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Research Paper

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Development of an Automated Home System with Infrared Sensors

John Nwankwo Chijioke[1*], Sadiq Thomas[2]

[1]Dept. of Electrical and Electronics Engineering, Nile University of Nigeria, Abuja, Nigeria
[2]Dept. of Computer Engineering, Nile University of Nigeria, Abuja, Nigeria

[*]*Corresponding Author: johnchijioke95@gmail.com, Tel: +234 705 768 0658*

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***Abstract*-** Recent advances in the field of control systems and information and communications technology have led to the introduction of automation to our homes. This paper presents a simple and inexpensive electronic solution to the challenge of comfort, security and the frequent manual switching of home appliances. The design is broken into two: the first is a passive infrared-based system that triggers an audio visual alarm when motion is detected. The second is an infrared sensor-based system that increments a counter when a person makes an entrance into a room and decrements when an exit is made. The resulting number of people left in the room is displayed on a seven-segment display. As long as the count on the display is one or more, the appliances are turned on. Peripheral Interface Controller microcontroller drives the switching process, through a relay, by comparing the outputs of the infrared receiver pair. The passive infrared sensor used to add security feature to the home system was set to a 3-second delay and 2-meter range to achieve a faster and more efficient response. Costing only NGN 32,120 (about 88 USD), this design is not only comparatively cheaper than other home automation solutions reviewed in this paper but also the most power efficient, with an energy expenditure rate of only 1.41 watts.

***Keywords*-** Automation, Home Security, Internet of Things, People Counter, Infrared, Microcontroller

I. INTRODUCTION

In the last few decades we have witnessed an astounding boom in control engineering and information technology. This has enormously eased the tasks of men both at home and in the industries. It is for benefits like this that a lot of fund is being annually injected into Control Technology and Information and Communication Technology [1].

Automation is the application of control engineering and ICT in the reduction of human intervention during goods production and service delivery. Automation is different from industrial mechanization where machines are merely used to carry out mechanically tasking jobs. It applies not just strength but intelligence, in reducing human mechanical, sensory or mental involvement in our day-to-day activities [2].

Despite the rising concerns that machines may replace humans in the future, automation has unstoppably gained more and more traction over the years as is manifested in autonomous cars, planes, ships, industrial machines and our homes.

These concerns have been allayed with a debunking theory termed *paradox of automation*, which argues that although human involvement may be very minute in more efficient automation systems, it is also very critical for humans to monitor the systems to avoid devastating errors [3].

Home automation is the practice of making certain home appliances such as lighting, HVAC (Heating, Ventilation, and Air-Conditioning) to operate autonomously and/or remotely over a central computer. Although the idea of automating our homes has been in existence in fantasy science fiction books, it was only in the mid-twentieth century that the first automated home device, ECHO (Electronic Computing Home Operator) IV was seen. ECHO IV, a kitchen computer which never made it to the market, was capable of computing kitchen lists, regulating kitchen temperature, and turning appliances on and off [4].

Though different automated home service providers make products with different aims in mind, all modern home automation devices have the following features in common: expandability, interoperability, upgradeability, remote accessibility, user interface variety, energy saving, protection [4]. The purpose of this paper is to implement a low-power system that autonomously operates the home appliances.

This aims of this paper are as outlined below:

- To develop an inexpensive, low-power automated home prototype by means of a visitor counter circuit using infrared sensors.
- To build a burglary or intrusion alarm based on a passive infrared motion sensor.
- To compare the performance and cost of some automated home designs with this proposed here.

The rest of this paper is organised as follows, Section I contains the introduction of home automation, Section II contains the related works on home automation, Section III contains measures followed in obtaining the result in this work, Section IV describes the results and discussions, and Section V presents the conclusion and scope of future works.

II. RELATED WORKS

Copious amount of work and research have been conducted on automation of our homes. While some of these designs are suitable for domestic purposes, others are best for the industries. Most common technology for existing modern home automation systems employ image processing for security. But this system suffers two major drawbacks: firstly, cameras do not get clear images of people at night. Secondly, in some legal settings, surveillance cameras are seen as a violation of people privacy. [5] [6]

A people counter system for tracking and displaying the number of people entering or exiting the room was proposed and designed in [7]. The system was realized with a microcontroller operating fuzzy control logic. Two sensors were placed at the entrance in a way that a person entering or exiting would have to cross the field of view of the sensors, and depending on the order in which the sensors are crossed a control logic would decide whether an entrance or an exit is being made, and display the number of people still occupying the room on an LED seven-segment display. The limitations of this design are that the proposed system does not use the information provided by the sensor to automate the room appliances. It is also only capable of making a maximum of 9 counts after which overflow error occurs at the seven-segment display.

