

Design and Implementation of Microcontroller-Based Building Automation for Smart Computer Laboratory

Puspanda Hatta

Informatics Education

Faculty of Teacher Training and Education

Universitas Sebelas Maret, Indonesia

Email : hatta.puspanda@staff.uns.ac.id

Dimmapraha Fatuardi D

Informatics Education

Faculty of Teacher Training and Education

Universitas Sebelas Maret

Aris Budianto

Informatics Education

Faculty of Teacher Training and Education

Universitas Sebelas Maret

Abstract:

This research provided device management automation for computer laboratories using Arduino. Some devices in computer laboratories such as Air Conditioners and LCD Projectors were always on while the device not used. It caused inefficient uses of electricity resulting in increased electricity bills and reduce the device lifetime. Device automation made the electronic devices work automatically. The first automation we applied on the Air Conditioner, the other one was on LCD Projectors. This schematic developed based on Arduino Uno R3 with several components such as the infrared transmitter, humidity sensor DHT11, relay board and I2C OLED display. Arduino Uno R3 provided as the central controller. The two methods of testing were used for measuring this system performance. The first test was done by testing the performance of the components used, such as the IR Transmitter, DHT11, relay board, and I2C OLED Display. The second test was done by testing the functionality of Arduino Uno R3 as a controller. This test resulted that the automation system can work properly with fully automatic control LCD projectors and air conditioners by periodically stabilizing room temperature and turning on the projector's LCD automatically when needed.

Keywords: Arduino, Building Automation, Computer Laboratories, Microcontroller.

Introduction

Electricity is very important for activity in modern society. Current energy-related issues are a big problem and there are still many instances where people are in a hurry and forget to turn off lights and air conditioners. In such situations, a system that saves electricity is very useful. As well as the automation system for devices that can make electronic devices work automatically, efficiently and save energy at this time. Not only in the industrial segment, but the educational institution also need the cost-effective for electricity. Computer laboratory is a place of scientific research, experiments, training or scientific training related to computer science and has several computers in a network for use by certain community. Computer laboratories are generally found in educational institutions. As a place that uses a lot of electronic devices, computer laboratories require efficient management of electricity usage

Computer laboratories that need ease and cost-effectiveness in meeting the needs and completing a job, for example in the use of electronic devices such as lights, air conditioner, LCD projectors and so on (Oktariawan et al, 2013). These electronic devices are always used in every lecture conducted in a computer laboratory. But the use of electricity in electronic devices is not efficient. Often when lecture activities have been completed, this device is still in living condition. The inefficient use of electronic devices creates waste of electricity that requires electricity bills (Giyartono, 2015). Based on the results of the analysis carried out by Oktariawan (Oktariawan et al, 2013) and Giyartono (Giyartono, 2015), there were several problems that existed in the computer laboratory. Like LCD projectors that are often not turned off after use during lecture hours, and Air Conditioner devices are always turned on in the coldest conditions even though the room temperature is already very low. This will result in electricity waste because the electricity used is continuously increasing while the device has not been used or is no longer needed.

Some solutions that can be done referring to previous research are controlling Air Conditioners automatically and temperature monitoring via Arduino-based websites (Laili, 2014), and controlling LCD projectors remotely with Wi-Fi based on Arduino-uno (Saputro, 2017). Laili with her research developed a system that can control and monitor air conditioners in a room with control media in the form of a website by utilizing an AC remote and connecting the on-off button with the help of a relay. While Saputro developed a remote control system for the projector by integrating the IR Code on the remote projector into a website that can be accessed on a local network.

However, the two solutions (Saputro, 2017) (Laili, 2014) are ineffective because the operation of the laboratory automation devices is not yet fully automatic. In Laili and Saputro's research, both use websites as controllers of electronic equipment. Even though it is internet based through operation via website, it is still classified as conventional automation. Because the operation through the website still involves the role of the administrator manually to monitor the condition of the device being monitored through the website. The mechanism still allows letting electronic devices in the laboratory stay on if the administrator does not monitor the electronic devices in real time through the website. One solution to overcome this problem is to apply automation. Automation not only aims to reduce human intervention, but also the energy efficiency used and time savings (Deepali Java et al, 2013).

Through a study of the previous research, this research perfected the automation mechanism of the device in a computer laboratory, namely the LCD Projector and Air Conditioner. LCD projectors and air conditioners are electronic devices that are often forgotten by the laboratory user. This results in ineffective use of electricity This research developed automation mechanism on the two electronic devices is full automation, with the help of an Arduino-based microcontroller and supporting sensors. With the implementation of an automatic control system, there are two advantages including making the electronic device not easily damaged and using electricity more efficiently. With the automation of electronic devices available in computer laboratories, it is expected to increase the lifetime of these electronic devices because LCD projectors and air conditioners will only live when the device is needed so that it works more efficiently and there is no electricity waste.

