International Journal of Engineering Trends and Technology Volume 71 Issue 2, 249-258, February 2023
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V71I2P228

Original Article

Effective LoRa – Based Centralized Digital Water Meters: Real Case Study in Vietnam

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Received: 21 December 2022 Revised: 07 February 2023 Accepted: 16 February 2023 Published: 25 February 2023

Abstract *- At present, analog water meters to measure the amount of water consumption are still widely used in Vietnam. In addition, the monthly manual recording of measurements has been resulting inaccurate data and time-consuming work, strongly affecting the revenue of water companies. This problem can be completely solved using digital water meters, which can send water readings to a processing center. This paper presents a step-by-step design of an electronic water flow meter using Lora wireless communication technology, which can communicate data to a local water supply company up to a distance of roughly 200 meters to a middle receiver through a common 3G/4G standard or Wi-Fi. Based on the idea of integrated technology, this paper comes up with a detailed design of digital water meters in combination with management and monitoring systems together with a mastering technology to reduce the cost of products (about 50% compared to an equivalent imported equipment). One of the most significant benefits for customers is that the water index can be monitored in real-time, assisting the water supply company reduces labor costs, easily managing the amount of water and detecting some incidents, e.g. broken water meters and leaking water pipes, such as soon as possible.*

Keywords *- Digital water meter, Analog water meter, LoRa gateway, Wireless communication network, IoT.*

1. Introduction

It is a fact that electronic flow meters have taken the place of mechanical water usage meters in smart cities around the world's most industrialized nations. In Vietnam, the Electricity of Vietnam Corporation (EVN) has been using electronic energy meters since the changeover process started a few years ago in major cities like Hanoi Capital and Ho Chi Minh City. Additionally, water meters have been gradually changed across the nation in industries, industrial parks, and certain apartment buildings that consume a lot of water. Digital water meters connecting to distant hubs are, therefore, highly sought-after. The following water meter products are currently on the Vietnamese markets (see Figure 1):

(i) OWD-SD25 electronic clocks (Omnisystem-Korea) have high accuracy and great battery life, being able to connect to the system via RS485 wired network.

(ii) Finetek EPD electronic clocks with 0.5% accuracy, RS485 wired communication interface and digital display.

Digital water meters have been in use worldwide for a while and are gaining popularity. This is also in great demand now in Vietnam because of the need for openness in the water sector and the need to cut down on measurement errors. There are already businesses in the nation using electronic water meters that are imported and cost a lot of money. These companies use electronic water tanks made in China, Europe, Taiwan, Korea, etc.

Despite the fact that electronic flow meters are becoming more and more popular in Vietnam. There are not any specific studies on the development and production of electronic flow meters. There are no domestically manufactured electronic flow meters available in Vietnam. Suppose you can take the effort to teach domestic businesses how to make electronic flow meters. In that case, it will help the process of modernizing the manufacture of high-tech equipment to satisfy demands for domestic and commercial use.

Fig. 1 OWD-SD25 and Finetek EPD

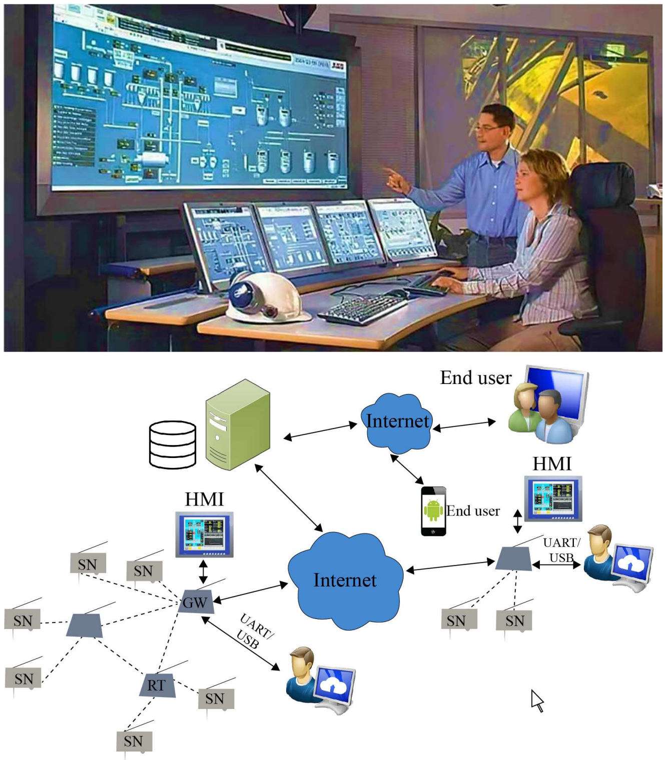


Fig. 2 Automatic water number recording and management system

The following advantages can be attained by measuring water consumption with an electronic meter:

- Increase automation, reduce human costs, and increase transparency in the way that water supply providers and end users monitor water quality.
- Using cutting-edge technology to improve people's lives by assisting customers in learning about water usage and automatically adjusting their demands for an affordable and sensible use of water resources in the contemporary digital world now.
- For clients to access real-time (within 15, 30, or 60-minute measurement cycles) information on water quantity (m^3) or water amount via a website, text message or email. After that, assisting customers to self-regulate their water use activities.

