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DESIGN AND IMPLEMENTATION OF A MICROCONTROLLER BASED SPLIT AIR CONDITIONER CONTROL SYSTEM

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ABSTRACT. Different methods should be developed to work on energy efficiency in the electrical systems that do not allow outside intervention in the control part. In this study, the command and control of split air conditioners is carried out through hardware and software designed using the embedded system board. Infrared signals in the remote control device of the air conditioner were read with the developed circuit and recorded in the internal memory of the card, and these codes were used for energy efficiency studies. The obtained codes were used in 2 different applications. Thermal camera technology has been used instead of the traditional presence and motion sensors, which cannot achieve the desired success in asset detection in the absence of motion in the implemented applications. In this way, the presence of living things in the areas where the application is made has been detected with a much higher sensitivity regardless of the movement. As a result of the realized studies on the existing systems, 30% energy saving potential is determined approximately.

1. INTRODUCTION

Depending on the development of technology, the need for energy has also increased. The energy consumption of buildings, especially in cities, has risen dramatically in recent decades as a result of population growth, improved building services, and increasing levels of comfort [1]. In industrialized economies such as the Europe and the United States, buildings consume a significant amount of energy [2]. Buildings consume up to 31% of worldwide energy demand, 47.6% of total US energy consumption, and nearly 40% of total European energy consumption [3-5].

Keywords. Split air conditioner, energy efficiency, SAC control, microcontroller, remote control, thermal control.
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When the studies are reviewed in detail, it is seen that energy efficiency and saving studies focus on two different approaches as reducing energy consumption and using renewable energy sources [6]. With the effect of global warming, the demand for air conditioning devices has increased. Naturally, energy consumption and, accordingly, energy generation costs have also increased. Consequently, it has become a necessity to adopt high energy efficient air conditioners and to carry out energy efficiency studies in low efficiency air conditioners [7].

Air conditioners and electric fans used to keep an ambient cool are accounted for 20% of the total energy consumption in buildings. Due to the economic growth of the world, the living standards of human beings have increased. Due to the economic growth of the world, the living standards of human beings have increased. The increase in living standards will increase the rate of air conditioner usage and this trend will continue in the future due to global warming [8,10].

The purpose of air conditioning systems is to improve the air quality inside buildings in terms of temperature and humidity, as well as to provide a healthy and comfortable environment [11]. In the literature, it has been seen that researchers and manufacturers have started to pay more attention to thermal comfort [12,13].

A split air conditioner (SAC) consists of an indoor unit and an outdoor unit, including evaporator, compressor, condenser and capillary tube [14,15]. In some investigated sources, the capillary tube is named as an expansion valve. The main parts of a SAC have shown in Figure 1. SACs have a significant detrimental influence on global environmental pollution and energy consumption, despite the fact that it enhances human living conditions [16].

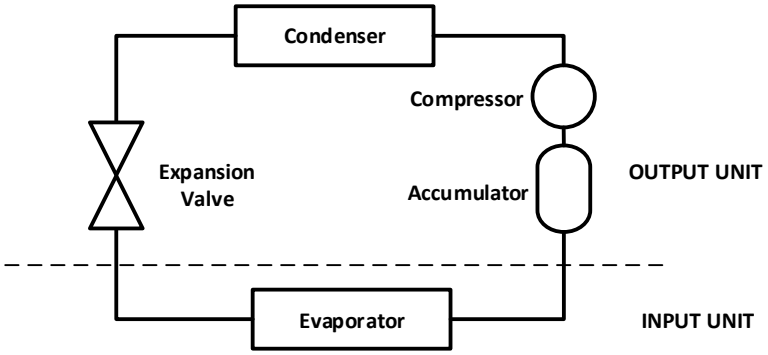

FIGURE 1. The main parts of a SAC.

The most energy consuming part of the air conditioner is the compressor. The most classical method used to reduce the energy consumption of the compressor is the use of an inverter. When the studies in the literature are scrutinize in detail, it is seen that most of the studies are related to compressor [17].

