USING ENERGY EFFICIENT TEMPERATURE SENSOR FOR AUTOMATIC CONTROL OF THE HEATING AND COOLING SYSTEM IN THE HOME

P. Oshevire[1,*], D. Okene[2] and E. Okhueleigbe[3]

[1, 2, 3] DEPT OF ELECTRICAL/ELECTRONIC ENGR. FED. UNIV. OF PETROLEUM RESOURCES EFFURUN, DELTA STATE, NIGERIA
E-mail addresses: [1]*ask4pat2001@yahoo.com,* [2] *okene.david@fupre.edu.ng,*
[3] *okhueleigbe.emmanuel@fupre.edu.ng*

ABSTRACT

With the development of modern technology, Smart Living is gradually changing people's life and thus providing a necessary technology to create convenience, intelligence and controllability. In this paper, a new Smart Living system is introduced for the Automatic Control of Heating and Cooling System in the Home. The 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. The main control system employed is a temperature sensor LM35 which serves as input signal to the central processing unit, which is the microcontroller whose function is for the overall control of the system. The output unit which consists of the relays which power on and off the 60 Watts bulbs (Heating system) and the fan (Cooling system) , and an LCD (Liquid Crystal Display) which help to make the results of the test visible. The results of the test showed that the system automatically switched on and off two 60watt light bulbs and a 0.14 Amps fan at the preset temperature value (below 25oC and above 30oC) through the LM35 temperature sensor.

Keywords: Smart Living, Temperature Sensor, Heating system, cooling system.

1. INTRODUCTION

1.1 Background Study

With advancement of technology things are becoming simpler and easier for us therefore automation plays an increasingly important role in the world economy and in daily experience this is why automatic systems are being preferred over manual system [1]. Therefore, home automation systems have been developed in recent years that make use of emerging technologies for development. It has become one of the upcoming fields that introduce many technologies for making the automatic control of home appliances easy [2]. In this project a method is devised to control the targeted home appliances through an independent temperature control system which responds to the ambient temperature conditions in the home. The proposed system is reliable, easy to setup, cost effective and overcome the downsides of existing systems. This system provides the variation in output corresponding to the change of surrounding temperature. It is more flexible, compatible and adjustable to any electrical and electronic devices [3]. The system is targeted for application in conventional homes for people with disabilities and the elderly. The design of this system will provide these people with added comfort in their own homes.

2. DESIGN OVERVIEW

Thermocouples, temperature dependent resistance elements (RTDs and thermostats) and semiconductor elements (diodes) are widely used to electrically measure temperature. Temperature measurement is not new in science and engineering field of study. Galileo invented a rudimentary thermometer capable of detecting temperature changes, and two hundred years later, See beck discovered the thermocouple. Given the long history of temperature measurement and its extensive use today [4], engineers over the years have continually designed and developed special devices called sensors which have been part of the advancement in temperature measurement device technology to enable automatic sensing, measurement

and control of the temperature conditions in a particular area.

The idea 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 as shown in figure1employs a temperature sensor to automatically activate connected home appliances at preset temperatures.

3. DESIGN ANALYSIS

The designed home automation system was analyzed with the associated theories and calculations, the system is comprised of PIC16F877A microcontroller,

LM35 temperature sensor enables automatic control of the appliances at preset temperature values, the three a. relays to which the electrical appliances are connected to, a ULN2003A relay driver for interfacing the relays with the microcontroller.

Figure2 below shows the full circuit with discrete components of this design. It is considered, here, as a temperature sensor LM35 which responses linearly with the temperature, the control circuit requires a 5V DC supply.

