Evaluation of of μ-controller PIR Intrusion Detector

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Abstract

Intrusion detection is simply the process of recognizing that an object is located in a place where it should not be at that moment. Two basic types of intrusion detection exist; intrusions detection from outside and from within. Intrusion detection systems are designed to provide security around valuables and premises, traditionally using human observers. This however has been found to be difficult to justify due to cumulative cost and human weaknesses. This work addressed the design and implementation of a device that will replace human surveillance around a particular perimeter. The design is premised on the fact that every object emits some levels of infrared energy which can be detected by a passive infrared module. The movement across the emission region assists in the detection of intrusion. The output signal from the passive infrared module was sampled by the designed microcontroller circuit which in turn is processed according to the programmed code. When there is intrusion, a piezo speaker beeps and also a visual indicator with light emitting diode blinks to indicate intrusion. For security, cost effectiveness and access control to certain areas of homes, offices and industries this system is a better replacement to human surveillance needed around our valuable goods and confidential materials.

Keywords: Infrared intrusion, microcontroller, security, sensors

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1.0 Introduction

Intrusion detection is the process of recognizing that something or someone is located in a place where they should not be at the given moment in time. A close surveillance or watch is needed around the perimeter of places where confidential documents, valuable goods and materials are kept. The most foolproof system of intrusion detection is probably placing a human observer at every location to constantly monitor the entire area to be covered. While this may be foolproof, it may well be imprudent, for the costs of such a "system" would be impossible to justify. Current intrusion detection systems [1, 2, 3] thus combine technologies that afford high levels of detection, using cost-effective methods and components e.g. Passive Infrared (PIR) Intruder Detector for designing indoor or outdoor advanced residential and commercial security systems. These components detect the movement caused by a human target moving across the detection field. The detector employs many features that are only available in the most advanced intrusion detection systems [4, 5].

There are different types of motion detectors. Some work by sensing sound, some send out light and sense when the beam is broken or reflected back. Others, known as the passive infrared motion detectors, work by sensing the infrared radiation emitted by objects which is above absolute zero. In categorizing intrusion detection sensors, two basic classes are identified; Exterior intrusion detectors (such as Microwave, Electric field, Active infrared and Fence disturbance sensors) and Interior intrusion detectors (such as Balanced magnetic switch, Interior microwave, Proximity, Dual-technology, and Video motion detection sensors) [6, 7].

Active infrared sensors are infrared beam-break sensors that detect the significant reduction or loss of infrared light transmitted to a receiver. Infrared light is invisible to the naked eye (though some digital or video cameras can detect it.) In its simplest form, an active infrared sensor consists of a single infrared transmitter that illuminates a single infrared receiver. In most security applications, an active infrared sensor will be composed of two columns of multiple infrared transmitters and multiple infrared receivers [8]. This arrangement can provide a detection volume of significant height. The infrared light is generally sequenced and modulated to decrease sensitivity to light from other sources, which allows the sensor to operate in daylight as well as night. The sequencing for some models allows the use of multiple sensor sets without mutual interference, in case they happen to be within the field of view of an adjacent sensor set.

Active infrared sensors vary in size, beam configuration, range of operation, and operational features. They typically operate in ranges that allow them to be compatible with the sector lengths used in exterior perimeter applications. Most models have sealed beam assemblies or heaters that keep frostiness from forming on the optical covers and lenses. Some units can be sequenced so they will operate if their transmitters are in the field of view of an adjacent sector's receivers. These and other features of the different models available should be considered, depending on the specific application and operational environment [8].

2.0 Materials and Methods

2.1 Components of the Conceptual Circuit Design

The components of the system/circuit consist of PIR module, microcontroller, power source and buzzer/visual indicator. A programmable microcontroller based design was chosen for ease of bringing together coding / programming of all system features and functionality. The block diagram of the system is presented in Figure 1.

