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Design and Construction of an IoT-based Body Mass Index (BMI) Measuring Tool Using an Android Application

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ABSTRACT

Body Mass Index (BMI) is a measure of a person's fitness level monitoring obtained from a comparison between weight and height using a separate measuring instrument and requires the energy of other people in the measurement process, namely using a manual meter and scales. Therefore, a height and weight measuring instrument is needed that is integrated into a BMI measuring instrument to determine body health which is categorized into 5, namely, very thin, thin, normal, fat, and obese. The purpose of making this final project is to design the tool, find out the function test, and find out the performance test of the tool. The research stage consists of needs analysis, design, manufacture, and testing of the measuring instrument. The results of this study are that an IoT-based BMI measuring instrument using an android application was successfully created. The results of the function test show that each component is in good condition. While the results of the tool performance test are the same as the application showing that height measurements by ultrasonic sensors and weight measurements by load cell sensors from measurements of 15 people have a good error rate with an average of below 5%, namely 0.64% and 1.50% respectively against manual measurements using standard measuring instruments.

Indeks Massa Tubuh (IMT) merupakan ukuran pemantauan tingkat kebugaran seseorang yang didapatkan dari perbandingan antara berat dan tinggi badan menggunakan alat ukur terpisah dan memerlukan tenaga orang lain dalam proses pengukurannya yaitu menggunakan meter manual dan timbangan. Oleh karena itu diperlukannya alat pengukur tinggi dan berat yang terintegrasi menjadi alat pengukur IMT untuk mengetahui kesehatan tubuh yang dikategorikan menjadi 5 yaitu, sangat kurus, kurus, normal, gemuk, dan obesitas. Tujuan pembuatan proyek akhir ini adalah membuat rancang bangun alat, mengetahui uji fungsi, dan mengetahui uji kinerja alat. Tahap penelitian terdiri dari analisis kebutuhan, perancangan, pembuatan, dan pengujian alat ukur. Hasil dari penelitian ini adalah alat pengukur IMT berbasis IoT menggunakan aplikasi android berhasil dibuat. Hasil uji fungsi menunjukkan bahwa setiap komponen dalam kondisi baik. Sedangkan hasil uji kinerja alat sama dengan aplikasi menunjukkan bahwa pengukuran tinggi oleh sensor ultrasonik dan pengukuran berat oleh sensor load cell dari pengukuran 15 orang memiliki tingkat error yang baik dengan rata-rata di bawah 5% masing-masing yaitu 0,64% dan 1,50% terhadap pengukuran manual menggunakan alat ukur standar.

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1. Introduction

Measurement is a field of science that involves the process of collecting data or information objectively. One of the pieces of information obtained in the measurement process is in the form of meters (m) for distance and kilograms (Kg) for mass. Every individual needs to meet the need for monitoring their health in the challenge of managing fitness. Therefore, measurements are taken of the comparison of height and weight to determine the BMI value. BMI is a measure used to monitor a person's fitness status which is obtained from the comparison of weight and height [1].

The tools that are often used to measure a person's height and weight are manual meters and scales. The measurement process is carried out with separate measuring instruments and requires other human labor in the measurement process. Because the measurement data is carried out manually and has not been integrated between tools, the process takes a long time to find out the BMI value. This method is not yet effective and efficient because it has not utilized technology that can combine the two measuring instruments. The use of technological assistance that makes it easier for humans, one of which is innovating tools for measuring height and weight into measuring tools for height, weight, and BMI that can work automatically [2].

In previous research conducted by Hidayat and Fajrianti in 2020 created a BMI measuring tool (categories underweight, ideal, overweight, fat, and very fat) using Arduino R3 and the measurement results were displayed on a Bluetooth-based android and GoogleSheet. Research by Fadil and Thamrin in 2020 created a BMI measuring tool (categories thin, ideal, fat, obesity for men and women) using Arduino UNO R3 with measurement results displayed on a 20x4 LCD, computer, and GoogleSheet. Research by Krisnadi and Ridwanto in 2021 created a BMI measuring tool (categories thin, normal, fat, and obesity) using ESP8266 with measurement results displayed on a 16x2 LCD and android. Meanwhile, research by Putra *et al*. in 2023 created a BMI measuring tool (categories thin and severe, normal, and obese and mild and severe) using ESP8266 with measurement results displayed on a 16x2 LCD and GoogleSheet.

Based on references to previous studies, there has not been a BMI measuring tool created with the categorization of very thin, thin, normal, fat, and obesity according to Balanced Nutrition Guidelines, in monitoring body health according to the current BMI categorization in Indonesia. In addition, there has also not been an application created that can store the results of measuring height, weight, BMI, and BMI categories that can be monitored periodically.

Here, we use the NodeMCU ESP8266 microcontroller to process data from the HC-SR04 ultrasonic sensor as a distance meter and a load cell sensor along with the HX711 amplifier module as a mass meter. The measurement results are displayed on a 20x4 LCD and an Android application. In the Android application, monitoring can be carried out in real time or periodically on the storage of measurement results. The measurement results displayed are height, weight, BMI value, and BMI category (very thin, thin, normal, fat, and obese) which are indicated by the LED lights. Red LED (very thin and obese), yellow LED (thin and fat), and green LED (normal). The tool will be designed in such a way by combining several components along with the development of IoT-based applications. Application development is designed using Firebase and the application is made using Thunkable which is a web application creation platform. With this tool, it is hoped that the process of measuring a person's height and weight and body mass index will be more effective and efficient and obtain accurate results.

2. Methods

2.1 Measurements

Measuring instruments are tools used to carry out the process of checking the size of an object. The use of measuring instruments in each measurement is determined by various functions, measurement limits and the accuracy of the measuring instrument. For example, to measure the length of an object that is estimated to have a length of 50 meters, the measuring instrument used is a meter with a minimum measurement limit equal to the length of the object being measured. Measurements using the measuring instrument must be carried out carefully to obtain accurate values [3]. The practical value in the design and development of a system needs to go through an operation process and testing of usability. The measurements required in the design of the BMI measuring instrument are measurements with standard length and standard mass. In the design of the BMI measuring instrument, the type of measurement carried out is direct linear measurement. The direct linear measurement method is a measurement using a measuring instrument whose measurement results can be read directly on a measuring scale that has been calibrated on the standard measuring instrument. The direct measuring instruments used in BMI measurements are meters to measure height and scales to measure weight [4].

2.2 Body Mass Index

Body Mass Index (BMI) is a measure of a person's fitness level monitoring obtained from the comparison between body weight and height. BMI is one indicator of whether a person has a weight that is appropriate for their height or not [5]. A person's health risk can increase significantly if the BMI value is outside the normal limit. Body mass measurement is basic information related to a person's body condition, which is used for medical diagnosis and activities that involve physical activity. Therefore, it is important to know the body mass index in order to determine the level of health [8].

The calculation of the BMI value is body weight in kilograms (Kg) divided by the square of the height in meters (m^2). The use of this formula can only be applied to someone aged 18 to 70 years, with a normal back structure, not an athlete or bodybuilder, and not a pregnant or breastfeeding mother [6]. According to Indonesian Ministry of Health, BMI can be calculated using the Eq. (1).

$$\text{BMI (Kg/ m}^2\text{)} = \frac{weight\ (Kg)}{height^2\ (m^2)} \tag{1}$$

Each person's BMI values and categories are different by not measuring body fat directly and also not taking into account age, gender, ethnicity, or muscle mass in adults. However, BMI uses a standard weight status that can help doctors track weight status across populations and identify potential problems in individuals [5]. The threshold for measuring BMI values is modified based on clinical experience and research results in several developing countries. The following is the current BMI categorization in Indonesia.

Table 1. Category of BMI

Category	BMI
Very thin	<17,0
Thin	17,0 - <18,5
Normal	18,5 – 25,0
Overweight	>25,0 – 27,0
Obese	>27,0

People who are included in the category of very thin and thin or or severely underweight need attention to increase their weight. Weight gain is done by providing sufficient nutrition in the body accompanied by exercise activities. A person must apply a healthy lifestyle in order to achieve a BMI level in the normal or ideal category. While someone with a BMI value in the overweight to obese category needs to be careful not to experience continuous weight gain. Therefore, it is advisable to immediately lose weight within the normal range [1].

2.3 Monitoring System

Monitoring is a process of collecting data and monitoring to determine the condition of an object. The measurement results monitored in the final project created are height, weight, BMI, and BMI category. Monitoring measurement results is one of the important things to do because it is to monitor body health in the challenge of managing fitness. In the Final Project created, the monitoring

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carried out is the measurement results by providing a report on the measurement results of an object in real time which can be monitored on the LCD screen or application and periodically on the application storage. Storage in the application is integrated with storage on Firebase, so if the storage of measurement results in the application is deleted, it will automatically be deleted on Firebase.

2.4 Internet of Things

Technology in the world today is developing rapidly with various innovations applied in everyday human life, for example smart homes, smart cars, automation machines, and so on. This is related to the important role of the internet as a medium for connecting devices through wireless data transmission. Advanced technology that can connect devices wirelessly is IoT. IoT is an advanced technology that aims to expand the benefits of internet connectivity by connecting all devices online. With an internet connection, connected devices can be accessed and operated with a remote-control system that makes it easy for users to control at quite distant locations via mobile devices. The advantages of IoT technology that provide ease and speed of sharing information can be a problem if the data is not protected. However, this is difficult to overcome because of the different varieties and production. Basically, the IoT architectural structure consists of three layers, namely the perception layer in the form of sensors, the network layer in the form of Wi-Fi and Firebase cloud computing, and the application layer in the form of creating applications using the Thunkable web application.

3. Designs

The process of designing the BMI measuring device consists of several stages consisting of needs analysis, design, manufacture, and testing. The following is a flow diagram of the tool manufacturing process.

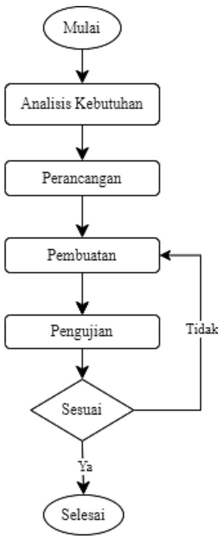

Fig. 1. Research flow diagram

Needs analysis is a stage that is a stage of analysis regarding the urgency of making a design for a BMI measuring device. This needs analysis stage is by conducting field observations and also literature studies. Field observations were conducted at one of the health centers in Semarang using a height measuring instrument using a manual meter and a mass measuring instrument using a scale which was carried out using a separate measuring instrument. While the literature study was conducted to find solutions to these problems based on various literature. The literature obtained was in the form of articles obtained from various journals.

3.1 Flowchart

The following is a flow diagram of the IoT-based BMI measuring system using an Android

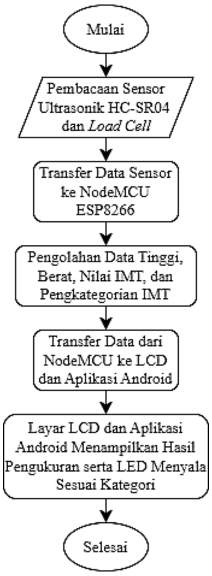

Fig. 2. Flowchart

Fig. 2 above is a system flow diagram of the IoT-based BMI measuring device design using an android application. The HC-SR04 ultrasonic sensor and load cell sensor perform the process of reading the height and weight of a person taking the measurement. The readings from the very small load cell sensor are converted using the HX711 module. Data from the readings of the two sensors will be transferred to the NodeMCU via cable, so that the data is stored in the NodeMCU ESP8266 program. The height and weight data of a person that is entered will be processed into height, weight, BMI and BMI category values. The processed data is sent to the LCD on the installed device hardware and to the programmed android application. The data is then displayed on the LCD screen and application in the form of height, weight, BMI and BMI category data. Delivery to the application may be delayed due to the complexity of the internet network and communication protocols used as well as the overhead of the process on the Firebase server. The categorization of BMI values is also displayed in the form of LED lights. The android application is programmed with a measurement result storage feature so that users can monitor the measurement results periodically

3.2 Hardware Setup

The hardware manufacturing process consists of two parts, namely electrical design and mechanical design. Electrical design includes the creation of electrical wiring diagrams, while mechanical design includes the creation of physical designs of tools and mechanical components of the tools to be made. The following are the results of hardware design.

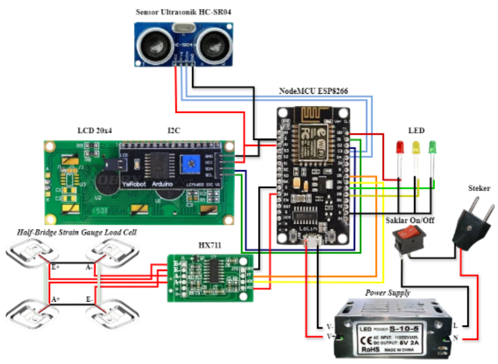

Fig. 3. Wiring Diagram of electronics components

Fig. 3 above is a wiring diagram of the IMT measuring instrument to be made. In the circuit there are several components used including the HC-SR04 ultrasonic sensor, 4 50kg load cell sensors

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installed in parallel, the HX711 module, NodeMCU ESP8266, 20x4 LCD, and I2C to facilitate the LDC connection to the microcontroller.

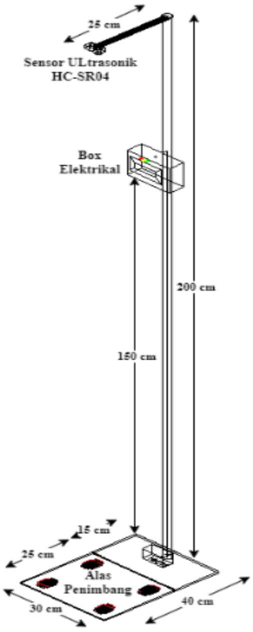
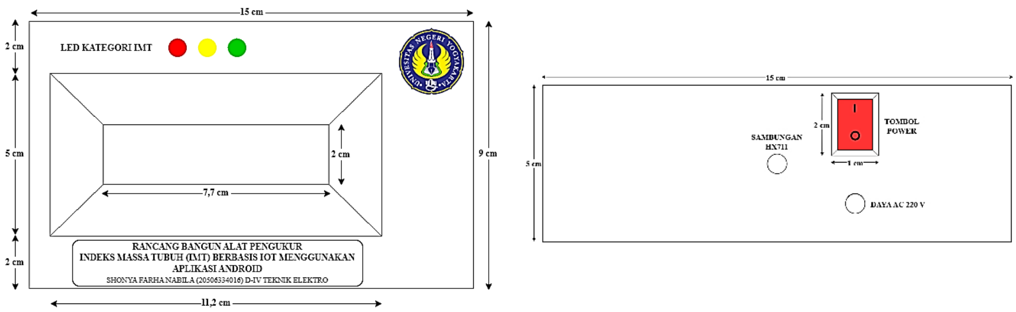


Fig. 4. Hardware design

Fig. 4 is the frame of the IMT measuring device with the height or distance of the HC-SR04 ultrasonic sensor with a weighing surface of 200 cm. While the distance or height of the LCD screen is 150 cm from the surface of the weighing platform. The size of the weighing board is 40x30cm.



Front Bottom

Fig. 5. Box design

Fig. 5 is a bottom view of the electrical box which contains a switch to turn the device on and off as well as a cable connection hole to the HX711 module and a plug connection cable to connect to a 220V AC power source.

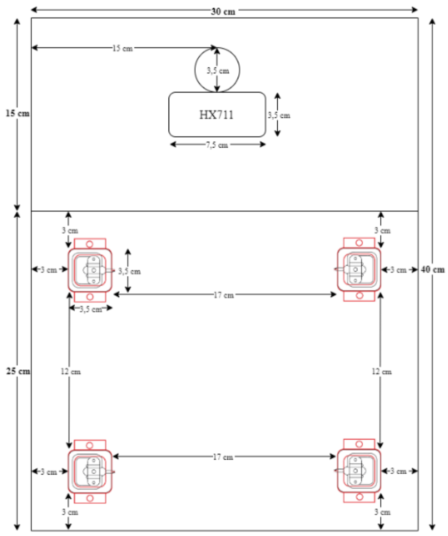


Fig. 6. Design of measurement device

Fig. 6 is a display of the placement of the load cell and HX711 module on the weighing base. Placing the load cell sensor on the board is important to ensure the accuracy and stability of the weight measurement. Some things to consider in placing the load cell include the central position according to the point where the load is most often applied so that the load distribution is even, the surface where the load cell is placed is flat and hard, and ensuring that the cable from the load cell is not pinched when the load is applied.

3.3 Software

This stage is carried out to find out the process of creating software design for an IoT-based BMI measuring system using an Android application. This software design is carried out in three stages, namely the stage of creating a program or coding in the Arduino IDE application, creating a Firebase link, and creating an application on the Thunkable web platform.

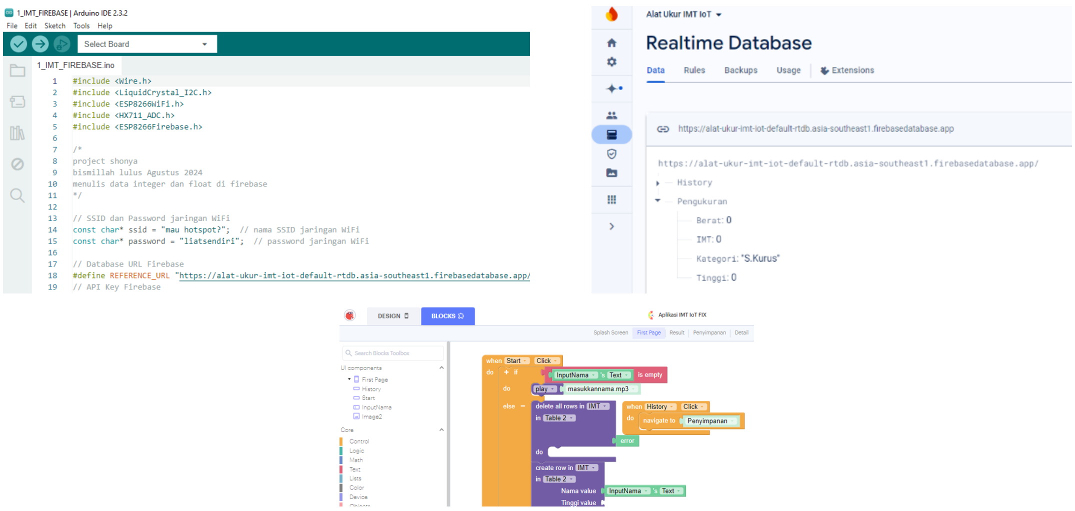


Fig. 7. Arduino IDE and Firebase

4. Results and Discussion

4.1 Hardware Analysis

The results of making the IMT measuring system hardware consist of making electrical and mechanical systems. The electrical system consisting of several components is made in a PCB so

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that the components used are neater and safer. After that, the electrical components are put into the box that has been made. The following is a picture of the tool that has been made.

