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Implementation of a Cup Availability Monitoring System in the Microcontroller-Based Automatic Milk Pasteurization Production Process at Luru Barokah MSMEs

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A B S T R A C T

Implementation of a Microcontroller-Based Cup Availability Monitoring System for the Automated Milk Pasteurization Production Process at MSME Luru Barokah. This research aims to design, build, and implement a microcontroller-based monitoring system to automate this process. The methodology includes observation, interviews, literature review, and documentation, with system development following the Research and Development (R&D) model encompassing analysis, design, development, evaluation, and implementation phases. The developed prototype utilizes an Arduino Uno R3 and an HC-SR04 ultrasonic sensor to continuously detect cup distance, using a calibrated threshold of 16 cm. The system also features a buzzer for audible alerts and red and green LEDs as visual indicators of cup availability status. Implementation results demonstrate 100% detection accuracy and a rapid response time of under one second, effectively assisting operators by eliminating the need for manual checks. This implementation is expected to enhance operational efficiency, minimize the risk of human error, and support the smooth operation and sustainability of milk pasteurization production at UMKM Luru Barokah

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INTRODUCTION

The rapid development of industrial automation technology has encouraged various business sectors, including Micro, Small, and Medium Enterprises (MSMEs), to adopt technology-based systems to improve efficiency and productivity. In the dairy processing industry, particularly in the pasteurization process, a system is needed that can support smooth production continuously and with minimal errors.

UMKM Luru Barokah, located in Dusun 2, Desa Bumi Ayu, Kecamatan Sukadana, Lampung Timur, is a pasteurized milk processing business that still relies on manual monitoring of cup packaging availability. This manual practice creates crucial problems, such as undetected empty cups that hinder the production flow, the potential for machines to stop suddenly, and the risk of milk being wasted during the sealing stage. Moreover, the conventional system makes it difficult for operators to monitor the condition of the cups in real-time amidst their busy tasks.

Previous research has shown that the implementation of microcontroller-based systems in industrial processes can enhance efficiency, accuracy, and speed in operational decision-making. Microcontrollers like Arduino are widely used due to their ease of implementation and flexibility in various automation.

Based on the aforementioned problem, this research aims to design, build, and implement a cup availability monitoring system based on the Arduino microcontroller that can operate automatically and in real-time to enhance the smoothness of the milk pasteurization production process at UMKM Luru Barokah.

LITERATURE REVIEW

Sistem Monitoring

A system is defined as a set of interrelated components that work together to achieve a goal, including input, process, output, and feedback. Monitoring is the process of continuously collecting, observing, and analyzing data to understand the condition of a system, ensuring the process runs according to plan, and enabling corrective actions if deviations occur.

Mikrokontroler Arduino Uno R3

Arduino Uno R3 is a microcontroller board that serves as the control center in automation systems, relying on the ATmega328 chip as the main processing brain. With an operating voltage of 5 Volts and an input voltage range of 7-12 Volts, this board has 14 digital input/output pins. Arduino Uno R3 was chosen because of its practical characteristics and abundant resources in the development of inventory monitoring systems.

Sensor Ultrasonik HC-SR04

The HC-SR04 ultrasonic sensor functions to convert physical quantities (sound) into electrical quantities. The emitted ultrasonic waves will bounce off when they hit the surface of an object, and the reflection will be received back and converted into an electrical signal by the piezoelectric element. Based on testing within the distance range of 0 to 50 cm, the HC-SR04 sensor showed an average error of ±0.03 cm with a coefficient of determination (R^2) of 0.9975.

Buzzer dan LED

The buzzer functions as an output component to provide an early warning in the form of sound, while the LED (Light Emitting Diode) serves as a visual indicator. The LED has the advantage of being an energy-efficient lamp with a sufficiently strong light intensity. The combination of the buzzer and LED provides an effective warning because it can be heard and seen by the operator.

METHODOLOGY

Time and Place of Research

The research was conducted from April 24, 2026, until the system development and testing process was completed. The research site is the Luru Barokah MSME located in Dusun 2, Bumi Ayu Village, Sukadana District, East Lampung Regency, Lampung Province.

