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A Power-Saving Passive Infrared Sensor Module

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Abstract - "A developed India by 2020, or even earlier, is not a dream. It need not be a mere vision in the minds of many Indians. It is a mission we can all take up - and succeed." - Dr. A.P.J. Abdul Kalam, India 2020: A Vision for the New Millennium. It is with these words in mind that we came up with the idea of a Power Saving Passive Infrared Sensor Module: a device that is simple yet effective, smart yet unpretentious: in short, truly Indian! The Passive infrared (PIR) sensors detect infrared energy radiating from objects within their field of vision without emitting any radiations (hence the name passive). The most common object a PIR sensor detects is the human body. This property of the PIR sensor has been used to detect when a person has left or entered an area. Depending on this movement, a power saving module has been designed, which switches on/off the power supply to a room automatically. This reduces the power expenses occurring due to human negligence in switching off lights, fans etc.

Keywords - Passive Infrared Sensor, Motion Detector, Ambient temperature, Power Saving, Pyro electrics, Power Saving

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1. Problem Definition

As the Vision 2020 plan envisions, power is one of the five core competencies on which development activities must be focused to transform India into a developed nation by 2020.

India's installed capacity for power generation now exceeds 101,000 MW. However, the total demand is expected to increase by another 3.5 times in the next two decades, even under a best-case scenario that envisions intensified efforts to modernize power plants, improve transmission and distribution efficiency, and adopt more efficient generation technologies. The soaring demand for power will necessitate a tripling of the installed generation capacity from 101,000 to 292,000 MW over the next two decades.

Increasing power generation at such a tremendous rate in face of global oil shocks and decreasing coal resources is not the only solution. Power must be saved in order to balance the growing demand.

The average household spends more than ₹18000 a year on electricity bills. Standard power saving modules available in the market are either too expensive for the common man to buy, or do not possess sufficient longevity to justify its price. This paper focuses on solving this problem by designing a power saving module that costs only ₹850, and is also durable enough to serve the customer for a good number of years.

2. Solution of the Problem Defined

2.1 Theoretical Concept

Pyro electricity is the ability of certain materials to generate a temporary voltage when they are heated or cooled. The change in temperature modifies the positions of the atoms slightly within the crystal structure, such that the polarization of the material changes. This polarization change gives rise to a voltage across the crystal.

Skin temperature is approximately 34°C, typically higher than ambient room temperatures. As a person walks past the sensor, their higher skin temperature generates an infrared wave of wavelength of 750 nm to 100 µm. This causes a voltage difference in the pyro electric material of the PIR sensor. The sensor has two slots, and depending on which slot is activated first, the direction of motion is detected. The electric potential generated is very small in amplitude and must be amplified significantly. An amplifier circuit boosts the small signal generated by the infrared energy. The DC component is then filtered by a simple

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RC-filter and fed into a differential comparator. The comparator detects the direction of motion and generates a logical one or zero. This triggers the output in the attached microcontroller. The microcontroller then switches on the light if a person moves into the room, and vice versa.

Ideally, the module should be fixed on the doors, gates etc. of rooms. It counts the no. of persons entering or leaving the area and turns the power supply on if this no. is greater than zero.

The entire module is simple to design, requires no separate power source (hence, the name passive) and is inexpensive to design. This reduces the burgeoning power expenses occurring due to human negligence in switching off lights, fans etc.

2.2 Experimental Proof of the Concept

The figure below shows a basic block diagram for the module. The bypass switch is the first part, which can be used to toggle between automatic and manual modes of operation of the device.

The PIR sensor consists of the pyroelectric materials, which form the core of the module. It acts as the motion detector and provides the main input signal to the rest of the module. This signal is then amplified and fed to the filter

The filter then removes noise and makes the signal more robust for the comparator to work.

The comparator and microcontroller work together in association to detect the direction of motion and triggers the final output.

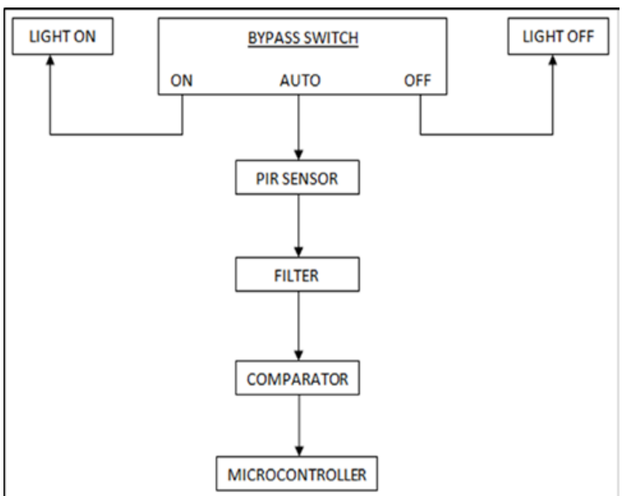

Figure 1. Block Diagram of the Power-Saving Module

2.2.1 Bypass Switch

The bypass switch allows the user to disable the motion sensor function of the switch thus making it just like a standard on-off switch. The only internal input that this switch is going to receive is the +Vcc voltage=5 volts. There is also the user input of switching the switch back and forth, that is, on or off. When the bypass switch is in auto mode, the PIR sensor activates.