Fig. 8. BMI measurement device

Figure 8 above is the design result of the BMI measuring tool that has been made. Based on the box image, the design consists of an LCD which is used to display data and also a power button which functions to turn on the device. Meanwhile, the component in the form of the HC-SR04 ultrasonic sensor is above and the load cell sensor is below the weighing base.

4.2 Software Analysis

The creation of this system software consists of creating a program on the NodeMCU ESP8266 microcontroller which is created using the Arduino IDE software. The NodeMCU ESP8266 microcontroller functions to control each component used. In addition, this microcontroller has a Wi-Fi feature that can be used to send sensor reading data to the IOT platform. The following are the results of creating a program on the NodeMCU ESP8266.

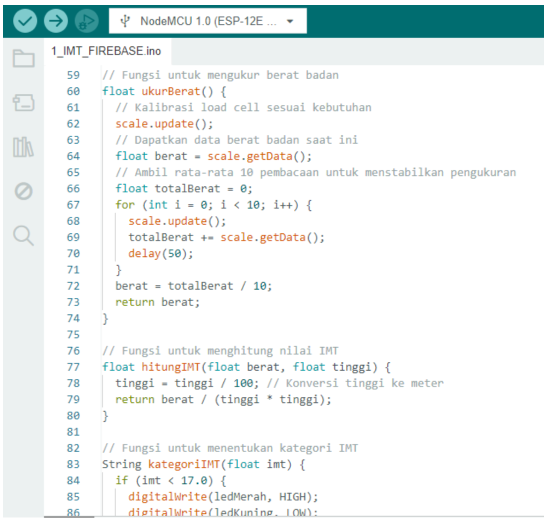

Fig. 9. Source code on Arduino IDE

After writing a program on Arduino IDE, the next step is to create a Firebase link. Creating a link in the form of an API KEY link and Database URL. The API Key and database URL that have been created are listed in the Arduino IDE programming and in the Thunkable Firebase setting menu. In the Firebase settings, you can also set the name of the application to be created and upload the application icon to be used.

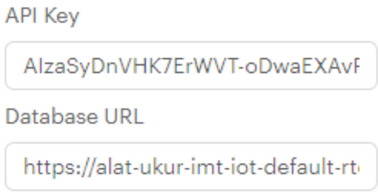

Fig. 10. Link Firebase

Next is the creation of the design and logic blocks of the application program adjusted to the desired design. The creation of the program in the application is done using the Thunkable web application. Thunkable is connected to Firebase which can send data from the NodeMCU ESP8266 microcontroller in real time. Connecting Firebase to Thunkable is done by setting the API Key address and Database URL in the Firebase Setting Thunkable.

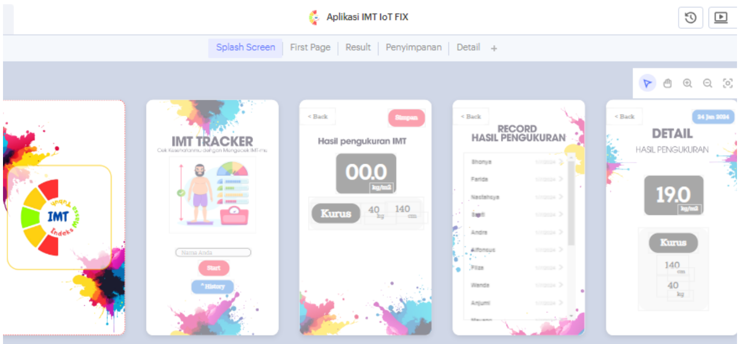

Fig. 11. Application design

4.3 Testing and Analysis

Manual measurement testing is carried out to determine the measurement values measured using a meter and scales. The results of the height and weight measurements will later be used to calculate the BMI value using equation (1), so that it can be categorized as very thin, thin, normal, fat, and obese. The following are the results of the height and weight measurement tests and the calculation of the BMI value that has been carried out.

Table 2. Manual Measurement

Persons	Height (cm)	Weight (kg)	Measurement Value IMT (kg/m^2)	Category
Person 1	160,4	41,4	16,09	Very thin
Person 2	155,1	59	24,53	Normal
Person 3	152,7	52,1	22,34	Normal
Person 4	162,8	45,7	17,24	Thin
Person 5	164,2	63,4	23,51	Normal
Person 6	168,5	64	22,54	Normal
Person 7	167,9	61,8	21,92	Normal
Person 8	142,3	34,6	17,09	Thin
Person 9	158,4	37,6	14,99	Very thins

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Persons	Height (cm)	Weight (kg)	Measurement Value IMT (kg/m^2)	Category
Person 10	157,7	81	32,57	Obese
Person 11	165,2	66,9	24,51	Normal
Person 12	157,2	47,2	19,10	Normal
Person 13	179,6	72,8	22,57	Normal
Person 14	165,5	61,8	22,56	Normal
Person 15	143,1	60,1	29,35	Obese

Table 2 is the result of manual measurements of 15 people using a standard meter to measure height and a manufacturer's scale to measure weight. The calculation is carried out using equation (1), obtained from the BMI value results of 2 people with a very thin BMI category, 2 thin people, 9 normal people, and 2 obese people. These manual measurements will later be compared with measurements on the tool or application to determine the level of error and the level of success of the tool. Furthermore, measurement testing on the tool was carried out to determine the results of the measurement values using the BMI measuring tool that had been made. The tests carried out were height measurements using an ultrasonic sensor and weight using a load cell sensor, as well as BMI value calculations and their categorization. The results of the measurements will be displayed on a 20x4 LCD screen that displays 4 data, namely height, weight, BMI, and category. The following are the results of height and weight measurement tests and BMI value calculations on the tool that have been carried out.

Table 3. Measurement using tools result

Persons	Height (cm)	Weight (kg)	BMI (kg/m^2)	Category	LED indicator
Person 1	161.9	41.5	15.83	Very thin	Red
Person 2	156.31	59.24	24.25	Normal	Green
Person 3	153.95	52.72	22.24	Normal	Green
Person 4	163.44	45.9	17.18	Thin	Yellow
Person 5	164.71	61.85	22.80	Normal	Green
Person 6	169.38	62.86	21.91	Normal	Green
Person 7	169.11	60.24	21.06	Normal	Green
Person 8	143.36	35.43	17.24	Thin	Yellow
Person 9	159.89	38.53	15.07	Very thin	Red
Person 10	158.52	82.72	32.92	Obese	Red
Person 11	166.25	66.16	23.94	Normal	Green
Person 12	158.63	48.39	19.23	Normal	Green
Person 13	179.93	71.95	22.22	Normal	Green
Person 14	166.77	61.24	22.02	Normal	Green
Person 15	143.68	59.67	28.90	Obese	Red

The test results carried out on the device can be monitored on the LCD screen, while the measurement results can be monitored and saved in the application. The measurement results displayed on the LCD screen and the Android application are the same, namely displaying 4 data, namely height, weight, BMI, and category. The BMI results obtained are the same as the results of manual measurements, namely there are 2 people with a very thin BMI category, 2 thin people, 9 normal people, and 2 obese people. The measurements of this tool will later be compared with manual measurements using standard measuring instruments such as meters and scales.

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Furthermore, the measurement test on the tool is carried out simultaneously with the measurements on the application because it is integrated in one program. This test is carried out to compare the display of measurement results between the LCD screen and the application whether it is appropriate or not. The measurement data received by the application via Firebase from the NodeMCU ESP8266 microcontroller is 2-4 seconds slower than the display of measurement data on the LCD. This is due to the complexity of the internet network and communication protocols used as well as the overhead of the process on the Firebase server. However, the display of measurement results on the application screen will remain the same as the display of measurement results on the LCD. The following are some examples of synchronization results between monitoring using tools and applications.

Fig. 12. Results on Apps

Fig. 12 is an example of synchronization of BMI test results in the very thin category between monitoring on the LCD screen and the application. The results of height, weight, BMI, and BMI category on the LCD screen match the application screen. The LED light on the device that is lit is red, while the background of the results on the application screen is also red. This indicates that the monitoring synchronization between the LCD screen and the application is in the appropriate condition. After getting the results of measuring a person's height which is measured manually using a meter and measured using a measuring device that has been made, the next step is to compare the measurement results to determine the level of error and success. The following are the results of a comparison of height measurements between manual measurements using tools or monitoring via applications that have been carried out.

Table 4. Height measurements

Persons	**Manual (cm)**	**BMI Device (cm)**	**Error (cm)**	**Percentage Error (%)**	**Accuracy (%)**
Person 1	160.4	161.9	1.5	0.94	99.06
Person 2	155.1	156.31	1.21	0.78	99.22
Person 3	152.7	153.95	1.25	0.82	99.18
Person 4	162.8	163.44	0.64	0.39	99.61
Person 5	164.2	164.71	0.51	0.31	99.69
Person 6	168.5	169.38	0.88	0.52	99.48
Person 7	167.9	169.11	1.21	0.72	99.28
Person 8	142.3	143.36	1.06	0.74	99.26
Person 9	158.4	159.89	1.49	0.94	99.06
Person 10	157.7	158.52	0.82	0.52	99.48
Person 11	165.2	166.25	1.05	0.64	99.36
Person 12	157.2	158.63	1.43	0.91	99.09
Person 13	179.6	179.93	0.33	0.18	99.82
Person 14	165.5	166.77	1.27	0.77	99.23
Person 15	143.1	143.68	0.58	0.41	99.59
Average			1.02	0.64	99.36

Table 4 is the result of a comparison of the height measurement test of a person who has been measured between manual measurements and measurements using a tool or application monitoring. Based on this comparison, the average results of the measurements of 15 people were obtained, the success rate of the tool based on the reading of the HC-SR04 ultrasonic sensor was 99.36% and the error rate was 0.64%. This shows that the accuracy value of the HC-SR04 ultrasonic sensor in detecting distance is in good condition because the success rate of the tool is high, and the error is less than 1%. The largest error value is 0.94% in the measurements of Person 1 and 9. While the smallest error value is 0.18% in the measurement of Person 13. After getting the results of a person's weight measurement measured manually using a scale and measured using a measuring tool that has been made, the next step is to compare the measurement results to determine the level of error and success. The following are the results of a comparison of body weight measurements between manual measurements using a tool or monitoring via an application that has been done.

Table 5. Weight measurements

Persons	Manual (kg)	BMI Device (kg)	Error (kg)	Percentage Error (%)	Accuracy (%)
Person 1	41.4	41.5	0.1	0.24	99.76
Person 2	59	59.24	0.24	0.41	99.59
Person 3	52.1	53.72	1.62	3.11	96.89
Person 4	45.7	45.9	0.2	0.44	99.56
Person 5	40.1	40.43	0.33	0.82	99.18
Person 6	43.9	45.18	1.28	2.92	97.08
Person 7	39.8	40.25	0.45	1.13	98.87
Person 8	62.5	61.92	0.58	0.93	99.07
Person 9	60.1	61.77	1.67	2.78	97.22
Person 10	50.2	49.78	0.42	0.84	99.16
Person 11	74.2	74.92	0.72	0.97	99.03
Person 12	61.8	62.55	0.75	1.21	98.79
Person 13	61.3	62.23	0.93	1.52	98.48
Person 14	64	62.86	1.14	1.78	98.22
Person 15	63.4	61.85	1.55	2.44	97.56
Mean			0.96	1.50	98.50

Table 5 is the result of a comparison of the weight measurement test of a person who has been measured between manual measurements and measurements using tools or application monitoring. Based on this comparison, the average results of the measurements of 15 people were obtained, the success rate of the tool based on the reading of the load cell sensor by the HX711 module was 98.50% and the error rate was 1.50%. This shows that the accuracy value of the load cell sensor by the HX711 module in detecting mass is in good condition because the success rate of the tool is high, and the error is less than 5% according to the tolerance limit of the load cell in general. The largest error value is 3.11% in the measurement of Person 3. While the smallest error value is 0.24% in the measurement of Person 1.

5. Conclusion

The design of an IoT-based BMI measuring device is used to measure height, weight, and BMI. This measuring device is made using NodeMCU ESP8266 which processes height measurement data by the HC-SR04 ultrasonic sensor and weight measurement by the load cell sensor with the help of the HX711 module to convert very small values from load cell readings. Both data variables are then processed into BMI values and can then be classified into 5 categories (very thin, thin, normal, fat, and obese) which are marked with LED lights as indicators. In addition to being monitored in real time on the LCD, measurement results can be monitored periodically using the Android application that has been created. Measurement data is stored by Firebase or the application. Functional testing of the IoT-based BMI measuring system using the Android application that has been carried out shows that each component used can function and work properly. The functional testing stages are carried out by providing a program to the component or checking the pin using a multimeter. This test is also carried out by comparing the test results with component specifications.

Performance testing of IoT-based BMI measuring devices using an android application was carried out to determine the level of error and success. The results of height and weight readings by the BMI measuring device were compared with standard measuring devices such as meters and scales. The average comparison value or error of ultrasonic sensor readings by 15 measuring persons was 0.64%, while the sensor success rate was 99.36%. The average comparison value or error of load cell sensor readings by the HX711 module against 15 measuring persons was 1.50%, while the sensor success rate was 98.50%. Based on the results of the height and weight reading test by both sensors, it shows that the device is in good condition because the comparison value is below 5%.

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Prototype Design of Toxic Gas (CO) Monitoring Equipment In Motorcycle Workshop

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ABSTRACT

Workshop is one of the places that contributes a significant amount of carbon monoxide gas, originating from motor vehicle exhaust. A workshop is also a place at high risk of fire. Due to the lack of awareness among visi- tors and workshop workers about the dangers of carbon monoxide gas and the potential for fires in motorcycle workshops, a tool is needed to monitor carbon monoxide levels and detect fire in the workshop. The aim of this final project is to design and develop a device, software, and demonstrate the per- formance of a system for monitoring carbon monoxide levels and detecting fire in a motorcycle workshop. This research uses the Research and Develop- ment (R&D) method. The results of the monitoring system created showed good outcomes. The sensor used was able to read carbon monoxide levels with an error rate of 5.56%, while the Flame sensor was able to detect fire at a maximum distance of up to 70 cm. The monitoring system functioned well, with carbon monoxide levels visualized using ThingSpeak. The DC fan also worked effectively, when carbon monoxide levels in the room reached 25 ppm or higher, the DC fan would turn on and help with air circulation.

Bengkel merupakan salah satu tempat yang menyumbang banyak gas karbon monoksida yang berasal dari gas buangan kendaraan bermotor. Bengkel juga merupakan suatu tempat yang berisiko terjadinya kebakaran. Kurangnya kesadaran para pengunjung dan pekerja bengkel akan bahayanya gas karbon monoksida dan rentannya terjadinya kebakaran pada bengkel motor, dibutuhkan alat yang dapat memonitoring kadar karbon monoksida dan api yang ada pada bengkel. Tujuan dari proyek akhir ini adalah untuk merancang bangun alat, software, dan melakukan unjuk kerja dari sistem monitoring kadar karbon monoksida dan api pada bengkel motor. Penelitian ini menggunakan metode Research and Development (R&D). Hasil dari pembuatan sistem monitoring yang dibuat mendapatkan hasil yang baik. Sensor yang digunakan dapat membaca kadar gas karbon monoksida dengan nilai error sebesar 5.56%, sedangkan sensor Flame dapat membaca adanya api dengan jarak maksimal sejauh 70 cm. Sistem monitoring yang dibuat dapat berjalan dengan baik, kadar karbon monoksida dapat divisualisasikan menggunakan thingspeak. Fan DC yang digunakan juga berfungsi dengan baik, ketika gas karbon monoksida yang berada di ruangan terbaca 25 ppm atau lebih maka fan DC akan menyala dan dapat membantu sirkulasi udara.

1. Introduction

Clean air is essential for the life of living things on earth, including humans [1]. Thus, the need for clean air becomes crucial for the sustainability of human life. However, along with the rapid development of technology, there are negative impacts in the form of increased human activities. Every activity conducted by humans can generate waste that leads to a decline in environmental quality [2].

Pollution arises from human activities, such as pollution from factory industries, motor vehicles, waste burning, agricultural residues, and natural events. This pollution can damage the clean air that is a crucial aspect of human survival. One example of air pollution is the exhaust gas from motor vehicles, namely carbon monoxide (CO) [3].

According to the World Health Organization (WHO), the exposure limit for CO in humans is 90-100 ppm for 15 minutes, 25-35 ppm for 1 hour, and 9-10 ppm for 8 hours. Meanwhile, the Occupational Safety and Health Administration (OSHA) recommends a maximum CO exposure limit of 35 ppm over 8 hours in a workday. Levels considered immediately dangerous to life or health are 1500 ppm [4]. According to WHO, high concentrations of CO in the blood within a few minutes can cause respiratory distress and death.

Workshop is one of the locations that significantly contributes CO emissions originating from motor vehicle exhaust gasses. This situation has become worse because exhaust gasses that should be dispersed and conditioned become stagnant, and many workshops still lack adequate systems for conditioning these exhaust gasses. CO levels in motor vehicle workshops have been found to reach as high as 600 mg/m^3, and the blood of the workshop workers can contain COHb up to five times higher than normal levels [5].

The threshold limit value for carbon monoxide, based on the Regulation of the Minister of Manpower and Transmigration on Threshold Limit Values for Physical and Chemical Factors in the Work- place, is 25 ppm. This regulation emphasizes the importance of monitoring CO levels in the work- place to ensure the safety and health of workers.

