Development of a Wearable Air Conditioner Control System

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Abstract— *Conventional air conditioner systems do not rely on occupancy. Due to this, excessive power is being wasted and human are being exposed to building related syndromes' (known as sick building syndrome) through air condition. This paper proposed a new wearable control strategy for use in an office or a single room, such that the occupant will wear the device on the wrist, thus controlling the air conditioner by wireless communication instead of the manual control and thus enhancing thermal comfort of occupants at all times. The developed control system ensures that air condition is not in operation at all the times as in the conventional control method but would be in operation only at certain period of times to satisfy occupant's thermal requirement thereby reducing waste of energy. The system response is evaluated using body temperature of different people with normal and above normal temperature. The result of the evaluation shows that the system mean response is 4.3 seconds to temperature below normal. Also, the system mean response to body temperatures above normal is 1.05 seconds faster than below normal.*

Keywords— ***air conditioner; wireless communication; control; thermal comfort; microcontroller***

I. INTRODUCTION

About 50% of the residential and commercial energy consumption in most developed countries is used by air conditioning systems [1]- [2]. Therefore, increasing the efficiency of Air Conditioning systems, therefore, can greatly reduce the overall energy footprint of a commercial building.

Nowadays, the main target of air conditioning control systems is to maintain the indoor temperature and humidity at an expected level. In a manufacturing process, the technique used is determined by values of certain parameters so that production can be of high quality and economical. However, for air conditioning systems aimed at thermal comfort of occupants in the building, people, instead of production, become the determining factor [3].

A typical air conditioning system is made up of a compressor, condenser, an expansion valve or a capillary tube, and an evaporator [4]. Conventional air conditioning systems can improve efficiency and maintain indoor thermal comfort by either controlling their compressors [5]- [7], or fan speeds [8]. Such control strategies can be achieved by dissembling the air conditioner units and connecting extra devices [4]. But the process may be difficult for occupants to handle. Another challenge is the temperature sensors which are not placed around occupants. Hence, traditional air conditioning control strategy can satisfy occupants of big commercial buildings. Such control strategy may not work well in terms of thermal comfort and energy efficiency. This is because thermal demand of occupants in room changes instantaneously, [9]. Thus, the thermal comfort of human beings must be taken cared of using a control strategy that includes human body temperature as regulating variable in residential buildings. This will also reduce waste of large amount of energy, [10].

This paper proposes a wearable control strategy for use in an office or single room to control air condition using wireless communication. This will enhance thermal comfort of occupants at all time.

II. RELATED WORKS

Lou, *et al.,* in [9], proposed a new strategy to control the indoor air temperature of air-conditioning systems in offices based on resident's feeling of comfort instead of traditional fixed indoor air temperature control method.

Combined with human's psychological reaction and the new signal transfer technique, the room air temperature is controlled by the signals sent from human body so that the resident's actual necessity is fulfilled without compromise. However, the system is not cost effective.

The work of [11] presented the conceptual design of an adaptive multi zone AC control system that utilized WSN for predicting the occupancy pattern of people in a building. Their control strategy involved turning off the AC in unoccupied zones and manipulating the set-point temperature. However human thermal comfort is not taken into consideration.

A hierarchical structure for the control of an AC system using the Model Predictive Control (MPC) algorithms and fuzzy control algorithms was proposed in [3]. The main task of the proposed hierarchical control system is to provide thermal comfort and minimize energy consumption. Their technique also showed a good comparison between two conflicted objectives; thermal comfort and energy consumption. However the systems were not cost effective.

In [12], an intelligent residential AC system controller that has smart grid functionality was introduced. The qualifier "intelligent" means the A/C system has advanced computational capabilities and uses an array of environmental and occupancy parameters to ensure optimal inter temporal comfort per cost trade-offs for the resident, conditional on anticipated retail energy prices. The term "smart-grid functionality" means that retail energy prices can depend on wholesale energy prices. However the systems were not cost effective.

