Technical White Paper

Bringing Intelligence and Efficiency to Smart Home Appliances with TI mmWave Radar Sensors

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ABSTRACT

As homes get smarter, there is an increased need to add more intelligence, increase energy efficiency, and lower the carbon footprint of the appliances, all of which allow for the integration of millimeter-wave (mmWave) radar sensors. mmWave radar has many unique advantages over traditional motion and presence detection sensors. mmWave radar has high sensitivity to motion detection and insensitivity to the changing environment as well as higher accuracy. In home appliances, such as air conditioners and major appliances, mmWave radar can provide a variety of intelligent experiences that can help save energy and reduce carbon emissions. mmWave radar's unique technology advantages can empower smart homes.

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1 Introduction

Millimeter wave is a radar technology that uses short-wavelength electromagnetic waves. Radar transmits electromagnetic wave signals that are reflected by objects in the signals' path. By capturing the reflected signal, a radar system can determine the range, velocity, and angle of the objects. TI's mmWave radar devices integrate both analog and digital components which include analog components such as transmitter, receiver, clocking, and digital components such as the ADC, MCU, memory, and hardware accelerator. These are different from traditional discrete components and can reduce power consumption and overall system cost. To understand the principle of mmWave radar, please see the white paper The fundamentals of millimeter wave radar sensors.

2 Motion Detection Technology Comparison

With the development of technology and increasing demand for intelligent sensing, more and more sensor technologies have entered daily life, such as passive infrared (PIR), LIDAR and 3D ToF, optical cameras, and microwaves. Figure 2-1 compares these technologies and lists the pros and cons.

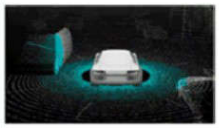
	Passive infrared (PIR)	Optical cameras	Active infrared (LIDAR, ToF)	Microwave (10 GHz or 24 GHz)	TI mmWave
					
Description	Measures changes in infrared light in order to detect motion	Analyzes imagery to determine people movement and behavior	Measures infrared light ToF	Discrete components assembled to create a radar for motion detection	TI single-chip radar sensor provides range, velocity and angle information about objects
Pros	✓ Simple, low-power consumption	✓ Algorithms applied for variety of applications ✓ Video for recording and monitoring	✓ High angular resolution provides a rich data set, similar to cameras	✓ High sensitivity to motion (breathing, typing) ✓ Extended range (+50 m) ✓ Insensitive to weather, changing environments	✓ High sensitivity to motion (breathing, typing) ✓ On-chip processing for single-chip tracking, classification ✓ Extended range (+50 m) ✓ Insensitive to weather, changing environments
Cons	✗ Low sensitivity to fine motion ✗ False detection outdoors from sunlight, temperature ✗ Limited range, no position or distance information	✗ False detection from shadows, occlusion, day/night, environment ✗ Complex software and processing requirements ✗ No position/range information ✗ Privacy considerations	✗ Limited range in the presence of sunlight (5-10m) ✗ Complex software and processing requirements	✗ Hardware and software design and integration complexity ✗ No position information ✗ Large form factor	✗ Lower angular resolution than cameras or active infrared

Figure 2-1. Comparison of common motion detection sensor technologies

Overall, compared to other sensor technologies, mmWave has many advantages, such as high sensitivity, extended range, and insensitivity to environment. Currently, mmWave radar is well known in automotive applications (the largest application market.) However, the industrial market includes intelligent transportation, security monitoring, smart home, smart health care, industrial measurement, and other fields. The most extensive application scenarios, among which smart home and smart health care are emerging application fields, has attracted high attention in the past two years, and has great development potential in the future.

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3 mmWave Used in Smart Home Appliances

3.1 Product Type

Millimeter wave radar is mainly used for people detection in smart homes. The specific functions include human presence detection, location tracking, sleep monitoring, and gesture recognition. According to the different product forms, millimeter wave radar can be divided into embedded type and independent type. Embedded type means the radar is embedded into a product for use and powered by the internal power of the product. Independent type means a separate radar module that does not need to be embedded in any product and is usually battery powered. Typical applications of millimeter wave radar in smart homes are shown in Figure 3-1.