3.1 Design Analysis of the Power Supply Unit:

The power supply section of this system comprises of a step-down transformer, a diode bridge rectifier, two a.c ripple filter capacitors and a voltage regulator. The block and circuit diagrams of the power supply unit are presented in figures 3 and 4 respectively.
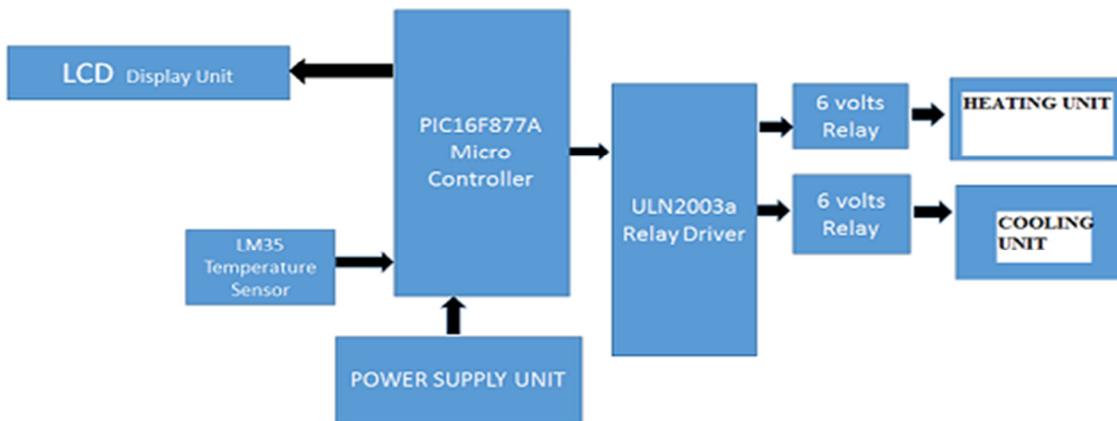

Figure 1: Block Diagram of Temperature Sensor Control System
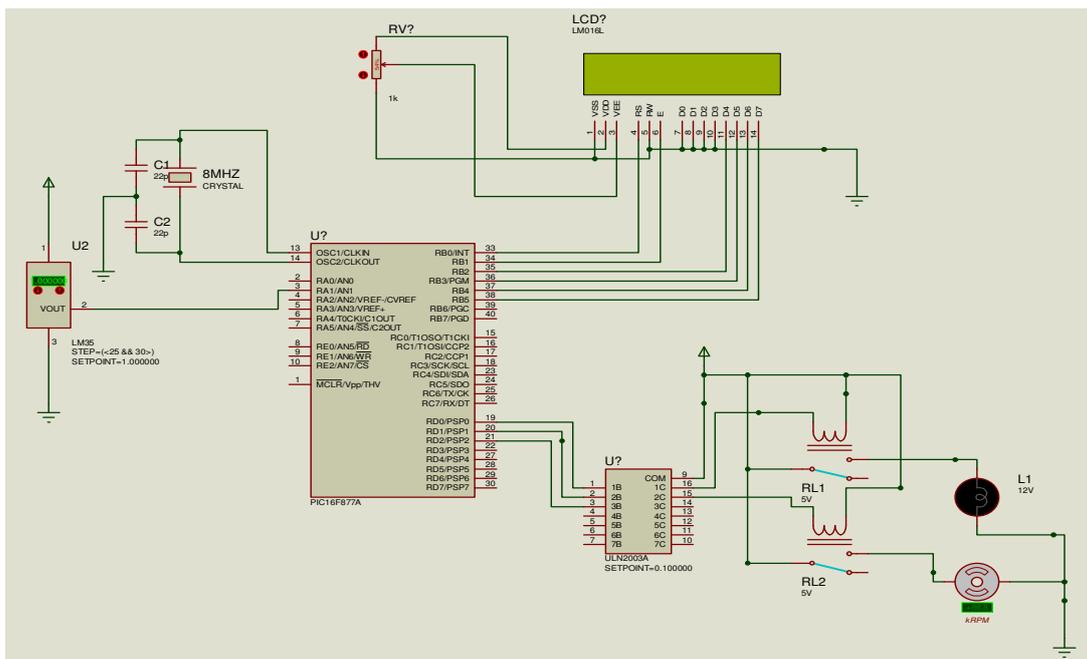

