Design of Human-Emissive Security Alert System for Residential Application

Anamonye U.G

Department of Electrical/Electronics Engineering, Delta State University, Abraka, Nigeria.
gabbosky@yahoo.com

ABSTRACT

The aim of this project is to design GSM based security system with feedback call capability for residential apartment. To achieve this the pyroelectric infrared radial (PIR) sensor, a transducer which has the ability to convert human body capacitance into electrical signal was used with all other discrete components built around it. The PIR sensor was used as input component which generates input signal used to drive integrated circuit components, which changes output state to energize a relay causing the device to be able to activate a feedback call. The design was successful and is capable of notifying the security personnel in less than ten seconds once an intruder is detected.

Keywords: Sensor, Pyroelectric, Feedback, Security, Pulse

1 Introduction

With the advancement of sensor and actuator technologies, our indoor environment, such as buildings, has been instrumented with various sensors, including temperature, humidity, illumination, CO₂ and occupancy sensor, and, thus, can be aware of changes in the user's state and surrounding, finally controlling building utilities to adapt their services and resources to the user's context, e.g., automatic lighting control, heating, ventilation and air-conditioning (HVAC) system adjustment, electrical outlet turn-off, unusual behavior detection and home invasion prevention [1]. Such context-aware systems have deployed occupant location as the principal form of the user’s context. Accordingly, indoor tracking and localization is one of the key technologies for providing activity-aware services in a smart environment. Motion can be detected by using either mechanical means or electronic means. In the mechanical means, a tripwire is a simple form of motion detection. If a moving object steps into the trip wire's field of view then a simple sound device like bells may alert the user. Mechanical motion detection devices can be simple to implement, but at the same time, it can be defeated easily by interrupting the devices mechanics like (cutting the wire).

Using electronic means, electronic motion sensing such as motion detectors, infrared ray detectors or pyroelectric infrared radial (PIR) sensors can prevent such mechanical intervention. The principal methods by which motion can be electronically identified are optical detection and acoustical detection. Infrared light or laser technology may be used for optical detection. Pyroelectric infrared (PIR) sensors are widely used as a presence trigger, but the analog output of PIR sensors depends on several other aspects, including the distance of the body from the PIR sensor, the direction and speed of movement, the body shape and gait [1].

This design is built around a motion detection devices, pyroelectric infrared radial sensor, that detects human movement, generates electrical pulses and sends the signal to a micro controller which in turn triggers an alarm and at the same time activate a mobile phone connected to it in order to establish a call to security personnel. This
intelligent security system with feedback call and automatically enabled voltage shock can basically be described as a system that detects the presence of an intruder (theft) and automatically send a feedback call to a security person. Section 2 contains the review of related literature and other theoretical background, section 3 discusses the design methodology, and section 4 gives explanation of the design assembly, while section 5 is the conclusion.

2 LITERATURE REVIEW

2.1 Review of Related Works

Hao et al. [2] presented a human tracking system using an MSP430 family microcontroller, an RF transceiver and a radial sensor module with eight PIR detectors with Fresnel lens arrays arranged around a circle. They showed that the system can be used to track a single human target by detecting its angular displacement while moving. Also Lee W. proposed a novel method of detecting the motion direction for an object moving in the field of view of a single PIR sensor, whose dual sensing elements are reversely polarized and aligned in the motion plane of the PIR sensor [3]. As Lee presented, the analog output signal of PIR sensors involves more aspects beyond simple on-off triggering, and such features have been exploited in several ways for recognizing motion direction.

Zappi et al.[4] built a low-cost PIR sensor-based wireless network system for detecting the direction of movement and distinguishing the number of people (two and three) walking in line, as well as walking side by side in a hallway. They showed the 100% correct detection of direction of movement and 89% correct detection of the number of people. The authors also built a cluster system composed of two PIR sensors facing each other in a hallway for detecting the direction of movement and distance intervals (close to one sensor, in the middle, close to the other sensor) when a person is walking [5],[6]. They extracted the passage duration and output amplitude from the PIR output signals and performed classification analysis using the support vector machine and k-nearest neighbor algorithms. The experimental results show 100% correct detection of the direction of movement and 83.49%–95.35% correct detection of distance intervals.