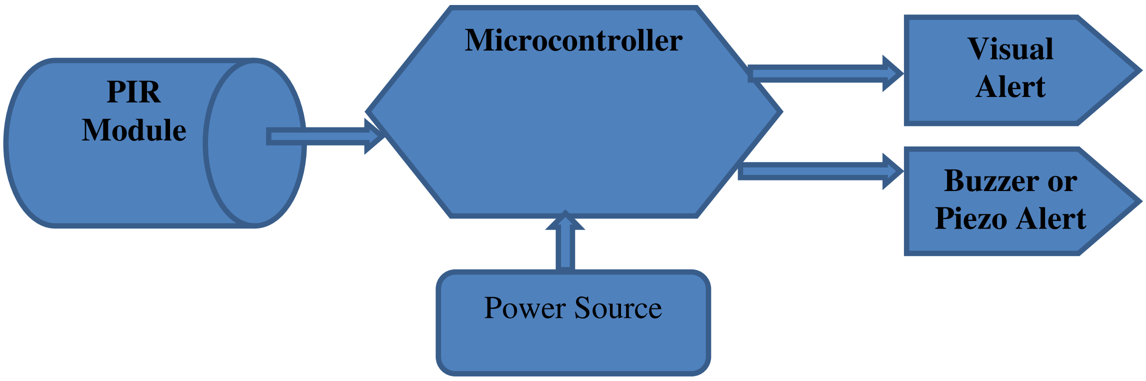


Figure 1: Block Diagram Showing Design Modules and the Direction of Data Flow

2.1.1 PIR Module

PIR sensors, also referred to as "Passive Infrared", "Pyro electric", or "IR motion" sensors are used to detect whether an object or has moved into or out of the range of the sensors. They apply the principle of sensing motion and are made of a pyro electric sensor which can discover the levels of infrared radiation radiated by objects. The motion detector's sensor is divided in two halves to detect actual variation in motion and not average infrared levels. The adopted PIR module for this work is the BISS0001 Micro Power PIR Motion Detector Integrated Circuit with associated supporting resistors, capacitors, circuitry and sensors shown in Figure 2. It has the following characteristics: the output is high digital pulse (3V) when motion detected (triggered) and low digital voltage when no motion is detected (idle). The sensitivity range is up to 6 meters within 110° x 70° detection range while input power supply voltage can range from 3V to 9V. However, the input voltage of 5V is used in this work.

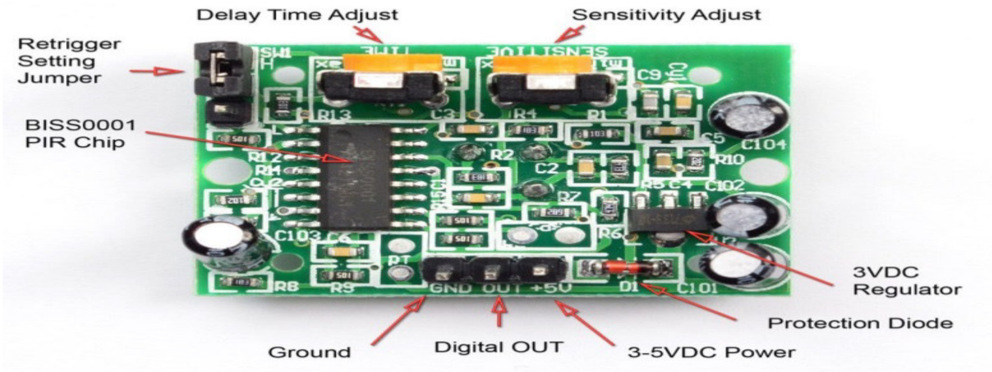


Figure 2: PIR module's upper view. (Source: PIR Motion Sensor, Adafruit 2014)

2.1.2 Microcontroller

A microcontroller is a small computer on a single integrated circuit designed for embedded applications, containing memory, processor core and programmable input/output peripherals. Microcontrollers typically contain from several to dozens of general purpose input/output pins (GPIO). GPIO pins are software configurable to either an input or an output state. When GPIO pins are configured to an input state, they are often used to read sensed external signals while configured to the output state; they can drive external devices like LEDs or motors [11, 12, 13]. The microcontroller that is used in this design is from Atmel Cooperation and from the At-mega family, and this is one of the families of microcontroller used in Arduino.

