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Bluetooth Based Home Control and Real-Time Energy Consumption Monitoring System through Smartphone

Yusnita Rahayu*
Department of Electrical Engineering, Faculty of Engineering, Universitas Riau, Indonesia

Muhammad Ibnu Hidayat
Department of Electrical Engineering, Faculty of Engineering, Universitas Riau, Indonesia

**corresponding author: Yusnita Rahayu, yusnita.rahayu@lecturer.unri.ac.id*

***Abstract*— Energy consumption is one of the most important, for it is necessary to control the use of home lighting as needed. Monitoring is important, in order to know the quality of electricity supply in the system, identifying disruption events, and to calculate the amount of electrical energy consumption periodically. To achieve the objectives mentioned above, two schemes for home control and monitoring the electrical quantities in real-time have been developed. The first scheme presents Bluetooth based home control. It uses an HC-05 Bluetooth module and Bluetooth Controller mobile application for switching on / off the appliances. Relay and LEDs are used as loads to demonstrate the working of the system. This system is based on Arduino Uno microcontroller board. Arduino Integrated Development Environment (IDE) is used for developing the necessary software. The second scheme uses the current sensor ACS712-20A for monitoring of voltage, current, and energy consumption. The measurement results include voltage, current, power, and the amount of energy consumption that is displayed by LCD 16*2.**

Keywords— ***Bluetooth, Smart Home, Monitoring System, Energy Consumption***

I. INTRODUCTION

Internet of Things (IoTs) can be described as connecting everyday objects like smartphones, internet televisions, sensors, and actuators to the internet where the devices are intelligently linked together to enable new forms of communication amongst people and themselves. The significant advancement of IoTs over the last couple of years has created a new dimension to the world of information and communication technologies. The advancement is leading to anyone, anytime, anywhere (AAA) connectivity for things with the expectation being that this extends and creates an entirely advanced dynamic network of IoTs. The IoTs technology can be used for creating new concepts and wide development space for home automation in order to provide intelligence, comfort and improved quality of life [1]. Home automation refers to the application of computer and information technology for control of home appliances and domestic features [2]. Mobile devices are ideal in providing a user interface in a home automation system due to their portability a wide range of capabilities.

Energy consumption should be monitored periodically in order to determine and calculate the total cost-utility bill monthly or even daily and yearly, thus energy efficiency is produced. The stability of voltage and current are very important to measure because they affect the performance and service life of the load and equipment used.

In [3], a system that monitors the voltage, current, power, and energy consumption has been presented. It presented that recording data during the monitoring process and remotely access through mobile application facilities was more effective and efficient. In this paper, a prototype Smart Home Control and Monitoring system is developed by using the Arduino Uno platform that works with the help of Bluetooth and current sensors ACS712-20A. Furthermore, power is calculated based on information obtained (voltage and current).

II. RELATED WORKS

In this section, we briefly discuss the existing smart home systems and applications. Gill et al [4] ZigBee based home automation system, which controls and monitors home appliances. The proposed system is composed of a home network device and a home gateway. As an essential part of the system, the home gateway supports interoperability between the external networks and home networks. Baoan et al [5] presented the design of a smart home system based on the Internet of Things (IoT). An approach based on SOA and component technology which can help to realize every changing dynamic semantic integration of the web services. Han et al [6] proposed a home energy management system (HEMS) using a ZigBee technology to reduce the standby power. The proposed system is composed of an automatic standby power cut-off outlet, a ZigBee hub, and a management server. Lei Li et al [7] presented a new method of direct current detection based on the hall sensor of ACS712, implemented protection inactive way on the humanoid robot DC controller to overcome the shortcomings of fuse

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protection only in the passive way and long response time. Temy et al [8] presented design the device to monitor the consumption of electric energy utilizing step-down transformer to measure Voltage source of PLN, while to measure the load current utilizing the current sensor ACS712 and microcontroller ATmega 328 artificial of ATMEL, functioned to process all the data of the parameters needed to obtain the value of electrical energy consumption), and displays it on the LCD character 20x4 to provide information to the user of electricity. Mario et al [9] proposed a novel energy management approach for smart homes that combines a wireless network, based on Bluetooth Low Energy (BLE), for communication among home appliances, with a Home Energy Management (HEM) scheme.

Bluetooth has implemented using an android mobile with Bluetooth controller application. With Bluetooth potentiality, you can use the android application using Bluetooth designed like an eclipse. This scheme provides an easy method of controlling the appliances with the range a few meters, but it cannot be used over a longer distance.

