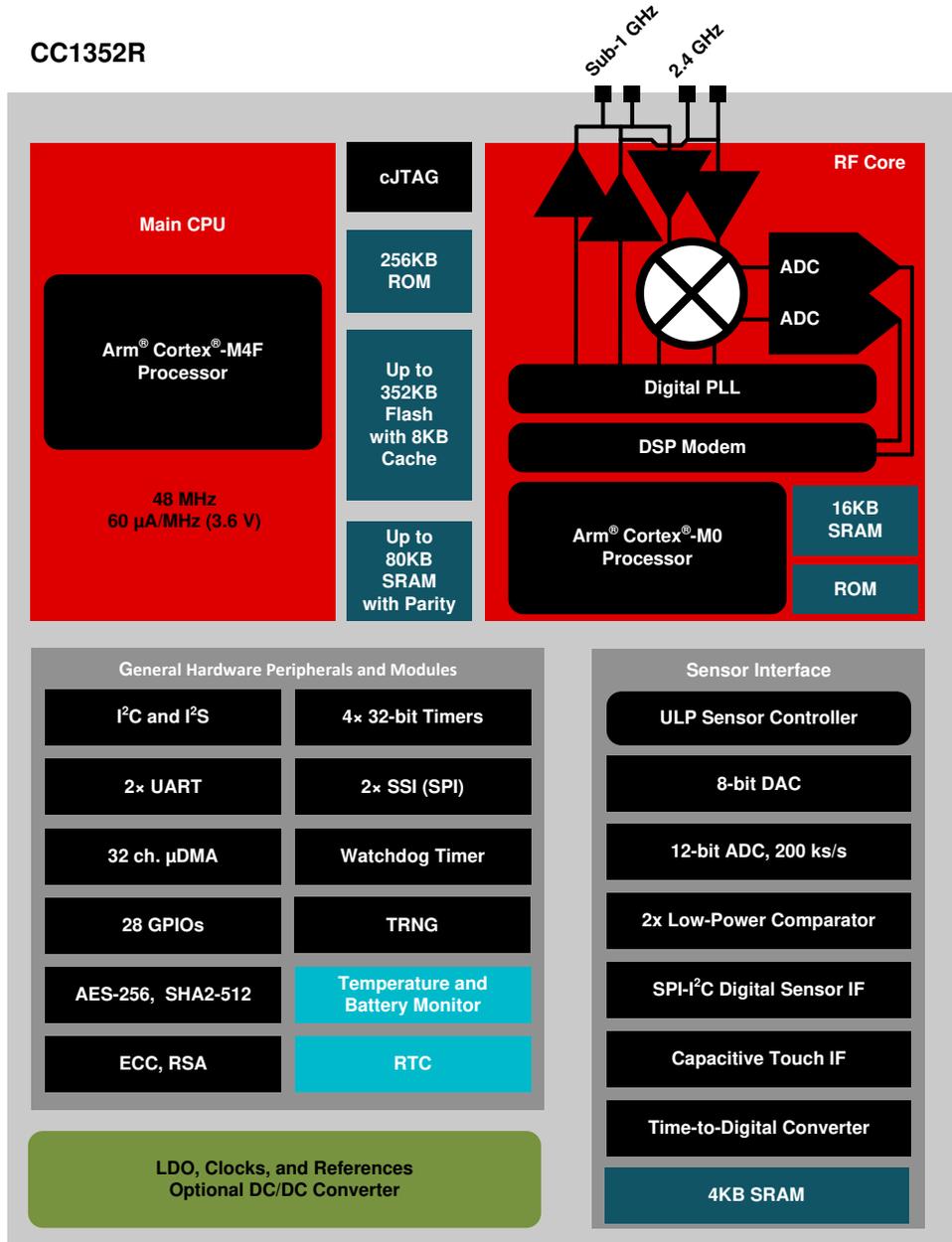


Figure 2-9. CC1352R Block Diagram

### 2.3.3 BQ25616

The BQ25616 (and BQ25616J) is a highly integrated 3-A switch-mode battery charge management and system power path management device for single cell Li-Ion and Li-polymer batteries. The device is highly integrated with input reverse-blocking field-effect transistor (FET) (RBFET, Q1), high-side switching FET (HSFET, Q2), low-side switching FET (LSFET, Q3), and battery FET (BATFET, Q4) between system and battery. The low impedance power path optimizes switch-mode operation efficiency, reduces battery charging time, and extends battery run time during the discharging phase.

The device features fast charging with high-input voltage support for a wide range of applications including speakers, industrial, and medical portable devices. The input voltage and current regulation deliver maximum charging power to the battery. The design also integrates the bootstrap diode for the high-side gate drive for simplified system design. The hardware setting and status report provides easy configuration to set up the charging design.

The device supports a wide range of input sources, including standard USB host port, USB charging port, USB compliant high voltage adapter and wireless power. The device is compliant with USB 2.0 and USB 3.0 power spec with input current and voltage regulation. The device sets default input current limit based on the built-in USB detection through D+ and D- pins. When the device built-in USB interface identifies the input adapter is unknown, the device's input current limit is determined by the ILIM pin setting resistor value.

### 2.3.4 TPS62850

The TPS62850x is a family of pin-to-pin 1-A, 2-A (continuous), and 3-A (peak) high efficiency, easy-to-use synchronous step-down DC/DC converters. The devices are based on a peak current mode control topology. Low resistive switches allow up to 2-A continuous output current and 3-A peak current. The switching frequency is externally adjustable from 1.8 MHz to 4 MHz and can also be synchronized to an external clock in the same frequency range. In PWM and PFM mode, the TPS62850x automatically enters power save mode at light loads to maintain high efficiency across the whole load range. The TPS62850x provides a 1% output voltage accuracy in PWM mode, which helps design a power supply with high output voltage accuracy, fulfilling tight supply voltage requirements of digital processors and FPGA.

The TPS62850x is available in an 8-pin 1.60-mm × 2.10-mm SOT583 package.

### 2.3.5 HDC3020

The HDC302x is an integrated capacitive based relative humidity (RH) and temperature sensor. The device provides high-accuracy measurements over a wide supply range (1.62 V to 5.5 V), along with ultra-low power consumption in a compact 2.5-mm × 2.5-mm package. Both the temperature and humidity sensors are 100% tested and trimmed on a production setup that is National Institute of Standards and Technology (NIST) traceable and verified with equipment that is calibrated to ISO/IEC 17025 standards.

Offset Error Correction reduces relative humidity (RH) sensor offset due to aging, exposure to extreme operating conditions, and contaminants to return device to within accuracy specifications. For battery internet-of-things (IoT) applications, auto measurement mode and ALERT feature enable low system power by maximizing MCU sleep time. There are four different I2C addresses that support speeds up to 1 MHz. A heating element is available to dissipate condensation and moisture.

The HDC3020 is an open cavity package without protective cover. Two device variants have a cover option to protect the open cavity RH sensor: HDC3021 and HDC3022. HDC3021 has removable protective tape to allow conformal coatings and PCB wash. HDC3022 has a permanent IP67 filter membrane to protect against dust, water and PCB wash.

### 2.3.6 OPT3005

The OPT3005 is a sensor that measures the intensity of visible light. The spectral response of the sensor tightly matches the photopic response of the human eye along with extreme rejection to 850-nm and 940-nm infrared light over a wide angle of incidence.

The OPT3005 is a single-chip lux meter, measuring the intensity of light as visible by the human eye. The precision spectral response and extreme infrared (IR) rejection of the device enables the OPT3005 to accurately meter the intensity of light as seen by the human eye regardless of light source and any stray light from 850-nm or 940-nm active illumination. The extreme IR rejection also helps to maintain high accuracy when industrial design calls for mounting the sensor under dark glass, especially with active 850-nm or 940-nm near infrared (NIR) illumination. Such systems typically have a lot of NIR stray reflections from the cover glass which can affect the light sensor measurement. The precision optical filtering of the OPT3005 is verified for resilience to such stray NIR reflection and truly measures the ambient light as perceived by the human eye. The OPT3005 is designed for systems that create light-based experiences for humans, and is a preferred replacement for photodiodes, photoresistors, or other ambient light sensors with less human eye matching and IR rejection.

