A system for managing and controlling hydraulic consumption of homes based on ESP32

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***Abstract*—The Northeast region of Brazil faces a harsh reality regarding water supply. According to Eco Nordeste, 27.6% of Northeasterners lack water in their taps, and 72% of the population does not have sewage collection. In certain areas, such as specific regions of Recife, water is distributed only one day per week, making this day crucial for filling water tanks. The goal of this research is to develop a system for managing and controlling hydraulic consumption in homes within an IoT context. To achieve this, a low-cost PCB will be designed and a web application will be created to manage the automated flow of water to fill water tanks. The system will be remotely controllable, enabling data from sensors and modules to be accessed and displayed on a smartphone app. The ESP32 microcontroller and the Blynk library were used to facilitate the implementation of the system and the communication between the application and the embedded platform.**

***Index Terms*—Water consumption, IoT, ESP32, Management.**

I. Introduction

Firstly, when analyzing the problem holistically, the primary dilemma affecting large parts of the Brazilian Northeast is the scarcity of water supply and the limited availability of days when water is accessible to the population. This situation necessitates constant readiness for the specific day and time water will be available [1]. To address this issue, the initial proposal involves developing an autonomous, fully electronic system that can be managed via a smartphone. This system would control water meters and pumps, providing feedback on the system's overall performance. It would automatically turn the system on and off and would use an internet-connected board to monitor its complete functionality [2].

Given this context, the objectives of this work are as follows:

- Develop a cost-effective Printed Circuit Board (PCB): The goal is to create a PCB that offers a practical and accessible solution to a complex problem, ensuring it is easy for everyone to reproduce.
- Automate water tank filling: Design a hardware system to automate the filling of water tanks in homes with unreliable water supply. This system will be monitored through a web application, aiming to minimize water loss during filling. The entire process will be controlled by software using the Blynk library, which can be accessed from any smartphone [3].
- Develop user-friendly software: Create software to manage the proposed platform, allowing implementation without extensive programming knowledge. The platform will be controllable remotely, enabling sensor and module data to be accessed and displayed in a smartphone application. Additionally, it will support load activation and various other functionalities.
- Assemble the system practically: Integrate sensors, relays, and various modules with connectors, secure the PCB, adapt the flow sensor to the home's pipes, and install the electric float to choose the optimal water level. The system will function in an integrated and synchronized manner.

II. Related works

In [4] presents the design and development process of a Wireless Data Acquisition System (WiDAS) which is a multi-sensor system for water level monitoring. An excellent system, however, without using Internet of Things (IoT) technology.

In [5] presents the implementation in IoT context, open source hardware and software, used the NodeMCU microcontroller for the Sensor Node Module, and the Java language was used for the Server Module. A system has excellent applications, but in practice, it adds a lot of Java language, large lines of code and more complex servers for synchronizing information.

In [2] presented a solution using Arduino, bluetooth, level sensor, and an Android app developed by a program called APP Inventor, from which the residential resident can monitor the volume of water from a smartphone or a tablet.

Table I presents a list of 4 systems (Water level detection controller [6], Wireless fully automatic electronic water [7], Automatic water level control system [8] and WNK 4G NB/Lora IoT water level sensor [9]) similar to the system proposed in this research. All these systems are already commercially available, although most have a higher cost and do not apply to the IoT context.

TABLE I: comparative analysis of hydraulic management and control systems.

Systems	Price ($)	Communication	IoT
Water level detection controller [6]	93.57	Serial	No
Wireless fully automatic electronic water [7]	61.46	RF	No
Automatic water level control system [8]	108.18	RF	No
WNK 4G NB/ lora IoT water level sensor [9]	150	Wi-Fi	Yes
The proposed system in this research	**68.13**	**Wi-Fi**	**Yes**

III. THE PROPOSED SYSTEM

The system for managing and controlling the hydraulics consumption of homes proposed is inserted in the IoT context. The system architecture can be analyzed in Figure 1. The sensors facilitate all interactions between the real world and the digital world. For the board to activate the water pump and fill the tank, two pieces of information are necessary: the presence of water in the street and the water level in the tank being below normal.

The first signal input device is the electric float, which is connected to the two-way KRE connector. The electric float's blue and black wires connect to the "BOIA" connector, opening and closing the contact as the float level rises and falls. This action indicates a low water level to the microcontroller.

The second crucial signal is the presence of water in the street. Activating the pump without street water could damage the pump. The flow sensor provides this information by indicating whether water is flowing in the street. It is connected to the residence's water network piping, downstream of the water meter. When water flows, the microcontroller receives a signal from the flow sensor (the blue LED lights up on the board and in the Blynk app), indicating the presence of water.

When both conditions are met—water in the street and a low water level in the tank (the red LED lights up on the board and in the Blynk app)—the microcontroller (ESP32) activates the relay (the green LED lights up on the board and in the Blynk app), which in turn activates the water pump. During the filling process, if either signal is lost, such as if street water is no longer available or the tank becomes full, the microcontroller will turn off the relay, stopping the pump.

