UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

SMART ENERGY SAVING SYSTEM USING A PIR SENSOR IN A CLASSROOM

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AUGUST, 2015

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AUGUST, 2015

DECLARATION

STUDENT'S DECLARATION

I, Cynthia Twumasi, declare that, this Dissertation with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: …………………………………………..

DATE: …………………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of the Dissertation were supervised in accordance with the guidelines on supervision of Dissertation laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: MR. FRANCOIS SEYERE

SIGNATURE: …………………………………………..

DATE: …………………………………………………

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To God is the glory. I am very grateful to Almighty God for His guidance and protection throughout my study.

My next thanks go to my mother, Madam Dora Donkor who is the backbone of my education and to all my family members and friends especially Dr. Benjamin Akorli who has been my source of inspiration in my academic pursuit.

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Finally, to all those who helped in diverse ways in my education and in this Thesis, I say God richly bless you all.

DEDICATION

This work is dedicated to my late father, Mr. Yaw Twumasi who did not live to reap the fruit of his labour. May his soul rest in perfect peace.

I also dedicate it to the poor and needy.

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ABSTRACT

Energy saving methods vary and includes human action (manual operation) and automation (programming). Depending upon the type, mode of operation can significantly provide a unique way of saving energy. This research presented a proposed smart energy saving system using a PIR sensor in a classroom; this uses infrared (IR) remote control system to switch „on" or „off" an energy system in the absence of human beings. Satisfactory results of signal transfer from the remote control to the fan and light was achieved. The circuit consists of PIR and Temperature sensors, and a microcontroller-based automation along with a temperature and motion display using LCD to switch „on" and „off" fan and light circuits. An embedded system was employed in constructing the energy saving system. Four different softwares were used for the testing to authenticate the performance of the work. They are Windows operating system (windows 7), Cadsoft EGLE software, Multism software and Hyper terminal (arduino 1.6.3). The testing was done with an intelligence signal at different stages. The test results indicated a successful implementation of the work compared. The device is made up of two sensors, and a time delay of 10mins. More than two sensors can be used to achieve more clearance and a time delay of 60 seconds. The findings of this research will be very meaningful to many stakeholders.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Project

Energy in no doubt is one of the most important ingredient needed to carry out developmental project in every country. Electricity is a commodity that is widely used by all to the extent that, in the absence of it, a lot of work cannot be done. Ghana as a developing country has not been able to generate enough power to meet the growing demand; this has resulted in frequent power outages. There is the need to conserve and to use wisely the little that we generate to avoid power outages. It is against this background that the ministry of energy has embarked on a sensitization programme to educate the masses on the need to conserve energy. Though, people have been educated on the need to put off their appliances when leaving their rooms, yet a large amount of energy is wasted due to forgetfulness.

The purpose of this work is to correct this through the use of motion sensors that will automatically make appliances such as lights and fans turn off when there is no human presence. A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a number of other environmental phenomena.

1.2 Statement of Problem

People in public and private sectors offices, most of them are not interested in switching off the electronic appliances such as fan and lamb if they are not present. Power consumption in homes and offices tends to increase as a result of this attitude.

There has been an effort to reduce the power consumption in homes (Chinnan & al., 2011). Most students usually forget to switch off the fans and lamps in their classrooms which results in energy being wasted.

1.3 Objectives

The aim of this work is to continuously monitor the absence of students in timely base of 30 minutes. While the absence is effective, then the fan and lamp circuit will go off in respect of "30 minutes".

The propose work will design a smart energy saving system using a PIR sensor in a classroom through the following activities:

i. to design an energy saving system using wireless sensor devices.
ii. to construct a prototype circuit coupled with PIR sensor to control fans and lamps in a classroom.

1.4 Research Questions

The work aims at finding answers to the following questions

i. how can an energy saving system using wireless sensor devices be obtained?
ii. how can the expected results of the design in energy saving system for a classroom be realized?

1.5 Significance of the Project

The importance of this project cannot be overemphasized due to the immense relevant benefit it will bring the community and the country as a whole. This project will benefit the students since energy consumption in the school will be reduced. Students will understand the need to conserve energy despite the fact that they have been using energy saving appliances in their homes.

1.6 Limitations / Delimitations

The work considered a typical classroom size of 12m by 14m when using one sensor. It further assumes a permanent exit of students with a maximum detecting absence of 30 minutes respect to the last student"s exit.

The propose designed may be applicable to public work spaces with a maximum size of 12m by 14m and a minimum size of 12m by 12m.

1.7 Scope and Structure of the Project

This project consists of five chapters. Brief descriptions of each chapter are given below.

Chapter one gives an overview of the entire project including project background, statement of problem for the project, objectives of the project, significance of the project, limitations and delimitations of the project.

Chapter two presents the literature review, which highlight related work on this project. Chapter three focuses on how the circuit is been designed, the materials and components needed to construct the circuit, how to test the components and its properties, the instrument used and software analysis

In chapter four the results which provides relevant information on the outcome of the research is being explained.

Lastly chapter five summarizes the project and provides some conclusions, including recommendation for future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Brief Overview of Automation

The technology of automation evolves from a manually switching of devices „on‟ or „off‟. The first industrial robot, used in 1965 was controlled by a computer and worked in an automobile assembly plant. Since the 1980‟s the use of computer machines has greatly stimulated development. (Stephanie, 2002) IBM in 1981 introduced its personal computer (PC) for use in home, offices and schools prior to this time there had been several MS-DOS compatible personal computers that ran DOS programs. As smaller computers became more powerful, they could be linked or networked to share memory space, software and information and also communicate with others. Organizations have come a long way in using technology over the past years. From the early 1980 through the mid- 1990s, Organizations for the most part used PC based automated system to boost efficiency and cut cost. Many roles for human industrial processes presently lie beyond the scope of automation.

Automated control systems have reduced the need for a client to use his hand in controlling electrical appliances in a hotel. In general, automation has been responsible for the shift in the world economy to industries in the 19th century and from industrial to services in the 20th century. (Watt, 1987) a Scottish engineer constructed a device called a fly ball governor to regulate the speed of a steam engine The use of the fly ball governor marked the first industrial application of automation. These days, technology and automation have advanced to the stage of controlling some of the electrical appliances (equipment) in the home, office, industries, hotels etc through manual switch. This led to the design of this project "circuit controlling fan and light with sensor".

2.2 A Review on Related Research Work

In the beginning of electrification, switching electrical devices has been done by means of connecting or disconnecting them to the power grid. In recent year disconnecting a device from its energy source has become less popular.

Instead, switching is done electronically (automatically). This means that the inner device is separated from the switching circuit. As a consequence, the device can be powered „on" or „off" by a remote control unit or by an automated switching circuit based on occupancy. Some computer main boards may even allow reaction to power network events, It was then argued in (Adetiba & al, 2011) that the downside of the switching unit keeps consuming energy as long as it stays on.

In (Liji & al., 2005) , a system was designed and built to control the intensity/speed of electrical lights and fans using a TV remote control in the infrared (IR) set range of frequency. The control of light intensity and fan speed was successfully achieved through microcontroller. The system followed a linear profile and provided regulation against power supply voltage. It supplied voltage frequency independent.

This could be also used to cater for output power of high consuming power loads like fridge. A mathematical model was simulated in (Jaafar L. B., 2013) to control air conditioning system using Matlab/Simulink based on adaptive fuzzy and analyzed the performance of that controller. Matlab Simulink tools were used to evaluate the physical application, through simulation.

A device that would detect the presence or movement of persons in a room was designed and implemented. This controlled the switches of the lamp and fan based on a predefined temperature of the room. The Automatic switch was successfully implemented and its interface was integrated with software called Proteus.

Authors in (Adewale & al., 2013) proposed a light dependent resistor (LDR) that included a circuit to turn off the lamp when there was a good luminance and vice versa.

The design by (Prasanna & al., 2013) focused in places where the security was paramount. An alarm system was designed to alert when someone was passing by. The significance of the design, was that it turned the appliances „on" and „off" automatically.

More power could be conserved. This could be improved by adding a timing system that would delay the operation for sometime before applying the principles when a person is detected.

In (Sravani & al., 2014), the study investigated electronic circuit that made use of a Passive Infra-Red (PIR) sensor module to develop a motion sensor alarm detector. A message showing „motion detected" would be displayed on a PC whenever the sensor detected a motion with the aid of AT89S51 microcontroller.

The system could also be applicable to various loads like pressure, force etc, when the number of ports of the microcontroller were increased. This could be developed without wires such that different sensors in different places would be put in place. The proposal could also be used to reduce power consumption in electricity.

The application could be extended to indoor lamps and fans with a delayed timer. It was investigated in (Lunawat & Gokhale, 2015), the daily electricity consumption by using LCD which used GSM to alert consumption. Home utility signals, customer preference and presence were taken into account in case of an emergency. Keil (µ vision IDE) and Micro Flash were the software‟s used to achieve the dimming of light intensity according to user preference and thus energy management.

The PIR sensors and the Advanced RISC (reduced instructions set computer) Machnines (ARM) Processor remote control were used to provide a comfortable home management. This has shown an efficient energy management and reduces wastage of electricity in the absence of people in a room. This could also detect appliances that are faulty and as a result could consume more power.

A remote control for a fan regulator was designed and implemented in (Samiran & Pabitra, 2014), Infrared (IR) remote control signal decoder was implemented using a decade counter and TRIAC software. The control system was reliable and easy to operate. This could also control the intensity of light.

