

PROJECT REPORT ON PIR SENSORS

C.S.GOUTHAM
HARSHITH N.P
ARJUN KRISHNA

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INTRODUCTION

PIR sensors stands for passive infrared sensors. They work on the principle of pyro electricity i.e. they convert the infrared radiation received by the sensor into a small output voltage. They basically consist of four major elements – Fresnel lens, differential infrared radiation sensing element, amplifiers and comparators. Additionally, they may also have time delay circuitry. As the name suggests, passive sensors are the opposite of active sensors such as ultrasonic sensors in the sense that they do not emit energy of their own. Hence, they consume much less energy than active sensors. Pyroelectric passive infrared sensors are widely used in daily life. They are a key component in motion detection and can be used for security systems, automatic doors, or automatic light control. They are commonly used to detect humans. For example, when someone is detected in a specified area an alarm may be triggered or a specific room may be lit.

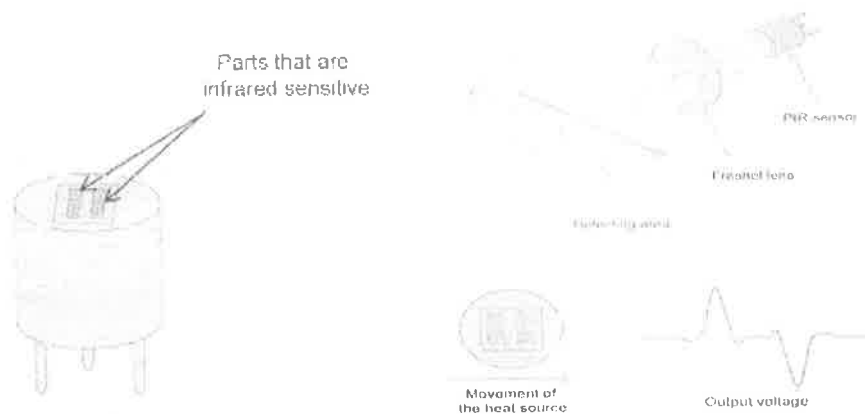
AIM

The purpose of this project is –

- To create a low cost and effective lighting solution based on human motion, overriding the need for manual switches.
- Conventional PIR sensors make use of human motion as a basis for triggering a lamp. This is a drawback if the lamp has to be triggered when a person is not in motion. This project aims at giving viable ideas to implement a human presence detector at a relatively low cost.

HOW THE PIR SENSOR WORKS

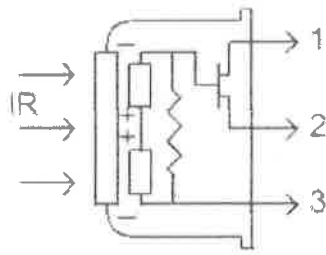
Everything on earth radiates infrared energy at all times. The amount of infrared radiation depends on various parameters such as temperature of the object, its colour etc. The infrared radiation sensing element has two pyroelectric elements mounted on it. If the infrared radiation emitted by an object as seen by the two pyroelectric elements amounts to be equal, then the output voltage provided by the sensor is zero. On the contrary, if the amount of infrared radiation as seen by the pyroelectric elements are different, then by virtue of this difference a small A.C voltage is given out which is centred around a D.C (the offset depends on the type of the sensing element used).



The figure above shows how the output voltage of the sensor varies as an object moves across it. The area of the two rectangles that is IR sensitive is small. Hence, it would be better to increase the IR sensitive area. This can be done in two ways –

- 1) By increasing the number of sensors
- 2) By using a Fresnel lens

The latter method is widely used as it is inexpensive and it multiplies the area visible to the sensor and focuses the reception of the infrared radiation onto the pyroelectric material.