Researches show that speed control of the compressor motor usually has been carried out either using inverter or pulse width modulation (PWM) devices. While the designing of the PWM devices, microcontroller based embedded cards are preferred additional to PIC or other integrated circuits. Sometimes desired results could be obtained without the need for additional devices by simply using an embedded card. In [18], A microcontroller based PWM device has been designed by Podder and his friends to reduce the energy consumption of SAC. As a result of their studies, it has been determined that at least 50 percent savings can be made.

Many different methods are used in the energy saving studies of SAC. In [19], Harby and Amri provided that the air entering the air conditioner was pre-cooled before entering the air conditioner to perform energy saving in their experimental study. As a result of the pre-cooling, energy savings of up to 20% have been achieved. A similar study was carried out by Yang et al. in 2021. In this study, unlike the other study, condensate water was used to decrease the air flow temperature around the condenser of SAC. Depending on the operating mode of the SAC, energy savings were made at different rates. The maximum amount of savings achieved is around 20% [20]. In addition to these two studies, another similar study was performed by Atmaca and his friends. In this third study, evaporative cooled condenser was proposed. In this experimental study, the condenser in the outdoor unit is cooled by an evaporative pad with water circulation. As a result of this study, while the total electricity consumption reduced by up to approximately 12.4%, the total cooling capacity rose up to 18.6% [21].

Some air conditioners in schools, hospitals and similar public buildings continue to operate by leaving them on at noon, evening and even late at night. SACs which have left on after working hours consume unnecessary energy. Usually, the responsible personnel manually check whether the air conditioners are on or off. Consequently, some SACs remain open for a long time [22].

Most of the studies in the literature need to internal modification of the SACs. It means the intervention in the control unit and electronic parts of the SACs. In this proposed study, it is aimed to control the air conditioner using only remote control codes without interfering with the cards and control units of the air conditioner. Existing control codes are read by using IR receiver and saved in the internal memory of the embedded card and then with the helping of developed algorithm and these codes, SACs can be controlled without any intervention. Proposed study has been used in two different scenarios and determined to success realization of energy savings.

2. Material and Method

2.1. **Material**

2.1.1. **Design and implementation of SAC control system**

2.1.1.1. **The controlling of SAC.** SACs have been controlled by IR (Infrared) remote controls. If desired to control by using computer instead of the remote controller, IR codes must be read firstly. After the codes is read and the saved, recorded codes must be send to the SAC with IR transmitter. Because of this, realized study consists of two parts mainly. First section is for receiving and second section is for transmitting. This implementation will be used for controlling of SACs. Realized study were written by using C# and ASP.Net. Desktop application was written by using C# in Microsoft Visual Studio. Web application was written by using ASP.NET in Microsoft Visual Studio. The main screen of C# and ASP.NET software has been shown in Figure 2. Although the two figures are similar in terms of appearance, the software codes and their components are different from each other.

2.1.1.2. **Case 1: The live checking implementation in empty room**. In this study, the time interval specified by the user, in room when presence detection the air conditioning switching off is to save energy via embedded system card. It has been

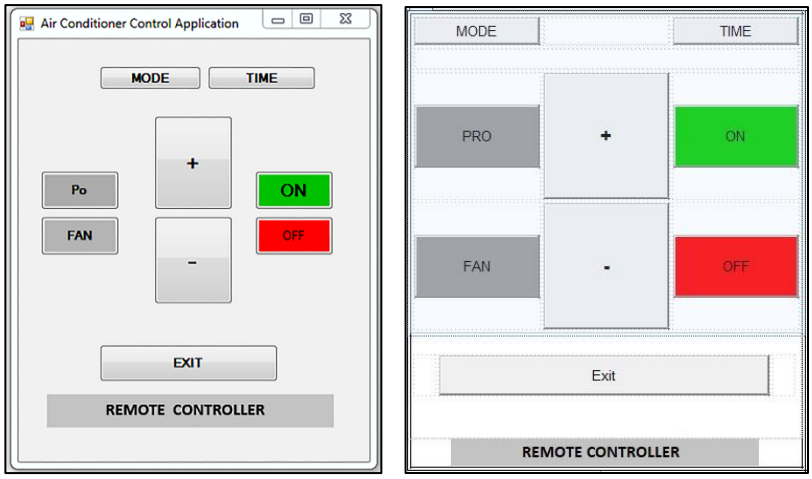

FIGURE 2. SAC remote controller form designs. C# form design (left); Asp.Net form design (right).