It would be better to integrate an alarm system to the design give signals promptly when there is a fault and the webcam cannot capture and record videos as a result.

In (Sharma, 2010), a Comparative study on the energy consumption for wireless sensor networks that was based on random and grid deployment strategies was reported. The relationship between energy consumption and the deployment strategy was underlined.

2.3 Lighting Controller and Manual Systems

A manual switching system is operated by controlling a switch by hand. A switch can be pressed or pushed to turn „on" or „off" an appliance. In a multi-throw switch, there are two possible transient behaviors as you move from one position to another. In some switch designs, the new contact is made before the old contact is made before the old contact is broken. This ensures that the two contacts are never short-circuited to each other.

A Switch controls a circuit when it opens or closes the circuit. It causes the circuit to operate between discrete specified levels. Lighting Controller is responsible for directing or controlling the light automatically whether remotely or locally in contrast with the manual control where people need to go to the located switch to turn on or off the light. This reflects the evolution from Energy Management Systems in which a central computer is used to control the lamps in a building. Tasks can range in levels of complexity from simple tasks such as turning on or off lights through to fully automating the majority of electrical systems within the building (Tubukare, 2010).

2.4 Overview of Fan Controller

The speed of the fan can be controlled with respect to the temperature and the motor. It can be manually turn „on" or „off" by tuning the regulator icon (Leviton).

Temperature controlled fan is an alternative way to deal with the speed of the motor. Temperature control is a process in which the temperature of an object is measured and the passage of heat energy into or out of the object is adjusted to achieve a desired temperature. A thermostat is a simple example for a closed control loop. It constantly measures the current temperature and controls the heater's valve setting to increase or decrease the room temperature according the user-defined setting. A simple method switches the heater or cooler either on, or off completely and controlled temperature must be expected (Ariffin N. L., 2006).

2.5 Sensor

Sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Sensors are used in everyday objects such as touch-sensitive elevator buttons and lamps which dim or brighten by touching the base. There are also innumerable applications for sensors of which most people are never aware. Applications include cars, machines, medicine, manufacturing and robotics. Because sensors are a type of transducer, they change one form of energy into another. For this reason, sensors can be classified according to the type of energy transfer that they detect. There are all types of sensors available for usage: Thermal, electromagnetic, mechanical, chemical, optical radiation, motion, distance and many more. A good sensor should be sensitive to the measured property, insensitive to any other property and should not influence to the measured property.

2.5.1 Theory of Sensor Propagation

2.5.2 Fresnel Lenses

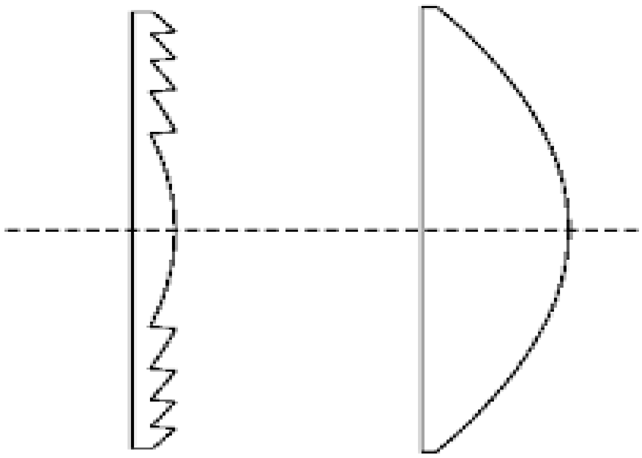

Fig.: 2.1a A Comparison of a Fresnel lens (left) and a "conventional" plano-convex lens (right).

Lenses work by refracting light beams.

Fresnel lenses consist of a series of concentric grooves etched into plastic. They are most often used in light gathering applications, such as condenser systems or emitter/detector setups. They can also be used as magnifiers or projection lenses in illumination systems, and image formulation. Fresnel lens simulates the shape of the conventional lens using individual grooves (Fresnel Lens).

The direction of propagation of light does not change within a medium unless scattered. Light rays are only deviated at the surfaces of a medium. As a result, the bulk of the material in the center of a lens serves only to increase the amount of weight and absorption within the system.

In 18^{th} century, physicists began experimenting with the creation of Fresnel lens. Grooves were cut into a piece of glass in order to create annular rings of a curved profile. This curved profile when extruded formed a conventional curved lens either spherical or aspherical due to this similar optical property compared to a conventional optical lens, a Fresnel lens can offer slightly better focusing performance depending upon the application. In addition, high groove density allows higher quality images, while low groove density yields better efficiency. When high precision imaging is required conventional singlet doublet or aspheric optical lenses are the best. An optical system produces highly-parallel beams like a spotlight. The imprecise nature of a Fresnel lens precludes their efficient use to efficiently collimate coherent light. Fresnel lens can be used in the following applications; light collimation, light collection and magnification (Advantages of fresnel lens).

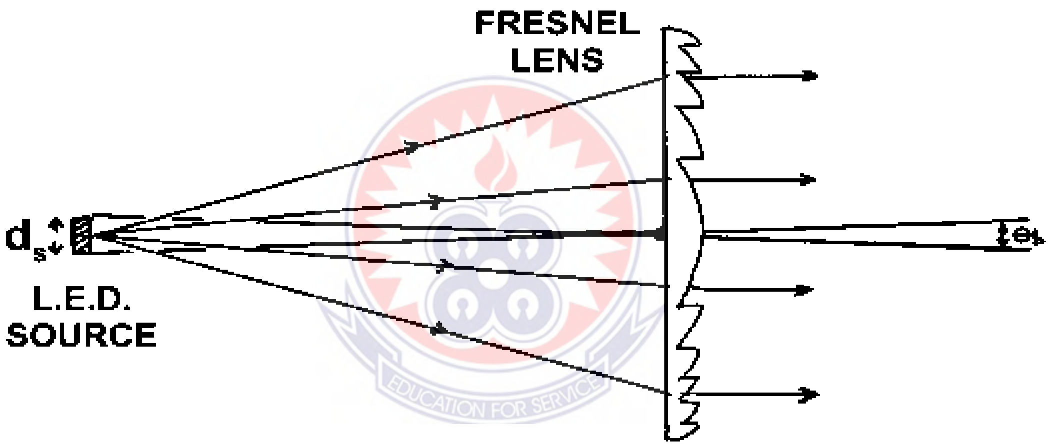

Fig. 2.1b: Fresnel lens being used to collimate light from an LED.

In "reverse", it can be used to concentrate parallel rays of light from a distant source onto a detector. In a practical system, a "secondary" lens would be placed very close to the LED to reduce the angle over which the LED's light was cast to allow a much greater percentage of it to reach the lens.

2.6. Passive infrared (PIR) Sensor

The PIR (Passive Infra-Red) Sensor is a 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 trigger a transistor which could switch high voltage devices. This is a good sensor for monitoring an area for motion. (McComb, 2012)

This sensor has two revisions: Revision A and Revision B.

Both revisions of this sensor use the same Fresnel lens, and basic functionality remains the same between the two. However, there were a number of improvements and updates made to Revision B. (PIR Sensor (Rev A)_910_2827_Parallax Inc)

The Revision B (555-28027) of a PIR sensor is shown in fig. 2.2.

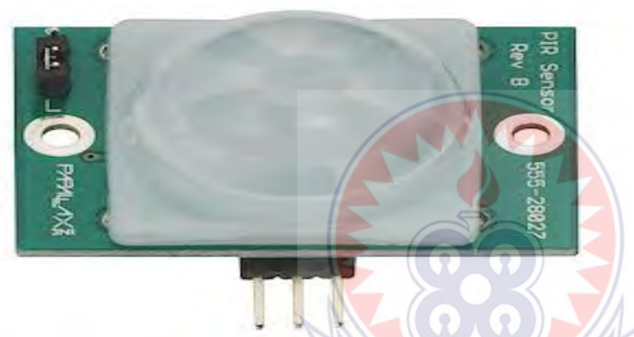

Fig. 2.2: PIR sensor Rev B

The sensor detects motion by sensing changes in the infrared (radiant heat) levels emitted by surrounding objects. The motion can be detected by checking for a sudden change in the surrounding IR pattern with a wide lens range. When motion is detected the PIR sensor outputs a high signal on its output pin. This logic signal can be read by a microcontroller so that it can be used to control a load. It detects a person up to approximately 30 feet away or up to 15 ft away in reduced sensitivity mode.

2.6.1. PIR Sensor Sensitivity and Distance Dependency

The sensitivity of the sensor is in the range of 10m at an angle of±15℃.

The PIR Sensor‟s range is affected by; the sensitivity jumper setting, the size and thermal properties of nearby objects and environmental conditions including ambient temperature and light sources.

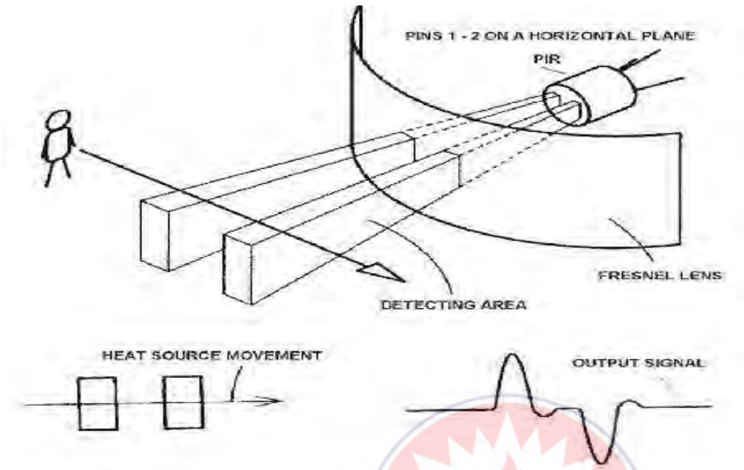

Fig. 2.3: Distance and sensitivity of PIR sensor.

