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Design and Construction of a Home Automation System Using a Smart Phone

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Abstract

Home automation system involves introducing a level of computerized or automatic control to certain electrical and electronic systems in the home. These include lighting, temperature control, and so forth.

This project is aimed at designing and constructing a microcontroller based home automation system, used to turn on and off the home electrical appliances when the temperature rises above or falls below a preset temperature range (between 25^{o}C and 30^{o}C). The inputs signals from both the temperature sensor LM35 and the signal sent from the bluetooth connection of the Android smart phone to the HC-05 Bluetooth Module serves as inputs to the microcontroller. Output units which comprise of the Liquid Crystal Display (LCD) and the relays which powers on and off the fan and bulbs, are incorporated in the circuit to make the results of test visible and complete the system design for the smart home. The result of the test shows that the system automatically switched on and off light bulbs, turned on sockets and a.c fans at the preset temperature value (below 25^{o}Cand above 30^{o}C) through the LM35 temperature sensor. And through the HC-05 bluetooth module the system was able to switch on and off the home appliances.

Keywords: Home automation systems (HASs), Smart home, home appliances, Bluetooth, Android.

1.0 Introduction

A. Overview

The ease of putting our appliances, lighting points and sockets on or off has made it necessary to develop the home automation system in order to control our appliances, lighting points and sockets from a central point through an automatic remote control system. The problem of always forgetting to switch our appliances OFF when going to sleep at night or when leaving the house has often caused fire outbreak and explosion in homes. Home automation system is designed to assist and provide support in order to fulfill some of the needs of elderly and disabled in the home as the elderly and the disabled are often in dire need of controlling their home environment. There is also the need to manage energy consumption in the house, leaving the lights on, the fans or air conditioner, the television, the home theater system and stereo when they are not needed consumes energy. Also, leaving ones comfort zone to manually put off redundant home appliances is often tasking after a long day's work or when one is just simply too lazy to get up.

The "Home Automation" idea has existed for a long time. The expression "Intelligent Home", "Smart Home", took after and has been used to present the concept of networking appliances and devices in the house. Home automation Systems (HASs) represents an incredible research opportunity in creating new fields in engineering, computing and architecture. HASs is getting to be the mainstream nowadays and entering rapidly in this emerging market. Be that as it may be, end users, particularly the incapacitated and elderly because of their multifaceted nature and expense, don't generally acknowledge these systems [1].Home automation systems face some challenges [2]; some of these are inflexibility, high cost of ownership, difficulty achieving security and poor manageability.

These days, smartphones are getting to be all the more influential with strengthened processors, richer entertainment functions, larger storage capabilities, and more communication methods. Bluetooth, which is chiefly utilized for information trade, add new peculiarities to cell phones. Bluetooth innovation, created by telecom merchant Ericsson in 1994 [3, 2], demonstrates its advantage by integrating with smartphones. It has changed how individuals use digital devices at home or office, and has exchanged traditional wired digital devices into wireless devices. A host Bluetooth device is now capable of communicating with up to seven Bluetooth modules at the same time through one link [4, 3].

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Considering its typical working range of within eight meters, it is particularly useful in a home environment. Thanks to Bluetooth innovation and other comparable methods, the idea of Smart Living has offered better opportunity in comfort, convenience and security which incorporates centralized control of air conditioning, lighting, heating and cooling at home, and service robots[(4,5,6].

With sensational increment in cell phone users, smartphones have continuously transformed into a generally useful portable device and provided people for their day to day use [6, 7].In recent years, an open-source platform Android has been broadly used in smart phones [7,8].

Nowadays home and building automation systems are used more and more. On the one hand, they provide increased comfort especially when employed in a private home. On the other hand, automation systems installed in commercial buildings do not only increase comfort, but also allow centralized control of heating, ventilation, air condition and lighting. Hence, they contribute to an overall cost reduction and also to energy saving which is certainly a main issue today.

Existing, well-established systems are based on wired communication. Examples include BACnet, LonWorks and KNX [9, 8]. Employing a traditional wired automation system does not pose a problem as long as the system is planned before and installed during the physical construction of the building. If, however, already existing buildings should beaugmented with automation systems, this requires much effort and much cost since cabling is necessary.

