

Design and Development of a Microcontroller Based Automatic Switch for Home Appliances

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ABSTRACT: Home Automation is the interconnection of electrical devices in a household together to perform a function without human intervention. Home Automation can be many different things. It may be remote lighting control, it may be setting your lights and temperature on a schedule to conserve energy and make sure you come home to a warm, well-lit house every night, and so on. In this work, we design and implement a device that would detect the presence or movement of persons in a room and switch on the light (240V) if this condition is true and off if false, and also turn on or off the fan in the room based on a certain temperature of the room and if a presence or movement is detected.

KEYWORDS: Home Automation, Remote Lighting Control, Electrical Devices, Temperature.

I. INTRODUCTION

The first technology of home automation is the x10 technology which is one of the protocols of home automation which was developed in mid 1970's [1], [2], [3], [4], [5]. In 1970, a group of engineers started a company called Pico Electronics in Scotland. Pico revolutionized the calculator industry by developing the first single chip calculator. Today, X10 claims that this Contrary to popular belief, this calculator IC was the world's first microprocessor. Pico went on to develop a range of calculator ICs which were manufactured by General Instruments and sold to calculator manufacturers.

In 1974, the Pico engineers jointly developed a record changer that would select tracks on a regular vinyl LP with BSR, which at the time was the world's biggest manufacturer of record changers. The Accutrac could be operated by remote control based on a device Pico developed using ultrasonic signals. This led directly to the idea of remotely controlling lights and appliances. In 1975, the X10 project was conceived. (It was simply the tenth project that Pico had worked on. There were 8 different calculator IC projects and the Accutrac was project X-9) The concept of using existing AC wiring to transmit signals to control lights and appliances was born [6]. In 1978, after several years of refining the technology, X10 products began to appear in different stores. A partnership with BSR was formed, known as X10 Ltd, and the BSR System X10 was born. The system at that time consisted of a 16 channel Command Console, A lamp module, and an Appliance module [7], [8]. Soon afterwards came the Wall Switch module and the first X10 Timer. By 1984, Pico had developed a joint venture with GE for a product called the Homeminder. It was a VCR styled package a bit bigger than a cable set top box. It connected to the TV and was operated by an infrared remote. Eventually the GE division responsible for the Homeminder was closed and the units were repackaged and sold to Radio Shack.

Shortly after the Homeminder, X10 developed their first computer interface for Mattel's short-lived Aquarius computer. X10's Aquarius computer interface eventually morphed first into the Radio Shack Color Computer Interface, and then into X10's long lived CP-290 unit, which was sold until the X10 replaced it with the ActiveHome controller in the late 1990s. Over the years, the CP-290 has had a long list of both "official" and shareware software so that it could be used with Apple IIs, Macs, DOS, and Windows in all of its many versions.

In 1989, X10 introduced the first low-cost self-installed wireless security system. Then came the Voice Dialer security system, the Monitored security system, as well as Personal Assistance versions. In 1995, X10 set up its own monitoring station called Orca Monitoring Services in Seattle, Washington. Today, it monitors security systems developed and manufactured by X10 for Radio Shack, Phillips Consumer Electronics, (Magnavox) and the X10 Powerhouse brand [9].

II. MATERIAL AND METHODS

The system is made up of different components which when incorporated or interfaced gives the expected outcome which is the automatic switch for home appliance. The block diagram features include the following:

- Passive infrared sensor
- Temperature sensor
- Power supply
- Main controller
- Fan control
- Opto- triac controlled switch.

Fig. 1 is a block diagram of the automatic switch for home appliance.

