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Smart Device Testing for Energy Management

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Abstract – *Nowadays, the use of electricity has become a basic need, especially with the use and demand for AC (Air Conditioners) which continues to increase. With relatively large power, intense use, AC usage can cause electricity bills to rise drastically, as well as play a role in global warming. In addition, the use of AC so far does not meet needs, its use is not wise, does not pay attention to energy savings, is not managed well, as evidenced by the AC being left on continuously when not in use or when no one is around. Therefore, this research will create a smart device to manage AC usage. In this study using the R & D (Research and Development) method, to produce a product. The product that has been made needs to be tested for its function whether it can operate properly and according to expectations. By testing first, you can get an idea of the reliability and improvements of this tool so that it can be further refined.*

Keywords: *Energy management, Air Conditioner, Human Sensor*

I. Introduction

In Indonesia, the natural resources or primary energy sources used to generate electrical energy are predominantly non-renewable and exhaustible. These include petroleum, coal, and natural gas. In 2019, coal was the largest energy supplier, accounting for 35.9% of the total, followed by petroleum at 33.7% and natural gas at 17.8% [1]. If the use of electrical energy is not managed properly, the supply of primary energy will deplete more rapidly, leading to increased imports and rising prices.

The use of AC (Air Conditioner) from year to year is increasing, even in the last 10 years the increase in AC use has been very significant. In buildings (offices, government, shopping centers, educational facilities, health care facilities, and hotels) the use of electrical energy for air conditioning systems is the most dominant (45-70%) [2]. According to research conducted by Lawrence Berkeley National Laboratory in 2013, the growth rate of AC sales in Indonesia reached 10-15% annually [3]. The latest analysis from the International Energy Agency (IEA) shows that the global demand for AC will triple by 2050 and will become one of the largest contributors to electricity consumption [4]. In addition to significantly impacting energy consumption, air conditioning (AC) also contributes to greenhouse gas (GHG) emissions and ozone depletion. According to the Kyoto Protocol and the Montreal Protocol, the chemical compounds responsible for these issues are hydrofluorocarbons (HFCs) and chlorofluorocarbons (CFCs) [5]. In addition, the current use of air conditioning does not meet our needs. Its implementation lacks wisdom, fails to prioritize energy savings, and is poorly managed. This is evident from the fact that air conditioning units are often left on continuously, even when they are not in use or when no one is present.

Therefore, this study aims to develop a smart device for managing air conditioning (AC) usage. Efficient energy management is crucial not only for reducing operational costs but also for achieving sustainability objectives. Data from the World Resources Institute (WRI) indicates that the energy sector accounts for over 70% of global greenhouse gas emissions [6]. By employing smart devices, both companies and individuals can more effectively monitor and manage their energy consumption,

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thereby helping to reduce carbon emissions.

The importance of efficient energy management is further reinforced by government policies that increasingly promote the adoption of green technology. According to the Ministry of Energy and Mineral Resources (ESDM) of the Republic of Indonesia, the government has established a target to reduce national energy intensity by 1% annually until 2030 [7]. Thus, the integration of smart devices in energy management is both relevant and urgent. These devices provide a range of innovative solutions to enhance energy management.

II. Method

Smart devices that have been designed and built need to determine their effectiveness and efficiency in practical use. The process of designing and testing smart devices is seen in the flow diagram below.

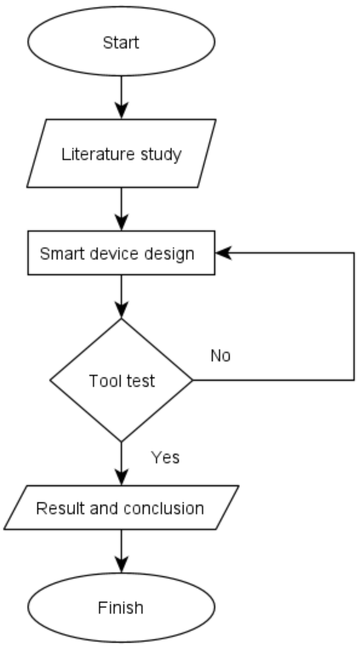
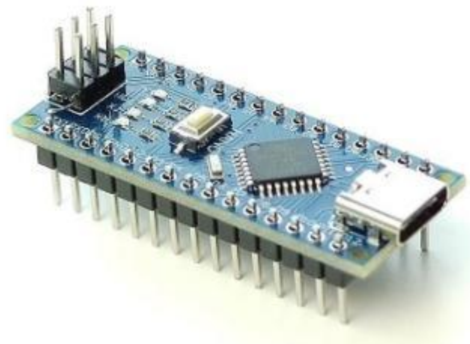