The importance of raising awareness and safety among workers is essential and can create a work environment with minimal risks. Workshops are also places that are at risk of fire. Fires can be triggered by fuel leaks, sparks, or workshop equipment operating at high temperatures. Along with the increasing demands for the safety of workers and visitors, there is also growing awareness of the impact of exhaust gasses in motorcycle workshops.

This device uses an MQ-7 sensor that can detect exhaust gasses from motor vehicles in workshops, specifically CO gas, and a flame sensor that can detect fire in case of a fire in the workshop. The output of this device is a monitoring system that can monitor the CO level in the room and a DC fan that will turn on when the CO level in the room reaches a dangerous point. The device is expected to help and raise awareness among workers and customers to create a healthy and safe working environment.

2. The Proposed Method

2.1 Carbon Monoxide

Carbon monoxide is a colorless, tasteless, and odorless compound produced by incomplete combustion. Inhaling high concentrations of carbon monoxide gas can have negative effects and pose dangers to humans and the surrounding environment. Carbon monoxide is a dangerous gas that can cause poisoning and even death if inhaled by the human body in large amounts.

Motor vehicles are one of the contributors to carbon monoxide gas, which comes from emissions due to incomplete combustion. The human body can experience disturbances and even death if exposed to concentrations exceeding normal exposure limits. According to the Regulation of the Minister of Manpower and Transmigration on the Threshold Limit Values for Physical and Chemical Factors in the Workplace, the threshold limit for carbon monoxide is 25 ppm.

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2.2 Internet of Things

Internet of Things (IoT) is a concept where devices connected to the internet can exchange data and communicate with other devices to help simplify tasks for users. IoT devices include several components such as sensors used to read and collect data, devices like microcontrollers to process the data, and devices that can be used to store and present the received data.

The process begins with using sensors or detection devices installed on specific objects or in certain environments. The primary task of the sensor is to collect data from the object or environment being measured. Then, the data collected by the sensor is gathered and processed by a device such as a microcontroller. After the data is collected and processed, the device transmits it through a communication network. The transmitted data can then be further processed and stored in databases, computers, or other systems. Users can subsequently access the data via the internet or cloud services using devices such as computers, smartphones, laptops, or other smart devices.

2.3 NodeMCU ESP32

Espressif Systems Processor, commonly known as ESP, is an open-source microcontroller integrated with Wi-Fi and Bluetooth features. Several types of ESP microcontrollers commonly used are the ESP8266 and ESP32. The way the ESP8266 and ESP32 work is almost the same, but the ESP32 is superior with features such as dual-band Wi-Fi, Bluetooth, and higher computational capabilities compared to the ESP8266. The frequency they operate on also differs, with the ESP8266 having a frequency of 80MHz, while the ESP32 operates at 160MHz.

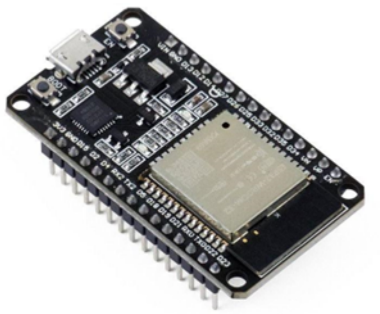

Fig. 1. NodeMCU ESP32

The NodeMCU ESP32 is a hardware development module that utilizes the ESP32 chip. This module facilitates the development of Internet of Things (IoT) projects, supported by Wi-Fi and Bluetooth features, providing robust wireless connectivity. The NodeMCU ESP32 is equipped with numerous General Purpose Input/Output (GPIO) pins that can be configured as digital inputs and outputs, analog inputs, and other functions. The availability of these pins makes it easier to manage additional circuits.

2.4 MQ-7 Sensor

MQ-7 sensor is a sensitive gas sensor capable of detecting various harmful compounds in the air, such as smoke (CO), CO2, NH3, NOx, alcohol, and other gasses. The working principle of the MQ-7 sensor involves detecting changes in resistance when exposed to gas.

The MQ-7 sensor has a relatively low dependency on temperature and humidity, making it suitable for applications in air quality monitoring and CO level detection. The resistance of the MQ-7 sensor, which varies depending on the concentration of each gas, determines how the sensor should be calibrated. To calibrate the sensor readings to ppm values, the Rs/Ro graph from the MQ-7 sensor datasheet is used. Here, Rs represents the sensor's resistance at a given gas concentration, and Ro represents the sensor's resistance in clean air. The MQ-7 sensor provides air quality detection results as changes in analog resistance values on its output pin.

Fig. 2. MQ-7 Sensor

3. Method

In the research conducted, the Research and Development (R&D) method was used. The Research and Development method is a research approach aimed at developing a product through several stages. After completing each stage, the effectiveness of the product is then tested. The Research and Development method involves several steps. Product development begins with gathering information and conducting a literature review on the existing problems. This is followed by the design of a validated product. Once the design process is complete, the next stage is product creation, which is then followed by various tests until the product is ready for implementation.

3.1 Units

In this research process, it is necessary to identify the requirements needed for creating the device. This identification includes aspects of Hardware, Software, and tools that meet the project's needs. The purpose of this identification is to ensure that the selection of Hardware, Software, and tools aligns with the requirements of the project to be developed. Below is the identification of the needs required for the final project.

- **ESP32**, It is used as a microcontroller that functions to process data and control other devices, such as sensors that can connect to a Wi-Fi network to support Internet of Things (IoT)-based systems.
- **MQ-7 Sensor**, MQ-7 sensor is a sensor that will be used to measure the concentration of CO gas in the workshop area. This sensor is sensitive to toxic gasses such as CO, CO2, NH3, CH4, and other hazardous gasses.
- **Flame Sensor KY-026**, The KY-026 Flame Sensor is a sensor used to detect the presence of flames in the workshop.
- **Arduino IDE**, Arduino IDE is the software used to program the ESP32 microcontroller.
- **Thingspeak**, hingSpeak is used for testing the monitoring system website.

3.2 Design

The hardware needed to make this final project is adjusted to the needs of the tools to be made. The component used is ESP32 which is connected to a Wi-Fi network to support the interests of Internet of Things-based circuits. MQ-7 sensor to measure CO gas concentration in workshop rooms. Flame Sensor KY-026 to detect fire in the workshop room. Buzzer is an alarm or warning that can emit a sound when the surrounding gas reaches a danger value. DC Power Adapter 12V as a power source in microcontrollers, sensors, actuators. L298N Motor Driver for controlling DC motors or fans. Mini fan DC as an actuator.

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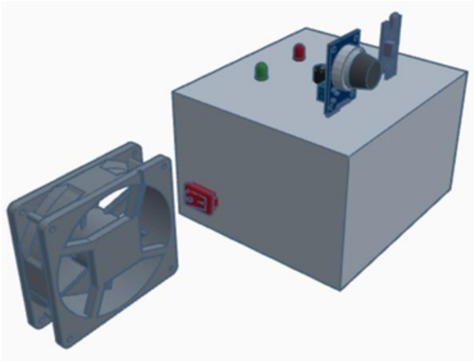

Fig. 3. Device design

3.3 Testing Methods

The testing method is carried out to obtain research data from the problem statements that will be used for analysis. The testing is done by evaluating the design of each component and the entire system that has been created. This testing is conducted to ensure that the entire system functions and operates according to its intended purpose.

- **Sensor Testing**: Sensor testing is conducted to determine the accuracy and performance of the sensor in measuring how accurately it can operate. This testing is done by comparing the results from the MQ-7 sensor with a standard carbon monoxide gas detector. The testing process for the MQ-7 sensor involves connecting the sensor to a microcontroller to measure the carbon monoxide levels in the room. The testing of the KY-026 Flame Sensor is conducted to determine if the sensor can detect the presence of a flame when it is ignited.
- **Motor Driver L298N**: This testing is conducted to determine whether the motor driver can operate correctly. The testing involves evaluating the direction of rotation and the speed of the DC fan according to the commands given by the microcontroller. This testing is performed to ensure that the motor driver functions as intended.
- **Buzzer**: Buzzer testing is conducted to determine whether the buzzer can function properly. The testing is performed by connecting the buzzer to the microcontroller to produce an output according to the given commands.
- **Performance Testing**: This testing is conducted to assess the functionality of the assembled components, with the aim of determining whether each component used is working properly and to evaluate the overall operation and functionality of the device as expected.

4. Result and Discussion

4.1 Implementation

Fig. 4. Implementation of device design

In this process, several main hardware components are involved, including electronic components, the PCB, and the device casing. Once these components are ready, the assembly of each component is carried out step by step. The optimization of this device involves several key components, including the device casing and a NodeMCU ESP32 as the microcontroller, which is mounted on the PCB along with components such as sensors, LEDs, a buzzer, the L298N motor driver, and a 12V DC fan pin.

The Internet of Things platform results using ThingSpeak can be accessed through http://thingspeak. com by first logging in with an account that has been created. The monitoring system dashboard using ThingSpeak can be viewed in the Fig. 5.

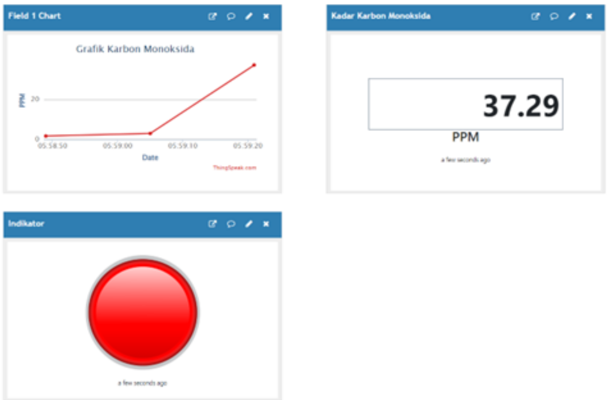

Fig. 5. Thingspeak dashboard

4.2 Microcontroller Testing

Testing of the ESP32 microcontroller is conducted to determine whether the input and output voltage values meet the specified standards. This testing is performed because the microcontroller is a core component of the system that has been developed. The test involves measuring the Vin and Vout of the microcontroller using a multimeter to identify any error in the voltage currents entering and exiting the ESP32 microcontroller. To calculate the error value, the formula used is:

$$\%errorr = \frac{x - x_i}{x_i} \tag{1}$$

The test results show that after conducting the test three times, there was a 3% error observed when measuring Vout, both with and without a load. Meanwhile, for the Vin measurement, the results matched the specified value of 5V.

Table 1. ESP32 Testing

No	Aspect	Specification		Result		Error	
		Vin	Vout	Vin	Vout	Vin	Vout
1	Without voltage load	5V	3.3V	5V	3.2V	0%	3%
	Using voltage load	5V	3.3V	5V	3.2V	0%	3%
2	Without voltage load	5V	3.3V	5V	3.2V	0%	3%
	Using voltage load	5V	3.3V	5V	3.2V	0%	3%
3	Without voltage load	5V	3.3V	5V	3.2V	0%	3%
	Using voltage load	5V	3.3V	5V	3.2V	0%	3%

4.3 MQ-7 Sensor Testing

The purpose of testing the MQ-7 sensor is to determine its accuracy and the error by comparing it with a reference device, specifically a carbon monoxide detector available on the market. The testing is conducted by comparing the custom-built device with the monitoring system display.

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Table 2. MQ-7 Sensor Testing

Sensor MQ-7 (ppm)	Carbon Monoxide Detector (ppm)	Difference
999.99	990	9
365.29	350	15.29
338.07	330	8.07
168.90	160	8.90

The testing was conducted by placing the sensor and the comparison tool close to the motorcycle's exhaust. There were two values recorded: the highest and the lowest. At the highest value, the sensor and the comparison tool reached the maximum reading limits of 999 and 990, with a difference of 9. Meanwhile, the lowest value was obtained when the sensor and the comparison tool were placed 1 meter away from the motorcycle's exhaust. The results for the lowest reading were 168.90 and 160, with a difference of 8.90. The %error was calculated to be 0.9% for the highest value and 5.56% for the lowest.

4.4 Flame Sensor Testing

The Flame Sensor testing was conducted to determine the accuracy of the sensor's readings. The testing process involved burning paper at a predetermined distance. This test was carried out four times, each at different burning angle. The purpose of this testing was to assess the Flame Sensor's ability to detect environmental conditions when a fire is ignited.

Table 3. Flame Sensor Testing

No	Angle	Range	Condition	Result
1	0	10 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
2	0	20 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
3	0	30 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
4	0	40 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
5	0	75 cm	Flame on	Sensor off
	30			Sensor off
	60			Sensor off
	90			Sensor off

The table above shows the results of the Flame Sensor testing. The Flame Sensor was able to detect the presence of fire at a distance of 70 cm at angles of 0, 30, and 60 degrees. However, at an angle of 90 degrees, the sensor was unable to detect the presence of fire.

4.5 Buzzer Testing

The results of the buzzer testing indicate that the buzzer performed effectively and correctly in all aspects of the testing conducted. The ESP32 successfully connected to, controlled, and utilized the buzzer according to the testing requirements. These results demonstrate that the buzzer can be reliably used in applications using ESP32 microcontrollers.

Table 4. Buzzer Testing

Aspect	Result
Turning on buzzer	Success
Set buzzer sound	Success
Set buzzer sound pattern	Success
Use the buzzer as an indicator tool	Success
Connect buzzer with ESP32	Success

4.6 Motor Driver L298N Testing

The Motor Driver L298N was tested to determine whether it could receive commands from the ESP32 microcontroller through the available inputs on the motor driver. The testing also aimed to assess whether the motor driver could control the output, specifically the DC Fan being used. The results showed that the Motor Driver L298N successfully received commands from the ESP32 microcontroller to turn on, operate, and turn off the fan as instructed. These findings indicate that the motor driver can be effectively used for the intended application.

4.7 System Performance

The overall testing of the device was successful, with all components connecting and functioning as intended. As shown below, the device operates according to the assigned tasks. The MQ-7 and Flame sensors effectively detected CO levels and fire, and the microcontroller processed the data and sent the readings to a database, which were then visualized on a website. The output components responded correctly across the board: the DC Fan activated when fire was detected or when the carbon monoxide levels exceeded 25 ppm, and both the buzzer and LED functioned properly, lighting up according to the given conditions.

Table 5. System Testing

MQ-7 Sensor (ppm)	Flame Sensor	Fan DC	LED Indicator	Buzzer	Result
15.30	0	Off	Off	Off	Accurate
10.21	0	Off	Off	Off	Accurate
12.67	0	Off	Off	Off	Accurate
13.58	0	Off	Off	Off	Accurate
9.70	1	On	On	On	Accurate
18.10	1	On	On	On	Accurate
23.25	1	On	On	On	Accurate
24.60	0	Off	Off	Off	Accurate
25.17	0	On	On	On	Accurate
45.83	0	On	On	On	Accurate
56.34	0	On	On	On	Accurate
70.22	0	On	On	On	Accurate
120.19	0	On	On	On	Accurate
90.54	0	On	On	On	Accurate

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40.78	0	On	On	On	Accurate
26.14	0	On	On	On	Accurate
20.80	0	Off	Off	Off	Accurate
13.68	0	Off	Off	Off	Accurate
8.82	1	On	On	On	Accurate
9.55	1	On	On	On	Accurate

5. Conclusion

This research successfully realized the design of hardware for a device that monitors carbon monoxide levels and detects fire. The device effectively detects carbon monoxide levels and the presence of fire using the MQ-7 and Flame sensors. It also includes an LED, Buzzer, and DC Fan that activate when the sensors detect fire or when the carbon monoxide levels exceed 25 ppm. Addition- ally, the device features a monitoring system using localhost, which can be used to monitor carbon monoxide levels in a room.

This research can realize the design of software for a carbon monoxide monitoring and fire detection device. The Arduino IDE is used to create the code for the ESP32 microcontroller, utilizing several available libraries. Thingspeak can implement the monitoring design using a website that displays the readings from the MQ-7 sensor.

The performance of the carbon monoxide monitoring and fire detection device operates as expected. The components used function properly. The Flame Sensor can detect fire at distances and angles that align with its specifications. Meanwhile, the MQ-7 sensor is effective in measuring carbon monoxide levels in a room, although there is a discrepancy compared to a reference device used for measuring carbon monoxide in a motorcycle exhaust, with a difference of 8.90 ppm or a 5.56% error at the lowest value when measuring carbon monoxide at a distance of 1 meter from the motorcycle exhaust. The sensor readings are successfully visualized on a website, which can be used to monitor room conditions. The outputs, including the Buzzer, LED, and DC Fan, work effectively in response to the sensor readings regarding the room conditions.

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Prototype of Voltage, Current, Temperature, and Oil Level Monitoring System in Transformers

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ABSTRACT

A distribution transformer is the most crucial component of the electric power distribution system. The output values of parameters such as voltage, current, temperature, and oil level vary, necessitating monitoring. This final project aims to design and build, determine the functional testing of the device, and assess the performance accuracy of its components. The system design results show that the components used in the prototype system are the INA219, AHT10, and HC-SR04 sensors. The measurement results from the sensors are displayed on an Android application and stored in a logger. Functional test results indicate that all components used in the prototype monitoring system function normally, and the measurement errors are within the datasheet limits of each component. The percentage error values from the accuracy testing of the sensors show values below 5%, with the largest error being 3.2% in current measurement and the smallest error being 0.0% in distance measurement. Therefore, the sensors are in good condition, and these values are below the IEC 13B-23 standard limits.

Transformator distribusi merupakan komponen terpenting dari sistem distribusi tenaga listrik. *Output* nilai parameter tegangan, arus, suhu, ketinggian minyak bervariasi, sehingga diperlukan monitoring. Proyek akhir ini bertujuan untuk merancang bangun, mengetahui uji fungsional alat, mengetahui kinerja keakuratan komponen. Hasil rancang bangun sistem yang telah dilakukan menunjukan komponen yang digunakan pada sistem prototype adalah sensor INA219, AHT10, HC-SR04. Hasil pengukuran dari sensor ditampilkan pada aplikasi android serta tersimpan pada logger. Hasil uji fungsional menunjukan seluruh komponen yang digunakan pada alat prototype sistem monitoring dapat berfungsi dengan normal dan nilai error pengukuran sesuai dengan batas datasheet dari masing-masing komponen. Nilai persentase error pengujian keakuratan sensor menunjukan nilai dibawah 5% dengan nilai error terbesar pada pengukuran arus sebesar 3,2% sedangkan nilai error terkecil pada pengukuran jarak sebesar 0,0%, sehingga sensor dalam keadaan normal serta nilai tersebut dibawah batas IEC 13B-23.