2.6.2. Temperature Dependency

Pyroelectric devices, such as the PIR sensor, have elements made of a crystalline material that generates an electric charge when exposed to infrared energy. The changes in the amount of infrared energy striking the element change the voltages generated, which are measured by an on-board amplifier. The device contains a Fresnel lens, which focuses the infrared signals onto the element. As the ambient infrared signals change rapidly, the on-board amplifier trips the output to indicate motion. The onboard jumper allows the user to select between normal operation and reduced sensitivity. The sensitivity of the PIR Sensor varies with temperature and other environmental conditions. Generally, when in reduced sensitivity mode, the PIR sensor will detect an object at up to half the distance it would in normal operating mode. (Parallax)

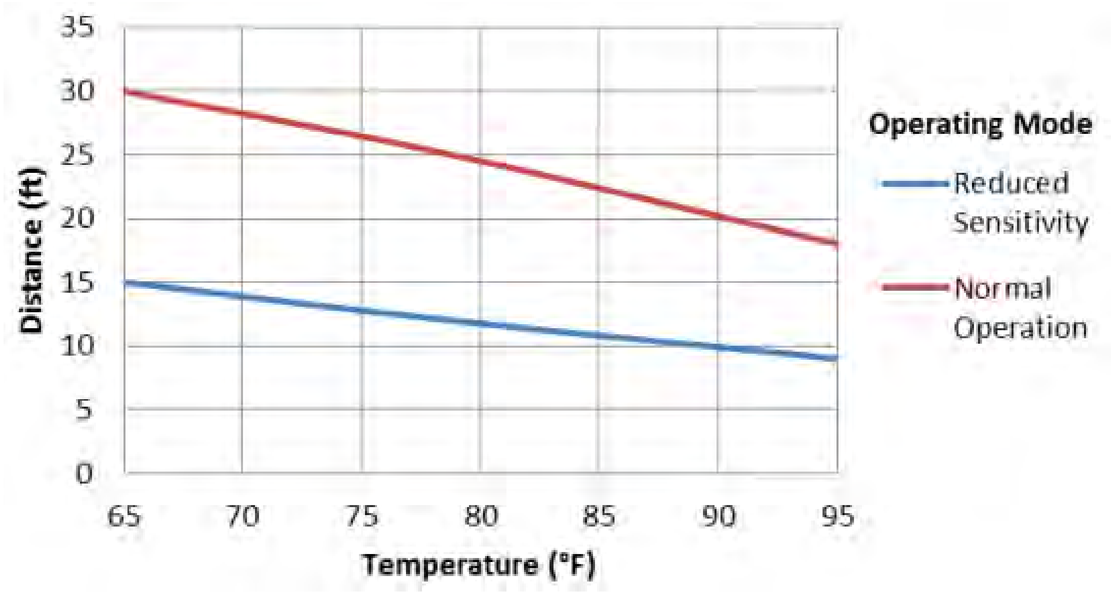

Fig. 2.4: Effect of temperature on PIR distance detection

2.7 Wireless Sensor Technology

2.7. 1 ZigBee Technology

ZigBee is a set of specifications created specifically for control and sensor networks. It is a mesh network specification for low-power wireless local area networks (WLANs) that cover a large area. It is often used in industrial automation and physical plant operation (Zigbee)

Its establishment was based on IEEE 802.15.4, the standard for low data rate wireless personal area networks (WPANs). The ZigBee systems require low latency, low data rates, low cost, and low energy consumption. ZigBee specification has become the global control/sensor network standard for a wide and varied range of residential, industrial, and commercial applications. It enables wireless two-way communications between commands and controls (e.g. boiler and thermostat), travels as far as 75-100 meters, and controls sensors that perform many different tasks.

Residential and commercial applications include lighting controls, smoke and CO2 detectors, HVAC controls, home security, automatic utility meter readings and communication between a remote control and a digital set-top box.

In industry, examples are monitoring medical equipment, building and industrial automation, and environmental controls ZigBee‟s very low energy consumption (door opening sensors, for instance, can run for five years on an ordinary (AAA battery) is an economic and ecological advantage. It is related to the way ZigBee networks work. ZigBee‟s wireless open standard technology is asserting itself globally as the energy management. It is playing a major role in how energy is priced and used, giving consumers and companies the chance to play a role in energy conservation.

The environmental gains are clear: it saves energy and reduces pollutions as there are no batteries to be disposed of. (Schneider electric). ZigBee as a standard has also defined what are called Application Profiles. These profiles describe how ZigBee devices interact, specifically between products of certain types and within certain markets. For example, the Home Automation profile describes how switches can control lights, how a temperature sensor sends its data to a thermostat and how that thermostat controls a heating or cooling unit (heater or air conditioner). ZigBee also defines application level compatibility through Application Profiles. Application Profiles describe how various application objects connect and work together, such as lights and switches, remotes and televisions.

The devices could be plugged into a real ZigBee network, within an actual home or small office and the lights could be controlled by switches in the network and the switch could control other lights in the network, regardless of vendor. The real secret to low power consumption in ZigBee, in addition to radios and microcontrollers that can sleep, is low duty cycle. In fact ZigBee networks are often quite silent. A temperature sensor may rep ort only once per hour, unless the temperature suddenly changes. A light switch may be toggled 6 or 10 times per day, possibly less. (Newnesspres).

2.8 Basic Components

2.8.1. Relay Single pole double throws (SPDT)

Relays control a circuit by a low-power signal. This switch has a single input and can be connect and switch between two outputs. This means it has one input terminal and two output terminals. It can serve a variety of functions in a circuit. It can serve as an on-off switch, depending on how the circuit is wired. Or it can serve to connect circuits to any two various paths that a circuit may need to function. It has five terminals as shown in Fig. 2.5.

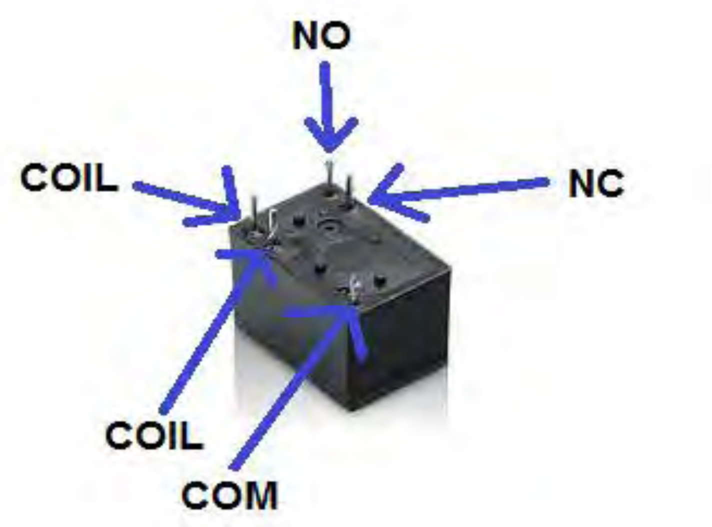

Fig. 2.5: Terminal pins of SPDT relay.

2.8.1.1. Principles of Operation

The two coils are the terminals where voltage is applied to give power to the coils which then will close the switch Polarity does not matter in this case unless a diode is used. One side gets positive voltage and the other side gets negative voltage. NO is the normally open switch. This is the terminal where the load is connected to so that it can be powered by the relay when it is powered the coils receive sufficient voltage. The load connected to the NO switch will be off when the relay has no power and will turn on when the relay receives power.

NC is the normally closed switch. This is the terminal where the load is powered by the relay. The load connected to NC will be on when the relay has no power and will turn off when the relay receives power. COM is the common of the relay. When the relay is powered and the switch is closed, the COM and NC have continuity. This terminal of the relay is first connected to the circuit. (How to connect a single pole double throw (SPDT) relay in a circuit)

2.8.2. Transistor

A transistor can perform two different works. It can work either as an amplifier or a switch: When a circuit produces a low signal it makes it high in this case it serves as an amplifier. In other words it is switch when a voltage is applied from the base to emitter the transistor is turned on allowing a current to flow from collector to emitter. It can be categorized two NPN and PNP. It has three pins namely; base, collector and emitter. The base is activates the transistor, the collector is the positive lead and the emitter is the negative lead. The main difference between an NPN and a PNP transistor in a circuit is the direction in which electrons flow between emitter and collector.

2.8.3 Electrolytic Capacitor

An electrolytic capacitor is a polarized capacitor which uses an electrolyte to achieve a larger capacitance than other capacitor type. An electrolyte is a liquid or gel containing a high concentration of ions. Almost all electrolytic capacitors are polarized, which means that the voltage on the positive terminal must always be greater than the voltage on the negative terminal. Electrolytic capacitors can be either wet-electrolyte or solid polymer.

