

# Designing Smart, Energy-efficient Air Conditioning Using TI mmWave Occupancy Sensors



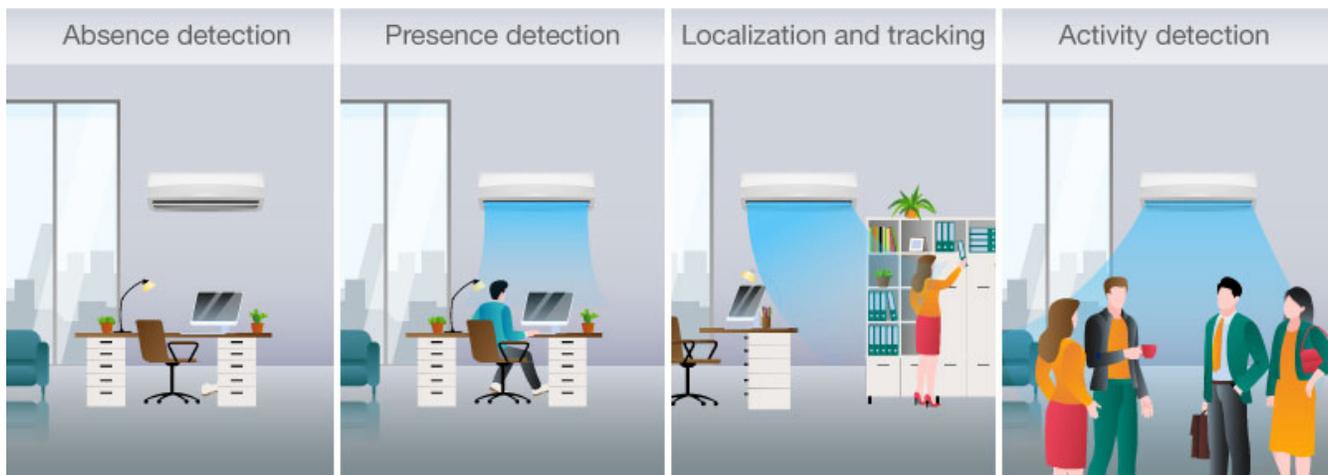
Abdulraheem Killedar

More than ever, as people in both developed and developing countries rely on air conditioners (ACs) for a comfortable living space, there's been a rapid increase in energy consumption.

According to “[The Future of Cooling](#),” a report from the International Energy Association, ACs account for 10% of the total energy consumed today. This usage is expected to triple by 2050, which is equivalent to the current combined electricity capacity of the United States, European Union and Japan. The number of ACs in residential and commercial buildings globally will grow to 5.6 billion by 2050, compared to 1.6 billion today. This amounts to 10 new ACs sold every second for the next 30 years.

## The role of occupancy sensing with ACs

Human occupancy sensing can make ACs smarter and more energy-efficient by adapting to in-room activity levels and directing airflow where it's needed most. [Figure 1](#) illustrates a few scenarios where feedback from occupancy sensing like presence/absence, activity and people position detection helps conserve energy and makes environments more comfortable by modulating room temperatures and directing airflow toward room occupants.



**Figure 1. Scenarios depicting how feedback gained from occupancy sensing determines AC usage**

Passive infrared sensors and camera solutions are two technologies used in AC occupancy sensing. Passive infrared sensors are low cost and consume little power, but have higher false-detection issues in bright daylight and lack sensitivity to fine motion. In contrast, cameras offer the highest resolution available, but have the potential for higher instances of false detection, particularly with shadows and pictures of humans.

While occupancy sensing is being adopted to achieve energy savings, the industry is moving towards making ACs more intelligent with edge processing. Apart from controlling the AC operation for user comfort with presence detection, the movement towards a single sensing technology is ongoing. In the future, ACs will integrate additional features for user safety monitoring such as fall event detection and vital sign monitoring, including heart rate and breathing rate.

## Advantages of millimeter-wave sensors for occupancy sensing

TI millimeter-wave (mmWave) sensors provide a rich data set with precise range, velocity and direction of arrival information for each object in the area of interest. With a digital signal processor (DSP) performing object detection, classification and tracking, it becomes possible to derive people occupancy information such as presence, absence, count and the precise position of people relative to an AC unit. The AC unit can use this information to make intelligent decisions; for example, when a person enters the room, the sensor tracks the presence of that person for a minimum preset duration before turning on. If they remain in the room, using tracking/localization information, the AC can direct airflow to that person for comfort. Based on the number of people in the room, the temperature of the AC will adjust accordingly for maximum comfort and energy savings.

Beyond the accuracy and precision of data, TI's mmWave sensors provide many advantages when creating smart and energy-efficient AC solutions, including:

- Reduced false detection.
- The ability to function in harsh environments.
- Aesthetically pleasing product designs and small sensor sizes.
- Reduced privacy concerns due to sensing technology instead of camera use.

## Enabling intelligence at the edge

TI mmWave 60-GHz sensors integrate a frequency-modulated continuous wave transceiver, an on-chip monitoring and calibration mechanism, an Arm® Cortex®-R4F microcontroller, and C674x DSP on a single chip. This integration enables intelligence on a highly integrated sensor with real-time data processing on the device itself.

[One sample application](#) uses TI's IWR6843 60-GHz mmWave single-chip sensor to implement occupancy sensing for commercial and residential ACs. The sensor processing the data uses Capon beamforming for people detection and is smart enough to classify objects to minimize false detections. This sample application demonstrates the +/-10cm detection accuracy for people, both moving and stationary, for up to eight meters indoors. The people count accuracy is 100 percent for less than five people and 85 percent for up to nine people in the room with a count density of three people per two meters.

In the near future, ACs will become entirely self-reliant, data-based systems with no need for remotes or human interaction through an AC control unit. The sensing technology in ACs will constantly gather data to optimize comfort. For example, over time in an office setting, the sensor will determine that the highest amount of people are in office from 9 AM to 5 PM. Based on this data, the system will learn to direct more air during busier times and limit or turn off airflow during non-peak times, leading to less energy consumption which will save the business money.

As demand for residential and commercial ACs continues, tripling by 2050, occupancy sensing using mmWave technology may reduce overall AC energy consumption by as much as 35%. As we move to the future, mmWave technology will continue to have a greater impact on not only the way that HVAC systems operate, but the reduction of overall emissions into our environment.

## Additional resources

- Check out the [People Counting and Tracking Reference Design Using mmWave Radar Sensor](#).
- Read the white paper, "[Bringing Intelligent Autonomy to Fine Motion Detection and People Counting with mmWave Sensors](#)."

## 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