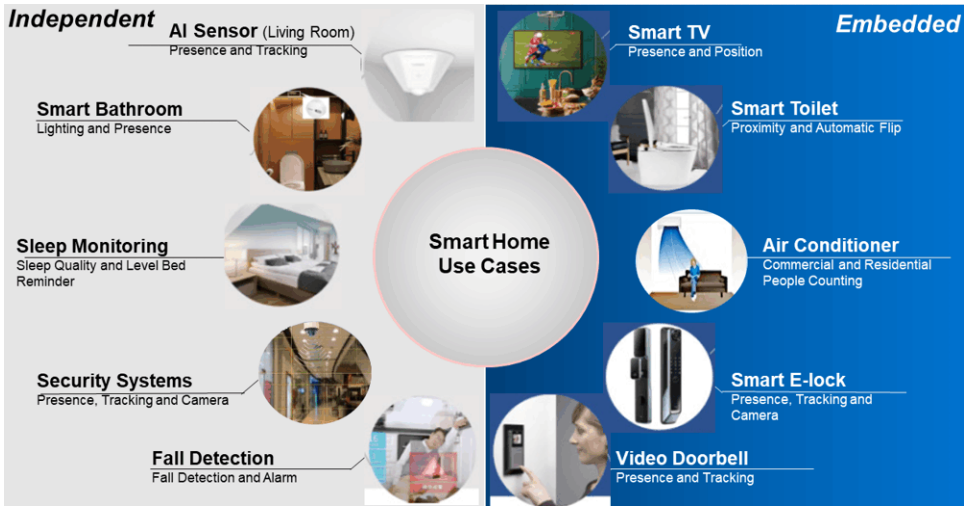

Figure 3-1. mmWave typical application in smart homes

Embedded

Embedded millimeter wave radar sensors are also replacing infrared sensors in smart homes, such as smart speakers, smart air conditioners, smart lighting, automatic doors, smart toilets, E-locks, video doorbells, and central control screens. In these applications, mmWave radar can be embedded into these products, making power supply and installation more convenient.

Independent

Independent household millimeter wave radar is mainly used for detection and identification of people. 60GHz radar can be used for detecting the presence, location and direction of people, and tracking. Independent radar can also coexist with lighting equipment, environmental equipment, and home appliances. In the existing technology, independent is commonly used for motion sensing in video surveillance or infrared sensors. Video surveillance is intrusive, while infrared human body sensing can only be used to determine the presence or absence of a person, and is therefore difficult to use to obtain the precise location of people. Millimeter wave radar can effectively make up for the shortcomings of both technologies.

3.2 Air Conditioning Application Scenario Analysis

Air conditioners are being developed with more features and intelligence. Adding millimeter wave radar technology to air conditioners can enable new functions like the prescence, number, and location of humans so the device can adjust operation accordingly. This can reduce energy loss and enhance the product value.

- **Presence Detection:** mmWave can detect people present in the room, and can enable automatic shut off when there is no person detected in the room or living area for a long time. This avoids the air conditioner having to be turned ON all the time and thus helps save electricity and reduce carbon emissions.
- **Localization and People Counting:** By detecting the location of people, the device can automatically adjust the air outlet of the air conditioner to blow in the specific direction where people are present, this makes the experience more customer centric and efficient. For example, when the day is hot, adjust the air outlet to

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a place where people gather, or at night, adjust the air outlet so that the air does not blow directly towards people as shown in Figure 3-2.

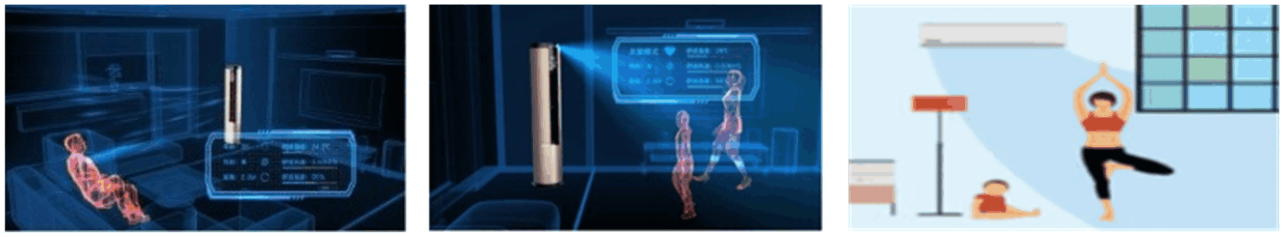

Figure 3-2. Localization using mmWave

- **Vitals Sensing and Sleep Monitor:** Another potential use case is to detect vitals information (breathing and heart rate), adjust air flow, and provide alerts by detecting the sleeper's posture and motion at night. The device can provide feedback on sleep quality (as seen in Figure 3-3), which can be very important data for the elderly.