Related Work

There are several work related to the development of this Arduino-based Smart Laboratory. Table 1 shows several work that contain the development of Smart Laboratory.

Table 1. Related Work

Author	Method	Result
(Saputro, 2017)	Development of LCD projectors with Arduino and WIFI	This research utilized Arduino Mega 2560, IR and Wifi as a core system. Arduino Mega 2560 has the role as a microcontroller, IR using to transmit signal, and WIFI as a communication infrastructure. In this study, controlling this LCD projector uses a web browser to access the user interface that has been created.
(Prihatmoko, 2016)	Design and implementation of a room temperature controller based on Arduino Uno	In this study, a temperature control system developed using the fan as an air conditioner. If the room temperature exceeds 28°C, the Arduino will turn on the fan. If the room temperature is less than 25°C, Arduino will turn off the fan.
(Nathan & Chima, 2015)	Design of a Home Automation System Using Arduino	The design of the system in this study uses Arduino Mega 2560 as a microcontroller and Bluetooth, wifi and cellular data as a controller for monitoring of electronic devices in the house. But in this study, the Air Conditioner device didn't control automatically. The system only monitoring room humidity.
(Kang et al., 2017)	Room Temperature Control and Fire Alarm/Suppression IoT Service Using MQTT on Amazon Web Services	The researcher created a smart home using Message Queue Telemetry Transportation (MQTT broker) on Amazon Web Server. Access to electronic devices at home can be accessed globally over the internet protocol. It didn't fully automatically, only globally accessible
(Boonsawat, 2010)	XBee Wireless Sensor Networks for Temperature Monitoring	The researcher developed an embedded wireless sensor prototype for temperature monitoring at Sirindhorn International Institute of Technology. This system used to measure the temperature of each classroom in this institute. The system developed using Arduino, XBEE shield, and Ethernet shield as a communication medium between one node and other nodes.
(Baraka, Ghobril, Malek, Kanj, & Kayssi, 2013)	Low cost Arduino/Android-based Energy-Efficient Home Automation System with Smart Task Scheduling	Researchers developed a system that combines both cable and wireless (Zigbee) technology for home automation infrastructure. The system was very flexible, can be scaled, and extended to large households. On the software side, the system can be controlled with an Android application that ensures the system provides energy savings for devices like air conditioning, TV, lights and DVDs. The system didn't support full automation yet.
(Kumar, 2014)	Ubiquitous Smart Home System Using Android Application	This research developed internet-based smart home systems that can be controlled by a user based on authentication. The controller developed using Android to communicate with micro web servers through the internet using REST-based web services. Any Android supported device can be used to install the smart home application and control and monitor the smart home environment.

With consideration of the above research, This research conducted with combining Internet of Things technology with full automation to develop a smart laboratory. The smart laboratory configured using Arduino Uno embedded with the Atmega328 microcontroller. This research will combine various alternative affordable smart laboratory concept with Arduino Uno.

Research Method

The research and development model used to develop this Arduino-based smart laboratory refers to the steps owned by Borg and Gall, a process used to develop a product. This method consists of 5 stages, namely Research and information gathering, Design and Analysis, Develop preliminary form of product, Preliminary field testing and Implementation (Haryati, 2012). The steps were explained in Figure 1 as follows.



Figure 1. Research Method Steps

Research and information gathering

A research started from a problem and in this research appoin the issue of wasteful electricity resources in the Computer Laboratory. The problem was found after making initial observations at the place. Collecting the literature and information can be used as product planning.

In this research the problems found in the Computer Laboratory are wasted electricity resources when electronic devices are used in laboratories. This is because the electronic devices used are often not turned off when the lecture ends. Therefore we need an development of automation for electronic devices that are often used when lectures are running that can turn on and off automatically. The following are the results of observations made in the field :

1. On observations made in the field, electronic devices that can be automated are LCD Projector and Air Conditioner.
2. The device often lights up when not in use and the lack of awareness of laboratory users to immediately turn off the device makes wasted of electricity resources.
3. Both devices are installed on the roof of the room, connected directly to the electrical power source and controlled using remote control. Equations of these 3 aspects make it easier in the process of developing a product.