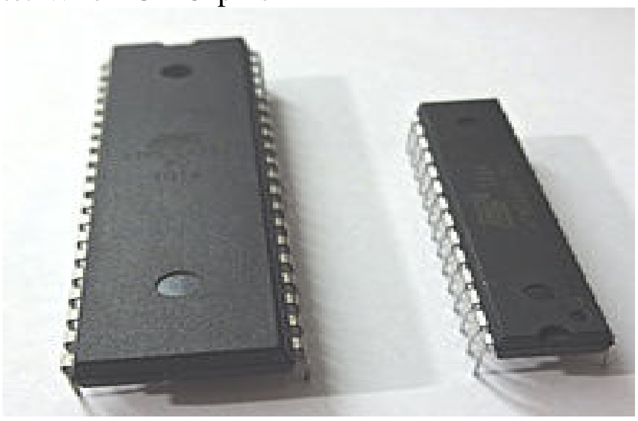


Figure 3: Atmega32 and Atmega8 Microcontroller. (Source: *Microcontroller Wikipedia 2014)*

2.2.1.3 Power Source

The power source is the source of energy and power which allow for the flow of electrons throughout the circuits. The 78xx (sometimes L78xx, LM78xx, MC78xx...) is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is commonly used in electronic circuits requiring a regulated power supply due to their ease-of-use and low cost. For ICs within the family, the xx is replaced with two digits, indicating the output voltage, for example, the 7805 has a 5 volt output, while the 7812 produces 12 volts [12].

II.1.4. Buzzer and Visual Alert Indicator

Buzzers or beepers are components needed to sound alarm or attention using an audio signaling device, which may be electromechanical, mechanical, or piezoelectric [14]. This design made use of light-emitting diode (LED) as a visual indicator shown in Figure 4. A light-emitting diode is a two-lead semiconductor light source that resembles a basic pn-junction diode, except that an LED also emits light and has a limiting resistor (330 ohms) to limit the current into the LED.

Figure 4: A buzzer symbol and an RGB Light Emitting Diode.

The value of LED limiting resistor can be calculated from Ohm's law as:

$$V = I*R \qquad (1)$$

where V: source voltage in volts,
I: desired current in milliamps,
R: needed resistor in ohms.
Red light emitting diodes have a forward voltage drop (VD) of around 2volts when on, so this has to be subtracted from the source to get the voltage across the resistor. The resistor value is calculated as:

$$R = (V - VD)/I \qquad (2)$$

Five volt is used as our source voltage and 10ma as the desired current that need to flow in the light emitting diode and 2 volt as the forward voltage drop of the LED because the design is operated at 5volts. Placing all these values into equation (2) we get:

$$R = (5v-2v) / 10ma \quad R = 300 \text{ ohms}$$

but in the design a standard value 330 ohms is used.

2.2. The System Schematic

Diagram

The circuit in figure 6 was developed from the conceptual block diagram in figure 1 after some test were carried out on the Arduino hardware platform (ARDUINO UNO) shown in figure 5. The Arduino platform was chosen for ease of use and availability of toolset. This circuit schematic was drawn with KICAD an electronic circuit suite.

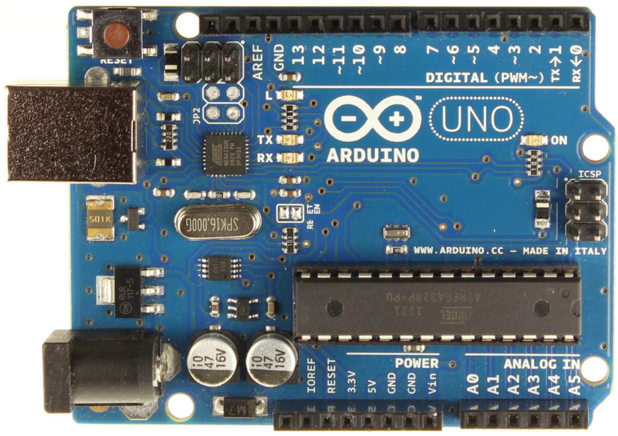


Figure 5: Most commonly used Arduino hardware platform. (Source: Arduino Boards)