They are commonly made of tantalum or aluminum. Super capacitors are a special subtype of electrolytic capacitors, also called double-layer electrolytic capacitors, with capacitances of hundreds and thousands of farads. These types of capacitors are mostly used in DC circuits because they are polarized. (Capacitor Guide)

2.8.4. Diode (IN4004)

A diode is an electronic component with two electrodes; anode and cathode. It allows current to flow in one direction and blocks the current that flows in the opposite direction. Most diodes are made with semiconductor materials such as silicon, germanium, or selenium. Diodes can be used as rectifiers, signal limiters, voltage regulators, switches, signal modulators, signal mixers, signal demodulators, and oscillators. (Swagatam, 2010)

2.8.4.1 Principles of Operation

The diode operate in a circuit is as „Biasing" when a DC voltage signal is applied across its terminals. Since it acts like a one way switch, the biasing is forward when a high voltage is applied to the cathode or the anode this makes the diode in the „on" state. In other words the biasing is reverse when a low voltage is applied to the cathode or anode the diode is said to be off state. (Engineers Garage)

2.8.5. Resistor

A resistor is one of the basic components of an electrical or electronic circuit. They can be connected together in series and parallel combinations to form resistor networks which can act as voltage droppers, voltage dividers or current limiters within a circuit (How do Resistors Work , 2016).

Resistors are passive devices because they do not contain source of power or amplification but only attenuate or reduce the voltage or current signal passing through them. This attenuation results in electrical energy being lost in the form of heat as the resistor resists the flow of electrons through it. They have bands printed in colored ink on their bodies which are used to determine their resistance values and tolerance. These colored painted bands produce a system of identification generally known as a resistors color code (Resistor Color Code and Resistor Tolerances Explained, 2016)

Resistors can be categorized into three main types namely; fixed, variable and special resistors. They resist the flow of electrons by using the type of conductive material from which they are composed. It can be used to reduce the available voltage or current present in a circuit. The resistance of a resistor is measured in Ohms (Ω). The resistance is also related to the type of material from which a resistor is made of. Different materials have different resistivity; conductors have much lower resistivity than insulators. This increases linearly with temperature. The resistivity of a material is measured in Ohm meters (Ωm) (Chris, 2016)

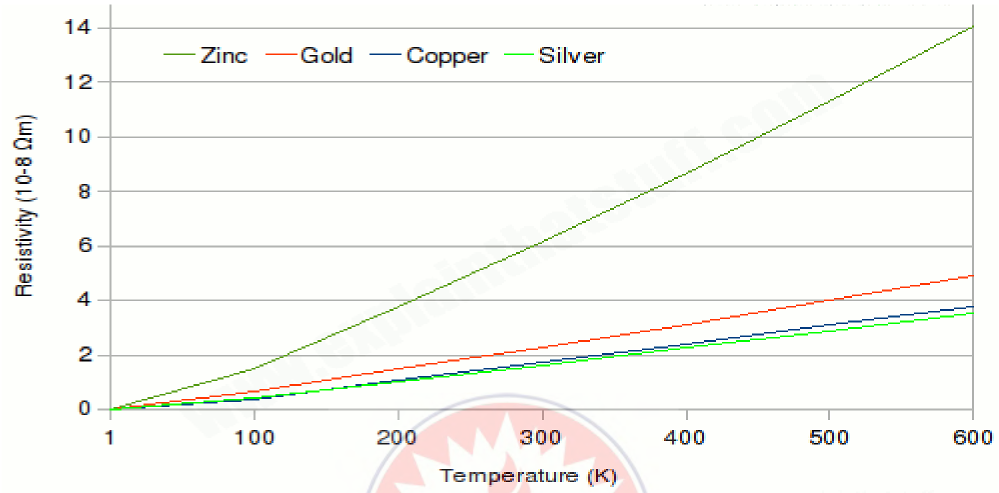

Fig. 2.6: Resistivity of Copper, Gold, Palladium and Silver at a temperature of 600K (327^{o}C).

2.9. The Infrared (IR) Frequency

Infrared radiation is a type of electromagnetic radiation such as radio waves, ultraviolet radiation, X-rays and microwaves. Infrared light is the part of the electromagnetic spectrum that people encounter most in everyday life. It is invisible to human eyes, but it can be felt as heat. Infrared radiation is one of the three ways heat is transferred from one place to another. The other two are convection and conduction. Everything with a temperature above about 5 degrees Kelvin emits IR radiation. The sun gives off half of its total energy as IR, and much of its visible light is absorbed and re-emitted as IR (Lucas, What Is Infrared, 2015)

Electromagnetic waves are formed when an electric field couples with a magnetic field. The magnetic and electric fields of an electromagnetic wave are perpendicular to each other and to the direction of the wave. (Jim, www.electromagnetic radiation.htm, 2015). They are produced by the motion of electrically charged particles. These waves are also called "electromagnetic radiation" because they radiate from the electrically charged particles. They travel through empty space as well as through air and other substances (Electromagnetic Radiation)

Electromagnetic radiation spans an enormous range of wavelengths and frequencies. This range is known as the electromagnetic spectrum. The electromagnetic spectrum is divided into seven regions in order of decreasing wavelength and increasing energy and frequency. The common designations are: radio waves, microwaves, infrared (IR), visible light, ultraviolet (UV), X-rays and gamma rays. Lower-energy radiations such as radio wave are expressed as frequency and microwaves; infrared, visible and UV light are usually expressed as wavelength. Higher-energy radiations such as X-rays and gamma rays are expressed in terms of energy per photon.

Infrared is in the range of the electromagnetic spectrum between microwaves and visible light. It has frequencies from about 30 THz up to about 400 THz and wavelengths of about 100 micrometers (μm) to 740 nanometers (nm). IR light is invisible to human eyes, but we can feel it as heat if the intensity is sufficient.

2.10. The Embedded System

Embedded system is devices used to control, monitor or assist the operation of equipment, machinery or plant. It is an engineering artifact involving computation that is subject to physical constraints arising through interactions of computational processes with the physical world. (Engineers Garage).

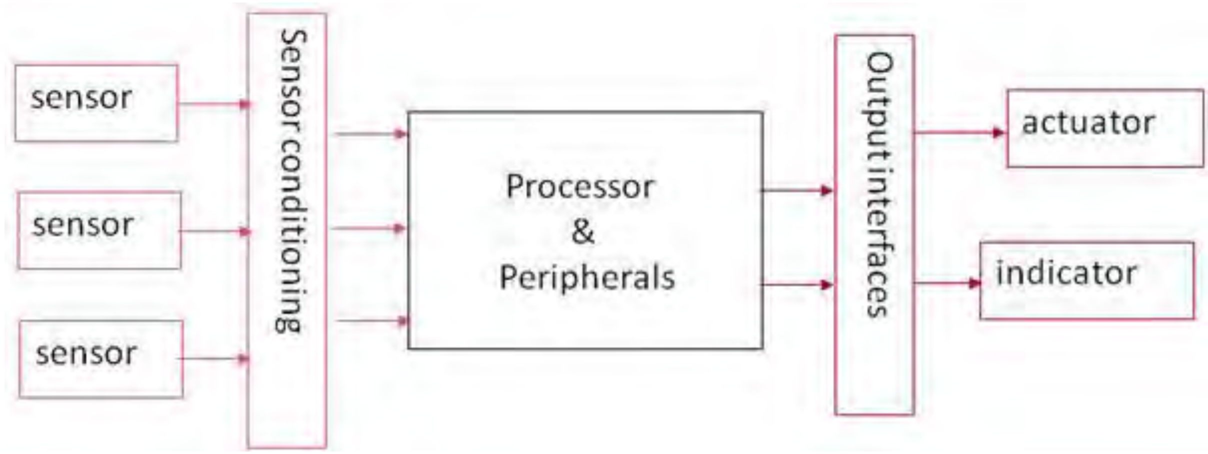

Fig. 2.7: Block diagram of an embedded system

The embedded systems have the following characteristics

Embedded systems are application specific and single functioned; the programs are executed repeatedly.

Efficiency is of paramount importance for embedded systems. They are optimized for energy, code size, execution time, weight and dimensions and cost.

Embedded systems are typically designed to meet real time constraints; a real time system reacts to stimuli from the controlled object or operator within the time interval dictated by the environment. For real time systems, right answers arriving too late (or even too early) are wrong.

Embedded systems often interact (sense, manipulate and communicate) with external world through sensors and actuators and hence are typically reactive systems; a reactive system is in continual interaction with the environment and executes at a pace determined by that environment.

Generally, they have minimal or no user interface.

CHAPTER THREE

METHODOLOGY

3.1 Research Design and Procedures

The research design is depicted by the flow chart showing in figure 3.1. It comprises of the various components and commands used in the construction of the energy saving device.

