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Arduino-Based Air Pipe Leak Detection System

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ABSTRACT
Leakage in water pipelines can lead to significant losses both economically and environmentally. To address this issue, this study presents the design and implementation of a leakage detection system using the Arduino Nano microcontroller and YF-S201 flow sensors. The system works by comparing water flow data at two points in the pipeline. If there is a significant difference in flow rate, the system detects it as a leak and activates a buzzer as an alarm while displaying information on an LCD 16x2 I2C. Testing results showed that the system is able to accurately detect leaks with an average delay of less than 1 second.
***Keywords**:leakage detection, Arduino Nano, flow sensor, water pipe, microcontroller.*

INTRODUCTION
Water is a natural resource that is crucial for human life. In modern society, clean water is used not only for consumption but also for hygiene, industry, agriculture, and other daily activities (Djana, 2023). One common method of clean water distribution is through a pipeline network. However, this system often faces various technical problems, particularly pipe leaks. Leaks in water distribution systems can occur due to corrosion, excessive pressure, loose connections, or mechanical damage. Although seemingly small, undetected leaks can lead to water waste, reduced water pressure, and increased operational costs. In Indonesia, water leaks reportedly account for 20–30% of total water distribution in some pipeline networks (Hakim & Islami, 2024).

Manual leak detection is often difficult due to pipes being hidden underground or within building structures. This makes leak identification time-consuming and expensive. Therefore, several studies have proposed an automated system that uses a water flow sensor and a microcontroller such as an Arduino to detect leaks (Wahyu Santoso, 2022).

This system works by comparing the incoming and outgoing water flow in a pipe. If there is a significant difference, a leak is considered. The system will issue a warning via a buzzer and display the information on an LCD. This system is simple, inexpensive, and can be applied in both household and institutional environments. This research aims to design and build an Arduino-based water pipe leak detection system utilizing two water flow sensors. With this system, users are expected to be able to detect leaks early and initiate repairs promptly, thereby increasing water efficiency and minimizing losses.

METHOD
This research used a Research and Development (R&D) approach to design and build an Arduino microcontroller-based water pipe leak detection system. This method was chosen because it can produce a prototype device that can be directly applied in a simple, efficient, and effective household environment (Aribowo & Irwanto, 2021). The research was conducted at the researcher's home in Jombang Regency, East Java, from June to August 2025. The location was chosen because it allowed for direct simulation of actual household water distribution system conditions, thus simplifying the testing and monitoring process.

The hardware design in this study consists of several main components: an Arduino Nano as the system control center, two YF-S201 water flow sensors installed at the beginning and end of the pipe line to compare incoming and outgoing water discharge (BRAMANTYO, 2022), a 16x2 I2C LCD to display sensor readings and system status, and a buzzer as an audible indicator in the event of a leak. These

components are assembled into a single electronic system that operates automatically and in real time.

Meanwhile, the system software was developed using the Arduino programming language (C/C++) with a logic structure designed to detect differences in water flow. The program reads data from both sensors and calculates the difference. If the difference exceeds a predetermined threshold, the system displays a warning message on the LCD and activates a buzzer as an alarm. All sensor readings are taken periodically to ensure the system can detect leaks quickly and accurately.

The testing phase is carried out in two forms: testing each component individually and testing the overall system. Component testing aims to ensure that each device, such as the Arduino, flow sensor, LCD, and buzzer, is functioning properly (Nurhadiyono, 2024). System testing, meanwhile, simulates normal conditions (without leaks) and leak conditions (with partial pipe disconnections) to ensure the system can accurately detect differences in water flow. The test data is then analyzed to assess the system's performance in detecting leaks automatically and in real time.

RESULT AND DISCUSSION

At this stage, an Arduino-based water pipe leak detection system was successfully designed and tested in a domestic environment. The system consists of two YF-S201 water flow sensors installed at the beginning and end of the pipe, an Arduino Nano microcontroller as a data processing unit, a 16x2 I2C LCD to display information, and a buzzer as a leak warning indicator. The system works by comparing the water flow across the two sensors. If there is a significant difference in values, the system interprets this as an indication of a leak and issues an immediate warning.

Testing was conducted in three main scenarios. First, with the system off, all components are inactive, there is no water flow, and no data or warnings are displayed on the device (Figure 1). Second, with the system on and without leaks, both sensors display nearly identical water flow measurements, and the system does not trigger any warnings (Figure 2). Third, when a significant difference between the inlet and outlet water flows is detected, the system detects a leak, the buzzer sounds, and warning information is displayed on the LCD screen (Figure 3).

The test results for each component indicate that the entire device is functioning properly. The Arduino Nano is capable of reading data from the sensors and processing it in real time. Both flow sensors function normally, detecting inflow and outflow of water. The 16x2 I2C LCD clearly displays flow rate information and system status, while the buzzer successfully sounds when a leak is detected. Thus, this system has proven to be automatic, efficient, and accurate in detecting water pipe leaks.