More recently, Yun and Song [7] presented a novel method of detecting the relative direction of human movement in eight directions uniformly distributed with two pairs of PIR sensors whose sensing elements are orthogonally aligned. With the raw data sets captured from two orthogonally-aligned PIR sensors with modified lenses, they achieved more than a 98% correct detection of the direction of movement. They also found that with the reduced feature set composed of three peak values in the time domain for each PIR sensor, they were able to achieve 89%–95% recognition accuracy according to machine learning algorithms.

2.2 Theory of PIR Sensor

More advanced security systems include passive infrared (PIR) motion detectors. The “motion sensing” feature on most lights (and security systems) is a passive system that detects infrared energy. These sensors are therefore known as PIR (passive infrared) detectors or pyroelectric sensors. These sensors “see” the infrared energy emitted by an intruder’s body heat. When an intruder walks into the field of view of the detector, the sensor detects a sharp increase in infrared energy. If you have a burglar alarm with motion sensors, you may have noticed that the motion sensors cannot “see” you when you are outside looking through a window. That is because glass is not very transparent to infrared energy [8]. This unit consists of a passive Infred-Red sensor and its associated circuits. The PIR (Passive Infra-Red) Sensor is a pyroelectric device that detects motion by measuring changes in the infrared (heat) levels emitted by surrounding objects. When motion is detected the PIR Sensor outputs a high signal on its output pin. This logic signal can be read by a microcontroller or used to drive an external load. Figure 1 shows the picture of the passive infra-red sensor.
3 DESIGN METHODOLOGY

The implementation of this security system is based on hardware design and embedded software development. The hardware section comprises of various modules that are segmented on a Vero board as well as physical wiring. Embedded software development such as used for controlling this security system, requires the development process to be integrated with the development of the controlled physical product. Figure 2 shows the block diagram of embedded security using GSM based security alarm system.

Fig 1: Passive Infra-Red Sensor

Fig 2: Block diagram of GSM based security alarm system
The approach used in this work is the modular approach where the overall design was first broken into functional block diagram where each block in the diagram represents a unit of the circuit that carries at a specific function.

3.1 Power Supply Unit

240/12V Transformer, bridge rectifier, source filter, voltage regulator

Calculating for turn of the transformer

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} = n$$

(1)

$E_p = $ primary voltage, $E_s = $ secondary voltage, $N_p = $Number of primary turns, $N_s = $ Number of secondary turns, and $n = $ turns ratio.

But $E_p = 240V$ and $E_s = 12V$

Therefore, $N_p = 20 N_s$ ,

And $n = 20:1$

Fig 3: the bridge rectifier circuit

The output DC voltage of the bridge rectifier can be calculated using the formula

$$V_{dc} = 0.636(V_m - 2V_T)$$

(2)

Where $V_m$ is the transformer output voltage (12V) and $V_T$ is the voltage drop across the silicon diode (0.7 V).

Therefore, $V_{dc} = 7.5V$

Specifying capacitor value:

$$I = C \frac{dV}{dt}$$

(3)

$$C = \frac{I dt}{dV}$$

(4)

$F = 50Hz$

Recall: $dt = \frac{1}{2} \times 50Hz$ ie time between peak

Therefore $dt = 0.01s$

But $dV = V_{ripple} = 1V$

$C = \frac{It}{dV_{max}}$

$C = 1000\mu F$ 

$V_c = V(1 - e^{-\frac{t}{Rc}})$

(6)

As $t$ tends to infinity $e^{-\frac{t}{Rc}}$ tends to zero

$V_c = 12v$

N.B: The working voltage of this capacitor should be such that it can hold at least 4/3 of the maximum charging voltage.