Obviously, wireless systems can come to help here. Inthe past few years, wireless technologies reached their breakthrough. Wireless based systems, used every day and everywhere, ranges from wireless home networks and mobile phones to garage door openers. As of today, little comparative research of wireless automation standards has been done ,although such knowledge would provide valuable information to everyone looking for the most suitable system for given requirements [8, 9].

Android platform has support for Bluetooth network stack, which permits Bluetooth-empowered devices to communicate wirelessly with one another in a short distance [9, 10]. In this paper, a generic compatible bluetooth user interface application was used, and obtained from an open source website. The aim is to design and construct a microcontroller based home automation system, to turn on and turn of home appliances when the temperature rises above or falls below a preset temperature range (between 25^{o}C and 30^{o}C) and also to be able to turn on home appliances using an android smart phone through bluetooth. With this in view, the system helps to improve the living standard at homes by remotely controlling home appliances, with little or no effort and at the same time to design a flexible system in which new devices can easily be integrated into it, to meet specific needs of the user without restriction.

From existing systems, home automation describes a type of home appliance control system where the person must be positioned in the lie of sight of the appliance that is needed to be controlled and a predefined gesture according to their program instructions was used to turn on a device and another gesture was used by them to turn off the device. One disadvantage to this type of home automation system is that, user should always keep a Laptop computer to run software application and also should always be in line of sight with the infrared camera.

2.0 Methodology and System Design

The principle behind this project involves the basic principle of switching networks in embedded systems, using miniaturized small signal, low frequency electronic devices such as the PIC16F877A microcontroller chip, transistor IC chips to control high frequency, large power electrical appliances in the home.

The main control system employs a temperature sensor to automatically activate connected home appliances at preset temperatures and a wireless bluetooth technology to provide additional remote control access from an android smart phone. Bluetooth is an open wireless protocol for exchanging data over short distances from fixed and mobile devices, creating personal area networks (PANs).

The Home Automation System is divided into five sections as shown in Figure 1. Each of these sections forms an integral part of the entire system, designed to achieve the aim and objectives of this project. The sections comprises of the sensor unit, display unit, processing unit, relay unit, and the power supply unit.

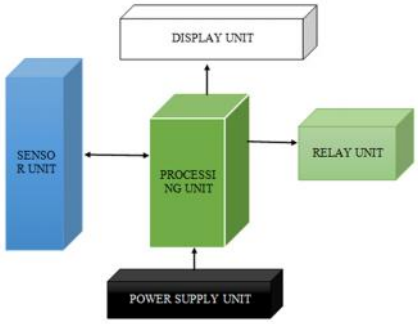

Fig 1: Block diagram of the Home Automation System

The Sensor Unit serves as the input to the system, it comprises of two sensors, one senses ambient temperature while the other serves as a communication link to receive control signal from an external source. Their functions are properly coordinated to service the operation of the processing unit. These sensors receives signal from the outside world and then communicates it to the microcontroller which serves as the processing unit, manipulating the input signal from the sensors to affect the desired result. The sensor unit is made up of theLM35 temperature sensor and a HC-05 bluetooth transceiver moduleas shown in Figure 2 and 3 respectively.

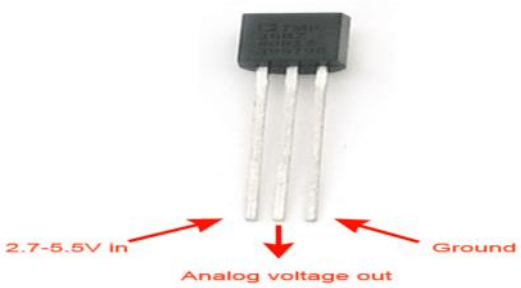

Fig 2: LM35 Temperature Sensor

LM35 is a three Pin (VCC, Output, GND) high precision temperature sensor having a resolution (i.e. scale factor) of 10mV/^{o}C. Therefore, the calibration of the temperature sensorstarting at 0V (i.e. an output of 0V represents a temperature of 0^{o}C), then at an output of 10mV the temperature is 1^{o}C, output of 20mV the temperature is 2^{o}C,at an output of 370mVthe temperature is 37.0^{o}C, and so on.