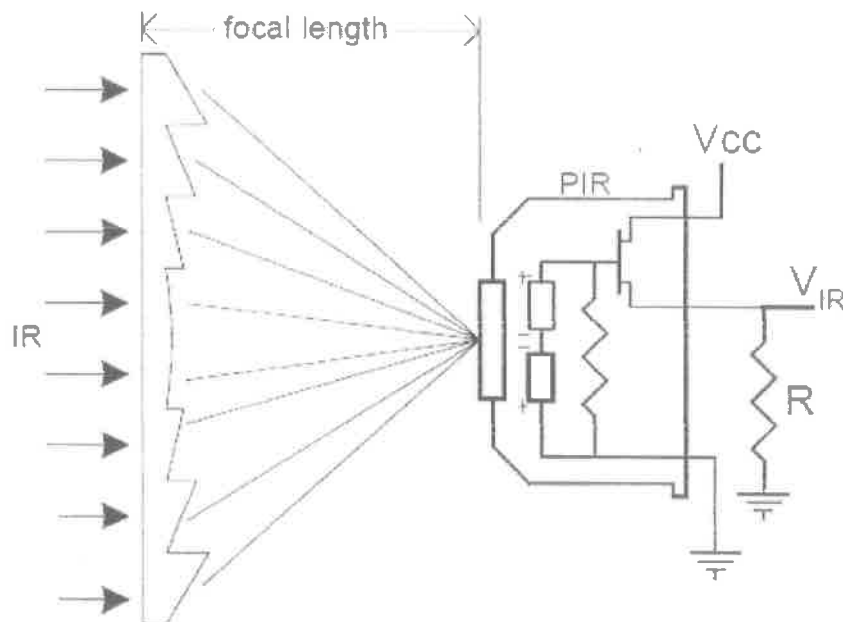
PIR

The dual element detector consists of an IR filter restricting the range of the infrared radiations coming into it within 5-15 micrometers in terms of wavelength. The two pyroelectric elements are connected together in series with their electric fields in opposite directions. The negative polarities of both the elements are connected via a pull down resistor. Terminal 3 (as well as the negative polarity of one of the elements) is connected to ground. Terminal 1 (the drain terminal of MOSFET) is connected to V_{cc} and the negative polarity of the other element is connected to the gate terminal of a MOSFET. The output is taken from terminal 2 which is the source of the MOSFET. Hence, motion in one direction across the sensor causes the output to move in one direction and motion in opposite direction across the sensor causes the output to move in the other direction.

FRESNEL LENS

The dual element detector, as it is, has a narrow field of view which is disadvantageous when we need to detect motion in any part of the room not restricted to the small field of view. The Fresnel lens is a special type of lens which is used to increase the field of view of the sensor. The Fresnel lens condenses light, providing a larger range of

IR to the sensor. It also focuses the radiations from around the room onto a particular point as shown.



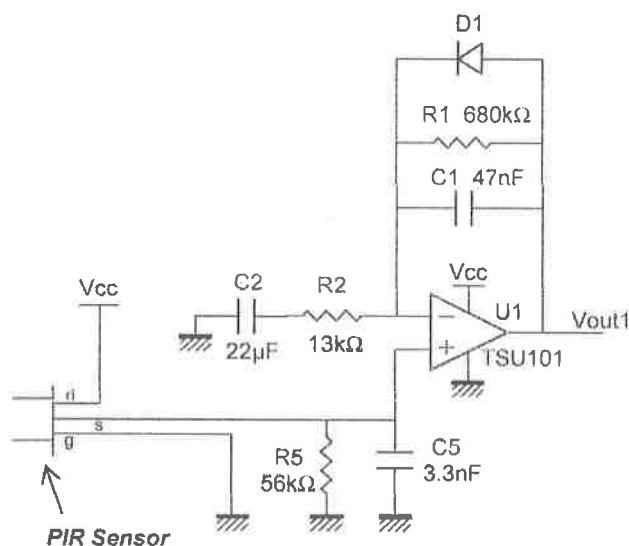
THREE STAGE ARCHITECTURE FOR DETECTING MOTION

The A.C signal produced by the sensor is very small to be of any use without amplifying it. Furthermore, it is superimposed over D.C signal which need not be amplified. Electrical noise, which is omnipresent in analog circuits needs to be eliminated too. For our study, we restrict the frequency of human motion across the sensing element to be between 0.6 Hz and 5 Hz.

Signals below 0.6 Hz are considered to be equivalent to D.C signal which need not be amplified. Signals above 5 Hz are considered to be noise signals and should not be amplified. Only signals whose frequencies are between 0.6 Hz and 5 Hz need to be

amplified. For this purpose, we resort to a three stage architecture where the first two stages are used for requisite A.C signal amplification and filtering techniques. The third stage is a comparator which makes use of two threshold values – a higher threshold value and a lower threshold explained in a later section.

FIRST STAGE



The PIR sensing element has three terminals – drain, gate and source. The drain is connected to Vcc. Gate is grounded and the output is taken from the source and given as input to the non-inverting terminal of the op-amp. A parallel RC combination (R5 and C5) is also connected to the non-inverting terminal of the op-amp with the other end grounded so as to hold the charge for some time. The output of the op-amp is fed back to its inverting terminal via three feedback elements – a diode (D1), a resistor (R1) and a capacitor (C1). A resistor (R2) is connected to the inverting terminal of the op-amp

whilst its other end is connected to a capacitor (C2) whose other end is grounded.