It is obvious that the automatic water number recording and management system can be successfully installed, as shown in Figure 2. The index of water on the meter is recorded by the camera and communicated to the server using a 3G wireless network in the study [1], which is one of several reports that have previously recommended various techniques for digitizing water meters. In [2], automatic water meter reading requests are made using the SMS service. While work [3] implements a remote valve controller depending on the amount of water the user has purchased, the study [3] offers to translate an image to the text of the meter value. Currently, the semiconductor industry, IoT technologies, and wireless sensor networks are rapidly developing. Numerous studies have been conducted for digitizing mechanical water meters, and various methods that use new technologies have been developed. For instance, in [5], a communication method employing a 433 MHz wireless transceiver is used to connect an intermediary transceiver (master) to water meters (enslaved person) at a maximum distance of 200 meters. The node is suited for battery-powered and long-term operation (2–5 years) since it rarely needs to communicate significant volumes of data at once, the transmission cycle is frequently long (8 hours/time), and it consumes little power. Because of its low power features and broad communication range, LoRa is frequently used in meters [6]. Compared to previous systems, LoRa maximizes battery life to be much better [7]. Additionally, it has the benefit of extremely low bandwidth transmission across very large distances [8]. As a result of the increased bandwidth requirements, it is also necessary to accommodate the server's needs for data transmission from many nodes.

The rest of this paper is as follows. Section II presents the development and design of a water metering system. Next, Section III describes practical experiment results and discussions. Finally, the conclusions will also be provided in Section IV.

2. Development and Design of the System

2.1. General Model of the System

The general model of the proposed system, as shown in Figure 3, comprises two primary components, namely Pi nodes and C stations. These two components work together to build a distant water consumption collection and management system (LoRa gateway). Each Pi node is an Internet of Things (IoT) device that monitors water flow, processes and transmits parameters, and wirelessly communicates with a gateway or intermediate base station. IoT has been widely used for high-quality wireless communication [15-17]. Data collection from each node is done via a gateway station that runs on main power and serves as a gateway to enable remote data access across 3G/4G, wifi, and Ethernet. Some specific applications are as follows:

- Wired Solution for Apartment (Ethernet);
- Wireless Solution for Independent house (Wifi).

Specifically, the design of an electronic water meter (Pi) has been developed, tested, and meets the following specifications and functions:

- Minimum flow rate is 0.05 m3/h, nominal flow rate is 2.50 m3/h, maximum flow rate is 5.00 m3/h;
- The water meter's inaccuracy is ≤ 2 percent;
- Utilizing the 200-meter (inside the city) Lora energy-efficient wireless communication technology, the gadget is powered by a battery;
- Save measurement information to the gadget's memory.

The Lora Gateway station's architecture gathers data from the nodes and serves as a gateway for distant data access through wifi/3G or Ethernet. The water authority can manage the data and access it on a web server after it is collected and transmitted to the server.

2.2. *Water Meter Design*

The overall diagram of the basic functional blocks of the device is shown in Figure 4. The primary parts of the meter are the flow sensor, the central control circuit, the enclosure for the device and the Lora wireless communication component. The converted signal from the sensor will first be processed by the converter and normalized before being fed as a pulse to the microprocessor, which will read it and count the pulses to determine the water flow (liters per minute).

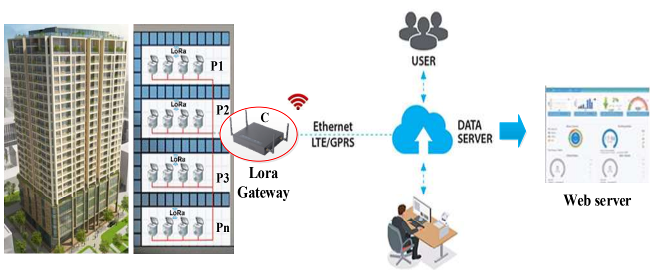


Fig. 3 General model of the system (Wired Solution for Apartment)

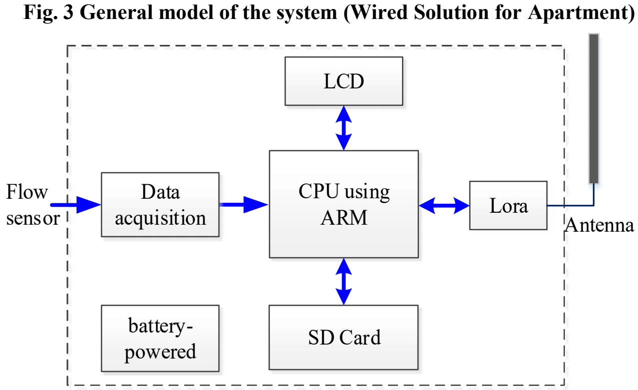


Fig. 4 Block diagram of the water meter

Alternatively, the amount of water (m3) that has flowed through the meter in cubic meters. The center will receive the calculation results in accordance with a pre-set cycle (for example, once every hour), store them in internal memory, and display them directly on the LCD panel. For battery-powered devices with a high capacity, several years can go by without a charge, therefore some accessories. A few peripherals use less power because battery-powered gadgets with large capacities can run continuously for two to three years.

2.2.1. Flow Sensor

Choosing a water flow sensor from the Huba Control [10]. Flow sensor Huba Control 210 with power and output diversity. The 210 flow sensor is extremely accurate and free of moving parts, pollutants, and pressure loss.