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1. Introduction

Electrical energy plays an important role in human life, seen from the electricity consumption that continues to increase every year along with the increase in industrial buildings, commercial buildings, and residential buildings. This increase causes the demand for power to increase, so that the construction of distribution transformers as distributors of electrical energy flow from the generating system to consumers is increasing. The need for distribution transformers is increasing, but it is not balanced with an increase in the maintenance system of the distribution transformers [1]. Lack of maintenance and real-time monitoring of transformers can cause transformer failures such as over voltage, under voltage. Failure of the transformer function causes losses to both parties, both the consumer side and the electrical energy distributor side.

Distribution transformers are the most important components of the electrical power distribution system and have the function of increasing or decreasing voltage. Step down transformers is considered to have an important role in distributing electrical energy from 20kV medium voltage lines down to 380V or 220V voltage directly to electrical energy consumers [2]. If the transformer is in good health, the transformer can work optimally, and the output voltage of the electrical energy will be more stable and vice versa.

Distribution transformer monitoring is an activity carried out to obtain information related to the performance of the distribution transformer system in distributing electrical energy, the information obtained is used to determine disruptions or system repairs in the distribution transformer in the future. The reliability parameters of the distribution transformer system whose data information is not known in real time can cause unexpected failures and loss of supply to a large number of customers [3]. Monitoring is included in predictive maintenance or maintenance before damage occurs during system operation, system performance will be measured continuously.

Distribution transformer monitoring is still carried out manually using measuring instruments by visiting the location of the distribution transformer, this is still less efficient in terms of time and information related to monitoring results is limited. The monitoring process can be carried out remotely to reduce utility operating and maintenance costs so that it can increase the reliability of electricity services [4]. Telemetry-based technology allows data to be sent from two separate places via sensors, microcontrollers and wireless data transmission [5].

The monitoring process is needed to determine system performance so that there are no greater disruptions that can damage components and even cause system failures that lead to consumer losses. In addition, monitoring is useful for monitoring fluctuations in voltage, current, temperature, and oil volume values. Fluctuations in voltage, current, temperature, and oil volume values can be used as a reference for repairing or overcoming disturbances that occur [6]. Routine maintenance is considered unable to solve the problem of when disturbances occur in distribution transformers in real time. Based on these problems, the title of the final project was taken "prototype of voltage, current, temperature, oil level monitoring system in transformers" data collection on distribution transformers related to voltage, current, temperature, oil volume. In addition, this final project uses the Telemetry concept so that it can monitor the collection of information data on distribution transformers remotely and in real time. The data that has been taken is then processed until it gets mature data and can provide notification regarding the condition of the distribution transformer monitored via the internet web.

2. Methods

2.1 Electric Power Distribution System

The electric power system is part of the distribution of electric power sourced from power plants, substations to consumers [7]. A step-down distribution transformer is one of the equipment in the electric power distribution system. A step-down distribution transformer has the function of changing the flow of high-voltage electric power into a flow of low-voltage electric power with the same frequency. The transformer works by utilizing the principle of electromagnetic induction, namely the connection of the primary coil with an alternating voltage source, so that there is a change in current that triggers a magnetic field, then the magnetic field is strengthened with an iron core and flows to the secondary coil [8].

2.2 System Monitoring Transformer Step Down

Monitoring is the process of collecting data and maintaining several conditions of an object. Settings with monitoring systems can be designed to maintain and keep track of objects. Virtual monitoring systems provide information and conditions of all objects by analyzing and detecting other abnormal conditions [9]. Energy from the transformer should be less than the main syringe per transformer. Gangguan such as overload, overheat, under oil, over voltage and under voltage.

The transformer monitoring system provides a wide range of transformer conditions for increasing power from the transformer or increasing the conditions from the transformer by measuring the parameter values and assumptions, decreasing the volume and increasing the quality. Each of these parameters then processes for many normal or abnormal conditions of the realtime transformer. The height, height, height, and volume are the most important parameters of the power supply of the transformer [10].

2.3 Telemetry

Telemetry includes system features and features that should be checked from the beginning. The telemetry system consists of a large number of components consisting of two components namely transmitter and receiver. Transmitter includes part of a telemetry system that includes functions for increasing data parameter objects within a wide range of communications required. For example, this transmitter functions to receive signals if data that is not received should be analyzed efficiently. The receiver consists of a telemetry system that contains mending functions and uses data parameter object content that is received by the transmitter and then stored during the integration of the cellular data [11]. Adanya system telemetry can remember to determine the parameter object shape available with access data achieved to determine the temperature line [12].

2.4 Prototype

Prototype is an initial concept used as testing material for the real concept entity of a technology in the field of manufacturing and software engineering. Prototype is made as a production plan that represents the shape and dimensions of the initial concept object it represents [13]. The prototype that is built has a structure, function, and system operation that represents a simulation of the actual product. Using a prototype, technical problems on the actual tool that may arise can be identified and overcome, so that the actual tool can function properly.

2.5 Thunkable

Thunkable is one of the internet of things (IoT) support platforms based on the internet web. Thunkable can be used by new users to program computers as software application makers for Android and iOS operating systems. The program code for the Android system is created using a program system that has been created from the Thunkable platform so that program creation is only by dragging and dropping blocks [14].

2.6 Google Spreadsheet

Google spreadsheet is a program developed by Google with a function as a data processor. Google spreadsheet is widely used as an output companion in the form of a data recorder or data logger from IoT projects. Data entered into Google spreadsheet can be stored in cloud storage from Google [15].

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3. Designs

The concept of tool design is a discussion related to the stages and processes of the final project entitled Prototype of Voltage, Current, Temperature, and Oil Level Monitoring System in Transformers consisting of identification and analysis of needs, design and design of tools, tool manufacturing and tool testing. The following is described in the form of a tool manufacturing flow

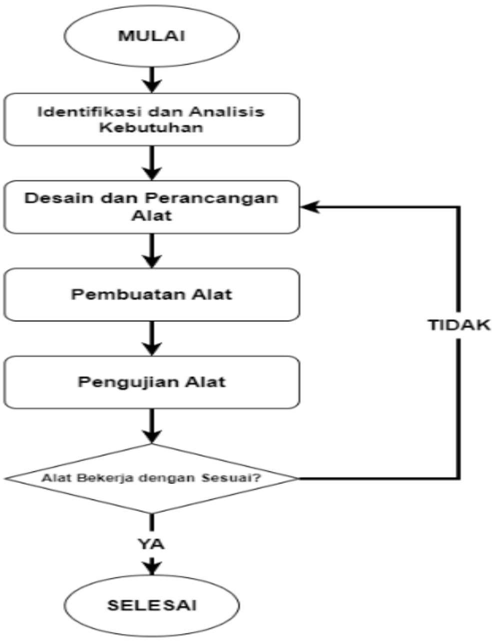

Fig. 1. Flowchart

Needs Analysis is a stage of analysis regarding the urgency of making a tool. This stage of needs analysis is by conducting field observations and literature studies. Field observations are carried out on routine maintenance of distribution transformers by PT. PLN. The process of monitoring transformers manually with hardware is considered less effective because it cannot be done in real-time. Therefore, a telemetry-based transformer monitoring system is needed that can monitor important parameters on transformers such as voltage, current, temperature, oil level. While the literature study conducted to find solutions to the existing problems is based on various literature. The literature obtained is in the form of articles obtained from various journals.

3.1 Flowchart

The following is a flowchart of the prototype monitoring system for voltage, current, temperature, and oil level in a transformer

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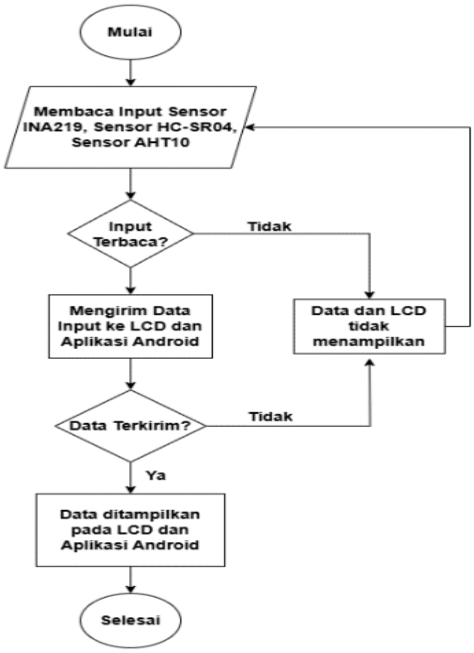

Fig. 2. Flowchart of the system

Figure 2 is a flowchart prototype of a monitoring system for voltage, current, temperature, and oil level in a transformer. Based on the system flowchart in Figure 2, the working process of the tool begins with reading the input of the INA219 sensor, AHT10 sensor, and HC-SR04 sensor. The system detects whether the input parameters from the transformer are read or not; if not read, the data on the monitoring will be empty and the system will reset, while if read, the parameters will be updated on the LCD and sent to the android application and 20x4 LCD. If the data is not sent, the monitoring display remains empty and the system performs re-detection. If sent, the data will be displayed on the android application and 20x4 LCD.

3.2 Hardware Design

The hardware manufacturing process consists of two parts including the creation of electrical design and the creation of mechanical design. Electrical design includes the creation of electrical wiring used in the system, while mechanical design includes the creation of physical design of the tool and the placement of components on the tool being made. The following are the results of the hardware design.

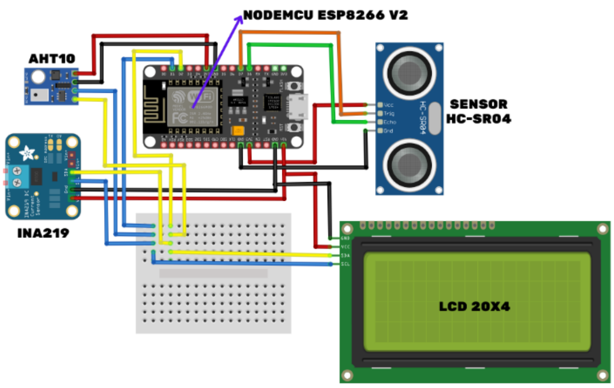

Fig. 3. Wiring components

Figure 3 is a wiring diagram of each component used in the monitoring system. The main components of the monitoring system used based on the image above are the INA219 voltage and

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current sensor, AHT10 temperature sensor, HC-SR04 distance sensor, 20x4 LCD, and NodeMCU ESP8266 microcontroller.

Fig. 4. Box design

Figure 4 is a box design image of a prototype monitoring system for voltage, current, temperature, and oil level in a transformer. The box is used to place electrical components used in the manufacture of the tool project.

3.3 Software Design

This stage is carried out to determine the process of making software designs used in the prototype monitoring system for voltage, current, temperature, and oil levels in transformers. The software design is divided into three stages, namely the stage of making programs on the NodeMCU ESP8266 microcontroller in the Arduino IDE application, making Android applications on Thunkable, and making Google spreadsheet programs on apps script.

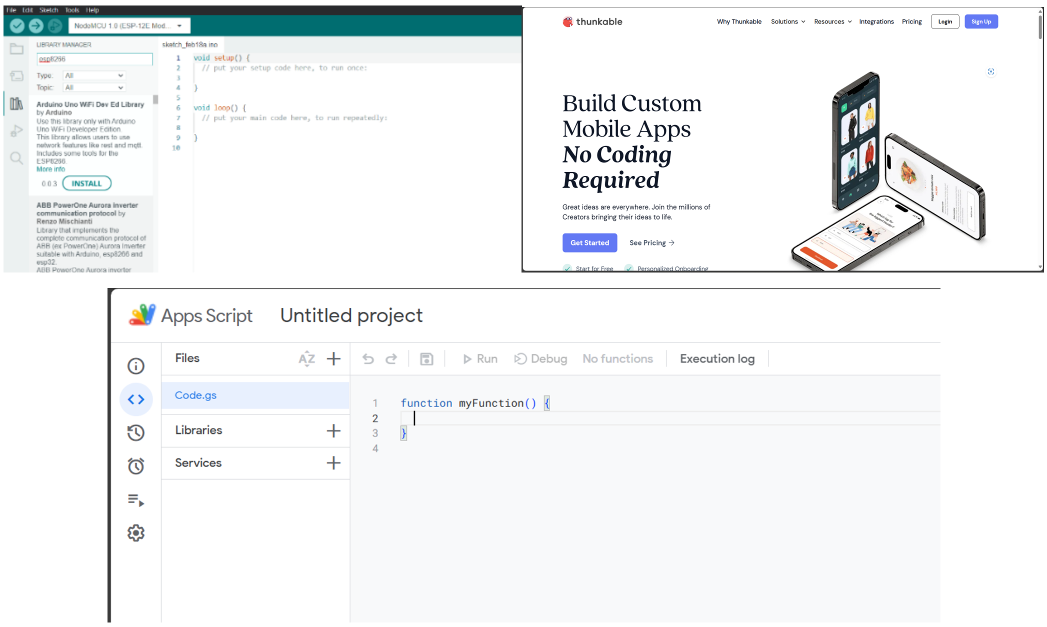

Fig. 5. Arduino IDE, Thunkable, and Apps Script

4. Results and Discussion

4.1 Hardware

The results of making hardware prototypes of voltage, current, temperature, and oil level monitoring systems on transformers consist of making electrical and mechanical systems. The electrical system is placed on a PCB so that the components are more organized and safe. After the installation on the PCB is complete, the PCB is placed in a box that has been made. The following is the display result of making electrical and mechanical systems on a box.

Fig. 6. Hardware Prototype

Figure 6 above is the result of making a hardware prototype of a monitoring system for voltage, current, temperature, and oil level in a transformer. Based on the image above, it can be seen that the front part has an LCD, 2 on-off load trigger switches, a voltage trigger potentiometer, and a push button reset button. For electrical components such as sensors, modules, and microcontrollers, they are in the monitoring system box.

4.2 Software

Software creation consists of three stages including creating an Arduino IDE program, creating an Android application, and creating a Google spreadsheet. The following are the results of creating a microcontroller program on the Arduino IDE application.

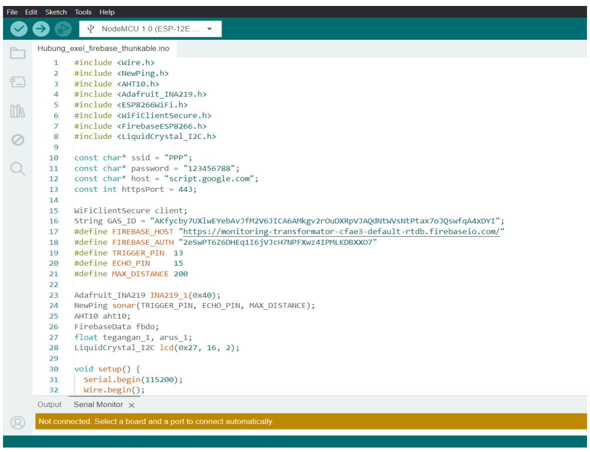

Fig. 7. Code Arduino IDE

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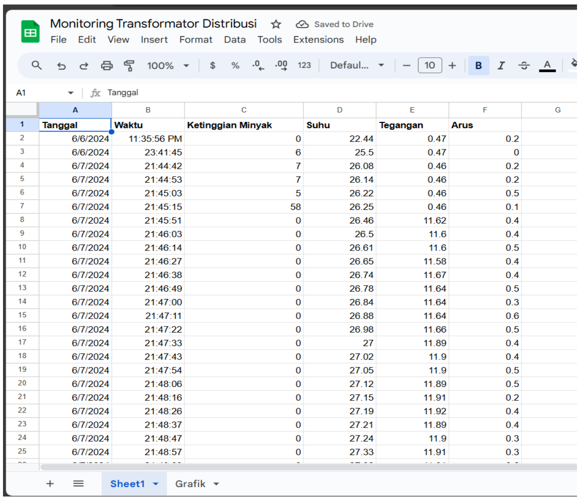
Figure 7 is a NodeMCU ESP8266 microcontroller program using the Arduino IDE application. The microcontroller is given a program so that it can receive input parameter values read by the sensor and can be processed, then sent to the android application and the value data is stored in a spreadsheet. The following is the result of the appearance of the android application that was successfully created.

Fig. 8. Android Application

Figure 8 is an android application that has been successfully created using the thinkable application. Then the last stage is the creation of a monitoring logger that is used to store incoming data. The following is a display of the monitoring logger that has been successfully created.



	Tanggal	Waktu	Ketinggian Minyak	Suhu	Tegangan	Arus
2	6/6/2024	11:35:56 PM	0	22.44	0.47	0.2
3	6/6/2024	23:41:45	6	25.5	0.47	0
4	6/7/2024	21:44:42	7	26.08	0.46	0.2
5	6/7/2024	21:44:53	7	26.14	0.46	0.2
6	6/7/2024	21:45:03	5	26.22	0.46	0.5
7	6/7/2024	21:45:15	58	26.25	0.46	0.1
8	6/7/2024	21:45:51	0	26.46	11.62	0.4
9	6/7/2024	21:46:03	0	26.5	11.6	0.4
10	6/7/2024	21:46:14	0	26.61	11.6	0.5
11	6/7/2024	21:46:27	0	26.65	11.58	0.4
12	6/7/2024	21:46:38	0	26.74	11.67	0.4
13	6/7/2024	21:46:49	0	26.78	11.64	0.5
14	6/7/2024	21:47:00	0	26.84	11.64	0.3
15	6/7/2024	21:47:11	0	26.88	11.64	0.6
16	6/7/2024	21:47:22	0	26.98	11.66	0.5
17	6/7/2024	21:47:33	0	27	11.89	0.4
18	6/7/2024	21:47:43	0	27.02	11.9	0.4
19	6/7/2024	21:47:54	0	27.05	11.9	0.5
20	6/7/2024	21:48:06	0	27.12	11.89	0.5
21	6/7/2024	21:48:16	0	27.15	11.91	0.2
22	6/7/2024	21:48:26	0	27.19	11.92	0.4
23	6/7/2024	21:48:37	0	27.21	11.89	0.4
24	6/7/2024	21:48:47	0	27.24	11.9	0.3
25	6/7/2024	21:48:57	0	27.33	11.91	0.3

Fig. 9. Logger Monitoring

4.3 Performance Testing

Performance testing is conducted to determine the accuracy of the parameters in the system compared to conventional measuring instruments. The parameters whose data are taken include voltage, current, temperature, oil level. Then the results of the comparison with the measuring instrument are compared with IEC (International Electrotechnical Commission) 13B-23 on electrical measuring instruments. The following are the results of the successful monitoring system accuracy test.