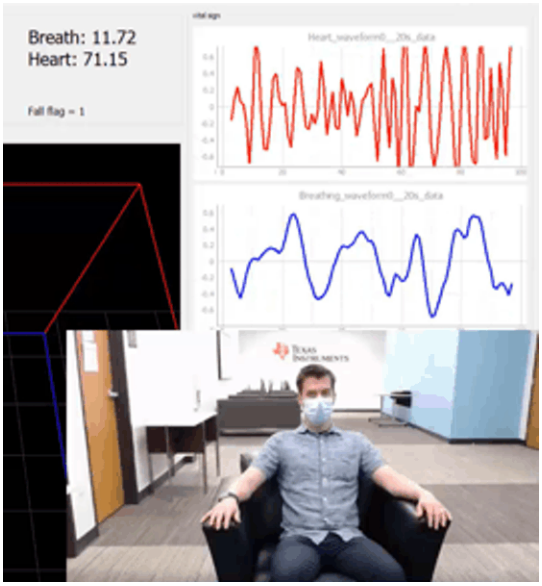

Figure 3-3. Vital sensing using mmWave

- **Gesture Recognition:** By detecting different gestures (up to down, left to right, push, pull, etc.), we can adjust air conditioning functions, such as temperature, wind speed, etc. as seen in Figure 3-4.

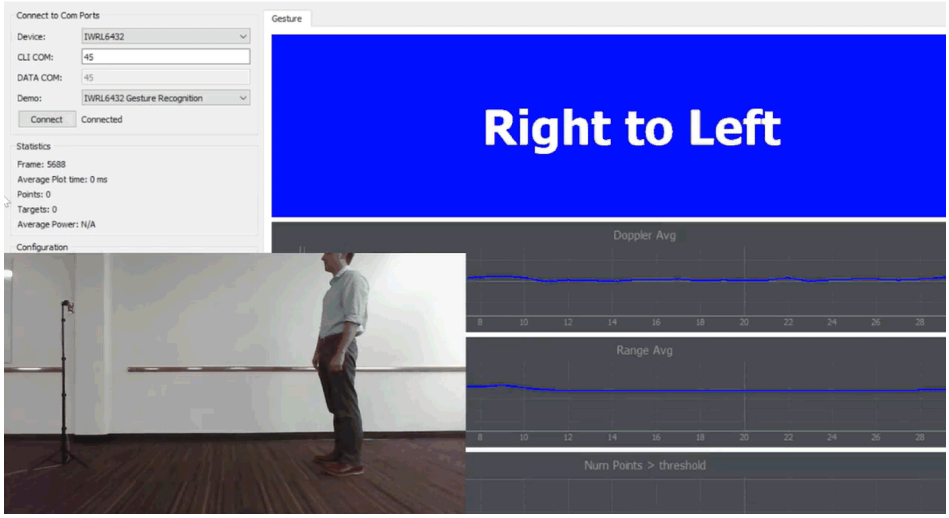

Figure 3-4. Gesture recognition using mmWave

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4 TI Designs to Faster Evaluate mmWave

4.1 Products and Design Resource

For 60GHz millimeter wave radar, TI has the following products:

- IWRL6432 – 3R2T low power, lower cost mmWave radar sensor w/ HWA
- IWR6843 – 4R3T 60GHz mmWave radar sensor w/ DSP & HWA
- IWR6843AOP – IWR6843 with integrated antenna on the package

For different application scenarios, customers can choose the most appropriate product. TI also provides many examples and software for different applications, such as:

- Presence and motion detection – Presence And Motion Users Guide
- Gesture Recognition – IWRL6432 Gesture Recognition Users Guide
- Vital Signs – Vital Signs With People Tracking User Guide

For more examples and demo resources, please refer to the Radar Toolbox.