- Fluid as the measuring medium Pipe diameter: DN 6/8/10/15/20/25 Measuring range: 0.5-150 liters/min;
- Measure flow with voltage, current, or both to produce a pulse or output frequency between 12 and 483 Hz;
- Excellent anti-interference capability (environment-free operation of the probe).

The connection diagram is depicted in Figure 5.

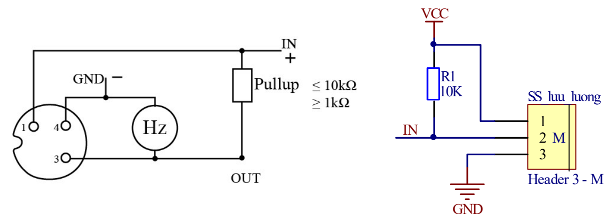


Fig. 5 Flow sensor connection diagram

The flow of water can be calculated as follows:

$$Q = \frac{Pulse}{s} * K_1 * \frac{60}{1000}(lpm) \qquad (1)$$

Where K_1 is set to 1.25 (corresponding to the diameter DN25).

2.2.2. LCD Display Block

The display HT1621 (HCMODU0136) is chosen by the device presented in [11].

- Connection schematics as presented in Figure 6.

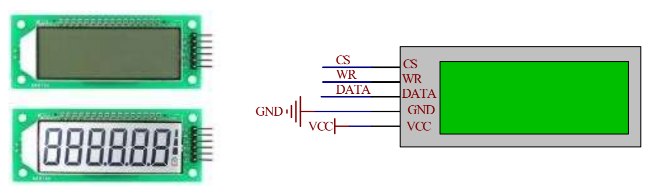


Fig. 6 LCD screen HT1621

Screen specifications shown in Figure 6 include:

- LCD screen size: 77x31 mm;
- I_2C standard communication;
- Power supply 2.4 V ~ 5.2 V.

2.2.3. LoRa Communication

Cycleo conducted the research and development for LoRa (Long Range Radio), which Semtech eventually purchased in 2012. This technology could transmit data over kilometers without using circuits with amplifying power. Along with the benefit of long-distance transmission, it also significantly reduces energy usage during data transmission and reception, making it appropriate for use with wireless, battery-powered sensors.

Data are hashed with high-frequency pulses to create a signal with a higher frequency range than the original data's frequency (this is called chipping), and then LORA uses this chipped signal to modulate the spread spectrum. Further coding of this high-frequency signal follows the chirp signal sequence. They are sinusoidal signals whose frequency varies with time. There are two forms of chirp signals, up-chirp and down-chirp, respectively; in theory, bit 1 will use up-chirp while bit 0 will use down-chirp for encoding. Before sending, the antenna must receive [8, 9]. This idea aids in lowering the complexity and accuracy needed by the receiving circuit to decode and re-modulate the data. This principle contributes to lowering the complexity and precision required by the receiving circuit to decode and re-modulate data. A range of working frequencies is from 430MHz to 915MHz for various regions worldwide.

The external Lora Ra-01 Module (SX1278) used in this article uses conventional GFSK technology in addition to LoRa (long-range) technology to cut current usage and avoid interference. The module supports the SPI communication protocol, 100mW strong signal transmission, and low-power long-distance transmission.

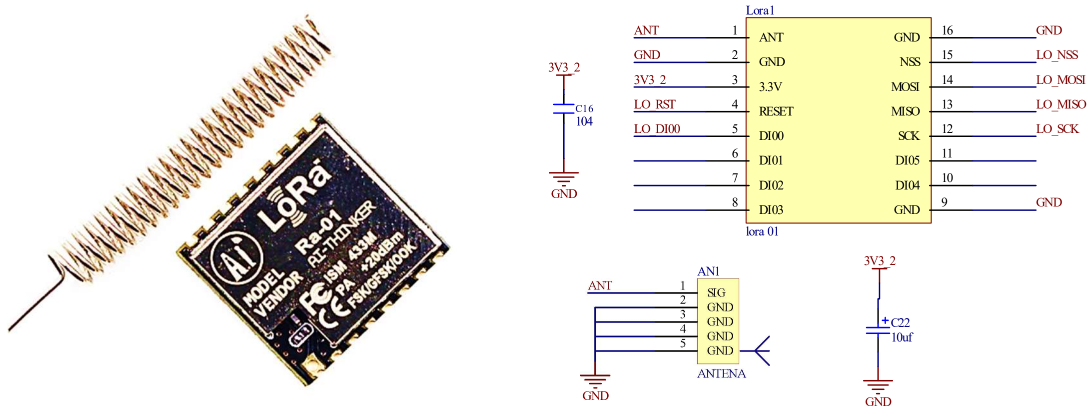


Fig. 7 Module Lora Ra-01 (SX1278)