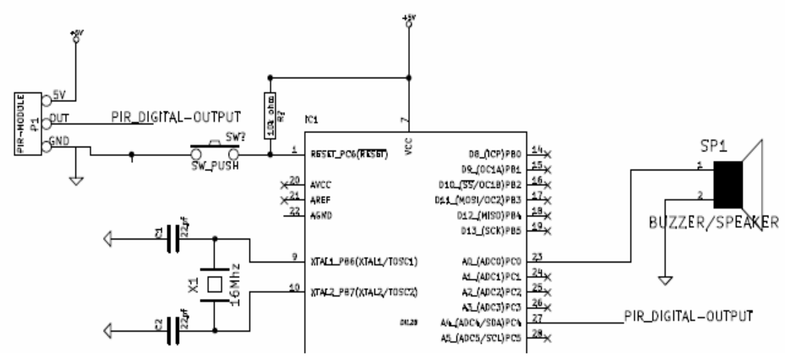


Figure 6: The Design Circuit Schematics

2.3 Intrusion Detection System Programming

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino development environment (program processing) and the Arduino programming language (electric wiring). Arduino sketches are based on C/C++ programming language and was compiled with the open-source compiler avr-gcc and linked against the open-source AVR Libc [6].

2.3.1. The System Software

The pseudocode that presents the idea of the code running on the microcontroller in human readable format is shown in Table 1.

The functional code is written in Arduino programming language which is a high level programming language that has a core based on electrical wiring and consists of three main parts: structure, functions and values [6]. The derived sketch is presented in the functional Arduino Code shown in Table 1.

Table 1: The Functional Arduino Program code

```
int PIRpin=2;   //pir output pin
int LEDpin=8; // LED pin for visual indication of intrusion
int buzzePin=12; // buzzer pin
 void setup()
{
 pinMode(PIRpin,INPUT);
 pinMode(LEDpin,OUTPUT);
Serial.begin(9600);
}
void loop()
{
 if (digitalRead(PIRpin))
digitalWrite(buzzerPin,digitalRead(PIRpin));
Serial.println("Movement detected");

else Serial.println("NO Movement");
digitalWrite(LEDpin, HIGH);   // LED on (HIGH is the voltage level)
delay(50);             // wait for a 50 millisecond
digitalWrite(LEDpin, LOW);    // LED off by making the voltage LOW
delay(1000);       // wait for a 1000 millisecond
}
```

2.4. Detection System Development

Each component and module in the circuit diagram of figure 6 were put together, by soldering onto a Vero board using soldering iron and lead to achieve the final product shown in figure 7.

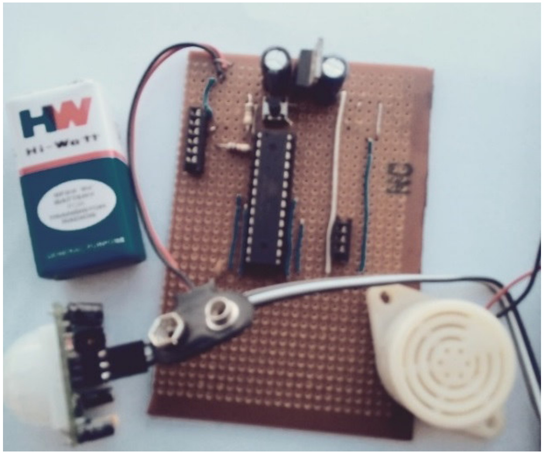
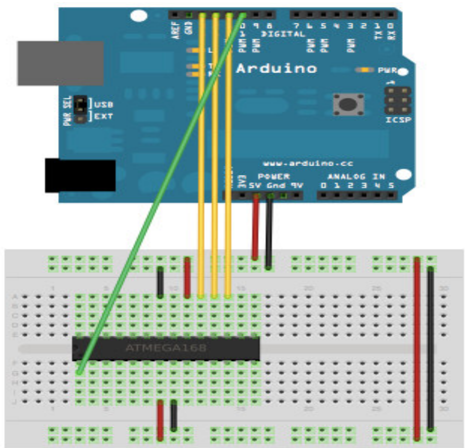


Figure 7: The Completed PIR Intrusion System Board

There are various ways for burning the code into the microcontroller but we have opted for the ISP method over other methods because the design is going to be standalone and the facility to carry it out is readily available on the Arduino Uno development board.



