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APPLICATION OF SMART TECHNOLOGY IN MONITORING AND CONTROL OF HOME APPLIANCES

A. A. Abdulrazaq*, A. A. Aboaba, G. M. Yelmis, M. Peter, S. S. Buba and A. K. Jibril

(Department of Computer Engineering, Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria)

**Corresponding author's e-mail address: ibnrazaaq@gmail.com, ibnrazaaq@unimaid.edu.ng*

Abstract

The inherent dependency of home appliances on human for monitoring and control has been found to be mainly responsible for power wastage, and increase in the rate of wear and tear, which invariably implies additional spending on the part of owners. The smart technology provides a way out. This paper presents an automated system which is based on arduino and android device for monitoring and controlling appliances to prevent the wastage of power. The system design is based on the Microcontroller MIKRO-C software, active sensors and wireless internet services which is used in different monitoring and control processes of fan, air-conditioner, light and heater. The system when tested performs efficiently in monitoring and controlling through switching the appliances in the room based on human presence and environmental changes due to light intensity and temperature variation.

Keywords: Home automation, Android device, Arduino, home appliances, GPRS, power waste

1. Introduction

Power waste remains a major problem in a typical household. Bulbs, fans, television sets and other appliances are usually switched on and left without anyone using them are common example on how electrical power is been wasted in typical households. The waste of electric power increases electricity bills and general cost of living. There is also issue of safety concern when electrical appliances are left unattended to have been known to cause fire outbreaks and damage of properties (Tejani *et al.*, 2011).

The need to curb wastage of power and improve safety has led to various proposed solutions to power management in households where the appliance can be controlled and monitored through home automation technologies. This is achieved using microcontroller for efficient responses and interactions with the environmental activities without human interferences. This in turn makes the home to be smart.

Smart home also known as automated home is a home with advanced electronic based systems for daily home activities including lighting, security appliances, temperature control, smoke detection, gas leakage alarm and water level monitoring (Mohamed *et al.*, 2014). Coded signals are sent using the microcontroller to switches and outlets to operate electronic devices and other appliance in all or selected part(s) of the home. Smart home can also provide an interface to the home appliances through a communication network including Bluetooth devices, telephone lines, android application and wireless transmission like the WIFI. Therefore, smart home provides house owner and occupant with adequate safety, comfort and security. It also offers powerful means for helping and supporting special needs of the elderly and disabled people while in general, providing adequate electrical power waste management in home by appliances (Piyare and Lee, 2013).

The past decade has seen significant advancement in the field of consumer electronics (Shiu, 2014). Various intelligent appliances such as cellular phones, air conditioners, home security devices, home theatres and many others are set to realize the concept of a smart home. They have given rise to Personal Area Network (PAN) in home environment, where all these appliances can be interconnected and monitored using a single controller (Shiu, 2014). Several works (Mohammed *et al.*, 2014; Mahesh, 2014; Khiyal *et al*., 2009; Kortuem *et al.*, 2010) have been done in the field of Home automation and some of these works have been channelled towards not just automating particular home appliances but also linking separate home appliances together. The idea of this is to have a standard smart home which will serve as a reference point for home automation and a complete system for control and monitoring of home appliances (Mohamed *et al.*, 2014; Shiu, 2014).

Over the years, a tangible amount of success has been achieved in this field and more is still anticipated as technology improves due to the advanced development in computer technology as microprocessors are readily available everywhere(Joseph Roundtree Foundation, 1999). Microprocessors are embedded in electronic appliances (EAs) and are made to cooperate with one another for easy monitoring and control. In (Mahesh, 2014), a GSM and web camera based intruder detection system was proposed which provides security to the home when the owner is absent. The web camera was installed within the house premises and connected with the PC to communicate using internet. The camera detects motion of an intruder within its range and communicates to the intended user via internet network and at the same time sounds the alarm.

A similar study which was a Short Message Services (SMS)-based wireless home appliance control system (HACS) for automating appliances and security was presented by Khiyal *et al*. (2009), it uses GSM technology to send the SMS to the owner and also activates security alarm against any intruders and fire outbreak. However, the major downside of Mahesh (2014) and Khiyal *et al.* (2009) is the fact that the systems depend on network service provider to perform most of its functions considering the risks involved in the transmission of data over a network.

Another approach to smart home is the use of Internet of Things (IoTs) to connect everyday objects like smart-phones, Internet TVs, sensors and actuators to the internet where the devices are intelligently linked to a microcontroller in order to monitor and control home appliances. IoTs enable new forms of communication between appliances, people and environment (Kortuem *et al*., 2010). IoTs technology is now applied to create a new concept and wide development space for smart homes to provide safety, comfort and improve the quality of life.

A low cost and flexible home control and monitoring system using an embedded micro-web server, with IP connectivity for accessing and controlling appliances remotely using Android based Smart phone application was presented by Piyare and Lee (2013). The system does not require a dedicated server PC with respect to similar systems and offers communication protocol to monitor and control the home environment with more than just the switching functionality. It utilized representational state transfer (REST) based Web services as an interoperable application layer that can be directly integrated into other application domains like e-health care services, utility, distribution, or even vehicular area networks (VAN).

