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Application Note

Ultrasonic and Passive Infrared Sensor Integration for Dual Technology User Detection Sensors

Executive Summary

The purpose of this application note is to inform the user about ultrasonic and passive infrared sensors and instruct the user on methods of integrating the sensors together to be put into a final application. First, an overview of both passive infrared and ultrasonic sensors will be given so the user may understand the different sensing technologies. Then the benefits of using the sensors in unison will be discussed. Finally, important considerations for integrating the two sensing technologies together and methods for integration will be given.

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Introduction

Over the years technology has been advancing at an exponential rate. As technology evolves, so too do the priorities of both manufacturers and consumers. Recently there has been an ever increasing focus on energy efficiency and energy conservation. Another growing trend in technology is the concept of home and workplace automation. These two fields often intersect with one another and are fields where user detection sensors, such as ultrasonic sensors and passive infrared (PIR) sensors, have found a niche. For example, in the copy room of the workplace there is no need to have the lights on while no one is in the room. However, the employees do not want to have to bother with walking to the light switch every time they enter or leave the room. Here, the use of user detection sensors will both conserve energy by turning out the lights when no one is around without sacrificing the convenience of not having to turn the lights on and off manually.

Sensor Background

This application note will deal primarily with sensor units rather than individual sensor components. That is, PIR and ultrasonic sensors which already contain the components and programming necessary for proper function as shown in the pictures below. On the left is the front and back view of a parallax PING))) Ultrasonic Sensor and on the right is the front and back view of a Parallax PIR Sensor. These sensors simply require a power supply, ground supply, and provide a signal out.

Figure 1: Parallax Ultrasonic Sensor

Figure 2: Parallax PIR sensor

Passive Infrared Sensors (PIR)

Theory of Operation

Infrared is a classification of electromagnetic radiation with a wavelength between roughly 700 nm to 300 μm. It is outside of the visible light spectrum but is emitted by all living beings and surrounding objects. It is often helpful to think of infrared in terms of radiated heat. In a PIR sensor, the sensing element is a pyroelectric device which generates a temporary electric potential when there is an increase or decrease in infrared radiation. The potential then disappears after the dielectric relaxation time allowing for continuous detection. A fresnel lens is then placed over the pyroelectric device to prevent false triggers, supply uniform sensitivity, and extend the field of view.

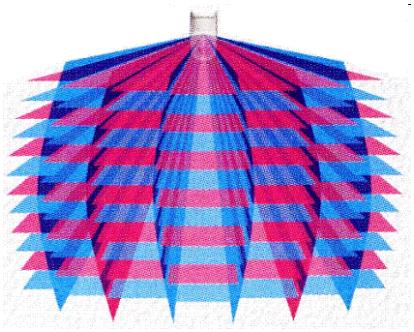

Figure 3: Fresnel Lens

The sensor's fresnel lens views its coverage area as a series of fan-shaped coverage zones, with small gaps in between like that shown figure 3 above. Movement between these zones is interpreted as user occupancy. It is most sensitive to motion that occurs between each zone lateral to the sensor. The farther one is from the sensor, the wider the gaps between these zones become, which decreases sensitivity proportional to distance. Most PIR sensors are sensitive to full body movement up to around 40 ft. but are only sensitive to hand movement, which is more discrete, up to about 15 ft. This is depicted below in figure 4.

