
An Arduino-Based Thermal Comfort System

By

Christopher Umerah Ngene and Musa Bello Gunda

Department of Computer Engineering,
University of Maiduguri, Borno State.

Email: ngene@unimaid.edu.ng

ABSTRACT

Conventional centralized heating ventilation and air conditioning (HVAC) systems cannot provide office workers with personalized thermal comfort because workers in a single zone share a common air handling unit and thus a single air temperature. Moreover, they heat or cool an entire zone even if a single worker is present, which can waste energy. Manual switching of these devices for thermal comfort have been employed over the years to control indoor temperatures and this manner of switching ON/OFF comes with challenges of power wastage hence wear and tear of parts. Both drawbacks were addressed in this project which was intended to design and construct a reliable thermal comfort system. This paper focuses on the replacement of manual settings of heating/air conditioning systems in accordance with temperature so that it detects temperature variations automatically and control the device effectively. The result of this work showed that the design regulates with more accuracy the temperature and humidity of an enclosure. The entire work was carried out in four stages using a modular design approach which includes Hardware design/Software design, simulation and physical construction. The project uses thermal sensor DHT11 and Atmega328p microcontroller on Arduino Uno board to control thermal comforting devices. The ranges of temperature used in this project include those below 20 °C, between 20 to 25 °C and above 25 °C for effecting heating, normal and cooling regulations respectively.

Keywords: Arduino Uno, Atmega 328P, Automation, Thermal comfort

INTRODUCTION

In this era, human centered automation has become a part and parcel of everyone's live. Today, we want all our work to be done automatically thereby making manual control of devices/appliances to become out-fashioned. Comfort and luxury has become a must for every capable individual. Thermal comfort as defined by ASHRAE (American society of heating, refrigerating and air conditioning engineers) standard is the condition of the mind which expresses satisfaction with the thermal environment (ASHRAE, 2013). Due to its significance, many applications in daily life involve the control of such process.

With the goal of developing new strategies for the control and improvement of indoor environmental conditions and reducing energy consumption, an automatic thermal comforting system is regarded as the most feasible way to achieve such goal. Air conditioners and room heaters are two devices that are helping in normalizing room temperature in most areas of the world. Automatically controlling those devices shows significant improvement in the automation arena for both domestic and industrial applications.

In relation to the reviewed literatures it can be seen that only Zainab et al (2016) designed a

thermal comfort system using Atmega328p microcontroller and thermal sensor DHT11 which was a prototype model and cannot support high voltage devices for cooling and heating (Unpublished).

Rebollo, et al. (2016), presented a paper during the 6th International Conference on Sustainable Energy Information Technology on Energy materials and person-hour savings through a new decentralized power supply for HVAC in large buildings. A case study: A shopping center in Spain. The paper focused on power supply installations of these Heating, Ventilation and Air Conditioning Systems (HVAC). It entails substantial savings in cost and CO₂ emissions.

Aboaba et al (2015) designed an automatic temperature controlled switch by providing automatic inter-switching requirements in accordance with changes in atmospheric conditions using discrete electronic components. This was achieved by designing four independent stages which were the control, comparator, amplification and switching stages. The design was relatively simple and cheap to execute, however, it could be improved either in the use of more sensitive components or the use of a microcontroller.

Igor, Igor, & Bernard, (2015), wrote a paper on Numerical Modeling of Thermal Comfort Conditions in an Indoor Space with Solar Radiation Sources. In their paper, a three-dimensional case of heat transfer and air flow was presented for indoor space cooling with a wall-mounted A/C unit during the summer in Rijeka, Croatia. Numerical modeling was used to analyze the effect of different air flow angles of the A/C unit on the temperature and air velocity distribution under standard conditions with and without a direct solar radiation source.

Ricardo, Natalia, & Roberto. (2015), A reviewed a paper on human thermal comfort in the built environment. This review does not contain simulation works and/or experimental studies without subjective results of people. Haiyan, Liu, & Joseph. (2014), published a Journal on Thermal comfort and building energy consumption implications. This journal focuses on thermal comfort research work and discussed the implications for building energy efficiency. Lizawati, (2012) the authors designed an automatic room temperature control by using adaptive fuzzy logic the controlling the compressor system in air conditioners through comparing the temperatures between the outside and inside room temperature which was assumed to affect the compressor speed in other to achieve the desired temperature set point. The result shows that the controller is able to show the input references and the output response of adaptive fuzzy control. The developed system addressed the issue of high cost of electricity. However, fuzzy logic is not as accurate and stable as a microcontroller based design.