A telephone and Programmable Interface Controller (PIC) based remote control system for smart home was also presented in (Yavuz *et al*., 2007). Another PC based home automated system for appliances control was proposed by (Ganiyu *et al*., 2015), but cannot be controlled by a mobile/cell phone. A Bluetooth based home automation system using mobile cell was proposed by (Piyare, 2011), which explored the advancement of wireless technology where several different connections such as GSM, WIFI, ZIGBEE, and Bluetooth were utilized. Other studies such as one presented in (Ganiyu *et al*., 2015) gave examples of web based home automation system.

This paper presents a combination of microcontroller and General Packet Radio Service (GPRS)-based system for smart home. It can be operated in both automatic and manual mode. The automatic mode operates with the use of arduino development board that is interfaced with certain sensors which allow the system to respond to changes in the environmental factors from set conditions without human interferences. On the other hand, the manual mode operates using the GPRS in an android platform to send command to the system. This allows house owner and occupant to control their appliance from outside the home as desired

2. Materials and Methods

2.1 Description of System and Operational Modes

The proposed smart home system independently controls and monitors four (4) appliances which include the heater, fan, lights and air conditioner. It has the ability to response to environment variable changes in terms of temperatures and light intensity variation to switch ON/OFF appliance to save electrical power loss through wastage. Figure 1 presents the block diagram of the entire system.

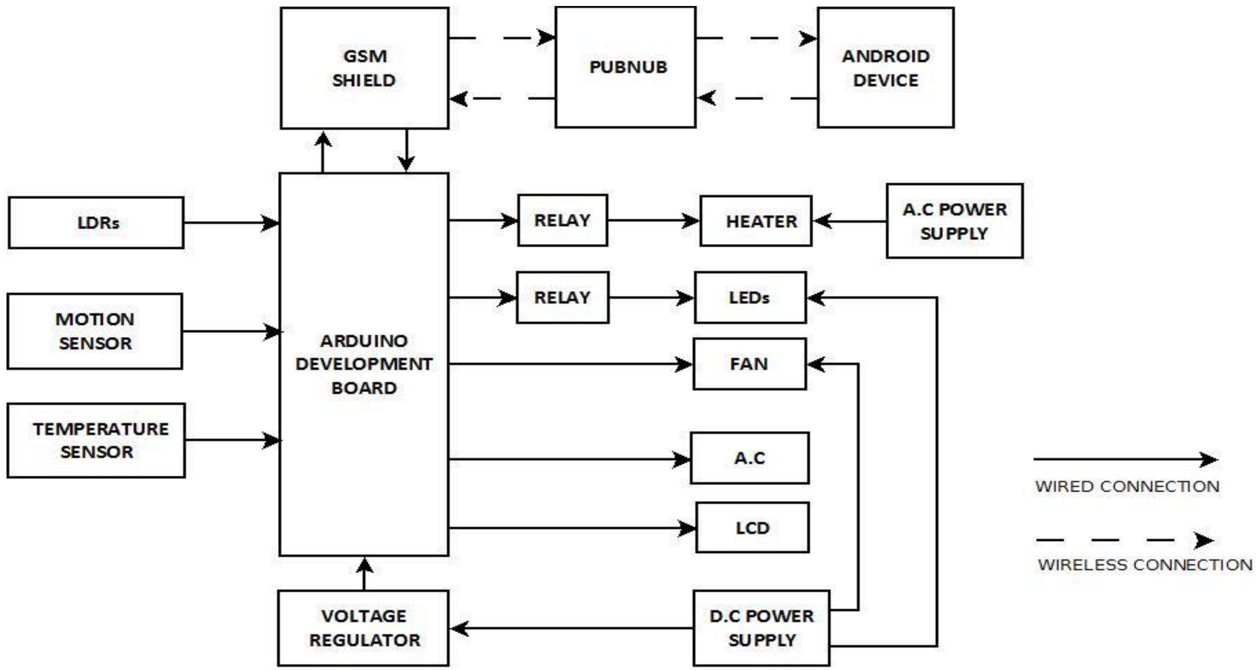


Figure 1: Block Diagram of Entire System (Component Setup)

The arduino GSM shield connects the arduino development board to the internet using the GPRS network. It also allows the making / receiving of calls and also sending / receiving SMS. The shield enables communication between an android device and the arduino board. The PUBNUB serves as an interface between the arduino and the android phone. The platform is used to create a channel where both devices can send and receive commands to and from each other. Commands are sent to and from each of the devices via PUBNUB and as such an android phone is used to control appliance through the arduino via the internet. The android device provide the application that is used to control the appliances and monitor the state of each appliance as its state changes. The application receives data via the PUBNUB network as sent from the arduino GSM shield.

The motion sensor is a 3-pin passive infrared sensor (PIR sensor) made up of a pyro-electric sensor and some supporting circuitry. It generates a temporary voltage when there is a change in temperature in its environment which is then interface with a microcontroller. Also, the LDR is used to detect changes in environmental light intensity and then interfaced with the microcontroller. Base on the input from the motor sensor, temperature sensor, LDR, and android device, the microcontroller either switches ON/OFF the fan, AC, heater or light.

The system operates in two distinct operational modes which include the automatic and remote mode. In the automatic mode, the system depends on the environmental changes while the remote mode solely depends on human decision.

2.1.1 Automatic Mode

When the system is powered on, all sensors will initialized and their output values read by a microcontroller. The system waits for motion to be recorded by the motion sensor. Once it is recorded that there is motion, meaning someone is in the room and all room appliances (heater, fan, lights and A.C) are switched ON or OFF based on the value read in by the microcontroller platform.