2.2.2 Sensor Module

The PIR sensor itself has two slots in it. Each slot is made of a pyro electric material that is sensitive to Infrared Radiations. When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. When a warm body like a human or animal passes by, it first intercepts one half of the PIR sensor, which causes a positive differential change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected. This results in good compensation of environmental temperature and excellent sensitivity for small changes of a spatial temperature pattern.

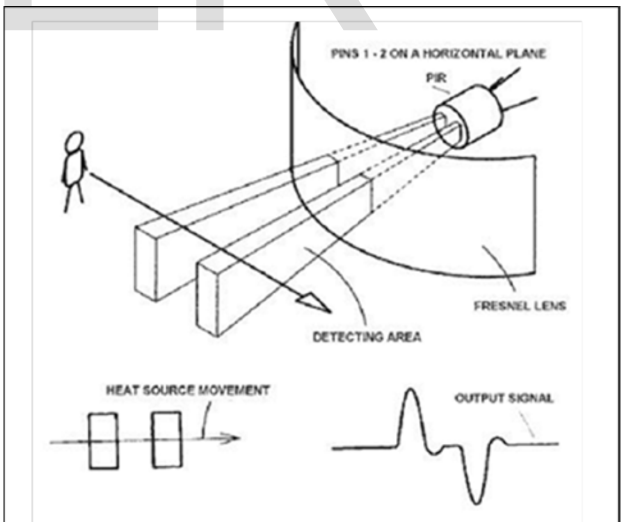

Figure 2. Generation of output differential signal by the PIR sensor

The voltage across the sensors controls a J-FET source follower impedance converter and thus modulates the output current of the PIR detector. The two IR sensors are placed in parallel in the device and

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they are connected in series to the JFET to cancel out common mode signals.

The numbers 1, 2 and 3 correspond to the different wires from the sensor. 1(Drain) is the input which is +Vcc(5V) . 2 is the output which is in the form of voltage pulses, positive and negative depending on direction of motion. 3 is connected to ground. The output is sent to the filter and amplifier which is the next module in the system.

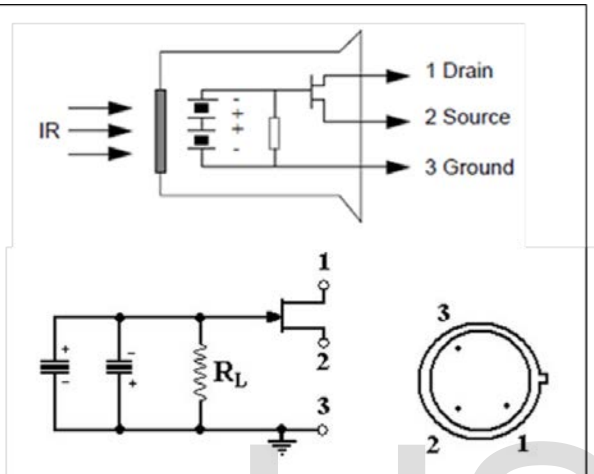

Figure 3. Connection of Sensor to the JFET

2.2.3 Filter Module

When given 5V DC, the output from the sensor ranges from 0.69V to 0.71V. This output is the input to the filter. The filter is just a capacitor that filters out the DC component of the signal. This reduces power consumption. This AC signal is then amplified by a two-stage op-amp based amplifier. This signal is then used by the comparator to see if the voltage is over a certain threshold voltage.

2.2.4 Comparator Module

The comparator will only output a voltage when the output from the sensor becomes greater than the threshold voltage, V1. When the output of this circuit goes high, it will trigger the microcontroller to turn on the light.

2.2.5 Microcontroller Module

The following Arduino Code is used to operate the microcontroller:

```
int ledPin = 13;
// choose the pin for the LED
int inputPin = 2;
// choose the input pin (for PIR sensor)
int pirState = LOW;
// we start, assuming no motion detected
int val = 0;
// variable for reading the pin status
void setup()
{
pinMode(ledPin, OUTPUT);
// declare LED as output
pinMode(inputPin, INPUT);
// declare sensor as input
Serial.begin(9600);
}
void loop()
{
val = digitalRead(inputPin);  // read input value
if (val == HIGH)
 {
// check if the input is HIGH
digitalWrite(ledPin, HIGH);  // turn LED ON
if (pirState == LOW) {      // we have just turned on
Serial.println("Motion detected!");
// We only want to print on the output change, not
state
pirState = HIGH;
}
} else {
digitalWrite(ledPin, LOW); // turn LED OFF
if (pirState == HIGH){
 // we have just turned of
Serial.println("Motion ended!");
 // We only want to print on the output change,
not state
pirState = LOW;
}}}
```

3. Discussions

Due to the relatively simplistic design, the module may suffer from some false alarm problems as well as "out-of-range" errors. Here two of the main problems are discussed in detail.

