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Watch winder based on the internet of things

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ABSTRACT

Watches are wearable devices that support human activities as timepieces. There are two types of watches based on their source driving energy: the quartz type, which uses a battery, and the automatic mechanical type, which uses a mechanical mechanism to convert the kinetic energy obtained when the clock is used as the energy to drive the hands. Automatic mechanical type watches have a time limit of 48 hours or two days until the energy turns off and the time stop. Therefore, a watch winder is needed to make movements to keep the automatic watch running while not in use. So, users can use their watch again without the need to adjust the time, date and other functions. The watch winder produced in this study employs a stepper motor that is controlled by an ESP32 microcontroller via a ULN2003 motor driver integrated circuit (IC). This type of stepper motor is used because it has a high rotor rotation precision to prevent the clock from over-winding problems. This watch winder device also has a watch condition monitoring feature through application-based temperature and humidity parameters. Users can monitor the condition of their watch and control the dial of the watch winder's modules through the integrated application.

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1. INTRODUCTION

A watch is a wearable device that supports the actions of a person who serves as a timekeeper. Quartz clocks, which use electrical energy from a battery to power the hands and display the time, are the prevalent type of watch technology now in use. In the early days of watchmaking, mechanical technology was used to power the movement. This style of timepiece is referred to as an automatic mechanical watch. For this type of watch to function, the wearer must wear it during daily activities or manually spin it to replenish the energy source that powers the clock's hands [1], [2]. The majority of automatic mechanical timepieces on the market have a maximum charge time of 48 hours or two days. Therefore, if the user leaves the clock on over the weekend, the clock will cease functioning or turn off. In order to keep automatic mechanical clocks running, a clock winder that is capable of movements is required. So that users can use the clock without having to manually alter the time, date, or other features [3], [4].

The watch winder must have the ability to set the number of clocks per day, adjust the rotation direction to clockwise (clockwise), counter clockwise (counterclockwise), or two-way combination (bidirectional), pause the cycle, and monitor the temperature and humidity in the case so that the clock remains in good condition. Utilizing internet of things (IoT) technology enables users to control and monitor the status of the device's clock in real time through an integrated application from any location. Research on this tool is expected to contribute to the development of wearable devices, especially watches and the integration of IoT technology with everyday devices. However, the IoT still has issues [5] including password security flaws [6], lack of patches-updates and poor maintenance mechanisms [7], insecure interfaces: IoT security [8], [9], inadequate data protection (communication and storage) [10], [11], and IoT device management issues [12], [13]. Furthermore, as technology advances and IoT research grows, we expect IoT implementation constraints to decrease, making people more confident and comfortable with IoT goods [14], [15].

2. METHOD

2.1. Watch winder mechanism

The "Controllable watch self-winding watches" patent [1] states that the watch winder is meant to perform self-winding or self-winding on mechanical watches, eliminating the need for manual twisting and resetting. The electrical circuit is designed to start and stop the spindle movement via motor control. The watch winder or watch winder should choose various rotation mechanisms according to the watch's specifications. The rotation mechanism types include the number of revolutions per day or turns per day (TPD) and a choice of clockwise, counterclockwise modes or a Bidirectional.

A watch winder functions to rotate the main spring on the automatic mechanical winding calibre when the watch is not in use [2]. In an automatic mechanical twisting motion, the centre of the rotational weight rotates on its axis by utilizing the physical movement of the hand. Thus, the main spring only rotates during use and stops during lay-off. A watch winder recreates physical movement to maintain calibre beats when not in use.

2.2. Integration of the internet of things with electronic devices

Information and communication technology (ICT) has a significant impact on economic management, production management, social management, and even the personal lives of individuals in the current period of globalization [16], [17]. Nowadays, IoT technology is developing, which is a comprehensive network technology that combines the internet and sensor devices such as radio frequency identification (RFID), infrared sensors, and satellite navigation systems global positioning system (GPS) [18]. The IoT application enables automatic and real-time object identification, discovery, tracking, and monitoring, as well as the initiation of events [19], [20] as shown in Figure 1. Utilizing IoT technology on the watch player device will facilitate the user experience in operating the device, monitoring clock conditions, and setting the clock rotation mode wherever the user is as long as within the range of an internet connection [21], [22].