Compared to the existing related research, in this paper, we focus on Bluetooth than Zigbee for wireless data transmission because it is more easily configured, lower cost, and the most smartphone has been widely adopted a technologically Bluetooth. This paper proposed two schemes for home automation control and monitoring. The first scheme presents a Bluetooth based home control and the second scheme uses the current sensor ACS712-20A for monitoring of voltage, current, and energy consumption.

III. Research Methodology

A. System Block Diagram

Android-based mobile phones are available with a large number of people around the world. Home automation is one of the major applications of Bluetooth technology [10]. Bluetooth operates over the unlicensed, globally available frequency of 2.4 GHz. It links digital devices within the range of about 13 m. In this paper, the Bluetooth based Smart Home design is presented. This system is used to control home appliances without going to the switchboard when the users are at home. This prototype is also purposed for monitoring voltage, current, and energy consumption.

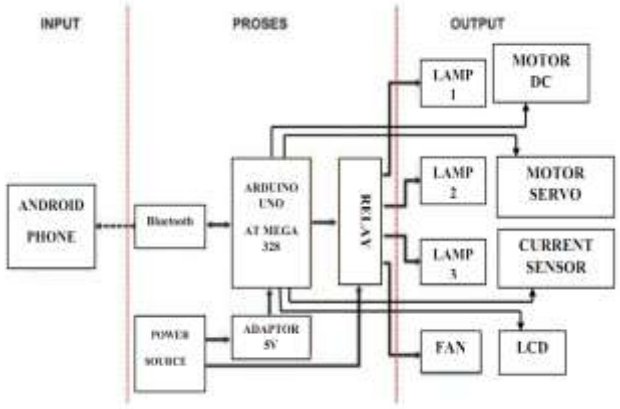

Figure 1: Diagram Block of Smart Home

The block diagram of Smart Home is shown in figure 1. It consists of HC-05 Bluetooth module and Arduino Uno board with an ATmega328P microcontroller. The Bluetooth is controlled by an android mobile having Bluetooth controller application installed. This system does not require an internet connection. There are six buttons for control on/off the appliances in a prototype Smart Home. The current sensor ACS712-20A is connected to the electrical load. The current sensor reading is sent to the ADC and Arduino Uno. Furthermore, Arduino Uno keeps the results of monitoring include voltage, current, power, and the amount of energy consumption and displays it to the LCD 16*2. Hall sensor ACS712-20A has higher detection accuracy, better linearity supplied by 5V DC. The output voltage is 4.5V when the current being detected is 20 A, there needs less circuit for data processing.

B. Interfacing Arduino Uno Board with Bluetooth Module

The HC-05 Bluetooth module has 6 pin. Vcc, GND, transmit (Tx), receive (Rx), Key, and State. It is preprogrammed to work in slave mode. So there is no need to connect the Key pin. The connection of the Bluetooth module with Arduino board is shown in Figure 2, Vcc pin of Bluetooth module is connected to 5V pin of Arduino. TX and Rx pins of Bluetooth module are connected to Rx and Tx pins of Arduino. GND pin of both the modules is shorted.

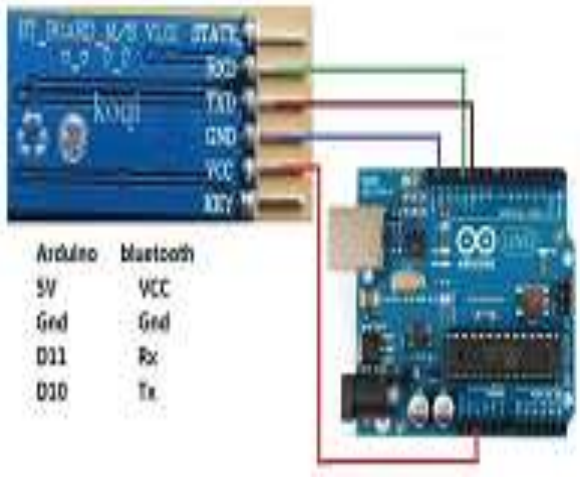

Figure 2: Interfacing of Bluetooth Module with Arduino

Interfacing of Arduino Uno Board with Current Sensor ACS712-20A

The Allegro ACS712 consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field that is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. The internal resistance of this conductive path is 1.2 mΩ typical. The ACS712 is provided in a small, surface mount SOIC8 package. 5µs output of rising time in response to step input current, total output error only 1.5% at 25°C, ACS712 typical circuit shown in Figure 3.

