Design Guide: TIDEP-01036

mmWave Radar Sensor Kick-to-Open Reference Design

Description

This design provides a low-cost and small form factor reference for a Kick-to-Open (KTO) end application based on AWRL1432, TI's single-chip 77GHz automotive radar sensor. The AWRL1432 device runs a machine learning based gesture sensing algorithm, which detects the kick gesture to activate a power lift-gate, power trunk, or power sliding door on an automobile.

Resources

TIDEP-01036	Design Folder
LMR43620-Q1	Product Folder
TPS628502-Q1	Product Folder
TLIN1021A-Q1	Product Folder

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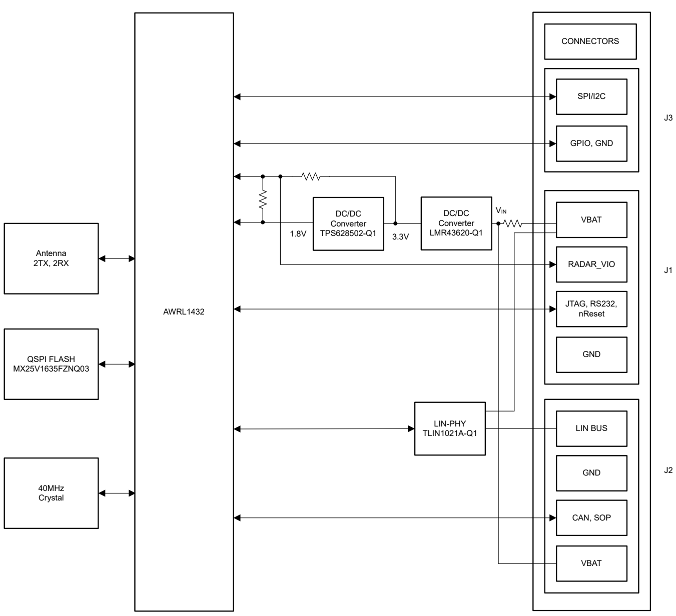
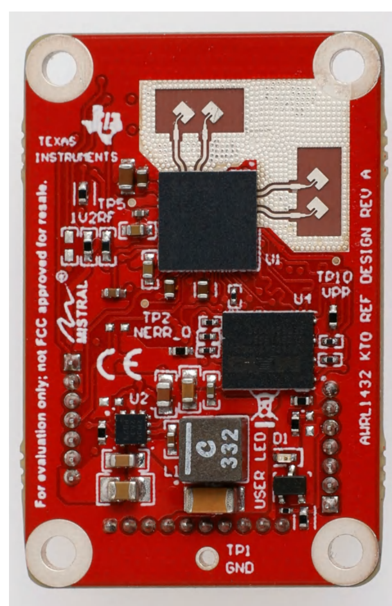
Features

- 12V automotive battery connection support
- Very small form-factor design (36mm × 24mm)
- Wide antenna with Field-of-View (FoV) — 120° (Azimuth) × 90°(Elevation) and 4dBi peak gain
- Low-cost Isola® FR408HR material used for PCB
- Onboard LIN PHY and CAN signal connections for directly interfacing with the automotive network
- 3.3V I/O support

Applications

- Kick to open module
- Obstacle detection sensor
- Automated parking
- Cross-traffic assist (Front)





1 System Description

This reference design utilizes AWRL1432, TI's 77GHz mmWave radar sensor and a fully automotive compliant Bill of Material (BOM). The small form factor allows an easy evaluation capability and integration into the end application system

AWRL1432 device operation is based on Frequency-Modulated Continuous Wave (FMCW) technology. Using two TX antennas for transmitting and two RX antennas for receiving RF signals, this FMCW radar system can capture various data points associated with the distance, angle, and velocity of the reflected radar signal that can be translated into specific gestures or presence being detected.

The battery power (DC supply – typically 12V) connects to the VBAT pin of the J2 connector. The wide VIN buck, LM43620-Q1, is utilized to convert this input supply to a 3.3V output. The TPS628502-Q1 then takes the 3.3V input and creates 1.8V rail. The AWRL1432 device powered by these two rails (3.3V and 1.8V) in BOM optimized power topology (3.3V I/O topology) enables the design to have an extremely small form factor.

The reference design comes with an onboard Local Interconnect Network (LIN) physical layer (PHY) which helps in communicating with an external automotive network. This design also supports an SPI-based raw data capture.

1.1 Key System Specifications

Table 1-1. Key System Specifications

PARAMETER		COMMENTS	MIN	TYP	MAX	UNIT
V_{IN}	Supply Voltage	Battery Input	3[(1)]	12	36[(1)]	V
$P_{presence}$	Power consumption in presence mode	V_{IN} = 12V		3.16		mW
$P_{gesture}$	Power consumption in gesture mode	V_{IN} = 12V		272		mW

(1) Even though LMR43620-Q1 supports a wide input voltage range of 3.0V to 36V with transients up to 42V, the recommendation is to operate the reference design under 3.6V to 20V for proper functional operation.