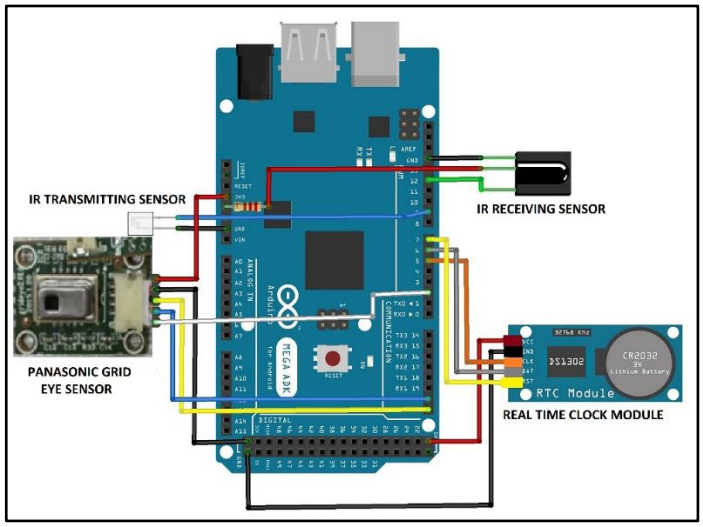

FIGURE 3. Empty room control circuit.

established using the Arduino Mega, fingerprint sensor, Panasonic Grid-Eye, IR receiver and transmitter sensor and the RTC module are used. Designed circuit is shown in Figure 3.

2.1.1.3. **Case 2: Energy saving implementation in air conditioners**. In the System Control Room (SCR) at a university hospital in Turkey, there are three SACs which have without any speed control devices. These SACs have been operated continuously for 7 days and 24 hours at the 22 ^{0}C temperature. Because SACs have not a speed control device, all of them work by STOP and START logic. In the realized study, conventional old SACs were operated such as SACs which have speed control devices. Whole SACs own the same trade mark and model. This situation provides some facilities such as the using of same IR code, management with same microcontroller. In addition to previous realized study, temperature sensor has been added in this study to measure ambience temperature and the grid eye sensor has been removed from the circuit because no asset detection is required.

2.2. **Method**

2.2.1. **Case 1: The live checking implementation in empty room.** In this circuit, Panasonic grid eye sensor was detected while a person is in the room or not. If the

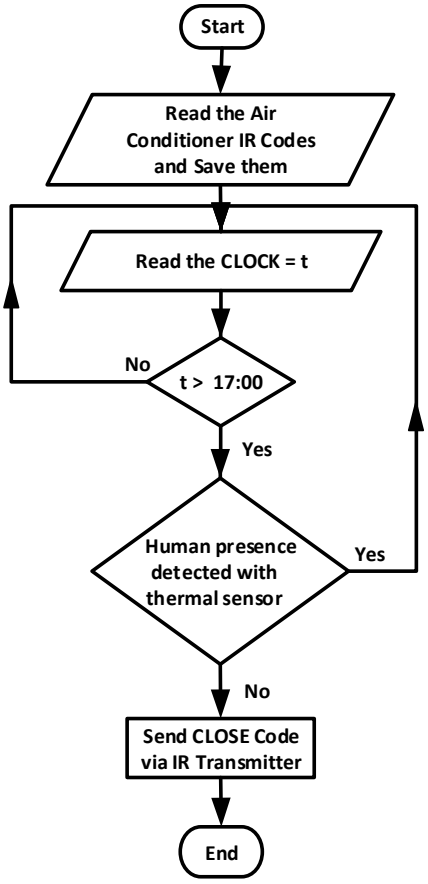

FIGURE 4. The algorithm flowchart of empty room control circuit.

room is empty and the time is after 5 p.m., SAC will be turned off automatically. The algorithm flowchart of the realized study has shown in Figure 4.