The room heater is switched ON when the room temperature read from the temperature sensor is below 18˚C and switched OFF if the read value is 18˚C and above. The fan and air conditioner are also turned ON when room temperature reaches 18˚C and above while OFF when temperature is below 18^oC. The lights have their brightness adjusted according to the amount of light that falls on the LDRs. If the room is dark, the lights in the room become very bright and if the room is bright, the lights in the room become dim or are switched OFF completely.

Switching ON or OFF an appliance in this mode does not require any human intervention at all as long as the system is powered. Also, in this mode, it operations depend on the presences of someone in the room. If motion is not recorded by the motion sensor after a preset time (one hour in this case) all appliances are turned OFF but once motion is recorded again the system starts again.

2.1.2 Remote Mode

This mode allows a user to turn ON/OFF the appliance from an android mobile device. This can be done from anywhere provided that GPRS network is available. As the system is powered ON, it starts in automatic mode but not before it connects to a GPRS network and a particular channel on PUBNUB (communication channel). As soon as a user sends a command from the android application and the command is received, the system stops working in automatic mode and goes to manual mode in order to execute the command sent by the user. The board also sends an acknowledgement message back to the user. This mode is entirely based on inputs from the user and not environment variables. This allows the complete control of the system by user at any time. The system is broken down into three subsystems which include lighting subsystem, temperature control subsystem and communication subsystem. The entire subsystem setup is presented in Figure 2.

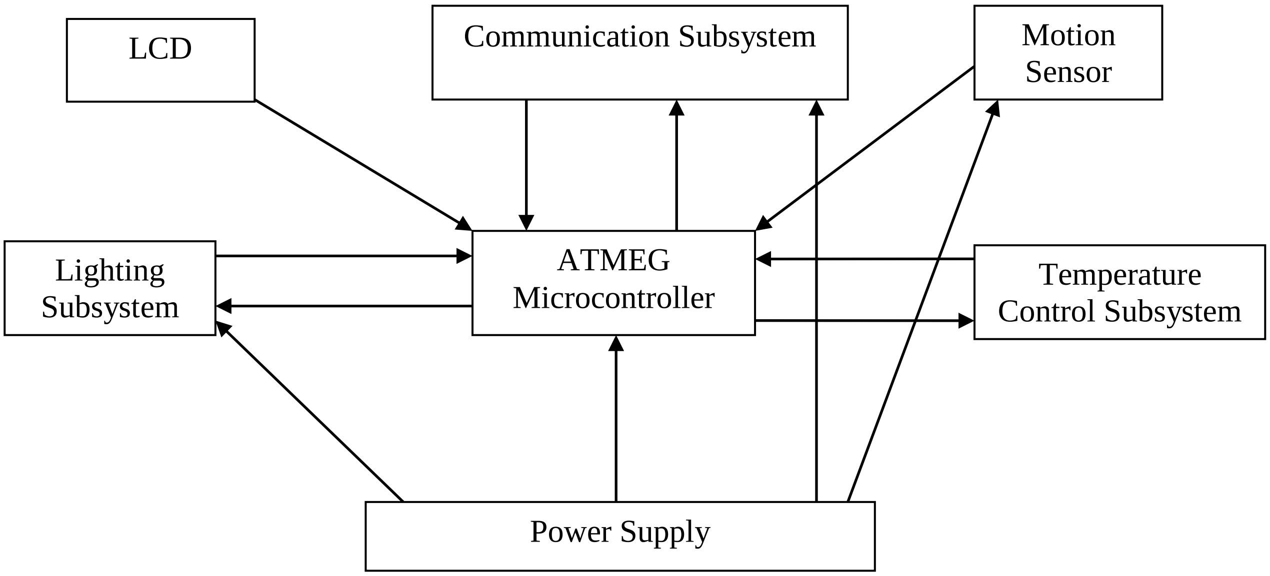


Figure 2: System Block Diagram (Sub-system Setup)

2.2 System Design and Simulation

The design and simulation of the entire system is divided into three different sub-systems for ease of articulation, units design and simulations. The sub-systems are explained as follows;

2.2.1 Lighting Sub-system

The lighting sub-system determines the brightness of the bulbs in a room depending on the amount of natural light (sunlight) going into a room. This sub-system will make sure that no unnecessary amount of electric power will be used to power the light bulbs in a room in presence of sufficient natural light in the room. The amount of natural light reaching the room is measured and relayed to a control unit. Two light dependent resistors (LDR) were used in measuring the amount of natural light going into a room. The LDR has a high value when no light is present, so no current flow, but as light intensity increases, the LDR resistivity decreases and current flow increases. The LDR varying resistance is converted to voltage value that can be measured by microcontroller. The voltage value ranges from 0 – 5V. At voltage of 3v and above, it indicates absent of light. At 0-2.9V indicate the present of light. i.e. the light intensity decreases as value increases.