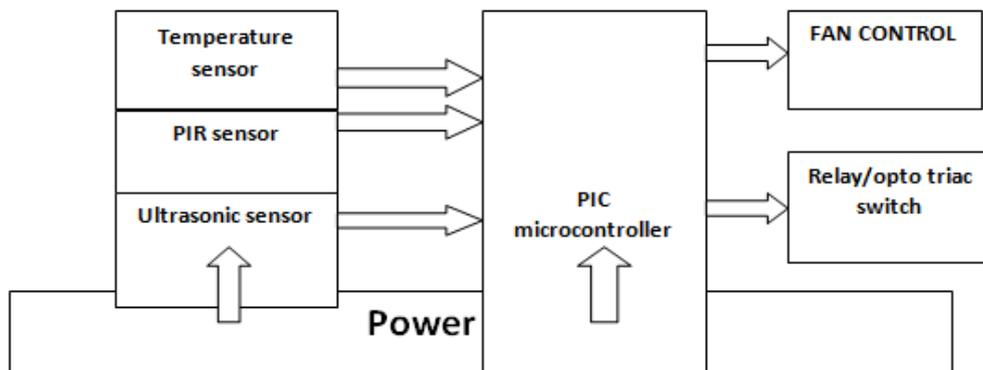


Figure 1: Block Diagram of The System

From the block diagram above, the sensor that we used in this work is an occupancy sensor/motion sensor which is a passive infrared sensor in conjunction with a temperature sensor. The passive infrared sensor is a device that measures infrared light radiating from its field of view. After a signal has been detected, it transmits it to the microcontroller for evaluation and necessary operation. The temperature sensor measures the temperature of the room and sends signal to the microcontroller. The microcontroller has the ability to supply voltage and evaluates signals being sent to it. Based on the programming of the microcontroller, an on/off signal is sent to the relay which is an electronic switch. When ON signal is sent to the solid state relay, the light comes on whose input is 240volts. When ON signal is sent to the transistor switch, the ventilation system comes on. To prevent the appliances from coming on due to false sensing, there has to be a set point for the motion detector which the controller evaluates if it is within the range before sending ON signal to the transistor switch and solid state relay. Fig. 2 is a control loop diagram for the whole system:

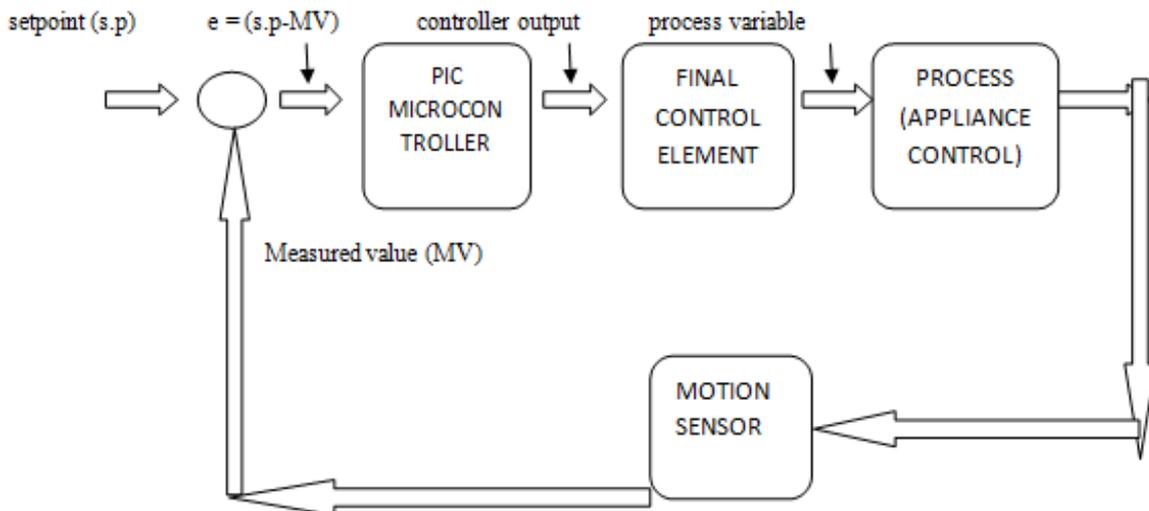


Figure 2: Typical Control Loop of System Performance

In order to eliminate the limitation of the ventilation system, a thermostat acts as the second switch that either comes on when it is within the set system coming ON even when the weather is cold.