[8] proposed and designed an automated system for the remote operation of a thermostat using Arduino Mega2560, CC3000 WiFi Breakout, temperature sensor, HC-06 Bluetooth module and relay switch. In this work, the thermostat was connected to a home network which allows it to be operated or regulated from a web-based button on a mobile phone connected to the same network. The project was further improved by allowing the operation and control of the thermostat from any network. Providing a global control of the thermostat. A similar work based on radio frequency and Atmega 8 was also implemented in [9].The project also offers opportunity for expansion in the event that the user wishes to automate more appliances in the future. This design lacks security features [8].

[10] discussed and implemented an inexpensive, high-accuracy active infrared motion sensor for security at home. Active infrared sensors operate like their passive counterparts except that active infrared sensors have an infrared emitter which generate infrared beams. To be triggered, this beams have to bounce off any objects in their field of view and return to an infrared receiver. The major drawback in this system is that it is not as energy efficient as its passive infrared counterpart.

[11] put forward the design of an automated home system using PIC184455 microcontroller, Nokia 6021 mobile phone, HIN232 microcontroller interface to communicate between the phone and microcontroller. Communication is established between the phone and the microcontroller through this platform. The mobile phone is then used to operate a relay connected to our home appliances through a driver. The downsides of this design are that it lacks security feature and that home appliances do not operate autonomously but rely on the user to operate them all the time.

III. METHODOLOGY

3.1 Materials Used:

The following components were used in actualizing this design: AC power source, transistor amplifier, resistors, PIC16F877A microcontroller, seven-segment display, PIR sensor, voltage source, oscilloscope, digital multimeter.

3.2 Software Tools

Software tools used in designing and simulating this work includes: MPLab Software, PICkit 2 Programmer, Microsoft Visio, Multisim NI Instrument, Proteus 8 Professional.

3.3 Software Tools

The design target in this module is to actualize a low-cost, high-accuracy motion detector suitable for the detection of burglary or any other form of intrusion in homes or industries. When motion is detected in the sensor's vield of view, an audio visual annunciator built using a beeper and an LED is expected to go off.

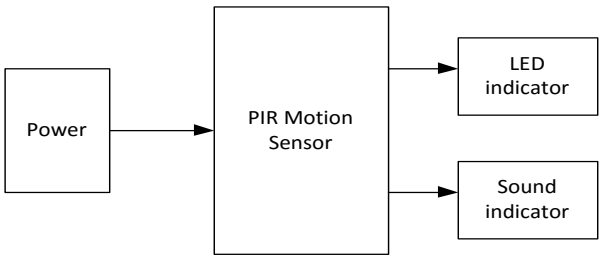

Fig. 1 Motion Sensor Module Block Diagram

In the figure below, the IR sensor is represented with the switch S1.

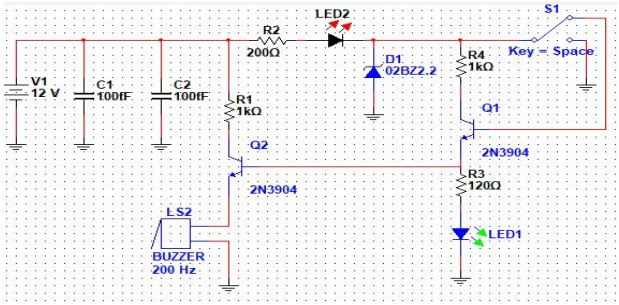

Fig. 2 Motion sensor module simulation with Multisim

3.4 Software Tools

In this module, the design aim is an electronic circuit capable of detecting and storing information regarding the influx or outflux of objects in its field of view. This information would be stored in a register, and based on the content in this register, the home appliances should then autonomously operate. Thus, this module requires sensors, display and models of the appliances used at home (see fig.4), in this circuit all the components are centred on the microcontroller. To optimise the design, a pair of IR receivers were used to detect IR lights from a single emitter. The states of each IR receiver were displayed on LEDs. While any IR receiver receives light from the emitter its indicator LED is off. But when an object blocks the IR light from reaching any IR receiver its state goes HIGH and its indicator LED comes on. The circuit diagram for this module is displayed in Fig.4

The home fan was modelled using a 5V DC motor with a current requirement higher than the microcontroller provides. To power the DC motor, the signal from the microcontroller was used to drive a 12V relay to switch a separate circuit to which the motor and LED are connected (see fig. 4).