2 System Overview

2.1 Block Diagram

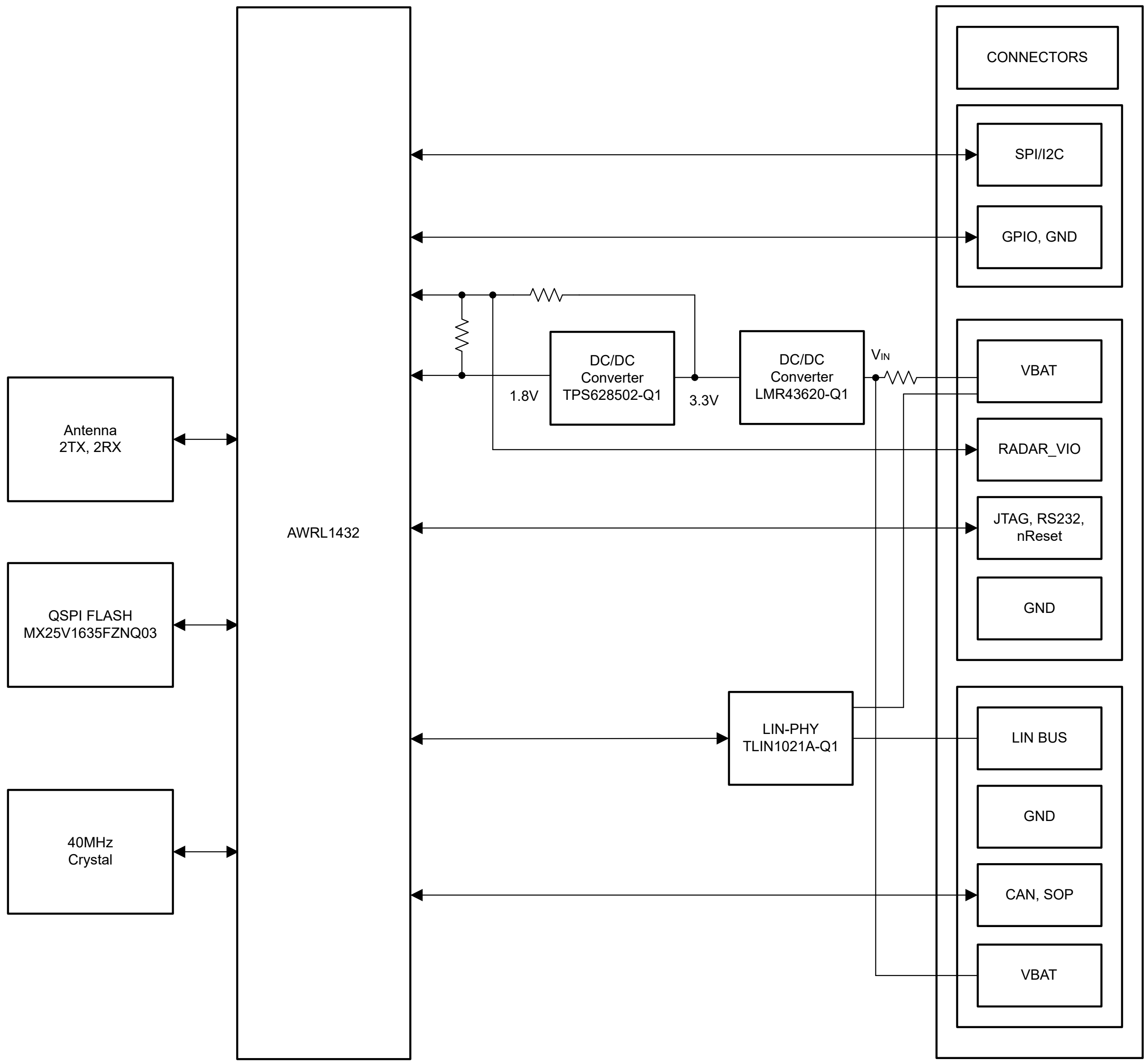


Figure 2-1. TIDEP-01036 Block Diagram

2.2 Design Considerations

This design is made to provide customers with a ready-to-use, small form-factor mmWave Kick-to-Open radar sensor with a highly cost optimized Bill of Materials. In this design, the AWRL1432 device powered by these two rails (3.3V and 1.8V) eliminates the need for an additional DC/DC converter to generate 1.2V externally and enables the design to have an extremely small form factor.

The antennas designed for this board are capable of providing 120°(Azimuth) x 90°(Elevation) Field-of-View and 4dBi peak gain with low-cost Isola® FR408HR material. This reference design also utilizes TI's low-cost, small form-factor, high-performance DC/DC converters and LIN PHY.

The onboard connectors (J1, J2, and J3) have various communication peripherals (UART, RS232, SPI, CAN, LIN, JTAG, I2C, GPIOs), SOPs, PWR, and GND being brought out, including a dedicated 10-pin connector (J1) for direct connection with LP-XDS110 which enables the ease of operation of the board. The onboard connectors used in the design have 1.27mm pitch, which also helps reduce the overall form factor of the board.

2.2.1 Power Topology

The reference design works in a BOM-optimized mode power topology with 3.3V IO support. In this mode the device is powered by using two rails (3.3V and 1.8V). A 1.2V is internally generated thus reducing the cost of an additional DC/DC converter.

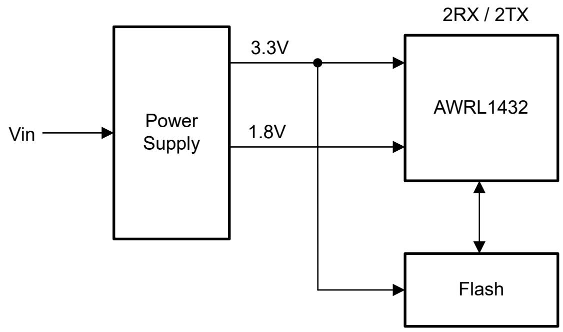


Figure 2-2. Power Topology

2.2.2 PCB and Form Factor

The goal of this reference design is to have a small compact radar module which is easy and ready to use for the KTO application. With the mounting holes, the board measures roughly 24mm × 36mm (0.9in × 1.4in). Figure 2-3 and Figure 2-4 show the top view and bottom view of the PCB.

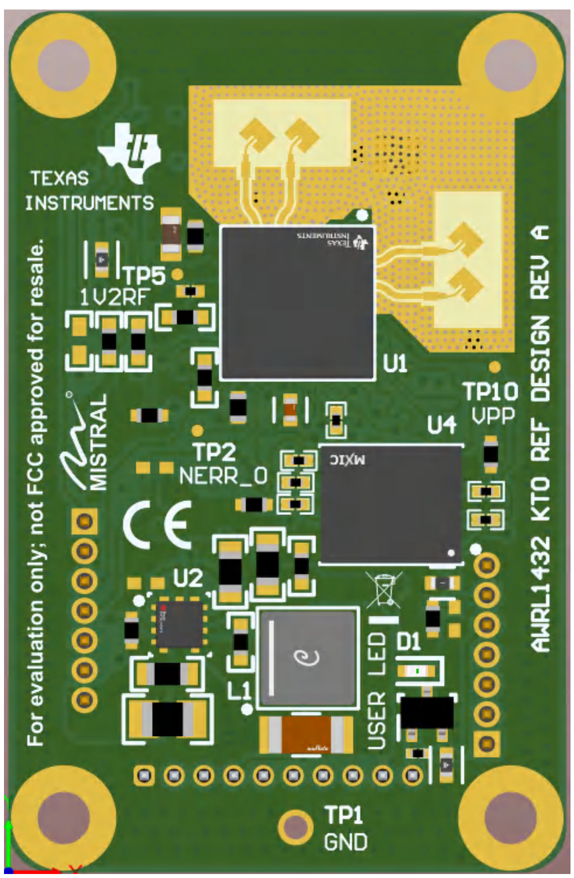


Image shown does not represent the actual size of the board.

Figure 2-3. PCB Top View

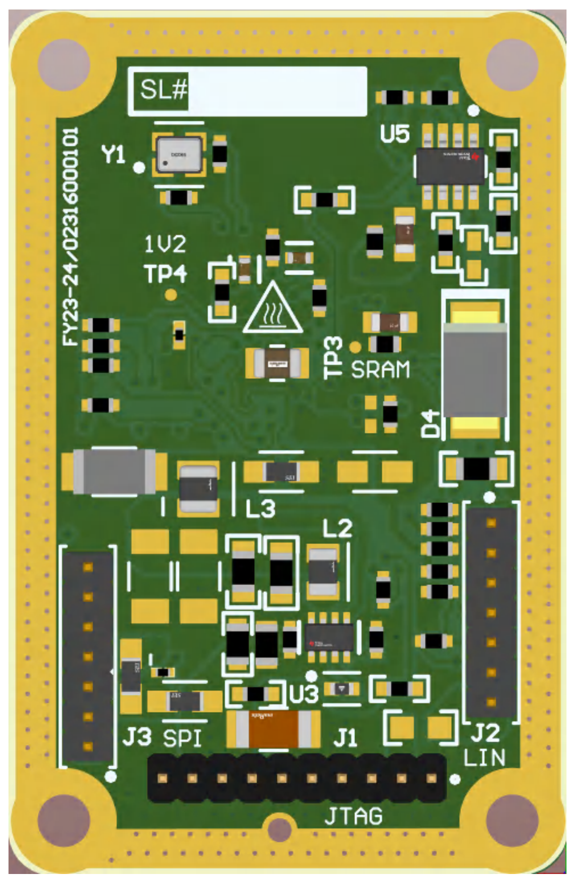


Image shown does not represent the actual size of the board.