From the system design, there are two major outputs:

- I. the fan control
- II. the light (240V) control

The fan control:

A 12V DC fan was chosen for this work. Since the fan is to be turned on or off based on certain conditions, a simple transistor switch will suffice. Fig. 3 is a diagram showing the design of this switch.

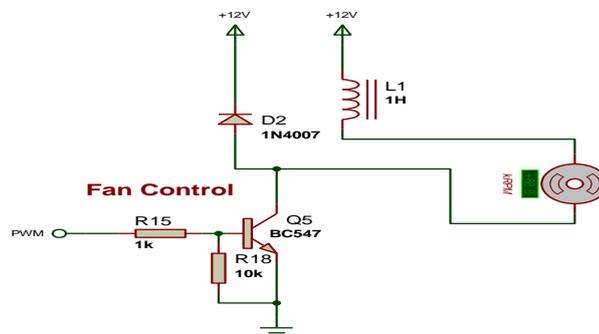


Figure 3: Fan Control

For this design a general purpose NPN power transistor, BD911 was used. Generally for switching applications using general purpose transistor like the one shown above, a strong base current from 1mA to 10mA is recommended. The resistor R15 (1KΩ) limits the base to this range. A normal digital output is at 5V max. Therefore with a 5V input to the base, the current flowing is:

$$\frac{5V}{1K} = 5mA$$

which is within the specified range. The resistor R18 (10kΩ) is to make sure that the base is fully turned off when no driving voltage is present. Also since this would form a voltage divider with R15 at the base of the transistor, its value must be much larger so that most of the voltage would be dropped across it which is also the base voltage of the transistor. However, this voltage must be greater than 0.6V, which is the turn on voltage of the V_{be} junction of the transistor. At 5V, the voltage across this resistor is:

$$\frac{10}{(10+1)} \times 5V = 4.5V.$$

which is more than required.

The light (240V) control:

The light to be controlled in this application is a 240V light bulb. A simple quick and safe method of doing this is to use a high voltage Solid State Relay (SSR).

Fig. 4 is the design of the light control using the Solid State Relay:

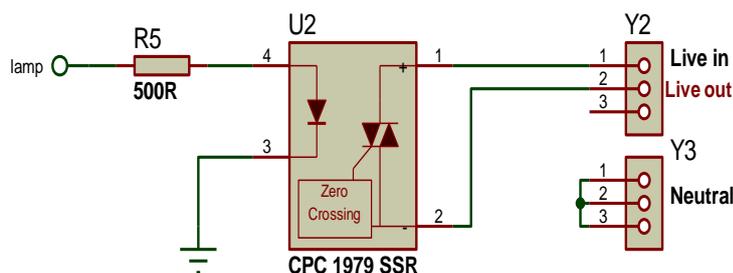


Figure 4: Light Control Using Solid State Relay

An SSR internally is made up of an LED and an opto switch. The opto switch is fully rated for its application. When the LED turns on, the opto switch is activated and current flows. The LED is treated like any ordinary LED with a turn on current from 1mA to 20mA. At 5V, the current through the LED in series with a 500Ω resistor will be:

$$\frac{5V}{500} = 10mA$$

which is within range. The SSR chosen for this project is CPC1979 which can switch high AC loads up to 600V. The load in this case is rated 240V; hence the SSR is very ideal.

From the system design, there are three inputs which can only be provided by the sensors highlighted below:

- the temperature sensor input
- the motion detection input
- the proximity sensor input

Temperature measurement is required in this work for the fan control. Chosen for this work is the DS18B20 digital temperature sensor. The device has a wide power supply range from 3.3V to 5V. Fig. 5, is a diagram showing its design:

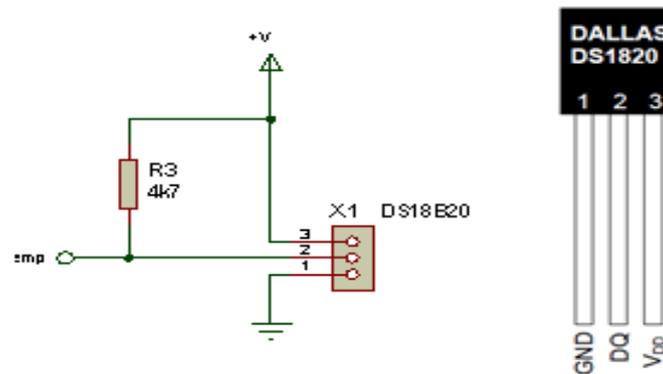


Figure 5: Design of Ds1820 Temperature Sensor

Since it's a digital temperature sensor, the temperature is readily available in digital format, no need for any analog conversions. The sensor interfaces with the host via a single wire (DQ) known as the **one wire interface** and Since it is a digital device, DATA READ and WRITE must take place for the temperature DATA to be retrieved. All these take place on this single line (DQ), (the one wire interface). The resistor R3 (4.7k) is a pull-up resistor which is one of requirement from the datasheet of the device. Below is a diagram showing the internal structure of the sensor.

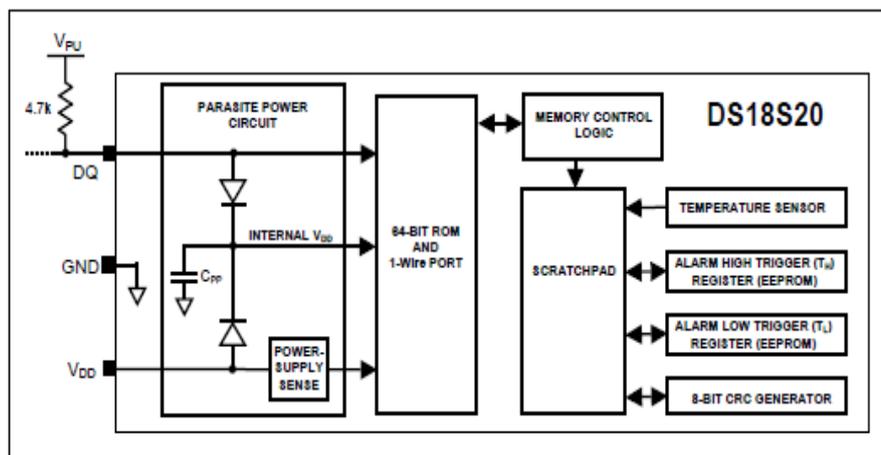


Figure 6: Internal Structure of Ds1820

The DS18B20 is composed of registers which hold configuration data as well as the temperature data. The configuration data defines the communication protocol between the host and the device, the temperature measurement resolution and other data. Two registers hold the temperature data in the device. This is shown in the diagram below. An area in the device known as the scratchpad is available where data is read to or from the device. To read the temperature data for instance, the host issues a read temperature and convert temperature command. The analog temperature is read, and after conversion it is then copied into the scratchpad which is then retrieved by the host which in this case is the microcontroller via the one wire interface. For motion detection, a passive infrared (PIR) sensor is needed. The one used in this project is the e-PIR sensor from Sparkfun Electronics.



Figure 1: ZMOTION™ Block Diagram

Figure 2 displays the ZMOTION™ Detection Module.

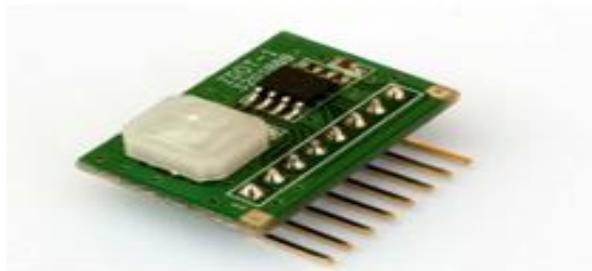


Figure 7: Passive Infrared Sensor

Below is the circuit design based on this device. It comes as device with 8 pins.