This system has the advantage of not requiring an internet connection and can be implemented on various scales, including in households, schools, and public facilities. This system also supports water conservation and piping infrastructure maintenance by providing early warning of leaks. These results align with findings in previous studies by (Widiatmika, 2015) and (Wahyu Santoso, 2022), which also emphasized the effectiveness of using dual flow sensors to detect water leaks. Overall, this system provides a simple yet effective solution to addressing water leaks, which are often difficult to detect visually.

Result

An Arduino-based water pipe leak detection system has been successfully implemented and tested in a domestic environment. The system consists of two YF-S201 water flow sensors installed at the beginning and end of the pipeline, an Arduino Nano microcontroller as the data processing center, a 16x2 I2C LCD to display water flow information, and a buzzer as a leak warning indicator. Testing was conducted by running the system under three conditions: the system was turned off, the system was turned on with normal water flow (no leaks), and the system detected a significant difference in water flow as an indication of a leak.

Table 1 System Testing

Time(Second)	Sensor 1(L/Hour)	Sensor 2(L/Hour)
10	5,4	5,9
20	5,2	6,1

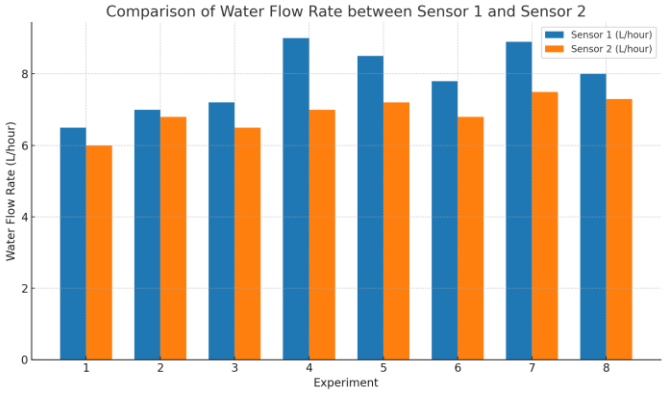

Figure 1. System Testing

In the first test, all devices were turned off and showed no activity, either on the LCD or from the buzzer. The second test was conducted with water flowing without any leaks, and the measurements from both sensors showed nearly identical flow values, and no warning was issued. In the third test, when a small leak was intentionally created in the pipeline, the sensors detected the difference in flow between the input and output. The system then displayed a warning on the LCD and the buzzer sounded to indicate a leak.

Overall, all components performed well. The Arduino Nano is capable of processing data from both sensors in real-time. The LCD displays flow data and system status, while a buzzer is activated when the flow difference exceeds a predetermined leak threshold. These results demonstrate that the system can be used effectively to monitor water distribution and detect leaks automatically and economically, especially in small-scale settings such as households or public facilities.

Discussion

The test results of the Arduino-based water pipe leak detection system show a difference in flow rate between sensor 1 and sensor 2. The graph shows that in each trial, the flow rate measured by sensor 1 was consistently higher than that of sensor 2. This indicates a possible water loss due to a leak occurring between the two sensor points.

For example, in the fourth trial, sensor 1 recorded a flow rate of 9 L/hour, while sensor 2 only recorded 7 L/hour. This 2 L/hour difference indicates that the system is capable of identifying a reduction in flow rate that should not occur under normal conditions. The greater the difference between the flow rates of sensor 1 and sensor 2, the greater the likelihood of a leak in the pipe.

This difference in values can be used as a basis for activating an alarm system (buzzer) as an early warning of potential leaks. Thus, the designed system has performed as intended, namely being able to detect changes in water flow rate in real time.

Overall, the system demonstrated good performance in identifying differences in flow rate as an indicator of leaks. This proves that the use of two flow sensors processed by an Arduino microcontroller is an effective and efficient solution in monitoring water distribution, especially at the household scale and other small agencies.

CONCLUSIONS

Based on the design and testing of an Arduino-based water pipe leak detection system, it can be concluded that this system is capable of detecting differences in water flow in real time using two flow sensors. Sensor 1 is installed at the beginning of the flow and Sensor 2 at the end of the pipe flow. The system works by comparing the measurements from both sensors. If there is a significant difference in water flow—for example, Sensor 1 registers 9 L/hour while Sensor 2 only registers 4 L/hour—the system will identify a potential leak.

This system successfully provides an alert via an LCD display and buzzer when a leak is detected, and demonstrated good reliability when tested under real-world conditions in a domestic environment. Therefore, this system can assist users in monitoring water distribution and detecting leaks early, thus minimizing water waste and expediting damage management.

Furthermore, this device has the advantages of being relatively inexpensive, easy to install, and does not require an internet connection, making it suitable for use in homes, schools, or other public facilities.

Future development of this system is expected to be enhanced by integrating additional features such as connecting to a remote monitoring application.

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