# Using Ultrasonic Technology for Smart Parking and Garage Gate Systems

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## Introduction

Automated parking guidance systems help drivers detect whether a parking spot is occupied or vacant, which can save the driver unnecessary search time to find an available spot.

Both drivers and cities benefit from these parking guidance systems because these systems can reduce traffic congestion caused by drivers looking for parking spaces. When a parking spot is vacant in a garage or parking lot, the guidance systems can also maximize the revenue of a paid parking area by alerting drivers about the open spot.

One way to detect whether a parking spot is empty or occupied is through contactless ultrasonic technology, as it is reliable in harsh outdoor environments. Gates to garages can also employ ultrasonic technology to make the ticketing process fully automated.

## Ultrasonic Theory of Operation

Similar to how bats use echolocation to determine the distance of objects while navigating in-flight at high speeds, ultrasonic sensors use high-frequency sound waves that are inaudible to human hearing to determine the distance between the sensor and the object. Figure 1 shows how ultrasonic technology detects objects through reflected sound waves.

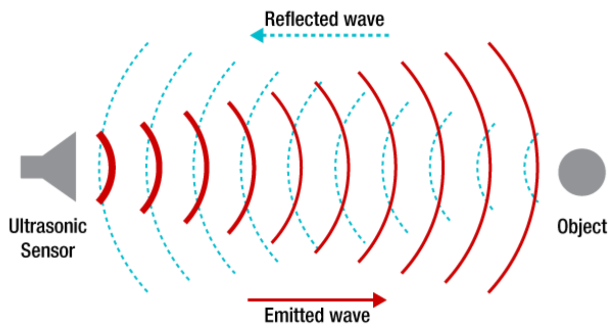


**Figure 1. Ultrasonic Sensor Theory of Operation**

Designers should consider multiple parameters of ultrasonic theory, such as frequency and temperature, when determining distance and gathering accurate results. As frequency increases, the resolution, directivity, and attenuation increase while the measurable distance decreases. The speed of sound is affected by the temperature of the medium the sound waves travel through.

The speed of sound increases in hot environments, but slows down in cooler environments. Equation 1 shows how temperature affects the speed of sound.

$$\text{Speed of Sound}\left(\frac{m}{s}\right) = 331\left(\frac{m}{s}\right) + .6\left(\frac{m}{s°C}\right) \times \text{Temperature}(°C) \tag{1}$$

## Transducer Mounting Considerations

Designers should consider the environment of the parking location before they mount transducers.

For indoor parking lots, TI recommends to mount the transducer face-down on the ceiling above the parking space. Mounting the transducer on the ceiling eliminates the worry of vehicle load, because the cars will not drive over the sensor. It also simplifies installation and wiring because there is no need to drill holes in the ground for these transducers.

Outdoor parking lots typically do not have ceilings, however, and these areas are exposed to harsh environments. TI recommends to mount the sensors face-up on (or embedded in) the ground. A transducer must be able to withstand different elements of nature, which calls for a closed-top transducer.

Designers can also integrate these sensors into garage gates to detect vehicles entering and exiting the garage due to the robustness of ultrasonic technology in outdoor environments. Figure 2 shows how the transducers were mounted for these experiments.

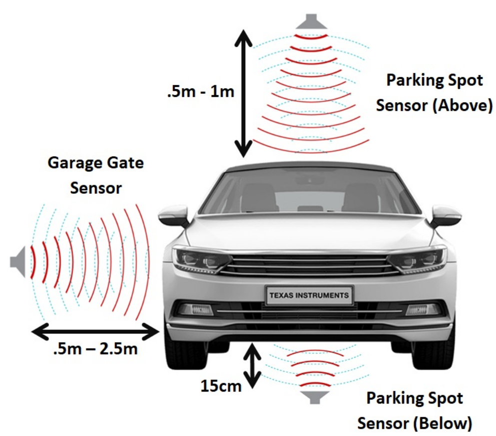


**Figure 2. Mounting for Vehicle Detection**

### Field of View

The average width of car parking spaces in America is between 2.3 m to 2.75 m, and the average width for motorcycle spaces is 1.2 m. The sensor must be able to detect a car or motorcycle within the intended space and not detect the neighboring spaces. Therefore, TI recommends to use a transducer that has a narrow field of view.

The PGA460 ultrasonic transducer driver and signal conditioner was used for these experiments, paired with the MuRata MA48MF14-7NN and Steminc SMATR400H99XDA transducers that have a directivity of 80° by 35° and 3° by 3° (H° × V°), respectively.