WORKING OF THE FIRST STAGE

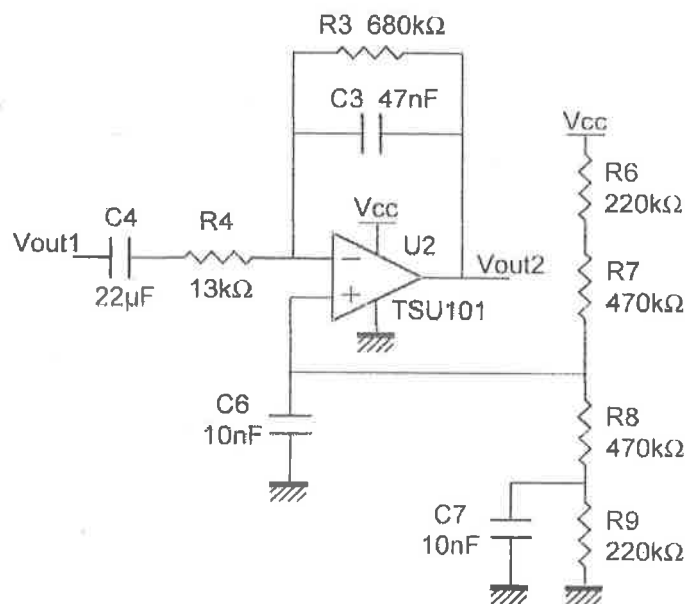
D.C signals cannot pass through capacitor C1 in the feedback network. Hence, they have two other paths through which they can flow – through resistor R1 or through diode D1. The D.C signals pass through the diode D1 since it is the path of least resistance. These signals, being D.C cannot pass through capacitor C2 and hence cannot flow through the path consisting of resistor R2 and capacitor C2. This is equivalent to the circuit appearing as a voltage follower for D.C signals. The output of the op-amp of the first stage is the same as the voltage at the inverting terminal (apart from the drop across the diode).

The peak value of the A.C signals produced by the sensing element are very small compared to the D.C voltage at the inverting terminal of the op-amp. The net result is that the diode D1 appears to be reverse biased for A.C signals. Hence, A.C signals cannot flow through diode D1 in the feedback network. They can flow through either of the other two paths in the feedback network i.e. through resistor R1 or through capacitor C1. The A.C signal can then pass to the ground depending on the conditions for which the path to the ground is established by virtue of capacitor C2 being open or closed.

The cutoff frequency for the R1-C1 network is $1/(2\pi R1 C1) = 5 \text{ Hz}$ and that for R2-C2 network is $1/(2\pi R2 C2) = 0.6 \text{ Hz}$. For frequencies of the A.C signals above 5 Hz, the impedance offered by capacitor C1 is zero. For frequencies of the A.C signals above 0.6 Hz, the impedance offered by capacitor C2 is zero. Hence A.C signals whose frequencies are above 5 Hz pass

through capacitor C1 and through C2 via R2 and finally passes to the ground. Ergo, these signals are not amplified since they do not pass through R1 and R2. For signals whose frequencies are below 0.6 Hz, capacitors C1 and C2 are open. The path to the ground is not established and hence, although the A.C signals pass through resistor R1, they cannot flow through resistor R2. This results in these signals not being amplified. Only those A.C signals whose frequencies are between 0.6 Hz and 5 Hz pass through R1 and R2 and are amplified $(1+R1/R2) = 53.3$ times.