The LDRs are connected in series with a 10kΩ resistor and then to ground to form a light sensitive voltage where inputs is given by

$$\frac{R_1}{R_1 + R_2} \times V_{in} \qquad (1)$$

where: R_1 = 10k Ω, R_2 = LDR resistance and Vin = 5V

The LEDs are connected in a series parallel arrangement to get a moderate current stability. A resistor limits the current flow in a circuit. The series resistor to the LEDs is given by

$$R_s = \frac{V_{in} - (V_{DI} + V_{D2})}{I_{Dmax}} \tag{2}$$

$$V_{D1} = V_{D2} = V_D$$

$$V_{D1} + V_{D2} = V_D + V_D = 2V_D$$

$$V_D = 3.6,\ I_D = 20mA,\ V_{in} = 12V$$

$$R_s = \frac{12 - (2 \times 3.6)}{20 \times 10^{-3}} = \frac{12 - 7.2}{0.02}$$

$$R_s = 240\Omega$$

Where R_s = Series resistor value.
Using standard design principles, a 270Ω resistor was used as a current limiting resistor for the LEDs during implementation.
When the voltage value measured by microcontroller is 3V and above i.e absence of light, the microcontroller sends a signal value to ON the LED but when measured value is below 3V, the microcontroller sends a signal to OFF the LED.
Figures 3 and 4 depict the block diagram and simulation of the lighting sub-system respectively.

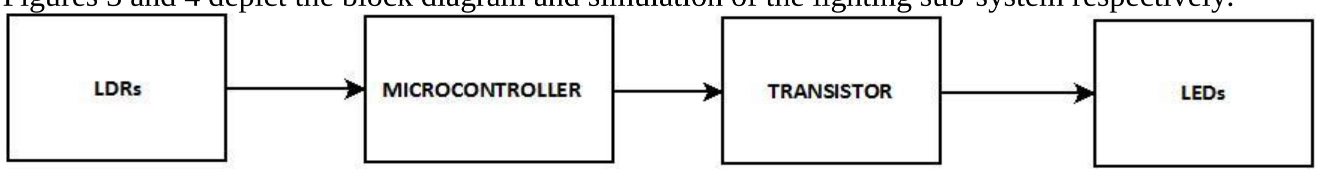


Figure 3: Block Diagram of Lighting Sub-system

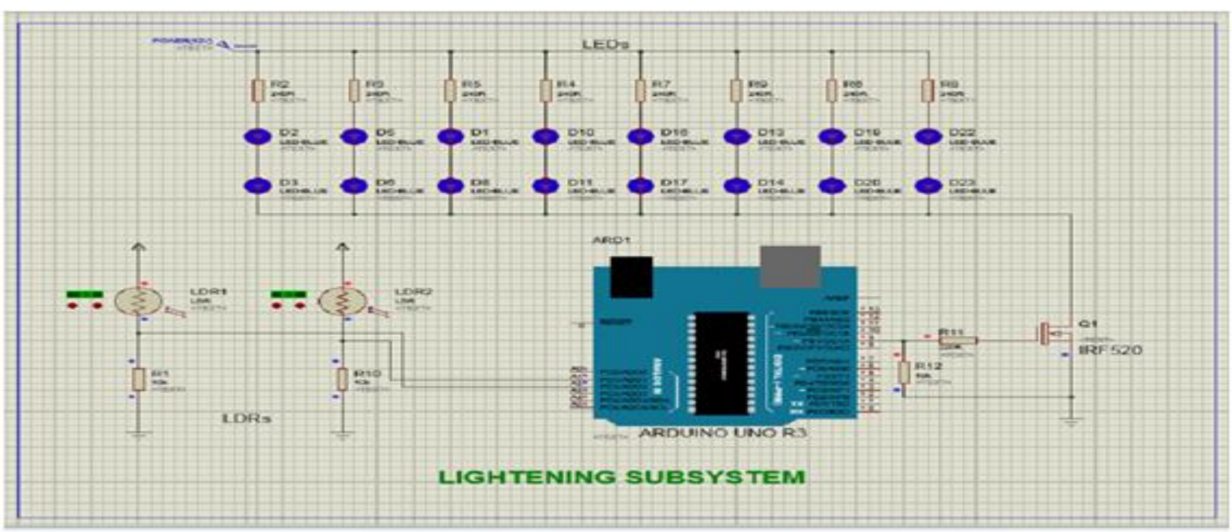


Figure 4: Simulation in Lightening Design Suite

2.2.2 Temperature Control Sub-system

The temperature of a room determines the behaviour of the fan, air-condition and heater whether to switch ON or OFF. This reduces power consumption in a household by switching OFF appliances that are not needed at certain temperatures (e.g. air-condition ON when room temperature is 5°C) or switch ON when needed.

A temperature sensor (TMP36) was used to measure the room temperature. The temperature value is feed into a microcontroller which then converts the value into temperature in degree centigrade. The microcontroller then sends out an appropriate signal based on the value of the temperature to either switch ON or OFF an appliance. Also, the speed of the fan is controlled via pulse width modulation. The temperature sensor (TMP36) connects to the ATMEGA microcontroller via analogue pin and 0.1µF capacitor is connected in parallel to the sensor to filter out noise.

To determine the value of the limiting resistor to the LED, Where V_{in} = 5V, V_{LED} = 2.1V and I_{LED} = 20mA.

$$R_s = \frac{V_{in} - V_{LED}}{I_{LED}} \tag{3}$$

$$R_s = \frac{5 - 2.1}{0.02} = 145\Omega$$

Hence, a standard limiting resistor of 150Ω was used. The air-condition (LED) was connected to the microcontroller and150Ω resistor is connected to the LED to limit the amount of current reaching it.