4.2 TIDA-010254 Reference Design

mmWave function and demo evaluation can be done by using TI's Single-chip 60GHz to 64GHz intelligent mmWave sensor integrating processing capability or Single-chip low-power 57GHz to 64GHz industrial mmWave radar sensor. However, for customers who have completed the demo evaluation and plan to do hardware design, please refer to TI's reference design Battery powered low-power, low cost mmWave radar solution. This design uses the IWRL6432 + CC1352 combination and aims to provide an option for customers with low power consumption and wireless data transmission. Figure 4-1 only gives a brief introduction to the IWRL6432 module.

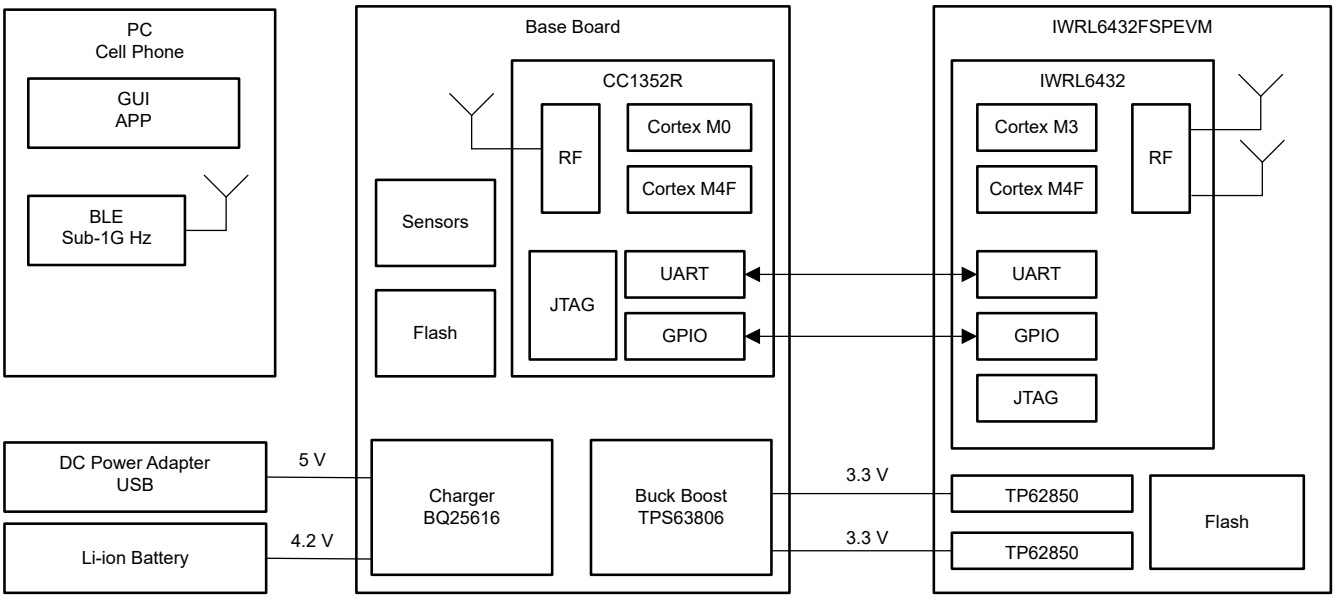

Figure 4-1. TIDA-010254 block diagram

Power Design

The system power supply of IWRL6432 is divided into the following four types: 3-Rail (3.3V, 1.8V, 1.2V), 2Rail (3.3V, 1.8V), 2Rail (1.8V, 1.2V), 1Rail (1.8V) as seen in Figure 4-2.

