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Application Note

A Guide to IR/PIR Sensor Set-Up and Testing

Instructions, Limitations and Sample Applications

Executive Summary

This paper provides an overview of Infrared (IR) sensors and Passive Infrared (PIR) sensors and how they are used. It starts by discussing the set-up procedures. It then indicates the limitations that might be encountered. It concludes by providing examples of IR/PIR uses in applications. When examples are needed, it will focus on the features of the Sharp GP2D12 Distance sensor and Parallax PIR Motion Sensor.

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Infrared Sensors and Passive Infrared Sensors Characteristics and Applications

Keywords:

Infrared (IR) sensor, Passive Infrared (PIR) sensor, triangulation, Fresnel lens, body sensing, sensor applications.

Introduction:

Today, as the IR sensing technology evolves, the sensors also come in various system designs. Active Infrared (IR) sensors can be an emitter and detector as a single unit operating at the same wavelength, or photoelectric sensor working with reflective surfaces. IR sensors can be categorized as retro-reflective sensors and diffuse reflection sensors. Retro-reflective sensors are more proper for harsh environment conditions and have much larger detection range than the diffuse reflective sensor. However, their durability takes their price range higher than diffuse sensors, as well. Sharp GP2D12 functions with the diffuse principle, which is detecting the object by direct reflection off the object for distance measurement and motion detection.

Passive Infrared (PIR) sensors are also known Pyroelectric Infrared sensors are ideal sensors because while they operate, their presence cannot be detected as in the active sensor cases. They detect difference in temperature, thermal radiation, in the environment caused by human body or an animal (Equation 2). PIR sensors are mostly used in integrated circuits. Parallax PIR Motion Sensor will operate as a human motion detector, and convert the detected infrared signal to electrical output signal to use in the integrated circuit system.

The Infrared and Passive Infrared sensors act as a transducer since they both take infrared signal as the input signal and convert it to analog electrical output signal. To understand the internal detection process, each sensor's circuitry drawings are illustrated in Fig. 1 and Fig. 4.

Technical Information and Test Instructions:

In this section, the specifications and the detection operation set-ups of Infrared and Passive Infrared sensors will be covered. The developments in the sensor field have changed many characteristics of the IR and PIR sensors. The IR sensors improved their immunity against the light changes and object colors with better circuitry design, and new PIR sensors with larger detection ranges came out. The specifications of the sensors are shown below, following the specifications table; the sensors' operation set-ups are described with the recent data updates.

1.1. IR Sensor:

1.1.1. Sharp GP2D12 IR Distance Sensor Specifications:

Table 1:

Parameter	**Symbol**	**Rating**	**Rating (recommended)**
Supply voltage	V_{CC}	-0.3 to +7 Volts	+4.5 to +5.5 Volts
Output terminal voltage	V_O	-0.3 to (V_{CC} +0.3) Volts	
Detecting Distance	ΔL	10cm to 80cm	
Dissipation current	I_{CC}	Max. 35mA	33mA
Operating temperature	T_{opr}	-10°C to +60°C (= +14°F to +140°F	25°C - 77°F
Storage temperature	T_{stg}	-10°C to +60°C	
Output type		Analog voltage	
Typical start up delay	t_s	44 ms	
Typical response time	t_r	39 ms	
Detection area diameter		6 cm at 80 cm	

1.1.2. IR Sensor Testing:

iv. Connect the IR sensor to the breadboard using an IR interface cable with 3-pin header. Connect **Ground** to the – pin, **Power** to the + pin of the PIR sensor.
v. Connect one red LED to the **OUT** pin of the sensor. Make sure the LED is oriented the right way.
vi. Connect a resistor within the range of 0.1K -1KΩ from the other end of the LED to **Ground** (The LED and the resistor can switch positions).
vii. To expand the detection range, two LEDs could be connected to the OUT pin of the sensor, one red and one green LED, each one with a resistor.
viii. Connect your power supply to the breadboard. The recommended power is within the range of +4.5 - +5.5 Volts.
ix. Fix the sensor to a table or wall so that it has 180 degrees of detection range.
x. Check your circuit, and turn on your power supply to test the IR distance sensor.
xi. Wait for approximately 44 milliseconds for the IR to start up. If the LED is on, please wait until the LED turns off, as well.
xii. Place an object within the sensor's detection range. If the LED turns on, the sensor should have gotten the reflection back to its detector resulting in voltage change. If the LED does not turn on, please go back to the circuit and check again.