The HC-05 module according toHC-05 Manufacturer's Datasheet is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 2Mbps - 3Mbps modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Blue-core, 04-External single chip Bluetooth system with **CMOS** technology and with AFH (Adaptive Frequency Hopping) feature.The pre-written program for the bluetooth is:

KEY: if set to HIGH module goes into command mode for configuration
RXD: the RXD signal line – 5V safe
TXD: the TXD signal line – 5V safe
Vcc: connection for 5V supply voltage
GND: Ground
State : Not connected [11, 12]

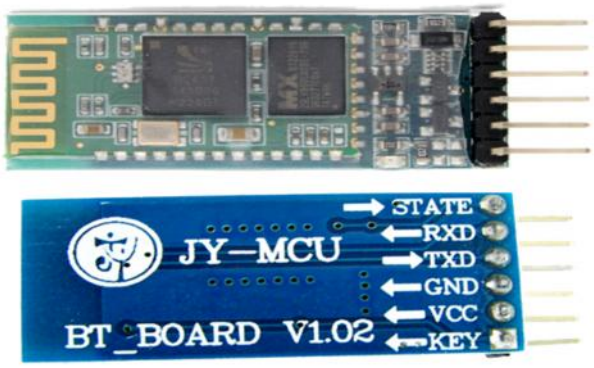

Fig. 3: HC 05 bluetooth module pin configuration

The display unit is a section in the home automation system that serves as a visual aid it gives the user of the system a visual description of the state of the appliances at any point in time. The display unit consists of the Liquid Crystal Display (LCD) 16 by 2 module is used in this design to display the temperature reading from the LM35 temperature sensor and as well display when an appliance is switched in the on or off state. From the manufacturer`s specification datasheet the required power supply is +5V (+3V optional), with supply current typically in the range 1.2mA--3.0mA. Where pin1=VSS= 0 volt (GND), pin2=VDD= +3volt or +5 volt. The circuit diagram is presented in Figure 4aand photo view in Figure 4b.

The 8 display pins DB0 to DB7 will be connected to the input/output pins on port B of the microcontroller. The RS, R/W and EN are the register select, read and write, and enable signal pins respectively. Pin3 (VEE) is connected to a 10k variable resistor was used to adjust the light intensity and contrast of the LCD [12, 13].

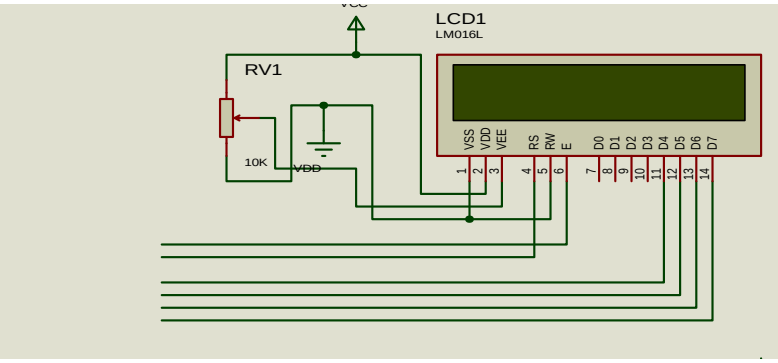

Figure 4a: LCD display unit with 10k variable resistor on Proteus 8

Figure 4b: Photo view of the LCD display unit

The processing unit is the central controller of the operations of the Home Automation System, the PIC16F877A is a Microchip built microcontroller product made up off the Microprocessor, RAM, ROM, I/O Ports and the Buses which are the Address Bus, Data Bus and Control Bus as shown in Figure 5.It receives inputs from the input peripheral devices and processes these signals and with respect to the code programmed into it, performs a set of operations accordingly.

From the Microchip PIC datasheet the PIC16F877A is a RISC type, 40 pin IC. This PIC differ from other PICs because of the features like 10 bit, 8 channels inbuilt ADC, inbuilt PWM, one 8 bit USART.

The analog input was converted to channel 1 to 10 bit digital number with low voltage reference (Vref-) 0v and high voltage reference (Vref+) 5V. The output is read and shown on the LCD and also determines the microcontroller section of the appropriate relay to switch. The Vref- and Vref+ can be changed by configuring the ADCON1 register.

0v represents a low in the system which in binary digits is 0000000000 for 10 bit digital number,

5v represents a high in the system which in binary digits is 1111111111 for 10 bit digital number.

$$\text{Resolution} = \frac{(\text{Vref+} - \text{Vref-})}{(1024-1)} = \frac{5}{1023} = 4.887\text{mV}(\text{as it is a 10 bit ADC}). \quad (1)$$

Thus it means that for a change in $4.887mV$, the binary output changes by 1.