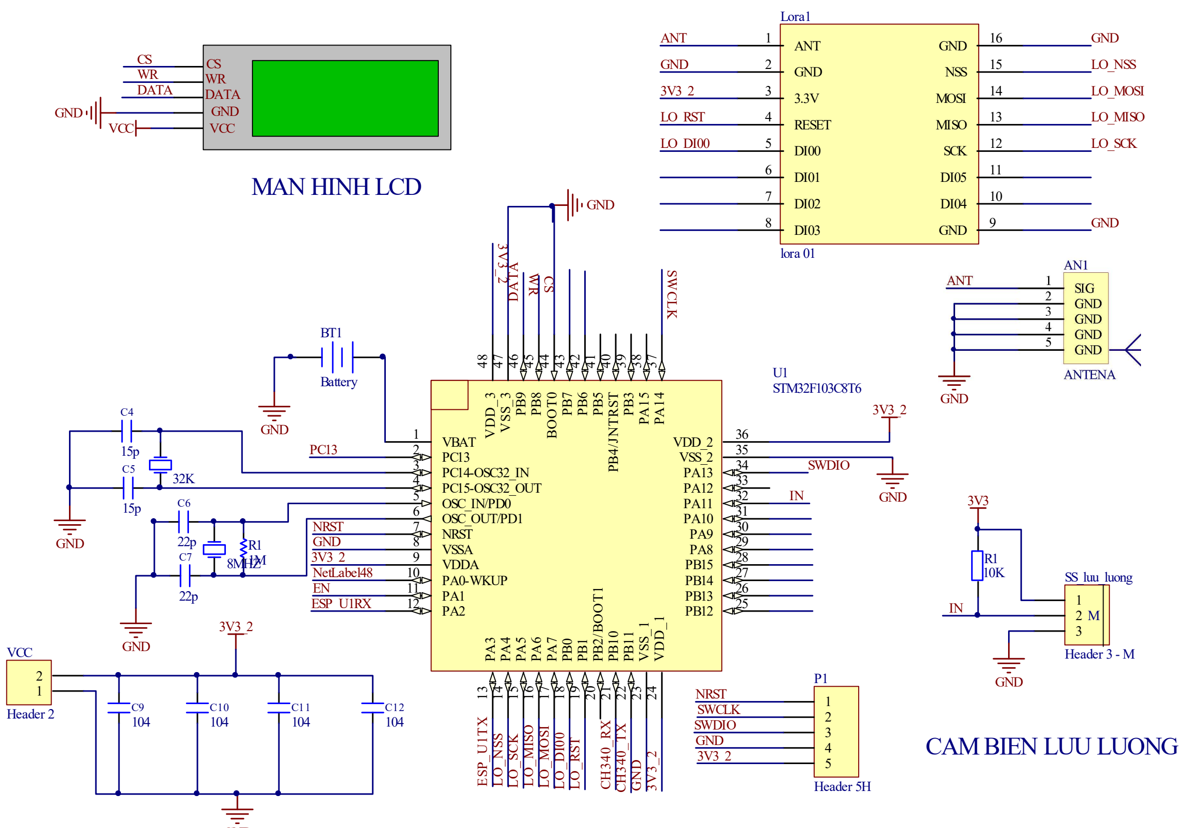


Fig. 8 The schematic diagram of the device

Any complicated application environment requiring wireless data transmission is suited for the Lora Ra-01 module, including smart home control, automobile electronics, security alarms, monitoring and control systems for industrial systems, and remote control systems for irrigation applications. The module can be sent up to a few kilometers depending on the planned application and energy consumption.

Specifications:

- Sensitivity: -136 dBm;
- Output power: +20 dBm;
- Data transfer rate: 300 kbps 127dB dynamic range RSSI;
- Modulation: FSK/GFSK/MSK/LoRa;
- Communication: SPI;
- Static current: 1uA;
- Operating temperature: -40°C to +80°C;
- 1.8 to 3.6 VDC is the supply voltage.

2.2.4. The Central Processor

The STM32F1x family of integrated circuits has identical properties and operational capabilities. The ARM cortex M3 STM32F103C8T6 (short for Advanced RISC Machine), a family of microprocessors made by STMicroelectronics, is an example of a 32-bit microprocessor structure that is frequently used in devices embedded style. They share the following characteristics:

- ARM 32-bit Cortex - M3 CPU with max clock: 72Mhz.
- Multithreaded interrupt control with 43 interrupt channels.
- Memory: 64Kbytes flash memory, 20 kbytes SRAM
- Operating voltage 2 - 3.6v.
- Use external quartz from 4Mhz -> 20Mhz
- Internal quartz uses RC oscillator in 8Mhz or 40khz mode.
- 2 sets of 12-bit ADCs with 9 channels for each.
- There are 7 timers.
- Support communication channels: 2 sets of I2C(SMBus/PMBus), 3 sets of USART (ISO 7816 interface, LIN, IrDA capability, modem control), 2 SPIs (18 Mbit/s), 1 set of CAN interface (2. 0B) Active), USB 2.0 full-speed interface.