A quantitative model for human thermal comfort called the predicted mean vote (PMV) model that is defined in the ISO 7730 Standard was proposed in [2]. The PMV model computes a numerical comfort level, called a vote; it describes the degree of comfort of a typical person in a moderate thermal environment. The PMV model predicts human comfort as a function of four environmental variables (air temperature, humidity, radiant temperature, and air speed) and two personal variables (clothing and physical activity). Given these variables, it predicts the mean value of a group of people's votes in a 7-point ASHRAE thermal sensation scale. However, the development of such system is very expensive.

Micheal *et al.*, in [10], applied a new control method to regulate the operation of an AC conditioning system in an office based on occupant thermal comfort as against the traditional method based on indoor temperature. The work suggested some improvements that contact sensor which required the occupant to seat on the desk can be made into contactless and wireless which will optimize its function.

The work of [13] utilized video magnification to determine skin temperature. The measured temperature served as feedback signal to control a HVAC system. Although, the work adopted an invasive approach to measure temperature using camera to obtain human thermal physiological signals, the developed system is not economical.

III. METHODOLOGY

The design of the wearable air conditioner control system is made up of two modules; Control unit and air conditioner system unit. Fig. 1 shows the block diagram of the wearable control unit.

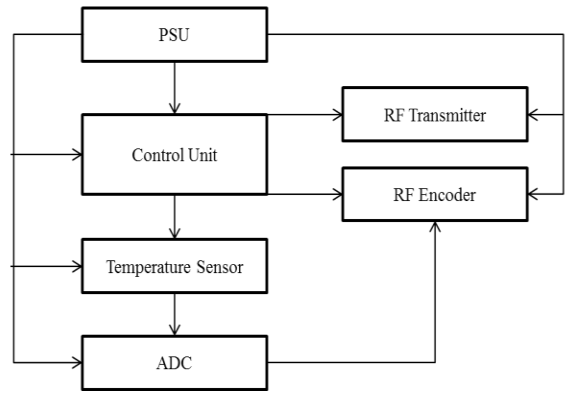

Fig. 1. Block diagram of a wearable air conditioner control device.

Fig. 2 shows the block diagram of the air conditioner unit.

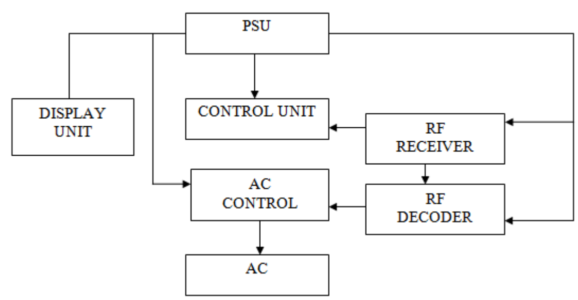

Fig. 2. Air conditioner unit.

A power supply unit (PSU) is utilized to provide a constant 5V DC for the wearable air conditioner control device. Fig. 3 shows the PSU circuit diagram for the wearable air conditioner control device.

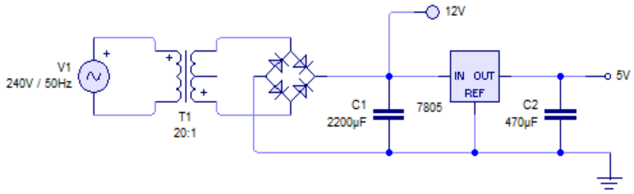

Fig. 3. PSU circuit diagram.

An analog temperature sensor is used to sense the thermal status of the subject due to unavailability of digital temperature, and the sense temperature is compared with the reference temperature (normal human temperature). However, the analog temperature sense is then converted into its digital equivalent by an analog to digital converter (ADC) in the microcontroller and the value is then displaced on a liquid crystal display (LCD). The choice of the microcontroller is the 8051. Kiel software is used to provide the software development tool for generating a HEX file.