$4/3 \times 12 = 16v$

Therefore the capacitor rating used in this section is $1000\mu F/16v$. 

3.2 Crystal Oscillator Unit

This unit controls the speed of the microcontroller. It is shown in Figure 4.

Fig. 4: Crystal Oscillator circuit

$C_1$, $C_2$ and $X_f$ forms the resonator circuit. $C_1$, $C_2$ is a capacitor and $X_f$ is a crystal oscillator. The values of $C_1$, $C_2$ and $X_f$ of AT89S52 are manufacturer specified:

$C_1 = C_2$ and ranges from 18pf – 33pf

$X_f$ ranges from 4mHz – 40mHz

The higher the frequency the faster the speed of instruction execution, but higher the frequency the more current drawn by the microcontroller.

Value of 30pf was used for $C_1$ and $C_2$ and 12mHz used for $X_f$.

$$\text{Speed of instruction execution} = \frac{\text{clock cycle}}{\text{frequency}} \quad (7)$$

for AT89C52, clock cycle per instruction = 12

speed of instruction execution = $\frac{12}{12\text{mHz}} = 1 \times 10^{-6}\text{sec}$

approximately 1 µsec per instruction

3.3 Reset Unit

Pin 9 is the reset input. A logic 1 on this pin for two machine cycles when the oscillator is running resets the device and causes program counter to jump to origin of the program. The reset circuit for this project work is shown in the Figure 5.
When the button is depressed, pin 9 is logic HIGH, when the button is released, the capacitor discharges through the resistor \( R_{\text{RESET}} \). Using:

\[
V_c = V(e^{-t/RC})
\]

\( V_c = 4.5v, V = 5v, t = 10ms, C = 10\mu F \) (from data book)

Substitute values and obtain

\( R_{\text{RESET}} = 948.7 \), preferred value is 1K

3.4 Display Circuit and Driver

This unit is composed of resistor, transistor and cascaded LED display. The cascaded LEDs are connected to the output port 1 and port 3 of the microcontroller. It does alpha-numeric display (both upper/lower case lifter). The NPN transistor that is connected so it has its collector being tied to Vcc. In this display section, the transistor acts as a switch. The connection is from the output port 1 bit (0-6) and output port 3 bit (0-6).
Since each LED takes a current of about 5-20mA [9]. So for a single display, LED will draw about 35-140mA. In order to allow about 5mA at 5v vcc, in each LED we use limiting resistor:

\[
V = IR
\]

\[R = \frac{V}{I} = 1\, \Omega\]

So 1kΩ resistors are connected to the common anode of the seven-segment display in this design.

For the value of biasing resistor, maximum base current (Ib) of transistor used in this design is 5mA. The supply voltage is 5v dc. The value of the biasing resistor (Rs) can be calculated using the formula.

\[
R_s = \frac{(V - V_{BE})}{I_b}
\]

Prefered value of 1kΩ was used.

3.5 Switching Unit

These units consist of a resistor, resistor and a relay as show in the Figure 3.15 below.
In the figure above a resistor is used to establish the current necessary to energize the relay in the collector circuit. When positive voltage is applied to the base of the transistor, the transistor turns on, energizing the relay coil. As the relay closes, it triggers the alarm buzzer connected to its terminals. A base resistor ($R_B$) is required to ensure perfect switch of the transistor in saturation. The diode protects the transistor from back EMF that might be generated since the relay coil presents an inductive load. In the case $R_c$, which is the collector resistance is the resistance of the relay coil, which is 400 $\Omega$ for the relay type used in this project work. Hence giving that $R_c = 400 \Omega$ (relay coil resistance).