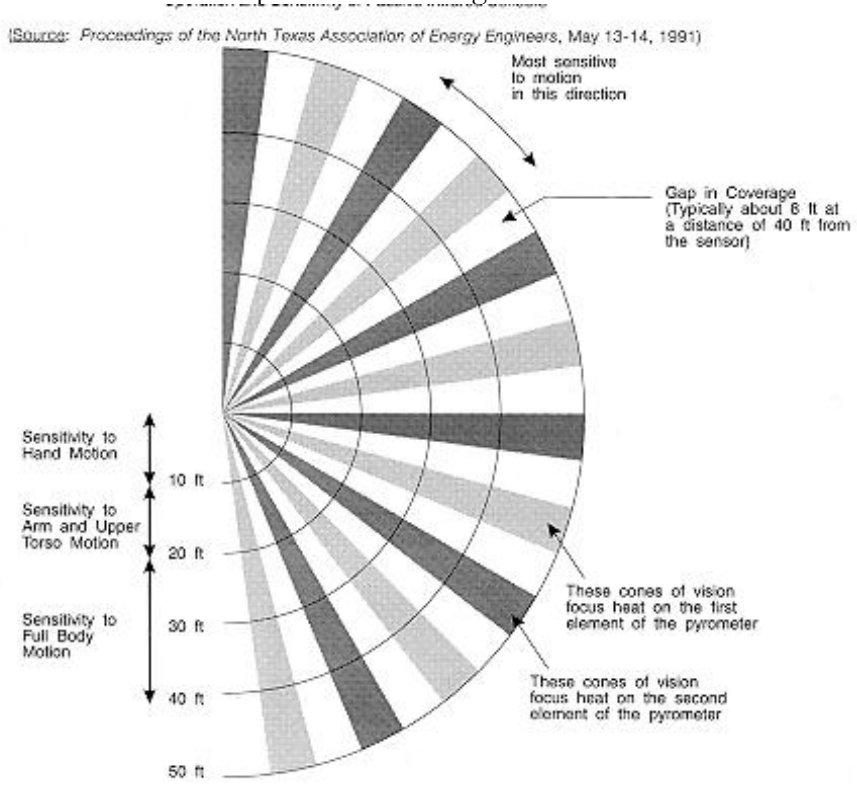

Figure 4: Operation and Sensitivity of PIR Sensors

Advantages

PIR have been used for many years as motion detectors due to their high reliability and resilience to false triggering. They are not adversely affected by airflow like some sensors can be. Also, due to their passive nature, PIR sensors are very low on power consumption and thus suitable for battery powered applications.

Disadvantages

While there are many advantages to a PIR sensor that make them an ideal choice for user detection applications, there are a few disadvantages to consider. PIR sensors require an unobstructed view of the occurrence of motion and cannot easily discern between humans and small animals. They are susceptible to "dead spots," which are areas where motion cannot be detected within the field of view. The farther one gets from the sensor the less sensitive it becomes. Also, PIR sensors cannot determine the distance of the user from the sensing device.

Theory of Operation

Ultrasonic sensors work in ways that are similar to radar and sonar utilizing the Doppler principle. A piezoelectric transducer converts electrical energy into an ultrasonic wave typically between 40-50 kHz. This high frequency sound wave, which is beyond the capability of human hearing, hits an object and is reflected back toward another transducer which converts the sound wave back into electrical energy. The distance of an object can be evaluated once this echo is received back using the following equation where d is the distance, c is the speed of sound, and t is the elapsed time of the signal

$$d = \frac{t \times c}{2}$$

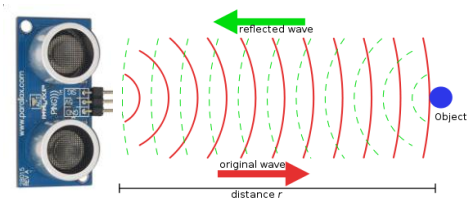

Figure 5: Ultrasonic Doppler effect

When the medium of propagation is air c is equal to 340.29 m/s. The control circuitry on the ultrasonic sensor can determine between stationary objects and objects in motion by interpreting change in frequency as motion in the space. Figure 6 below shows the operation and sensitivity for an ultrasonic sensor.