A. Hardware and software

Extensive testing was initially conducted using a protoboard for this project. However, to achieve better operational efficiency, a custom PCB was designed (Figure 2). The primary focus was on optimizing the board's performance by using

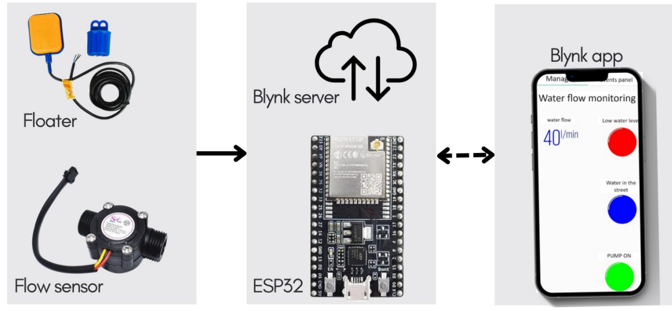


Fig. 1: System proposed architecture.

large 2.5mm pads and 1mm tracks to isolate external and internal interference. The PCB was developed with two layers (top and bottom) and has dimensions of 99.3 mm in length and 96.5 mm in height. An earth welding mask was included to reduce interference and noise, as well as to minimize the number of electric trails.

The PCB was manufactured by JLCPCB, which allowed for customization of various specifications, including thickness, pad material, PCB color, silkscreen, and protective resin. These specifications were chosen to enhance the board's overall performance.

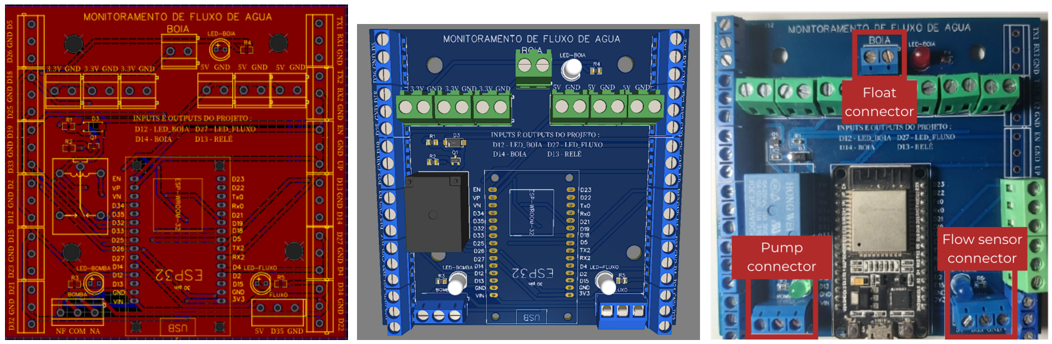
The ESP32 Wroom Devkit v1 was used as the embedded platform for this project. This platform consists of a series of low-cost, low-power microcontrollers with built-in Wi-Fi and dual-mode Bluetooth. The ESP32 was selected for this project due to its ease of access to embedded programming languages and its 100% compatibility with the Blynk platform. Blynk significantly reduces the software size, thereby simplifying the code.

The 1/2" YF-S201B Flow Switch Water Flow Sensor is a small valve equipped with a pinwheel-shaped rotor and an attached magnet. This sensor works with a hall effect sensor that sends a PWM signal. Connected to the input of the residence's water system, the rotor turns when water flows through it, influencing the pulse frequency emitted. Each pulse measures approximately 2.25V. The hall effect sensor's pulses allow the microcontroller to determine the water volume and flow rate entering the home, indicated by a blue Light Emitting Diode (LED) lighting up.

$$FlowMilliLitres = \frac{Flowrate}{60} \cdot 1000 \quad (1)$$

$$Flowrate = (\frac{1000}{elapsedTime}) \cdot pulseCount \quad (2)$$

The ANAUGER Sensor (Electric Float) is a floating switch used to monitor and indicate the water level in the reservoir. It operates like a standard relay, using NC (Normally Closed), NO (Normally Open), and common wires. In practical use, NC and NO terminals create a closed circuit when the float is in the vertical downward position (indicating a low water level, LED2 lights up) and an open circuit when the float is in the horizontal upward position (indicating a high water level,



(a) PCB Layout. (b) PCB 3D. (c) PCB.

Fig. 2: PCB of the system managing and controlling hydraulic consumption of home.

LED2 goes out), signalling that the tank is full. The electrical connections for the float can be seen in the electrical diagram in Figure 3a.

A 12V relay was used to control the pump, dependent on two signals: the empty tank signal (red LED) from the electric float and the street water signal (blue LED) from the flow sensor. The relay, supporting up to 10A - 125VAC or 10A - 250VAC, can handle the electrical consumption of the pump. When both signals are active, the microcontroller activates the relay (green LED1 lights up), activating the pump to fill the water reservoir. The relay has three connections: Common (C), Normally Open (NO) and Normally Closed (NC). When off, Common is connected to NC; when activated, it changes to NO. We can see all this in the relay electrical diagram in Figure 3b.