Figure 2-4. PCB Bottom View

2.2.3 Antenna

This reference design includes onboard etched-patch antennas for the two receivers and two transmitters. This antenna design provides a wide Field of View (FOV) in azimuth with good gain and bandwidth coverage. Figure 2-5 shows the antenna design.

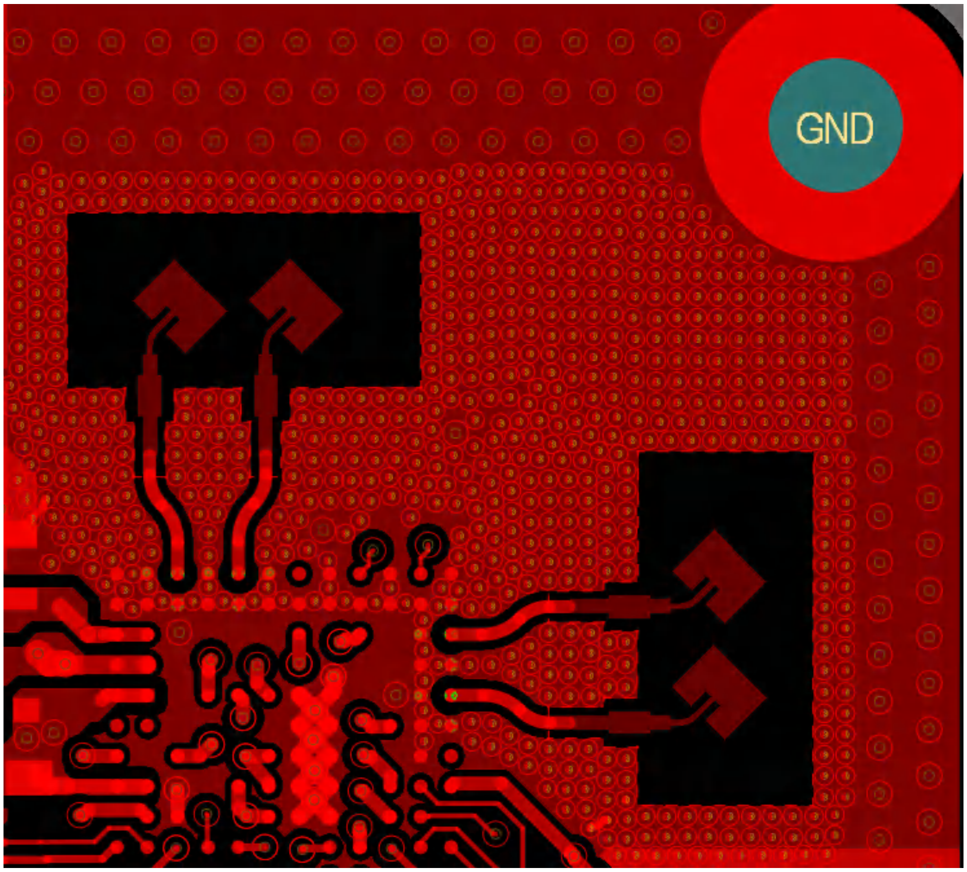


Figure 2-5. Altium Antenna Design

The antenna peak gain is greater than 4dBi across the operating frequency band of 76GHz to 81GHz. The performance parameters are listed in Performance Table.

Table 2-1. Performance Table

Parameters	Values
Gain	> 4dBi
FOV	120°(Azimuth) × 90°(Elevation)
Bandwidth	4.5GHz

Figure 2-6 shows the radiation pattern of one of the antenna elements in the horizontal plane (in red, Phi = 0°) and vertical plane at 79GHz (in green, Phi = 90°).

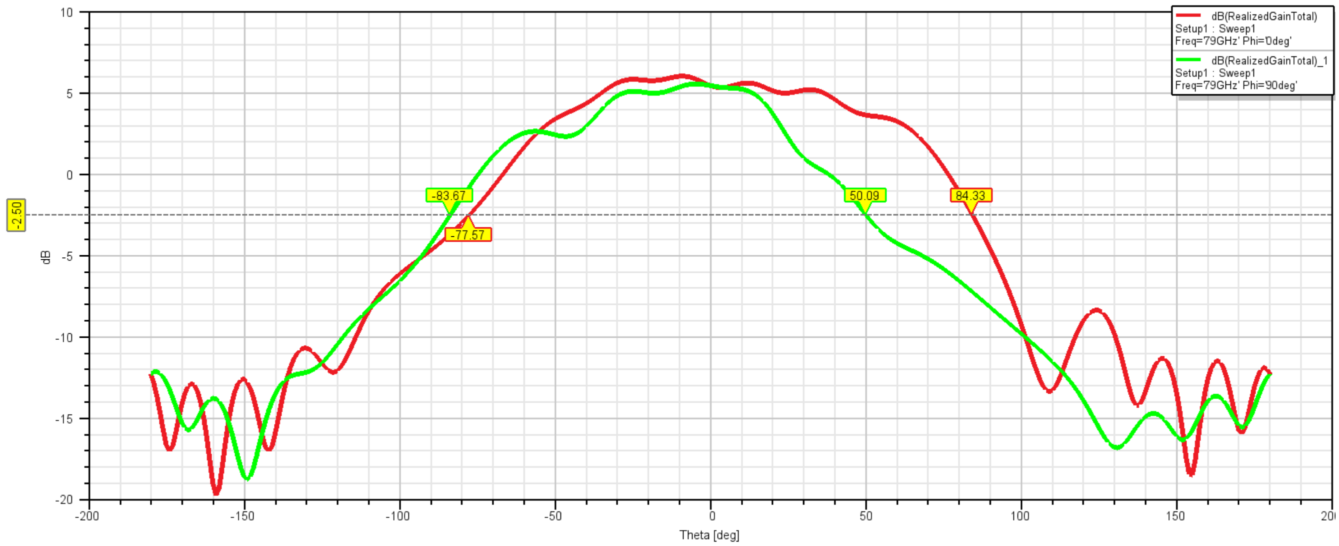


Figure 2-6. Antenna Pattern

2.3 Highlighted Products

2.3.1 AWRL1432BGAMFQ1

This integrated, single-chip frequency-modulated continuous wave (FMCW) radar sensor is capable of operation in the 76- to 81GHz band. The device is built with TI's low-power 45nm RFCMOS process and enables unprecedented levels of integration in an extremely-small form factor (SFF). The AWRL1432 is an excellent choice for low-power, self-monitored, ultra-accurate radar systems in the automotive space.

2.3.2 TPS628502-Q1

The TPS628502-Q1 is a 2A (continuous) high efficiency, easy-to-use synchronous step-down DC/DC converter. The switching frequency is externally adjustable from 1.8MHz to 4MHz. The device can also be synchronized to an external clock in the same frequency range. For mmWave radar sensor applications the recommendation is to operate the DC/DC converter in Forced-PWM mode with a higher switching frequency. Spread Spectrum Clocking (SSC) can be enabled to reduce both of the radiated and conducted emissions.