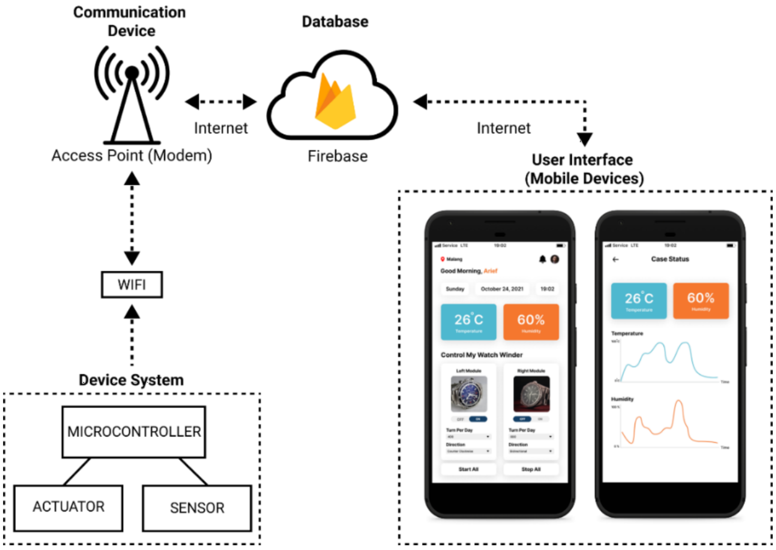


Figure 1. An overview of the IoT system

Data collecting is one of the primary roles of the IoT. A microcontroller with Wi-Fi connectivity is connected to the database via the internet to read and transfer data. Firebase offers real-time database access for iOS, Android, JavaScript SDK, REST API, and admin SDK, as well as available iOS and Android SDKs for mobile application development [23], [24].

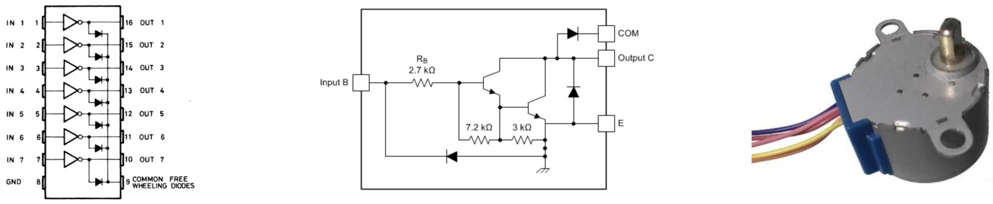
2.3. Stepper motor control using driver IC ULN2003

Stepper motors are the most incredible option for designing a system that demands precise rotor position measurement on the motor [25]. Stepper motors function differently from other DC motors; rather than continuously supplying a voltage and the rotor, the stepper motor rotates by activating a series of electrical pulses in the motor coils. Each pulse causes the rotor to revolve to a certain degree. These pulses are steps or steps, and the motors that produce them are known as stepper motors [26], [27]. Figure 2 shows the actuator configuration on an IoT-based watch winder.

Each rotational step of a stepper motor describes the angular movement that occurs when the motor rotates; this is known as the step angle. The step angle is defined by the number of coils in the motor, which, upon application of current, will cause the magnet in the stator to attract the rotor, causing the motor to rotate. The stepper motor has four windings on the stator and the four steps necessary for the rotor to complete one complete 360° spin. The stepper motor also has a 90° step angle [28].

The ULN2003 motor driver is one of the integrated circuit (IC) motor drivers typically used to operate stepper motors. IC ULN2003 is a Darlington transistor circuit comprised of seven pairs of transistors, with the second transistor's collector linked to the other transistor's base as shown in Figure 2(a) and Figure 2(b).