Bhatia et al (2013) presents a paper on the design and simulation of a novel fan speed control system based on room temperature using Pulse width Modulation Technique. The paper elucidated how the autonomous speed control of fan was done based on data from the temperature sensor. The design used the pulse duration technique with variant duty circles. The approach achieved automatic fan speed control depending on varying temperatures thereby, eliminating the need to regulate the speed manually. However comfort levels cannot be achieved with cooling alone as the temperature can be too uncomfortably cold, as such, here is a need to incorporate a heating unit which drifts back the deviated temperature into the comfort zone.

Rizman et al (2012) worked on automatic temperature control system for smart electric fans by enhancing the fan with a PIC microcontroller which controls the fan according to temperature variations. The design was effective in regulating temperature to comfort levels at high temperature but there was no provision to accommodate comfort state when temperature is low. As such, a heating variable is needed to attain maximum comfort on both sides.

In summary, the reviewed works, it was discovered that efforts had been made significantly to successfully achieve the regulation of air conditioning devices using different adaptive methodologies. However, such designs were not without limitations and others were made for large building while this project successfully overcome some of the limitations in the reviewed related works and this design was made for an enclosed area possibly for home or office automation (personal use) which requires 220V AC supply to power it for both the AC and room heater.

METHODOLOGY

In this section, the outlines of the various design stages and some of the techniques employed in each while carrying out the project work were discussed. The approach used was the modular approach where the entire design was subdivided into simpler functional blocks (stages) for convenience purposes. The entire work was carried out in four stages as follows:

Stage one – Hardware design, stage two – Software design, stage three – simulation with proteus, stage four – physical construction

Hardware design

The hardware section was also subdivided into simpler modules, the modules included in this project are:

- i. The power supply unit
- ii. The display unit
- iii. The LED indicator unit
- iv. The microcontroller unit
- v. The cooling unit
- vi. The heating unit
- vii. The temperature/humidity sensing unit

The block diagram of the automatic thermal comforting system is illustrated in the Figure. 1.

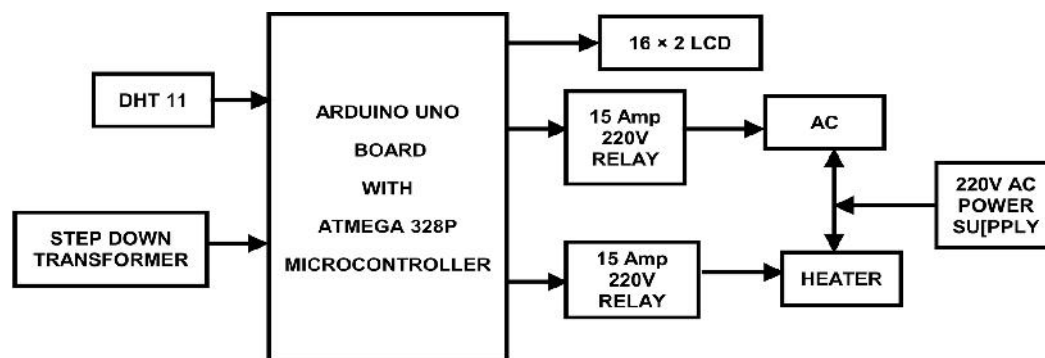


Figure 1: Block diagram of the design

Following the low output voltage of the microcontroller of 5v, a 15 Ampere 220 relay was provided to drive the AC and room heater by switching to the power supply. The microcontroller reads the analog voltage (using ADC) from DHT11 temperature and humidity sensor. Only the temperature readings were used to control the heating/cooling effects accordingly, however, it shall be established that controlling the temperature to attain room comfort levels also places the relative humidity comfort range within that level. The pin connections of each of the components to the Arduino board are shown in Table 1.

If the microcontroller observed the read temperature to be greater than 25 °C, it automatically switches the cooling unit on via the amplified power circuit, which also switches on the LED indicator for the cooling unit. If temperature is within the range of 20-25 °C, both the heating and cooling units remain off as this is the comfort zone, otherwise if temperature is below 20 °C, it automatically switches the heating unit on, which also switches on LED for the heating unit.

The display unit (LCD) was programmed to display in real time, temperature and humidity readings; it also displays the status of the heating/cooling units whether on or off as appropriately controlled by the microcontroller.