Table 1. Temperature testing

Time	Temperature		Error (C)	Percentage Error (%)	Status
	Sensor AHT10 (C)	Thermometer (C)			
7/29/2024 12:29:17	35.68	35.5	0.18	0,5	Safe
7/29/2024 12:29:32	36.47	36.2	0.25	0,7	Safe
7/29/2024 12:29:47	39.23	39.3	0.7	0,1	Safe
7/29/2024 12:30:02	43.65	43.8	0.15	0,3	Overheat
7/29/2024 12:30:17	45.87	45.2	0.67	1,4	Overheat
7/29/2024 12:30:32	48.42	48.6	0,18	0,3	Overheat
7/29/2024 12:30:47	53.41	54,1	0.69	1,2	Overheat
7/29/2024 12:31:02	57.48	58.3	0.82	1,4	Overheat
Average Error				0,74%	Accurate

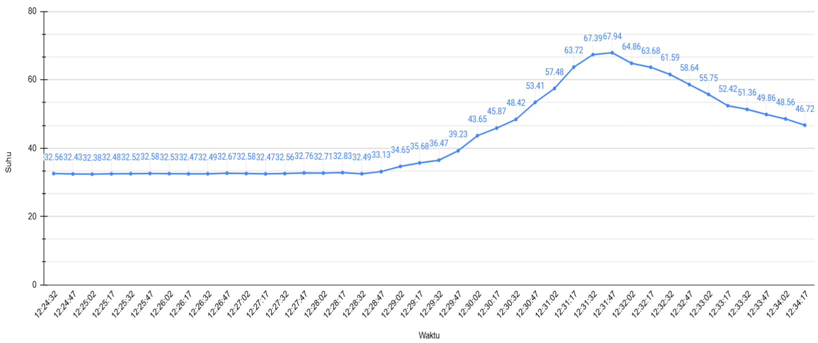


Fig. 10. Temperature Parameter Value Change Graph

Table 1 shows the results of the largest error value test, which is 1.4% when measuring temperatures of 57.48° and 45.87°, while the comparison of the smallest error value shows a value of 0.1%. The condition of the Android application shows that if the temperature is above 40°, it will provide an overheat check notification. The 2-minute test was carried out without adding temperature variations, the temperature (overheat) increased as the current value increased (overload). The results of the temperature increase value that was read were also displayed on the graph generated by the spreadsheet logger as in Figure 10. This shows that the sensor accuracy value is still in good condition.

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Table 2. Voltage Testing

Time	Trigger (V)	Voltage		Error (V)	Percentage Error (%)	Status
		Sensor INA219 (V)	Multimeter (V)			
7/29/2024 12:26:32	6	6.43	6.32	0.11	1,7	Undervoltage
7/29/2024 12:26:47	8	8.23	8.38	0.15	1,7	Undervoltage
7/29/2024 12:27:02	10	10.36	10.25	0.11	1	Safe
7/29/2024 12:27:17	12	12.26	12.39	0.13	1	Safe
7/29/2024 12:27:32	14	14.38	14.28	0.1	0,7	Overvoltage
7/29/2024 12:27:47	15	15.68	15.60	0.08	0,5	Overvoltage
7/29/2024 12:28:02	16	16.82	16.72	0.1	0,5	Overvoltage
7/29/2024 12:28:17	17	17.52	17.46	0.06	0,3	Overvoltage
Average Error					0,92%	Accurate

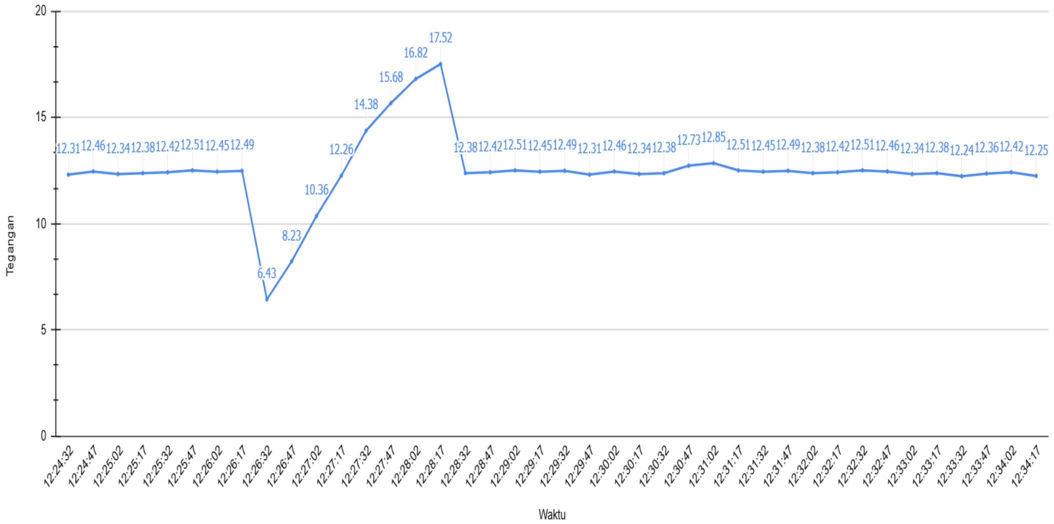

Fig. 11. Voltage Parameter Value Change Graph

Table 2 shows the results of the largest error value test, which is 1.7% when measuring the 6V and 8V voltage triggers, while the comparison of the smallest error values shows a value of 0.3%. The condition of the Android application shows that if the voltage is above 14V, it will provide an overvoltage check notification, while below 10V it will provide an undervoltage check notification. Then 2 minutes are added to the voltage variation value to produce an overvoltage or undervoltage condition. The results of the voltage increase value that is read are also displayed on the graph generated by the spreadsheet logger as shown in Figure 11. This shows that the sensor accuracy value is still in good condition.

Table 3. Current Testing

Time	Voltage (V)	Resistance (Ω)	Current Sensor INA219 (mA)	Current Ampere Meter (mA)	Error (mA)	Percentage Error (%)	Status
7/29/2024 12:28:32	12	5 W 22	540	545	5	0,9	Safe
7/29/2024 12:28:47		5 W 22	545	550	5	0,9	Safe
7/29/2024 12:29:02		5 W 22	542	560	8	3,2	Safe
7/29/2024 12:29:17		5 W 22	538	545	7	1,2	Safe
7/29/2024 12:29:32		5 W 15	786	800	14	1,7	Overload
7/29/2024 12:29:47		5 W 15	794	800	6	0,7	Overload
7/29/2024 12:30:02		5 W 15	792	800	8	0,1	Overload
7/29/2024 12:30:17		5 W 15	804	800	4	0,5	Overload
Average Error						1,15%	Accurate

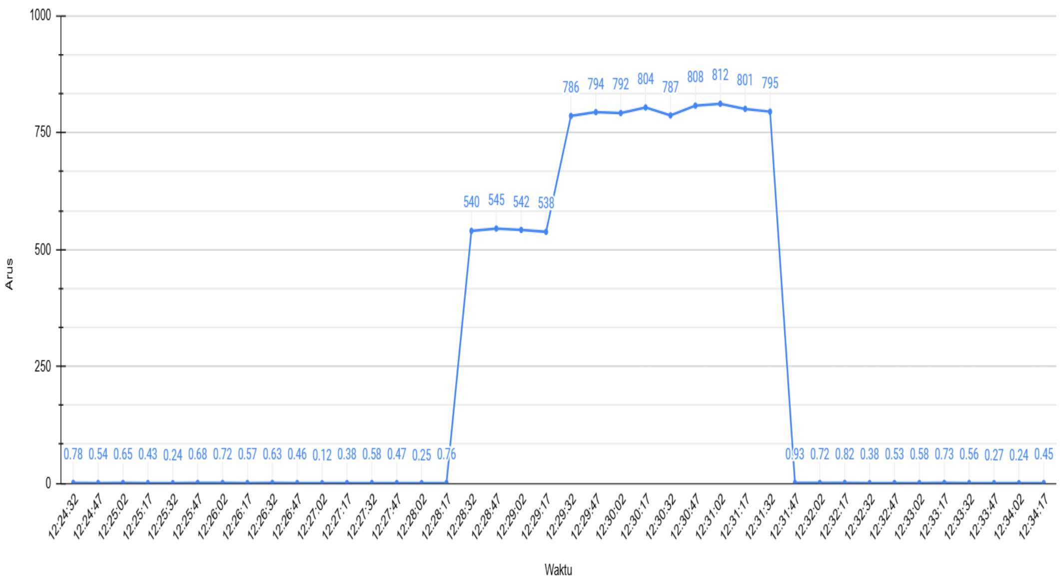

Fig. 12. Current Parameter Value Change Graph

Table 3 shows the results of the largest error value test, which is 3.2% when measuring a current of 542 mA with a 5W 22 Ω resistor load, while the comparison of the smallest error value shows a value of 0.1%. The condition of the Android application shows that if the current is above 600 mA, it will provide an overload check notification. The third 2-minute test was carried out by adding load variations 1 and load variations 2, resulting in an overload condition caused by excessive load. The results of the increase in the read current value are also displayed on the graph generated by the spreadsheet logger as in Figure 12. This shows that the sensor accuracy value is still in good condition.

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Table 4. Distance Testing

Time	Distance (cm)	Measurements		Error (cm)	Percentage Error (%)	Status
		Sensor HC-SR04 (cm)	Vernier calipers (cm)			
7/29/2024 12:32:32	5	5	5	0	0,0	Safe
7/29/2024 12:32:47	6	6	6	0	0,0	Safe
7/29/2024 12:33:02	7	7	7	0	0,0	Safe
7/29/2024 12:33:17	8	8	8	0	0,0	Safe
7/29/2024 12:33:32	10	10	10	0	0,0	Safe
7/29/2024 12:33:47	12	12	12	0	0,0	Under Oil
7/29/2024 12:34:02	13	13	13	0	0,0	Under Oil
7/29/2024 12:34:17	14	14	14	0	0,0	Under Oil
Average Error					0,0%	Accurate

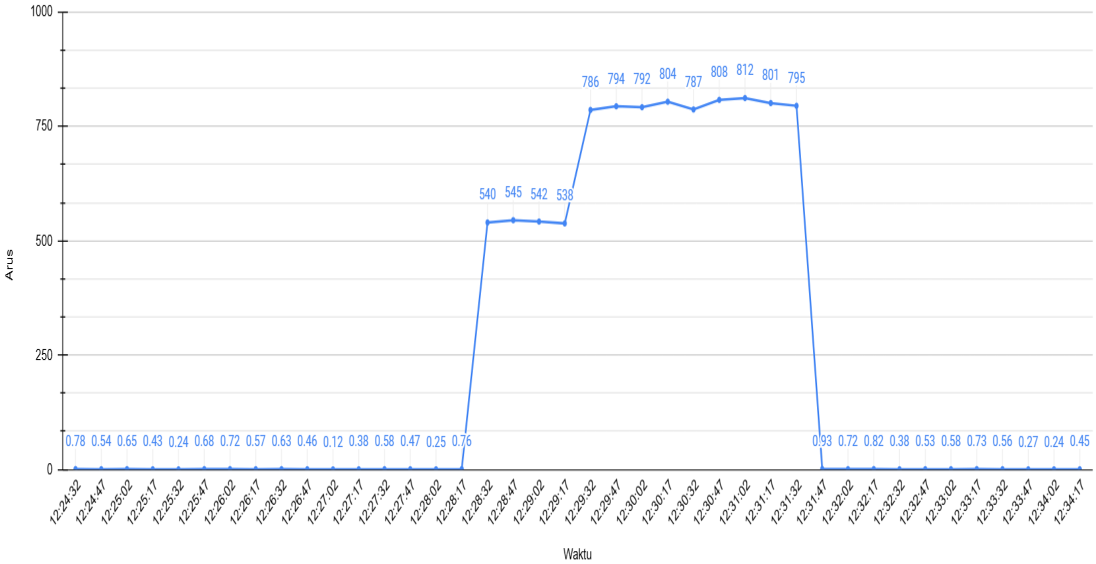

Fig. 13. Distance Parameter Value Change Graph

Table 4 shows the results of the largest error value test, which is 0.0%, while the comparison of the smallest error value shows a value of 0.0%. The condition of the Android application shows that if the temperature is above 10 cm, it will provide an underoil check notification. The 2-minute test was carried out by adding variations in oil height to produce an under oil condition. The results of the increase in the read distance are also displayed on the graph generated by the spreadsheet logger as in Figure 13. This shows that the sensor accuracy value is still in good condition.

Table 5. LCD Testing Comparison with Android Application

Time	LCD				Android Apps				Error	Results
	V (V)	I (mA)	Temp (C)	Distance (cm)	V (V)	I (mA)	Temp (C)	Distance (cm)		
7/29/2024 12:24:32	12.31	0.78	32.56	5	12.31	0.78	32.56	5	0,00	Accepted
7/29/2024 12:24:47	12.46	0.54	32.43	5	12.46	0.54	32.43	5	0,00	
7/29/2024 12:25:02	12.34	0.65	32.38	5	12.34	0.65	32.38	5	0,00	
7/29/2024 12:25:17	12.38	0.43	32.48	5	12.38	0.43	32.48	5	0,00	
7/29/2024 12:25:32	12.42	0.24	32.52	5	12.42	0.24	32.52	5	0,00	
7/29/2024 12:25:47	12.51	0.68	32.58	5	12.51	0.68	32.58	5	0,00	
7/29/2024 12:26:02	12.45	0.72	32.53	5	12.45	0.72	32.53	5	0,00	
7/29/2024 12:26:17	12.49	0.57	32.47	5	12.49	0.57	32.47	5	0,00	
7/29/2024 12:26:32	6.43	0.63	32.49	5	6.43	0.63	32.49	5	0,00	
7/29/2024 12:26:47	8.23	0.46	32.67	5	8.23	0.46	32.67	5	0,00	
7/29/2024 12:27:02	10.36	0.12	32.58	5	10.36	0.12	32.58	5	0,00	
7/29/2024 12:27:17	12.26	0.38	32.47	5	12.26	0.38	32.47	5	0,00	
7/29/2024 12:27:32	14.38	0.58	32.56	5	14.38	0.58	32.56	5	0,00	
7/29/2024 12:27:47	15.68	0.47	32.76	5	15.68	0.47	32.76	5	0,00	
7/29/2024 12:28:02	16.82	0.25	32.71	5	16.82	0.25	32.71	5	0,00	

The test results were obtained by directly testing the tool made using variations found in the prototype tool for monitoring voltage, current, temperature, and oil level in the transformer. The time taken for the test was 10 minutes with data collection every 15 seconds. The parameter values taken include voltage, temperature, current, and oil level distance. Based on table 5 above, the parameter results displayed on the android application and LCD are the same.

5. Conclusion

Voltage and current parameters are measured on the system using the INA219 sensor component, temperature parameters are measured on the system using the AHT10 sensor component, oil level parameters are measured on the system using the HC-SR04 sensor component. Sensor measurement data is processed using the NodeMCU ESP8266 microcontroller. The processed data is sent and displayed on the android application and 20x4 LCD using a WiFi network. Performance test results from the prototype system of voltage, current, temperature, oil level monitoring system on the transformer. The results obtained that the sensor accuracy is in accurate

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condition because the average error value is 0.74%, 0.92%, 1.15%, 0.0% between system measurements and measuring instruments below 5%. So according to IEC 13B-23 the measurement accuracy value on the prototype system is in accurate condition and can display notification results on the android application. The results of the tool performance test show that the system can function according to plan, namely displaying monitoring results from the android application and storing monitoring data in the spreadsheet logger

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Smart Charity Box with ESP32 and Chatbot

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ABSTRACT

The purpose of this project is to: (1) Create a security system tool on the door of the charity box at the Al Huda Mosque, Sirau Village, Kemranjen, Banyumas using the ESP32 microcontroller. (2) Know the function of all components used such as the ESP32 microcontroller, RFID, servo motor and ultrasonic sensor. (3) Know the performance test of Telegram to control the smart charity box project. Based on the design results, it shows that: (1) Produce a smart charity box tool using ESP32 components, ultrasonic sensors, RFID and servo motors as door drivers. The features it has can detect the remaining height of the charity box space and access the door via the RFID module or Telegram bot. (2) The results of functional tests on each component, both hardware such as ESP32, RFID, ultrasonic sensors, servo motors or software, can work well. (3) The results of the performance test show that this project can detect the remaining height of the space in the charity box and open the door by tapping the RFID card or accessing the Telegram bot.

Tujuan dari proyek ini adalah untuk: (1) Membuat alat sistem keamanan pada pintu kotak amal Masjid Al Huda Desa Sirau Kemranjen Banyumas dengan menggunakan mikrokontroler ESP32. (2) Mengetahui fungsi seluruh komponen yang digunakan seperti mikrokontroler ESP32, RFID, motor servo dan sensor ultrasonik. (3) Mengetahui uji kinerja Telegram untuk mengontrol proyek kotak amal pintar. Berdasarkan hasil perancangan menunjukkan bahwa: (1) Menghasilkan alat kotak amal pintar dengan menggunakan komponen ESP32, sensor ultrasonik, RFID dan motor servo sebagai penggerak pintu. Fitur yang dimilikinya dapat mendeteksi sisa ketinggian ruang kotak amal dan mengakses pintunya melalui modul RFID atau bot Telegram. (2) Hasil uji fungsional pada setiap komponen baik hardware seperti ESP32, RFID, sensor ultrasonik, motor servo maupun software dapat bekerja dengan baik. (3) Hasil uji kinerja menunjukkan bahwa proyek ini dapat mendeteksi sisa ketinggian ruang di kotak amal dan membuka pintunya dengan mengetuk kartu RFID atau mengakses bot Telegram.