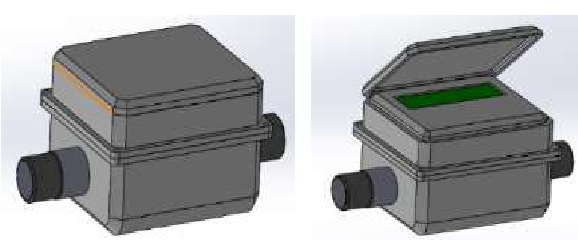


Fig. 9 A 3D-design image of the device shell

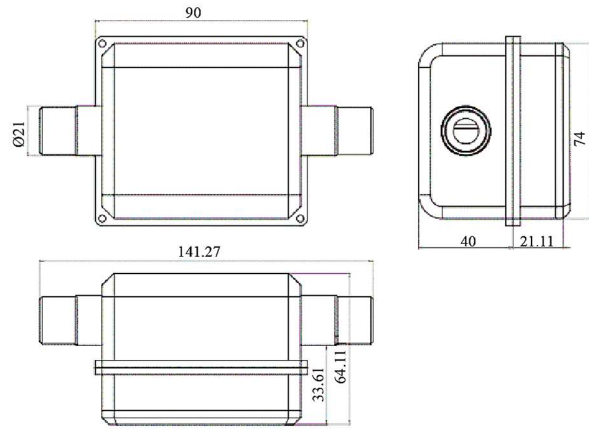


Fig. 10 Dimensional drawing of gauges

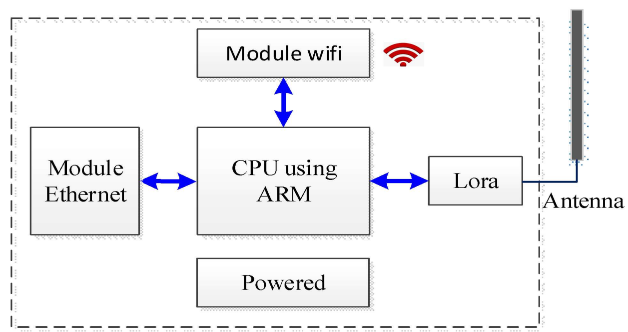


Fig. 11 LoRa Gateway's block diagram

2.2.5. Design of the Water Meter Skin

This is a 3D-image of the device's shell, which has been created of plastic based on the device's purpose, computation, and elemental selection.

2.3. Lora Gateway Station Design

This section will briefly present the design of Lora Gateway station. The basic functional block diagram of the device is shown in Figure 11. The station device collects data from each node and serves as a gateway for distant data access through wifi or Ethernet. Data are gathered and transmitted to a computer, managed by the water authority and seen on a web server.

- The major components used to construct the device (Communication using Lora Ra-01 module (SX1278), ARM-STM32F103C8T6 series CPU) are comparable to those used to construct meters. There are further gadgets as well.
- WiFi connectivity using the ESP32 module (illustrated in Figure 12) which is an improved version of the ESP8266 family. Espressif Systems are designed and developed by the ESP32 family. A dual-core, ultra-low power coprocessor is presented in the ESP32. It was created as a result of ESP2866's lax security.
- RS485 connectivity, which is used to connect to a conventional Ethernet module USR-TCP232-304 as shown in Figure 13.