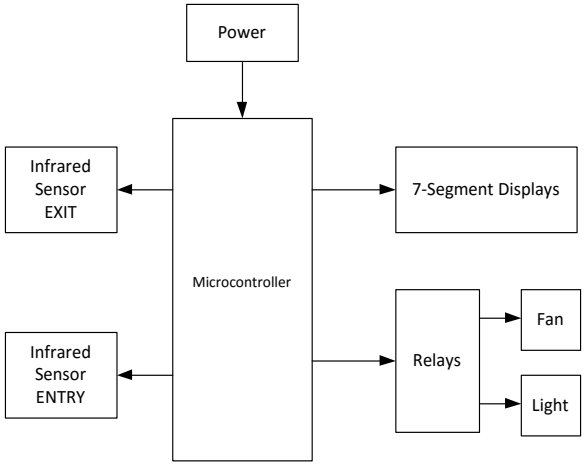

Fig. 3 Block Diagram for Visitor Counter module

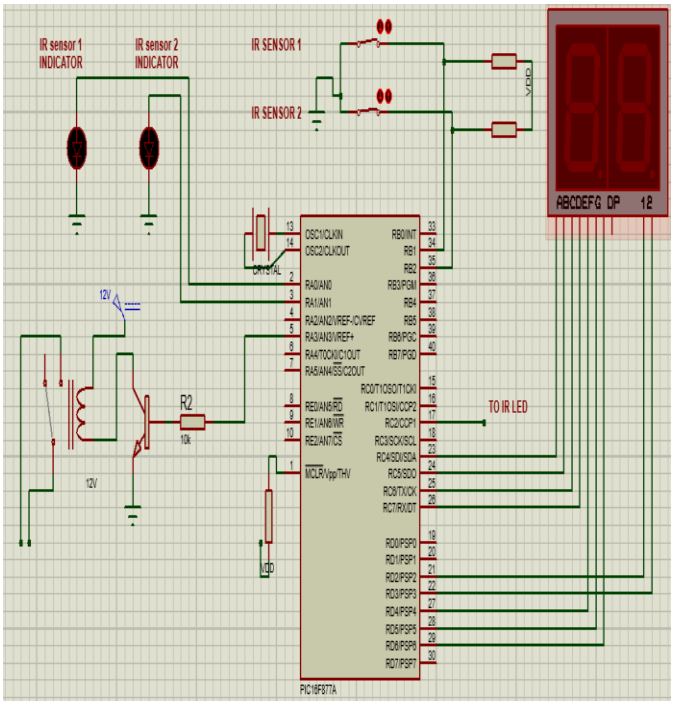

Fig. 4 Circuit diagram of the visitor counter module simulated with Proteus 8

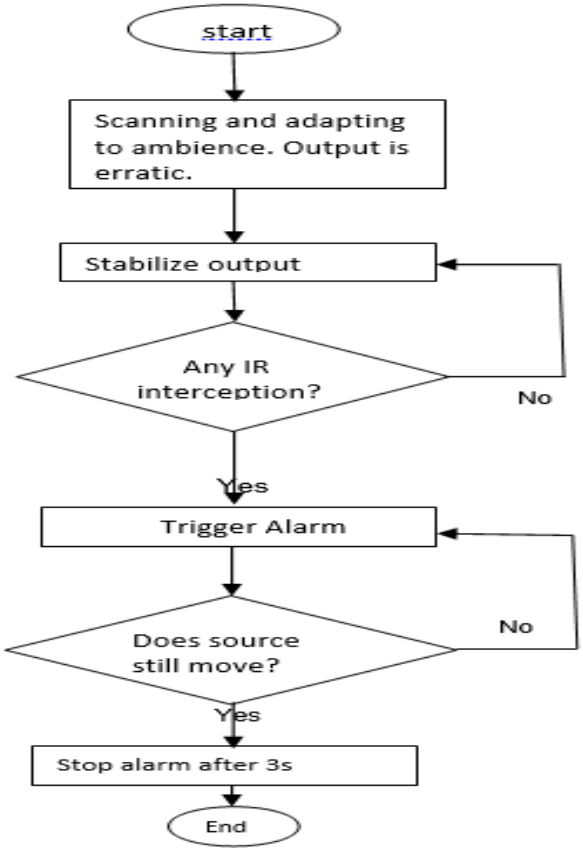

Fig. 5 Motion sensor operating flow chart

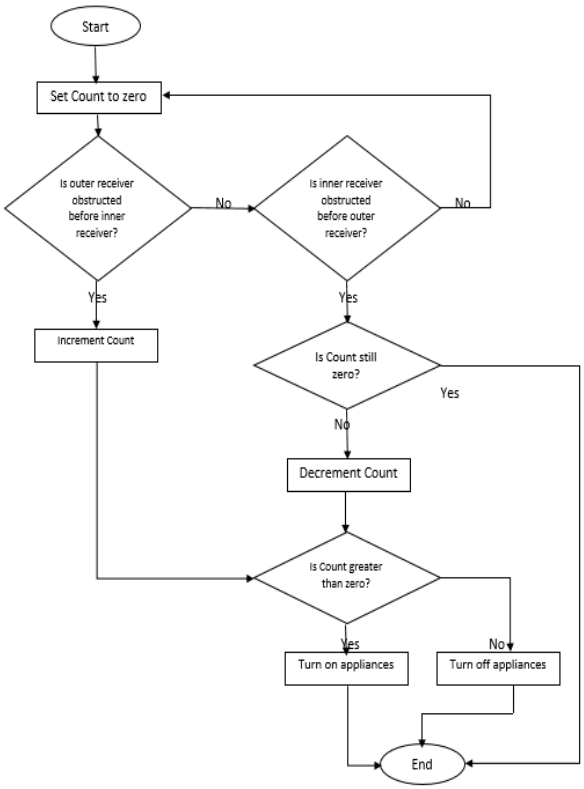

Fig. 6 Visitor counter operation flow chart

IV. RESULTS AND DISCUSSIONS

As a precautionary measure, a simple test with and LED, resistor and a 9V battery was used to ensure that the PIR motion sensor was working properly before the building began. In producing the Vero