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Implementation of an Embedded Microcontroller-Based Intrusion Detection System

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Abstract

This paper highlights the implementation of an embedded microcontroller-based intrusion detection system. The PIC16F84A microcontroller embedded in the system was programmed using the MikroC Language for the microcontrollers, to pick up an intrusion signal from the motion sensor, (which interprets the signal to be an electrical signal e.g. voltage), process it and then give a command to the display or output units. The output includes a 16x2 ALPHA liquid crystal display (LCD) and a buzzer (alarm unit), which in turn implement the command thereby notifying the environment of the presence of an intruder by displaying “Intruder Detected!” on the LCD and by a beeping sound with an interval of 0.5s delay by the alarm unit. The system was tested and was found to be efficient and suitable for solving myriad of security issues that confront us in modern times.

Keywords

Intrusion detection system
Microcontroller
Motion sensor
Security systems

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1. Introduction

The issue of security is as old as man. In a bid to secure his life and properties diverse methods have been adopted by man, ranging from the obsolete “hide-and-watch” method, to the modern day electronic security systems (Okundamiya, 2007; Kumar, 2012). Individuals are now aware of the dangers associated with relying on traditional methods to provide security to unauthorised areas of their apartments since criminals can easily break into such rooms or apartments (Oke *et al.*, 2009; Okundamiya *et al.*, 2009, Abdul, 2013; Aruna, 2013).

The need for a more fortified method to protect lives and properties has motivated the use of the alarm system. Several types of alarm systems that utilise different sensors were discussed by Khaing (2015). The alarm security systems can offer a better solution to tackling the problem of the intrusion and unauthorised entry into small apartments (whether residential, commercial or industrial), particularly when the user is not physically present in the apartment.

The objectives of this paper is the design analysis and implementation of an embedded microcontroller-based intruder alarm system, capable of detecting any intrusion within a range of 3m. This study is indeed apt and timely as the issue of insecurity is taking the centre stage in our national discourse in recent times. Nevertheless, it is worthy of note that so many high technology-based proximity and motion detection devices developed in tackling insecurity in the form of intrusion, in recent time, have been circumvented over time, by highly determined criminals, as no technology, can for now be said to be 100% efficient. Hence, there is need for improvement.

2. Methods and Materials

2.1 System Design and Analysis

To achieve the objectives of this paper, a motion sensor, which detects the presence of a person or object, beyond the penetrating power of the infrared sensor is used together with a microcontroller unit, for processing and control purpose; thus enhancing the circuitry for more effective security. At the output is the buzzer and LCD display, to alert user or security personnel of any illegal entry or intrusion attempt.

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The block diagram of the proposed embedded microcontroller-based intrusion detection system is shown in Figure 1. The parameters of the complete designed circuit (Figure 2) were computed using the basic circuit theorems – Ohms and Kirchhoff's laws (Okundamiya & Emakpor, 2017).

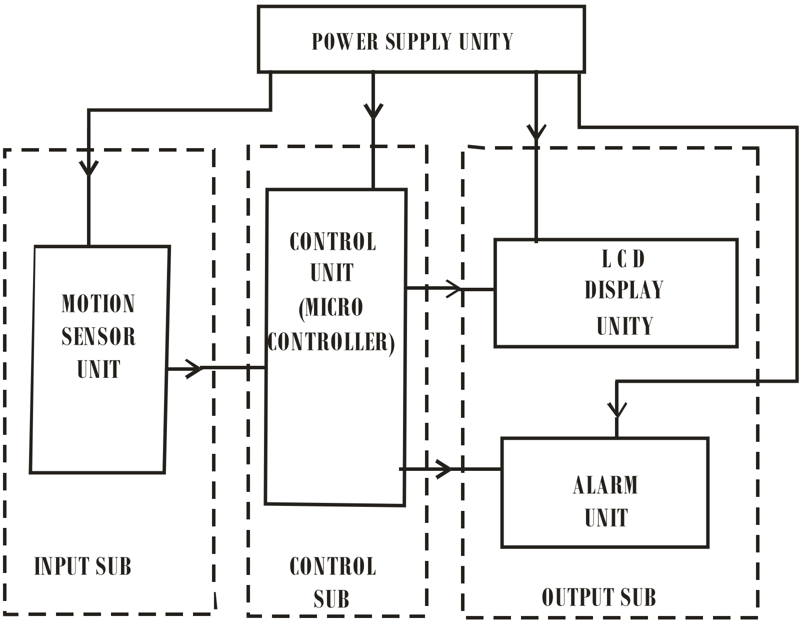

Figure 1: Block diagram of the embedded microcontroller-based intrusion detection system