Finally, the generated HEX file is burnt on the 8051 microcontroller to perform the control function. A radio frequency module which operates between 2 – 12V DC is chosen as the transmitter. While a radio frequency receiver which operates between 4.5 – 5.5V DC is selected as against the infra-red receiver. RF module was used along with a pair of encoder/ decoder. The encoder was utilized for encoding parallel data from transmission feed while reception was decoded by a decoder. Fig. 4 show the flowchart for the air condition system control.

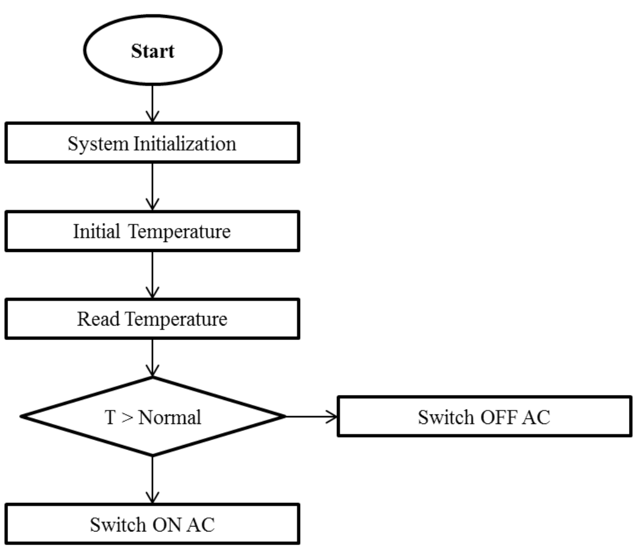

Fig. 4. PSU circuit diagram.

The diagram of the wearable control device is shown in Fig. 5. Fig. 6 shows the circuit diagram of the air conditioner system. Fig. 7 show the simulated air conditioner system.