Design and Analysis

In this stage, hardware requirements and product design are carried out from the Smart Laboratory system which will be developed based on the problems described in the problems described in the previous stage.

Requirement Analysis

Requirement analysis consists of analyzing software and hardware and is used for the minimum development requirements of this system.

- Arduino IDE
- Arduino UNO R3 Atmega328
- USB 2.0 A/B Cable
- Arduino 9V 1A Power Adapter
- DC Stepdown for Coolingpad power supply
- DHT11 Humidity & Temperature Sensor
- OLED I2C Display
- Infrared Transmitter
- 5V Relay Board

Product Design

In general, to explain the system design carried out in manifesting Smart Laboratory can be illustrated by the block diagram in the Figure 2. The overall system design of the Automatic AC Temperature Control Device and Automatic LCD Projector Control Device shown in Figure 3.

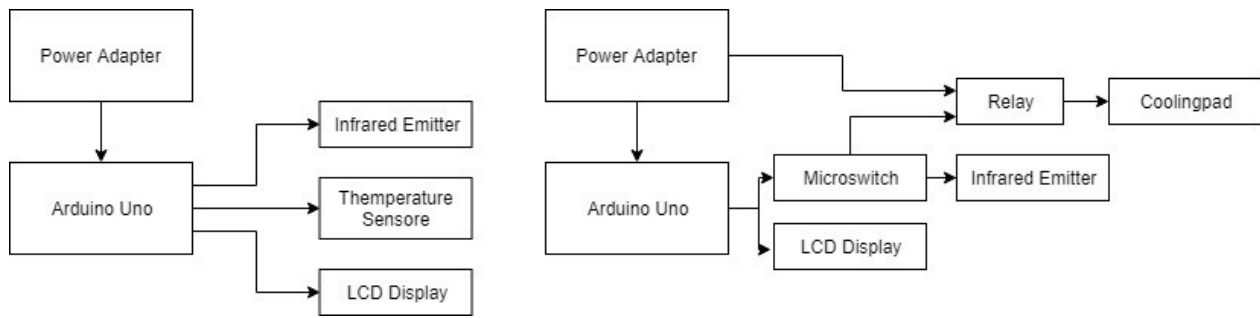


Figure 2. System Block Diagram

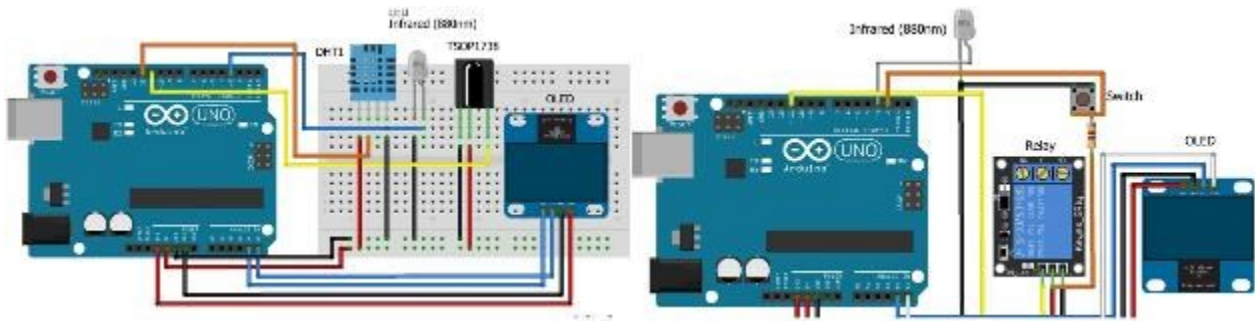


Figure 3. System Design of Smart Laboratory

At the design stage, Arduino will be arranged using a solderless board and wire jumpers to avoid the risk of electric short circuit and installation errors. At this stage it can be seen the component requirements that will be used in this study, such as DHT11 as a room temperature and humidity sensor, 5V relay board as a link between resources and cooling pad, OLED Display as information media that can be displayed by Arduino, IR Transmitter as a transmission media between Arduino with the AC and LCD Projector.

Preliminary Development

At this stage the product that has been designed will be assembled so that it is in accordance with the design that has been made. In this research there are two types of initial product development, namely the development of automatic AC temperature controller devices and Automatic LCD projector control devices.

The Result of Automatic AC Temperature Controller

This device is made using the Arduino Uno R3 microcontroller with the sensors needed, namely Infrared, DHT11 and OLED Display LCD. All sensors will be assembled to a printed circuit board according to the design that has been made. The results of the development of this device can be seen in figure 4.