1.1.3. IR Sensor Controlling:

xiii. Use the IR interface cable to connect IR sensor to the microcontroller hooking up the – pin to **Ground**, the + pin to **Power** , and **OUT** pin of the sensor to the I/O pin of the microcontroller (Table 3)

xiv. Set power supply to +5V, and power the microcontroller. Also, connect its ground pin to ground of the power supply.

- ❖ Mark several spots within the detection range and at various angle and distances, and check the detection capability of the IR sensor.
- ❖ The microcontroller keeps track of the state of the IR sensor. With the ADC feature of the microcontroller, the sensor could be programmed. By the software, the sensor's sensitivity could be improved.

➢ **Ideal IR Sensor Operation:** An Infrared sensor operates with a pin photo-detector with an X circuit to Y as shown in Figure 1. Infrared sensors detect object distance changes with infrared radiation. The operation starts by emitting a pulsed light beam from the transmitter and sending it back out to the scanning field. When the beam strikes an object, the infrared beam is interrupted. Thus, the light beam returns to the receiver with an angle after the reflection, then the receiver sends a high output signal. The method of triangulation is shown in Fig. 2.

Fig. 1: IR Sensor: The internal Circuit Architecture

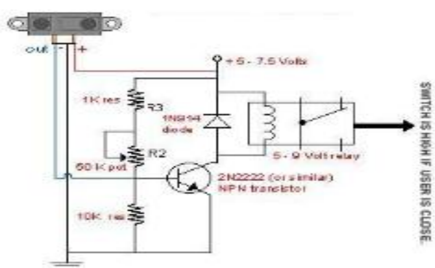
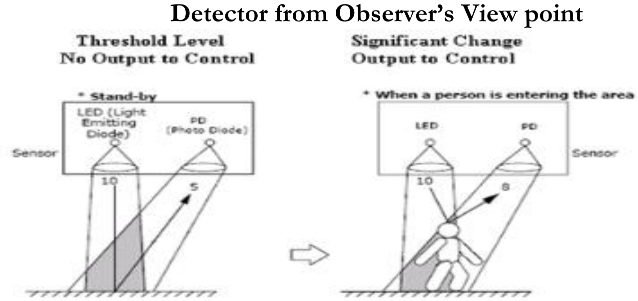


Fig 2: IR Sensor Object Detection: Detector from Observer's View point



Equation 1: **IR sensor Triangulation Technique:** $l = \frac{d}{\tan\alpha} + \frac{d}{\tan\beta} \longrightarrow d = l \,/\, (\frac{1}{\tan\alpha} + \frac{1}{\tan\beta})$

1.2. PIR Sensor:

1.2.1. Parallax PIR Motion Sensor Specifications:

Table 2:

Parameter	**Symbol**	**Rating**
Supply Voltage	V_{CC}	3.3 to 5 VDC at 100μA
Output terminal voltage	V_O	~ 3.3 VDC at 5VDC
Detection Distance	ΔL	20 feet
Operating Temperature	T_{opr}	+32 to +158 °F (0 to +70 °C)
Output type		Analog
Typical start up delay	t_r	10 – 60 sec

1.2.2. PIR Sensor Testing:

i. Wire the PIR sensor to the breadboard making sure that **Ground** goes to the – pin, **Power** to the + pin of the PIR sensor.
ii. Connect one red LED to the **OUT** pin of the sensor. Make sure the LED is oriented the right way.
iii. Connect a resistor within the range of 0.1K -1KΩ from the other end of the LED to **Ground** (The LED and the resistor can switch positions; the drive current of the LEDs will enable the user to modify the sensitivity).
iv. Connect your power supply to the breadboard. The recommended power is within the range of +3.3 - +5.0 Volts.
v. Secure the sensor to a table or wall so that it is facing parallel to the scanning surface.
vi. Check your circuit, and turn on your power supply to test the PIR motion sensor.
vii. Wait for 10 to 60 seconds for the PIR sensor to calibrate itself. If the LED is on, please wait until the LED turns off, as well.
viii. Now, make a movement in front of the sensor, if voltage values change, and the LED turns on when there is a movement; the sensor detects the motion. If there is no detection, please go back to the circuit and check again.

1.2.3. PIR Sensor Controlling:

ix. Wire the PIR sensor to the microcontroller making sure that **Ground** goes to the – pin, **Power** to the + pin, and **OUT** pin of the PIR sensor to the I/O pin of the microcontroller. This could be done by a servo extension cable, as well (Table 3).
x. Power up the microcontroller with +5V and connect its ground pin to ground of the power supply.