This design results in the second transistor amplifying the output current of the first transistor. Each pair of Darlington transistors can drive loads with a maximum current of 500 mA and a voltage of 50 V. The 28BJY-48 stepper motor consumes 240 mA of current (typical) as shown in Figure 2(c). To operate a stepper motor with an ESP32, a ULN2003 motor driver IC is required due to the ESP32's maximum output current rate of 12 mA at the GPIO [29], [30].



(a) (b) (c)

Figure 2. Actuator configuration (a) ULN2003 pin configuration [31], (b) block diagram of ULN2003 [32], and (c) stepper motor 28BJY-48

2.4. Development method

An overview of the development of the watch winder based on IoT is explained in this subsection. The design of the system and method we build includes a block system diagram; hardware design consists of electrical and mechanical design, and software design, namely program flowchart and application design. The block diagram for the proposed model is depicted in Figure 3, consisting of input components, process, and output components.

Input components include two sensors for monitoring watches condition and are also connected to the cloud, MCP9808 temperature sensor and BME280 humidity sensor. ESP32 microcontroller processes and controls the system with a Wi-Fi connection. Two stepper motors are actuators to spin two watch modules, and a display user interface completes the output components. Stepper motors spin with two settings: rotation direction and TPD. As most automatic watch brands require, TPD options available are 650, 700, and 800. There are three possible rotation directions: clockwise, counterclockwise, and bidirectional. Data parameters consist of rotation configuration settings and sensor readings transmitted to the Database Firebase using access point (AP) with the internet network. The application retrieves data from the database and displays it on the user interface. It also happens the other way by sending control data from the smartphone to the database.

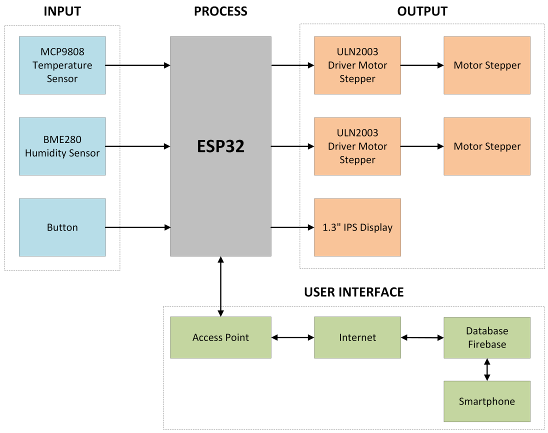
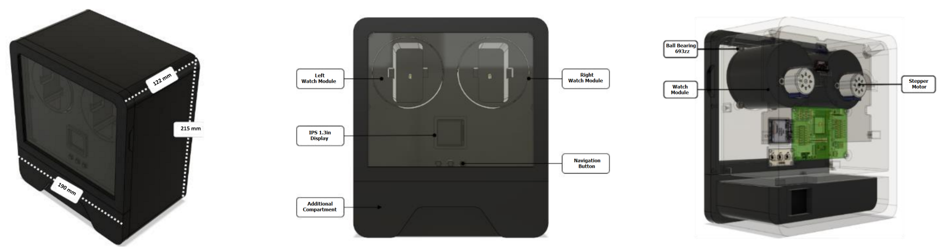


Figure 3. Block diagram

2.5. Mechanical design system

An excellent mechanical system dramatically affects the performance of devices that use actuators as their primary function. Therefore, the design of the mechanical part, in this case, the watch winder or clock winder module, must be made as precise as possible. Thus, the rotation of the motor will be effective. All mechanical devices are designed in CAD software, and all mechanical parts are printed using a 3D Printer. In addition, two stepper motors are used in this watch winder device, which rotates the right and left watch modules. The stepper motor is mounted on the departure body, and the motor shaft is connected to the watch winding module. Ball Bearing 693zz is used to minimize friction between the watch module and the front body so that the rotation of the watch module can be maximized and effective. Figure 4 shown specifications of the mechanical watch winder device are as follows: length 190 mm, width 122 mm, and height 215 mm as shown in Figure 4(a); actuators 28BJY-48 stepper motor; part material plastic (PLA+) and Acrylic; and weight 1.5 kg. Figure 4(b) and Figure 4(c) shown front view and component posision of the mechanical watch winder device.