3.0 Results

The performance evaluation of the developed system was carried out for Tangential (Arc) Path and Radial Path Testing which are relative measurement used in determining the efficiency of the intrusion detection. The work used the recommended walk test paths and directions for the performance testing of a PIR sensor outlined in [10] as shown in Figure 9.

3.1 Tangential (Arc) Path Testing

The walk test was conducted along the tangential paths since this approach has the likeliest chance of detection as the PIR sensor is most sensitive in this direction.

(1) Test object started outside detection area of the sensor and walked at 1 foot per second along the radial path.
(2) When an alarm occurs during the walk, a stop is made and the position is marked.
(3) Return to the start point, wait 30 seconds for the sensor to reset, and repeat walk test along the same path.
(4) Test 2 to 3 were repeated on that path. Multiple tests along each test line path are required to establish a probability of detection (PD). For example, in order to establish that a sensor has a minimum PD of 90 percent at a confidence level of 95 percent, the sensor would have to pass 29 out of 30 tests.
(5) Steps 1 through 4 were performed for the remaining tangential paths.

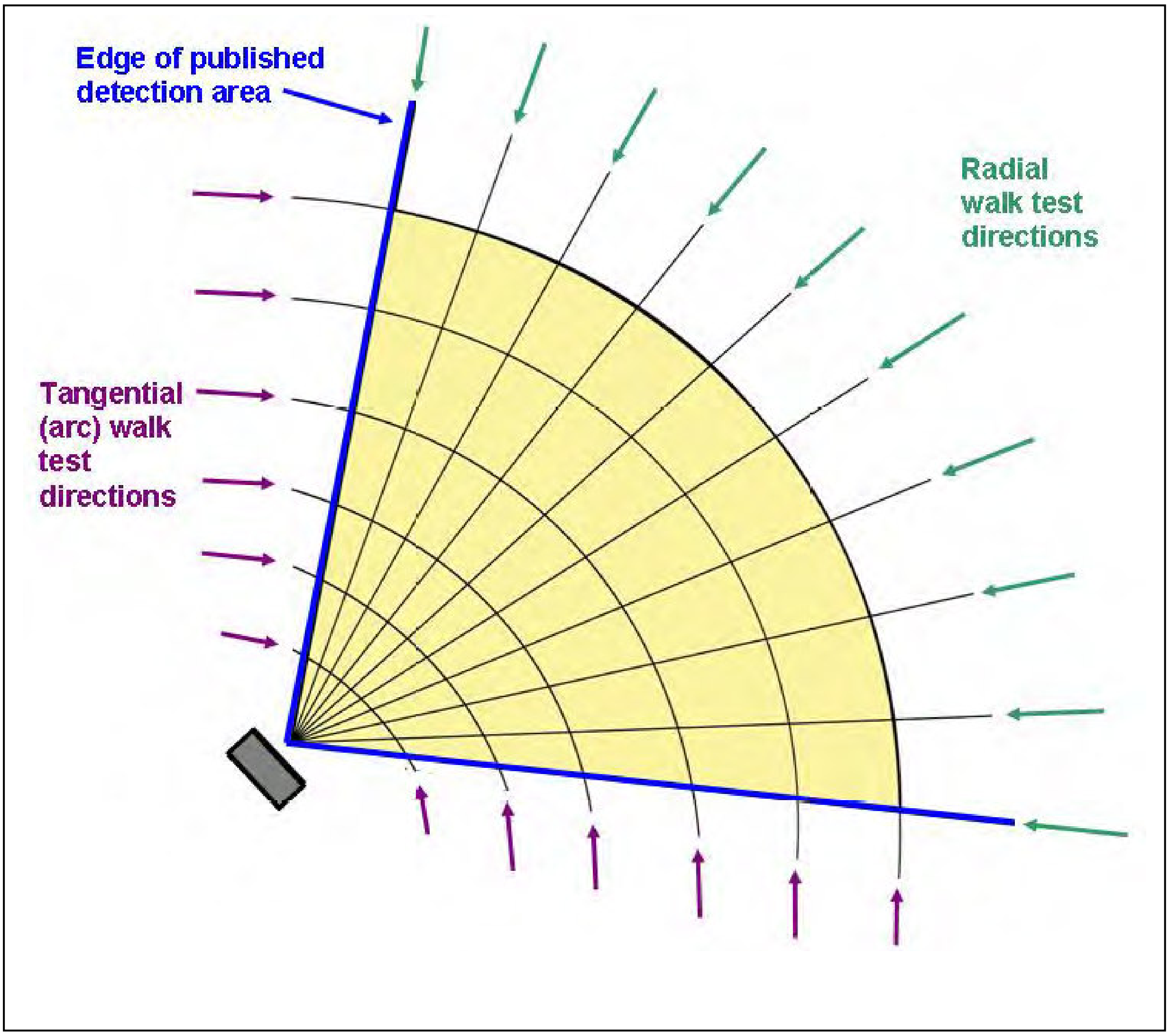


Figure 9: Recommended walk test paths and directions for the performance testing of a PIR sensor (Source: United States Nuclear Regulatory Commission

3.2. Radial Path Testing

(1) Test started outside detection area of the sensor and walked at 1 foot per second along the radial path.
(2) When an alarm occurs during walk one need to stop and mark that position.
(3) Return to the start point, wait 30 seconds for the sensor to reset, and repeat walk test along the same path.
(4) Tests 2 to 3 were repeated on that path. Multiple tests along each test line path are required to establish a probability of detection (PD). For example, in order to establish that a sensor has a minimum PD of 90 percent at a confidence level of 95 percent, the sensor would have to pass 29 out of 30 tests.
(5) Steps 1 through 4 were performed for the remaining radial paths.

3.3. Test Results