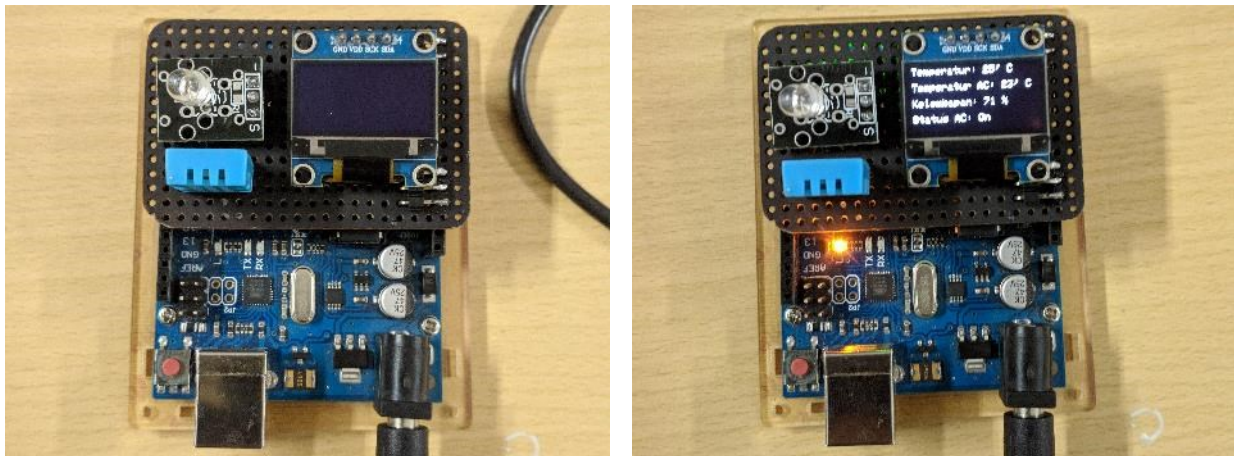


Figure 4. Automatic AC Temperature Controller made from Arduino Uno R3 in off and on condition

When the system is on, Arduino will use a temperature sensor to read the current room temperature. The desired temperature is applied to 24°C. If the room temperature is now 20°C, Arduino via infrared will send turn off command signal so that the AC is turned off and the OLED will provide information that the AC is off at the current room temperature. If the room temperature is greater than the 28°C, the Arduino will send a command to change the AC temperature according to the program and display the current room temperature and the last AC temperature sent via infrared. The system design flowchart can be seen in the figure 5 below.

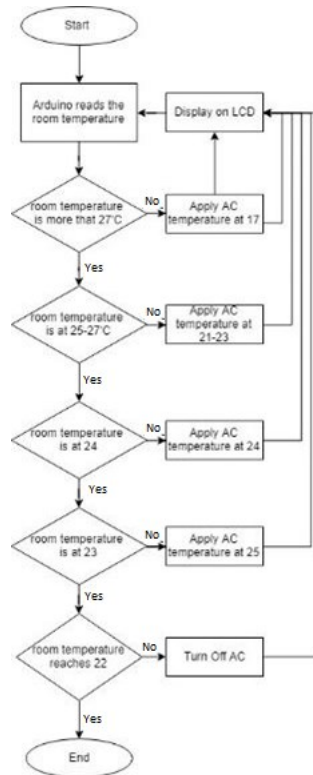


Figure 5. Flowchart for Automatic AC Temperature Controller

The Result of Automatic LCD projector controller device

This device is made using the Arduino Uno R3 microcontroller with the sensors needed, namely Infrared, Microswitch, Relay, and OLED Display LCD. This microswitch will be installed on a laptop cooling pad. Microswitch will be connected to Arduino as a trigger that the laptop is present and the LCD projector will turn on and also the relays installed on Arduino will connect power adapter to coolingpad. The results of the development of this device can be seen in Figure 6.