(a) (b) (c)

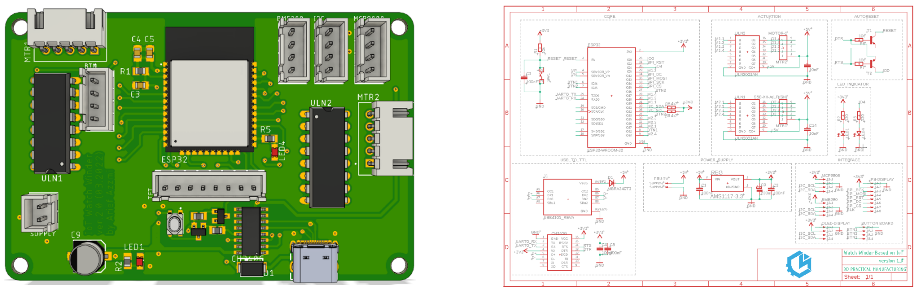
Figure 4. Mechanical design: (a) device dimension, (b) front view, and (c) components position

2.6. Electrical design system

The most critical system component besides the mechanical system is the electronic system. With an electronic or electrical system, the components of the mechanical system can work or move according to their function. For this reason, an excellent electronic system design is very much needed in designing this watch winder device. Figure 5 shows the PCB design of an IoT-based watch winder. The PCB layout in 3D and the electronic schematic are shown in Figures 5(a) and 5(b), respectively.

The electronic circuit of the input device consists of three buttons, the temperature sensor MCP9808 and the humidity sensor BME280; the electronic circuit of the processing device is ESP32. The output device's electronic circuit consists of an in-plane switching (IPS) display and two ULN20003 motor drivers that control two stepper motors. The watch winder utilizes a 5 V power supply. The supply voltage for stepper motors is 5 V; then the voltage is lowered using the AMS1117 low dropout voltage (LDO) IC to 3.3 V to supply the ESP32 module, IPS display, MCP9808 sensor and BME280 sensor.

BME280 and MCP9808 sensors communicate sensor data to the microcontroller using the inter-integrated circuit (I2C) communication protocol. I2C is a serial communication protocol in which data is exchanged bit-by-bit over a single cable, known as serial data interface (SDA). I2C is synchronous communication in which bit output and bit sampling are synchronized by a shared clock signal between master and slave. The master controls the clock signal using a serial clock (SCL). The IPS display component of the watch winder displays information and configuration menus and communicates using the serial peripheral interface (SPI) standard.

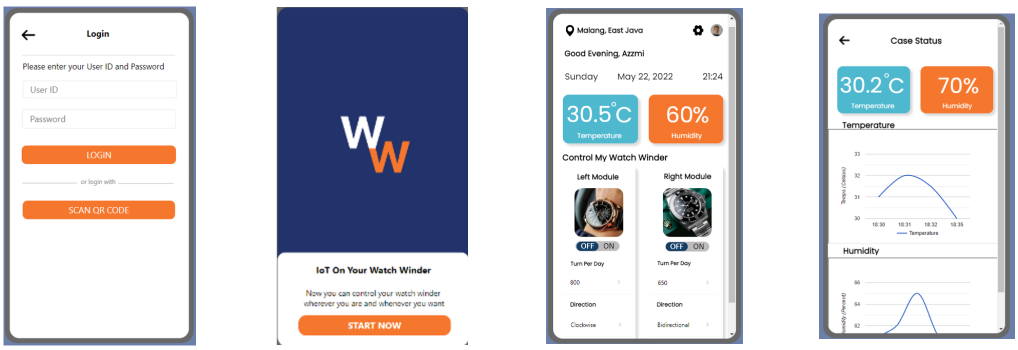


(a) (b)