2.3.3 LMR43620-Q1

The LMR43620-Q1 is the industry-smallest 36V, 2A, and 1A synchronous step-down DC/DC converters in a 2mm × 2mm HotRod package. This easy-to-use converter supports a wide input voltage range of 3V to 36V (recommended operating range 3.6V to 20V) for the reference design. The LMR43620-Q1 is specifically designed to meet low standby power requirements for always on, automotive applications.

2.3.4 TLIN1021A-Q1

The TLIN1021A-Q1 is a local interconnect network (LIN) physical layer (PHY) transceiver. LIN is a low-speed universal asynchronous receiver transmitter (UART) communication protocol, that supports automotive in-vehicle networking. This transmitter supports data rates up to 20kbps. The device is designed to support 12V applications with a wide input voltage operating range.

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

3.1.1 Getting Started With Hardware

This reference design can be powered up in two ways. The primary option to power up the design is by connecting the VBAT pin (J2.7) to a battery power (DC supply – typically 12V). The secondary option is to power up the device using the LP-XDS110 development kit. In both the ways, the LP-XDS110 is used for interfacing the device with the PC. LP-XDS110 has access to the onboard XDS110 (TM4C1294NCPDT) emulator which provides the following interfaces to the PC:

- JTAG for CCS connectivity
- Application or user UART (configuration and data communication to the PC)

3.1.1.1 Primary Power Up Option

Make sure that the R31 resistor remains unpopulated when the device is powered up using the battery power (DC supply).

3.1.1.1.1 Making the Connections in Primary Power Up Option

Figure 3-1 shows the connections for the primary power up option.

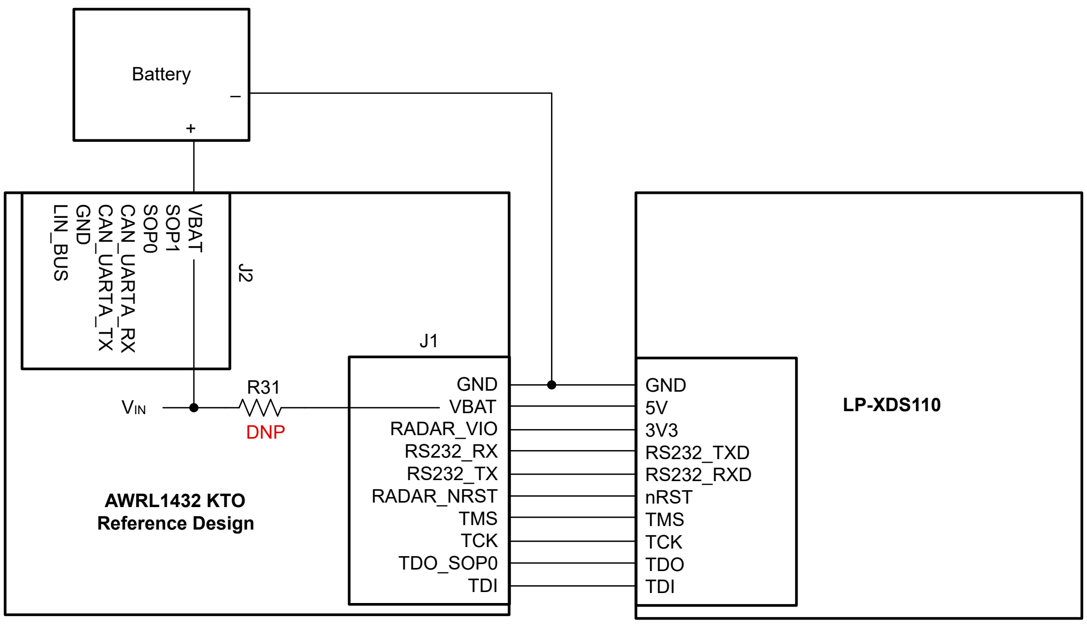


Figure 3-1. Connections in Primary Power Up Option

Use the following steps for powering up the reference design through the primary power up option:

1. Connect the J2.7(VBAT) pin to a 12V DC supply
2. Connect the GND pin of the DC supply to the GND pin of the reference design or to the GND pin of LP-XDS110 to provide the common GND across the setup
3. Put a jumper on the 2-3 pin of the P9 connector of the LP-XDS110 to make sure the 3.3V IO supply is provided by the reference design to the LP-XDS110
4. Connect the J1 connector with the bottom 10 pins of the LP-XDS110 using a female-to-female connector. See Figure 3-1.
5. Power up the LP-XDS110 using a USB Type-C® cable
6. Make sure the SOP lines are in correct configurations while powering up the device. See Section 3.1.1.3 for proper SOP configurations.
7. nRESET can be issued through the LP-XDS110 reset switch since the J2.6 pin connects to the LP-XDS110 nRST pin

3.1.1.2 Secondary Power Up Option

Populate the R31 resistor to power up the device using LP-XDS110 through J1.2 pin (VBAT). Do not connect the other VBAT pin (J2.7) to any external supply while the device is powered through J1.2 pin (VBAT).

3.1.1.2.1 Making the Connections in Secondary Power Up Option

Figure 3-2 shows the connections for the secondary power up option.

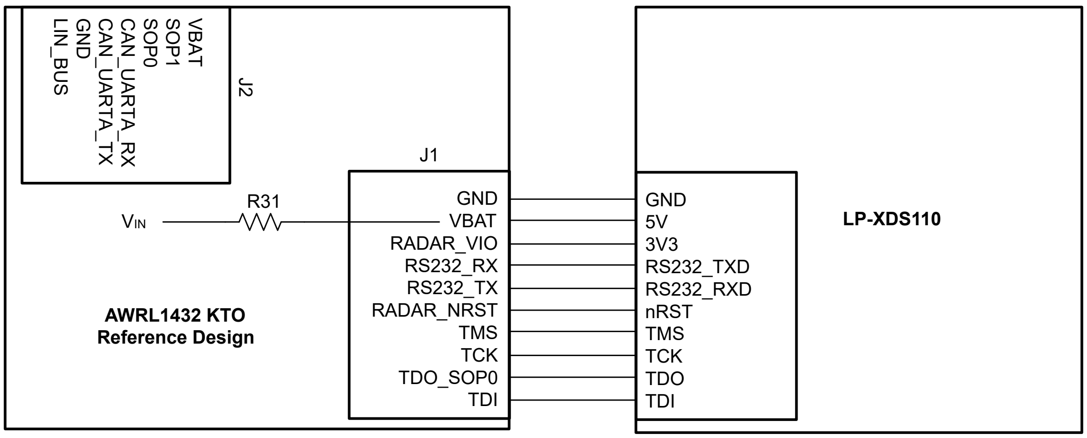


Figure 3-2. Connections in Secondary Power Up Option

Use the following steps for powering up the reference design through the secondary power up option:

1. Put a jumper on the 2-3 pin of the P9 connector of the LP-XDS110 to make sure the 3.3V IO supply is provided by the reference design to the LP-XDS110
2. Connect the J1 connector with the bottom 10 pins of the LP-XDS110 using female-to-female connector. See Figure 3-2.
3. Power up the LP-XDS110 using a USB Type-C® cable
4. Make sure the SOP lines are in correct configurations while powering up the device. See Section 3.1.1.3 for proper SOP configurations.
5. nRESET can be issued through the LP-XDS110 reset switch since the J2.6 pin connects to the LP-XDS110 nRST pin

3.1.1.3 Sense-on-Power (SOP)

The AWRL1432 device has 3 different boot mode (SOP mode) configurations, *Application mode* (Functional mode), *Device management mode* (QSPI flashing mode), and *Debug mode* (Development mode). The SOP mode configurations shown in Table 3-1 must be exercised first. After the correct SOP mode is set, an nRESET must be issued to register the SOP setting.