The microcontroller communicates with the bluetooth module through its TX and RX pins. The serial control command sent through the smart phone is received by the bluetooth module and processed by PIC microcontroller [12].

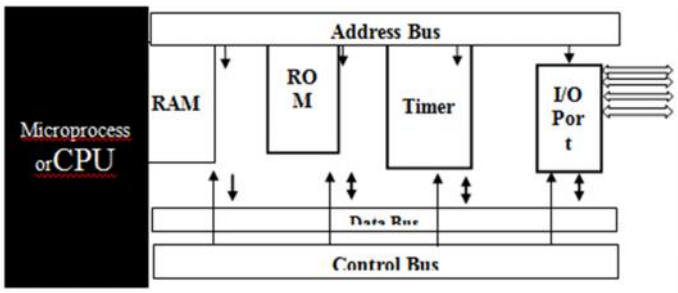

Fig 5: Block diagram of the Home Automation System processing unit

The MikroElectronika micro-C PRO for PIC v6.0.0 was used to write and compile the programming codes for the PIC16F877A microcontroller chip (diagram of the chip with the pins description and photo view of chip mounted on vero board are shown in Figures 6 and 7, the programming language used is in C programming language, micro-C PRO for PIC is an easy to use compiler that is very compatible with PIC microcontrollers, and a TopWin 2008 Programmer are used for compiling the source code and to program the microcontroller chip respectively. This is shown in Figure 8.

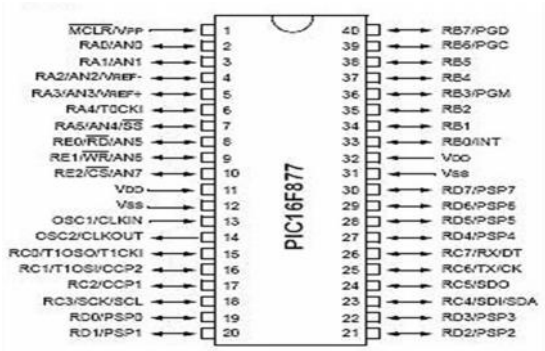

Fig 6: Microcontroller show input/output pins of PIC16F877A

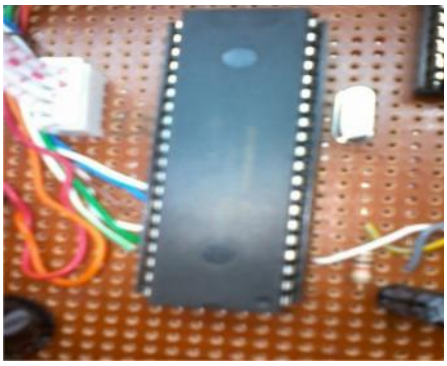

Fig. 7: Photo view of the PIC16F877A mounted on connector socket with external 8MHz crystal

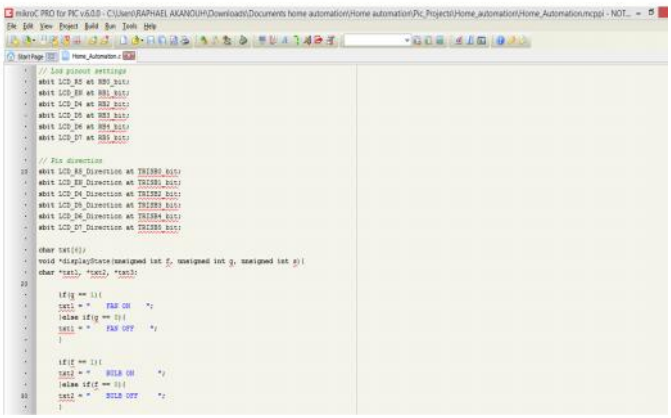

Fig. 8: Micro C PRO for PIC Compiler (Code View)

The relay unit is made up of the relays (6V a.c.) and the relay driver IC ULN2003a which switches on the appropriate relay based on the microcontroller trigger. The ULN2003a is employed to reduce the use of transistors and resistors in the circuit. Any home appliance operating under A.C voltage supply could be connected directly with this relay interface circuit. To add more appliances to the system additional relays may be added and connected to the relay interface circuit and then programmed to work with the microcontroller. The relays and relay interface circuit connection to microcontroller is shown in Figure9.