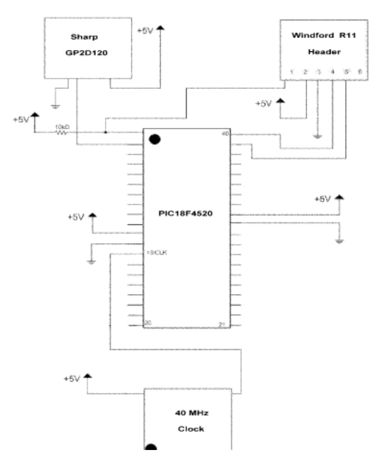
❖ Mark several spots within the detection range and at various angle and distances, and check the detection capability of the PIR sensor.
❖ The microcontroller enables the PIR sensor have a digital output by its ADC feature. When the trigger is left in the high position, the sensor will be retriggered every time there is a change in the PIR beam detection range. Thanks to the microcontroller, the duration of the retriggering could be modified.

- IR and PIR sensors can use the same type of interface cable with three-pin header since the same circuitry structure could be used for both of the sensors. There is sample circuitry diagram of the Sharp IR sensor. To implement the same operation, basically IR sensor could be removed from the circuitry and replaced with Parallax PIR sensor.

Table 3:

Red:	Voltage input: (V_{CC})	(+5V)
Yellow:	Voltage output: (V_O)	(< 2.5V)
Black	Ground: (GND)	(0V)

Fig. 3: IR/ PIR Sensor interfacing with Microcontroller:



- **Ideal PIR Sensor Operation:** The PIR sensor operates with the radiation of the body heat of the intruder as it changes the room temperature equilibrium within its detection area. The hotter the detected object is the more emission occurs in the Passive Infrared sensor. The Fresnel lens collapsed on the pyroelectric (i.e.: crystalline or ceramic material) chip generates electric charges with this electromagnetic radiation. As long as the motion remains continuous, the output voltage remains high.

Fig. 4: PIR Sensor: The internal Circuit Architecture

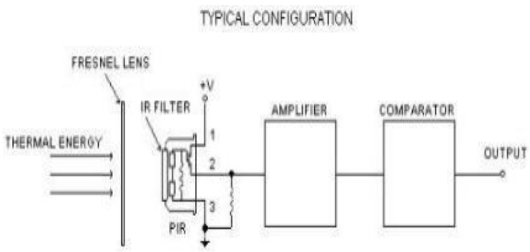
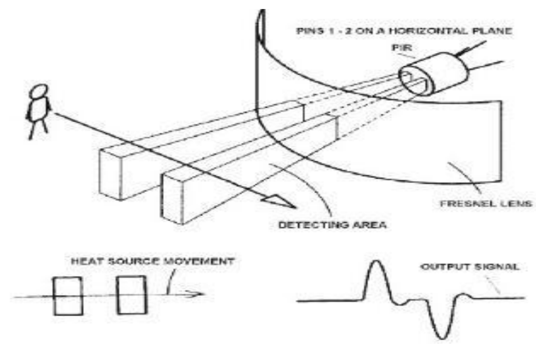


Fig. 5: PIR Sensor Detection: Detector from Observer's View point



Equation 2: Object Temperature Calculation: (based on Stefan-Boltzmann Law):

$$T_c = \sqrt{T_s^4 + \frac{\Phi}{A\sigma\varepsilon\varepsilon_s}},$$

[T_s = sensor's surface temperature T_c = object's temperature in Kelvin]

[Φ = magnitude of net thermal radiation flux Φ, ε = emissivity of the object]

The Limitations:

Performance of Infrared sensors has traditionally been limited by their poor tolerance to light reflections such as ambient light or bright object colors. The Passive Infrared sensors have had their own tolerance issues with temperature limit values. Currently, circuit designers are still working on overcoming these limitations. Below several advantages and disadvantages of these two sensor types are listed by looking at the two Sharp GP2D12 and Parallax PIR motion sensors.