Measurements can be made from 20 mlux up to 166 klux without manually selecting full-scale ranges by using the built-in, full-scale setting feature. This capability allows light measurement over a 23-bit effective dynamic range.

### 2.3.7 DRV5032

The DRV5032 device is an ultra-low-power digital-switch Hall-effect sensor, designed for the most compact and battery-sensitive systems. The device is offered in multiple magnetic thresholds, sampling rates, output drivers, and packages to accommodate various applications.

When the applied magnetic flux density exceeds the BOP threshold, the device outputs a low voltage. The output stays low until the flux density decreases to less than BRP, and then the output either drives a high voltage or becomes high impedance, depending on the device version. By incorporating an internal oscillator, the device samples the magnetic 54 and updates the output at a rate of 20 Hz, or 5 Hz for the lowest current consumption. Omnipolar and unipolar magnetic responses are available.

The device operates from a VCC range of 1.65 V to 5.5 V, and is packaged in a standard SOT-23, TO-92, and small X2SON.

## 3 Hardware, Software, Testing Requirements, and Test Results

### 3.1 Hardware Requirements

This reference design includes:

- A Base Board, and an IWR6432FSPEVM connected to this base board.
- A LAUNCHXLCC1352R1 wireless MCU LaunchPad™: communicate with the base board via BLE and UART emulation over a USB link with the PC GUI.
- An 18650 Li-ion Battery is used as base board and IWR6432FSPEVM's power source.
- A PC with GUI which visually shows radar sensing data and detecting result.

#### 3.1.1 Getting Started Hardware

##### 3.1.1.1 IWR6432FSPEVM Initialization: IWR6432 Programming

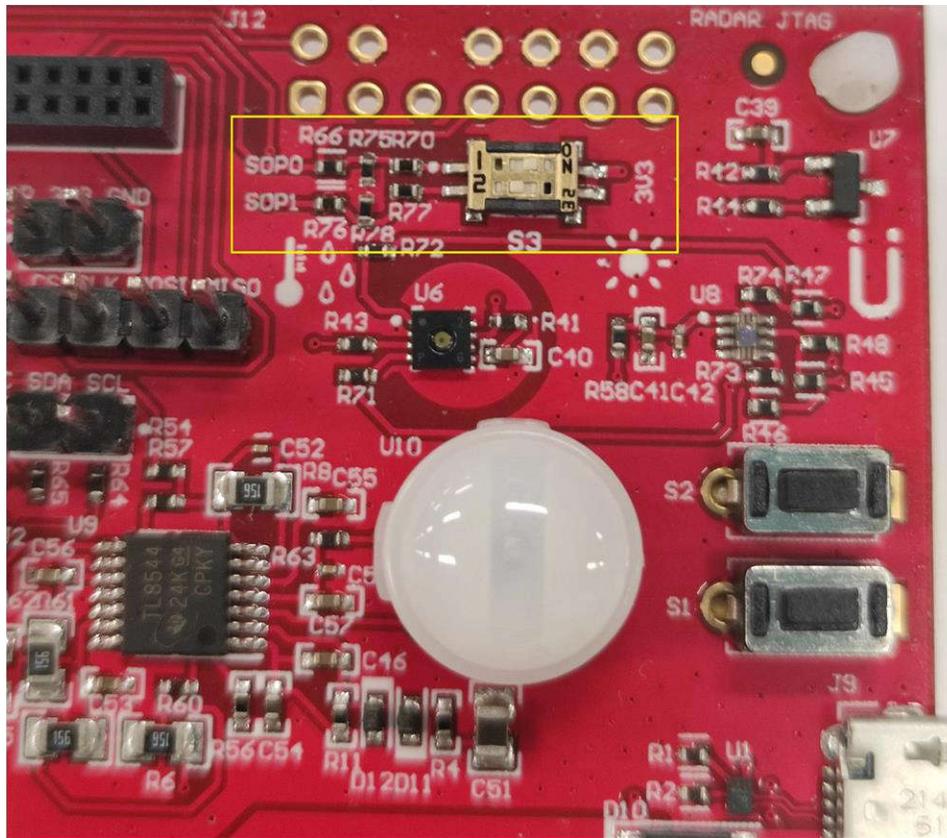
Complete the following steps to initialize the IWR6432FSPEVM:

1. Connect the IWR6432FSPEVM to the receptacle connector on the base board (J1).
2. Select IWR6432 Sense-on-Power (SOP) mode, by using S3 on the base board. [Table 3-1](#) provides a description of the SOP modes. A "0" represents pulling the pin low and a "1" represents pulling the pin high. The switch S3 position "off" represents "0" and "on" represents "1".

**Table 3-1. SOP Mode**

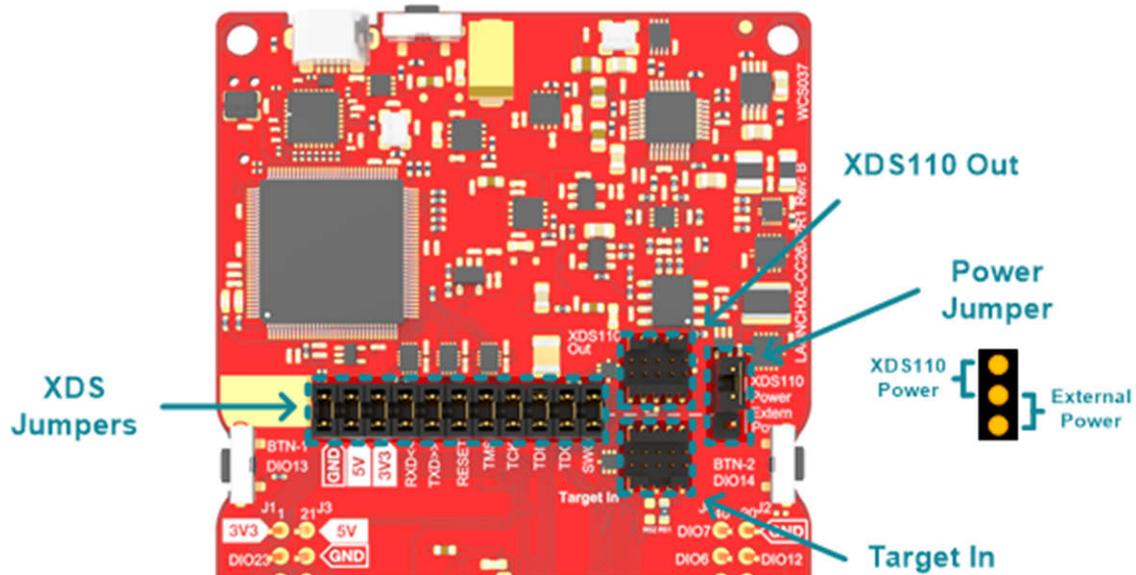
MODE	SOP0	SOP1	MODE DESCRIPTION
1	0	0	Flashing mode: IWR6432 flashes the user application to QSPI flash
2	1	0	Functional mode: IWR6432 loads the user application from QSPI flash to the internal RAM and runs application from RAM.

- Set the SOP mode to flashing mode, as [Figure 3-1](#) shows.