Connector pins J2.5 and J2.6 are dedicated for SOP0 and SOP1, respectively. By default, SOP0 and SOP1 are pulled high in the design. Therefore, the device boots up in *Debug mode* when J2.5 and J2.6 are not connected externally. Connect J2.5 or J2.6 (or both) to GND (GND pins of the LP-XDS110 can be used) to switch between different SOP modes.

Table 3-1. Different SOP Modes

SOP MODE	PMIC_CLK_OUT, TDO	COMBINATION (SOP1, SOP0)	CONNECTION REQUIRED FOR SOP1	CONNECTION REQUIRED FOR SOP0
SOP_MODE1	Device management mode (QSPI flashing mode)	00	GND	GND
SOP_MODE2	Application mode (Functional mode)	01	GND	NC
SOP_MODE4	Debug Mode (Development mode)	11	NC	NC

3.1.1.4 AWRL1432 Initialization: Board Programming

Once the board is powered with the 12V connection, a program must be loaded into the external flash. The radar toolbox provides the application binaries, chirp configuration, and GUI to run the Kick-to-Open demonstration (see Section 3.2 for more details). TI also provides the mmWave low-power Software Development Kit (L-SDK). This is a unified software platform for the AWRLx family of mmWave sensors, which enable evaluation and development. The use of this design environment is covered in the *mmWave Radar Visualizer User's Guide*. Use the following steps for loading an application image file:

1. Install the UniFlash software, which is available for download at: http://www.ti.com/tool/uniflash. Proceed to the next step after installation.
2. Connect the board with the PC using either of the power up options mentioned in Section 3.1.1.1 or Section 3.1.1.2.
3. Open the UniFlash software. Select *mmWave* from the *Category* header, select *AWRL1432* from the field of available devices, and then click the *Start* button (see Figure 3-3).

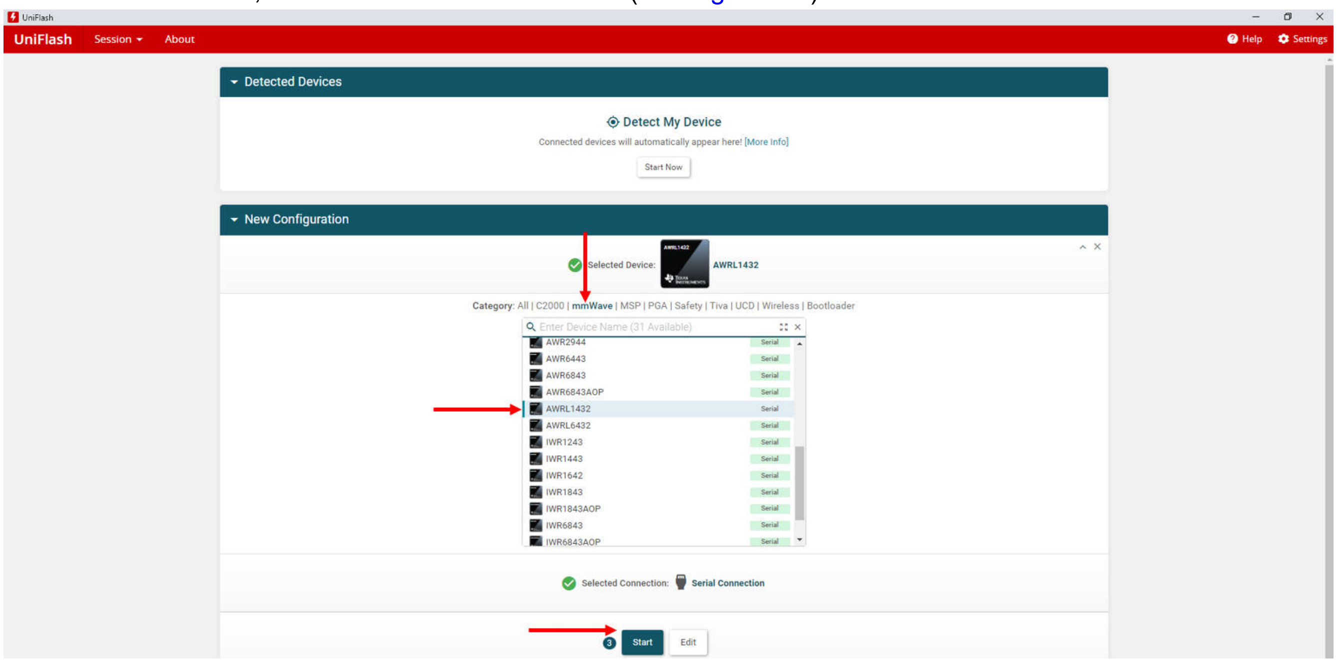


Figure 3-3. UniFlash Configuration

4. Click the *Browse* button and navigate to the application image file to load. The file path and name is `<RADAR_TOOLBOX_INSTALL_DIR>\radar_toolbox latest version\source\ti\examples\Kick_to_Open\prebuilt_binaries\gesture_recognition_demo.Release.appimage`. After the name of the file populates the field, click on the *Settings & Utilities* menu on the left side of the program (see Figure 3-4).