For adequate illustrations, the appliances to be controlled are represented in the proteus design using an LED for air-condition, incandescent light bulb for the heater and a PC fan for a regular room fan. The heater is turned ON when the room temperature is below 18°C otherwise it stays OFF. The fan is turned ON with a duty cycle of 50% when the room temperature is 27°C or less than 30°C; at a temperature of 30°C or less than 33°C the duty cycle is of the fan is increased to 75% while at of 33°C or above, the fan's duty cycle is increased to 100% and also the air-condition is turned ON at this temperature (> 33°C). When the room temperature is between 21°C and 27°C all appliances are switched OFF. Figure 5 gives the block diagram for is temperature control subsystem.

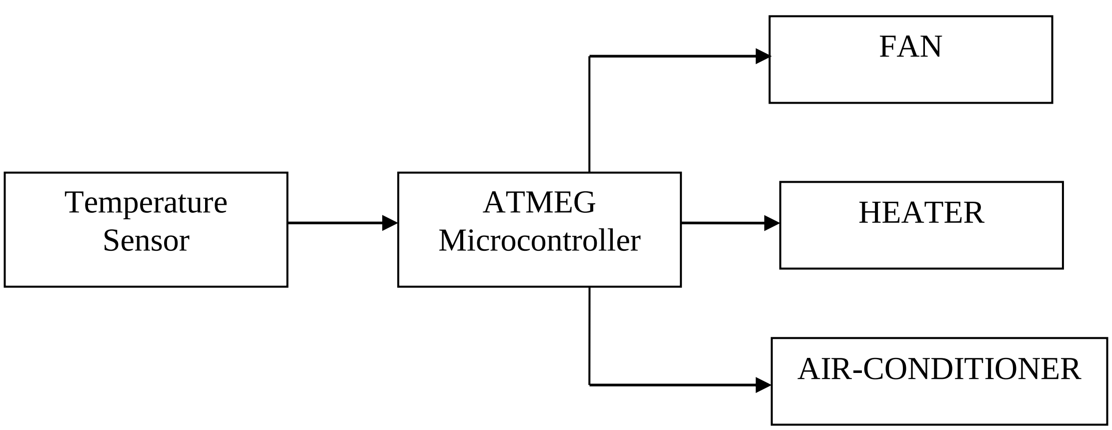


Figure 5: Block Diagram of Temperature Control Sub-system

The simulation of the temperature design suite was carried out at different temperature variation (19°C, 29°C, 30°C and 34°C) as presented in Figure 6.

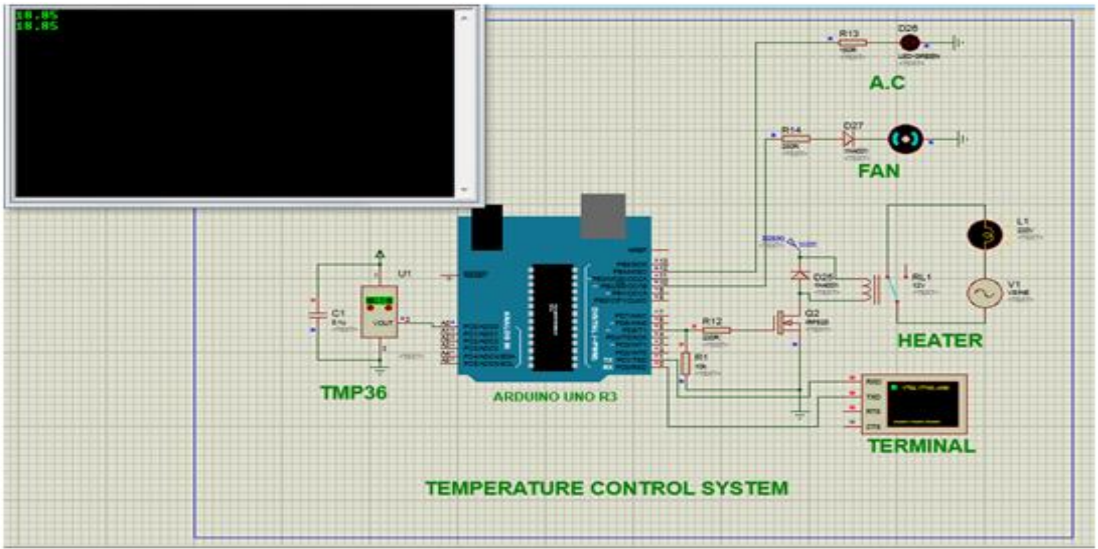


Figure 6: Simulation in Proteus Design Suite at different Temperatures

2.2.3 Communication Sub-system

The communication sub-system enables the user to control lighting and temperature subsystem from an android device. A command to turn ON/OFF a device is sent from an android device to the ATMEGA microcontroller over the internet using GPRS. This command first goes from the android device to an internet data stream network (PUBNUB), the arduino GSM (Global System for Mobile Communication) shield then picks up the command from PUBNUB and then sends it to ATMEGA microcontroller which then executes the command. The command sent and executed is either to turn ON or OFF a device. After executing the command, the ATMEGA microcontroller sends a response to the android device via the GSM shield over the internet. The response reaches PUBNUB from where the android device picks up the response command, notifying the user that the command sent has been executed. The communication subsystem is presented in figure 7.