IR Sensor: Sharp GP2D12 IR distance sensor:
Disadvantages:

- Dead zone between 0 - 4cm No object recognition any closer than 4 cm.
- No accurate detection results with transparent or bright colored materials
- IR distance detection sensor for solid-state and gas are two different units
- Detection accuracy loss with increasing reflection distance
- Change in detection results due to the differences in weather conditions
- Decreased the sensing reliability with moisture and humidity
- Heavy processor to convert the non-linearity of analog output voltage vs. reflective object distance curve

Advantages:

- Low power consumption with low lost
- Low dissipation current at OFF-state
- External control circuit unnecessary
- Good low-light sensitivity with high resolution
- Strong human recognition and identification
- Easy set-up and wiring procedure
- Microcontroller connection against the ambient light reflection sensitivity

PIR Sensor: Parallax PIR Motion Sensor:

Disadvantages:

- Long calibration time
- Specifically sensitive to thermal radiation
- Unequally sensitive to various distances of the detection range
- Insensitive to very slow motions or the object (i.e. a body) in standing mode
- Narrower sensor field view for high temperature range with less sensitivity
- Wider sensor field view for lower temperature range with distant object sensitivity

Advantages:

- Reduced product price
- Passive detection system unlike the radar systems
- Relatively low power consumption (less than IR sensor)
- Accurate detection in narrow areas with precision optics
- Compatible to work with microcontrollers
- Unobtrusive design and small size for its surrounding
- Improved noise and external light interference resistance for performance enhancement

The Operations:

In this section, active and passive Infrared sensors' operations are discussed including their specific application fields.

IR Sensor Operations:

Pulsed IR detection: High and Low duty cycle pulses will prevent ambient light effect on the sensor's readings. The design will be used in seeing the obstacles within the detection range. It is oriented to motion detection, robotics, alarm systems, auto light switches, and space applications.

Communication systems: IR sensing is used for the IR data transmission in the communication systems field. The light emitting LEDs that is placed in the remote acts as the transmitter and the LED in the appliance functions as the receiver side. Home appliances and consumer electronics with remote controllers are some of the application examples.

Automatic door presence sensor: The sensing technology is used to automatize the door by using the computer interfacing option. The infrared sensor senses when there is something in front of the door to open the door automatically.. Other than active IR sensor, PIR sensor is another way to provide this feature.

Transportation and traffic surveillance: For this application Inductive loop detectors (ILD) are the best choice regarding the harsh environment conditions. The purpose of the system is to gather data about traffic intensity and road occupancy. When a vehicle comes into the loop area, inductance of the system decreases due to the car's presence in the detection area. The system is composed of embedded wire loops connected to a control center. After the car detection, data is analyzed by a computerized traffic management system.

PIR Sensor Operations:

Thermal Imaging/Passive Infrared Imaging: Infrared sensor is modulated inside of a thermal imaging device that detects the thermal radiation of the object with a great accuracy and generates images of the received infrared radiation. The difference in the temperature will be seen on the image with various colors. Thermal imaging is used in security services such as airport customs control, fire department, industrial machine controls for heat leakages, and military equipment.

Infrared Homing: This application takes places in the missile guidance system. The tracking system works with the emitted electromagnetic radiation from the target. Target tracking is connected to heat radiation detection. This technique is very common for heat sensitive military equipment

Human body detection: When a moving human body enters the detection zone, the sensor generates a High signal. The emitted infrared radiation is sent from the human body is to the PIR sensor's receiver. Human detection systems are in demand for various applications such as automatic doors, security systems, medical purposes, surveillance and civil applications.

Flame Detection: Passive Infrared sensors detect the emitted light from the flames by observing the flame. Since emitted light of the flames will be varying within the entire electromagnetic spectrum, several other detectors will be involved for UV region, as well. PIR sensors are seen as the better option compared to point smoke and fire detector due to their wide detection range.

Conclusion:

This application notes covers the technical specifications of Sharp GP2D12 IR Sensor and Parallax PIR Motion Sensor. In addition to these two specific sensor choices, it informs about the general testing procedure, limitations, and applications of Infrared sensors and Passive Infrared sensors. In conclusion, the research of IR and PIR sensors shows that even though they have different designs there are many applications where both of the sensors could be an option interfacing with computerized systems.

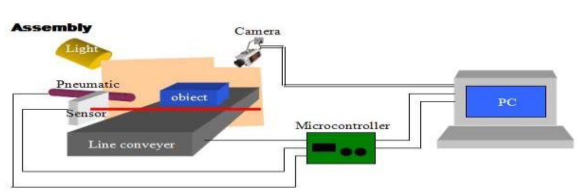


Fig. 6: Active/Passive IR Sensor Computerized Detection Operation:

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