3.1 Static Thermal Triggering

Due to the relatively simple and cost effective arrangement, this setup can also be tripped by any source of rapidly changing heat, such as the flash of

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bright lights or reflections off objects during hot, sunny days.

A Fresnel lens positioned in front of the sensor performs two functions. It concentrates the IR energy emitted over a wider area onto the sensor and it divides the area into hot and cold zones of sensitivity.

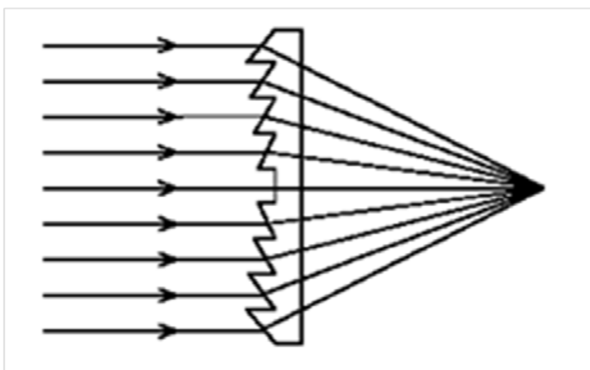

Figure 4. Fresnel Lens at work

As a person walks across the zones, the sensor sees a changing IR value that produces a varying output signal from the sensor indicating motion. The comparator looks for and responds to this changing signal. Hot items that don't move, like heaters and lights, do not produce output variations. The comparator ignores these constant IR sources.

Secondly, the Fresnel lens provides a much larger range of infrared-radiations to the sensor than a basic plano-convex lens.

4. 3.2 Day Time Triggering

The PIR sensor is based on infrared radiations, and as such, does not respond to changes in visible light radiations. This means it will also keep functioning in the day time, switching on lights whenever a human passes in front of it. Thus, it will require considerable manual over-riding to make it viable, that is, manually switch it off during the daytime, which undermines the very ground of automation on which it was conceived.

This problem is solved by the use of a photocell and an OR gate.

The photo cell is responsible for keeping the sensor shut off when there is enough ambient light in the room, for example in the middle of a sunny day in a room with many windows. The photo cell is a light sensitive resistor that has a value of 10 kΩ when its light and 100 kΩ when it is dark.

The output from the photo cell is run into an OR-gate. The other input of the OR-gate will be the output from the microcontroller. The output from the gate will be directed into the PIR sensor. The modified circuit will be as shown.

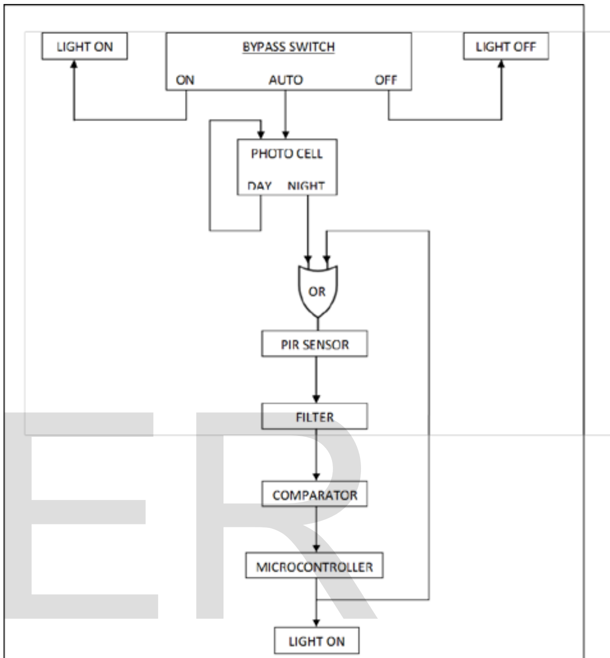

Figure 5. Block Diagram of the Power-Saving Module with Photo Cell and Or Gate

5. Results

The following items are needed to prepare a working prototype:

1. RE200B PIR costs about ₹600.
2. NL11NH LENS costs about ₹40
3. Microcontroller costs about ₹200.
4. LDR unit costs about ₹10.

The entire prototype can thus be constructed within a budget of ₹850 at most. Once installed this device would help us cut down our electrical bills to a significant level and thus help us to conserve non-renewable energy, the primary sources of energy in most of the towns and cities still now.

6. Summary

The present paper is directed to a power-saving module based on Passive Infrared Motion Detectors.

The module consists of a PIR sensor having two pyro electric elements. The sensor is designed with a lens that provides a very narrow field of view and two pyro electric infrared sensors that produce a waveform with two voltage swings of opposite polarity when a warm object moves past the sensor. The waveform is filtered and amplified before it is passed on to a comparator. The comparator triggers off the extremes of each waveform. The comparator includes two outputs that are normally high, but go low when a change in infrared radiation is detected. A microcontroller then makes the switching on/off operation.

7. Acknowledgments

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