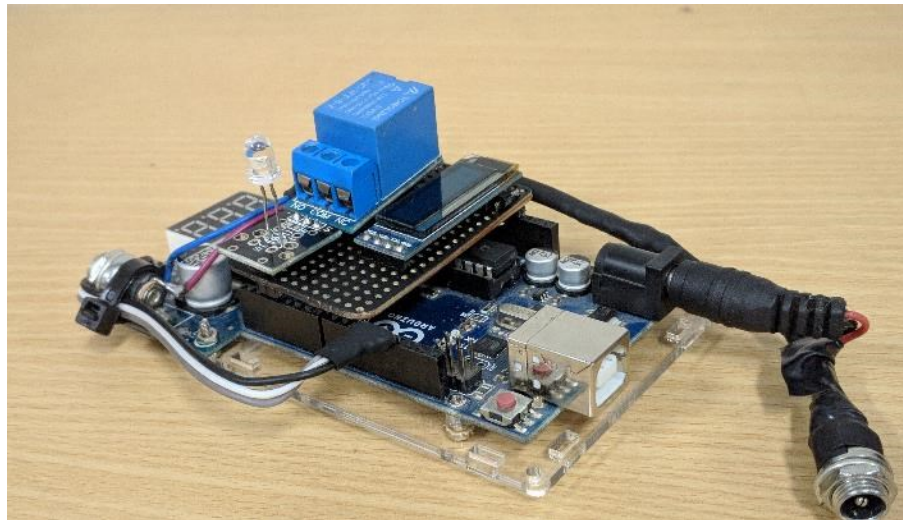


Figure 6. Prototype of Automatic LCD projector Controller

When the system is on, Arduino will read the microswitch status installed on the cooling pad. If the microswitch is pressed for 5 seconds, the Arduino will send live commands to the LCD Projector, turn on the cooling pad and provide active status on the OLED. If the microswitch is not pressed for 5 seconds, the Arduino will turn off the LCD projector and cooling pad, and give the OLED inactive status. The system design flowchart can be seen in the figure 7 below.

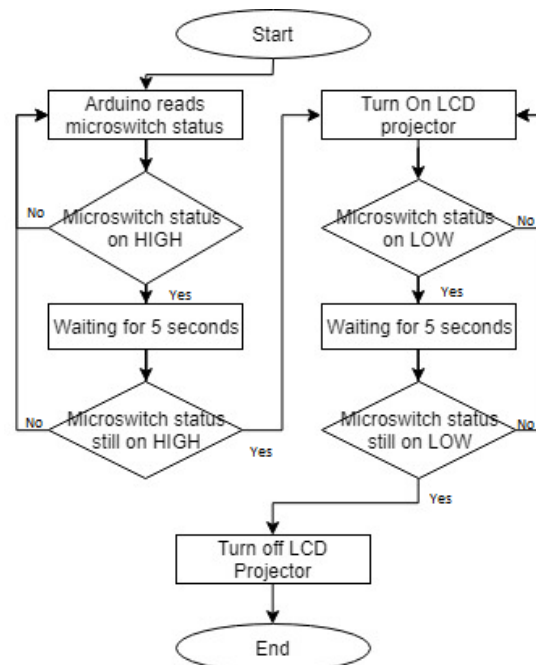


Figure 7. Flowchart for Automatic LCD projector Controller

Preliminary field testing

The initial evaluation process is carried out before product assessment by related experts. This evaluation is done by installing Arduino Uno with each sensor installed. The results of Arduino Uno performance test will be discussed in the Performance Testing segment. After the performance test is completed, the product will then be tested by the related experts and the results can be seen in the Usability Testing segment

Implementation

Implementation is carried out after passing the previous step. The step taken at this stage is to put the two finished devices into a computer laboratory. During the installation stage, this device does not make any changes to the electrical installation in the laboratory

1. Automatic AC Temperature Controller device

AC used in a computer laboratory is central air conditioning, AC with an air cooling process centered in a location which is then channeled to several places. The AC in the laboratory installed on the roof, so that the device that has been made can be placed under the air conditioner so that the device can still reach the air conditioner.

2. Automatic LCD Projector Controller device

This device is placed right below the LCD projector. With the LCD projector placed on the roof, the microcontroller cannot be placed too far from the LCD projector. However, the location of the coolingfan as a trigger can be placed separately from the microcontroller because the coolingfan and microcontroller are connected using a cable.

Then after implementing, usability testing was carried out using the usability questionnaire adapted from Permana & Iswanto (2018) with respondents from product experts.

Result

Research Result

This study produced an Arduino Uno-based Smart Laboratory product that aims to automate devices that often wasted energy. This device uses infrared as a transmitter between Arduino and AC / LCD projectors. Testing this device is done by placing the microcontroller into the laboratory and testing the performance of each sensor and testing the functions of the device's overall integrity. The following is an Arduino implementation in the computer laboratory.