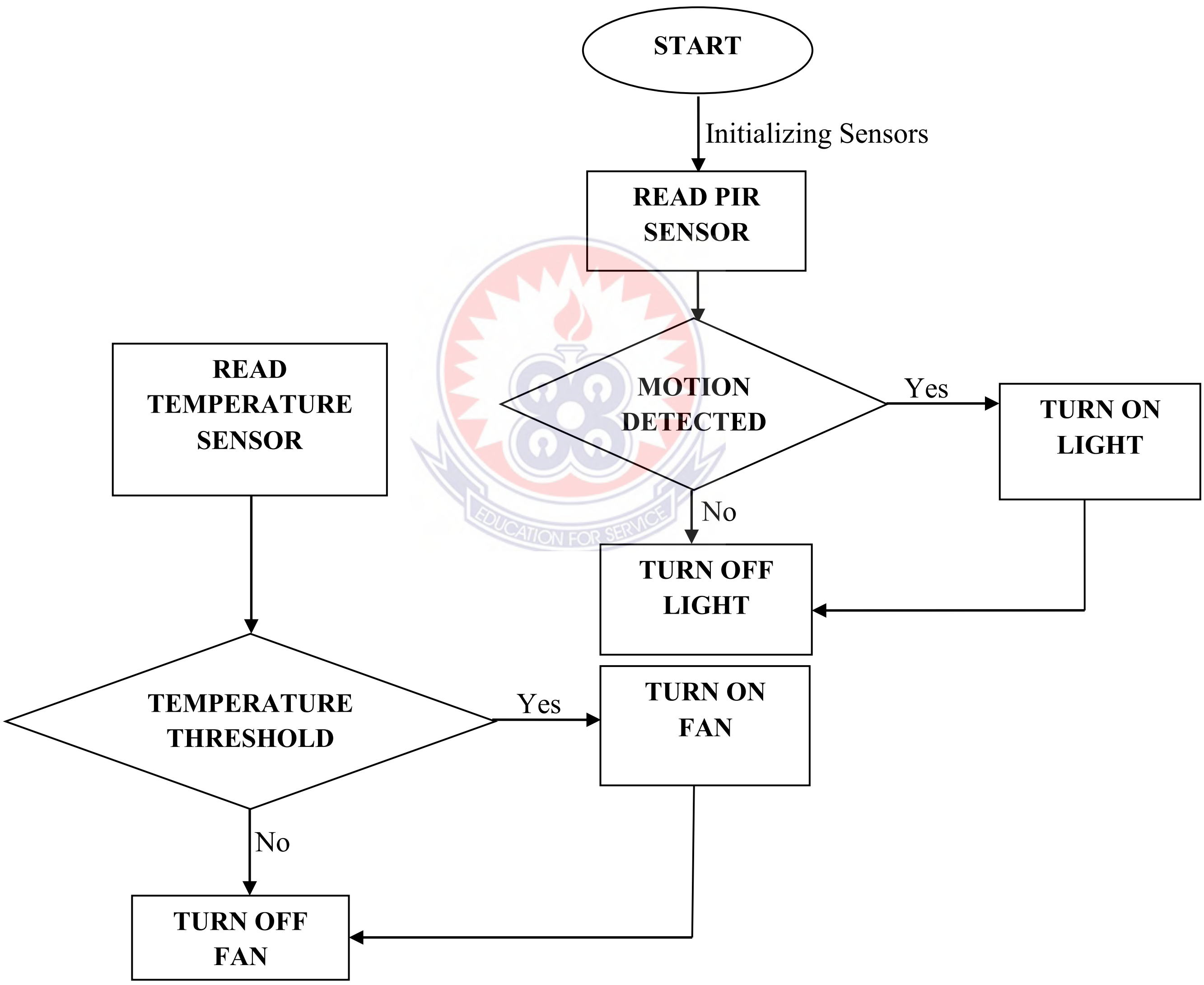

Fig. 3.1: Flow chart of the device circuit

3.2 Software Requirements

For the implementations of the design, the following software were used

- Windows operating system (windows 7)
- EGLE cadsoftware
- Multism software
- Hyper terminal (arduino 1.6.3)

3.3 Hardware Requirements

The Arduino

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. The Arduino board, called Arduino Uno is able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED.

Fig. 3.2: Arduino Uno

Arduino Uno Rev3 is a microcontroller board based on the ATmega328P, an 8-bit microcontroller with 32kB of Flash memory and 2kB of RAM. It contains everything needed to support the microcontroller. A set of instructions is sent to the microcontroller on the board, by the use of Arduino programming language (based on wring) and Arduino Software (IDE) based on Processing. It is connected to a computer with a USB cable or powered with an AC-to-DC adapter or battery to get it working. (www.arduino store community and electronics.htm).The specifications of the Arduino uno is presented in table 3.1.

Table 3.1: Specifications of Arduino uno

Discription	**Specification**
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output
PWM Digital I/O Pin	6
Analog Input Pins	6
DC Current per I/O Pin	20mA
DC Current for 3.3V Pin	50mA
Flash Memory	32Kb (ATmega32P) of which 0.5kB used by bootloader
SRAM	2Kb (ATmega328P)
EEPROM	1Kb (ATmega328P)
Clock Speed	16MHz
Length	68.6mm
Width	53.4mm
Weight	25g

3.4 View of the study area and Positioning of the PIR sensor.

The study area is a classroom of an area 12m by 14m.

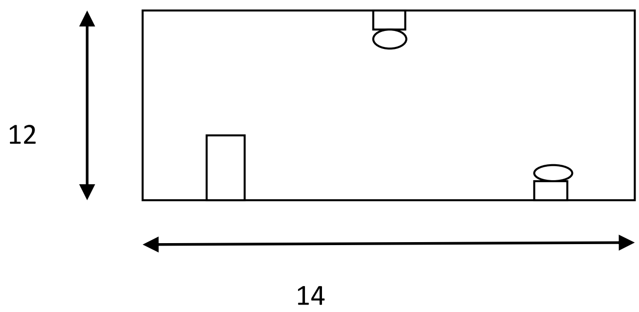

Figure 3.3: Area of classroom centered.

Two sensors were positioned diagonally in the classroom to cover the entire area. The second consideration was based on Fresnel zone thus the sensors were placed above the fan and the lamp so that the clearance is met, in such that the sensors can detect every motion in the classroom to switch fan or lamp off automatically.

3.5. The Device Elements

These comprise the following:

Table 3.2: Device elements specifications

Item no	Description	Specification	Quantity
1	PIR Sensor	Rev B. 555-28027	2
2	Relay	JZC-20F (4088) 10ADC12V	2
3.	Transistor	P2N2222	2
4.	Diode	IN4004	4
5.	Potentiometer	10K	1
6.	Capacitor	Electrolytic 470µF 25V	2
7.	Resistor	Fixed 1kΩ 27^{o}C	2
8.	Resistor	Fixed 220Ω 27^{o}C	2
9.	Resistor	Fixed 220kΩ	2
10.	Temp. Sensor	TMP36	1
11.	LCD	16 x 2	1
12.	Push Button	Lock-Red	1
13.	Push Button	Momentarily-Amber	1

3.5.1 Construction of Light Circuit

The circuit is powered by 12V DC (battery). This circuit causes the bulb to glow to give off light. It is connected to the output of the device through a 12V SPDT relay which controls the lamp.

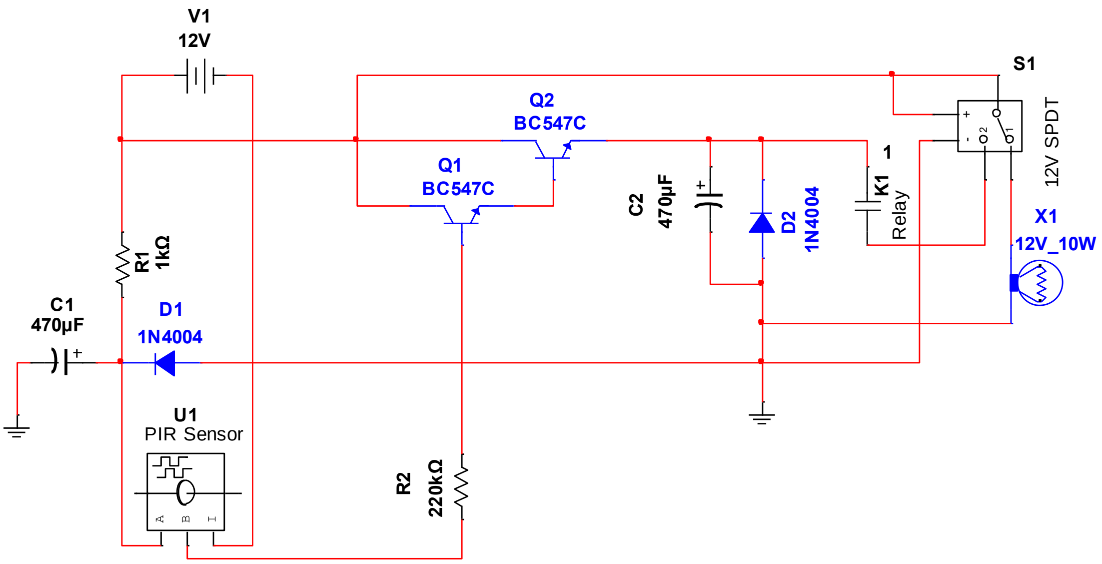

Fig 3.4 Light Circuit

3.5.2 Construction of Fan Circuit

The circuit was powered by a DC (battery) voltage of 12V. This circuit causes the fan blades to rotate when the set temperature of the room is obtained. The fan is connected to the output pins of the device through a 12V SPDT relay which controls it.