Figure 2.Complete Circuit Designed on Proteus
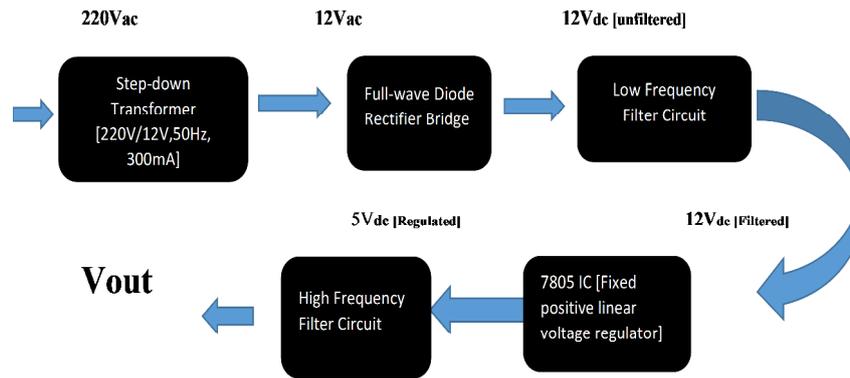
Figure 3: Block diagram of power supply unit
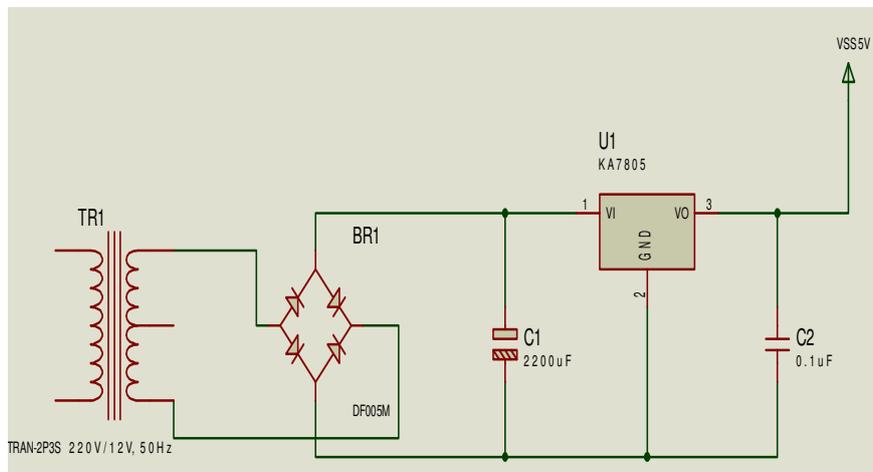
Figure 4: Power supply unit designed on Proteus 8

A step down transformer of 220V/12V, 50Hz, 300mA was used for the design to power the controller and the relay section. It was chosen because the output voltage was safe and also enough to power the microcontroller section of the circuit which needed between 2.5V – 5.5V for it to function properly.

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 is 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

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

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

3.1.1 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: $C = \frac{5\,I_o}{f\,V_p}$ where C is the capacitance of the capacitor; Io is the output or load current of transformer; f is the frequency and V_p is the peak voltage.

For the transformer, output current I_o = 300mA, frequency is 50Hz and V_p of 15V was used. Therefore fixing in our values we have that $C = \frac{5 \times \times 300 \times 10^{-3}}{50 \times 15} = 2000\mu F$. Therefore the preferred market value of 2200uF capacitor was chosen for effective reduction of ripples in the signal.

After rectification of the mains supply, an unfiltered dc voltage with ripples is obtained. To reduce these ripples we use filters. It comprises of two filters low frequency ripple filter and high frequency ripple filter. To reduce low frequency ripples electrolytic capacitor was used.

The capacitors C_1 and C_2 act as filter circuit to reduce the effect of ac ripples from the power supply. The

voltage rating of capacitor C1 must be double from incoming dc supply e.g. 2200µF/25V for the 12V dc voltage. It blocks dc voltage and feeds it to the output terminal while passing the a.c. ripples to ground. The output filter capacitor is a 0.1µF/50V capacitor which helps to remove a.c ripples that might have escaped the first ripple filter [5].

The specifications of KA7805 IC voltage regulator from the National Semiconductor products datasheet was given as follows: regulated output voltage 5V, output current 1A [6].

3.2 Design Analysis of the Sensor Unit

The sensor unit is made up of the LM35 temperature sensor and is analyzed in the next session.