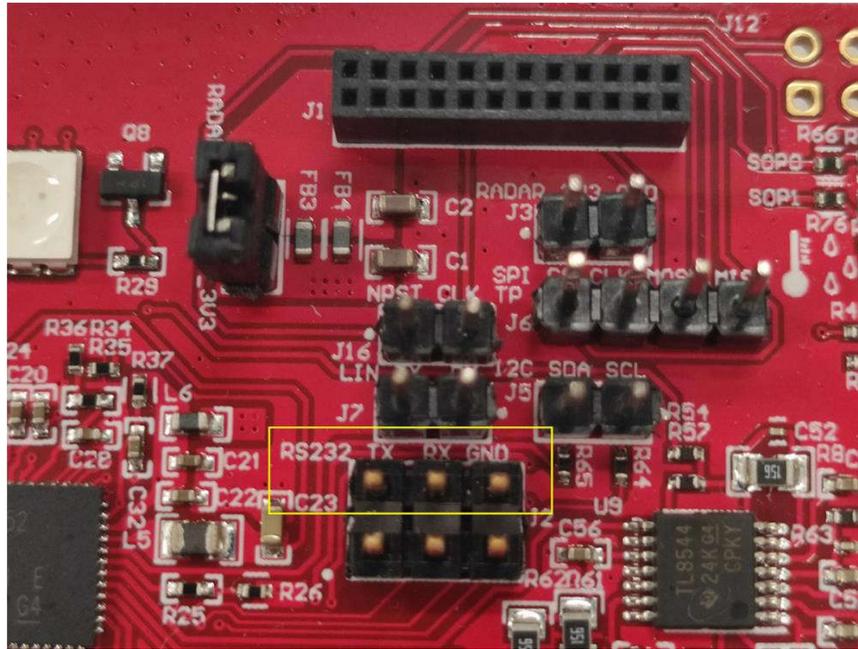
**Figure 3-1. Setting the SOP to Flashing Mode**

[Figure 3-2](#) illustrates using a LaunchPad and removing the XDS jumpers.



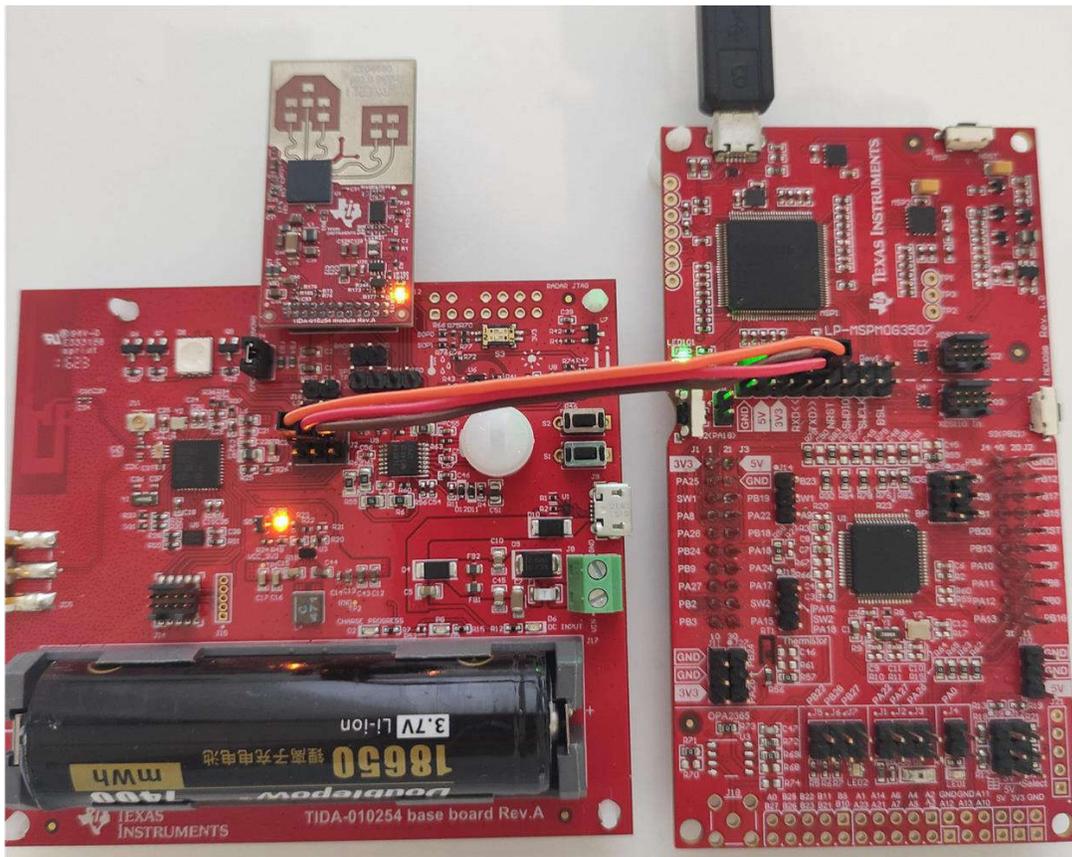
**Figure 3-2. Removing XDS Jumpers**

- Use jumper wires to connect the IWRL6432 UART port on the base board to the LaunchPad XDS110 UART pins of the debugger.



**Figure 3-3. IWRL6432 UART Port on the Base Board**

- Use an 18650 Li-ion battery, 5-V USB, or external DC power to power the base board and IWRL6432FSPEVM.



**Figure 3-4. IWRL6432 Hardware Setup for Programming**

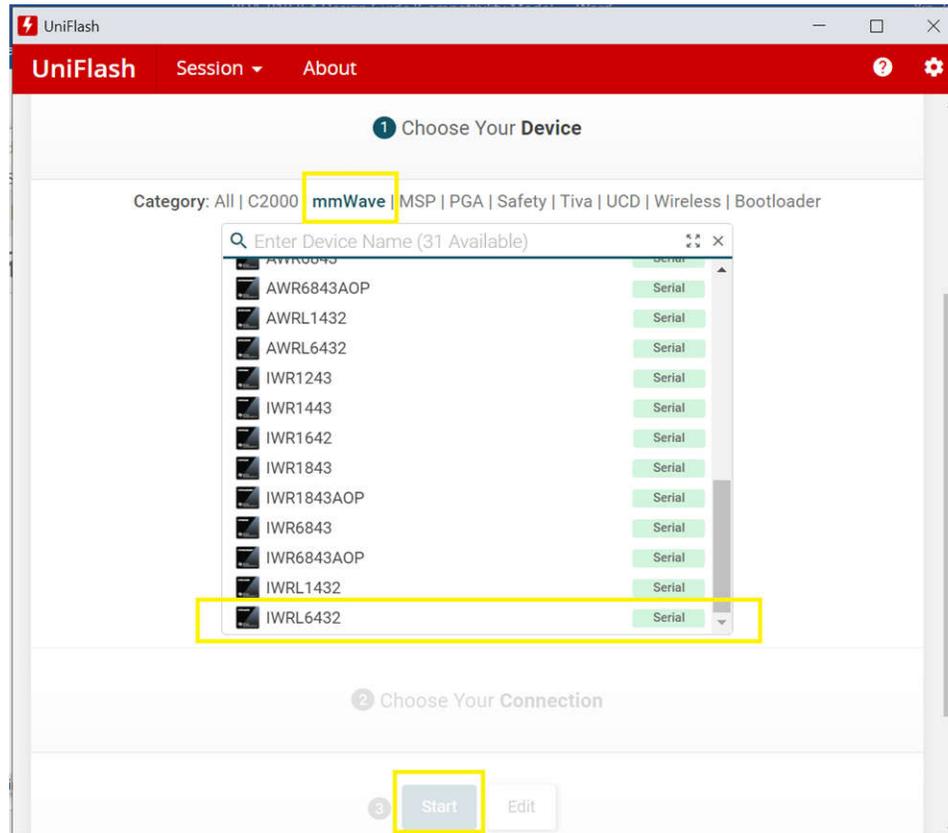
The IWRL6432 is ready for programming.