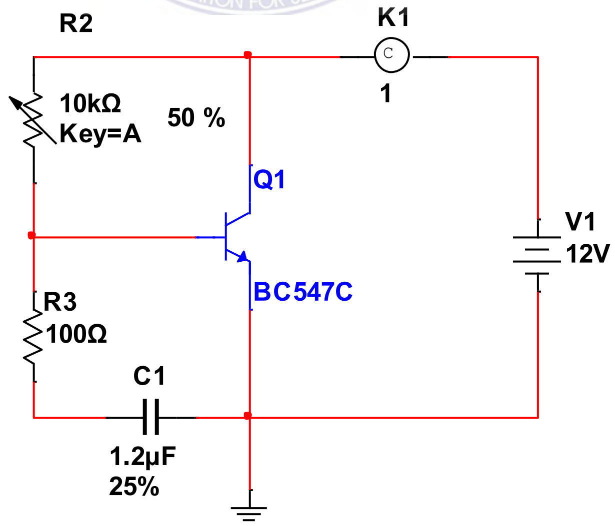

Fig 3.5 Fan circuit

3.5.3. The set-up of the Device

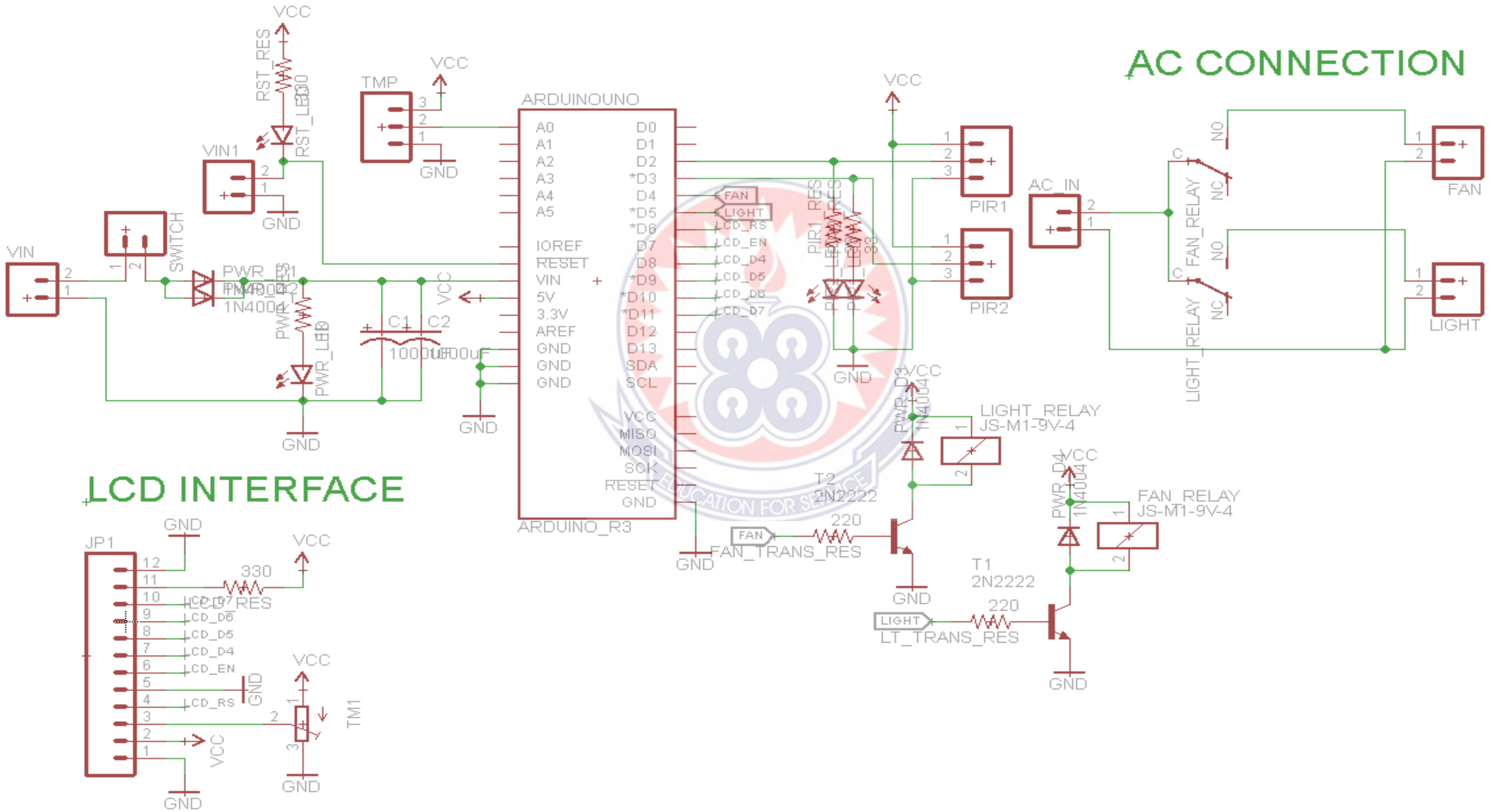

Fig. 3.6: **Set-up of the device**

3.6. Description of the Device.

The device is powered by 9V, 1.5W DC. It has two sensors (555-28027) and TMP 36 which is connected to the Arduino Uno with an LCD screen interfaced which displays the temperature of the room and motion detected by the PIR sensors.

The PIR sensor detects motion and sends a signal to the Arduino Uno to trigger the relay to switch on the lamp and fan. The fan switches on when the temperature sensor senses a room temperature of 25°C – 30°C.

3.7. Design Procedure of the Device

After considering the topic and its requirements, a circuit was designed and analyzed using CadSoft EAGLE software. The designed was reviewed and a prototype was built and tested on a bread board. After tweaking the values of the resistors and other components used, the final design was made using the same EAGLE circuit design software. The circuit board was printed on a copper plated board. Continuity test was made on the circuit board; thus testing the efficiency of each copper trace. After the continuity test and corrections, the circuit components were transferred unto the PCB (Printed Circuit Board) and soldered. The Soldering was done with a 60W soldering iron which ensured minimum heating of the circuit components being soldered. The solder used was 0.8 mm in diameter and made of 60/40 alloy of lead. A case was created using Perspex. With the help of super glue adhesive, the various parts of the case were assembled. The circuit was then mounted inside the package and the case was sprayed with an aerosol black and silver spray. The circuit was then ready for testing and analysis.

CHAPTER FOUR

RESULTS AND DISCUSSION

Multism software was used to design the lamp and fan circuits and Cadsoft EAGLE software was used in designing the device.

The device was powered by a bench AC power supply and tested. It was able to perform as it was designed and programmed. The activity of the device is displayed on the LCD. Whenever the rooms are occupied the fan and lamp are automatically switched „on" and are put „off" when there is no occupant in the room. The fan switches „on"only when the temperature of the room is in the range of 25^{O}C- 30^{O}C.

4.1. Power consumption test

The total power of the device is the product of the voltage and current. The minimum and maximum voltage and current were recorded and the power consumption calculated as follows:

Table 4.1.: Measured values from the research conducted

Voltage (V)	Current (mA)	Power (mW)
7	87	609
9	100	900
12	120	1440

The device was quite unstable and caused the microcontroller to restart when it was powered with the 7 V power supply. The 9 V power supply run the device smoothly without any glitches. And the current at which the device operated was efficient. The 12 V caused the arduino micro-controller to heat up. This was because the arduino has on it a 5 V voltage regulator that operates at an optimum voltage of 7V. Although the technical specifications says it can handle up to a maximum of 18 V, heating will cause inefficient use of power. Therefore, after considering the voltage range, the 9V power supply was selected for its availability and less heating.

4.2. The View Angle and Range Test

This test was to measure the view area of the device. The device was once again mounted on the ceiling of a room of dimensions 10 m x 5 m x 4.5 m. The device was able to detect the presence of a human being right at the entrance and also at the end of the room. This made it possible for the device to keep the light „on" so far as the person was in the room and the fan „on" when the temperature of the room was at 30^0C.

The power button (On/Off) is positioned at the left side of the device. The green light indicates that motion has been detected and the temperature of the room is in the range of 25°C-30^OC, therefore the fan is „on". The red light also indicates that motion has been detected and the lamp is „on".

Fig. 4.1: View angle and rage test result.

Fig. 4.2: Front side of the device design.

Fig. 4.3: Back side of the device design.

Fig. 4.4: Internal components of the device.

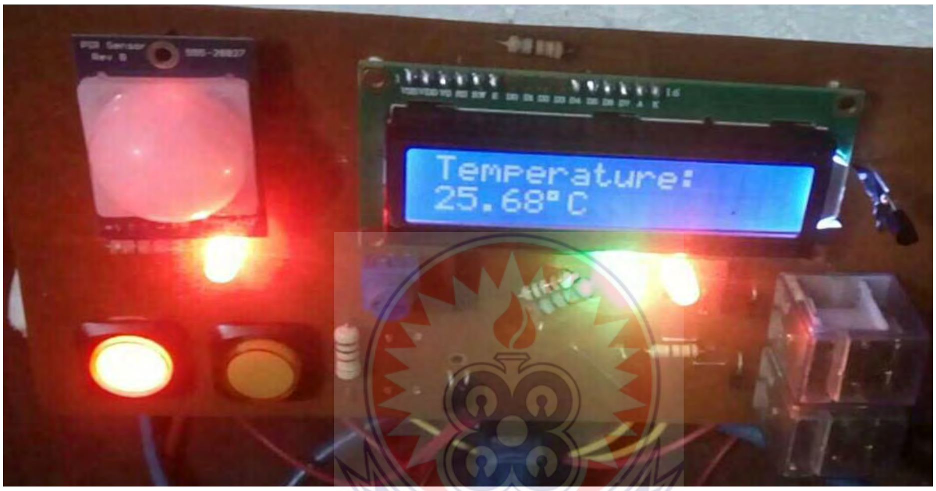

Fig. 4.5: Testing of device with fan before assembly.