Blynk[1] was developed for use in IoT projects, which describes how real-world objects are connected in a network and accessible via the internet. The key feature of Blynk utilized in this project is its ability to facilitate communication with a microcontroller/embedded platform using compact code. It relies on a server to synchronize all hardware information with the smartphone, allowing for efficient operation with minimal lines of code, thereby reducing the risk of bugs and crashes.

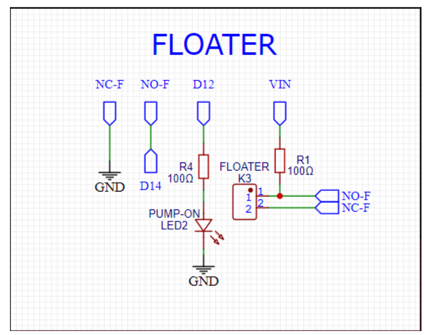
B. Budget Estimate

With all components defined, the implementation cost can be estimated, as shown in Table II. It is important to note that this is just one approach, and there are multiple ways to implement a solution that achieves the desired results.

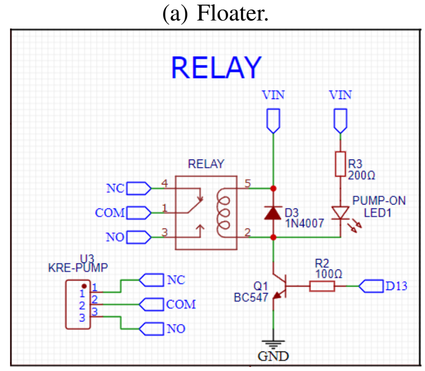
The selection of components was based on their functionalities and cost. Compared to other similar systems in the IoT context, the proposed system had the lowest cost, approximately $68.13.

IV. System Evaluation

To confirm the practicality and correctness of the project, it was implemented in a real-life scenario at a residence experiencing water scarcity. The specific location chosen for installing the board was selected because it was close to all the



(a) Floater.



(b) Relay.

Fig. 3: Electrical diagram.

elements interacting with the PCB. The board was fixed using conventional nails and positioned near the router to ensure Wi-Fi access, enabling communication with the Blynk app. This setup provided complete feedback, allowing us to monitor the process entirely.

The next paragraphs propose possible improvements to the project:

- Blynk Platform Integration: Using the Blynk platform was complex due to the need to manage virtual variables and interface with the Arduino IDE. However, this approach significantly reduced the code size, compared to developing a custom application for management.
- Hardware Component Access: All hardware materials, except the PCB, were purchased from Recicomp, while

[1]https://blynk.io/

TABLE II: Estimated prices for components described in the proposed system.

Electronic components/Materials	Price ($)
PCB Prototyping	25.47
Esp32 Wroom Devkit v1	11.97
Flow Sensor 1/2 YF-S201b	6.63
ANAUGER Sensor	12.34
Relay Module 12V - NA187	5.51
Diode 1N4007 SMD (M7)	0.037
Transistor BC547 SMD	0.055
11 connectors KRE of 3 vias	3.85
7 connectors KRE of 2 vias	1.68
5 Resistor 100\Omega SMD 0804	0.46
3 Diffuse LED	0.14
Total	**68.13**

the PCB was manufactured by JLCPCB. Manual soldering using 1mm Cobix solder presented some difficulties with smaller pads, but these were resolved with a quality Hikari soldering iron.

- PCB Prototyping: Designing the PCB tracks with EasyEDA's standard autoroute was challenging due to DRC errors on a densely packed board dimensioned at 10cm by 10cm to minimize costs. This issue was mitigated by creating a copper area (solder mask) to manage excessive tracks.
- Practical Installation: Installing the PCB and components required knowledge of water pressure and plumbing, particularly for the flow sensor, which needed two 25mm sleeves—one side threaded and the other not—making installation more complex.
- Testing with Various Configurations: Wireless tests revealed occasional connection issues. A critical test case involved the distance between the board and the router, as long distances resulted in unstable connections or failure to connect to the internet.
- Custom Application Development: Developing software independent of the Blynk platform would focus on the project's main purpose, addressing connection issues, and optimizing ESP32 device memory.
- Additional Sensors: Adding more sensors could estimate the water tank's content, detect sudden pressure variations, identify potential leaks, and calculate monthly water costs. A solenoid valve could also be included to control the street water valve based on specific voltage inputs.

V. Conclusion

The proposed system for managing and controlling hydraulic consumption of homes involved creating a PCB to receive information from sensors and send it wirelessly to an application, thereby automating repetitive processes and making it easier to control the water pump. This automation aimed to streamline the process of filling the water tank, which is essential for residential water use.

It can be asserted that the proposed system, with a cost of $68.13, is the most cost-effective compared to existing commercial IoT systems designed to monitor and manage hydraulic consumption of homes. This research aims to facilitate quicker adoption of this technology by a larger population, thereby mitigating impacts on residential water supply.

The system was exhaustively tested for about a week at the chosen residence, yielding highly satisfactory results and ensuring its stability in that location, as shown in this link [2].

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