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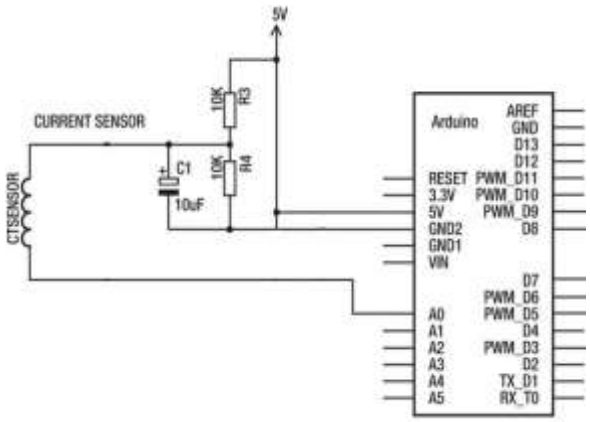

Figure 3: The Typical Application of ACS712

In this system, the design software can be divided into two parts, namely the design of software in the module main controller (Microcontroller Board Arduino Uno) and the design of controller software on the android smartphone as an interface for users employ the Eclipse Juno.

C. Software Design on the Arduino

The first step is to determine the logic applied to home appliances (lights, fans, gates, doors), which will be controlled, then implement the algorithm using the Arduino IDE. The flowchart is shown in Figure 4.

D. Software Design on Android Smartphone

Design GUI software on the android smartphone in this system is a form of displaying the programs that appear on the screen, intending to provide an overview of the application to be built. Software Eclipse Juno is used in this design. Figure 5 shows the designed GUI on Android smartphones.

E. Program Design

The Programming IDE includes:

- Reading of the measurement sensor
- The calculation to obtain the desired quantity
- Record the results of measurements displays in LCD

Figure 6 output of the system is the value of voltage, current, power, and energy consumption, can be explained as follows:

- The rated voltage obtained from the voltage sensor readings.
- The current value obtained from the current sensor readings ACS712-20A.
- Energy consumption value obtained from kWh meter digital readings.
- Value kWh is the product of power by time, so if the value of kWh has known the amount of the power.

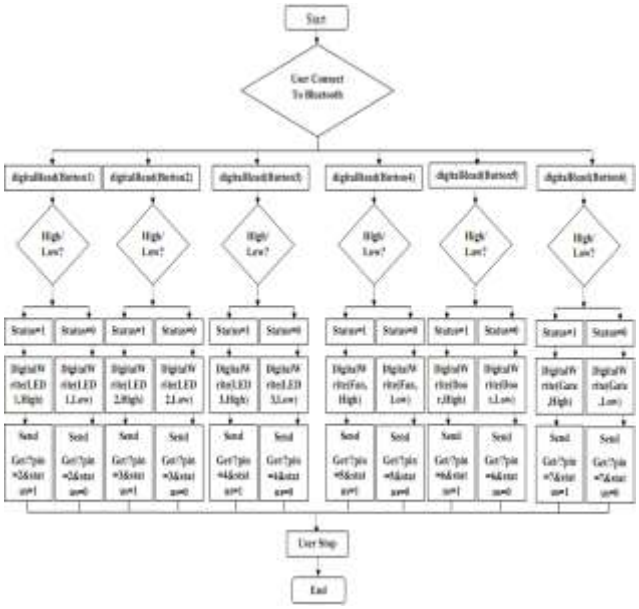

Figure 4: Flowchart of Process Up-loading Code Program

Figure 5: GUI on Android Smartphone

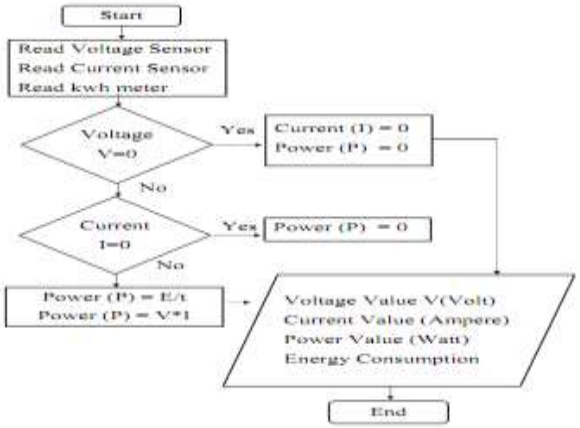

Figure 6: Flow Chart Program

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IV. IMPLEMENTATION

Figure 7 shows a prototype of Smart Home Control and Monitoring. The main microcontroller is Arduino Uno R3. It is used for performing the main tasks such as complex event processing. A Bluetooth Module is used for communication with other Arduino Uno.