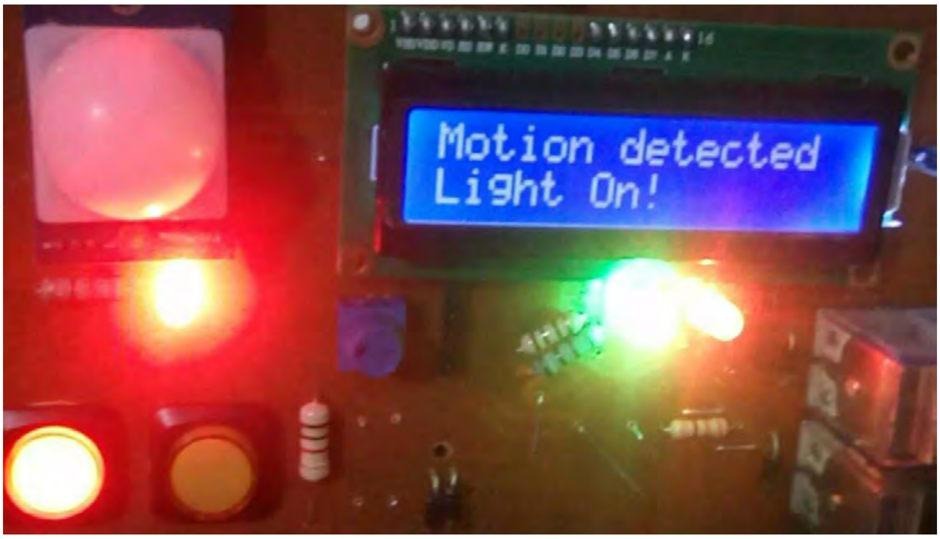

Fig. 4.6: Testing of device with light before assembly.

Fig. 4.7: Complete assembly of the device.

4.3. Device Sensitivity Test

The sensitivity of the device is a measure of how fast it responds to a change in its state. The device was mounted in a room and three people engaged in an abstract activity in the room. The device maintained the „on‟ state of the lamp as far as the people were in the room. After exit of the three people, the device switched off the lamp after 10 seconds, exactly as it was programmed. The temperature test was quite challenging. To measure this, the device was stationed close to an incandescent bulb mounted in the room. The threshold temperature was set between 25^{o}C- 30^{o}C and a standing fan was connected to the device‟s fan output. The fan was started automatically by the device when the temperature rose to 25^{o}C. The fan continued working until the room temperature cooled to 20^{o}C that was the minimum temperature set in the device‟s programming.

Fig.4.8: Device before test

Fig. 4.9: Device during test (only lamp is „on")

Fig. 4.10: Device during test (Both fan and lamp are „on")

4.4. Light Circuit Simulation Results

Multism software was used to simulate to determine the output DC voltage, 4.37V was obtained. The output from the oscilloscope after simulation showed a continuous DC signal.

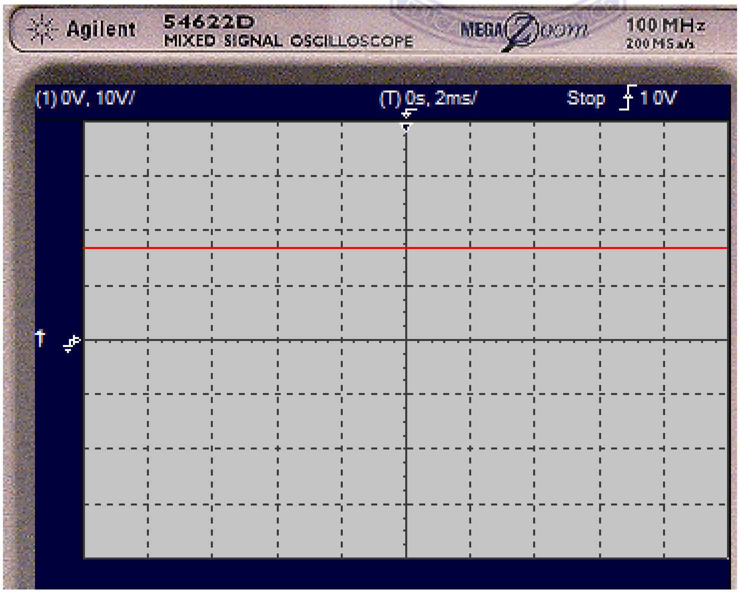

Fig. 4.11: DC output shown on oscilloscope

4.5. Fan Circuit Simulation Results

An output DC voltage of 2.6V was obtained when Multism software was used in simulation. The output from the oscilloscope of the simulating results from the Multism showed a continuous flow of DC signal.

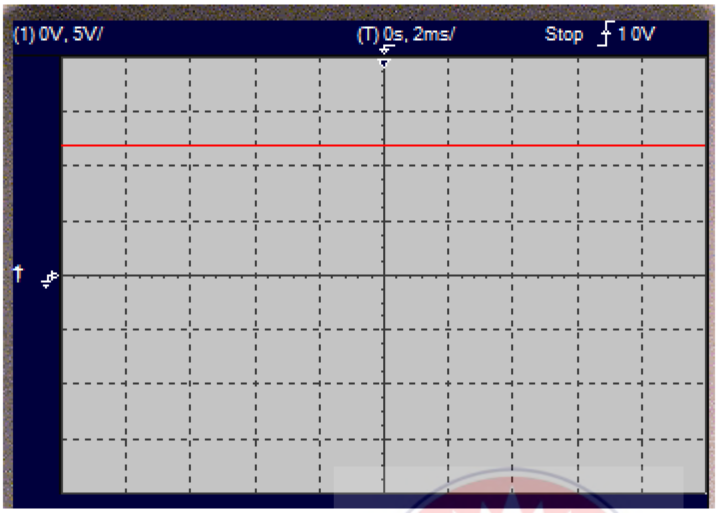

Fig 4.12 DC output shown on oscilloscope

4.6. Cost Analysis

Estimated cost of the research work mounted up to $ 392.50.

Table 4.2: Cost analysis

Material / item	Amount($)
PIR sensor	129
Mailing of PIR sensor	62.50
Arduino Uno	55
Circuit components	33
Transport	50
Workmanship	63
Total	392.50

4.7. Discussion

In the first scenario the built device was placed at the main entrance. It was realized that its sensitivity limit was low. As a result of this a second one was placed at the far end diagonally to improve the sensitivity limit.

When a student enters the classroom, the Infrared energy emitted from the living body is focused by the Fresnel lens segment and the PIR sensors activate and give to the microcontroller which acts as power saving device according to the relay. When motion is detected the relays trigger and switch the fan and light „on‟ and after ten minutes switch „off‟ the fan and light when motion has not been detected. The fan only switches „on‟when the room attains a temperature of 25^0C-30^0C.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The study proposes an energy system using a wireless sensor. The Passive Infrared (PIR) sensor was embedded to Arduino hardware. The design system comprises a motion detector and temperature sensing component. The motion detector is meant to detect any human being displaced through the infrared (IR) heat generated by human body.

The temperature detector operates when the room temperature is above a given threshold. For this project the room temperature is summed to be in the range of $25^{O}C$ to $30^{O}C$ in other to meet the weather condition experienced in Ghana. Two sensors were used and placed diagonally in other to cover the entire classroom.

5.2. Recommendations

Based on the test results, the following were recommended for future work and improvement:

- Addition of a buzzer to give signals when motion has not been detected and there is occupant in the room.
- A shorter recovery time for the device to switch off the lamp and fan in a span time of 60 seconds when there is no occupancy.
- More than two sensors configuration should be considered.

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APPENDIX

Fig. 1: Planning of glass plate.

Fig. 2: Gluing of glass plate to make a package.

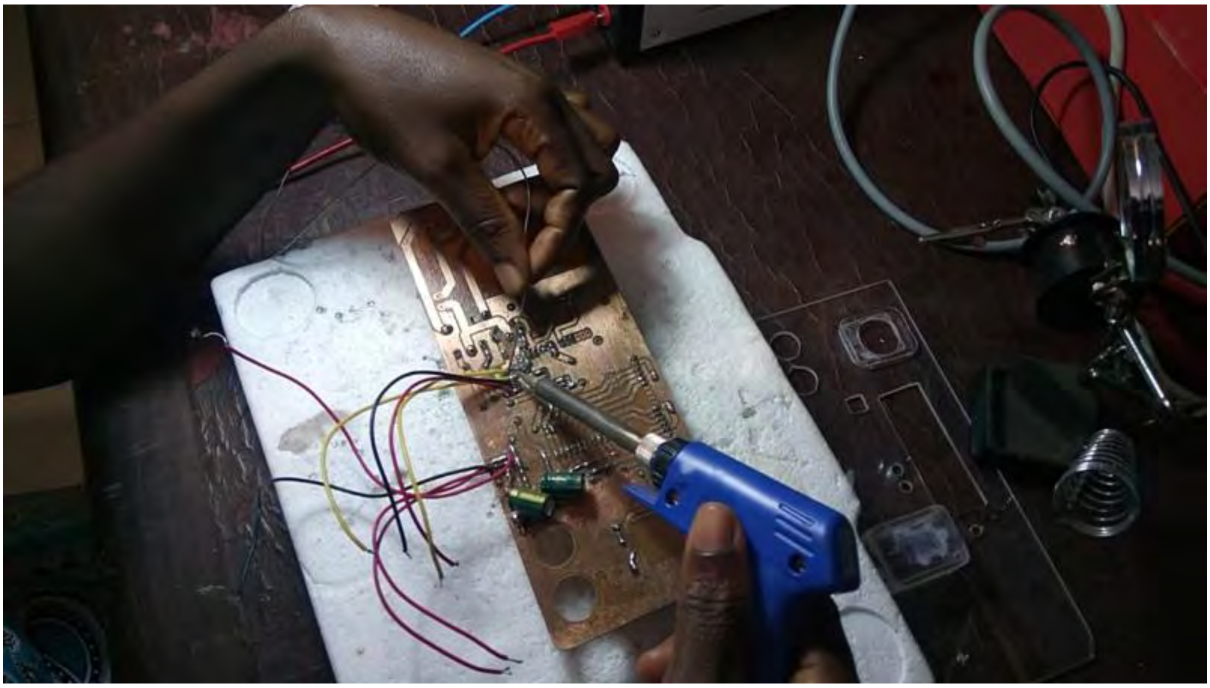

Fig. 3: Soldering of components on overboard.