Motion sensor unit

The motion of an intruder is a variation, which the PIR motion sensor (Figure 2), converts into electrical signal. For this unit, the pre-set value is such that can disallow much current to be sunk to the ground. Thus, I = 0.5mA (chosen) and V_c = 5V. Therefore:

$$R = \frac{V}{I} = 10k\Omega \tag{1}$$

$$P = I^2R = 2.5mW \tag{2}$$

Hence a pre-set value of 10kΩ will comfortably do the work

Control unit

The signal received from the PIR motion sensor is processed by the control unit and sent to the display units. The microcontroller (PIC16F84A) used in this design consist of 18 pins arranged in a "U" fashion as shown in Figure 2. Pins 15 and 16, connected to the crystal oscillator, are used for clocking purpose, while pin 14, is connected to HIGH (5V).

Alarm unit

The alarm unit gives a beeping sound with a delay of approximately 0.5s upon reception of signal from the microcontroller, when the sensor is triggered by an intruder motion, placing the neighbourhood and security personnel, on red alert, indicating the presence of an intruder. The delay is made possible by an NE555 timer set in the mono-stable mode. In this mode, the duration in which pin 3 (output pin) can remain high is given by the equation:

$$T = 1.1\,RC \tag{3}$$

where *R* is the resistor value and *C* is the capacitor value used in the design.

To build a one minute timer, a resistor of 55kΩ and a capacitor of 1000µF are required. In this design, a 47µF capacitor and a 10kΩ resistor were used, thus:

$$T = 1.1\,x\,10\,x10^3x\,47x10^{-6} = 0.52s \tag{4}$$

The basic design (Figure 2) is achieved by the use of resistors, which act as a current limiter, and then an NPN BC 547 transistors. This transistor is configured as a switch. For proper biasing, the base current (I_b) must be ten times smaller than the collector current (I_c). Given that: I_c = 1mA, V_c = 1V, then R is deduced as follows:

$$R = \frac{V}{I} \quad = \quad 1k\Omega \tag{5}$$

For a current of 1mA to flow via the collector, a buzzer with a 1k**Ω** resistor is employed at the transistor collector·

The LCD display unit

This unit displays the system's output, according to how the microcontroller is programmed. As shown (Figure 2), the last adjacent four pins (D_4, D_5, D_6, D_7), are connected to pins 17, 18, 1 and 2 respectively while pins D_0, D_1, D_2 and D_3 are grounded. The complete design of the embedded microcontroller-based intrusion detection system is shown in Figure 2.

The requisite voltage is supplied by the power supply unit for the system to function. When the PIR motion sensor detects the motion of an intruder, which is a variation, the sensor converts the variation into electrical signal voltage. The signal is sent to the microcontroller. The "embedded controller" otherwise known as the microcontroller, acts as a control/processing unit, which picks up the signal from the sensor, and then activates the indication components.

The signal voltage then activates the output units, i.e. the system produces a beeping sound to alert the neighbourhood, by way of repeatedly sounding an alarm (with a little delay interval of approximately 5s made possible by the timer circuit), when an intruder passes. The LCD displays the result of the instruction (as processed by the microcontroller) to display the inscription "Intruder Detected". The system can be reset to deactivate it.