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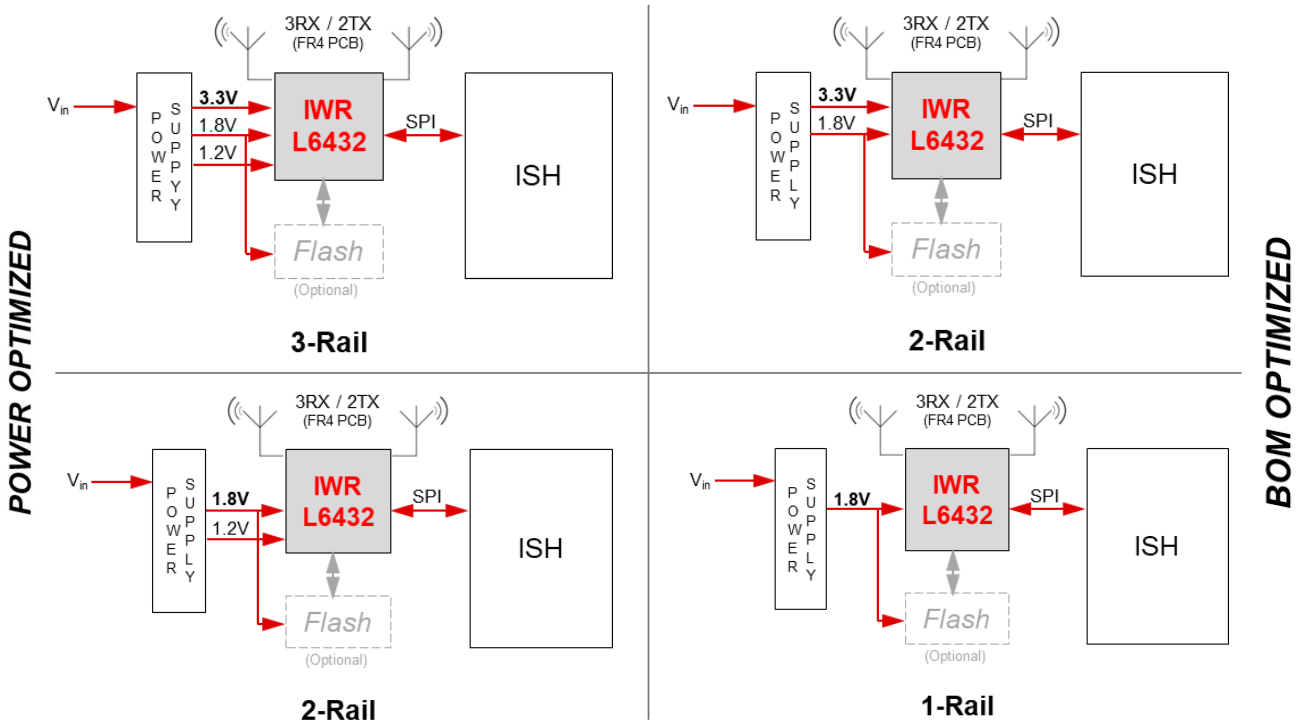

Figure 4-2. IWRL6432 power supply

For low power consumption, use the power supply option on the left. If there is no requirement for low power consumption but a requirement for BOM cost, choose the power supply option on the right. The 3D PCB view of this IWRL6432 module is shown below, the PCB size is 41mm × 21mm. For detailed information, please refer to Battery-powered mmWave radar sensor with sub-1-GHz and Bluetooth® 5.2 reference design.

In many application scenarios, especially for battery power application, power consumption is a very important consideration and is also a concern for many customers when designing radar sensor systems. Low power consumption is one of the advantages of TI IWRL6432 module as shown in Figure 4-3. We also run some power consumption test of this board.

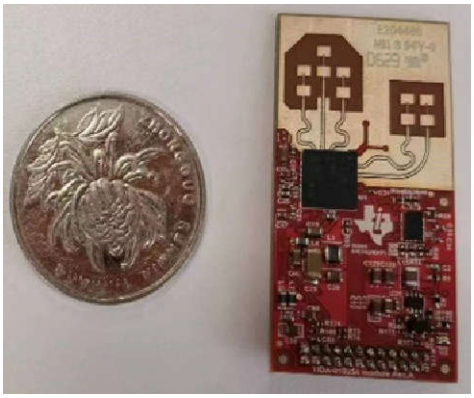

Figure 4-3. TIDA-010254 IWRL6432 module

Use Keysight 34460A multimeter and Keysight BenchVue software to record the current data and waveform. The test environment is shown in Figure 4-4. To run the motion detection power test, choose “motion_and_presence_detection_demo.appimage” from SDK to flash the radar device, and use the below configuration parameter to run this test.