The input voltage is about 30V, the ULN2003a IC has seven input pins, the voltage sunk into each of its input pins is 5volts, therefore given the number of pins connected to port say 5 pins, 6pins or 7pins, the input voltage to the relay interface unit will be 25volts, 30volts, 35volts to the IC chip respectively, also the output voltage of the IC is more than enough to drive the 6 volts relays connected to its output.

The ULN2003A has a 2.7kΩ series base resistor for each Darlington pair for operation directly with TTL or 5-V CMOS devices.

500-mA-Rated Collector Current (Single Output)

High-Voltage Outputs ... 50V [13].

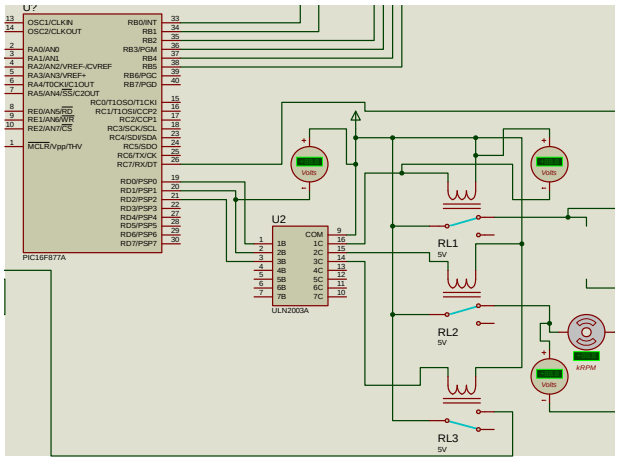

Figure. 9: Relays with relay driver ULN2003a.

According to the PIC16F877A Datasheet, The power requirement of the PIC16F877A microcontroller with its entire pins active i.e. at maximum operating condition is a DC power supply of 5V, 300mA. Therefore this poses the need for a proper well-designed power supply unit to meet the required specifications. This is why the following design is carefully chosen to avoid inconsistency in the behavior of supply of power to the system.

The power supply unit for this project comprises of four sections. The power coming from the mains is stepped down from 220V, 50Hz by a 220/12V 300mA 50Hz step down transformer, the output from this unit which is an AC supply is converted to DC (unipolar voltage) supply by a rectifier circuit. Furthermore, the output of the rectifying unit is filtered by a filtering circuit to produce a nonsinusoidal voltage and current. This available power is not still suitable for use with the home automation system and so it is passed through a voltage regulation to get a pure DC supply that is suitable for use by the system. The circuit for power supply is shown in Figure 10.

The bridge rectifier diode used for the design has the following specification:

Forward voltage drop of 0.7V x 2 = 1.4V

Max current of the rectifier = 1A.

Since a voltage of 12Vrms AC is supplied by the transformer the equivalent DC Voltage in R.M.S is given by

Vrms (DC) = Vrms (AC) – Forward Voltage Drop of Diode = 12V – 1.4V = 10.6V DC (2)

Therefore the peak Voltage Vp = Vrms (DC) x √2= 10.6V x √2= 14.998V(3)

In this design 15Volts an approximate value was used in subsequent calculations.

Choice of Filtering Capacitor

In other to minimize ripple to at least 10%, an electrolytic capacitor was used and its value was calculated using the formula

$$C = \frac{5\,Io}{f\,Vp} \quad (4)$$

Where C = Capacitance of the capacitor;Io = output or load current of transformer;f = frequency; and

Vp = peak voltage.

For the transformer, output current Io = 300mA, frequency is 50Hz and Vp of 15v was used. Therefore fixing in our values we have that

$$C = \frac{5 \times 300 \times 10-3}{50 \times 15} = 2000uF \quad (5)$$

Therefore the preferred market value of 2200uF capacitor was chosen for effective reduction of ripples in the signal [12].