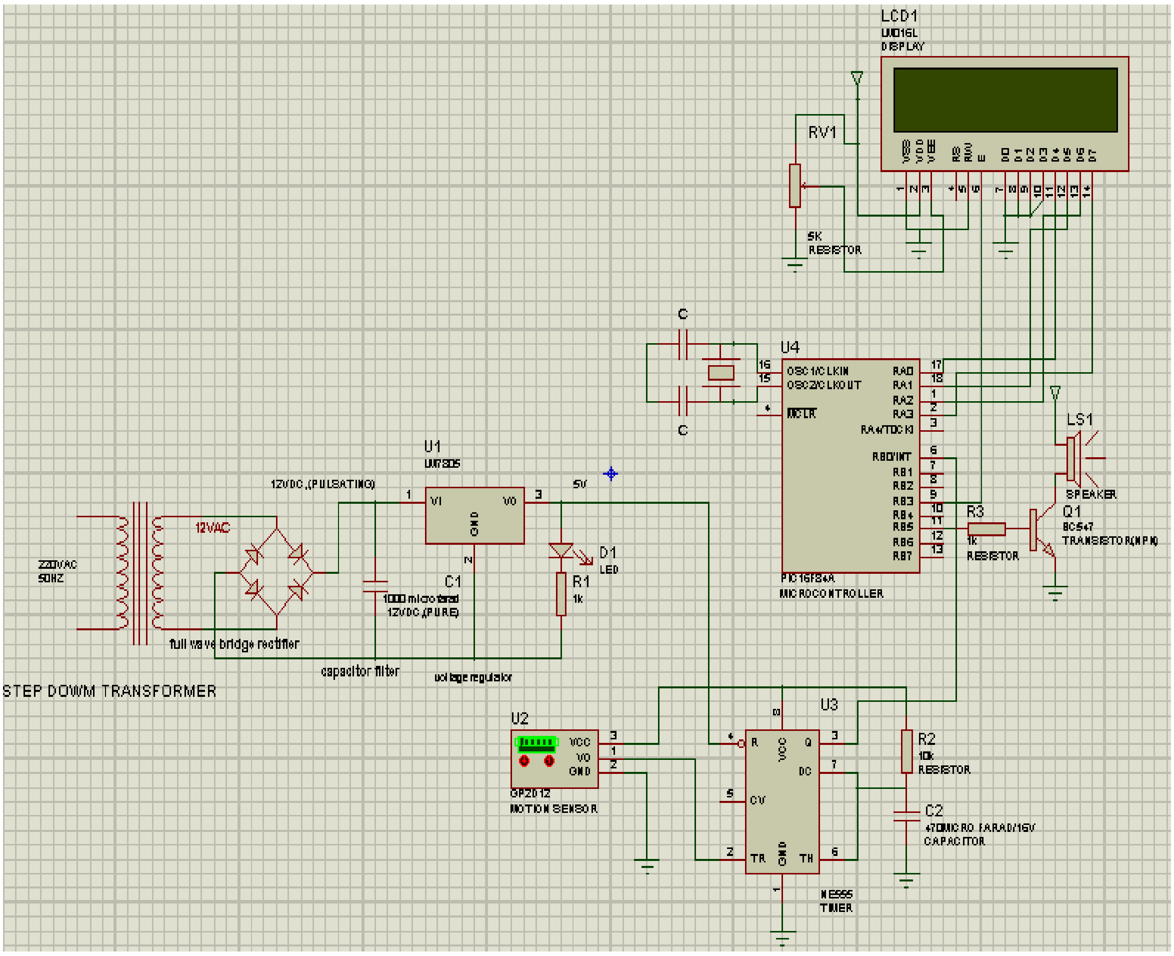

Figure 2: Complete design of the microcontroller-based intruder detection system

2.2 Fabrication and Testing

To be able to ascertain that designed circuit is effectively implemented, the component parts installed, must yield the desired results. Consequently, the assembly of the component parts becomes a very vital aspect of the design process. The components used in the fabrication were locally sourced from an electronic market in Benin City (Nigeria). The designed circuit of Figure 2 was first connected on a breadboard, to verify its workability, before the various components were assembled and thereafter soldered on a Vero board and as shown in Figure 3.