Figure 7: Prototype Smart Home

We used a 250 kbps/2.4 GHz Bluetooth Module. The metering circuit plays a role in the measurement of the power consumption and observation of the power state. The power group is composed of a Switched-mode power supply (SMPS). The LCD display unit shows a variety of information such as power, voltage, and current as well as temperature and humidity. The relay is used for shutting off the standby power and also used for remote control.

V. EXPERIMENT AND RESULTS

A. *Testing the system*

The test system is intended to test all elements of hardware and software made in conformity with the expected. Figure 8 shows the experimental setup of the Bluetooth based. It consists of the Arduino board connected to the Bluetooth module.

Figure 8: Experimental setup of Bluetooth

Bluetooth controller application is used to control the home appliances (lamp, fan, door, gate). In this design, six buttons are used to switch ON or OFF the home appliances. When the button 'LAMP1 ON' is pressed, the Bluetooth module sends the code 'a' to the Arduino board, which in turn switches ON LAMP1. Similarly, LAMP1 OFF, LAMP2 ON, LAMP2 OFF, LAMP3 ON, LAMP3 OFF, FAN ON, FAN OFF, DOOR OPEN, DOOR CLOSE, GATE OPEN, GATE CLOSE are used to switch ON or OFF the home appliances.

B. *Testing Bluetooth Module*

To activate the Bluetooth module, a voltage of 3.3 V is required. The results of testing the Bluetooth module are shown in Table 1. When the Bluetooth module is scanned using an android phone Bluetooth module detected result with the name of HC-05. With no obstacles, a Bluetooth module is detected at distances up to 13 meters away, and with no barrier (walls of the house) Bluetooth module is detected at distances up to 10 meters. These test results indicate Bluetooth module is functioning properly.

Table 1: Data Results Bluetooth Module

No	Distance of range	Delay	With barrier	Without barrier
1	1 Meter	0.1 s	ON	ON
2	2 Meter	0.1 s	ON	ON
3	3 Meter	0.1 s	ON	ON
4	4 Meter	0.1 s	ON	ON
5	5 Meter	0.1 s	ON	ON
6	6 Meter	0.1 s	ON	ON
7	7 Meter	0.1 s	ON	ON
8	8 Meter	0.1 s	ON	ON
9	9 Meter	0.1 s	ON	ON
10	10 Meter	0.1 s	ON	ON
11	11 Meter	0.1 s	OFF	ON
12	12 Meter	0.1 s	OFF	ON
13	13 Meter		OFF	OFF

C. *Testing Current Sensor Network*

To get fairly good calibration, and to test the flow sensor output current testing was performed using a multimeter Krisbow KW06-276 then compared it with the results of measurements using the minimum system microcontroller and sensor ACS712 on tools, testing methods in the load current using a multimeter. Burden used is incandescent lamps. Tested is a current sensor but the voltage is also used in a calculation, whereas the value of voltage based on PLN source. The results of this testing are shown in Table 2.

Based on the data of voltage, current, and power measurement indicates that the results of measurements using sensors have a small scale difference results if compared with the results of measurement using an analog measuring device and digital measuring devices, so that the sensors are made fairly used for monitoring system of electrical quantities on the LCD as shown in Figure 9.

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Table 2: Data Results Current Sensor

No	Load	Volt (V)	I(A)	P(W)	P(W) Calculated	Error (%)
1	No load	220	0	0	0	-
2	1 Lamp 20 W	220	0.08	17.6	20	12
3	1 Lamp 20 W	220	0.08	18	20	11.11
4	1 Lamp 9 W	220	0.04	8.8	9	2.2
5	Lamp R1, R2,R3	220	0.2	44	49	10.2

Figure 9: Display LCD 16*2

VI. Conclusion

This paper presents control and monitoring energy consumption based on Arduino Uno. The Bluetooth based can be used for controlling the home appliances when we are at home. Bluetooth based is implemented using an android mobile. This scheme provides an easy method of controlling home appliances, but as the range of Bluetooth is limited to a few meters, it cannot be used over longer distances. This prototype also can be monitoring of voltage, current, and energy consumption with current sensor ACS712-20A whereas ACS712-20A has higher detection accuracy, better linearity, less impacted by temperature, supplied by 5V DC, the output voltage is 4.5V when the current being detected is 20A, there needs less circuit for data processing. From the testing of the current sensor, it has been functioning properly, with a percentage of average error of 8.8775 %.

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