

Occupancy Detection Using Passive Infrared-Based Technology



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ABSTRACT

Current occupancy detection solutions tend to employ complex systems such as mmWave radar to detect stationary objects. Passive Infrared (PIR) technology, while simpler, can reliably detect motion but struggles detecting stationary objects. This application note explores using a mirror to simulate motion to create a PIR-based system capable of occupancy detection.

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1 Introduction

Passive Infrared (PIR) technology is currently widely used for motion detection applications due to the low power consumption and cost of this technology. However, when it comes to occupancy detection, most systems tend to employ more complex solutions, such as mmWave radar, due to the ability of mmWave radar to reliably detect stationary objects.

The challenge with PIR technology is the reliance on motion, because the sensors cannot detect stationary objects on their own. The PIR-based occupancy detector solves this problem by using a system of a motorized mirrors to feign movement of stationary targets to provide reliable occupancy detection.

2 Technical Overview

PIR-based technology relies on the movement of heat across a field of view. Two pyroelectric elements arranged with opposing orientations create an AC voltage response as an object moves in front of the elements.

Figure 2-1 demonstrates the produced AC signal from a PIR sensor that detects movement. As an object passes in front of the first sensor, a negative response is generated, and a positive response is generated as the object passes in front of the second sensor. The direction of the subject changes which response is generated first. In addition, the distance of the object changes the amplitude of the signal, with a subject that is farther away generating a smaller signal, effectively limiting the range of a sensor. The speed that the object passes in front of the sensor determines the frequency of the signal, being higher with faster moving objects.

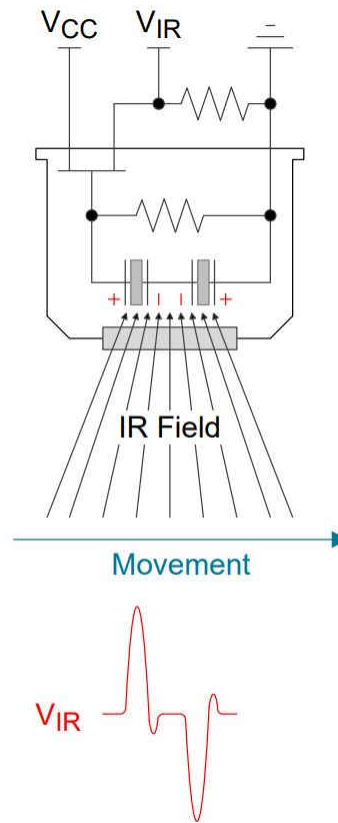


Figure 2-1. Voltage Response of Movement in Front of a PIR Sensor

Since a PIR sensor effectively uses two separate sensors to generate a voltage response with motion, this makes the PIR sensor a cheap and effective use for detecting moving objects. However, there are significant challenges that come from trying to detect stationary objects. Namely, a stationary object cannot generate any detectable response. However, with the use of a mirror, motion can be feigned, *tricking* the PIR sensor into detecting a stationary object as moving.

This can be done by pointing a PIR sensor at a mirror and rotating the mirror across a field of view, similar to [Figure 2-2](#).

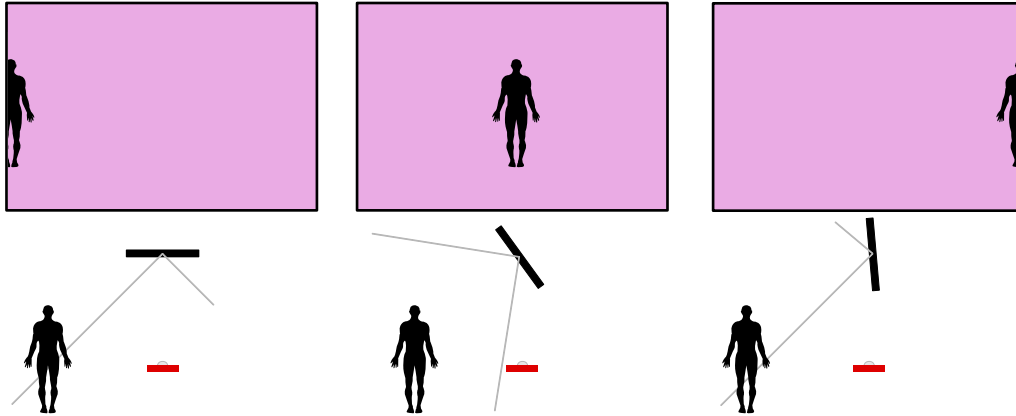


Figure 2-2. Infrared Images of a Stationary Object Being Swept With a Rotating Mirror

[Figure 2-2](#) demonstrates that through this method the PIR sensor detects a still object panning across the field of view. This is enough to trigger a differential response from the sensor, and can be used to detect stationary subjects.