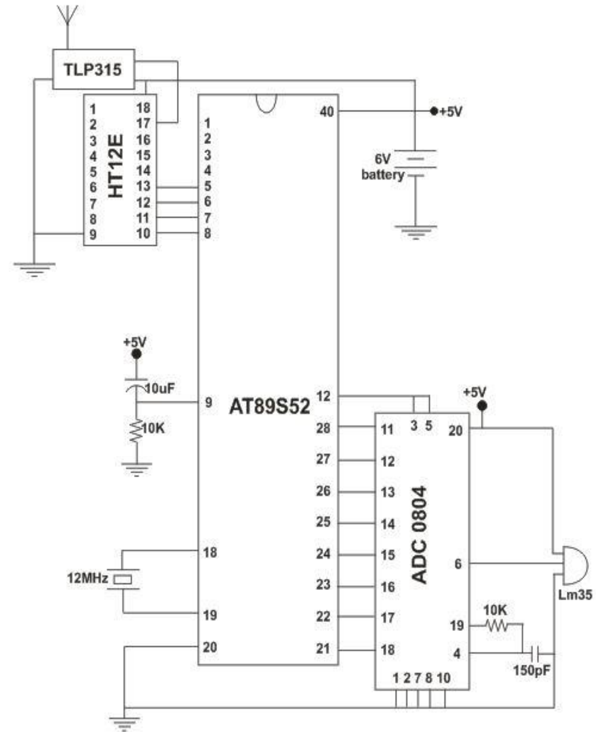

Fig. 5. Circuit diagram of the wearable control device

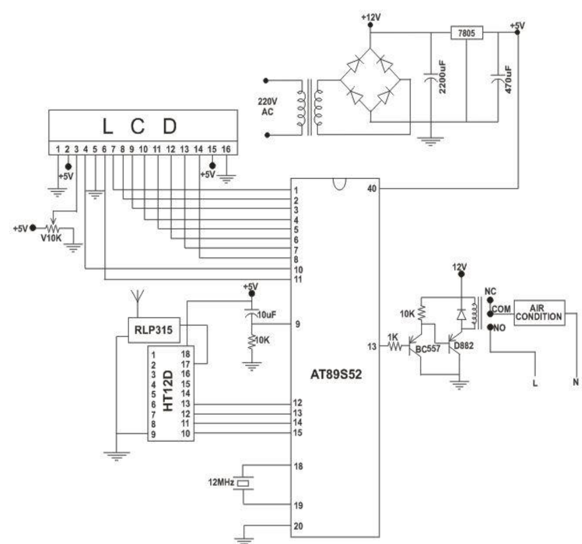

Fig. 6. Air conditioner circuit diagram

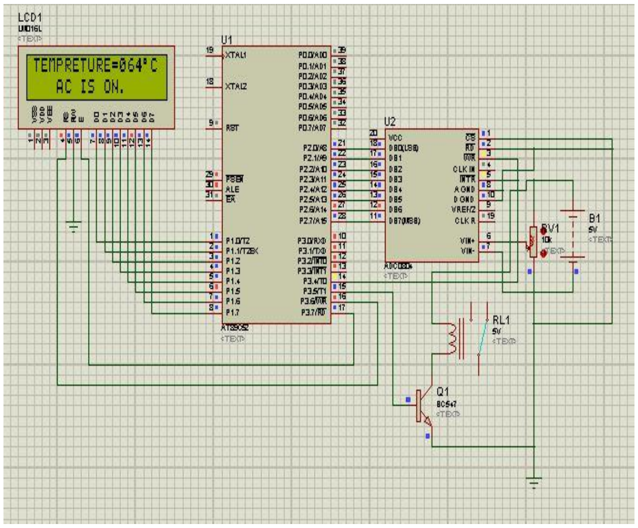

Fig. 7. Simulation of the air conditioner system

Table 1 shows the system response time for different people with normal and above normal body temperatures. The system response time of each person, at both normal and above normal body temperature conditions, is taken in turn.

TABLE I. TIME RESPONSE OF AIR CONDITIONER SYSTEM

Person	System Response (Sec)	
	Under Normal Body Temperature	*Above Normal Body Temperature*
1	4.34	3.12
2	4.57	3.78
3	3.98	3.13
4	4.63	2.98
5	4.09	3.23
Mean	4.3	3.25

From Table 1, the result obtained it shows that the system response faster to temperature above normal than temperature below normal. Fig. 8 shows the graphical representation of the results in Table 1.

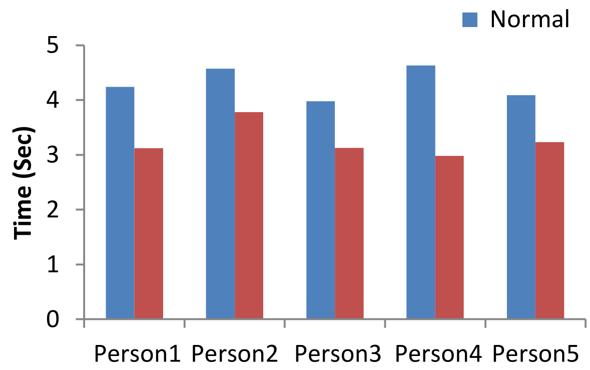

Fig. 8. Air conditioner system response.

A practical implementation of the constructed wearable air conditioner system controller is shown in Fig. 9.

Fig. 9. Working of the wearable air conditioner control system

V. CONCLUSION AND RECOMMENDATIONS

In this paper, a new method of controlling an air conditioner system, based on human body temperature, has been proposed, designed and developed. From the result of the system, the system responded faster to body above normal temperature than at normal temperature. One of the main advantages of this system is that the operation time is reduced due to the fact the regulation factor is the human body, this also go a long way in reducing the excessive power consume in AC. Also, the new control strategy stand a chance in reducing disease which are linked to poor air condition such as Also the new control strategy stand a chance in reducing disease which are linked to poor air condition such as Pneumonitis, legionnaire disease, asthma and hypersensitive. However, this design is still at its infant stage with higher demand of residents and development of technology, a precise, accurate, convenient, intelligent, healthy thermal comfortable control strategy can be realised in the future.

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