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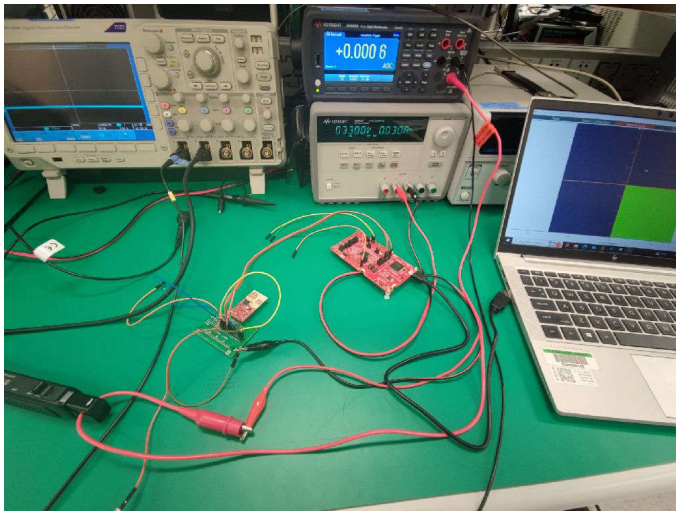

```
sensorStop 0
channelCfg 7 1 0
chirpComnCfg 12 0 0 64 1 12 0
chirpTimingCfg 18 25 0 100 61
frameCfg 4 0 260 1 333 0
guiMonitor 2 1 0 0 0 1 0 0 0 0 0
sigProcChainCfg 4 2 1 0 0 0 0 0.3
cfarCfg 2 8 4 3 0 9.0 0 0.5 0 1 1 1
aoaFovCfg -80 80 -40 40
rangeSelCfg 0.5 20.0
```

Figure 4-4. IWRL6432 Module power consumption test

Using Keysight BenchVue software to see the test result. As shown in Figure 4-5, the average current is 988uA @3.3V, so the average power is 3.2mW.

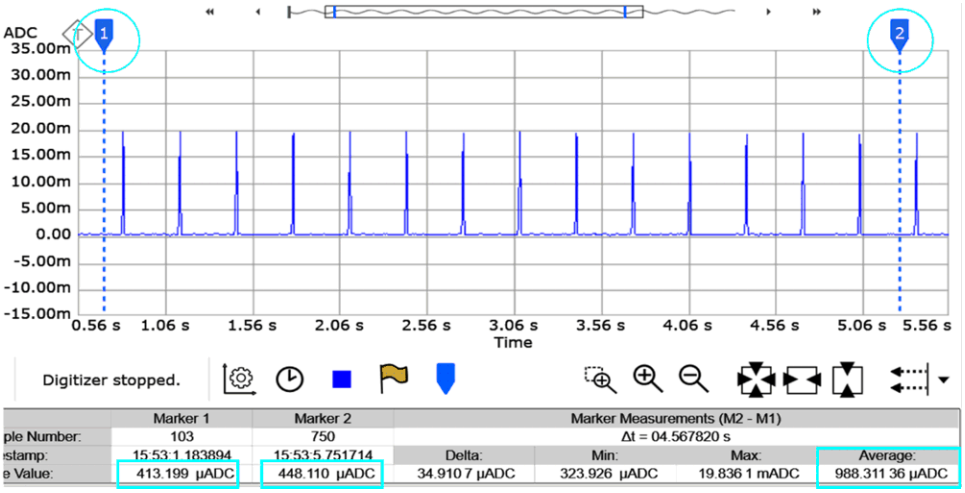

Figure 4-5. Motion detection power consumption test

Note

Please note that this is not the lowest power consumption, just the TIDA-010254 mmWave module power consumption under the current configuration file. Different application scenarios use different configurations, and the power consumption is also different.

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5 Conclusion

Smart homes with whole-house intelligence are already a trend. Millimeter-wave radar has unique advantages including high sensitivity to motion detection, robustness in multiple environmental conditions, no privacy issues, and detectability behind a plastic cover. These advantages allow millimeter-wave radar to continue to penetrate smart homes and many other industrial fields, and the 60GHz millimeter wave radar has better performance and is designed for more scenarios. TI has millimeter-wave radar options for high-performance IWR6843 and low-cost, low-power IWRL6432 respectively, and also has many resources to help customers design easier.

6 References

- Texas Instruments, Battery-powered mmWave radar sensor with sub-1-GHz and Bluetooth® 5.2 reference design
- Texas Instruments, Bringing intelligent autonomy to fine motion detection and people counting with TI mmWave sensors
- Texas Instruments, Radar Sensors to Enable Smarter Homes, Cities and Lives
- Texas Instruments, The fundamentals of millimeter wave radar sensors
- Texas Instruments, Getting Started with xWRL6432

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