The walk test conducted along the radial paths was found to have the least likely chance of detection as the PIR sensor is least sensitive in this direction the radial test result were found not to be effective for reason of inconsistencies in detection. The walk test conducted along the tangential paths was found to have the best chances of detection as the PIR sensor is most sensitive in this direction.

3.4 Making Use of the System

PIRs are installed so that the detection pattern covers the area or asset to be protected. This detection pattern can be pictured as a "searchlight beam" that gradually widens as the zone extends farther from the sensor with some segments being illuminated while others are not. This design characteristic allows the user to focus the beam on areas where detection is needed while ignoring other areas, such as known ..
sources of false alarms. Changes in the infrared signature of an object (including people) are most visible when the object moves laterally through the detector's range. Positioning a detector so that an intruder must walk across the detector's range is much more effective than positioning the detector so that an intruder would likely walk toward the detector. The presence and/or location of a passive sensor is more difficult for an intruder to determine than an active sensor, putting the intruder at a disadvantage.

Whenever this system detects intrusion (movement), the peizo sounds for 6 seconds and if the movement persist the sound also continues and will stop 6 seconds after movement had stop. The visual indicator kicks in immediately which comes on for 1000miliseconds and off for 50miliseconds.and continue at that rate until movement is detected.

4.0 Conclusion

An affordable intrusion detection system is made available with this design; human observers are relieved of round the clock duties or totally done without. The detection capabilities of PIR sensor should be walk tested in a different way, preferably random order every 7 days.

Sources of nuisance alarm in a PIR sensor include any object causing an appropriate temperature differential should be avoided as the system is installed. The temperature differential can be caused by rapid changes in localized heating and cooling, which may be effected by: Sunlight, Incandescent light bulbs, Radiators, Space heaters, and Hot pipes. We recommend incorporation of utility power source for extended power life and tamper proof facility in the next design.

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