board design (see fig. 7), caution was taken to avoid damaging the circuit components with heat while soldering.

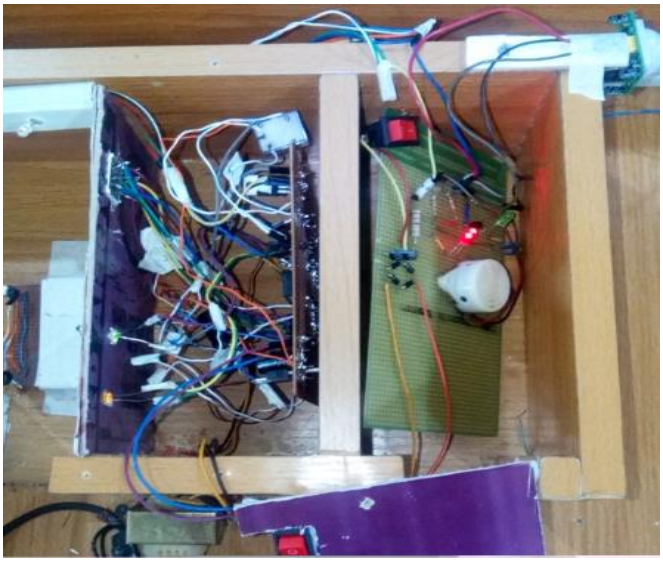

Fig. 7 Visitor counter in operation

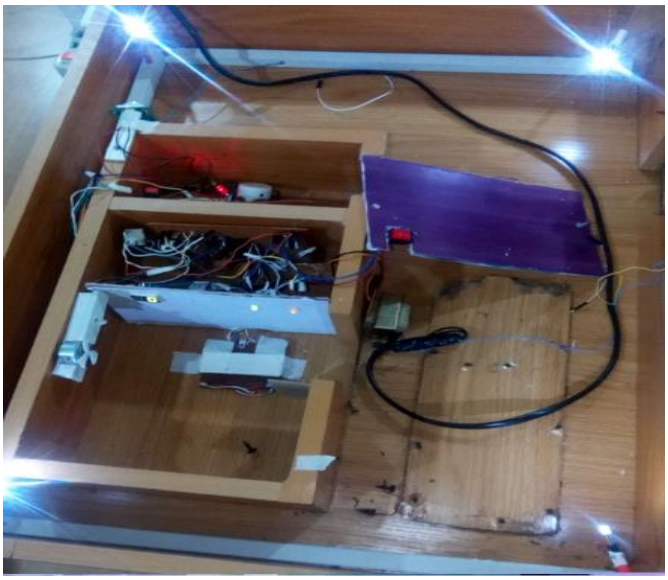

Fig. 8 The automated home with a single lighting and cooling model

4.1 COMPONENTS SPECIFICATIONS

Table 1 Component specifications

Parts	**Specification**
Transformer	24V Centre-tap, 500mA
DC Motor	5V, 50mA, 5000rev/min
7-Segment displays	5V, High contrast
PIR motion sensor	-55° to +55° field of view, 3s to 30s delay time, 6m detection range, 5V input, and 3.3V output