According to this algorithm, IR codes of SAC are read from the SAC remote controller and saved them primarily. After that, CLOSE command is sent after 17:00 pm if there is no the live in the room. Thus, after the working hours, open SACs will be automatically switched off.

In the realized study, printed wiring board has been designed as Arduino shield for the installation of used electronic devices. The designed printed wiring board figure has been shown in Figure 5. In addition, the picture of whole realized study is given in Figure 6.

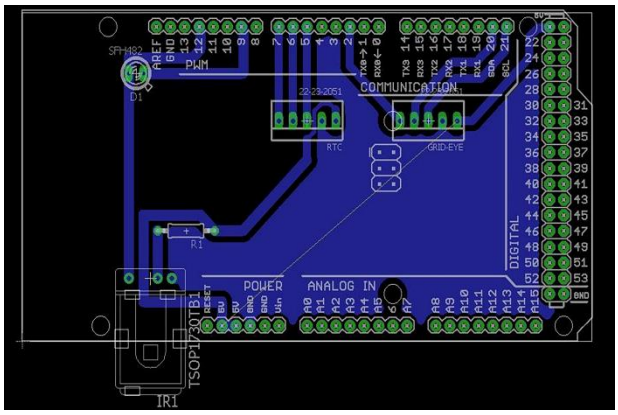

FIGURE 5. The printed wiring board of realized study.

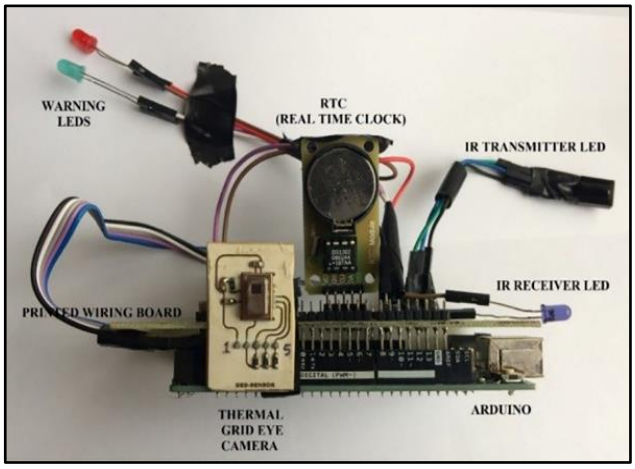

FIGURE 6. The picture of carried out empty room control circuit.

2.2.2. **Case 2: Energy saving implementation in air conditioners.** According to measured ambience temperature, SACs increase or decrease their own temperature value. Moreover, if all SACs do not need to work at the same time, SACs will be shut down respectively. If the SAC is needed to adjust the ambient temperature, the system will automatically activate the SAC as needed. Realized study is not only supported at the SACs in the existing SCR but also designed to manage the desired the numbers of SACs at the same time. The flowchart of carried out algorithm is shown in Figure 7.