Table 1: Pin Connections to the Arduino Board

LCD PINS	ARDUINO PINS
LCD PIN ₁ VSS	Negative power supply rail
LCD PIN ₂ VDD	Positive power supply rail
LCD PIN ₃ VEE	Potentiometer center PIN
LCD PIN ₄ RS	Arduino Analog Input PIN A ₅
LCD PIN ₅ RW	Negative power supply rail
LCD PIN ₆ E	Arduino Analog Input PIN A ₄
LCD PIN ₇ Do	Negative power supply rail
LCD PIN ₈ D ₁	Negative power supply rail
LCD PIN ₉ D ₂	Negative power supply rail
LCD PIN ₁₀ D ₃	Negative power supply rail
LCD PIN ₁₁ D ₄	Arduino Analog Input PIN A ₃
LCD PIN ₁₂ D ₅	Arduino Analog Input PIN A ₂
LCD PIN ₁₃ D ₆	Arduino Analog Input PIN A ₁
LCD PIN ₁₄ D ₇	Arduino Analog Input PIN A ₀
DHT₁₁ PINS	ARDUINO PINS
DHT ₁₁ GND PIN	Negative power supply rail
DHT ₁₁ +VE 5V	Positive power supply rail
DHT ₁₁ DATA PIN	Arduino Digital PIN ₄
OTHERS	ARDUINO PINS
Room Heater	Arduino Digital PIN ₅
Air Conditioner	Arduino Digital PIN ₆
Buzzer Alarm	Arduino Digital PIN ₇

Software Design

This section incorporates the algorithm for maintaining the thermal comfort of an enclosure. Proteus vsm was used for the programming of the microcontroller to ensure orderly control of the thermal comfort system. The complex and intricate operating routine of the software was achieved by writing sections as demonstrated in the program flowchart in Fig. 3 below. Arduino IDE (integrated developer environment) was used throughout the software building stage. The software was written in C language and was developed in sections for easy debugging and then later integrated. The integrated program was built and verified and the hex file was generated which was then loaded into the microcontroller. Fig. 2 below shows the complete circuit implementation after assembling all the subunits of the system.

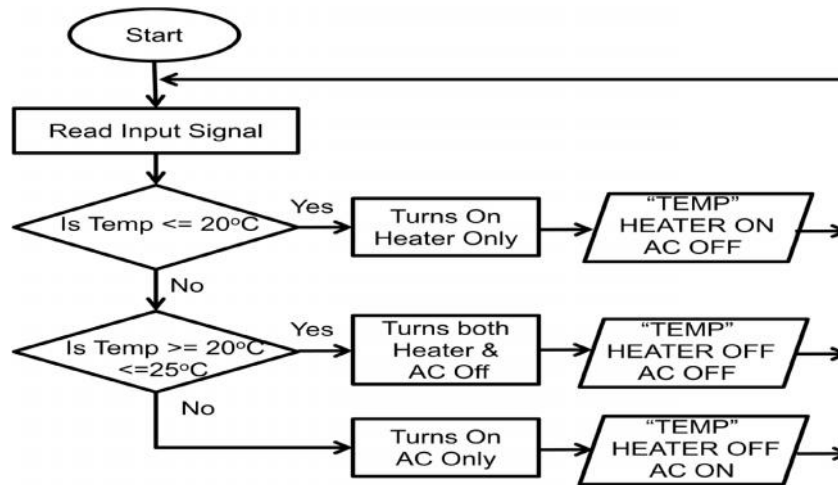


Figure 2: Operation Flowchart

Verification

After successful completion of stage one and two, the design was virtually implemented using proteus vsm software so as to detect likely logical errors in the program and improper operations if any in the hardware design as shown in Figure 3. During and after simulations on proteus, faults were detected and adjustments were made appropriately.

Construction of the Device

After the circuit was certified to provide the required functionality, the various components were assembled on a breadboard at first and were later wired on a Vero board as shown in Figure 4. The addition of each component is followed by appropriate testing to ensure that the interconnection functions properly and also to determine the health of the component. The pin connections are elaborately shown in Figure 4