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1. Introduction

Technology according to KBBI has the meaning of one of the scientific methods to achieve concise or practical goals, technology is also one of the applied knowledge. Technology cannot be separated from life because it has become an important part. Humans have known and used technology since hundreds of centuries ago, starting from symbols or signals. The development and growth of science and technology can be seen since the beginning of the emergence of humans [1]. Since that time, humans have had knowledge related to the situation and conditions of the surrounding nature. In addition, humans at that time have also created several technologies that can be used as answers to problems that can be accepted at that time.

The development of technology today is increasingly rapid, requiring humans not only to use technology, but also to have the ability to improve their skills in making innovative tools to facilitate daily activities. Technology is developing very rapidly starting from the fields of education, security, economics, communication and so on. Currently, digital technology has shifted from using human power to a computerized system that can be read by computers. The development of this technology is increasingly advanced, driven by the ability of humans to innovate and be creative.

One thing that is no less important than the development of technology itself is the security system. Security systems are a form of prevention from criminal acts or threats in the surrounding environment. In everyday life such as worship or charity, security systems are also no less important, especially for charity boxes in mosques. Mosques are places of worship for Muslims or places of prayer for Muslims, mosques are not only used as places of prayer but also as places to carry out all activities that contain spirituality or obedience to Allah SWT.

"Design and Construction of Charity Box Security with Fingerprint Access Using ESP32-Cam and IoT-Based Telegram". In this study, two controllers were used, the first main controller used as a data processor for the design, namely using Arduino UNO and the second using ESP32-cam as a receiver that will send notifications to telegrams in the form of photos or sentences explaining that the image from ESP32-cam has been sent. In addition, this study also uses two input sensors, namely fingerprints by attaching the registered fingerprint which will give a command to the solenoid to open and vice versa. The Limit Switch Sensor is used as a detector when the charity box door is opened by force, the buzzer will sound [2].

"Design and Construction of a Security System for a Punia Fund Box Based on a NodeMCU ESP32 Microcontroller and Telegram Application". In this study, the main controller used is the NodeMCU ESP32. Then the telegram application as monitoring to send notifications. This study also utilizes a magnetic sensor that can send notifications in the form of theft and a fingerprint sensor as access to open the punia fund box. The conclusion of this study is that the project can work well which is indicated by the functioning of all components used [3].

"Cash Charity Box Security System with Integrated Telegram Based on ESP32 Microcontroller". In this study, the design begins by using the block diagram method, selecting specifications or functions that are in accordance with the block diagram, designing flowcharts, installing hardware or circuits and programming the system. The main controller used in this study is using ESP32 as a data processor from sensors that can be connected to Wi-Fi and Arduino Nano controller for MP3 modules. This study uses a SW-420 vibration sensor to detect vibrations, a KY-036 sensor to detect metal and RFID as access to open and close the door lock [4].

"Door Security System with Android Using NodeMCU". In this study, the main components used are ESP8266 and solenoid door lock which are able to send notification messages as well as reply messages to telegrams to open or close the solenoid. The results of the experiments carried out were by opening and closing the door lock 7 times with an average delay time needed when giving the command to the device to open, namely 1.72 seconds and 1.68 seconds to close the door [5].

In general, the causes of theft include, among others, the opportunity to easily take valuables without being detected, the lack of security in places that are loopholes for theft, items that are easily stolen are valuables such as money, jewelry, electronics and other valuables, poverty felt by thieves so that thoughts arise to steal, environmental problems that are less safe or have minimal lighting, then the opportunity to commit crimes without significant consequences, meaning that the punishment for theft is not comparable to the stolen goods obtained. The author will create a security system based on the above problems in the form of a smart lock with ESP32, door access with RFID which can later only be opened or closed by mosque officers who have RFID cards that have been listed in the program. Then the author also adds a component in the form of an ultrasonic sensor that functions as a detector of the height or fullness of the money in the charity box and can later be sent via the Telegram API according to the program that has been created.

2. Problem Solving Approach

2.1 Smart Lock

Smart lock is a door lock security system that can be controlled with a mobile device, application or voice command [6]. One way to operate a smart lock is by using RFID or Radio Frequency Identification which is connected to the internet and some are not connected. The main function of a smart lock is to increase security compared to conventional locks, one of which is because the smart lock has the ability to record traces of entry and exit access where the owner is able to track who and when accessing the smart lock. In this study, the author created a smart lock project on a charity box that can be connected to the internet which can be seen as a notification with the telegram application. How the project works is that mosque officers who manage the charity box can access it by sending a message to the Telegram bot that has been created. In the Telegram bot there is an option "/ open" as a servo drive access connected to the door latch and "/ status" as monitoring to find out the height of the money in the charity box.

2.2 *ChatBot* Telegram

Telegram is a cloud-based application that is often used to send and receive messages, videos, share photos, voice and data [7]. The way to access the Telegram application is to have a data package or internet network. One of the telegram features that can be connected to the ESP32 microcontroller is the Telegram chatbot or Telegram bot, which is an account controlled by a virtual chat robot to answer questions from its users [8]. The answer to the command provides information or can execute a command from its user according to the command in the telegram. The benefits of this Telegram chatbot are to provide responses in a short time, can save costs, complete features and so on.

3. Tool Design

The process of making the project "Design and Construction of Smart Charity Boxes at Al Huda Mosque, Sirau Village, Kemranjen, Banyumas" consists of several stages, namely needs analysis, tool design, tool making, tool testing. The following is a flow diagram of the project making process:

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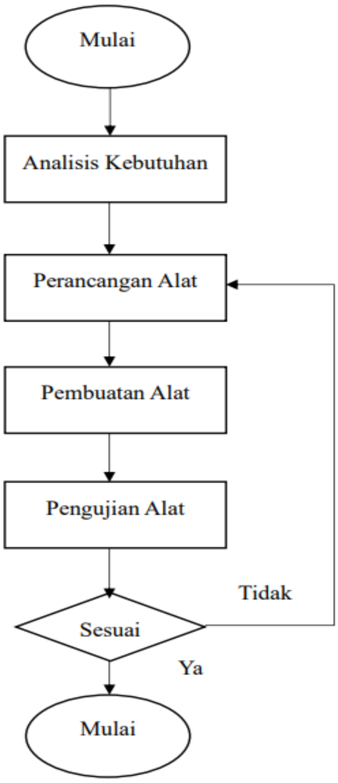

Fig. 1. Research Flow Chart

Needs analysis is the initial stage of research that aims to find out what needs will be needed before making a smart charity box design project at Al Huda Mosque, Sirau Village, Kemranjen, Banyumas. This analysis is carried out by conducting field observations and literature studies. Field observations are steps taken by observing what can be developed into a project and the title of the Final Project, while literature studies aim to find out what needs are needed to overcome problems found from the results of field observations.

3.1 System Flowchart

The image below is a working design of the system on the smart charity box. Access is used to open the charity box by tapping the RFID card or by sending the command "/open" to the Telegram bot that has been created.

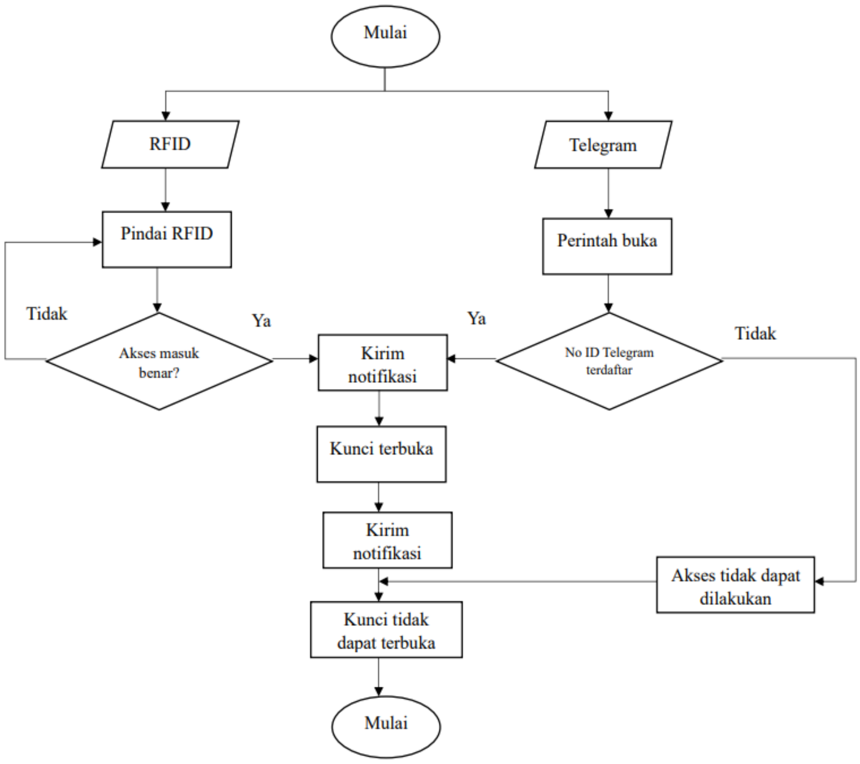

Fig. 2. RFID System Design

Ultrasonic sensors are used as detectors of the height of money in the charity box by sending a notification "/status" via the Telegram application. The flowchart design is made based on the placement of the components and software needed.

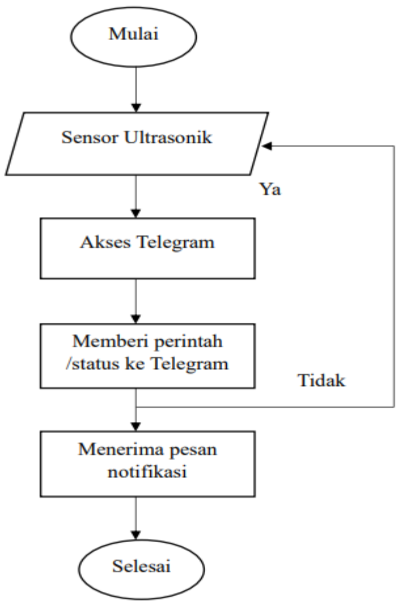

Fig. 3. Ultrasonic Sensor System Design

3.2 Hardware Design

Hardware design is divided into two, namely making electrical designs to design electrical wiring diagrams and making mechanical designs to design the physical form of the tools and

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mechanical components made. The following are the results of making hardware designs:

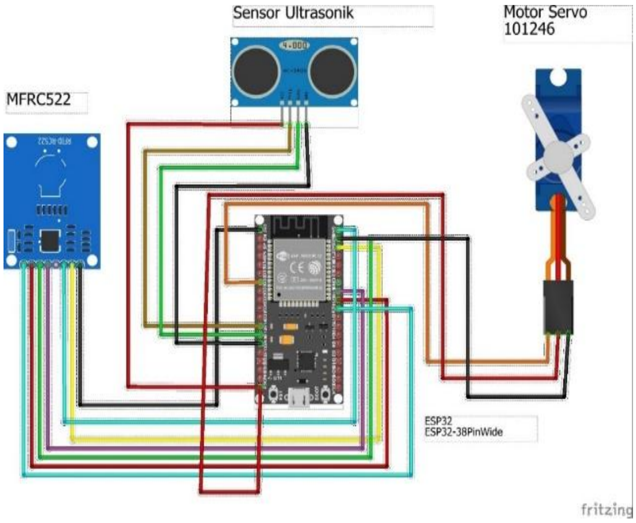

Fig. 4. *Wiring* Diagram

The image above is a wiring as a regulator of the design of use on each pin in components such as ESP32, RFID, Servo Motor and Ultrasonic Sensor. In addition to the wiring components, a charity box is also needed to store money and components used. The following is a design for a smart charity box project circuit.

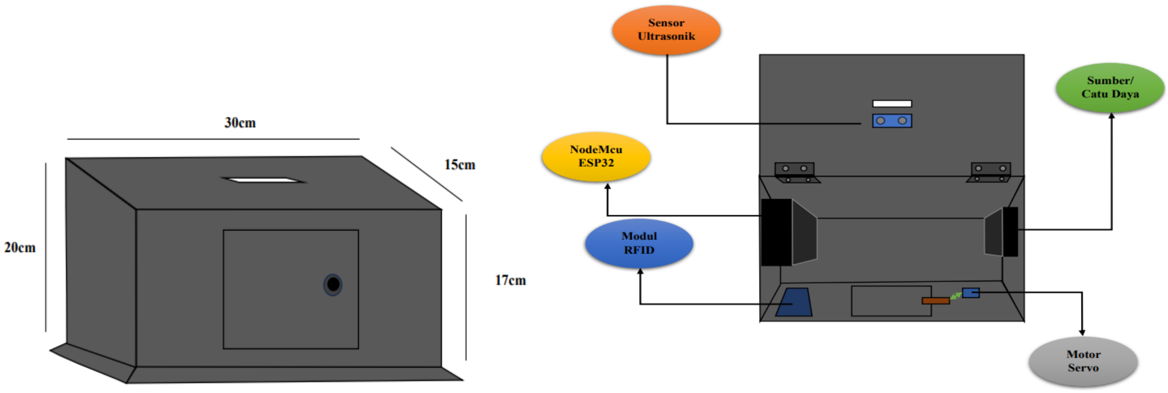

Fig. 5. Smart Charity Box

3.3 Software Design

The next stage is the creation of design and software design which aims to find out the process of creating a program from the smart charity box project. The creation of this program uses Arduino IDE software, the program contains to command ESP32 as a controller or controller of all components needed. The function of the components used is RFID to access the door lock using a registered RFID card or Telegram bot, then the servo motor as a door latch driver by accessing RFID first and an ultrasonic sensor as a detector of remaining space in the charity box. In addition to using Arduino IDE software, the Telegram application is also needed to send and receive message notifications, the following is a display of the Arduino IDE software and Telegram application.

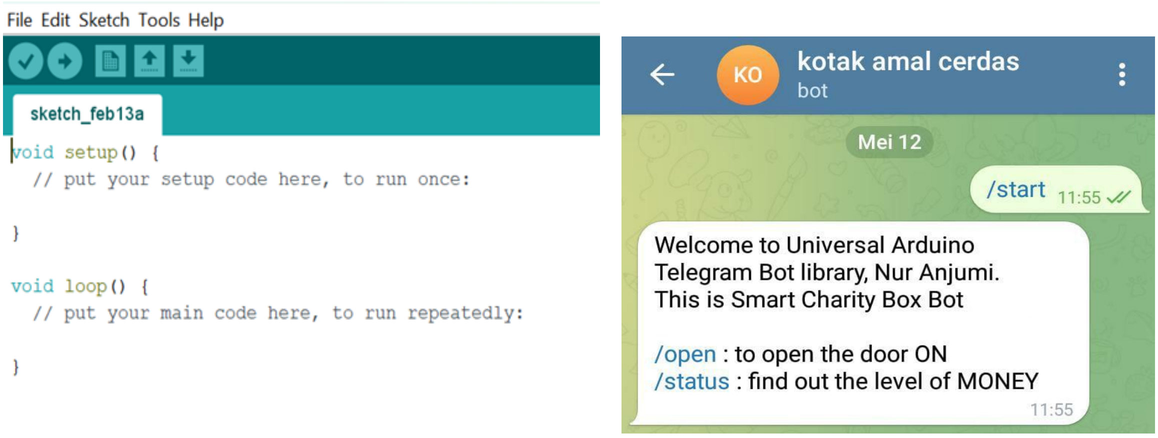

Fig. 6. View of Arduino IDE and Telegram Bot @smart charity box

4. Result and Discussion

4.1 System Hardware Creation Results

The results of making hardware consist of making electrical systems and mechanical systems. The electrical system is assembling all the tools and materials starting from installing cables to components to ESP32 properly and correctly according to the wiring diagram path that has been made and placed in a box-shaped box. The following is the result of the design of the smart charity box that has been made.

Fig. 7. Smart Charity Box

4.2 Results of System Software Creation

The creation of system software consists of two parts, namely creating a program using the Arduino IDE software and creating a display on the Telegram application. The following are the results of creating a program in the Arduino IDE software. The creation of the ESP32 program was done using the Arduino IDE software. The function of the ESP32 is as a controller for each component in this project so that it runs according to the function we want. ESP32 also has a feature in the form of Wi-Fi as a data sender so that it can read sensors to the IoT platform.

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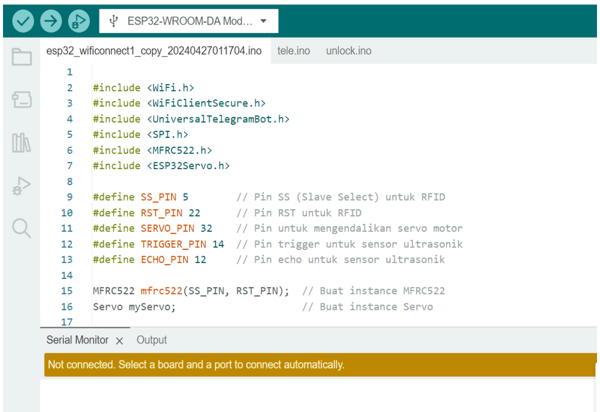

Fig. 8. Arduino IDE Programs

Telegram chatbot or commonly called Telegram bot is an account controlled by a virtual chat robot to answer questions from its users [8]. The answer to the command provides information or can execute a command from its user according to the command in the telegram. The benefits of this Telegram chatbot are to provide a response in a short time, can save costs, complete features and so on.