Data Collection Methods

The data collection methods used include:

1. Observation: Direct observation of the milk pasteurization production process
2. Interview: Conducted with the owners of SMEs and production operators
3. Literature Study: Studying references related to microcontrollers and sensors
4. Documentation: Collecting photos, videos, and research notes

System Development Method

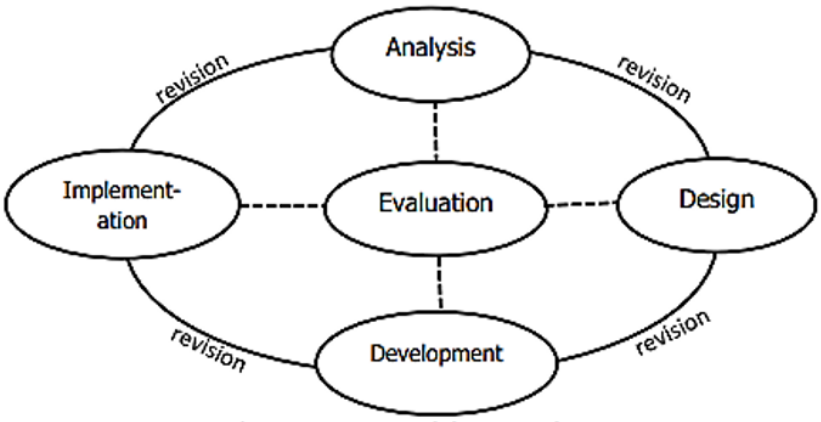

Figure 1. Flowchart of the R&D Research Process

The system development method uses a Research and Development (R&D) approach consisting of five stages.:

1. Needs Analysis: Identifying problems and system requirements through observation and interviews.
2. Design: Creating flowcharts, circuit designs, and program logic.
3. Development: Implementing hardware and software.
4. Evaluation: Testing the system using Black Box Testing.
5. Implementation: Applying the system in the actual production environment.

Flowchart of the R&D Research Process

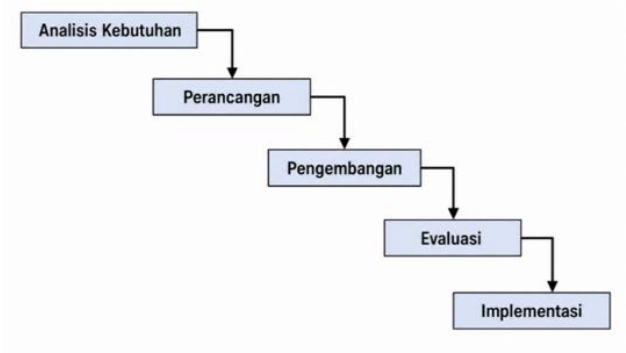

Figure 2. Picture R & D

Tools and Materials

Table 1. Hardware

No.	Device	Specification
1.	Laptop	Lenovo Thinkpad T470
2.	Prosesor	Core i5 – 6300U
3.	RAM	8 GB
4.	Storage	256 GB

Table 2. Software

No.	Device	Specification
1.	**Arduino IDE**	The main platform for writing code in C/C++, compiling, and uploading firmware to the Arduino Uno R3.
2.	***Tinkercad***	Online simulation platform for designing and testing electronic circuits (Arduino, ultrasonic sensor, buzzer) before physical implementation. Used for the initial validation of cup detection logic.

Table 3. Research Materials

No.	Research Materials	Explanation
1.	Arduino Uno R3	Arduino Uno R3 is the control center (brain) of the monitoring system. Its function is to read data from sensors, execute control logic, and send commands to display status or alerts.

2.	Ultrasonic Sensor	HC-SR04 (Measuring the Distance of the Cup Drop, 5V voltage)
3.	*Buzzer*	As an audio warning indicator when the cup is not detected.
4.	*Breadboard*	To Assemble Components.
5.	Jumper Cable	Male-to-female and male-to-male to connect components.
6.	LED Dioda	The LED will light up to indicate a certain status, such as when the cup is successfully detected by the ultrasonic sensor or as a marker that the system is active.
7.	Resistor	A resistor is a passive electronic component that functions to limit the electric current flowing in a circuit. In this study, a resistor is used together with an LED to prevent excess current that could damage the LED. The commonly used resistor value is 220 Ω, adjusted to the output voltage of the Arduino Uno R3 at 5 volts.