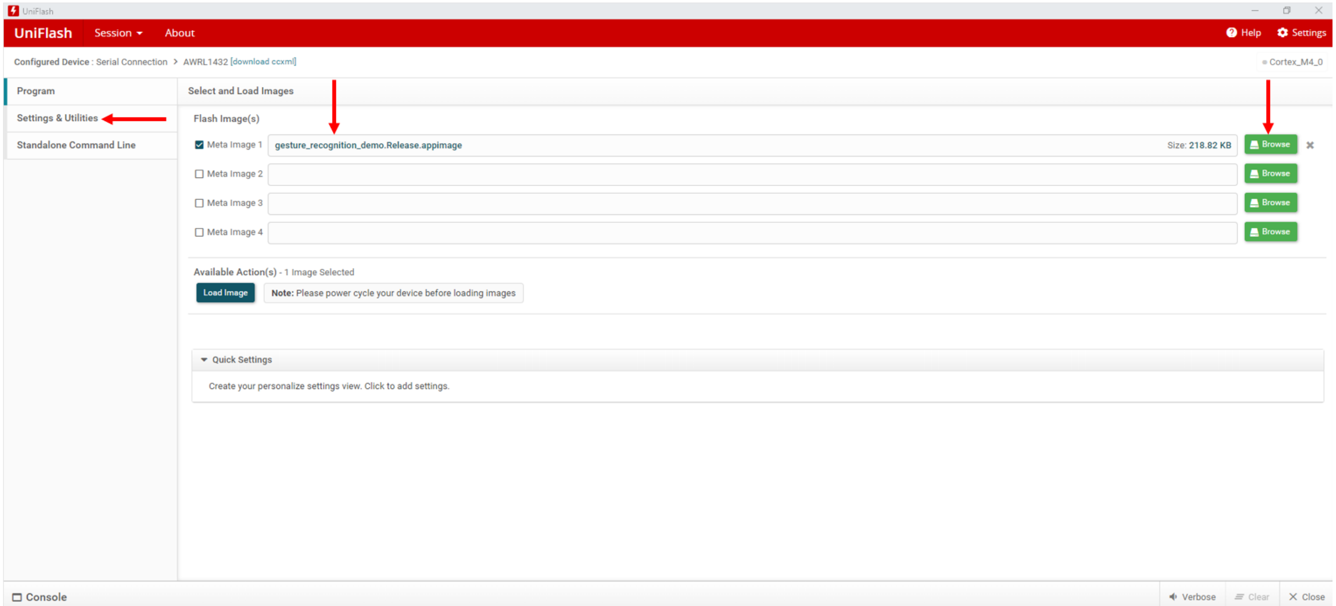


Figure 3-4. UniFlash Settings

5. After connecting the LP-XDS110 into the USB port, open the Microsoft® Windows® *Device Manager*. Find the *XDS110 Class Application/User UART* port and note the COM port number. The example in Figure 3-5 shows this COM port to be COM20.

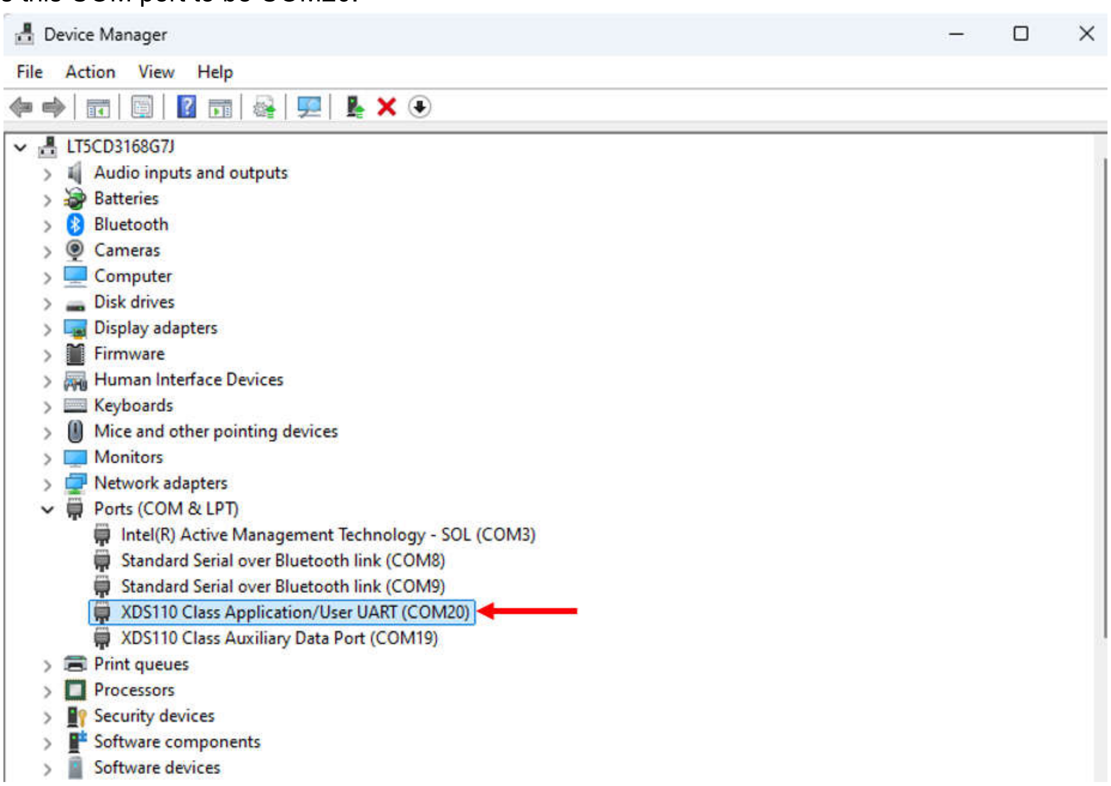


Figure 3-5. Determine COM Port

6. Return to the UniFlash software and enter the noted COM port number from the device manager. Then click the *Program* menu on the left side of the window to go back to the previous menu (see Figure 3-6).

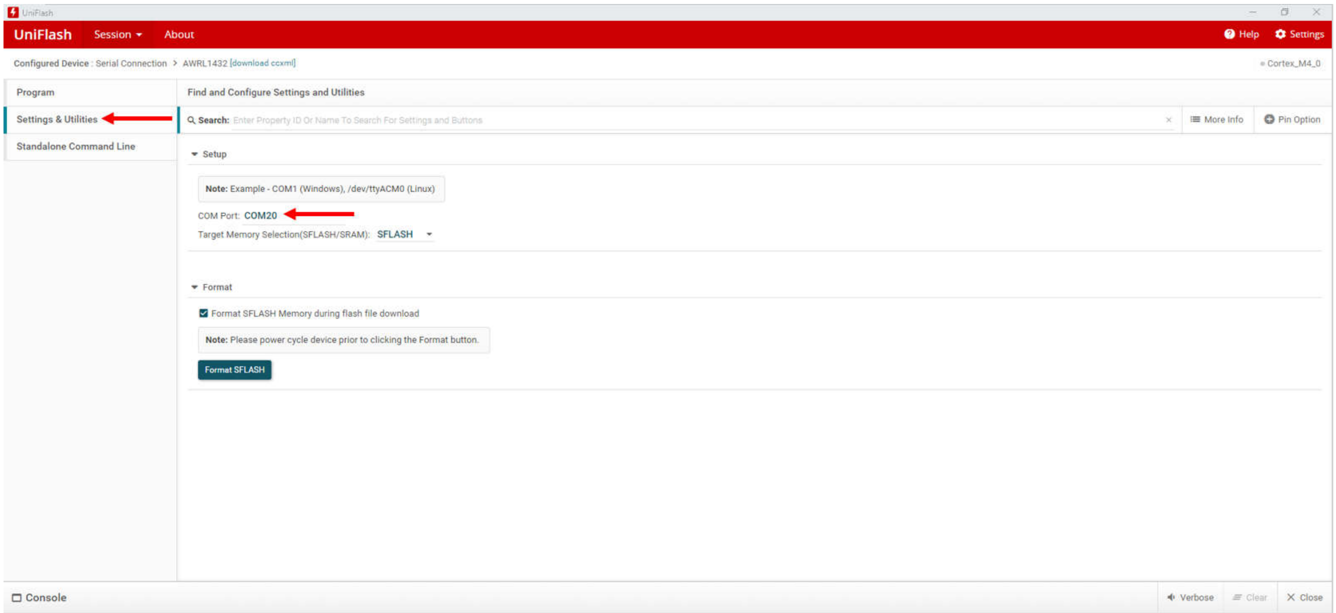


Figure 3-6. Enter COM Port

7. Reset the AWRL1432 device by pressing the reset button on the LP-XDS110. Then select *Load Image*. This action loads the program into the flash. To execute the program, change the SOP settings into functional mode. The program then runs.