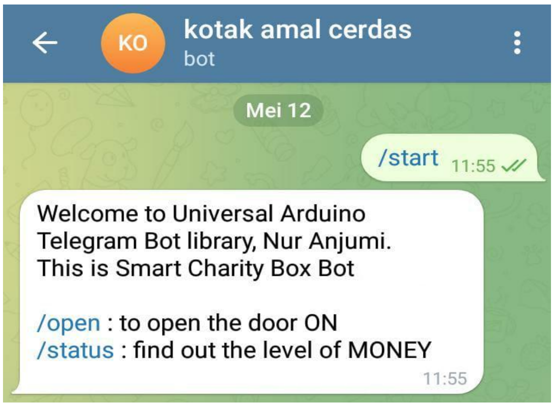

Fig. 9. Smart @charitybox Bot View

4.3 Performance Test Results

Project testing is the final stage in the creation of a smart charity box design tool at the Al Huda Mosque, Sirau Village, Kemranjen, Banyumas. At this stage, the Telegram chatbot is named @smart charity box, for testing the chatbot, it begins by giving a command in the form of "/start", the command "/open" to unlock the charity box and the command "/status" to find out the remaining height of the charity box space. The results of these commands can be seen in the table below, in addition to using the Telegram bot to access the door lock, the smart charity box can be accessed by tapping the RFID card whose UID has been registered in the program that has been created.

Table 1. Smart Charity Box Performance Test Results

No	Order	Trial Steps	Telegram View	Trial Results	Time Required
1.	“/start”	Type the command “/start” on Telegram. (@smart charity box)	A description is displayed that describes the name of the project created.	The menu can be displayed and can be used properly.	The time required to access this is 5 seconds according to the signal strength on the

		Then a menu such as "/open" and "/status" is also displayed.		cellphone and ESP32 with the XL AXIATA provider
2. "/open"	Type or click the "/open" command on Telegram. (@smart charity box)	Displays information that the door is open.	Information description can be displayed properly.	The time required to access this is 5 seconds according to the signal strength on the cellphone and ESP32 with the XL AXIATA provider
3. "/status"	Type or click the "/status" command on Telegram. (@smart charity box)	Displays information about the remaining height of the space in the charity box.	Information description can be displayed properly.	The time required to access this is 5 seconds according to the signal strength on the cellphone and ESP32 with the XL AXIATA provider
4. Tag RFID	Tapping the RFID module using RFID tags that have been registered in the program and those that have not been registered	Tapping notifications will appear on the Telegram bot (@smart charity box).	Notifications can be displayed properly on the Telegram bot (@kotak amal cerdas). The RFID tag that has been registered in the Arduino IDE program on this bot will provide a notification in the form of (Door Open!), then a trial using an unregistered RFID tag will display information in the form of (Access Failed/Denied!)	The time required to access this is 5 seconds according to the signal strength on the cellphone and ESP32 with the XL AXIATA provider

The table above is data from the trial project that has been created, the results of which are all components and notifications on the Telegram bot can function properly. This point will be explained regarding the discussion of how it works, access and trial images. How it works is the same as a smart lock in general, namely access to open and close without using a conventional door key. The author created this tool with Telegram API access and RFID tags, here are the steps:

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1. Enable Wi-Fi on your smartphone to connect the network to ESP32, after connecting to the network open the Telegram API (bot @kotak amal cerdas) then type "/start" to start. The image below is the initial display when giving the command "/start" to the kotak amal cerdas bot.

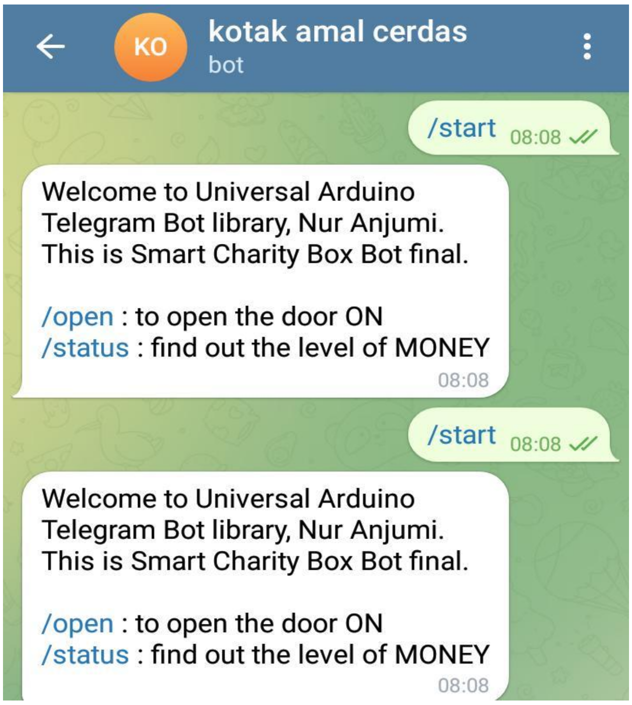

Fig. 10. Initial View "/start"

2. Next, to unlock it can be done in two ways, namely by accessing the Telegram API and RFID tags. Telegram bot @kotak amal cerdas type or select the option "/open" to be able to open the door latch. When it is open, Telegram will provide a notification in the form of an information message that the door has been opened such as "Door Open!". Then the RFID tag is used as tapping by bringing the RFID tag close to the RFID module. This experiment was carried out using two RFID tags that have been registered and unregistered in the Arduino IDE program, the following are the results of the trial.

Fig. 11. "/open" Command View

Figure 12 below is the result of the serial monitor by tapping an RFID card that is not registered in the Arduino IDE program with the UID tag 4E 7E 3E 7A.

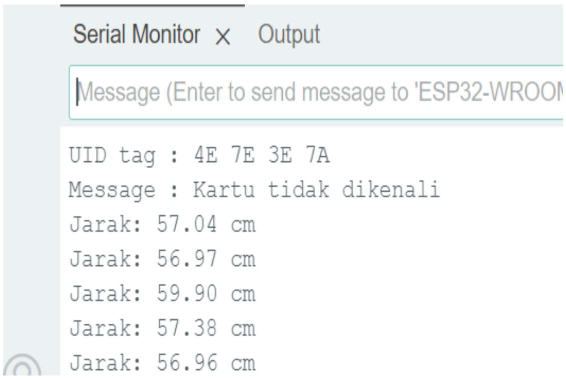

Fig. 12. RFID Card View Rejected

Figure 13 below is the result of the serial monitor by tapping the RFID card registered in the Arduino IDE program with the UID tag 53 87 21 AC.

Fig. 13. Tapping Registered RFID Card

Figure 14 below is a display of the smart charity box Telegram bot when trying to open the door with an incorrect RFID card or one that is not registered in the Arduino IDE program.

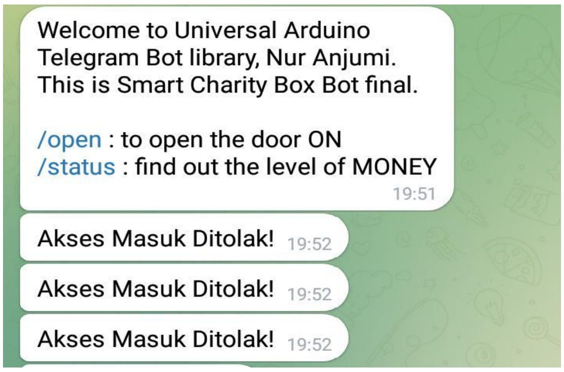

Fig. 14. Tapping Unregistered RFID Card

3. The experiment to find out the remaining height of the money space in the charity box was carried out by accessing the Telegram bot @smart charity box. Type or select the option "/status", if the ultrasonic sensor has been installed and detected the bot will send a notification in the form of an information message regarding the remaining height of the money space in the charity box. For example, the information message is "Remaining space in the charity box: 14.85cm", the following are the results of the notification test on the Telegram bot and the Arduino IDE serial monitor.

Fig. 15. "/status" Command View

Figure 16 below is the result of measuring the distance on the serial monitor which was measured using an ultrasonic sensor component.

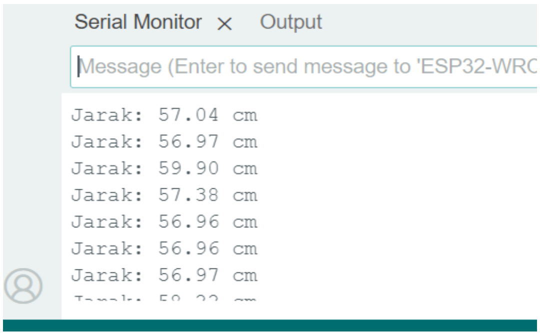

Fig. 16. Distance Display On Serial Monitor

5. Conclusion

The final project entitled "Design and Construction of Smart Charity Boxes at Al Huda Mosque, Sirau Village, Kemranjen, Banyumas" uses an ESP32 controller, RFID as door opening access, then an ultrasonic sensor as a detector of the remaining height of the space in the charity box and a servo motor as a door latch driver to open the charity box. The features of this project are that it can detect the remaining height of the space in the charity box and access the door via an RFID module or Telegram bot. Functional tests of each component that have been carried out such as ESP32, ultrasonic sensors, servo motors and RFID can function and work well. The test results are that ESP32, RFID, servo motors are in good condition and the ultrasonic sensor has an error of between 1.3% - 3.8%. The results of the tool performance test are: (1) Can detect the remaining height of the space in the charity box with a maximum height of the box made of 15cm. (2) Can access the charity box door by tapping the RFID card. (3) Can access the charity box door by giving the command "/open" to the Telegram bot. (4) It takes 5 seconds to be able to send or receive notifications on the Telegram bot.

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Telemetry System Design for Monitoring Electrical Energy in Residential Homes

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ABSTRACT

This project aims to (1) create and design a telemetry system for monitoring electrical energy in residential homes, (2) determine the functional tests of each component used, and (3) determine the performance tests of the tools being made. The manufacturing and testing process for this tool was carried out at the Electrical Installation Laboratory, Vocational Faculty, Yogyakarta State University. The data analysis technique used is calculating the percentage error between the tool data created and standard measuring tool data. The results obtained are (1) an electrical energy monitoring system was produced with components in the form of an ACS712 current sensor, ZMPT101B voltage sensor, Arduino Uno, NodeMCU ESP8266, LCD 20×4, buzzer, and Blynk application. (2) The functional test results show that each component has a good accuracy value. The error percentage level from sensor testing shows a value below 5%, so the sensor accuracy is good. (3) The results of system performance testing also show quite high accuracy. The highest percentage error rate was 4.4%, namely in refrigerator current and energy-saving lamp power factor data.

Proyek ini bertujuan untuk (1) membuat dan merancang sistem telemetri untuk monitoring energi listrik pada rumah tinggal, (2) mengetahui uji fungsi setiap komponen yang digunakan, dan (3) mengetahui uji kinerja alat yang dibuat. Proses pembuatan dan pengujian alat ini dilakukan di Laboratorium Instalasi Listrik Fakultas Vokasi Universitas Negeri Yogyakarta. Teknik analisis data yang digunakan adalah menghitung persentase kesalahan antara data alat yang dibuat dengan data alat ukur standar. Hasil yang diperoleh adalah (1) dihasilkan sistem monitoring energi listrik dengan komponen berupa sensor arus ACS712, sensor tegangan ZMPT101B, Arduino Uno, NodeMCU ESP8266, LCD 20×4, buzzer, dan aplikasi Blynk. (2) Hasil uji fungsional menunjukkan bahwa setiap komponen mempunyai nilai akurasi yang baik. Tingkat persentase error dari pengujian sensor menunjukkan nilai dibawah 5% sehingga akurasi sensor baik. (3) Hasil pengujian kinerja sistem juga menunjukkan akurasi yang cukup tinggi. Persentase tingkat kesalahan tertinggi sebesar 4,4% yaitu pada arus lemari es dan data faktor daya lampu hemat energi.

1. Introduction

The rapid development of technology causes changes in several things in life. The development of this technology certainly has benefits, namely that it can make human work easier to make it more effective (Kidi, 2018). An example of these changes is the development of electrical equipment to make household work easier, such as washing machines, water pumps, electric irons, refrigerators, and so on.

The use of electrical equipment requires a supply of electrical energy. In Indonesia, the electrical energy supply is managed by PT. PLN, so that policies on electricity user groups and electricity rates per group are also regulated by PT. PLN. Where is the electricity payment to PT. PLN is divided into two types, namely prepaid and postpaid.

For residential scale consumers, there are no devices used to monitor electrical energy completely, where in the monitoring system there are quantities of current, voltage, power, energy and electricity usage costs during a certain period. So that residential electricity consumers who subscribe to electricity using a prepaid or postpaid system cannot know the amount of electricity used. In fact, monitoring electrical energy in residential homes needs to be carried out so that the use of electrical energy in residential homes can be monitored in real time, as well as being able to find out various things that occur in residential electricity usage, such as excessive increases in loading voltage (Setiawan, 2022).

Based on the things described in the paragraph above, the author plans to design a telemetry system for monitoring electrical energy in residential homes. The design of this monitoring system aims to properly monitor the use of electrical energy in each electrical equipment in the home, so that electrical energy consumption can be regulated. Furthermore, the aim of using a telemetry system is so that the monitoring process can be carried out remotely in real time.

2. Problem Solving Approach

2.1 Electrical Energy

Electrical energy is a source of energy that is produced due to the movement of electrons from one place to another. The transfer of electron flow occurs due to the potential difference between one place and another. Electrical energy is produced when electrons move through a conductor. So if there is an electric voltage at the ends of the conductor, electrons start to move from one end to the other. These conditions will create the flow of electric current (Aliyah, 2024).

In general, electrical energy comes from various sources, namely hydroelectric power plants, wind power, solar power and fossil fuels. Where these materials do not produce greenhouse gas emissions. In this way, electricity becomes an alternative choice to reduce negative impacts on the environment and overcome climate change.

Electrical energy can be determined by multiplying the voltage value, current value, power factor and load usage time. The following is the formula for calculating electrical energy:

$$\boldsymbol{W = V \times I \times cos\varphi \times t} \tag{1}$$

Where :
W = Power
V = Voltage
I = Current
Cos φ = Power Factor
t = Time

2.2 Electricity Tariffs

Electricity tariffs are the amount of fees paid by electricity consumers to holders of Business Permits for Providing Electricity for Public Use (IUPTLU) who have Business Areas as producers. Electricity tariffs are determined by the Minister of Energy and Mineral Resources (ESDM) after

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obtaining approval from the DPR (Director General of Electricity, 2024). Electricity consumers are divided into three categories, namely residential, commercial and industrial electricity consumers. The types of loads and use of electrical energy for the three categories of electricity consumers are of course different, so the electricity rates are also different. Based on adjustment tariff data on the PLN website, the electricity tariff for residential consumers in the R1/T-R category with a power limit of 900VA is IDR 1,532,- during off-peak load times and during peak load times.

2.3 Telemetry System

Telemetry is the process of measuring the parameters of an object, which can be an object, space or natural conditions, the results of the measurement are sent to another device through a data transmission process either using cables or without cables (wireless), then the data is utilized directly or used for analysis purposes. . In general, a telemetry system consists of six supporting parts, namely measuring objects, sensors, transmitters, transmission channels, receivers, and displays. Long distance data transmission allows measurement data to be accessed from locations far from the measurement process taking place. (Rovianto, et al., 2008)

Alternative communication media for telemetry systems are not limited to cable, wireless, satellite or GSM. However, because telemetry systems are usually used as long-distance monitoring tools, the most widely used communication media is wireless.

2.4 Blynk

Various platforms for monitoring purposes are Thingspeak, Firebase, Arduino IoT Cloud Remote, Domoticz, Adafruit IO, and Blynk. The author chose the Blynk application as a data viewer on a cellphone. Blynk has three main components, namely Blynk app, Blynk server, and Blynk libraries. Blynk app is a mobile application available on iOS and Android which is a user interface where users can create dashboards to monitor and control IoT devices. Then there is the Blynk server which is an intermediary between applications and hardware. Meanwhile, finally there are Blynk libraries, which are libraries that are integrated with various hardware platforms such as Arduino, Raspberry Pi, ESP8266, and others. This library allows the hardware to communicate with the Blynk server and control it through the application. There are several advantages of Blynk compared to other monitoring applications, including:

- **Easy use**
  The intuitive, drag-and-drop user interface makes it very easy for users to create dashboards and applications without needing much programming experience.
- **Wide compatibility**
  It supports a wide variety of hardware platforms and provides libraries for various programming languages.
- **Monitoring and Control**
  Ability to monitor and control devices in real-time via mobile application with a very easy to understand dashboard display.
- **Complete libraries**
  Blynk has libraries that support up to 400 microcontroller boards, such as Arduino, ESP8266, ESP32, Raspberry Pi, and many more.
- **Connectivity**
  Blynk can be used not only via a WiFi connection but can also be connected to Ethernet, Cellular (GSM, 2G, 3G, 4G, LTE), and LoRaWAN connectivity (Anonymous, 2024).

Several advantages that have been stated above were the main considerations for the author in choosing Blynk as the monitoring media for this final project.

3. Device Design

Research methods are the steps taken so that research can be successful. The steps that will be carried out for this research are explained in the following research flowchart:

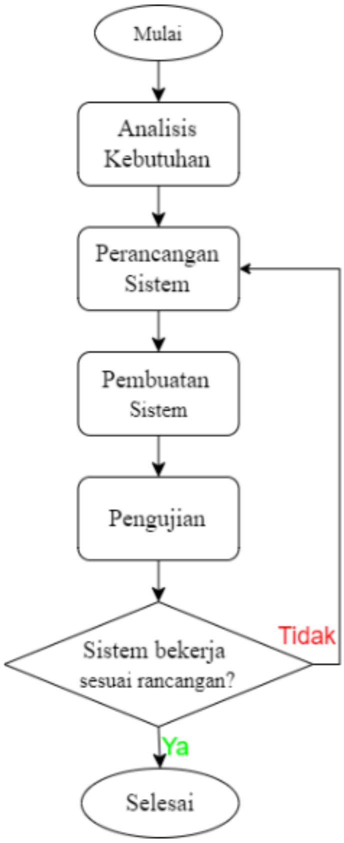

Fig. 1. Research Flowchart

Needs analysis is the first step in carrying out this research, which aims to find out what is needed to create a telemetry-based electrical energy monitoring system in residential homes. This needs analysis was carried out by means of field observations and literature studies.

Field observations are carried out by observing what things can be developed into the title of the Final Project for a residential house. This observation was carried out for about one week and the results obtained were that there was no telemetry system for monitoring electrical energy in residential homes which could monitor current, voltage, power, energy and cost values in one monitor. So far, monitoring of electrical energy can only be done by monitoring kWh meters, so monitoring cannot be done remotely.