TI provides a mmWave Software Development Kit (SDK) to flash a binary file to IWR6432. See the [MMWAVE-L-SDK](#) tool page to get this SDK.

The **UNIFLASH** software can also be used to flash the IWR6432.

Use the following steps to flash the IWR6432:

1. Open the UniFlash software
2. Select *mmWave* from the *Category* header
3. Select *IWR6432* from the field of available devices
4. Click the *Start* button.



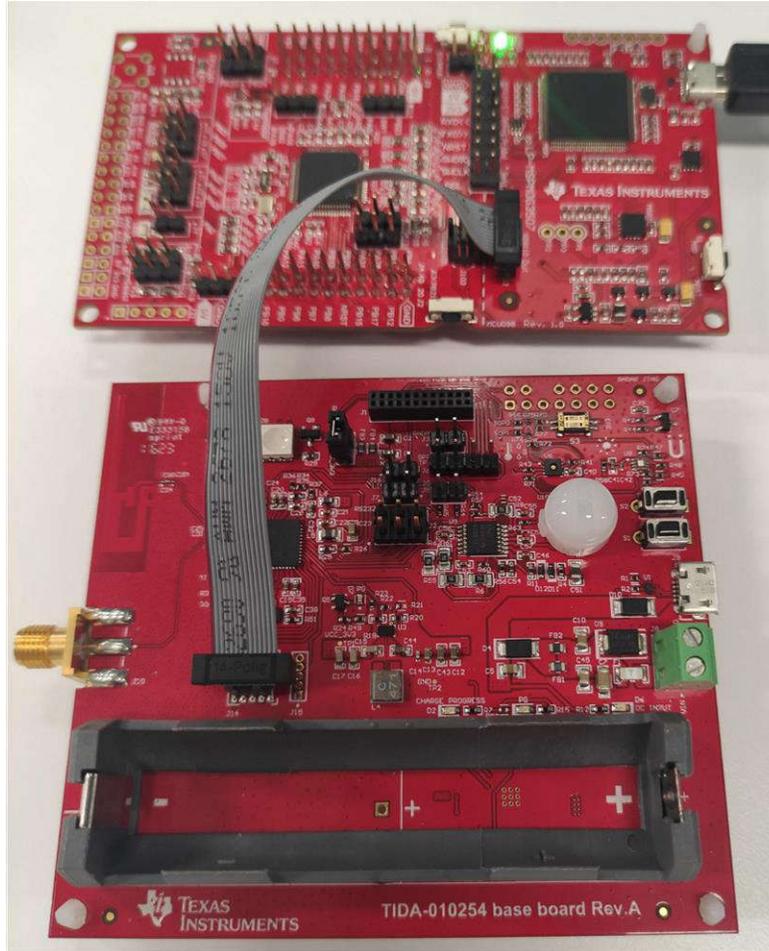
**Figure 3-5. UniFlash Software Configuration for IWR6432**

After the IWR6432 programming completes, remove the jumper wires on the IWR6432 UART port (J2) on the base board, and set the SOP mode to functional mode using the switch S3.

### 3.1.1.2 Base Board Initialization: CC1352R Programming

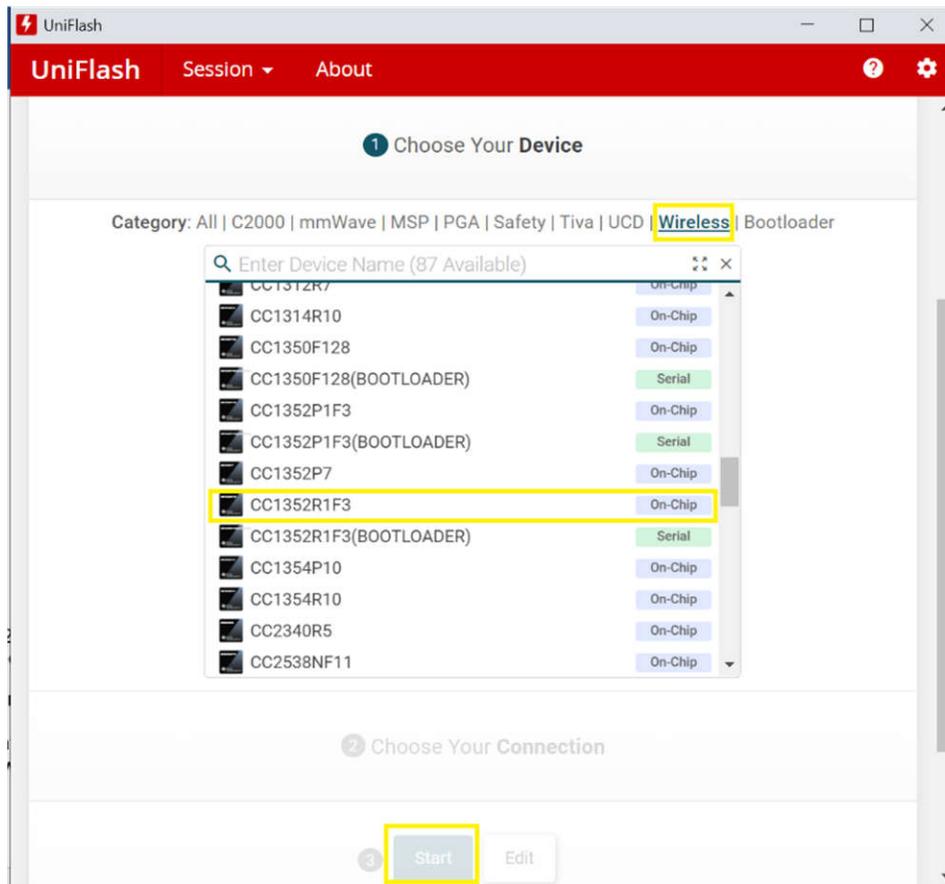
Follow these steps to initialize the CC1352R device:

1. Using a 10-pin flat ribbon cable, connect the JTAG connector (J14) on the base board to a LaunchPad XDS110 Out connector, as [Figure 3-6](#) shows.



**Figure 3-6. Cable Connection**

2. Use the UNIFLASH software or the Code Composer Studio™ software to flash a binary file to CC1352R. See the [SIMPLELINK-LOWPOWER-F2-SDK](#) tool page.
3. Open the UNIFLASH software.
4. Select *Wireless* from the *Category* header
5. Select *CC1352R1F3* from the field of available devices
6. Click the *Start* button.



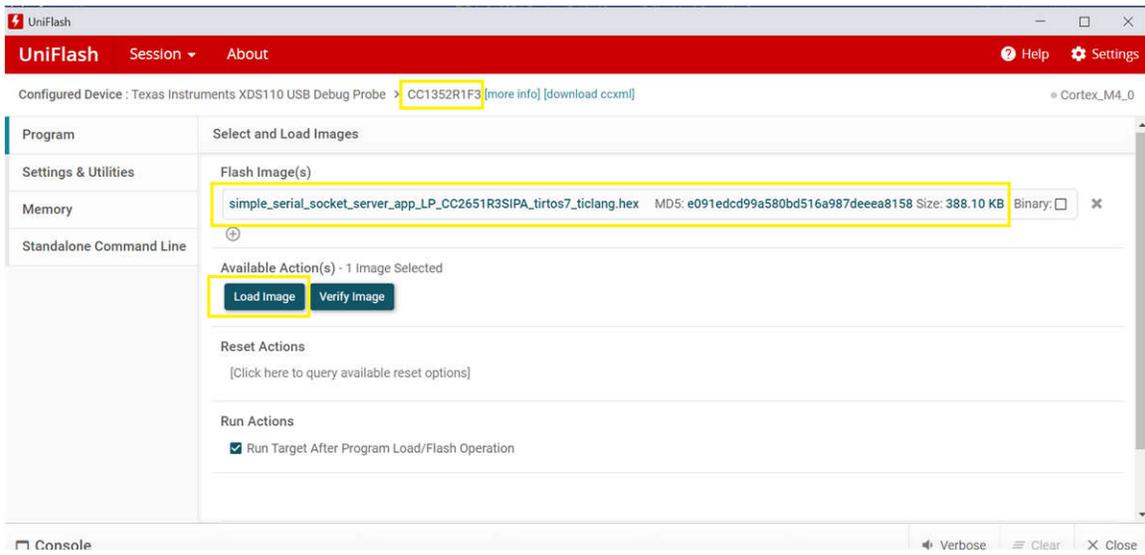
**Figure 3-7. UniFlash Software Configuration for CC1352R**