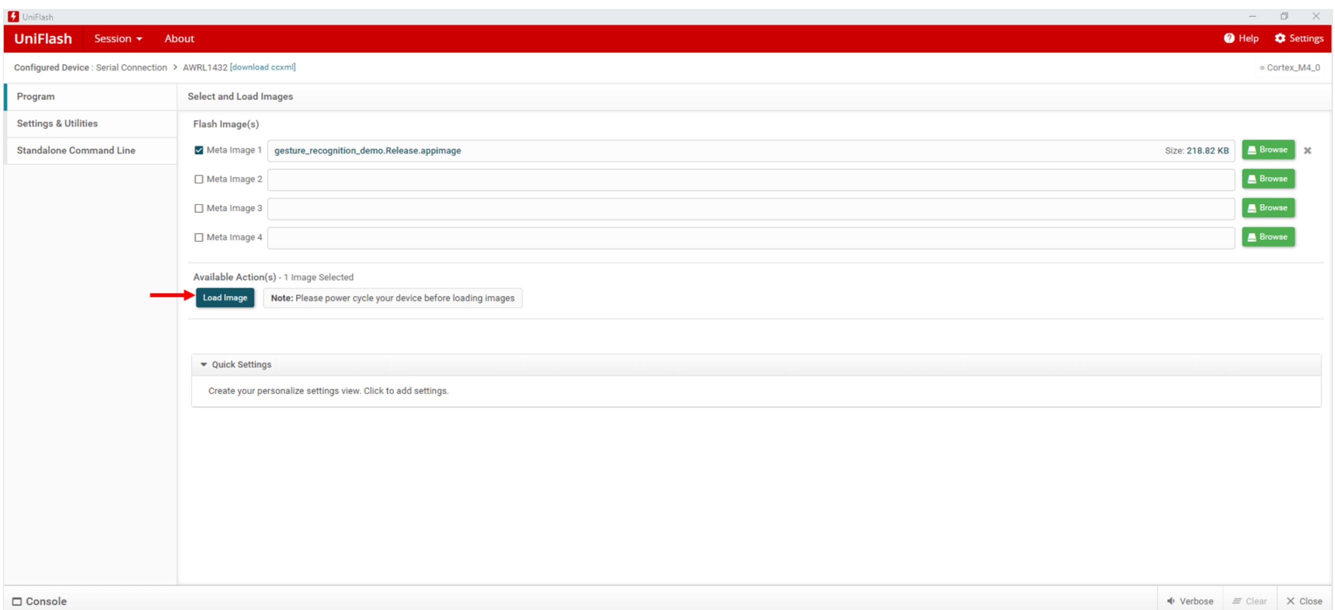


Figure 3-7. Load Image

3.2 Test Setup

Please follow the *Getting Started With Hardware* section for powering up the device and configuring the device in different SOP modes.
Install the latest *Radar Toolbox* present under `mmWave radar sensors\Embedded Software` in the *TI Resource Explorer*.

See the *AWRL1432 KTO Users Guide* located in `<RADAR_TOOLBOX_INSTALL_DIR>\radar_toolbox latest version\source\ti\examples\Kick_to_Open\docs` to run the KTO demonstration.

The Kick-to-Open capability on this reference design uses the low-power mode (Low Power Deep Sleep) on AWRL1432 along with a hybrid algorithm implemented in user application code space, which in real time allows switching between presence detection and gesture detection mode. This extremely low-power consumption feature is essential as a requirement for a Kick-to-Open end application.

3.3 Test Results

This section demonstrates two *modes*: a low-power presence detection mode and a gesture recognition mode. While in *presence detection* mode, the device operates on minimal power searching for a person within range of approximately 2m. In the KTO demonstration, by default the device is in *presence detection* mode.

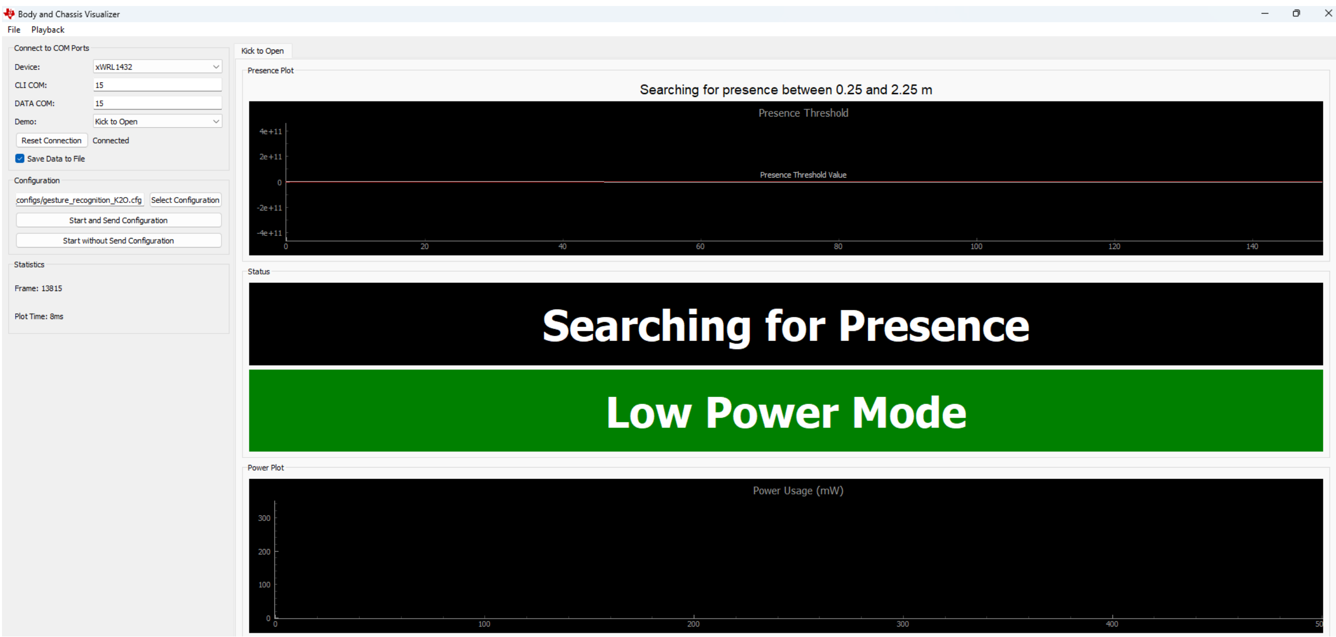


Figure 3-8. Device is in Presence Detection Mode

Once a person enters the presence detection range (roughly 2m), the device switches from *Low Power Presence Detection Mode* to *Gesture Recognition Mode*, in which the frame rate is much higher. Additionally, the device supports *Detection* or *Classification* of one gesture (at a range of 0–1m, and 0.5m left or right of the sensor), that is, *Kick*.