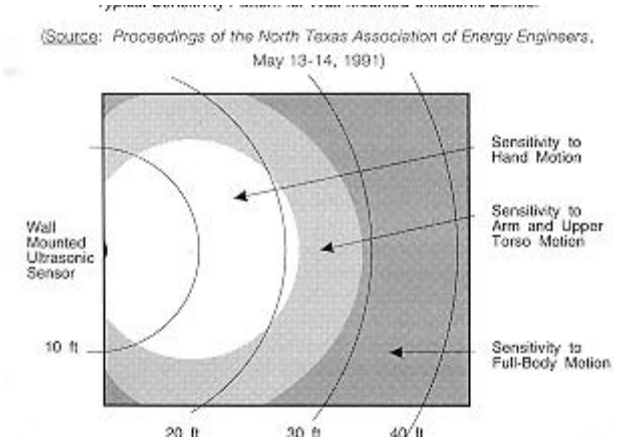

Figure 6: Operation and Sensitivity for an ultrasonic sensor

Advantages

Ultrasonic sensors do not have gaps in the coverage zone like a PIR sensor and can be sensitive to slight motions at nearly twice the distance. The overall detection range is comparable to that of a PIR sensor. The ultrasonic sensor also can detect motion behind partial obstructions. One of the key advantages of the ultrasonic sensor is the ability to calculate distance to the object in motion.

Disadvantages

One of the main advantages of the ultrasonic sensor is often one of the main disadvantages as well. Oftentimes the high sensitivity to ultrasonic sensors leads to false triggers. For example, excessive air motion from a fan or an HVAC system can cause the sensor to trigger.

Dual Technology Sensors

Dual technology sensors combine PIR sensors with ultrasonic sensors for maximum accuracy. The system will active either when both technologies detect motion or when only the PIR detects motion. This solves the problem of false triggers by the ultrasonic sensor due to things like air motion. However, the system will only deactivate when both technologies no longer sense motion. This solves the problem of the PIR sensor's lack of sensitivity to slight motions. The redundancy in detection method virtually eliminates the possibility of false-on and significantly reduces the possibility of false-off.

Integration of Dual Technology Sensor

When deciding to integrate ultrasonic sensors and passive infrared sensors into a single application there are some important things to consider. First one must figure out the different components that will be needed. Next, one has to choose their components and ensure compatibility with each other and the application.

Components Needed

The components needed when integrating an ultrasonic sensor and a PIR sensor will vary from application to application, however there are some basics. First and foremost, one will need both an ultrasonic sensor unit as well as a PIR sensor unit. In order to interface the sensors together, a microcontroller is needed; this will be the heart and brains of the system. Additionally, one may want to choose some wireless transmitters and receivers if he or she wishes to communicate the detection information to another location. One may also choose to have LEDs as indicators of motion or an LCD display user positions. Finally, proper housing for the sensors and its components are necessary.

Important Considerations

What will the power supply be?

One of the first things that must be considered before settling on final components is the power supply. If the final application is to be run off of battery power, one must look for sensors with low standby and active power consumption. Low active power consumption may not be as important in applications that will remain primarily in standby mode. Also one must decide how often he or she would be willing to change batteries. If the power supply will be a wall outlet, one must be careful to not exceed the power ratings of the sensors and microcontroller which is typically around 5 volts.

What are the cost constraints?

Cost constraints must be considered in every application. One must always choose a sensor within the cost constraints of the project. It's also important to remember that the energy efficiency of product often weighs heavily in the overall cost.

Where will the unit be used?

One must ask themselves what environments the sensors will be used in. Applications for outside use have different considerations than those for inside use such as robustness for weather and extreme temperatures. For example, the signals returned to the transducer of an ultrasonic will be affected by the temperature of the air. Also, PIR sensors are sensitive to drastic temperature changes, such as varying sunlight. The enclosure of the sensor must be designed so that the sensor is protected but the functionality is maintained. Some other considerations are room size and placement, and objects that may obstruct the field of view.

Compatibility

Finally, one of the most important considerations is compatibility amongst all chosen components. Certain sensors may not be compatible with some microcontrollers. To keep cost low, and the application as simple as possible, one must be sure all components will work together.

Sample Integration

For an example of integration using an ultrasonic and PIR sensor into a dual technology application the Parallax PING))) Ultrasonic Sensor and Parallax PIR Sensor will be used. Documentation on these sensors and example code can be found at the Parallax website www.parallax.com. These sensors were chosen because they are compatible with Basic Stamp microcontrollers which means they are also compatible to PIC microcontrollers, which are highly popular and widely documented. All three components run off of a 5 volt power supply.

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