Fig 1. Flowchart

In this study, indoor testing was conducted. The tools and materials used are as follows.

II.1. Arduino nano v3

The Arduino Nano v3 is a popular microcontroller board that was first introduced in 2012 as an upgraded version of the original Arduino Nano [8], [9]. It is based on the ATmega328P microcontroller and offers a compact and versatile size. The compact size of the Arduino Nano v3 will allow for easy integration into small enclosures.



. Fig 2. Arduino Nano v3 ATMega 328p Type-C USB

Arduino Nano v3 ATMega 328p Type-C USB with specifications [8]

- Microcontroller : ATMega328
- Architecture : AVR
- Operating Voltage : 5 V
- Flash Memory 32 KB of which 2 KB used by bootloader
- SRAM : 2 KB
- Clock Speed : 16 MHz
- Analog I/O Pins : 8
- EEPROM : 1 KB
- DC Current per I/O Pins : 40 mA (I/O Pins)
- Digital I/O Pins : 22
- PWM Output : 6
- Power Consumption : 19 mA

The Arduino Nano v3 is equipped with an ATMega 328p microcontroller, offering 32KB of flash memory and 2KB of SRAM, providing plenty of space for coding complex projects. One key aspect that would need to consider is the importance of Type-C USB connectivity in microcontrollers. Its Type-C USB interface allows for easy connectivity and fast data transfer, making it convenient to upload programs and interact with the board. Unlike the traditional USB connectors, Type-C USB offers faster data transfer speeds, higher power delivery, and reversible plug orientation [10], [11]. Additionally, the robustness and durability of Type-C connectors would ensure a reliable connection, reducing the risk of communication errors or system downtime.

Additionally, it has 23 general-purpose I/O pins, six analog input pins, and six pulse-width modulation (PWM) pins, providing ample connectivity options for interfacing with sensors, actuators, and other peripherals. The Arduino Nano v3 features 14 digital input/output pins and 6 analog input pins, giving users plenty of options for

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connecting sensors, actuators, and other electronic components.

II.2. *LED*

The 1602 16x2 LCD display is a commonly used alphanumeric display module consisting of 16 columns and 2 rows of characters. This display is a type of liquid crystal display that allows the display of 32 characters at a time. This allows for easy and clear communication of information to the user.

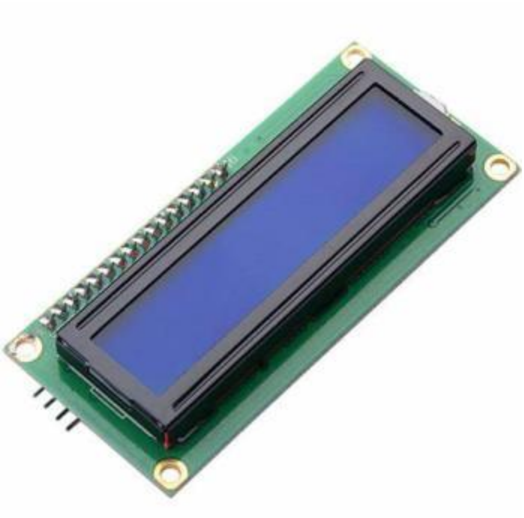

Fig 3. LCD Display 1602 16x2 Blue Blacklight Character White Writing.