$$V = 15v$$

$$V_{CE} = 0 \text{ (when transistor is switch)}$$

$$V_{in} = 5v \text{ (from the latch module)}$$

$$h_{fe} = 300 \text{ (from data sheet for BC547)}$$

$$R_B = \frac{v_{in} - V_{BE}}{I_B} \quad (11)$$

$$V^* = I_cR_c + V_{CE} \quad (12)$$

$$h_{fe} = \frac{I_c}{I_B} \quad (13)$$

$$\text{common}I_n = I_BR_B + V_{BE} \quad (14)$$

Where $I_c = \text{collector current}$, $I_B = \text{base current}$, $V_{in} = \text{input voltage}$, $V^* = \text{supply voltage}$, $V_c = \text{collector emitter voltage}$, $h_{fe} = \text{current gain}$, $V_{BE} = \text{base emitter voltage}$

Substituting values into equation (12), we obtained,

$I_c = 30mA$

From equation (13)

$I_B = \frac{I_c}{h_{fe}} = 100\mu A$

now using equation (14)

$$R_B = \frac{V_{in} - V_{in}}{I_B} \quad = 44K\Omega$$

### 3.6 Phone Unit

The phone used in this project is the nokia 1280. It is tapped with two wires from its keypad on the number 9 which is directly connected to $P_{2.2}$ on the micro controller. The number 9 is set to speed dial with a default number which activates upon receiving signal from the micro controller and makes a feedback call.

The charging unit is designed with a voltage comparator with reference voltage set at 3.7v using voltage divider network, when the phone battery is charged to about 3.7v it cuts off from charging.
Fig. 8: Complete circuit diagram
3.7 Mode of Operation

By default, when the circuit is connected to an a.c source, the power indicator connected to the power unit is turned on. The seven-segment display serves as an output screen to the microcontroller. When the PIR sensor detects body capacitance, it will automatically send a signal to the microcontroller. The microcontroller interprets the signal and sends to activate the buzzer and the relay simultaneously; the relay which is normally open will then switch state to activate the speed dial on the phone which has already been set to the number 9 keypad on the phone. The phone starts dialing and an inscription showing “calling” is then seen on the display scrolling pass then after 5 seconds, the word “Intruder” is seen on the display until the reset button is impressed. The oscillator is used to control or regulate the speed of the microcontroller. As this is happening, the phone battery is constantly charging, the charging will cut-off once the battery gets to 3.7v which is the standard for most phone batteries.

3.8 SOFTWARE DEVELOPING

This involves a series of steps or set of activities which are necessary. For the development of reliable and maintainable software, it is of great importance that hardware design cannot be used in microcontroller based system without dependable software. A typical microcontroller development system includes visual display unit (VDU), keyboard, Random Access Memory (Ram) which serves as store for the program and prom programmer. Software system is a term used to describe programs which was provided by the manufacturer to aid the development of user (application) programs. This includes program which convert assembly language into machine codes (assembly) or high level language into machine code (compiler). The text editor used in the software development of this work is M-IDE studio.

4 ASSEMBLY PROCESS

The circuit was mounted on Vero board and soldered in place. The microcontroller is programmed using the resultant HEX file generated from the source file in assembly language format. The programmer used uploading the HEX file into the microcontroller is Wellon VP-28A+ universal programmer.

Test was carried out after assembling the component parts on a vero board. After the test was carried out to ascertain the operation of the device, the entire assembly was then encased using a plastic material. A photograph of the complete assembled circuit components is shown in Figure 9.

5 CONCLUSION

A device used for motion detection for residential application has been implemented. The use of microcontroller and passive infrared ray sensor for this design reduces the size and hence the cost of the unit. The device was designed to be installed and used in a place were properties need to be secured from unrestricted persons. This design is built around a motion detection devices, pyroelectric infrared radial sensor, that detects human movement, generates electrical pulses and sends the signal to a micro controller which in turn triggers an alarm and activate a mobile phone connected to it in order to establish security call. The main purpose and objective of the project has been achieved, since the device sensor was able to detect and transmit needed pulse to the microcontroller unit for control purpose.
REFERENCES