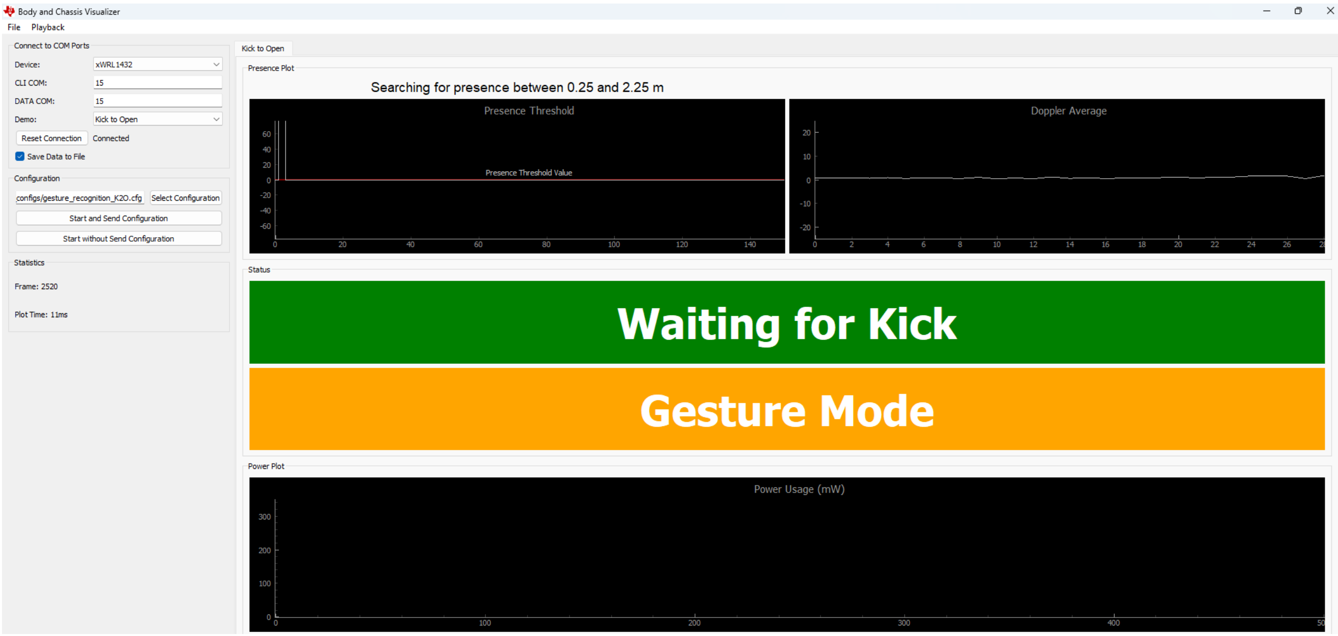


Figure 3-9. Device is in Gesture Recognition Mode

Once the kick gesture is performed, the gesture is detected and the *Kick* confirmation is displayed in the GUI as shown in the Figure 3-10.

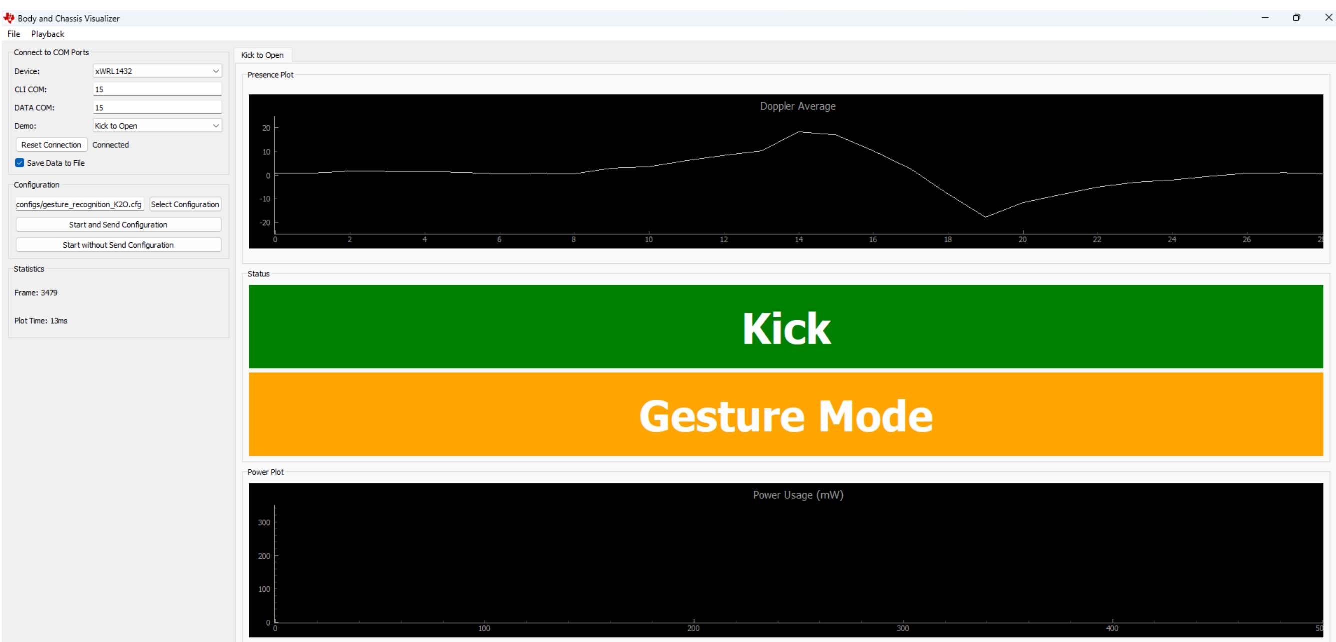


Figure 3-10. Kick Detected

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDEP-01036.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDEP-01036.

4.1.3 Layout Prints

To download the layer plots, see the design files at TIDEP-01036.

4.1.4 Altium Project

To download the Altium project files, see the design files at TIDEP-01036.

4.1.5 Gerber Files

To download the Gerber files, see the design files at TIDEP-01036.

4.2 Tools and Software

Tools

Radar Toolbox for mmWave Sensors	The Radar Toolbox is a collection of demonstrations, software tools, and documentation designed to assist in the evaluation of TI Radar Devices.
UNIFLASH	UniFlash is a software tool for programming on-chip flash on TI microcontrollers and wireless connectivity devices and onboard flash for TI processors. UniFlash provides both graphical and command-line interfaces.
MMWAVE-L-SDK	mmWave software development kit (SDK) for xWRL1432 and xWRL6432: The mmWave low-power software development kit (SDK) is a collection of software packages that enable application evaluation and development on our low-power mmWave sensors. This tool includes MMWAVE-L-SDK and companion packages to support customer design needs.

4.3 Documentation Support

1. Texas Instruments, *LMR436x0-Q1, 36V, 1A / 2A, Automotive Buck Converter With < 2.5µA I_Q at 150°C T_{JMAX} in 4mm2 HotRod™ QFN Data Sheet*
2. Texas Instruments, *TPS62850x-Q1 2.7V to 6V, 1A / 2A / 3A Automotive Step-Down Converter in SOT583 Package Data Sheet*
3. Texas Instruments, *TLIN1021A-Q1 Fault-Protected LIN Transceiver with Inhibit and Wake Data Sheet*
4. Texas Instruments, *AWRL1432 Single-Chip 76- to 81GHz Automotive Radar Sensor Data Sheet*

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.

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