System Flow Design

The flowchart illustrates the system flow starting from pin initialization, ultrasonic sensor reading, decision-making based on the distance value against the 16 cm threshold, to the activation of the buzzer.

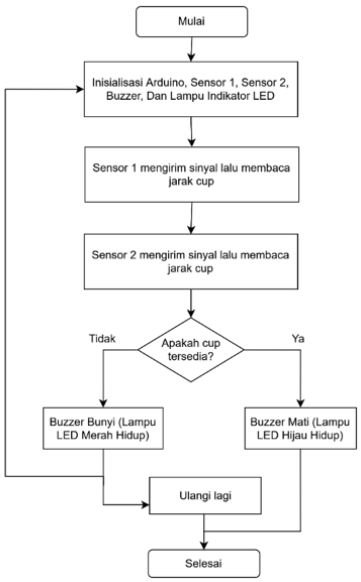

Figure 3. System Flow Design Diagram (Flowchart)

RESEARCH RESULT AND DISCUSSION

System Design Results

The cup availability monitoring system is designed using the Arduino Uno R3 as the control center, two HC-SR04 ultrasonic sensors to detect cups from the left and right sides, a buzzer as an audio indicator, and red and green LEDs as visual indicators.

The system flow starts from the Start stage, where the system is powered on by supplying power to the Arduino Uno R3 via the USB port or adapter. After the system is active, the Arduino performs Pin Initialization, which involves defining the pins that will be used for communication with the ultrasonic sensor (Trigger and Echo pins), buzzer, and LED indicator. This initialization is important to ensure that each component is properly connected and ready to receive commands from the microcontroller.

After the initialization is complete, the Arduino starts the Ultrasonic Sensor Reading process. This process is carried out by sending a trigger pulse through the Trigger pin for 10 microseconds, which instructs the sensor to emit ultrasonic waves toward the stack of cups in the storage container. The ultrasonic waves travel through the air until they hit the surface of the top cup, then they are reflected back toward the sensor. The wave reflection is received by the Echo pin, and the Arduino calculates the travel time of the wave from the moment it is emitted until it is received back. Based on that travel time.

After the distance value is obtained, the Arduino proceeds to the Decision-Making stage by comparing the measured distance value against the threshold value that has been determined through the calibration process. The threshold value used in this study is 16 cm. The decisions made are as follows:

1. If the Distance ≤ 16 cm (threshold value), then the system assumes the cup is still available in the containment container. This condition means that the ultrasonic waves are reflecting off the surface of the cup that is within close range. The Arduino then issues a command to turn off the Buzzer and turn on the Green LED as a visual indicator that the cup is in a safe condition. Next, the program flow returns to the sensor reading process to perform continuous monitoring (looping).
2. If the Distance > 16 cm (threshold value), then the system considers the cup unavailable or out of stock. This condition means that the ultrasonic wave is bouncing off the bottom of the container or a farther surface because there is no cup in front of the sensor. The Arduino then issues commands to Activate the Buzzer as an audible warning and Turn On the Red LED as a visual warning, while the Green LED is turned off. The buzzer will continue to sound as long as the cup is unavailable, and the program flow returns to the sensor reading process to monitor whether the cup has been refilled by the operator.

The process of reading sensors, making decisions, and activating indicators occurs continuously (looping) with a minimum delay of 100 milliseconds to ensure a fast and real-time system response. With this system flow, production operators can immediately know when the cup supply is running low or out through a buzzer sound alert and a red LED visual, allowing for quick cup refilling and preventing production disruptions.