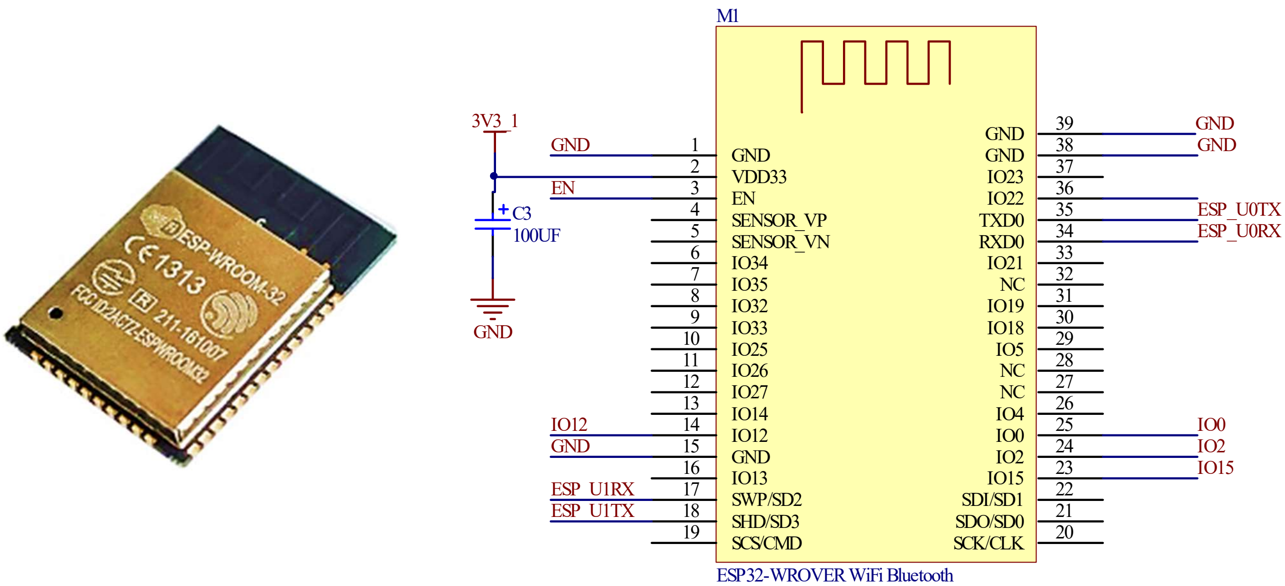


Fig. 12 Picture and connection diagram of ESP32

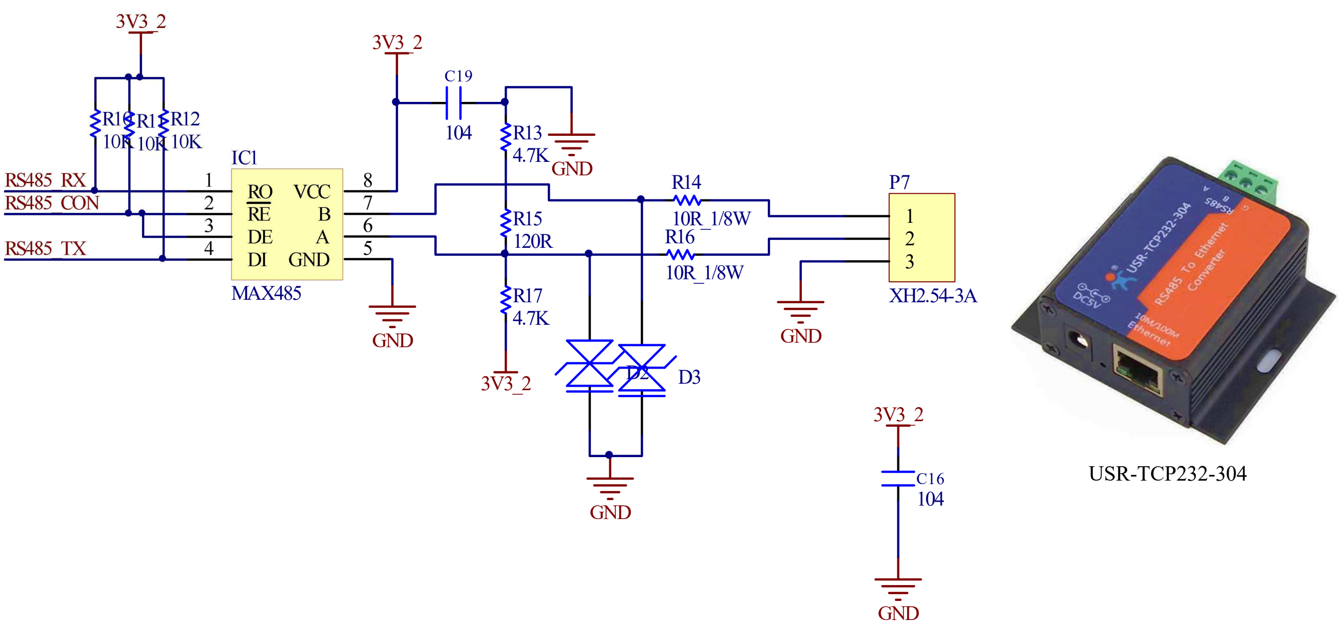


Fig. 13 Principle diagram to connect to the ethernet module USR-TCP232-304

Table 1. Measurement Test Results

Level	Q (liters/hour)	Indicator on the meter (liter)			Vc (liter)	Error (%)
		V_{1d}	V_{2d}	V_d		
QI	2000	122.3	223.5	+101.2	100	+1.2
		225.1	326.5	+101.4		+1.4
		328.8	430.1	+101.3		+1.3
Q_{II}	1000	435.2	486.2	+51.0	50	+2.0
		487.5	538.1	+50.6		+1.2
		540.1	590.9	+50.8		+1.8

Figure 14 is the specific device's schematic diagram.