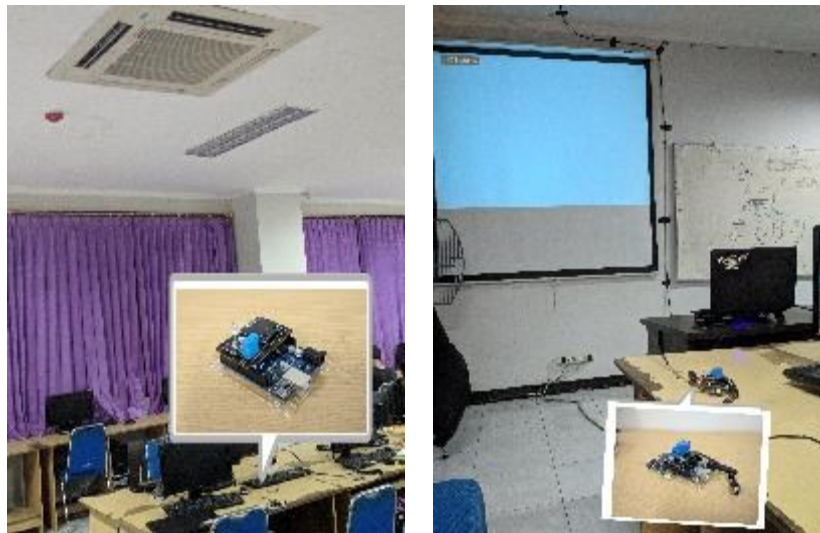


Figure 8. Controller Configuration in the Computer Laboratory

Performance Testing

The next step carried out by researchers is to test the performance, function and usability of the devices that have been developed. The first test is to test the performance of the microcontroller and each sensor used such as DHT11, IR Transmitter and Relay. The following are the results of the tests that have been carried out:

The first test was carried out by testing the Arduino Uno microcontroller. Testing is done by checking each digital pin on the Arduino with the LED and sensor installed. The test results show that Arduino works well and is very feasible to use.

Table 2. Arduino Uno Pin Performance Testing

Arduino Pin	Arduino 1		Arduino 2	
	Test phase with			
	LED	Component	LED	Component
3.3v	Succeeded	Succeeded	Succeeded	Succeeded
5v	Succeeded	Succeeded	Succeeded	Succeeded
Gnd	Succeeded	Succeeded	Succeeded	Succeeded
D2	Succeeded	Succeeded	Succeeded	Succeeded
D3	Succeeded	Succeeded	Succeeded	Succeeded
D4	Succeeded	Not Used	Succeeded	Not Used
D5	Succeeded	Not Used	Succeeded	Not Used
D6	Succeeded	Not Used	Succeeded	Not Used
D7	Succeeded	Not Used	Succeeded	Not Used
D8	Succeeded	Not Used	Succeeded	Not Used
D9	Succeeded	Not Used	Succeeded	Not Used
D10	Succeeded	Not Used	Succeeded	Not Used
D11	Succeeded	Not Used	Succeeded	Not Used
D12	Succeeded	Not Used	Succeeded	Succeeded
D13	Succeeded	Not Used	Succeeded	Succeeded

The second test conducted by testing the transmitter's main sensor, infrared. This test aims to determine the ability of the range of areas that can be reached in sending signals to the destination device. IR Transmitter testing is done by sending data in the form of raw data that is recognized by devices controlled by infrared. In this test a raw data transmission simulation will be carried out to turn on the AC and projector with a distance difference per one meter. The IR Transmitter test obtained results as in table below.

Table 3. IR Transmitter Performance Testing

Range (m)	Result	
	Air Conditioner	LCD Projector
1	Succeeded	Succeeded
2	Succeeded	Succeeded
3	Succeeded	Succeeded
4	Succeeded	Succeeded
5	Failed	Failed

The third test was carried out by testing the DHT11 sensor. In this test Arduino can read room temperature and room humidity, but the value obtained has not been calibrated with the original thermometer temperature so that the room temperature can be inaccurate. The temperature sensor results are then compared with the temperature of the thermometer and the difference is calculated. The difference obtained shows the error value that occurred in the measurements obtained by the DHT11 sensor. The error value can be calculated using the following formula.

$$E = \frac{\Delta T}{t} \times 100\%$$

Description :

E = Error Value

ΔT = Difference in measurement of thermometers with DHT11

t = Thermometer value

In testing the DHT11 sensor the results are as shown in the following table

Table 4. DHT11 sensor test results.



In table 4, it can be seen that the error rate in DHT11 is quite small but the difference in measurement with a thermometer at a temperature between 24C to 28C looks stable with a difference of approximately about 1°C.

The fourth test was carried out by testing the relay module. Testing this relay module uses a method by connecting the relay module directly with the Arduino board. The thing that will be considered in testing this relay module is whether common will be connected to NO (Normally Open) if given a HIGH signal from the microcontroller and returns to NC (Normally Close) if the LOW signal is given or no signal is given at all. In testing the relay sensor the results are as shown in the table 5.