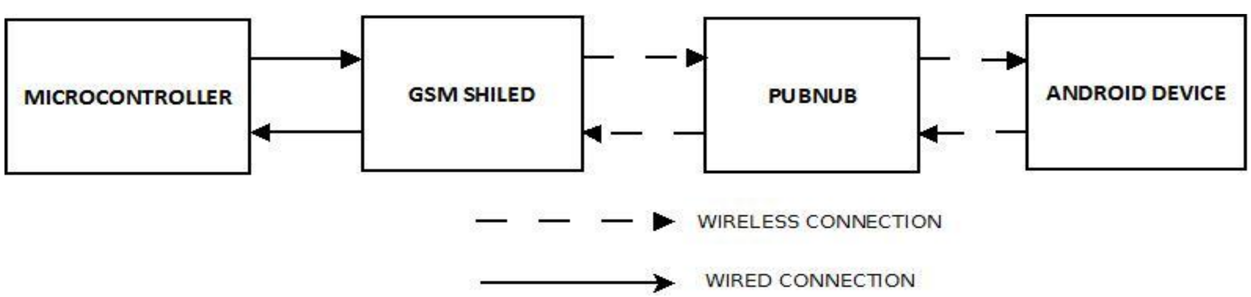


Figure 7: Block Diagram of Communication Sub-system

This sub-system is made up of Arduino GSM Shield, Microcontroller, PUBNUB, Android Device/Application. The arduino GSM shield connects the arduino development board to the internet using the GPRS network. It also allows the making / receiving of calls and also sending / receiving of SMS. The shield enables communication between an android device and the arduino board. In this work, PUBNUB serves as an interface between the arduino and the android phone. The platform was used to create a reserve known as a channel where both devices can send and receive commands to and from each other. Given that the devices cannot communicate with each other directly, communication is achieved via PUBNUB since both devices can communicate directly with it. Commands are sent to or from each of the devices via PUBNUB and as such an android phone is used to control appliance through the arduino via the internet.

The android application controls and monitors the state of each appliance as its state changes. The application receives data via the PUBNUB network as sent from the arduino GSM shield. An application is written to receive and respond to certain commands and also to send commands to the arduino via the PUBNUB network and GSM shield. The application is used to remotely switch the appliances ON/OFF. The application was written using the android software development kit (SDK) and java programming language based on the android API. It uses the android internet access feature in the android API to receive and send data to and from the arduino via the PUBNUB network. The Complete System Design and Simulation is presented in Figure 8. It presents the interface of all sub-section that forms the entire system.

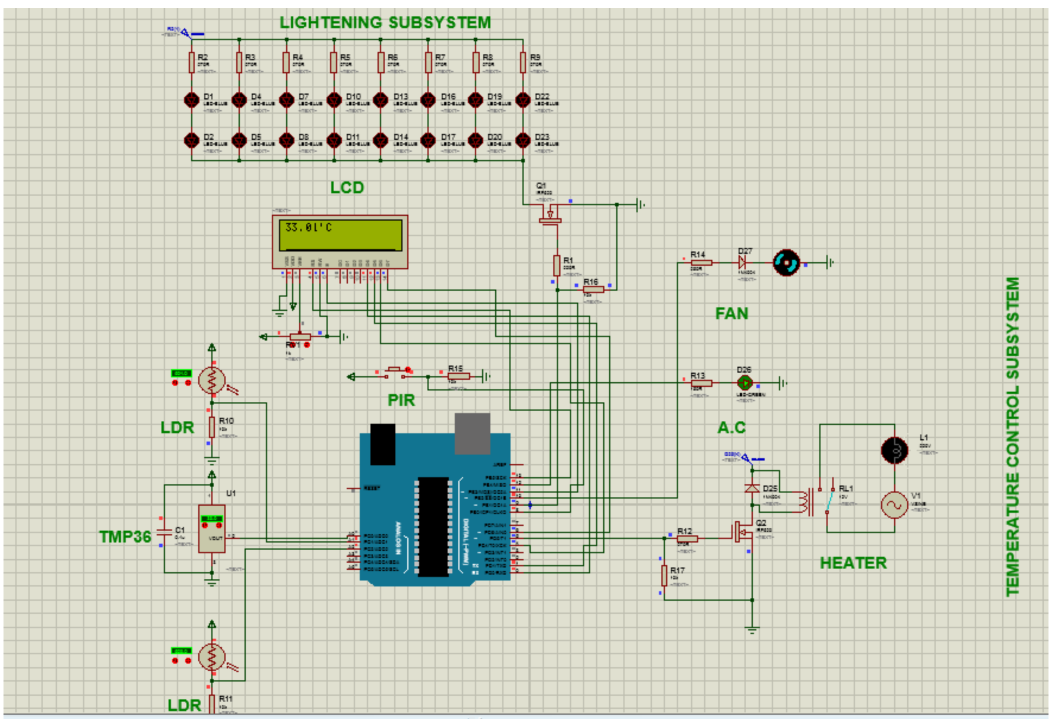


Figure 8: Complete System Simulation in Proteus Design Suite

3. System Performance Tests and Analysis

The system was tested for functionality, correctness and reliability. Tests were carried out on individual subsystems before being integrated into the main system. Tests were also carried out on individual components that made up these subsystems. The tools used to carry out this test include Breadboard, Digital Multimeter, Arduino Serial Monitor, Android Simulator and PUBNUB Debug Platform. Test was carried out on the system by implementing the lightening subsystem schematic on a breadboard. The system worked effectively on the breadboard while current drawn by the system was measured by the multimeter to be 90mA after the system had worked for 30 minutes. The arduino serial monitor was used as a debugging to display the light intensity falling on the LDRs. The breadboard Implementation of lighting subsystem is presented in Figure 9.