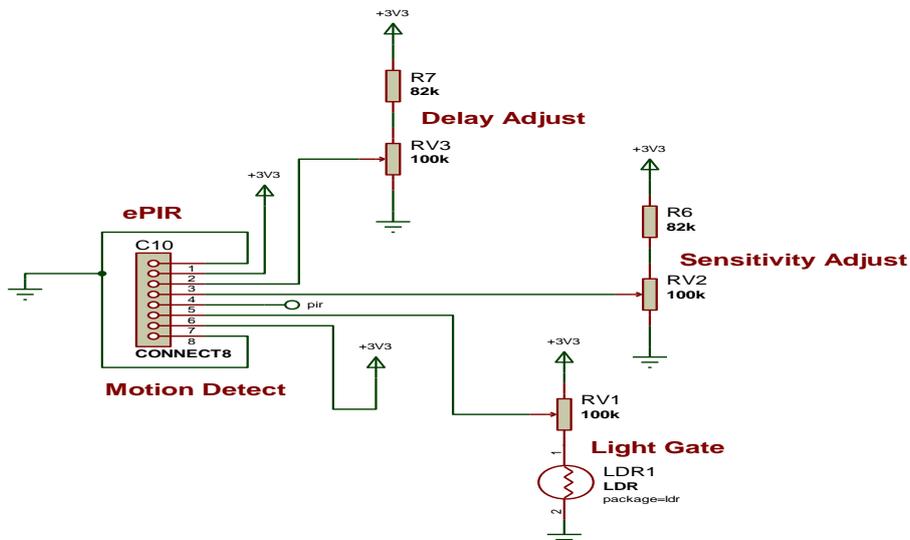


Figure 8: Circuit Design of the PIR

This device is powered from a max 3.3V supply. This device can be operated in two modes: the hardware mode and software mode. The hardware mode is the easiest and less complicated to use. In the hardware mode, the output (pin4) goes low (active low = 0) when motion is detected. For proximity detection, an ultrasonic ranging sensor was employed as shown in Fig. 9.

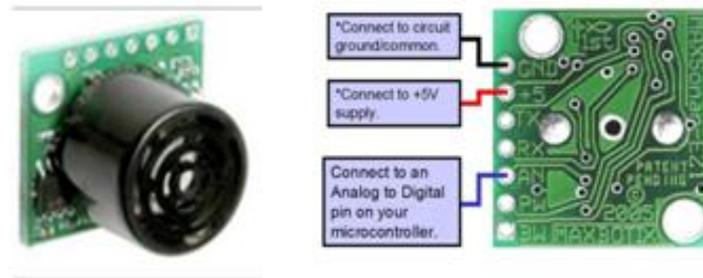


Figure 9: Ultrasonic Sensor

The ultrasonic sensor outputs voltage proportional to the distance between itself and an obstacle. This voltage is analog, hence an analog to digital conversion would be needed at the host side in order to detect an object (in this case, presence). For operation it requires only three simple connections as shown above. From the datasheets, the device outputs 9.8mV/inch @ 5V supply and 6.4mV/inch @ 3.3V supply. The device has a wide power supply range from 3.3V to 5V. Below is the circuit design on this device. The capacitor C9 (100nF) is to stabilize the analog output of the sensor.

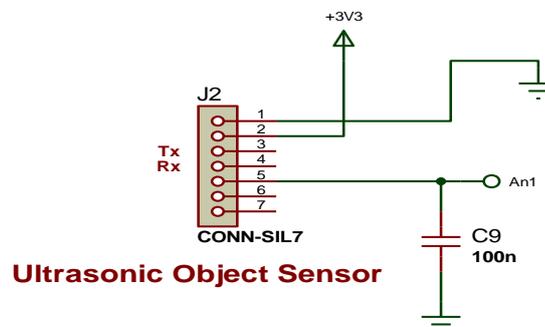


Figure 10: Pin Diagram of the Ultrasonic Sensor

The next block in the system is the interface. This determines how the inputs and outputs must communicate with the main controller and hence the choice of the main controller. Starting from the outputs, the loads that would be driven are the transistor switch and the SSR. These can be driven by normal digital outputs for the controller. Therefore in this design, two digital outputs are needed. For inputs, the temperature sensor and the motion sensors require normal digital inputs while the ultrasonic sensor requires an analog input. Therefore in summary, two digital outputs, two digital inputs and one analog input are needed. The chosen microcontroller must therefore be able to provide these as ports. The micro-controller is the brain behind the proper operation of the system. It ensures that the appropriate signal sent to it by the passive infrared sensor is properly evaluated to turn on the appropriate appliance.