3.2.1 The LM35 Temperature Sensor Unit

This unit as shown in Figure5 is made up of the LM35 analog temperature sensor IC.
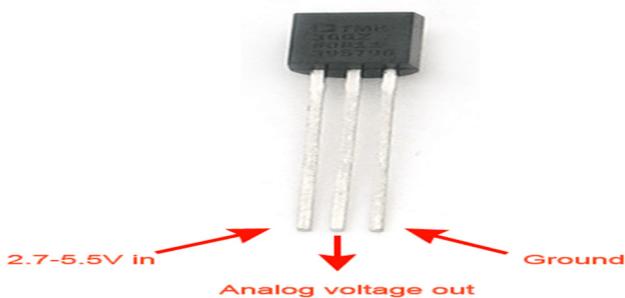
Figure 5: LM35 Temperature Sensor

It is a low cost and precision Integrated Circuit Temperature Sensor whose output voltage is linearly proportional to Centigrade temperature scale. Thus LM35 has an advantage over other temperature sensors calibrated in Kelvin as it does not require subtraction of large constant voltage to obtain the required Centigrade temperature. It doesn't requires any external calibration. It is produced by National Semiconductor and can operate over a full -55 °C to +150 °C temperature range. Its output is linearly proportional to Centigrade Temperature Scale and it output changes by 10 mV per °C.

The LM35 temperature sensor has zero offset voltage, which means that the Output = 0V, at 0°C. Thus for the maximum temperature value (150 °C), the maximum output voltage of the sensor would be 150 * 10 mV = 1.5V. If the supply voltage (5V) is used as the Vref+ for Analog to Digital Conversion (ADC) the resolution will be poor as the input voltage will only drive up to 1.5V and the power supply voltage variations may

affect ADC output. So it is better to use a stable low voltage above 1.5 as Vref+.

3.2.2 Converting ADC Reading to Celsius degrees

Knowing that the ADC has a step size of 4.883mV, converting our digital reading back to voltage is simply done by multiplying the digital reading by the step size: Vin (in Volts) = Digital Reading * 0.004883

Now, knowing our sensor's sensitivity is 10mV/C, converting this voltage to Celsius is simply done by dividing the input voltage by 0.01,

Therefore temperature (C) = Vin/0.01 = Digital Reading x 0.4883 [7].

3.3 Design Analysis of the Processing Unit

3.3.1 PIC16f877a Microcontroller

A PICF16f877A microcontroller is employed in this design and since it has all the unique interface for both input and the output control, making it possible for a reduction in the number of discrete electronic components. This is an integrated circuit which was programmed with a TopWin2008 flash programmer to receive input signals and relating it to other interfaced sub-unit attached to it for their corresponding signal generation.

It receives inputs from the input peripheral devices and processes these signals with respect to how it is programmed, and performs a set of operations accordingly. The PIC16F877A microcontroller is a 40 pin RISC IC. This PIC microcontroller differs from other PICs because of the features like 10 bit, 8 channels inbuilt ADC, inbuilt PWM, and one 8 bit USART.

The inbuilt Analog to Digital Converter (ADC) eliminates the use of external ADCs like ADC2803 and its family. PIC ADC module has software selectable high and low voltage reference input to some combination of VDD, VSS, RA2 and RA3.

In this project we converted the analog input 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 = 0000000000

5v = 1111111111

$\text{Resolution} = \frac{(Vref+ - Vref-)}{(1024-1)}$ (as it is a 10 bit ADC) $= \frac{5}{1023}$ = 4.887mV .
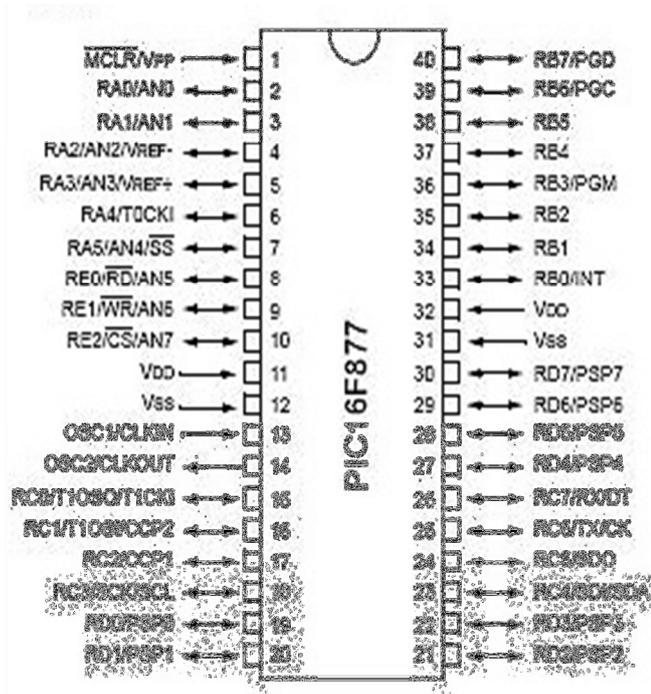
Figure 6: Microcontroller show input/output pins of PIC16F877A