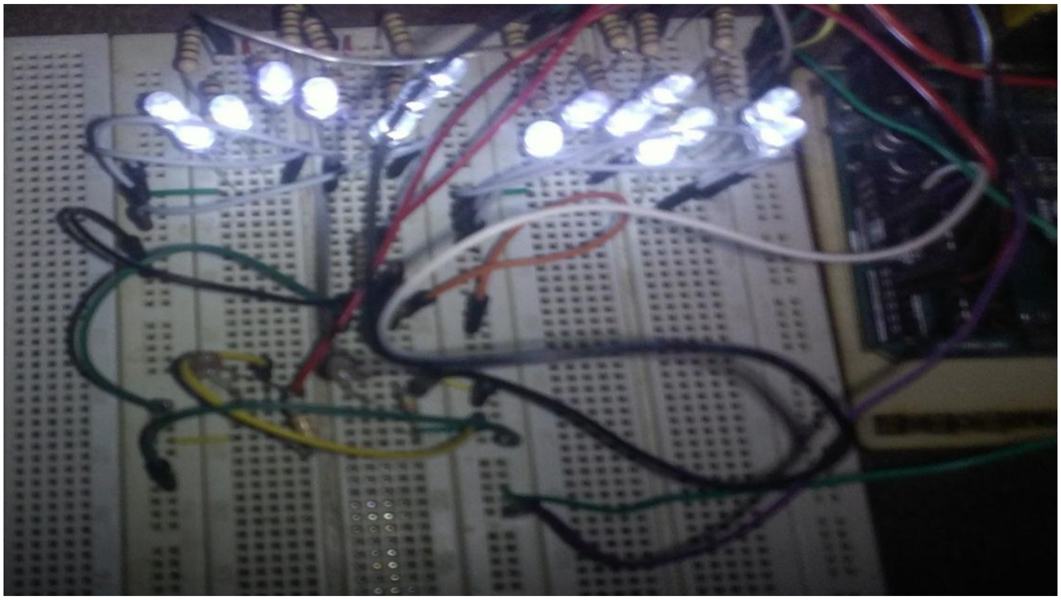
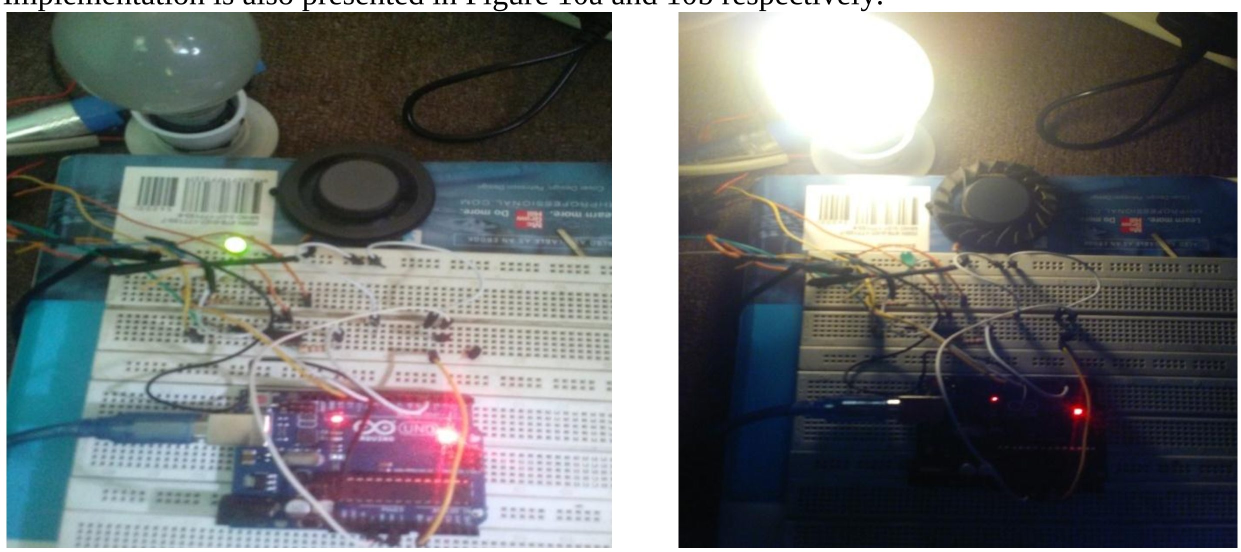