### 3.2 Software Requirements

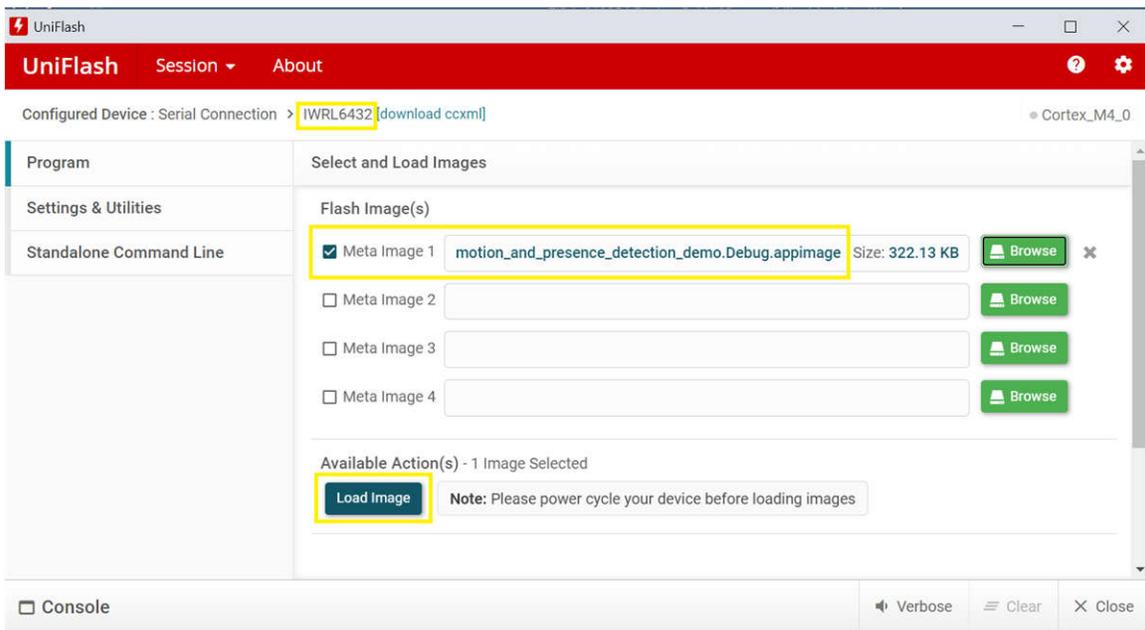
This reference design includes:

- Motion and presence detection example from mmWave SDK, which was flashed to IWR6432 with a fixed UART baud rate of 1250000. The mmWave SDK is available from [MMWAVE-SDK](#). Change the flash setting in syscfg of the example to support W25Q16JVUXIQ on IWR6432FSPEVM.
- Simple serial socket server example from SimpleLink SDK, which is flashed to CC1352R on the base board with fixed UART baud rate 1250000. This special SimpleLink SDK is available from [simplelink\\_cc13x2\\_26x2\\_sdk-4.10.00.00](#).
- Simple serial socket client example from SimpleLink SDK, which is flashed to CC1352R on the LAUNCHLCC1352R1 wireless MCU LaunchPad™ with a fixed UART baud rate 1250000. The SimpleLink SDK available from [simplelink\\_cc13x2\\_26x2\\_sdk-4.10.00.00](#).
- GUI with IWR6432 configuration file: the software visually shows the radar data.

Use the UniFlash software or Code Composer Studio™ software to flash the binary file of these examples to the relate device.



**Figure 3-8. UniFlash Software Load Image for CC1352R**



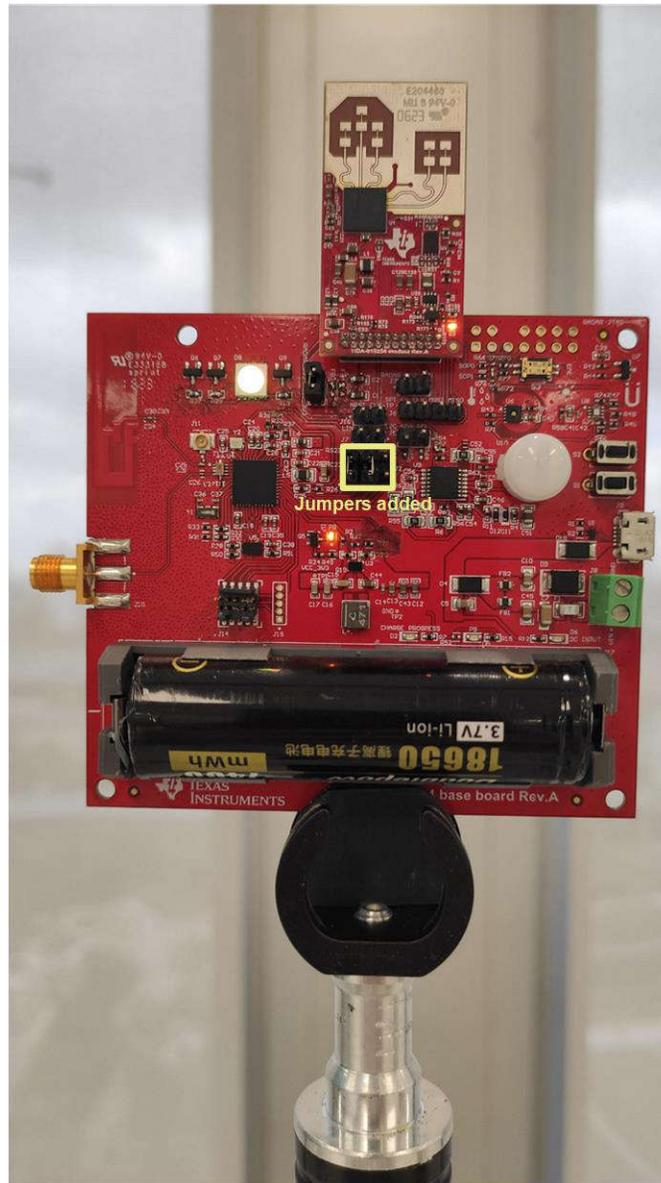
**Figure 3-9. UniFlash Software Load Image for IWRL6432**

### 3.3 Test Setup

#### 3.3.1 Demonstration Setup

Use the following setup procedures for the demonstration:

1. Clamp the base board and IWR6432FSPEVM on a tripod. The height is 1.9-m high from the ground, and there is no downward tilt: 0 degree.
2. Power up the base board and IWR6432FSPEVM with an 18650 Li-ion battery.



**Figure 3-10. Base Board and IWR6432FSPEVM on a Tripod**

- Use a USB cable to power up and connect the LAUNCHXLCC1352R1 wireless MCU LaunchPad™ to a PC.