Figure 5. PCB design (a) board layout in 3D and (b) electrical schematic

2.7. Application for cloud data accessing

The watch winder controller application is designed using the Thunkable platform, a block program-based app developer platform. The database used to transmit data from watch winder devices into the application in real time is the Firebase database. The data variables sent are the temperature sensor readings, humidity, and motor rotation settings. These variables relate to the function of this application, which is to monitor the temperature and humidity values in the watch winder case, as well as control the number of motor revolutions per day TPD based on the specifications of the user's watch. Changes in temperature and humidity values in the case can be seen in graphical form on the application. For example, if the sensor detects a reading value that exceeds the standard limit, a pop-up notification will appear to warn the user. The application design as shown in Figure 6. This application consists of a login page (Figure 6(a)), splash screen page (Figure 6(b)), dashboard page (Figure 6(c)), settings page, and case status page (Figure 6(d)).



(a) (b) (c) (d)

Figure 6. Application design: (a) login, (b) splash screen, (c) dashboard, and (d) case status

3. RESULTS AND DISCUSSION

This section aims to show the specific data and the suitability of the device's performance that has been made. The data obtained at the testing stage are compared with previous design plans, and comparisons are made with the existing measuring instrument. Then, the error value is calculated so that the location of the error and lack of equipment will be known. The device testing stage consists of the following:

3.1. Stepper motor rotation control

Stepper motor rotation control evaluation is carried out to ensure the number of revolutions per day TPD and the direction of the motor following the settings that have been ordered. The ESP32 microcontroller regulates the rotation of the stepper motor by entering the program for the required number of motor rotation steps, and the direction of rotation is determined by the step value being positive (+) or negative (-). This method causes the stepper motor to rotate with great precision. The stepper motor rotation mode is tested by utilizing an external circuit, namely the Arduino nano microcontroller, magnetic hall effect sensor, organic light-emitting diode (OLED) display to display data and placing magnets on the watch module. The hall effect sensor will detect the presence of a magnetic field in each rotation cycle so that the number of turns can be calculated with the counter function.

$$RPH = \frac{TPD}{24\ hours} \tag{1}$$

The data from the stepper motor control test were obtained by entering three modes of the number of revolutions per day (TPD), namely 650, 700, and 800 revolutions per day. Then, the accuracy of the rotation is tested with the rotation counter function. Table 1 shown stepper motor rotation test result.

Table 1. Stepper motor rotation test result

No	Watch module	Setpoint		Real		Error(%)
		TPD	RPH	RPH (deg)	Duration per rev (s)	
1	Left	650	27 R + 2	27 R + 30	4.2	0
2	Left	700	29 R + 4	29 R + 60	4.2	0
3	Left	800	33 R + 8	33 R + 120	4.2	0
4	Right	650	27 R + 2	27 R + 30	4.2	0
5	Right	700	29 R + 4	29 R + 60	4.1	0
6	Right	800	33 R + 8	33 R + 120	4.1	0
					Average rotation duration	4.17 s
					Mean error	0

where:
TPD: turns per day; RPH: rotation per hour

The following explains the Table 1 of test results : the number of TPD is divided by the 24-hour time unit, so the value of the number of rounds per hour (RPH) is obtained. When looking for the RPH value for the three TPD values, the results have 2, 4, and 8 turns remaining. The remainder of the rotation is multiplied by the whole angle of rotation (360 degrees) and divided by 24 hours. Furthermore, the RPH value of each TPD is added with the additional angle from the calculation results.

From the tests carried out above, the stepper motor rotation error on both the left and suitable modules is 0 %, and the rotation time is 4.2 seconds. The error values are obtained in the three types of TPD modes or the number of revolutions per day, namely 650, 700, and 800. The precise rotation of the watch module is obtained because it uses a stepper motor actuator. Stepper motors move based on pre-programmed steps. For example, in a 28BJY-48 stepper motor, one complete revolution is worth 4,096 steps. The RPH value of each TPD mode is multiplied by the number of steps for one full rotation. Therefore, the second rotation of the watch can be precise, and the error is 0%.