Table 2 Design Electrical Properties

Module	Voltage (V)		Current	
	Operating	Idle	Operating	Idle
Motion Sensor	8.89	9.59	0.046	0.031
Visitor Counter	11.36	12.55	0.088	0.046

Idle power consumption,
$= (IV)_{motion\_sensor} + (IV)_{visitor\_counter}$
$= (0.031*9.59) + (12.55*0.046)$
$= 0.29729 + 0.5773$
$= 0.875$ watts

operating power consumption,
$= (IV)_{motion\_sensor} + (IV)_{visitor\_counter}$
$= (0.046*8.89) + (11.36*0.088)$
$= 0.40894 + 0.99968$
$= 1.41$ watts

The power need of this project is significantly less when compared to [12] which uses a television and a personal computer. The average power need of these items are estimated at 80 watts.

4.2 COST COMPARISON

To support the claim of cheap design, this section provides the cost of implementation of other related projects in comparison with the design implemented here.

Table 3 Related Works and Cost Comparison

Home Automation Models	Design Specification	Cost ($)	Naira Value (#)
Room Occupancy and Monitoring Device[a] **[7]**	Counts and monitors movements, DC battery powered, single 7-Segment display, no security features, packaging no appliances automation designed without.	73.45	26,500
Automated Room Light Controller with Visitor Counter **[13]**	Personal Computer involvement in the control, uses AT89S52 with 8KB flash memory, counts, and dims the light, no security features	114[b]	42,000
Home Automation and Security System **[12]**	Fire and smoke detection, wireless control of home appliances from smart phones, ability to send notification to user, security cameras and motion sensor.	142[c]	52,000
Implemented Design	Motion sensor alarm for security, dual 7-segment displays, wooden home prototype, home lights and fan models	88	32,120

It is observed that the design approach employed in this paper results in an optimized design in terms of implementation cost, operation efficiency and power consumption.

[a] Cost was converted from Ksh 5899 to the prevailing exchange rate in 2010
[b] Estimated cost while also considering the average cost of a PC
[c] Appraised dollar cost of implementing this system in Nigeria

V. CONCLUSION AND FUTURE WORKS

A cheap low-power consumption system has been offered as a solution to home automation problem in this paper. Using visitor counter, a simple method of counting objects was developed to count and display the total number of people still occupying a space , and by applying suitable algorithm this information was used to automate the home lighting system. A security feature was also added to curb the menace of burglary and intrusion rampant in homes today.

For future work and research efforts to improve on this project, the following items should be considered:
Instead of simply using an exception in the program to stop the seven-segment display from going below zero, since this is illogical, a visual error indicator such as a blinking red LED and a reset button could be implemented to warn user when an object leaves after the display records zero. A scenario could be a person who sneaked in through the window or roof and then attempts to exit through the door. The reset button would be used to stop the blinking LED and return back the display value to zero.

Small architectural designs like beds, couches, wardrobes, TVs etc could be added to this work for aesthetic purpose.
To improve on the floodlight, reflective aluminium caps and transparent plastics could be used. This imitates the real-world floodlights and traffic lights.

As an improvement on the alarm of the motion sensor, a siren noise IC could be used to generate more realistic sound.
The physical design was heavy due to the nature of wood used for the construction. The use of less dense polished wood for future work is highly recommendable.
As it stands, the IR receivers cannot differentiate human obstruction from object obstruction. It can also not differentiate when it experiences simultaneous obstruction from multiple sources. A sensor capable of accurately telling when a human crosses and when two or more people cross at the same time could serve to make this work better.

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AUTHOR(S) PROFILE

John Nwankwo Chijioke obtained his BEng (Hons) degree from Nile University of Nigeria in 2018. He is currently working in Nile University of Nigeria.

Sadiq Thomas is an associate professor and the head of department of Computer Engineering department in Nile University of Nigeria. He obtained his bachelor's degree from the University of Brunel, UK, in 2002, and in 2005, he obtained a doctoral degree in Finite Modelling of EMAT from the University of Leeds, UK.