3 Block Diagram

[Figure 3-1](#) shows the main components of a PIR-based occupancy detector system; the PIR-sensor itself, a motor to move the mirror, an MCU to control both, and a way to provide power. The [Section 4](#) section describes the reasoning behind the selected parts.

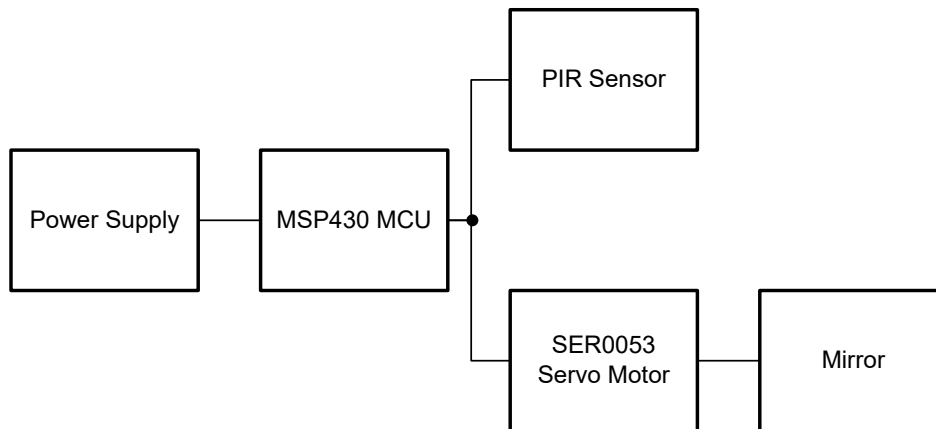


Figure 3-1. System Block Diagram

4 Part Selection

While the system consists of relatively few parts, consideration had to be made about the cost and power consumption of the components. First, the selected MCU is the MSP-EXP430G2ET. The MSP430 platform was considered an excellent choice for this application due to the low cost and ease of use. The DFRobot SER0053 was selected as the motor due to the PWM interface, low power consumption, and low cost. Additionally, the low current draw of the motor means that a dedicated motor driver was not necessary, further reducing the cost and complexity of the system.

The PWM interface allows for precise positioning by varying the duty cycle. On this motor, one duty cycle corresponds to one position. For example, a duty cycle of 1% corresponds to 0° of rotation, while a 50% duty cycle corresponds to 150° of rotation. Other servo motors considered are controlled by the applying voltage to one of the two pins on the motor. A high voltage applied to the clockwise pin results in a fast rotation clockwise, while a lower voltage applied to the counterclockwise pin produces a slower motion in that direction. While simple, this makes accurately positioning the motor, and therefore the mirror, significantly more difficult.

For powering the device, there are two options: line and battery. A rechargeable battery increases the price of the unit and adds the issue of battery life, but makes the device significantly more portable and easier for home use. For the battery life calculations in the [Power Consumption](#) section, a 3.2-V, 1.5-Ah rechargeable lithium iron phosphate battery was chosen. This offers a good battery life at an economical price.

5 Stationary Target Detection

The test procedure used focuses on two different scenarios at a variety of distances. The Field of View (FOV) of the device is limited. This is because as the mirror rotates in front of the sensor, the visible portion of the mirror becomes less due to the angle of the mirror. Therefore, two scenarios were tested, one with the target directly in the middle of the FOV of the device, and one with the subject at the edge.

For all testing, the mirror was rotated constantly through the entire range of the mirror at a rate of 3.24 seconds to rotate to the maximum extent of the mirror and back.

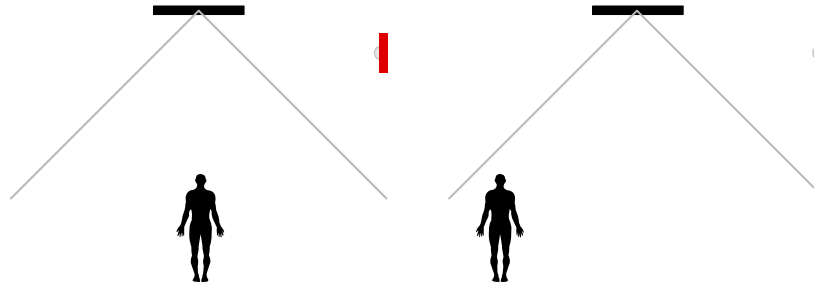


Figure 5-1. Normal Angle (Left) and Wide Angle (Right)

A baseline test of nothing in the field of view was performed. The baseline test in [Figure 5-2](#) shows that the sensor correctly identified zero people in the FOV, because no voltage response was produced.