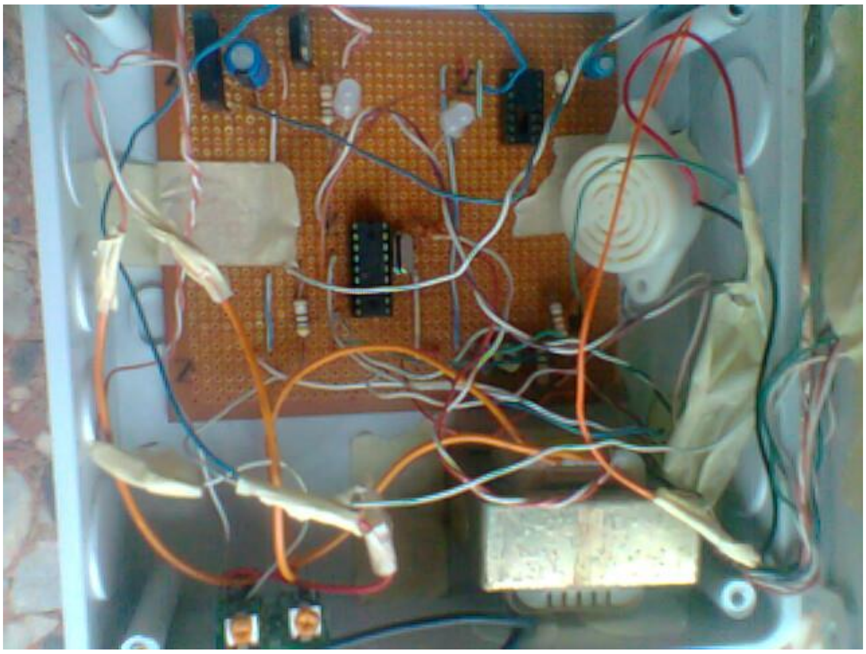

Figure 3: Fabrication of complete circuits on a Vero board.

Testing is a vital process in the development and realisation of any design. The continuity, reliability, short circuit and sensitivity tests were carried out to ascertain the viability of the design.

Continuity Test

This test was carried out by applying a small voltage, using the probes on the digital multi-meter, set on continuity across the chosen path. This was performed in order to ensure that current flows through components on the same potential on the Vero board. Voltage values were also obtained during this process.

Short Circuit Test

Short circuit test was performed to ensure that bridging while soldering, as well as improper placement of components on board during layout did not occur. This test was carried out using probes of the multi-meter and none of the aforementioned case occurred. The results confirmed that current flow is unobstructed along all components.

Reliability Test

This test was carried out to ensure reliability of the system as well as to detect any abnormal working condition. The fabricated microcontroller-based intruder detection system was tested repeatedly for 7 times. The result of the test is shown in Table 1.

Sensitivity Test

This test was performed to demonstrate the response of the device with respect to distance. The PIR motion sensor has a sensing distance of about 3m. Any intrusion beyond this distance goes undetected. The result of the test is shown in Table 1.

3. Results and Discussion

To ensure reliability of the developed system and to be able to detect abnormal working conditions, the system was tested repeatedly for seven times. As can be seen from Table 1, the system was tested at various distances to also ascertain if at a certain distance or more, the working condition will be affected. Table 1 shows the reliability and the sensitivity test results. As observed (Table 1), intrusion beyond the specified range of distances (3m in this study) is not detected. This helps to minimise the possibility of false alarm.

Table 1: Reliability and sensitivity test results.

Test Number	Intruder Distance from Sensor (m)	Alarm Unit Response	System Operation
1	1.0	ON (alarm triggers ON)	Worked Properly
2	1.5	ON (alarm triggers ON)	Worked Properly
3	2.0	ON (alarm triggers ON)	Worked Properly
4	2.5	ON (alarm triggers ON)	Worked Properly
5	3.0	ON (alarm triggers ON)	Worked Properly
6	3.5	OFF (alarm does NOT trigger)	Not functioning
7	4.0	OFF (alarm does NOT trigger)	Not functioning

Based on results from the various tests carried out as clearly discussed above, the microcontroller-based intrusion detection system is able to provide adequate and swift detection of intrusion or movement around the premises, provided the distance of the intruder from the sensor is less than or equal to 3m. In addition, the system can through the various display units, notify anyone concerned, that an intruder is around the premises. The probability of false alarm is minimised due to the use of the PIR motion sensor capable of detection relatively short distances ($\leq$ 3m). A guide around the knob of the sensor can also help to reduce the possibility of false trigger.

4. Conclusion

This paper describes the design analysis and implementation of an embedded microcontroller-based intruder alarm system, which uses a PIR motion sensor to detect any intrusion within a range of 3m. The microcontroller was programmed using the MikroC Language for PICs. The results showed that the developed system is efficient and suitable for both domestic and industrial use in addressing myriad of security issues that confront us in modern times. The implementation of the proposed security system can minimise the frequent occurrence of arm robbery and breaking and entry into people's apartments and offices.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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