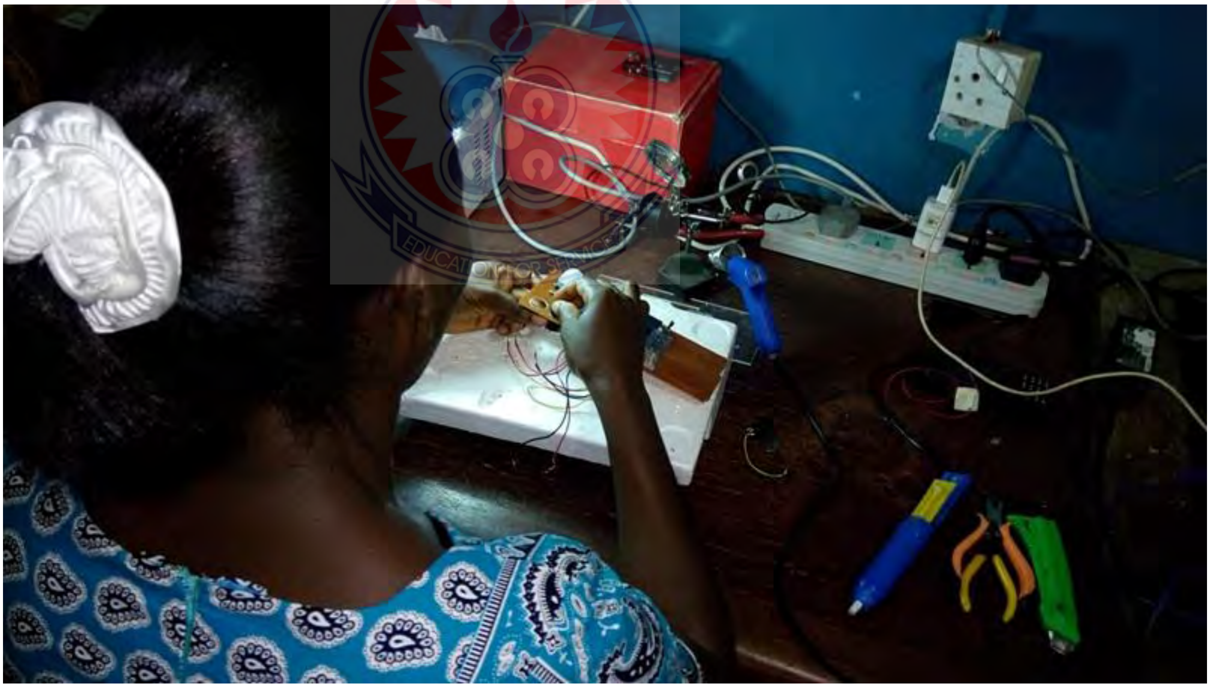

Fig. 4: Fixing and assembling of circuit parts and accessories.

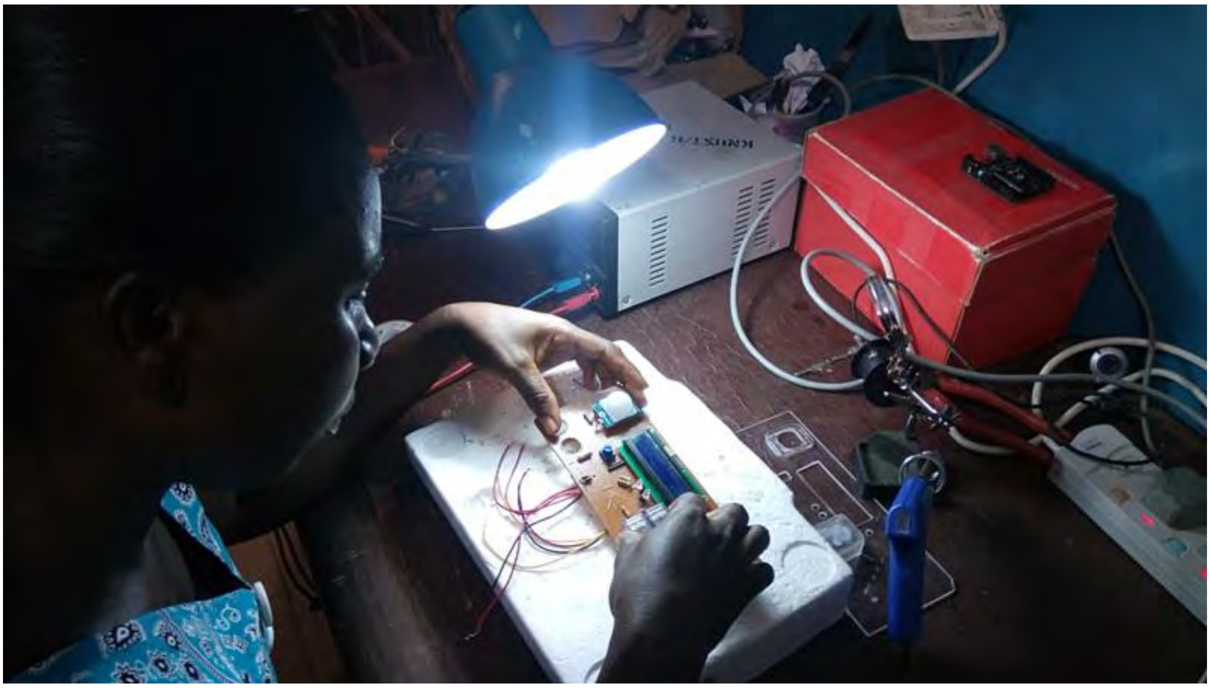

Fig. 5: Checking of proper connections of circuit accessories.

CODE

```
#include <LiquidCrystal.h>

//pin declaration

const int tmp = A0;

const int lcd_rs = 6;

const int lcd_en = 7;

const int lcd_d4 = 8;

const int lcd_d5 = 9;

const int lcd_d6 = 10;

const int lcd_d7 = 11;

const int fan = 12;

const int light = 13;

const int pir = 3;

bool lightCtrl = false;

bool fanCtrl = false;

double tmpVal = 0;

double maxTmp = 28.0;

// initialize the library with

the numbers of the interface
```

```
pins
LiquidCrystal lcd(lcd_rs,
lcd_en, lcd_d4, lcd_d5,
lcd_d6, lcd_d7);
void printLCD(String r1,
String r2 = "");
void initLCD();
double getTemp();
long lightDuration = 10000;
long lightTimer = 0;
void printStatus();
void setup() {
  initLCD();
  printLCD("Initializing",
"digital pins...");
  pinMode(pir, INPUT);
  pinMode(fan, OUTPUT);
  pinMode(light, OUTPUT);
  digitalWrite(fan, LOW);
```

```
  digitalWrite(light, LOW);

  printLCD("System status:",
"Ready!");

  delay(1000);

}

void loop() {

  if (digitalRead(pir) == HIGH
&& !lightCtrl) {

    if (!lightCtrl) {

      lightCtrl = true;

      digitalWrite(light,
HIGH);

    }

    if (getTemp() >= maxTmp) {

      if (!fanCtrl) {

        fanCtrl = true;

        digitalWrite(fan,
HIGH);

      }
```

```
    }
  } else if (lightCtrl &&
digitalRead(pir) == HIGH) {
    lightTimer = 0;   //reset
timer
    if (getTemp() >= maxTmp) {
      if (!fanCtrl) {
        fanCtrl = true;
        digitalWrite(fan,
HIGH);
      }
    }
  } else if (digitalRead(pir)
== LOW && lightTimer >=
lightDuration && lightCtrl) {
    if (fanCtrl) {
      digitalWrite(fan, LOW);
      fanCtrl = false;
    }
```

```
    digitalWrite(light, LOW);

    lightCtrl = false;

    lightTimer = 0;

  } else if (digitalRead(pir)

== LOW && lightTimer <

lightDuration && lightCtrl) {

    if (getTemp() >= maxTmp) {

      if (!fanCtrl) {

        fanCtrl = true;

        digitalWrite(fan,

HIGH);

      }

    }

  }

  printStatus();

  delay(1000);

  lightTimer += 1000;

}

void printLCD(String r1,
```

```
String r2) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print(r1);
  lcd.setCursor(0, 1);
  lcd.print(r2);
}
void printStatus() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print((lightCtrl) ?
"Light: ON" : "Light: OFF");
  lcd.setCursor(0, 1);
  lcd.print((fanCtrl) ? "Fan:
ON " + String(getTemp()) +
String(char(223)) + "C" :
"Fan: OFF " +
String(getTemp()) +
String(char(223)) + "C");
```

```
}

void initLCD() {

  lcd.begin(16, 2);

  for (int i = 0; i <= 100;

i++) {

    printLCD("Initializing",

"System..." + String(i) + "%");

    delay(50);

  }

  delay(200);

}

double getTemp() {

  return (((analogRead(tmp) /

1024.0) * 5000.0) − 520.0) /

10.0;

}
```