Figure 7: Micro C PRO for PIC Compiler

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

With four (4) I/O ports, it is suitable for this project with a whole lot of reserved pins in case the projects gets more complex and there is need to use the redundant I/O pins [8].

3.3.2 Programming of the PIC16f877a Microcontroller Chip

The MikroElectronika micro-C PRO for PIC v6.0.0 (Figure 6) was used to write and compile the programming codes for the PIC16F877A microcontroller. The programming language used was Micro-C programming language for PIC. Top Win 2008 Programmer was used to program the microcontroller chip. This is shown in Figure7, while figure8 represents the source codes.

4. IMPLEMENTATION

The construction of this project was done on a Vero board. Vero board is also called a strip board. It is a widely-used type of electronics prototyping board characterized by a 0.1 inch (2.54 mm) regular (rectangular) grid of holes, the type used has parallel strips of copper coating along the entire length of the board in one direction. When using the Vero board some of the parallel copper linings were stripped off to create a break around the holes, this helped to

prevent continuous electrical lines where it is not needed.

4.1 Implementation of the Processing Unit

Figure9 shows the processing unit. This is the most essential section of the system as it is the component in charge of controlling the functionality of the entire home automation system. A 40-pin series microcontroller socket was mounted and soldered on the Vero board inside the socket the two 10pf ceramic capacitors were soldered, then the PIC16F877A microcontroller was mounted on the socket. The 8MHz crystal was mounted and soldered in between the two terminals of the capacitors beside the microcontroller.
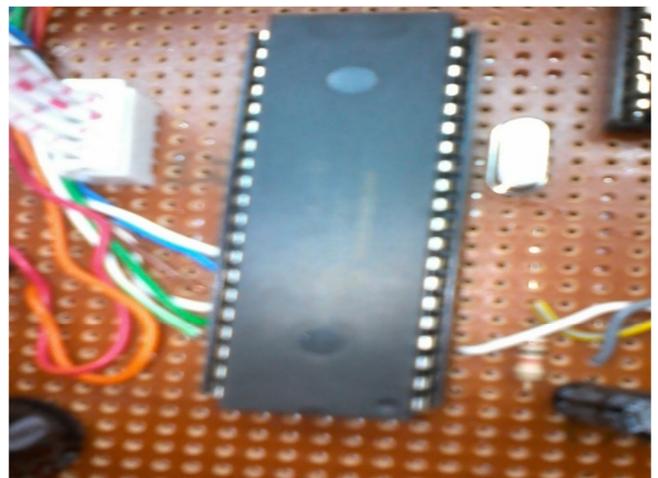
Figure 9: Photo view of the PIC16F877A mounted on connector socket with external 8MHz crystal
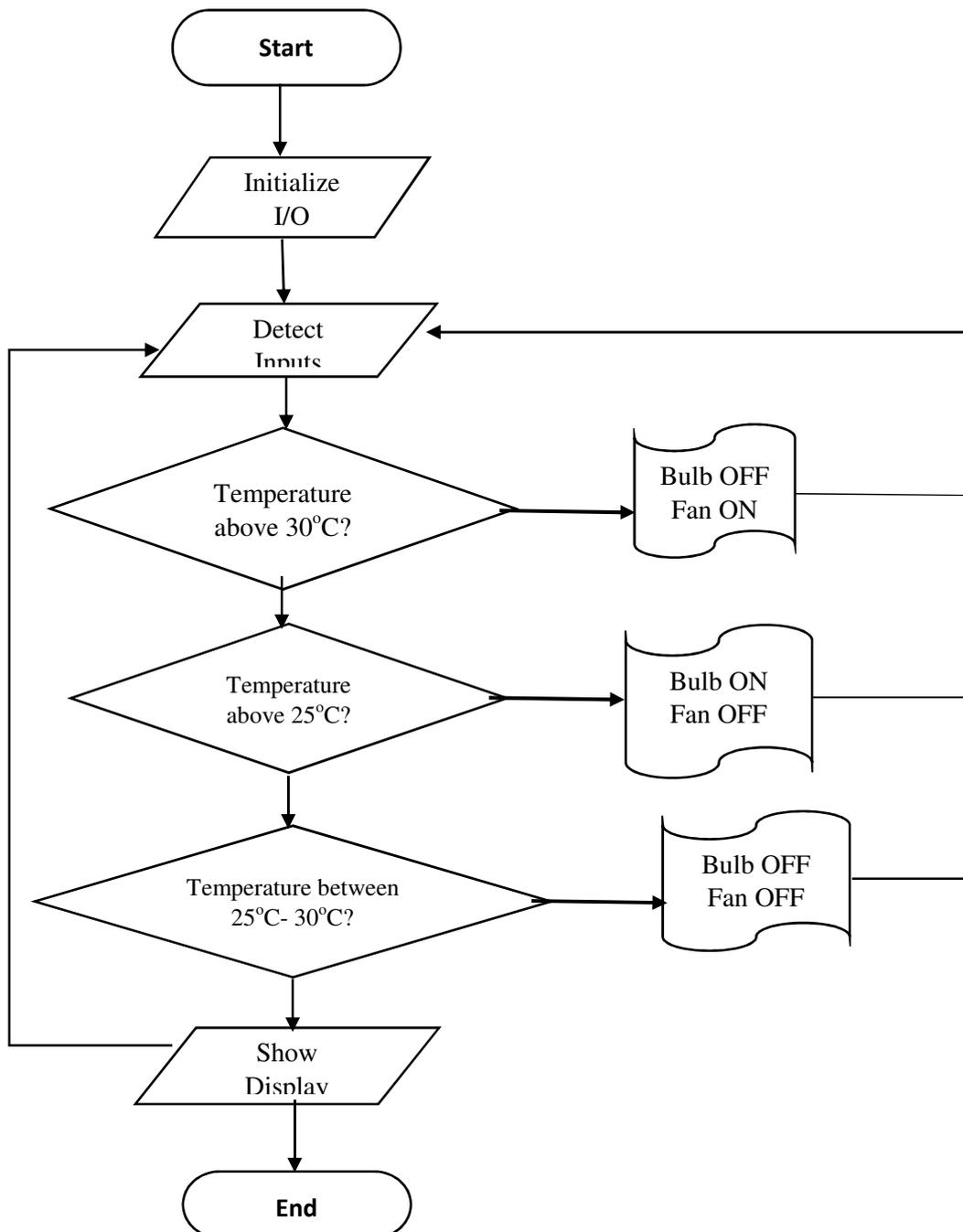
Figure 8. Flow Chart Programming of the Home Automation System

4.2 Implementation of the Display Unit

The hardware set up of the LCD display module interface with the PIC16F877A microcontroller was achieved by connecting the following pins of the LCD;
Pin 1 was solder to a jumper wire connected to ground and pin 2 using a jumper wire was connected to the +5 volts supply (figure10).

4.3 Implementation of the Sensor Unit

LM35 The LM35 was first soldered on a small piece of Vero board, one end of jumper wires was soldered to the terminals of the temperature sensor on the Vero

board then the other end was soldered to the analog pins of port A of the microcontroller to complete the hardware connection.

For the software part of implementation of the temperature sensor LM35 the A/D Port Configuration Control bits from the PIC16F877A manufacturer's data was used to configure the analog pins AN0 to AN7 at port A of the microcontroller, this enabled the smooth interface control of the LM35 sensor on the microcontroller with the written program codes.