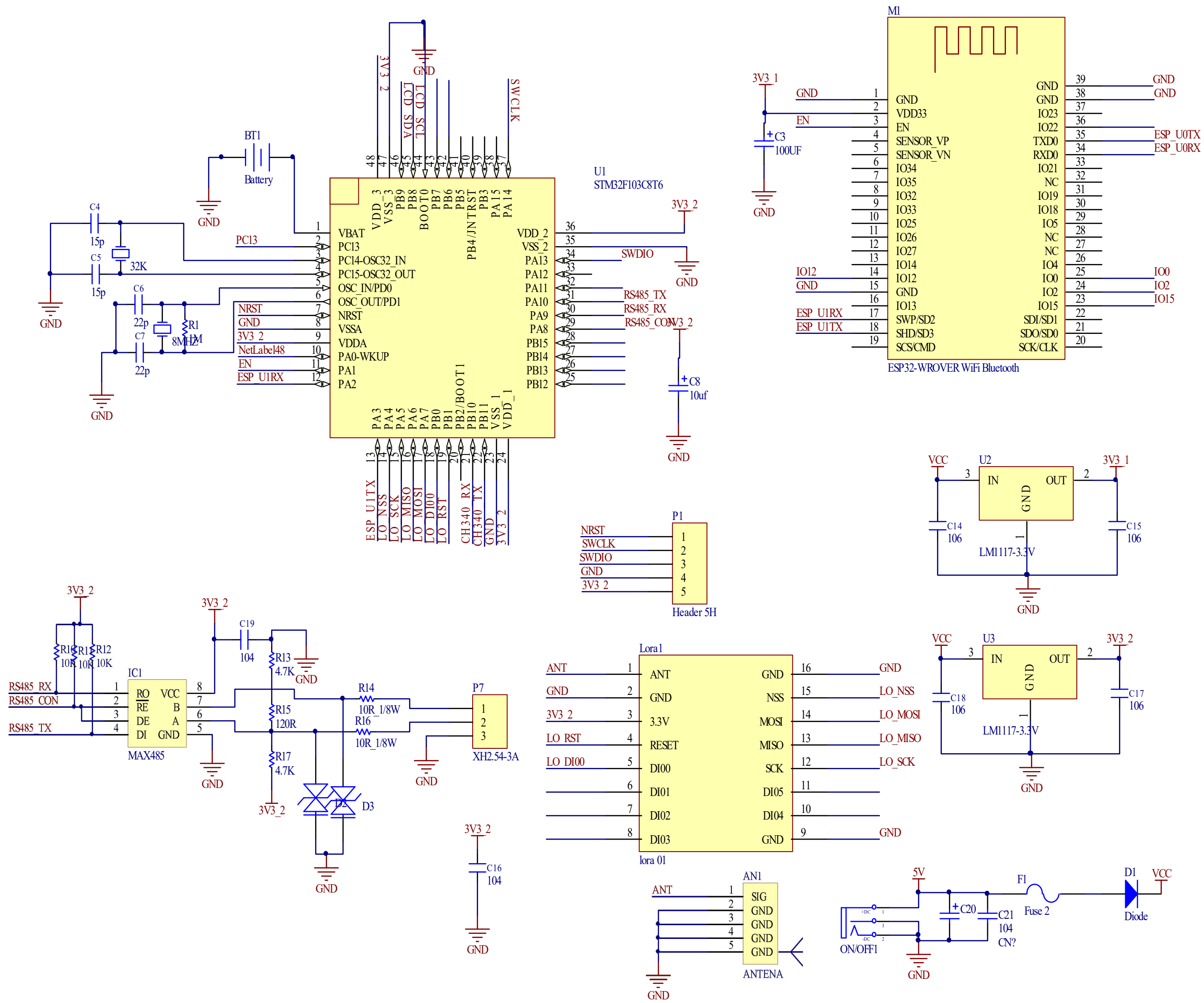


Fig. 14 The principle diagram of Lora Gateway station

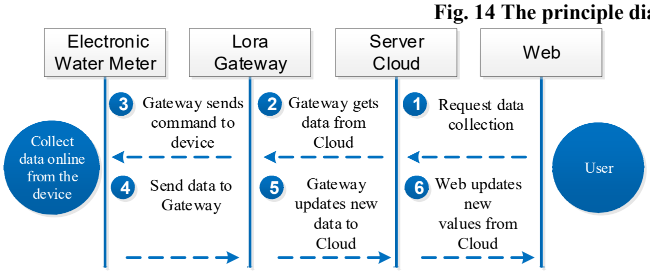


Fig. 15 Data collection protocol

Fig. 16 Gauges after complete assembly

Fig. 17 Watch checking at the inspection center

2.4. Building Data Management Software

In this paper, Firebase data [13] to store the data is employed. Firebase is a real-time database service that enables and assists users in web development. The data from the water meter will be collected in steps, as depicted in Figure 15.

3. Experiments and Results

From the results of the analysis and selection of hardware devices in the above section, a complete electronic water meter and a central controller have been practically designed and installed, as shown in Figures 16-20.

The apparatus is accuracy-tested at the quality control center, as shown in Figure 17.

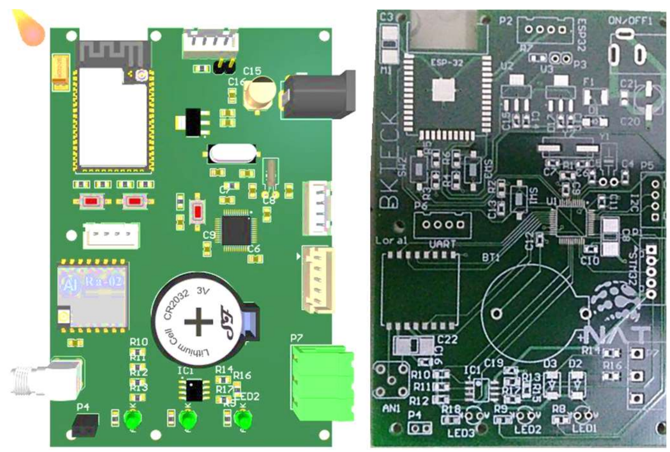
In this example, two cases of 1000 and 2000 liters of water per hour are used to test the designed meter. Measure three times using a 100-liter sample of water, pump the water at a rate of 2000 liters per hour through the meter, and record the measurement (liters) on the dial both before and after pumping (V_1 and V_2, respectively). If V_c is 50 (liters) and the flow rate is 1000 (liters per hour), the measured water is computed using the following formula:

$$V_d = V_{2d} - V_{1d} \quad (2)$$

The following equation is used to determine the number:

$$\delta = \frac{V_d - V_c}{V_c} * 100\% \quad (3)$$

The measurement results meet the design criteria, with a maximum error of 2 percent and the lowest of 1.2 percent, as shown in Table 1. Future testing at various Q flow rates and V_c sample water levels are still required. If the clock's operating time is extended, the design, manufacture, and market distribution accuracy can be determined, and the watch's dependability and stability may be verified.