LCD Display 1602 16x2 Blue Blacklight Character White Writing memiliki spesifikasi [12]

- Operating voltage: 5V DC
- Module dimensions: 80 x 36 x 12 mm
- Display screen dimensions: 64,5 mm x 16 mm

The LCD display 1602 16x2 is known for its low power consumption and high contrast ratio, making it ideal for use in outdoor or high brightness environments. Its ability to display text, numbers, and symbols on a single screen adds to its convenience and efficiency in conveying information to users.

II.3. *Radar Sensor*

This smart device utilizes a radar sensor to detect the movement of humans or objects. The RCWL-0516 is a microwave radar motion sensor that uses the Doppler effect to detect movement. Unlike PIR sensors, which rely on heat signatures, the RCWL-0516 can detect motion from any object, making it more reliable in hot environments. This sensor module operates at a frequency of 5.8 GHz. It is equipped with a built-in amplifier and automatic gain control to ensure accurate and reliable detection of motion.

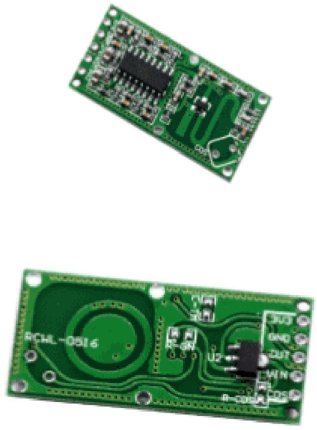

Fig 4. Sensor radar RCWL-0516

Data sheet sensor radar RCWL-0515 [13]

- Operating Voltage: 4-28V
- Operating Current: 2.8mA (typical), 3mA (max)
- Detection Distance: 5-9 meters
- Transmitting Power: 20mW (typical), 30mW (max)
- Output Voltage: 3.2-3.4V
- Output Voltage Driving Capacity: 100mA
- Operating Temperature: -20 to 80°C
- Storage Temperature: -40 to 100°C
- Dimensions: 36 x 18 mm
- Weight: 2 grams

Pinout

- 3V3: Regulated 3.3V output
- GND: Ground reference
- OUT: Trigger output (high at 3.3V if motion detected, 0V normally)
- VIN: Voltage input
- CDS: Light sensor related (optional)

Features

- Utilizes microwave radar technology for motion detection
- Adjustable sensitivity and delay time
- Non-contact detection
- Suitable for various applications like intrusion detection and automation

The ability to detect motion and track objects in real-time is essential for efficiency in many applications. The RCWL-0516, in particular, has gained popularity for its compact size and low power consumption, making it ideal for use in consumer electronics.

II.4. *Relay*

The relay utilized is a 5V 1 Channel Output Relay 250VAC 30VDC 10A Module

Fig 5. Relay 5V 1 Channel Output 250VAC 30VDC 10A Module

This relay operates at 5 V, and the maximum relay output is AC 250 V. 10A dan DC 30V 10A. A 5V 1-channel relay module is suitable for controlling a single device or circuit with a maximum current of 10A and a maximum contact voltage of 250V AC and 30V DC. It is designed to control high voltage and current loads and is easy to interface with microcontrollers like PIC and Arduino [14]. The relay is installed on the phase line connected to the alternating current (AC) and functions to automatically turn the AC off and on again.

The design of a smart device, which includes several components such as the Arduino Nano V3, an LCD, a radar sensor, and a relay, along with connecting cables, is illustrated in Figure 7 below.

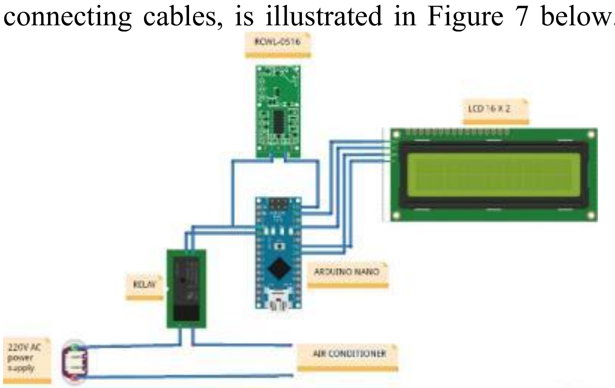

Fig 6. Design of Smart Device

The smart device is installed in an electromedical laboratory that measures 7.8 meters in length and 4.35 meters in width, as seen in figure 7.