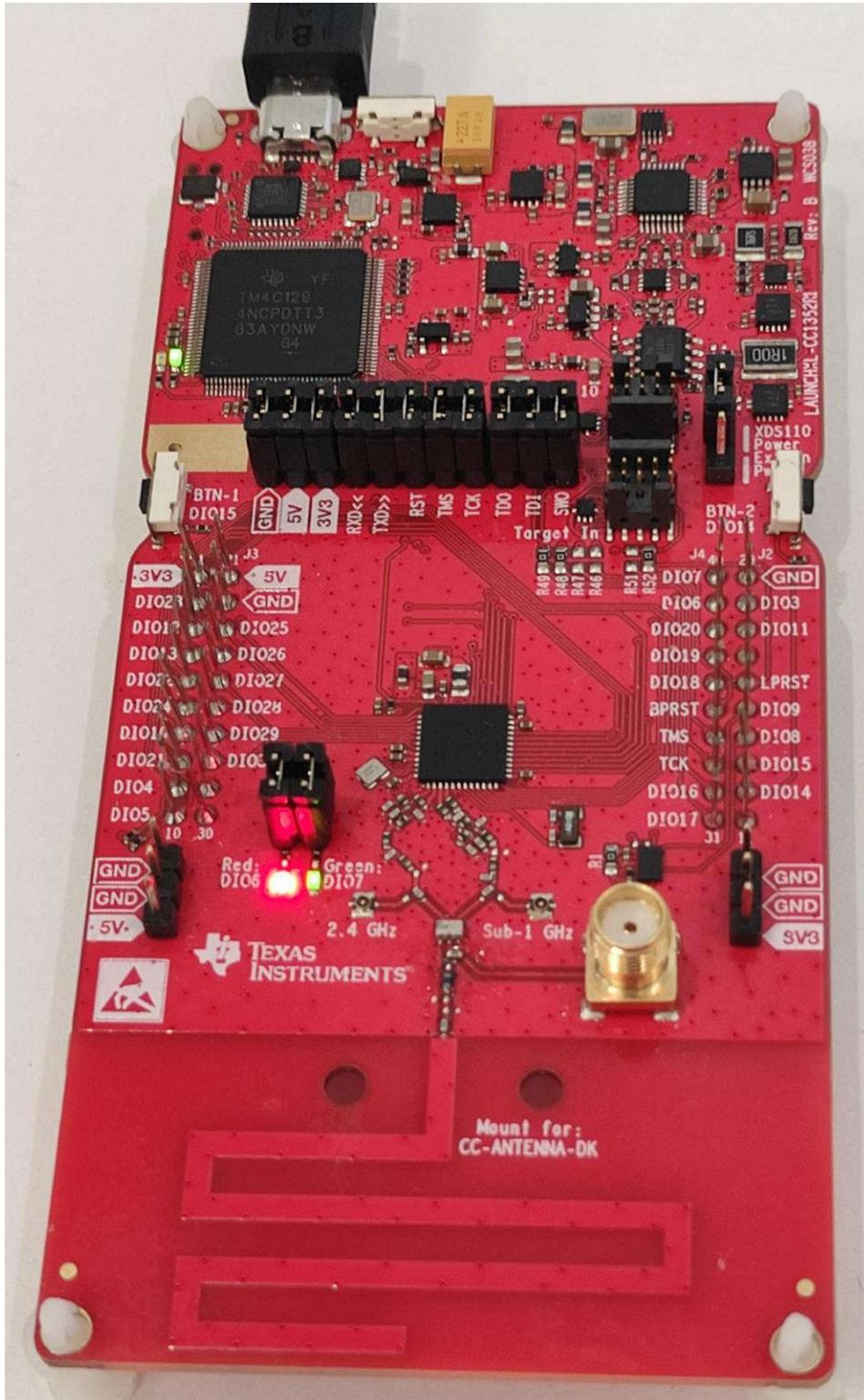


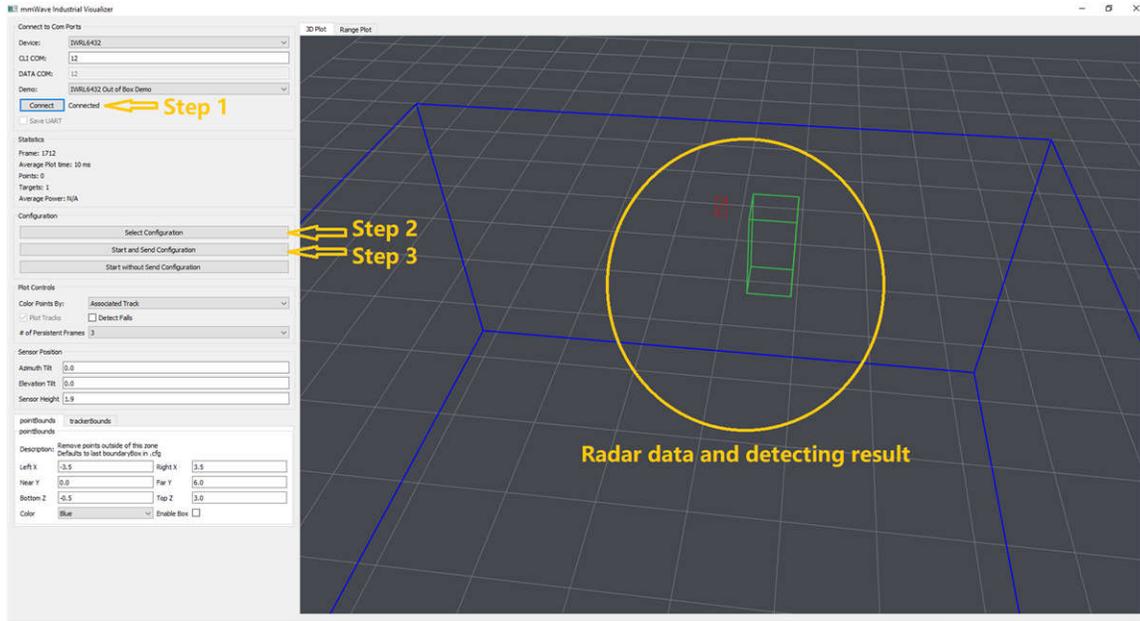
Figure 3-11. LAUNCHXLCC1352R1 Connected to a PC

4. Position the LAUNCHXLCC1352R1 less than 1 m from the base board and IWRL6432FSPEVM.



**Figure 3-12. Demonstration Position Setup**

- Run the GUI software on a PC and start the demonstration. Click the button with the 3 steps shown in [Figure 3-13](#). See the GUI configuration file in step 2 at [TIDA-010254](#).



**Figure 3-13. GUI Software for Demonstration**

### 3.4 Test Results

#### 3.4.1 Radar Detect Distance Measurement

The IWRL6432FSPEVM utilizes the same FR4 based antennas on the PCB as the XWRL6432BOOST. These antennas include three receivers and two transmitters.

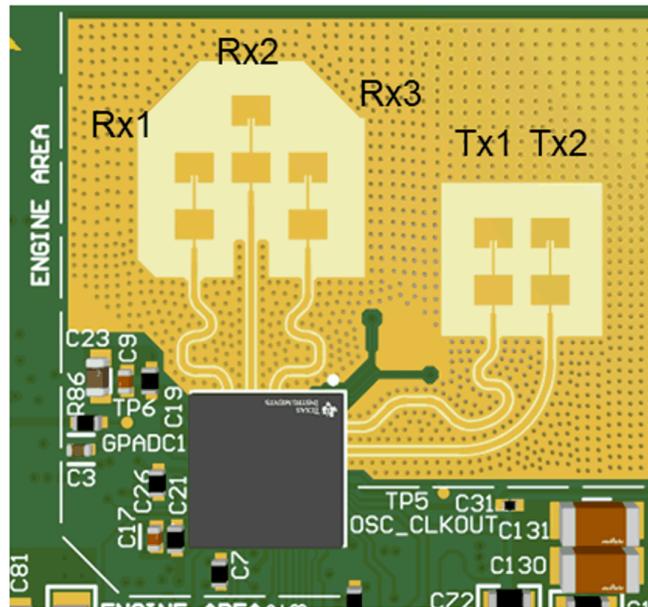


Figure 3-14. TX and RX Antennas of the EVM

**Note**

The XWRL6432BOOST has an antenna gain of about 5–6 dBi across different antenna pairs.