After making observations, the next step is to conduct a literature study. This literature study was carried out with the aim of knowing what things are needed to overcome the problems found during field observations. This literature study was carried out by reading online journals, online theses and websites. After conducting a literature study, it can be seen that monitoring electrical energy in residential homes needs to be carried out so that the use of electrical energy in residential homes can be monitored in real time, as well as being able to find out various things that occur in residential electricity use, such as an increase in excessive loading voltage (Setiawan, 2022).

3.1 Design Flowchart

The first stage in the system design process is making a flowchart for the design of the device to be made, namely a telemetry system for monitoring electrical energy in residential homes. Figure 2 below is a flowchart for the design of the tool to be made:

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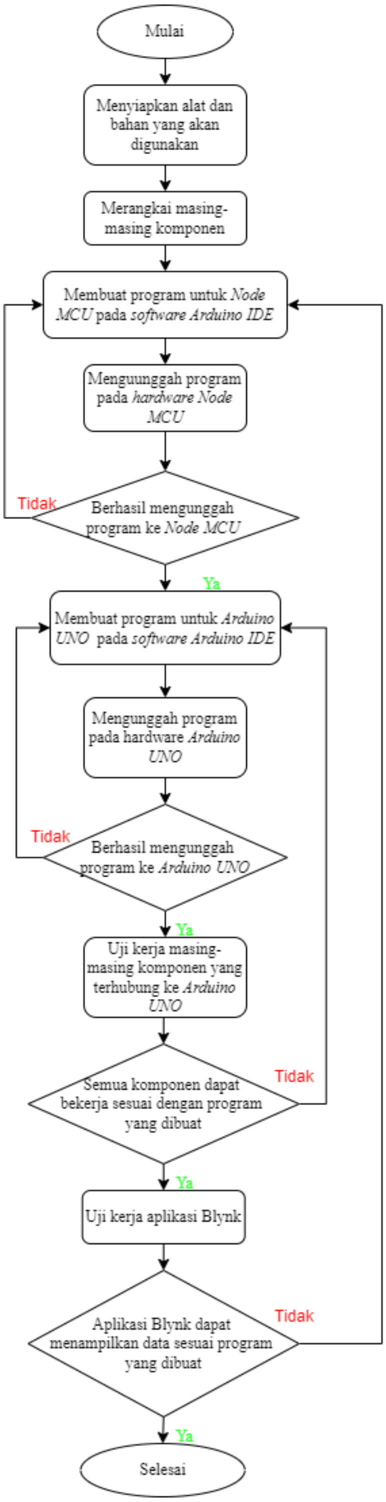

Fig. 2. Design Flowchart

3.2 Block Diagram

This block diagram is made so that the system work process can be more easily understood. Figure 3 shows the block diagram of this final project.

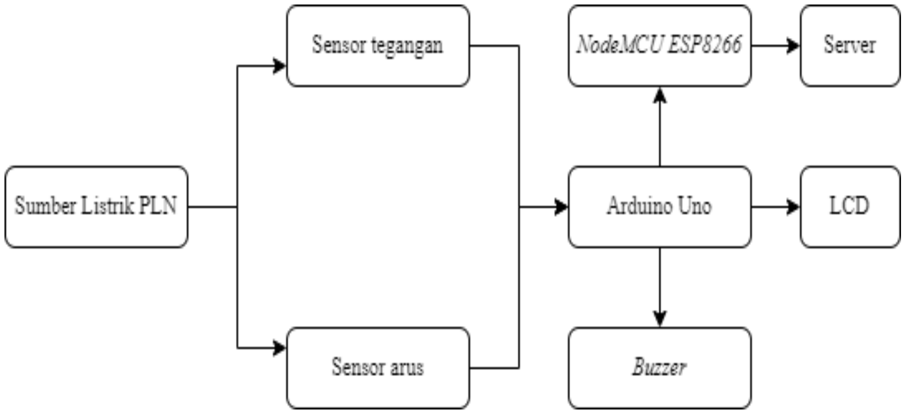

Fig. 3. Block Diagram

The way this system works starts from a voltage sensor and a current sensor which take data from the installed load. Next, the data from the sensor readings will be processed using the Arduino Uno microcontroller. The results of data processing on the Arduino Uno will be displayed on the 20×4 LCD. Furthermore, the results of data processing by Arduino Uno are also displayed in the Blynk application with the help of NodeMCU. The Arduino is also connected to a buzzer where if the time shows less than 2 (two) minutes before the initial reset, the buzzer will sound and electricity usage costs can be monitored.

3.3 Wiring Diagram

The wiring diagram is designed so that the connections between the components used can be identified. The purpose of making this wiring diagram is to make it easier to assemble each component used. Furthermore, this wiring diagram can also function as a reference in carrying out repairs if there are errors or deficiencies when testing the system. This wiring diagram design was created using Fritzing software. Figure 18 shows the wiring diagram design that has been created.

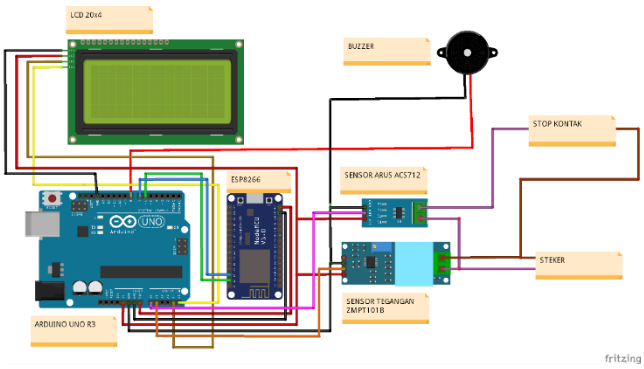

Fig. 4. Wiring Diagram

3.4 Software Design

The next step in the device design process is software design. The aim of designing this software is to understand the coding process for a telemetry system for monitoring electrical energy in residential homes. The software design process is divided into two stages. The first stage is making the main coding in the Arduino IDE, where two codes will be made to be uploaded to the Arduino Uno R3 and NodeMCU ESP8266 hardware respectively. Next, the second stage is creating a dashboard on the Blynk website which is used as a remote monitoring device. Figure 5 below is the default display of the Arduino IDE software:

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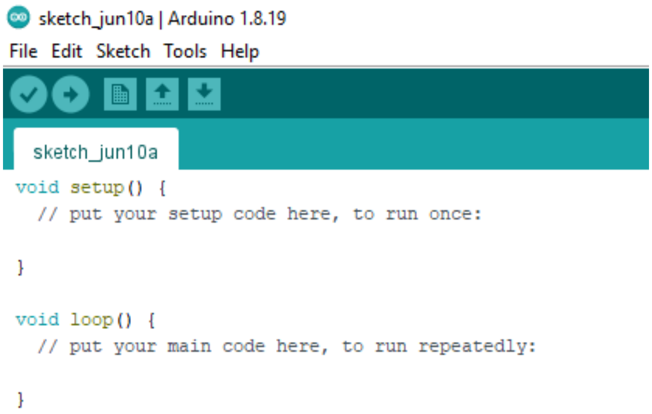

Fig. 5. Arduino IDE Default Display

Furthermore, the platform used to carry out remote monitoring of the telemetry system design for monitoring electrical energy in residential homes is Blynk. Figure 6 is a display of the Blynk Website.

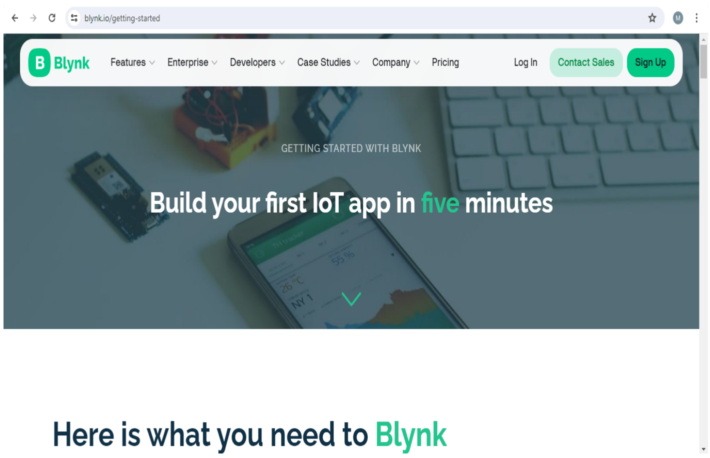

Fig. 6. Blynk Default Display

The image above is the initial appearance of the Blynk website. The first step to take if you want to create a project is to create an account first. Once the account has been created, the next step is to create a template and fill in the name of the template, the hardware used and the type of connection used. The next step is to create a datastream for the project to be created. Creating the datastream begins with selecting the type of pin that will be used, then filling in the data according to the project parameters. The data that must be entered is the parameter name, pin number, data type, units, as well as the minimum and maximum values of the data displayed. The next stage is to add widgets to the dashboard. Widgets function to display data and control devices.

4. Results and Discussion

4.1 The Results of Creating System Hardware

The stages of making hardware are divided into two, namely making mechanical systems and electrical systems. Making an electrical system is the process of assembling each component according to the wiring diagram design that has been made. while making a mechanical system is making a box design that is used to place the electrical circuit. Figure 7 below is the result of making an electrical and mechanical system.

Fig. 7. Hardware Manufacturing Results

4.2 The Results of Creating System Software

Making software for the telemetry system for monitoring electrical energy in residential homes is divided into two, namely making coding for the Arduino Uno as the main microcontroller and coding for the NodeMCU ESP8266 as a WiFi module. The program for the Arduino Uno will function as a command to control components such as the current sensor, voltage sensor, LCD and buzzer. Arduino Uno will also send data to the NodeMCU ESP8266 to be displayed in the Blynk application. Meanwhile, the program for the NodeMCU ESP8266 contains commands to receive data from sensors sent by the Arduino Uno, then the data is displayed on the Blynk application. Figure 8 below is the result of creating system software

Fig. 8. The Result of Creating System Software

4.3 System Performance Test Results

4.3.1 System Voltage Test Results

Table 1 is data from voltage readings by the ZMPT101B sensor which has been assembled in the system and compared with voltage measurement data from a multimeter. Based on Table 24, it can be seen that the sensor accuracy level shows good results because the error percentage is still below 5%. The highest error percentage was found in the cell phone charger load, namely 1%, while the lowest error percentage was found in the large fan load, namely 0.047%.

Table 1. System Performance Accuracy Testing Results

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Load	Measurement Results		Difference	%*Error*	Hasil
	Measuring Instrument (V)	Voltmeter (V)			
Small Fan	214,2	215	0,0037	0,37%	Normal
Cell phone charger	209,2	211,3	0,001	1%	Normal
Night light (filament)	212,1	212,6	0,0024	0,24%	Normal
Refrigerator	213,7	214,08	0,0018	0,18%	Normal
Magic jar	209,6	210,9	0,0061	0,61%	Normal
Dispenser	207,6	208	0,002	0,2%	Normal
Hair dryer	210,1	211	0,0043	0,43%	Normal
Big Fan	213,1	213	0,00047	0,047%	Normal
Iron	207,1	208	0,0043	0,43%	Normal
Laptop Charger	213,6	214,3	0,0032	0,32%	Normal
Energy Saving Lamps	214,7	215	0,0013	0,13%	Normal

4.3.2 System Current Test Results

Table 2 is data from current readings by the ACS712 sensor which has been assembled in the system and compared with current measurement data from ampere pliers. Based on Table 2, it can be seen that the sensor accuracy level is good because the error percentage is still below 5%. The highest error percentage was found in the refrigerator load, namely 4.4%, while the lowest error percentage was found in the hair dryer load, namely 1.3%.

Table 2. System Current Performance Accuracy Testing Results

Load	Measurement Results		Difference	%*Error*	Results
	Measuring Instrument (A)	Amperemeter (A)			
Small Fan	0,15	0,145	0,034	3,45%	Normal
Cell phone charger	0,2	0,204	0,019	1,96%	Normal
Night light (filament)	0,11	0,112	0,018	1,8%	Normal
Refrigerator	0,59	0,617	0,044	4,4%	Normal
Magic jar	0,25	0,264	0,014	1,4%	Normal
Dispenser	1,17	1,2	0,025	2,5%	Normal
Hair dryer	1,48	1,5	0,013	1,3%	Normal
Big Fan	0,24	0,246	0,024	2,4%	Normal
Iron	1,13	1,1	0,027	2,7%	Normal
Laptop Charger	0,31	0,325	0,015	1,5%	Normal
Energy Saving Lamps	0,14	0,145	0,034	3,4%	Normal

4.3.3 System Power FactorTest Results

Table 3 below is data from a comparison of the power factor value on the measuring instrument made and the power factor measurement value on the cosphimeter. The comparison results show that the error percentage is not too high. The highest error percentage was found in the Energy Saving Lamp load, namely 4.4%, while the lowest error percentage was found in the night light (filament) load, namely 1.8%.

Table 3. System Power Factor Performance Accuracy Testing Results

Load	Measurement Results		Difference	%*Error*	Results
	Measuring Instrument	Cosphimeter			
Small Fan	0,4	0,41	0,024	2,4%	Normal
Cell phone charger	0,34	0,35	0,029	2,9%	Normal
Night light (filament)	0,55	0,56	0,018	1,8%	Normal
Refrigerator	0,45	0,46	0,021	2,1%	Normal
Magic jar	0,32	0,33	0,03	3%	Normal
Dispenser	0,83	0,85	0,023	2,3%	Normal
Hair dryer	0,97	0,99	0,02	2%	Normal
Big Fan	0,44	0,46	0,043	4,3%	Normal
Iron	0,8	0,82	0,024	2,4%	Normal
Laptop Charger	0,49	0,5	0,02	2%	Normal
Energy Saving Lamps	0,47	0,45	0,044	4,4%	Normal

4.3.4 System PowerTest Results

Table 4 below is data from a comparison of the power values on the tool being made and the power values on the wattmeter. The comparison results show that the error percentage is not too high. The highest error percentage was found in the cell phone charger load, namely 4.3%, while the lowest error percentage was found in the hair dryer, namely 0.16%.

Table 4. System Power Performance Accuracy Testing Results

Load	Measurement Results		Difference	%*Error*	Results
	Measuring Instrument (W)	Wattmeter (W)			
Small Fan	13,04	13,2	0,012	1,2%	Normal
Cell phone charger	14,09	14,72	0,043	4,3%	Normal
Night light (filament)	12,83	13,26	0,032	3,2%	Normal
Refrigerator	56,27	57,13	0,015	1,5%	Normal
Magic jar	16,55	17	0,026	2,6%	Normal
Dispenser	200,5	201	0,0025	0,25%	Normal
Hair dryer	303,5	304	0,0016	0,16%	Normal
Big Fan	22,68	23	0,014	1,4%	Normal
Iron	187,9	188,67	0,004	0,4%	Normal
Laptop Charger	32,99	33.6	0,018	1,8%	Normal
Energy Saving Lamps	14,03	14,2	0,012	1,2%	Normal

4.3.5 System Energy Test Results

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Table 5 below is data from a comparison of the energy values on the measuring instrument made and the energy values measured on the kWhmeter. The comparison results show that the error percentage is not too high. The highest error percentage was found in the small fan load, namely 3.5%, while the lowest error percentage was found in the refrigerator load, namely 1.1%.

Table 5. System Energy Performance Accuracy Testing Results

Load	Measurement Results		Difference	%*Error*	Results
	Measuring Instrument (Wh)	kWhmeter (Wh)			
Small Fan	0,55	0,57	0,035	3,5%	Normal
Cell phone charger	0,43	0,44	0,023	2,3%	Normal
Night light (filament)	0,38	0,37	0,027	2,7%	Normal
Refrigerator	0,81	0,821	0,011	1,1%	Normal
Magic jar	0,62	0,64	0,031	3,1%	Normal
Dispenser	1,23	1,26	0,024	2,4%	Normal
Hair dryer	9,5	9,72	0,023	2,3%	Normal
Big Fan	0,58	0,6	0,033	3,3%	Normal
Iron	4,56	4,69	0,028	2,8%	Normal
Laptop Charger	1,09	1,12	0,03	3%	Normal
Energy Saving Lamps	0,5	0,516	0,031	3,1%	Normal

4.3.6 Cost Data for Each Electricity Load

The cost data that has been obtained from each electricity load can be used to estimate the estimated electricity load usage for one month (30 days). Data sampling for each electrical load was carried out over a period of 15 minutes. The cost calculation is done by multiplying the energy by the electricity tariff for residential consumers with non-subsidized 900VA power, which is IDR 1,352.-. Table 6 below is an estimate of costs for 30 days.

Table 6. Cost Calculation for Each Electricity Load

Load	Cost for 15 minutes (Rp)	Cost for 1 hours9 (Rp)	Estimated time for 1 day (hour)	Estimated time for 30 day (hour)	Estimated cost for 30 days (Rp)
Small Fan	0,74	2,96	8	240	710,4
Cell phone charger	0,58	2,32	4	120	278,4
Night light (filament)	0,51	2,04	7	210	428,4
Refrigerator	1,1	4,4	24	7200	31.680
Magic jar	0,84	3,36	12	360	1.209,6
Dispenser	1,66	6,64	24	7.200	47.808
Hair dryer	12,84	51,36	0,25	1,75	89,88
Big Fan	0,78	3,12	12	360	1.123,2
Iron	6,17	24,68	3	90	2.221,2
Laptop Charger	2,16	8,64	6	180	1.555,2
Energy Saving Lamps	0,67	2,68	3	90	241,2
Cumulative Costs					**87.345,48**

5. Conclusion

The results obtained are (1) an electrical energy monitoring system was produced with components in the form of an ACS712 current sensor, ZMPT101B voltage sensor, Arduino Uno microcontroller, NodeMCU ESP8266 wifi module, 20×4 LCD, buzzer, and Blynk application. (2) The results of functional testing show that each component has good accuracy values so that the components used can work well. The percentage error rate from sensor testing shows a value below 5%, so the sensor accuracy is good. (3) The results of system performance testing also show quite high accuracy. The highest percentage error rate of the entire data was 4.4%, namely in refrigerator current data and energy-saving lamp power factor data. The telemetry system that has been created can also work well by being able to monitor in real time via the Blynk application.

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