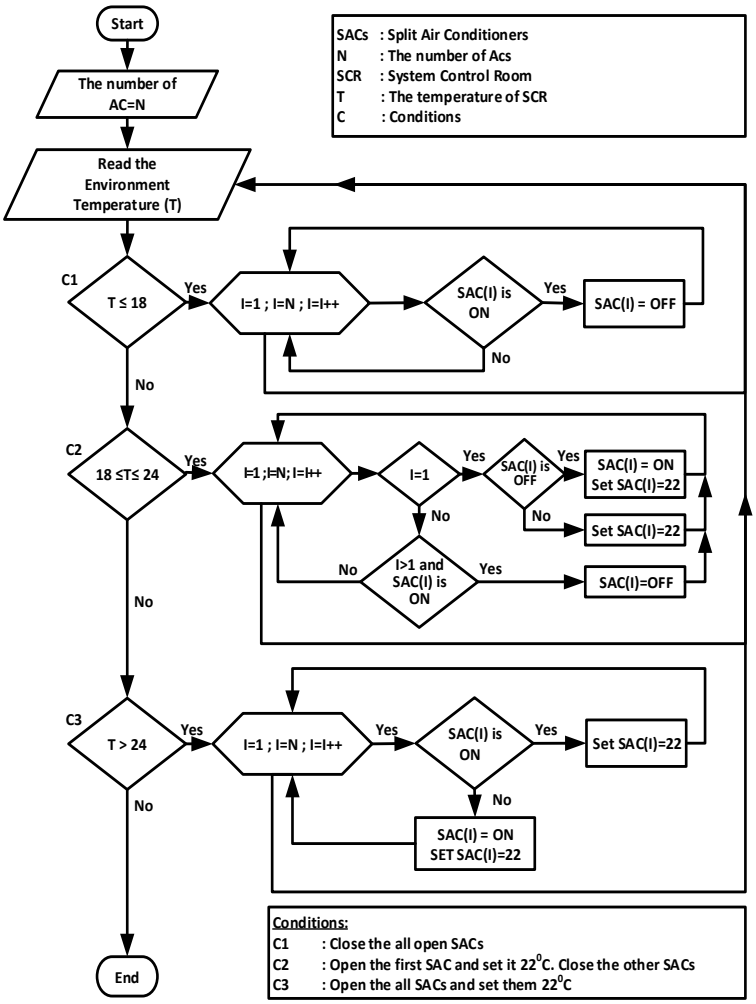

FIGURE 7. The flowchart algorithm of SACs management system.

The flowchart algorithm of the SAC management system can be summarized with the following steps.

1. Input the total number of air conditioners to be used (N)
2. Measure the ambient temperature (T)
3. C1: (Condition 1)
   If ambient temperature T is less or equal to 18^0C then, all the air conditioners are checked. Furthermore, the open ones will be turned off and when the loop ends it returns to reading the environment temperature level
4. C2: (Condition 2)

If the ambient temperature T is between 18^0C and 24^0C then all the air conditioners are checked. If the first air conditioner is turn off, it will turn on and set to 22^0C.The other air conditioners will be turned off if they are on and when the loop ends it returns to reading the environment temperature level

5. C3: (Condition 3)
   If the ambient temperature is greater than 24^0C then all the air conditioners are checked and the open ones will be set to 22^0C. If the air conditioner which is checked is off, it will be turned on and will be set to 22^0C and when the loop ends it returns to reading the environment temperature level.

3. Results

Total energy consumption of existing SACs has been measured for a week. Later, SAC management system has been activated and same measurement, with the same software and the same smart plug, has been realized again. The studies were carried out in December. Energy consumption was measured by a low cost intelligent device (iDEV) which has %2 accuracy. iDEV was designed and implemented by Timur and his friends [23]. Total energy consumption of the whole SACs was measured as approximately 1,008 KWh. When the SAC management system is active, nearly 706 KWh total energy consumption for whole SACs were also measured. As a result of realized measurements, it was determined that approximately 30% energy saving was performed by using AIRCON management system. This means that one of the three SACs is working unnecessarily in December.

4. Conclusions

In this study, microcontroller-based hardware and software design has been carried out in order to achieve energy efficiency in split air conditioners. First of all, the codes of the control of the air conditioner to be worked on were read by the infrared receiver and recorded in the memory of the embedded card. These saved codes were sent to the split air conditioner with the infrared transmitter circuit, allowing the air conditioner to be controlled. Test applications were carried out on desktop and web-based using C# and ASP.NET platforms. Then the obtained codes were used in two different applications. In the first application, it was ensured that the air conditioners that were open outside of working hours were turned off when there was no one in the environment. In the second application, 3 split air conditioners working simultaneously in the system room were operated in a controlled manner in a sequential manner. Thus, devices that cause energy loss by being operated when not needed are prevented from throwing away energy (energy wasting). Although the

applications made save energy at different levels according to the months worked, the results obtained showed that at least 30% energy saving was achieved.

Author Contribution Statements Authors are equally contributed to the paper. All authors read and approved the final copy of the manuscript.

Declaration of Competing Interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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