Table 5. Relay testing result

Signal given to relay	Relay Condition	Number of trials	Percentage of success
No Signal	NC	3	100
HIGH	NO	3	100
LOW	NC	3	100

Functional Testing

Testing Results of Automatic AC Temperature Controller

In the code uploaded in this device, Arduino will replace the AC temperature based on the room temperature obtained from the DHT11 sensor. If the room temperature is more than 28°C, the air conditioner will turn on at 18°C until the room temperature reaches 28°C. after that the ac will stabilize the room temperature by changing the AC temperature within a distance of 20-28°C. If the room temperature reaches 19°C, the AC will automatically turn off. This test was carried out in a computer laboratory with a closed room condition but with an uncertain number of laboratory users. The following are the results of testing the AC Automatic Temperature Control Device

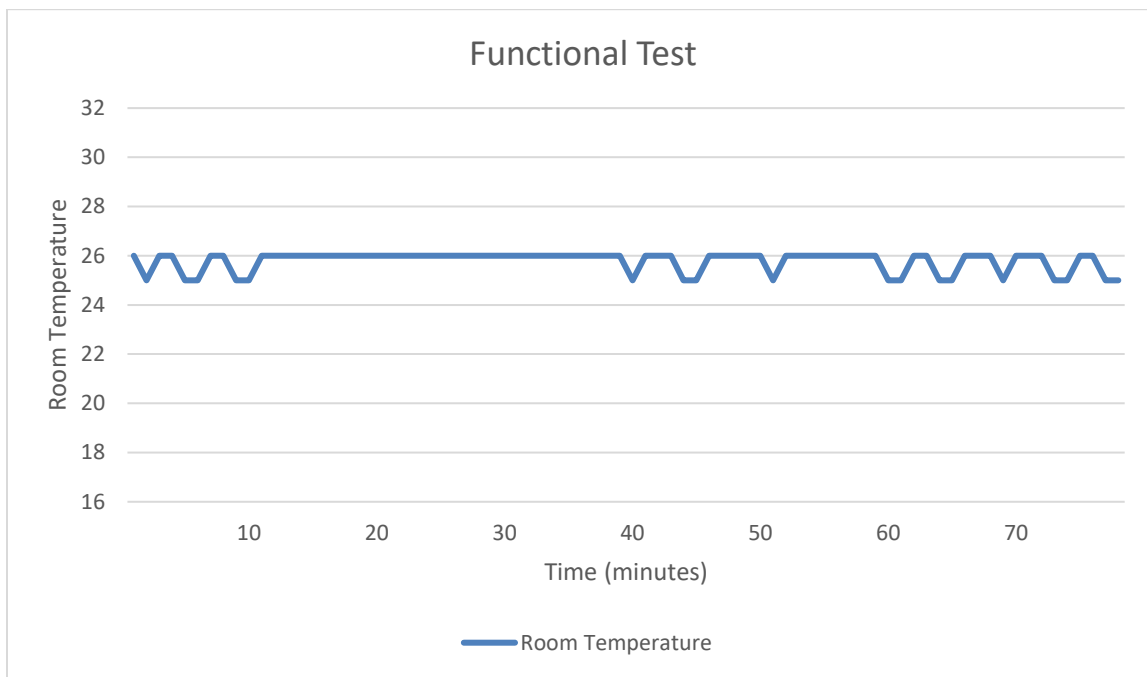


Figure 9. Laboratory room temperature in 120 minutes.

In figure 9, the temperature conditions are stable at 25-26°C with the desired temperature value on Arduino 24°C. The room temperature does not touch at 24C due to the number of laboratory users reaching 22 users and the density of practical activities in the computer laboratory so that the AC has difficulty to cool the room temperature at 24°C.

Testing Results of Automatic LCD projector controller device

Testing on this device is done by installing an Arduino with a fully installed sensor condition and testing it according to the conditions needed so that the LCD projector can turn on and turn off automatically. In the program on Arduino, Arduino will read the status of the microswitch installed in the cooling pan. If the laptop is placed on top of the cooling fan and presses microswitch, Arduino will give a command to the relay to connect the cooling fan to the resource and send live commands to the projector's LCD via the IR Transmitter. Conversely, if the laptop is taken from the cooling fan, Arduino will give a command to the relay to disconnect the relay between the resource and the cooling fan and turn off the LCD projector. The following are the results of testing the Automatic LCD projector controller device.