Figure 9: Breadboard Implementation of Lighting Subsystem

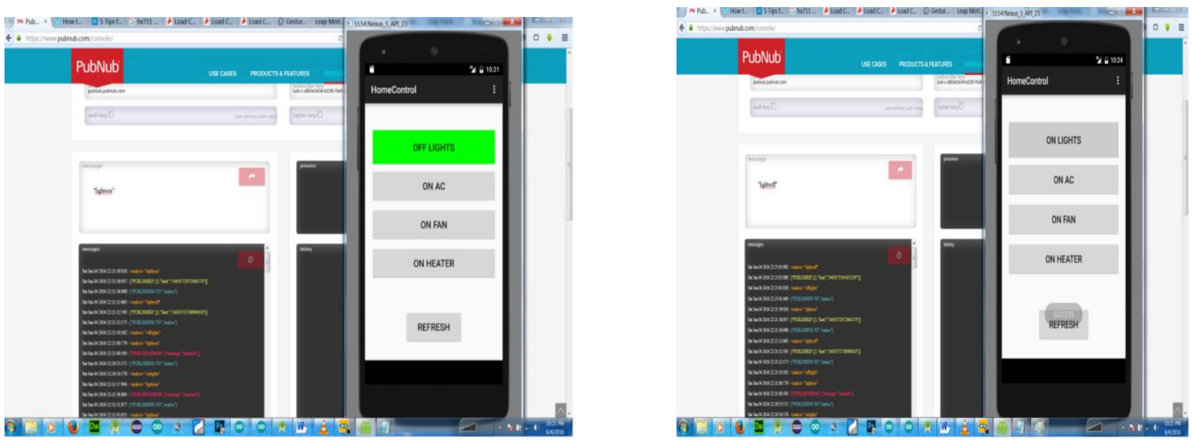
Similarly, Test was carried out on this system by implementing the temperature control subsystem schematic on a breadboard. The system worked efficiently on the breadboard. The main problem encountered during the test was that of electrical noise affecting the temperature sensor, this makes the sensor to give wrong outputs in some cases. The arduino serial monitor was used as a debugging to here to display the output of the temperature sensor. The breadboard Implementation is also presented in Figure 10a and 10b respectively.



(a) **(b)**

Figure 10: Breadboard Implementation of Temperature Control Sub-system

For the communication subsystem, it was tested by sending messages to the PUBNUB channel for both the arduino and android device. This was to ensure that communication took place and that the devices can stay connected hence allowing control of appliances. PUBNUB was tested using a web browser and the android application was tested using an android virtual device (AVD) which comes with the android SDK. The Debugging in PUBNUB and Android Simulator are presented in Figure 11a and 11b respectively.



(a) (b)

Figure 11: Debugging in PUBNUB and Android Simulator

Finally, all the subsystems were put together to form the whole system. It was tested and evaluated for both manual and automatic mode, commands were sent (ON/OFF) from the android device and the system responded accordingly. Similar, the environmental conditions were also varied in terms of temperature and light intensity, the system also responded accordingly. Hence, the results were satisfactory as all units functioned and communicated effectively. Figure 12 presents the prototype of the room system.

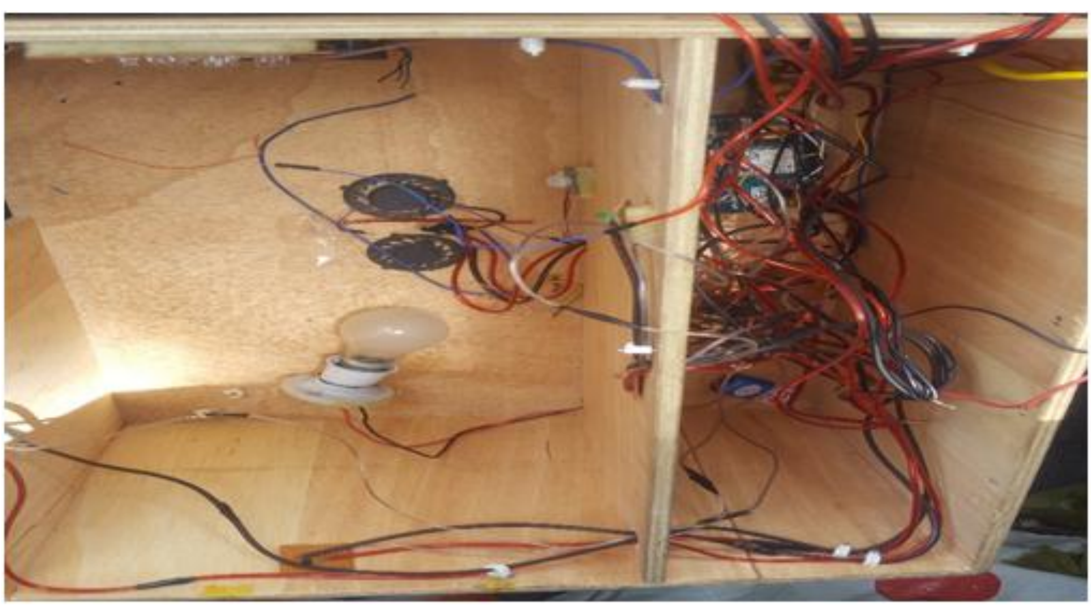


Figure 12: Top View of the Finished Prototype

4. Conclusion

The room monitoring and control system was successfully built and tested. The lighting and temperature control subsystems were all designed constructed and tested successfully. The GSM shield was successfully interfaced with the arduino development board giving a clear access through PUBNUB. The written android application functioned well with PUBNUB and served as an interface for the system. The system was built using open source resources making it less expensive. The networking of the devices was achieved using GSM/GPRS which is available in most developing countries that this work is targeted at. The android application is user friendly and easy to install and set up and therefore can be used by any individual with little or no technological knowledge or skill.

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