The IWRL6432FSPEVM has same azimuth and elevation antenna radiation patterns as the XWRL6432BOOST.

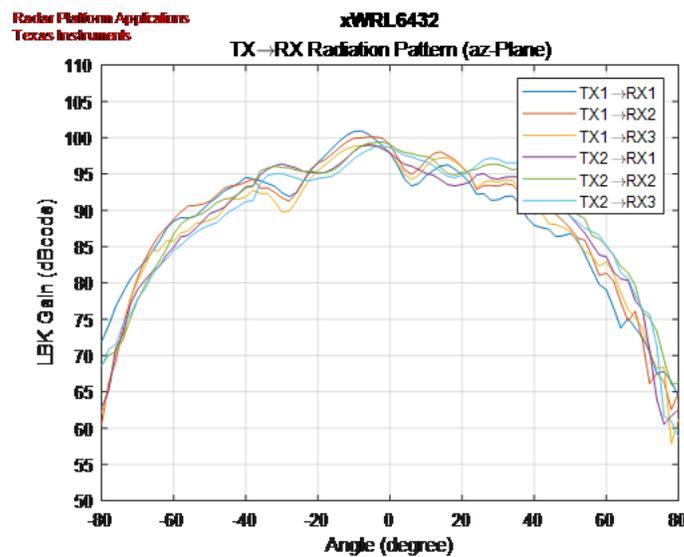


Figure 3-15. Azimuth Antenna Radiation Patterns

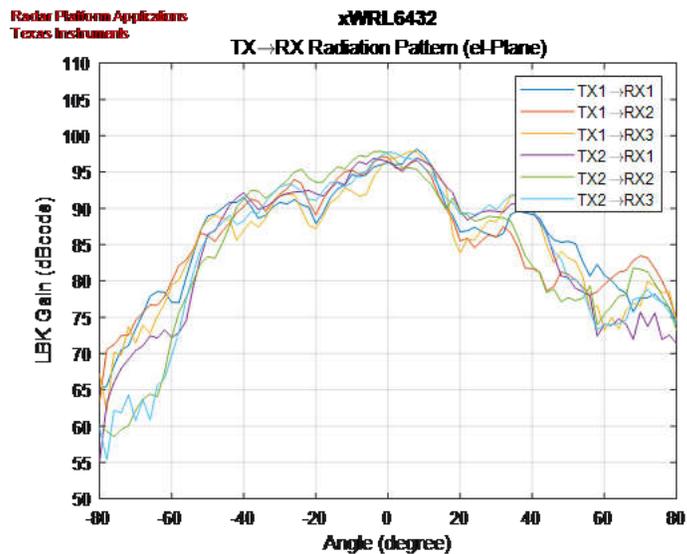


Figure 3-16. Elevation Antenna Radiation Patterns

The results of the radar detect distance measurements are given in Table 3-2.

Table 3-2. Radar Detect Distance

AZIMUTH ANGLE (DEGREE)	0	30	60
Motion localization example <sup>(1)</sup>	9 m	8 m	5 m
Static localization example <sup>(1)</sup>	10 m	9 m	6 m

(1) No test beyond 10 m, due to test environment limitation.

### 3.4.2 People Counting Test Results

The demonstration shows three-person tracking in the GUI software.

For more detailed information on the mmWave people tracking and people-counting test results, see [IWRL6432 People Tracking](#) user guide.

### 3.4.3 Wireless Range Test Results

This demonstration utilizes Bluetooth Low Energy (BLE) Serial Port Profile (SPP) protocol to transmit the radar detect data to the GUI software. The BLE configurations like *connection interval* uses the minimum value in the simple serial socket client example.

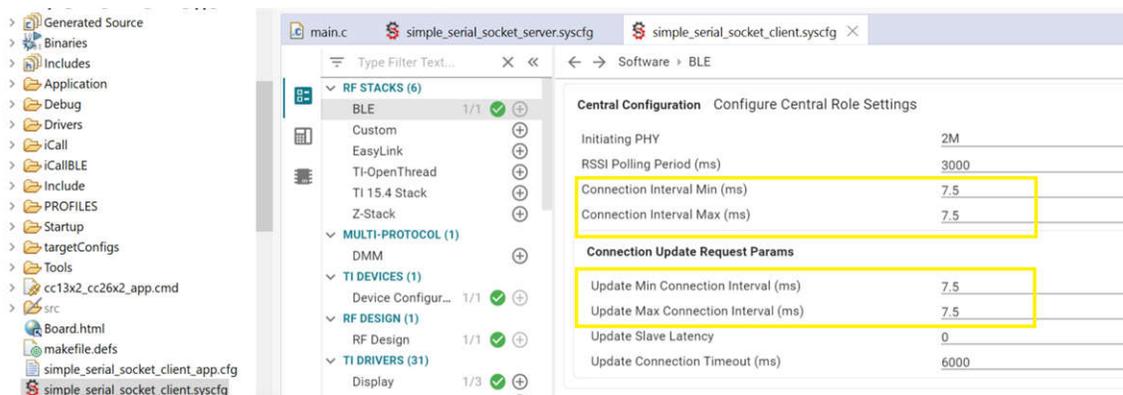


Figure 3-17. CC1352R BLE Protocol Configurations

The demonstration suggests that the location of LAUNCHXLCC1352R1 is near the base board and IWRL6432FSPEVM. During the demonstration, the distance was measured to be approximately 8 m in an office environment with open air.



**Figure 3-18. Wireless Range Test**

### 3.4.4 Power Consumption Test Results

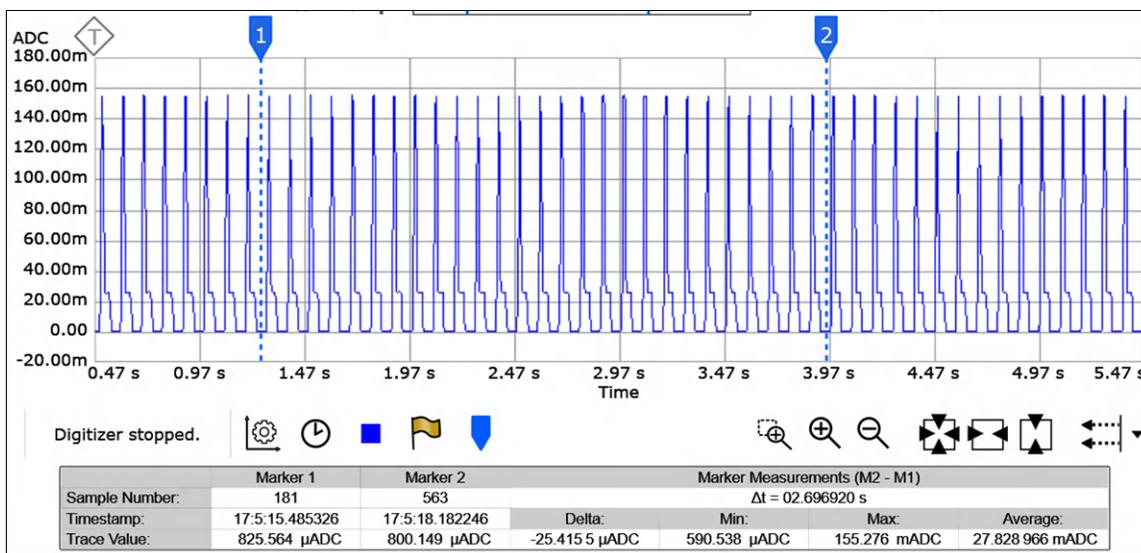
The demonstration results indicate that the location of the LAUNCHXLCC1352R1 is near the base board and IWRL6432FSPEVM.