(a) (b)

(a) Design of a 3D-printed circuit
(b) Printed circuit board – PCB after machining
Fig. 18 Printed circuit

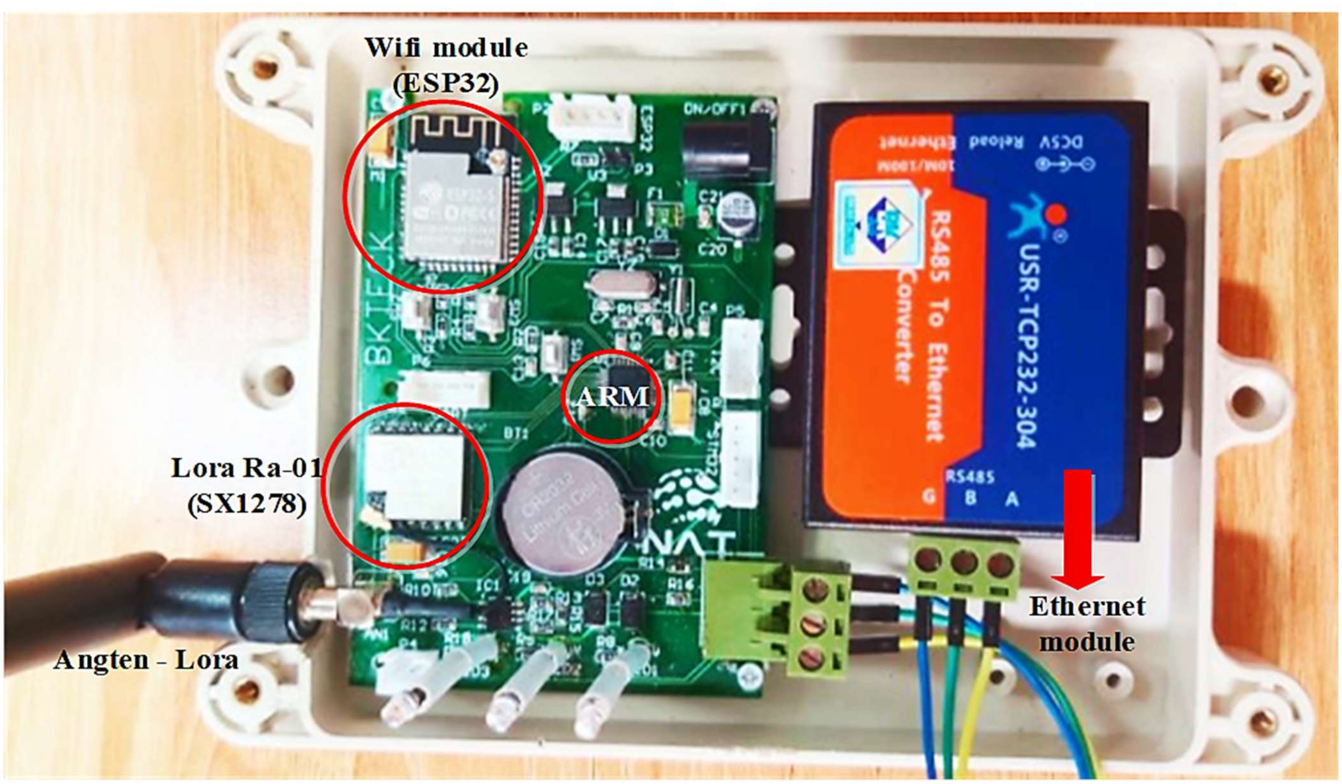


Fig. 19 Layout of equipment inside

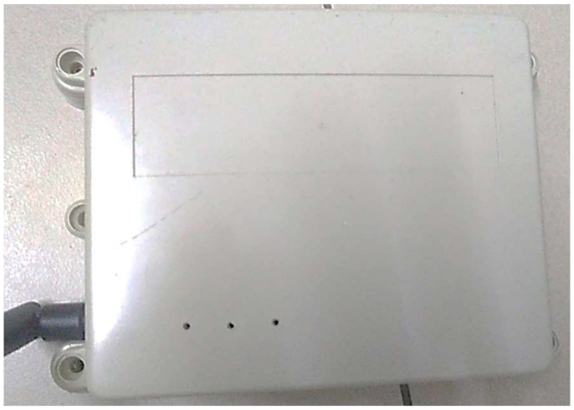


Fig. 20 Lora Gateway after assembly

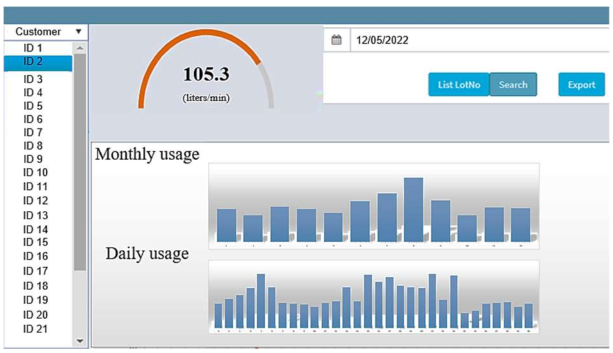


Fig. 21 Automatic water management system

Using the database on Firebase, a webserver to monitor is designed to manage the data of electronic water meters in buildings and with the long-range wireless communication module. The web has the interface as shown in Figure 21. The manager can monitor the apartments' water consumption and the statistical flow chart by day and month. It is truly significant in practice.

4. Conclusion

This paper has presented a step-by-step design for an electronic water flow meter which can be applied effectively in Vietnam. The gadget is quite tiny because of the IC's ability to combine substantial functionality. The entire design, including wireless connectivity, the control circuit and the casing, have also been successfully built. A facility that specializes in testing water meters performed quality checks on the gadget. It is anticipated that software to access internet databases, create invoices to collect a payment, calculate water usage automatically, and show online parameters on the web and smartphones would all be possible. Therefore, the digital water meter system proposed in this paper is highly feasible to be applied in Vietnam.

Funding Statement

This work was supported by the Project Granted number [18-2021-RD/HĐ – ĐHCN], Hanoi University of Industry.

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