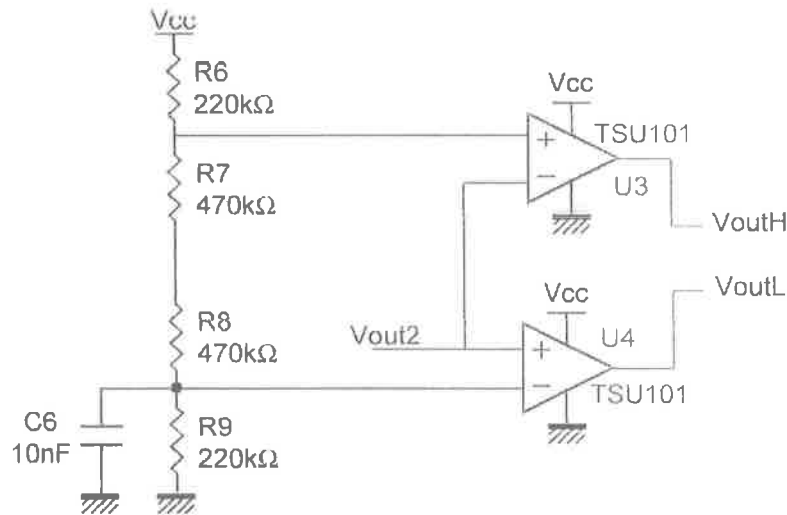
THE SECOND STAGE



The second stage is similar to the first stage. The output of the first stage is given as the input to the second stage. Only signals above 0.6 Hz are allowed to pass to the second stage and only the signals within the range of 0.6 Hz and 5 Hz are amplified $(R1/R2) = 52.3$ times. Hence, the overall magnitude of amplification due to the two stages for these A.C signals is approximately 2800 times. A voltage divider

network is used to provide some D.C offset which helps in ease of setting threshold values for the comparators which is the next stage.

THE THIRD STAGE



The threshold levels for the comparators are derived from the voltage divider network of the second stage itself. Op-amps itself are used as comparators. There are two threshold levels – the upper and the lower level. The upper and the lower levels are given respectively as input to the non-inverting terminal of one op-amp (U3) and inverting terminal of another op-amp (U4). The output of the second stage is given as input to the inverting terminal of U3 and non-inverting terminal of U4.

The upper threshold level is $0.84 \cdot V_{CC}$ and lower threshold level is $0.16 \cdot V_{CC}$. The output of the two comparators are given as input to a NAND gate. If the output of the second stage is higher than the upper threshold level of the comparators or lower than the lower threshold level of the comparators, then the output of the NAND gate is a logic high. If the output of the second stage is between these two threshold

Vout2	Output U3	Output U4	Output NAND gate
$V_{out2} < 0.16 * V_{cc}$	High	Low	High
$0.16 * V_{cc} < V_{out2} < 0.84 * V_{cc}$	High	High	Low
$V_{out2} > 0.84 * V_{cc}$	Low	High	High

levels, the output of the NAND gate is a logic zero. This can be summarised in the form of a table shown below.

Since the required frequencies are amplified 2800 times, the upper and lower peak value of the A.C signal is well above or below the pre-set threshold level and causes the output of the third NAND gate to be logic high which can be used to trigger a lamp.

OBSERVATIONS

The supply voltage for the dual element detector used was 5 volts. The reference voltage used for the voltage divider in the second and third stages was 0.6 volts. The output of the first stage was observed to be in the millivolts range by keeping the CRO in the A.C mode and a shift in the level of the signal was observed by moving our hands around the sensor. The output of the second stage was an amplified version of the output of the first stage and a similar shift in its A.C level was observed as we moved our hands around the sensor. This signal was given as an input to the third stage consisting of the comparators and its output was clamped at +12 volts and as we moved our hands around the sensor, its level dropped to -12 volts for a very small duration of time.

CONCLUSION

For experimental purpose while rigging up the circuit, we made use of the LM741 dual supply op-amps which were easily available rather than TSU101 as suggested. The pyroelectric dual element detectors used for sensing motion used was LHI778 whose supply voltage is within the range of 2-12 volts. We had supplied 5 volts to the drain and grounded the gate. The field of view of LHI778 is 70 degrees horizontally and 70 degrees vertically. By using the Fresnel lens, it was increased to 110 degrees.

Using the LM741 dual supply op-amp increases power consumption since it uses a power supply of +12 volts and -12 volts. Hence, it is preferable to use single supply op-amps which work at lower voltages such as LM358 while producing for the mass market.

SCOPE FOR IMPROVEMENT

The PIR sensor as such is capable of detecting only human motion. This can be a barrier if we need it to work as an occupancy/presence detector. The idea which we came up with is to create a relative motion between the sensor and the environment at all instances with the help of a small rotating fan (of two blades) placed between the sensor and the Fresnel lens. Each individual blade must cover each of the two differential elements completely initially and as they turn, the portion of the element that they uncover must be the same. In this way, if there is no occupant in a room, the differential amount of radiation each element sees is zero and hence the lamp/buzzer is not triggered. But if there is any occupant in a room, the amount of radiation seen by one of the elements is different from what the other

one sees (assuming the person is not standing symmetrically about the axis of the sensor, which is a highly unlikely scenario). Due to the rotation of the fan, a sense of motion across the sensor is created due to the frequent covering and uncovering of the elements by the blades. The advantage of this theoretical suggestion is that it should ideally work only for detecting humans since the Fresnel lens used restricts the infrared radiations coming into it within 5 – 15 micro meter in wavelength which is the characteristic of human infrared radiation.

REFERENCES

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