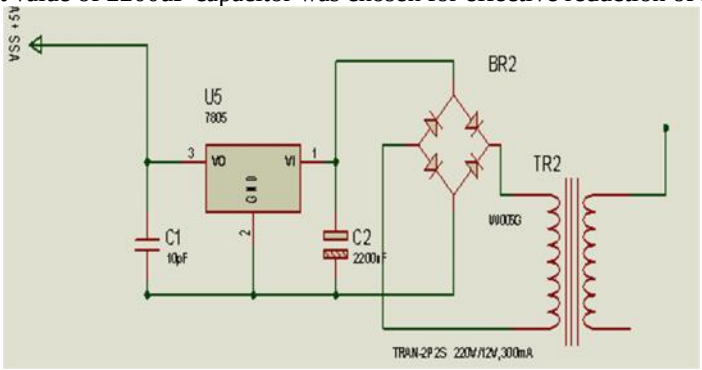

Figure 10: Power supply unit designed on Proteus 8

3.0 Mode of Operation

The home automated system functions off the program code written into the microcontroller to accept inputs, process them and generate the necessary outputs or take actions with regards to the inputs it receives with respect to the code written into it. The inputs signals from both the temperature sensor LM35 and HC-05 Bluetooth Module serves as inputs to the microcontroller, since the microcontroller is the central processing unit, its function is for the overall control of the system, output units which comprises of the Liquid Crystal Display (LCD) and the relays which powers on and off the fan and bulbs are incorporated in the circuit to make the results of test visible and complete the system design. A power supply of regulated DC voltage of 5V was employed in the design to power the microcontroller and relay unit. The entire circuit diagram can be seen in Figure 11

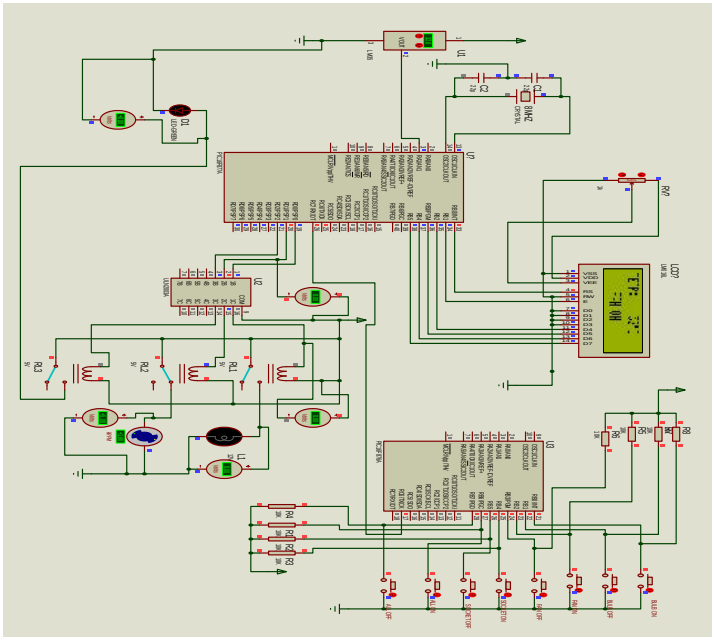

Figure 11: The complete working Home Automation System Design on Proteus 8

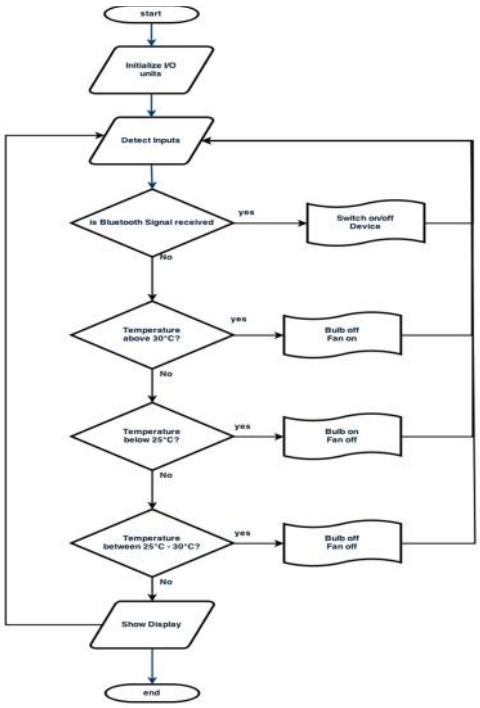

Figure 12: Flow Chart Programming of the Home Automation System

4.0 Results

After the results of the various tests carried out, the system switched on and off a 60watt light bulb and a 220volt, 0.14amp a.c fan at the preset temperature value through the LM35 temperature sensor, and the user interface on anandroid phone was used to remotely control the 60watt light bulb, A.C fan (220volt, 0.14amp), and a 13amp electrical outlet socket through the bluetooth module communication protocol as seen in Fig. 13 and 14.

Fig. 13: Photo view of the user interface on Android smart

Fig 14: The Home Automation System House Model

5.0 References

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