### Vehicle Detection Using Ultrasonic Sensors

When a vehicle comes into view of the ultrasonic sensor, an echo response is observed. Figure 3 shows how the Steminc SMATR400H99XDA performed when mounted underneath a vehicle with a ride height of 15 cm.

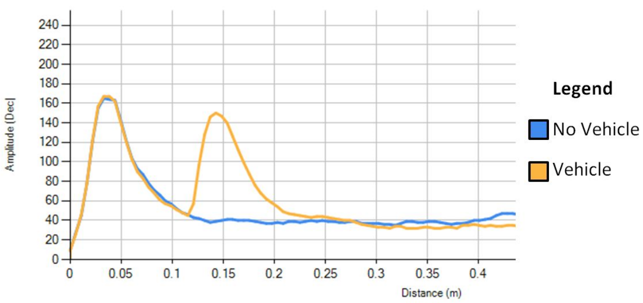


**Figure 3. Occupancy Detection Below Vehicle**

Figure 4 shows how the MuRata MA58MF14-7N was able to detect a car when mounted 0.5 m and 1 m above the vehicle. In a separate experiment using the same configurations, the sensor was able to detect a motorcycle at a distance of 1 m.

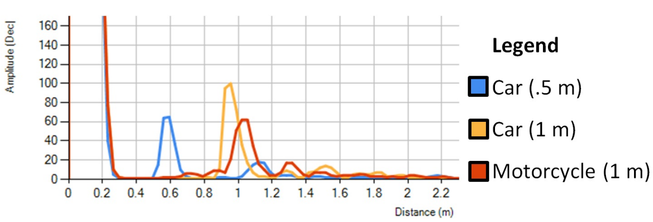


**Figure 4. Occupancy Detection Above Vehicle**

### Garage Gate Sensors

When exiting a parking garage, there is usually an arm that raises and lowers when a vehicle is within view. Ultrasonic technology is ideal for this application because of the high reliability of detection, despite harsh outdoor conditions.

The body of vehicles are typically made of recycled steel, which is a material that allows sound waves to reflect off effectively. However, because some vehicles have grooves, some of the sound waves may be deflected in unintended directions.

Figure 5 shows how the MuRata MA58MF14-7N was able to detect the vehicle at different distances ranging from 0.5 m to 2.5 m.

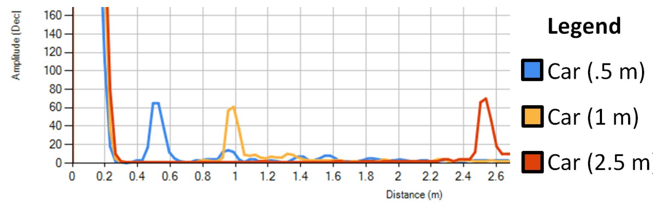


**Figure 5. Vehicle Detection For Garage Gate**

### Power Consumption

Because these systems will operate throughout the day, it is important to take power consumption into consideration. To conserve energy, the system should sample the parking space in intervals rather than continuously. By using USART/SPI communication, the system can quickly sample and yield results while providing a power-efficient solution, since each sample interval requires 10.047 ms to power on, communicate with the transducer, and receive incoming data. Figure 6 shows data collected from the PGA460 GUI. Notice how cutting power to the device after the burst-listen interval reduces power consumption.

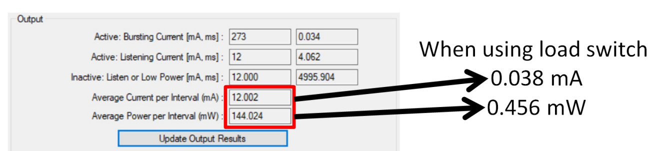


**Figure 6. Power Optimization**

### Device Recommendations

The transducers will be exposed to harsh conditions regardless of the parking lot they are implemented in, therefore TI recommends that designers use a closed-top monostatic transducer with the PGA460 for reliable detection results. Table 1 includes a list of collateral resources to help ensure proper usage of the BOOSTXL-PGA460, along with compatible transducers. For more information, go to ti.com/ultrasonic.

**Table 1. Recommended Collateral**

| COLLATERAL | DESCRIPTION |
|---|---|
| Application Note | PGA460 Ultrasonic Module Hardware and Software Optimization |
| Quick Start Guide | PGA460-Q1 EVM Quick Start Guide |
| Excel Spreadsheet | PGA460: Air-Coupled Ultrasonic Transducers & Transformers Listing |

## IMPORTANT NOTICE AND DISCLAIMER



Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265