Fig 7. Smart device connected to AC

III. Result and Discussion

The results and analysis present data in the form of images, graphs, numbers, and other formats, which reflect the outcomes of the experiments conducted, along with their corresponding analyses. Below is a display from a smart device that indicates that when there is no movement, the air conditioning unit activates.

Fig. 8. LED display when there is no movement AC becomes ON

When the radar sensor detects no movement, the AC turns off.

Fig 9. LCD display no movement AC becomes off

The radar sensor detects no movement, from AC on to AC off there is a time gap of several seconds (according to the setting), in the picture there is a time gap of 3 seconds (can be adjusted according to needs).

Fig 10. LED display delay time

After the specified time delay is over, the AC turns back on.

Fig 11. LED display when movement is detected by the radar sensor, prompting the air conditioning unit to turn on immediately

Smart device testing is carried out with four angle variations, namely 90°, 70°, 45°, and 20°. From each angle, the radar sensor can detect how far it is tested. The first table of tests features a 90° angle.

TABLE I
RADAR SENSOR TESTING WITH 90° ANGLE

Distance	Sensor detection capability
1 meter	Detect
2 meter	Detect
3 meter	Detect
4 meter	Detect
5 meter	Detect
5,7 meter	Detect
6 meter	Not detecting

The sensitivity of the radar sensor is tested across various distances, perpendicular to the tool (90°). It can detect movement from a distance of 1 meter up to 5.7 meters. However, beyond 5.7 meters, the radar sensor is unable to detect movement.

The second test was conducted at angles of 70°, 45° and 20° as shown in tables 2, 3, and 4.

TABLE I
RADAR SENSOR TESTING WITH 70° ANGLE

Distance	Sensor detection capability
1 meter	Detect
2 meter	Detect
3 meter	Detect
4 meter	Detect
5 meter	Detect
5,7 meter	Detect
6 meter	Not detecting

TABLE III
RADAR SENSOR TESTING WITH 45° ANGLE

Distance	Sensor detection capability
1 meter	Detect
2 meter	Detect
2,25 meter	Detect
3 meter	Not detecting

TABLE IV
RADAR SENSOR TESTING WITH 20° ANGLE

Distance	Sensor detection capability
1 meter	Detect
1,2 meter	Detect
2meter	Not detecting

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At an angle of 70 degrees, the sensor's sensitivity level is equivalent to that at an angle of 90 degrees. However, at an angle of 45 degrees, the sensor's sensitivity distance is diminished compared to both 90 and 70 degrees, allowing detection up to only 2.25 meters from the device. When the angle is further reduced to 20 degrees, the sensor's sensitivity decreases even more, detecting only up to 1.2 meters.

Energy management efforts are also carried out by other researchers, such as those carried out by [15] by conserving energy in the cooling system, namely by turning off the AC if the room is not in use. [16] Carried out energy savings in the lighting system by replacing the type of TL lamp with energy-saving lamps. Socialization, counseling, education, and providing understanding to the community were also carried out by [17], [18], [19], in behaving energy-saving, regulating, and managing energy.

In an effort to reduce waste, a system was created that can control electricity usage remotely via the web and a system that can monitor electricity consumption data in real time and display it in graphs and calculate the amount of electricity rates spent each month[20]. The development of technology (IoT) can also support energy management [21].

IV. Conclusion

From this study it can be concluded that smart devices can be applied to air conditioning (AC) systems. If no movement is detected, the AC will turn off. The delay time from when no movement is detected until the AC turns off can be set according to needs. If movement is detected again, the AC will immediately turn back on. Radar sensors are able to detect the movement of objects or humans. The range of the radar sensor will decrease as the angle decreases.

Acknowledgements

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