3.2. Data parsing time to database Firebase and application interface responsiveness

The test of sending (parsing) data to Firebase is conducted to test the responsiveness of sending parameter data on the watch winder device. Table 2 shown the data parsing time test and observed reaction testing results for the winder application. The data parameters consist of the MCP9808 temperature sensor readings, the BME280 humidity sensor readings, the power status of both modules, the number of revolutions per day (TPD) mode on the right and left modules, and the direction mode. The test is carried out by calculating the time of sending parameter data on the device to Firebase by being monitored through a serial monitor. Internet speed maximum speed is 10 Mbps. The average time to parse data from the device to Firebase is 5.0531 seconds.

Application interface responsiveness testing tests the time it takes to control the device through the application interface. Testing is done by giving commands to the application, namely pressing the on/off switch on each module setting and calculating the time until the device responds to the given command. The results of the response time test are influenced by the internet network and, or commands on the previous device.

Table 2. Data parsing time-interface responsiveness test result

Data delivery no.	Data parsing time test result Time (s)	Application interface responsiveness test result Time (s)
1	5.033	7.32
2	5.024	5.23
3	4.82	7.36
4	5.076	4.98
5	5.118	8.19
6	5.058	6.46
7	5.055	3.16
8	5.046	7.75
9	5.076	6.8
10	5.225	2.53
Average time	5.031	5.978

3.3. MCP9808 temperature sensor and BME280 humidity sensor

MCP9808 temperature sensor is used to read the temperature value on the watch winder case. MCP9808 sensor was chosen because it has a high-temperature reading accuracy, a maximum of 0.5 °C in a temperature range of -20 to 100 °C. MCP9808 sensor testing is carried out to test the accuracy of sensor readings on a measuring instrument, namely a thermometer. The BME280 humidity sensor is used to detect the humidity value inside the watch winder case. Testing and comparing sensor readings to measuring instruments is also a parameter at the calibration stage. Table 3 shows temperature and humidity test result, respectively. Based on the sensor testing, it was found that the percentage of error obtained from the comparison of sensor readings and measuring instruments after calibration was carried out was around 0–2.63%, and the average error was 1.17%. The error value obtained is assessed for precision to monitor the state of the watch winder in real-time.

Table 3. Temperature and humidity test result

Data testing	Temperature (^{0}C)		Error (%)	Humidity (%)		Error (%)
	Thermometer	MCP9808		Hygrometer	BME280	
1	29.5	29.5	0	76	78	2.63
2	29.3	29.4	0.34	78	79	1.28
3	29.4	29.5	0.34	79	79	0
4	30.7	30.5	0.66	78	77	1.28
5	30.7	30.6	0.33	78	79	1.28
6	30.5	30.5	0	77	78	1.28
7	30.3	30.3	0	78	78	0
8	30.3	30.4	0.33	76	78	2.63
9	30.3	30.3	0	77	77	0
10	30.4	30.4	0	77	78	1.3
	Mean error		0.2	Mean error		1.17

4. CONCLUSION

In this paper, we aim to integrate IoT technology with watch winder devices and make it easier for users to control and monitor their watches. The 28BJY-48 stepper motor control method to rotate the clock module on the watch winder is to set the number of steps required in each rotation mode. In this watch winder, the stepper motor is controlled in a half-step mode where one full rotation requires 4,096 steps. The direction of rotation is set with the polarity of the step value, which is positive for clockwise and negative for counterclockwise. The watch winder device is connected to the app using the ESP32's Wi-Fi communication. The observing rotation mode control parameter and sensor monitoring data are parsed and stored in the Firebase database. Data from Firebase will be shown on the app. Finally, the IoT technology opens the way to ease and convenience in monitoring and controlling our home devices, one of which is a watch winder.

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