From facts gathered from above, the type of controller can easily be chosen as seen below:

- The motion sensor can only be operated from a max supply of 3.3V. The other sensors too can also be operated from 3.3V. Hence to reduce component count on the final design, the entire circuit can be run on 3.3V. Therefore, the controller chosen must also be able to run on 3.3V.
- The main controller must be able to provide the needed inputs and outputs. In this case, four in/outs would be needed.

- The ultrasonic sensor requires an analog to digital conversion to determine the presence of an object. Hence the main controller must have an inbuilt ADC hardware.

Many microcontrollers are available but the PIC family of microcontrollers is readily available and relatively cheap. Therefore, PIC was chosen for this project. For most microcontroller projects, the PIC18f series is more than sufficient. These groups of controllers are very powerful, come with lots of useful integrated hardware (ADC, timers, OP-amps, EEPROM etc) and are very easy to program with a good support for the C programming language. From the requirements outlined above and looking into the PIC18F catalogue and also checking for availability, the PIC18F26K20 was chosen. This controller has 24 in/outs, inbuilt ADC, and Oscillator. This is more than enough for the project application. Below is the pin out diagram of this controller.

28-Pin SPDIP, SOIC

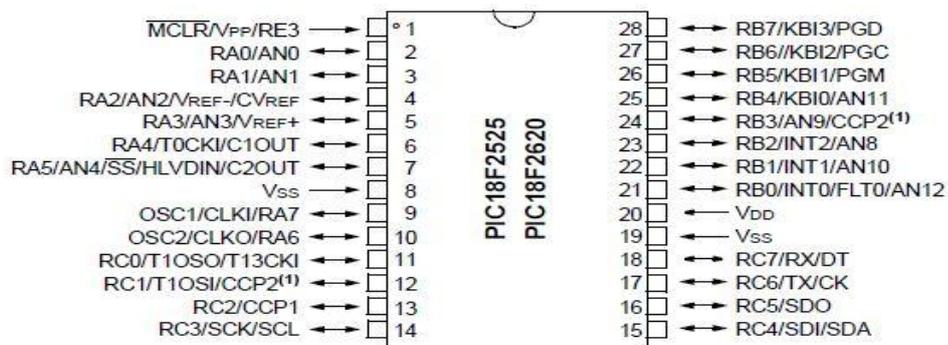


Figure 11: Pin Diagram of Pic18f26k20

The final part of the system is the power supply. The power requirements from all the above will determine the design of this stage.

- The fan requires 12V.
- The main controller and all sensors require 3.3V.

From the above, it can be easily seen that a 12V DC supply stepped down to 3.3V by voltage regulator is all that's needed. Below is the circuit design of this stage.

This is the part of the circuit that deals with conversion of AC voltage to DC voltage since we are dealing with digital circuit. In the conversion process, different stages are involved to get the DC without ripples. These stages include transformation, rectification, voltage regulation and filtering. Figure 12 is the circuit diagram of the power supply system used in our work.