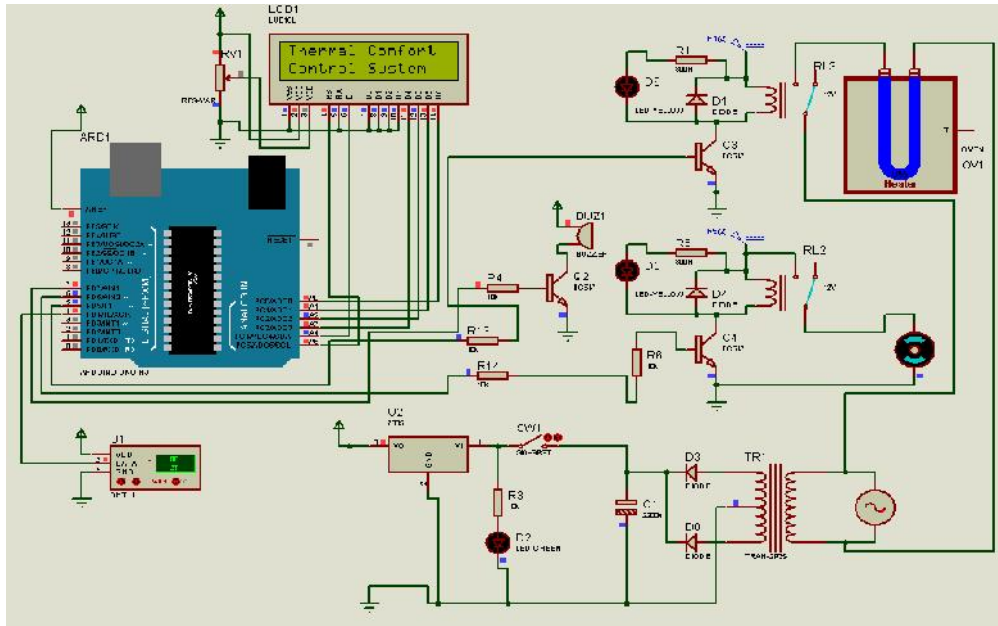


Figure 3: Design Simulation of the Assembled Components



Figure 4: Assembled Thermal Comfort System

RESULTS AND DISCUSSIONS

The constructed model was connected to a 220v AC outlet and as rightly said earlier it had two (2) 15 Amp sockets for which one was designed and labeled for Air conditioner and the other for the room heater. As soon as the constructed model was connected to power, the L.C.D displayed preliminary information about the project designer and the supervisor. The DHT11

temperature/humidity sensor reads the temperature and humidity of the environment, feeds the analog readings to atmega328p microcontroller through its 3rd pin. The microcontroller digitized the analog readings and used the information to control the heating/cooling effect of the environment accordingly in order to attain the desired thermal comfort level. When the temperature was greater or equal to 25 °C, the cooling unit (AC) which was connected to pin of the microcontroller via a relay automatically switches ON. When temperature was between 20 to 25 °C, both the heating and cooling units were turned OFF as this was the desired thermal comfort level range. When the temperature was equal or less than 20 °C, the heating unit (room heater) automatically switched ON via a relay.

All readings of temperature and humidity together with status of devices were displayed in real time on the L.C.D. This was a parametric as well as a closed loop system which continuously controlled the temperature of a desired environment to the desired thermal comfort levels. The design was purely automatic as such had zero human intervention. In order to test the functionality of the design a 220V bulb was brought close to the DHT11 sensor so that the heat generated from the 220V bulb could be detected by the sensor as the temperature rises continuously while the corresponding status and reading was shown on the L.C.D display screen. The AC automatically switched on as soon as the temperature reading reached 26°C and remained in the ON state as long as the temperature is above that range. An ice block was also brought close to the sensor in order to detect drop in temperature. As the temperature reached 25°C the AC automatically turned OFF and both the AC and the Heater remained in OFF state until the temperature reached 19°C when the room heater automatically switched ON. This means that as long as the temperature is within the comfort zone that is between 20°C and 25°C both devices will remain OFF which eventually saves energy consumption and prevents wear and tear of the device parts from frequent switching ON and Switching OFF which satisfied the problem statement, aim and objectives of the project.

Figure 4 shows the temperature reading of 32°C where the A.C/Fan is in ON state while the heater remains OFF, hence the green LED indicates the cooling unit is active while Figure 5 shows the status of the device on the LED screen.



Figure 5: LCD showing status of device.

Figure 6 below shows that the room temperature is 24°C which falls within the comfort level and indicating that both the A.C/Fan and Heater will remain in OFF state thereby saving electrical energy consumption since both devices were inactive.



Figure 6: Both heating and cooling units are OFF.

From the discussions above, it can be seen that the microcontroller only uses the value of the sensed temperature (without using the value of the sensed relative humidity) to control the appropriate heating/cooling unit in order to attain comfort levels.

CONCLUSION

The detailed methodology adopted in devising the solution and implementation of such methodology through designing, simulating, bread boarding, Vero boarding and casing as well as the results obtained were also discussed appropriately in accordance with the project objectives and comparison of related work from the literature review. The aim of this project is partly to help in adopting theories into practical realization for the benefits of mankind. This particular project was done by a student in the undergraduate level which was only a prototype as stated in the literature review. The main aim of the design which was to achieve an automatic thermal comforting in an enclosure was however implemented successfully as included in her recommendation to use alternating current that switches ON/OFF AC and room heater respectively.

In the future, this project can further be extended or improved to be used in public transport vehicles using either D.C or A.C supply or both. It can also be made to detect temperature readings in four different conditions and switched on the required device when temperature is either *EXTREMELY LOW*, *LOW*, *HIGH*, *NORMAL* and *EXTREMELY HIGH* condition not only "*HIGH*, *NORMAL* and *LOW*" as was designed in this project which will automatically adjust and regulate the speed of the heating or cooling device.

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