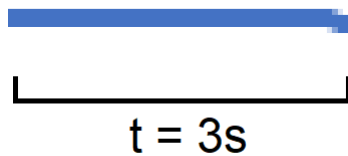


Figure 5-2. Baseline Test Voltage Response

The next test performed was with a subject in the middle of the FOV of the device. [Figure 5-3](#) shows that a stationary subject up to 10 ft produces a consistent voltage response in the PIR.



Figure 5-3. Object in Middle of FOV at Ranges of 4, 8, and 10 ft From Left to Right

Two tests were performed with the subject at the edge of the FOV of the sensor, one at 5 feet, and one at 8 feet.

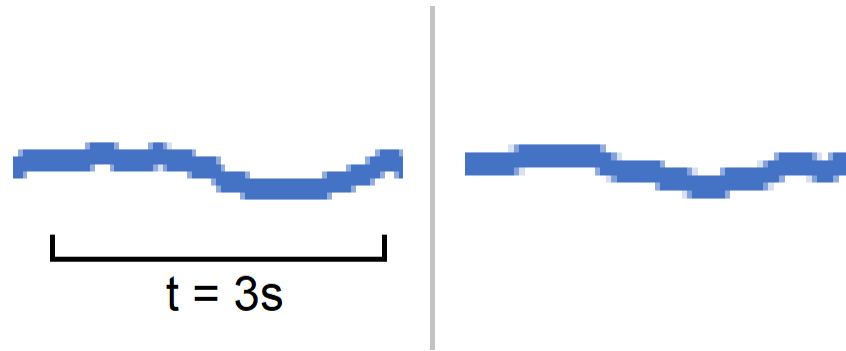


Figure 5-4. Subject at the Edge of FOV at Ranges of 5 ft and 8 ft, From Left to Right

The PIR sensor can still accurately detect a stationary object at the edge of the field of view up to a range of 8 feet. The use of larger mirrors can be used to increase the accuracy of the system, but at the expense of creating a larger form factor.

6 Power Consumption

While the PIR sensor itself consumes very little power, the required motor poses a challenge. The measured power consumption of the system with the chosen motor comes out to be 0.036 mAh per cycle. A cycle is defined as the mirror rotating in one direction to the extent of the field of view and then rotating back. This provides the PIR with two opportunities to detect the feigned motion. The 1.5-Ah battery discussed in the [Part Selection](#) section therefore allows for a total of 41,667 cycles under ideal conditions.

There are two simple ways to significantly reduce power draw: use a less powerful motor or reduce the rate of sweeps of the device. Due to the relatively light weight of the mirror and flat operating conditions (that is, the motor does not have to rotate the mirror against gravity), a low torque motor is the best choice. For example, the SER0050 is the high-torque counter part of the chosen motor, the SER0053. This motor has a 40% increase in rate torque, but at the expense of double the current draw at the same voltage.

The other solution to consider is how often the device is scanning for occupancy. While a battery has a fixed number of cycles for which it can power the device, optimal spacing for these cycles can significantly increase the operating period of a charge. The first thing to consider is when to actually start scanning for occupancy. Since the PIR operates based off of motion, it does not make sense to start scanning for occupancy until somebody has been detected moving into a room. This can be done by simply positioning the mirror at a desired angle, turning off the motor, and leaving the PIR sensor to detect motion as normal. Once motion has been detected, the motor can be activated and can continue sweeping until occupancy is no longer detected.

Once somebody has been detected entering a room, the frequency that the device scans for occupancy can be adjusted based on the desired accuracy and battery life. Using the previously-stated number of 41,667 cycles for a 1.5-Ah battery, with one scan per minute, a battery life of about 28.5 days when running 24 hours per day, 7 days a week can be expected. However, this is considered maximum use, since the device is unlikely to need to be scanning a room for occupancy at this frequency. A more typical use is scanning for occupancy for about 8 hours a day. This results in an expected battery life 86.5 days. As expected, using larger batteries significantly increases the lifespan of a charge, but is also more expensive. Alternatively, the device can be wired up to a line, negating the need for recharging, but at the cost of a trickier installation process. Since this data was captured using a basic prototype model, battery life can be extended further by using a custom design. This can include using a low power motor or a lighter mirror.

7 Conclusion

PIR sensors provide a means to detect occupancy of a room at a much lower cost than other technologies. This method overcomes one of the key design challenges with PIR technology and allows the design to expand more into building security uses. The flexible part selection of the system allows for a variety of industrial and home applications.

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