4.4 Implementation of the Power Supply Unit

The following components were used to set up the power supply unit as shown in figure11;

• 220/12V 300mA 50Hz Step-down transformer

• First filter component 2200µF, 25V electrolytic

capacitor, second filter component

…0.1uf/50vcapacitor

• Diode Bridge rectifier, and

• 5V voltage regulator

The primary side of the transformer was connected to a 220V AC mains while the 12V secondary side was connected to the alternating voltage input pins of the bridge rectifier.

The DC output of the bridge rectifier was passed through the first a.c. ripple filter component 2200µF, 25V electrolytic capacitor, and then sent to the LM7805 5V voltage regulator which supplies the constant 5V voltage supply needed by the PIC16F877A before passing it through the second filter component 0.1µf capacitor.

The soldering process was carried out using a lead and a 6w soldering iron. This was done by joining terminals together before soldering. And after soldering each unit, test was carried out using a multi-meter to ensure good contact. A patrax box was used for the enclosure of the project Patrax is an electrical installation box used for housing electrical/electronic components. It is made of plastic material, 50×20mm rectangular shape with 10mm thickness. This box shown in Figure12 houses the control unit.
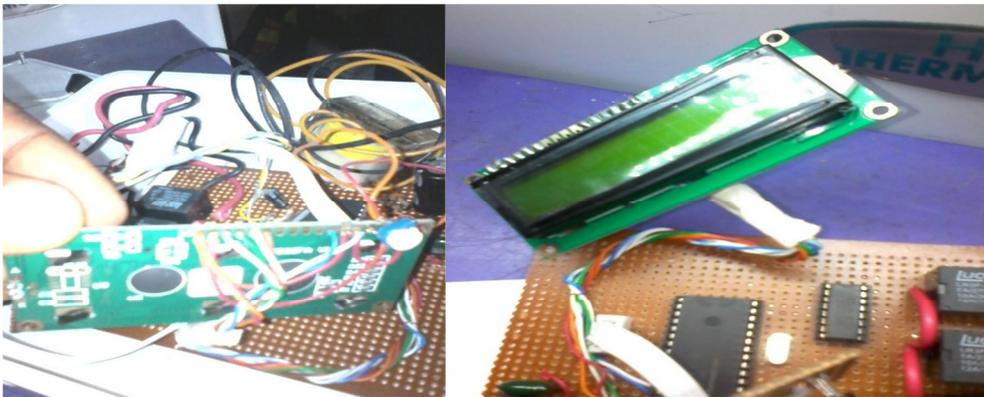
Figure: 10. Liquid Crystal Display Unit showing variable resistor on the back panel
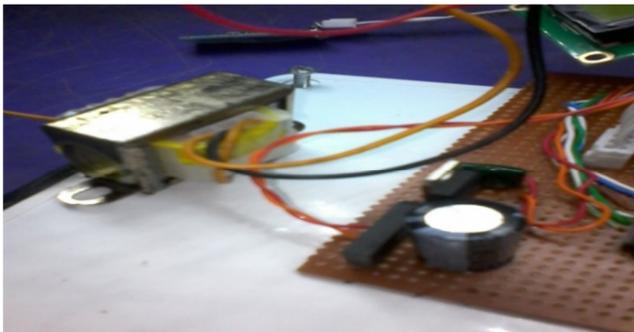
Figure: 11. Photo view of the Power Supply Unit of the Home Automation System

Figure 12: Photo view of Patrax box housing the entire control system

(Heating and Cooling Units in OFF state)

(Heating and Cooling Units in ON state)

Figure 13.Photo view of The Home Automation System House Model.

5. RESULTS

The automatic temperature sensor control system was able to switch on and off a 60watt light bulb and a 220volt, 0.14amp a.c fan through the LM35 temperature sensor at the preset temperature value, below 25°C and above 30°C. At temperatures between 25°C and 30°C the connected appliances were not activated.

6. CONCLUSION

The designed automatic temperature sensor control system was tested a number of times and certified to control, the air conditioning system, fans , heating system, (this is as long as the maximum power and current rating of the appliance does not exceed that of the used relay).

It is evident from this work that the system can be made cheaply from low-cost locally available components and better still, the components required are so small and few that they can be packaged into a small inconspicuous container.

7. ACKNOWLEDGEMENT

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