Table 6. Testing Results

Procedure	Projector Response Delay (s)			Delay Relay (s)			Percentage of success
	First trial	Second trial	Third trial	First trial	Second trial	Third trial	
Put the laptop on the cooling pad				0,168	0.021	0.170	100%
Lift the laptop from the cooling pad				0.305	0.171	0.194	100%

The test results shown in table 6 above show good and appropriate results for the purpose of this device. When the laptop is on the cooling pad, the relay will automatically connect the resources to the cooling pad while Arduino will turn on the projector's LCD via infrared. If the laptop is lifted from the cooling pad, Arduino will send turn off command to the LCD projector and disconnect the relay so that the cooling pad will turn off. The delay response on the projector and relay on average takes less than 1 second.

Conclusion

This research produced a Smart Laboratory support product based on the Arduino Uno microcontroller. The benefits obtained from the realization of the developed system are quite large. This can be seen from the

functional tests that have been carried out, the room temperature becomes more stable at 24-26°C and the LCD projector is turned on and off automatically.

References

- Baraka, K., Ghobril, M., Malek, S., Kanj, R., & Kayssi, A. (2013). Low cost arduino/android-based energy-efficient home automation system with smart task scheduling. *Proceedings - 5th International Conference on Computational Intelligence, Communication Systems, and Networks, CICSyN 2013*, (November 2015), 296–301. <https://doi.org/10.1109/CICSYN.2013.47>
- Oktariawan, I., Martinus, M., & Sugiyanto, S. Pembuatan Sistem Otomasi Dispenser Menggunakan Mikrokontroler Arduino Mega 2560. *Jurnal Ilmiah Teknik Mesin FEMA*, 1(2).
- Giyartono, A., & Kresnha, P. E. (2015). Aplikasi Android pengendali lampu rumah berbasis mikrokontroler ATmega328. *Prosiding Semnastek*.
- Boonsawat, V. (2010). XBee wireless sensor networks for temperature monitoring. *The Second Conference on Application Research and Development (ECTI-CARD 2010), Chon Buri, Thailand*. https://doi.org/http://www2.siiit.tu.ac.th/somsak/pub/final_XBeeWSN_100328.pdf
- Deepali Javale ; Mohd. Mohsin ; Shreerang Nandanwar ; Mayur Shingate. (2013). Home Automation and Security System Using Android ADK. *International Journal of Electronics Communication and Computer Technology*, 3(2), 382–385. Retrieved from [http://www.ijecct.org/v3n2/\(382-385\)0302M22.pdf](http://www.ijecct.org/v3n2/(382-385)0302M22.pdf)
- Haryati, S. (2012). "Research and Development (R&D) sebagai salah satu model penelitian dalam bidang pendidikan." In 37.1 (p. 15).
- Kang, D. H., Park, M. S., Kim, H. S., Kim, D. Y., Kim, S. H., Son, H. J., & Lee, S. G. (2017). Room Temperature Control and Fire Alarm/Suppression IoT Service Using MQTT on AWS. *2017 International Conference on Platform Technology and Service, PlatCon 2017 - Proceedings*. <https://doi.org/10.1109/PlatCon.2017.7883724>
- Kumar, S. (2014). Ubiquitous Smart Home System Using Android Application. *International Journal of Computer Networks & Communications*, 6(1), 33–43. <https://doi.org/10.5121/ijcnc.2014.6103>
- Laili, A. N. (2014). Sistem on-Off Ac (Air Conditioner) Pada Ruang Penyimpan Barang-Barang Berharga Berbasis Mikrokontroler Atmega16 Dengan Monitoring Via Web.
- Nathan, D., & Chima, A. (2015). Design of a Home Automation System Using Arduino. *Clay Barriers for Embankment Dams. Proc. Conference, London, 1989*, 6(6), 73–86.
- Permana, H., & Iswanto, B. (2018). Development of Thermal Radiation Experiments Kit Based on Data Logger for Physics Learning Media Development of Thermal Radiation Experiments Kit Based on Data Logger for Physics Learning Media. <https://doi.org/10.1088/1757-899X/335/1/012080>
- Prihatmoko, D. (2016). Perancangan dan implementasi pengontrol suhu ruangan berbasis mikrokontroler arduino uno. *Simetris*, 7(1), 117–122. Retrieved from <http://jurnal.umk.ac.id/index.php/simet/article/viewFile/495/530>
- Saputro, R. D. (2017). Pengendali proyektor lcd dari jarak jauh dengan wifi dan arduino.