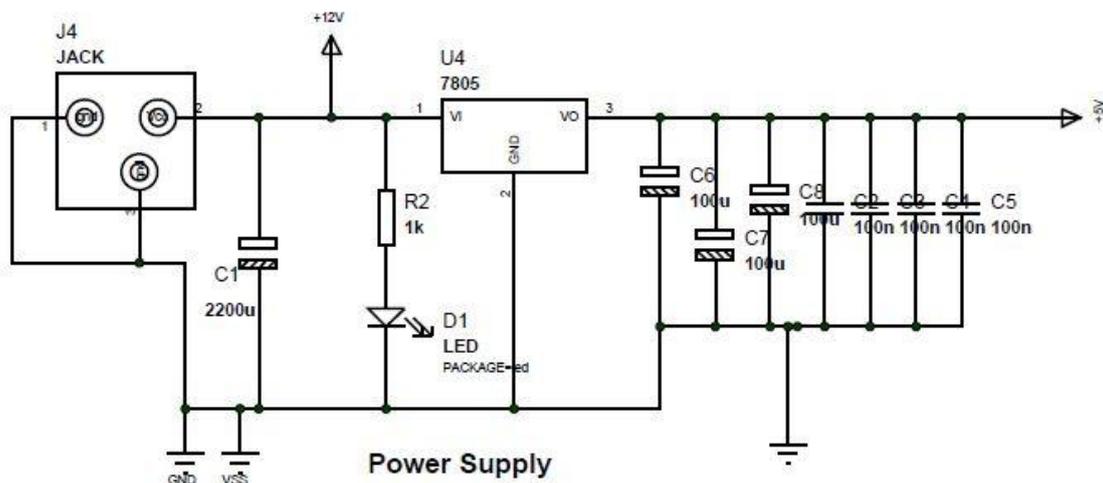


Figure 12: Power Supply Circuit Design

Software design starts with the algorithm. Below is the algorithm

- (1) Idle state, go to 2
- (2) Measure temperature. If its greater than 30, turn on fan, else turn off fan and go to 3
- (3) Check the motion and presence sensors. Any detection, then turn on lights else turn off lights and go to 1

III. RESULTS

In implementing the system, the whole subsections as described in the system design was implemented on a single PCB board. The PCB was implemented using the toner transfer method. Proteus a type of software that has both the schematic and the PCB side was used to draw the design of the circuit diagram. This schematic was transferred to the PCB part of the software and a layout is generated. The layout is printed on a special paper known as the toner transfer paper.

A copper clad board was cut into size according to what had been designed. The printed layout was put on the copper board and heat was applied. The board was soaked in water and the paper peeled off leaving the circuit on the copper board. After holes have been drilled on the PCB board, the various components in the automatic switch were mounted by soldering them on PCB boards. During this process, it was ensured that the heat produced by the soldering iron does not cause damage to the PCB boards or any of the mounted components. As well as component testing, continuity tests and human eye inspection tests were carried out on the entire circuitry of the system. The PCB transmission lines were also checked to ensure that bridging was avoided.

The microcontroller was programmed using assembly language due to its simplicity and speed. After the program had been written, it was run using the MPLAB and compiled. All errors within the program were corrected until the build was successful. In circuit serial programming is the method that was used to transfer the hex file of the codes to the microcontroller. Having created a point of connection on the circuit board, this is done by connecting the PIC programmer to this point and the codes are transferred via this medium.

System testing was done to test the complete integrated system. System tests were performed under real conditions and real life signals from humans. The system testing was carried out by using different people moving and standing in front of the sensors. This was done in order to test for the desired output and correct any errors that might lie within the constructed system. In conducting the system testing, three parameters were used: Distance, network, duration.

Duration: the duration of the testing at each time ranged from 3 minutes to 20 minutes and the device work continuously throughout this time.

Temperature: since there is a temperature sensor within, it was required that the ventilation system only comes on at a particular temperature and above that temperature. This was tested by heating up the sensor and the ventilation system worked but outside this condition, the sensor was certified not working.

Distance: during the testing, different distances were measured in order to test the range of the device. The range of this device is configured 10cm for the purpose of this model.

IV. CONCLUSION

Automatic switch which is a variance of home automation has been successfully achieved. The achievements of this project include: The successful interfacing of sensors with a microcontroller, the use of assembly language to successfully program the microcontroller to be able to perform its functions and the successful design and implementation of the system which has been tested and certified working.

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