Table 3-3 lists the results of the power measurements. The current was measured at the input of the IWRL6432FSPEVM and 18650 Li-ion battery.

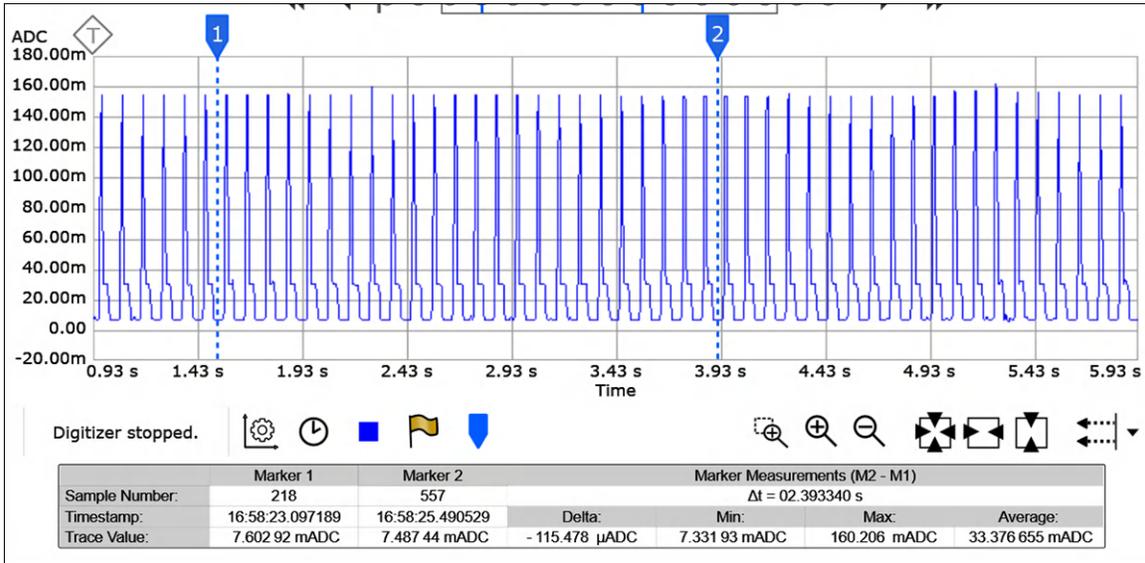
**Table 3-3. Power Consumption**

MEASURE DEVICE	MIN CURRENT	AVG CURRENT	MAX CURRENT
18650 Li-ion battery	7.33 mA	33.37 mA	160.20 mA
IWRL6432FSPEVM <sup>(1)</sup>	0.59 mA	27.82 mA	155.27 mA

- (1) IWRL6432FSPEVM is optimized in low-power consumption mode. For example, LED and some pullups are removed during the power consumption tests.



**Figure 3-19. IWRL6432FSPEVM Current Waveframe**



**Figure 3-20. 18650 Li-ion Battery Current Waveframe**

## 4 Design and Documentation Support

### 4.1 Design Files

#### 4.1.1 Schematics

To download the schematics, see the design files at [TIDA-010254](#).

#### 4.1.2 BOM

To download the bill of materials (BOM), see the design files at [TIDA-010254](#).

#### 4.1.3 PCB Layout Recommendations

##### 4.1.3.1 Layout Prints

This design IWRL6432FSPEVM uses PCB material FR408HR from Isola to meet the 60-GHz antenna and transmission lines requirements. The rest of the layers use FR409HR 3x1652, 2x2116, and 1080.

#	Name	Material	Type	Weight	Thickness	Dk
	Top Overlay		Overlay			
	Top Solder	Solder Resist	Solder Mask		0.8mil	3.2
1	Top Layer		Signal	1oz	1.378mil	
	Dielectric 1	Isola FR408HR (DUAL PLY, 2x1067, SPREAD GLASS )	Core		5mil	3.3
2	L2_GND1		Signal	1oz	1.2mil	
	Dielectric 6	Isola FR408HR 1080 RC65	Prepreg		2.86mil	3.36
	Dielectric 5	Isola FR408HR 1080 RC65	Prepreg		2.86mil	3.36
	Dielectric 4	FR408HR 0.71 1652*3+2116*2	Core		27.95mil	3.85
	Dielectric 7	Isola FR408HR 1080 RC65	Prepreg		2.86mil	3.36
	Dielectric 2	Isola FR408HR 1080 RC65	Prepreg		2.86mil	3.36
3	L3_PWR1		Signal	1oz	1.2mil	
	Dielectric 3	Isola FR408HR (DUAL PLY, 2x1067, SPREAD GLASS )	Prepreg		5mil	3.3
4	Bottom Layer		Signal	1oz	1.378mil	
	Bottom Solder	Solder Resist	Solder Mask		0.8mil	3.2
	Bottom Overlay		Overlay			

**Figure 4-1. IWRL6432FSPEVM PCB Layer Stackup**

#### 4.1.4 Altium Project

To download the Altium Designer® projects, see the design files at [TIDA-010254](#).

#### 4.1.5 Gerber Files

To download the Gerber files for the board, see the design files at [TIDA-010254](#).

#### 4.1.6 Assembly Drawings

To download the assembly drawings for the board, see the design files at [TIDA-010254](#).

## 4.2 Tools and Software

### Tools

**Code Composer Studio™** Code Composer Studio is an integrated development environment (IDE) for TI's microcontrollers and processors. Code Composer Studio comprises a suite of tools used to develop and debug embedded applications. Code Composer Studio is available for download across Microsoft® Windows®, Linux®, and macOS® desktops. This product can also be used in the cloud by visiting the [TI Developer Zone](#).

### Software

**UNIFLASH** UniFlash is a software tool for programming on-chip flash on TI microcontrollers and wireless connectivity devices and on-board flash for TI processors. UniFlash provides both graphical and command-line interfaces.

## 4.3 Documentation Support

1. Texas Instruments, [IWRL6432 Single-Chip 57- to 64-GHz Industrial Radar Sensor](#) data sheet
2. Texas Instruments, [CC1352R SimpleLink™ High-Performance Multi-Band Wireless MCU](#) data sheet
3. Texas Instruments, [IWRL6432BOOST BoosterPack™ plug-in module for single-chip low-power mmWave radar sensor](#)
4. Texas Instruments, [Low Power mmWave Radar Solution Enables New Functionality in Battery Powered Proximity Sensing Products](#) application brief

## 4.4 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

## 4.5 Trademarks

LaunchPad™, TI E2E™, SimpleLink™, Code Composer Studio™, and are trademarks of Texas Instruments.

Bluetooth® is a registered trademark of Bluetooth SIG, Inc.

Zigbee® is a registered trademark of ZigBee Alliance.

Arm® and Cortex® are registered trademarks of Arm Limited.

Wi-SUN® is a registered trademark of Wi-SUN Alliance.

Wi-Fi® is a registered trademark of Wi-Fi Alliance.

Microsoft® and Windows® are registered trademarks of Microsoft Corporation.

Linux® is a registered trademark of Linus Torvalds.

macOS® is a registered trademark of Apple Inc.

All trademarks are the property of their respective owners.

## 5 About the Author

**JUSTIN YIN** is a Systems Engineer on the Building Automation System Engineering & Marketing (SEM) team at Texas Instruments, where he is responsible for developing sensing reference design solution for building security system and fire safety system. He obtained his Master of Control Engineering degree from the Shanghai Jiao Tong University and his Bachelor of Science in Automation from Shanghai University of Engineering and Technology.

**COLIN HICE** is a Systems Engineer on the Building Automation System Engineering and Marketing (SEM) team at Texas Instruments. Colin holds a BS in Electrical Engineering from Colorado State University. He has helped develop smart sensing designs for building automation applications, including radar and passive infrared solutions.

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2023, Texas Instruments Incorporated