Program Implementation

The program was developed using Arduino IDE with the following logic:

```
// ============================================================
//  2 SENSOR HC-SR04 + LED INDICATOR PER SISI + BUZZER
//  KIRI : TRIG=5, ECHO=6  |  KANAN : TRIG=9, ECHO=10
//  LED MERAH KIRI=7, HIJAU KIRI=8
//  LED MERAH KANAN=11, HIJAU KANAN=12
//  BUZZER=4
// ============================================================

#define trigKiri   5
#define echoKiri   6
#define trigKanan  9
#define echoKanan  10
#define Buzzer     4

#define RED_KIRI    7
#define GREEN_KIRI  8
#define RED_KANAN   11
#define GREEN_KANAN 12

float jarakKiri, jarakKanan;

void setup() {
  pinMode(trigKiri, OUTPUT);
  pinMode(echoKiri, INPUT);
  pinMode(trigKanan, OUTPUT);
  pinMode(echoKanan, INPUT);
  pinMode(Buzzer, OUTPUT);

  pinMode(RED_KIRI, OUTPUT);
  pinMode(GREEN_KIRI, OUTPUT);
  pinMode(RED_KANAN, OUTPUT);
  pinMode(GREEN_KANAN, OUTPUT);

  Serial.begin(9600);
  Serial.println("Sistem Deteksi Cup - Kiri & Kanan");
}

// Fungsi baca jarak dari satu sensor
float bacaJarak(int trigPin, int echoPin) {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(5);
  digitalWrite(trigPin, LOW);
  long duration = pulseIn(echoPin, HIGH);
  float jarak = duration * 0.0343 / 2; // cm
  return jarak;
}

void loop() {
  // Baca kedua sensor
```

```
jarakKiri = bacaJarak(trigKiri, echoKiri);
jarakKanan = bacaJarak(trigKanan, echoKanan);

// Tampilkan di Serial Monitor
Serial.print("Kiri: "); Serial.print(jarakKiri);
Serial.print(" cm, Kanan: "); Serial.print(jarakKanan);
Serial.println(" cm");

// ---------- LOGIKA LED PER SISI (INDEPENDEN) ----------
// Sisi Kiri: Hijau jika cup terdeteksi (< 16 cm), Merah jika tidak
if (jarakKiri < 16) {
  digitalWrite(GREEN_KIRI, HIGH);
  digitalWrite(RED_KIRI, LOW);
} else {
  digitalWrite(GREEN_KIRI, LOW);
  digitalWrite(RED_KIRI, HIGH);
}

// Sisi Kanan: Hijau jika cup terdeteksi (< 16 cm), Merah jika tidak
if (jarakKanan < 16) {
  digitalWrite(GREEN_KANAN, HIGH);
  digitalWrite(RED_KANAN, LOW);
} else {
  digitalWrite(GREEN_KANAN, LOW);
  digitalWrite(RED_KANAN, HIGH);
}

// ---------- LOGIKA BUZZER ----------
 // Buzzer berbunyi jika ada sisi yang TIDAK mendeteksi cup (jarak > 16)
if (jarakKiri > 16 || jarakKanan > 16) {
  digitalWrite(Buzzer, HIGH);
} else {
  digitalWrite(Buzzer, LOW);
}

delay(10); // jeda pembacaan
 }
```

Simulation Results with Tinkercad

The testing of the Arduino-based cup detection system with two HC-SR04 ultrasonic sensors was conducted in two stages, namely simulation testing using Tinkercad and direct testing on the production tool. The purpose of the testing is to verify the system's functionality, the accuracy of distance measurements, and the response of the LED indicator and buzzer according to the designed logic.

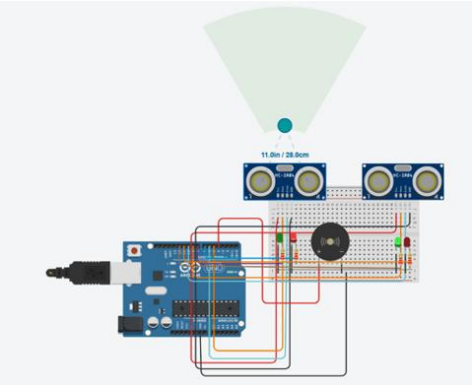

Figure 4. Image of the left sensor distance reading display

The testing was conducted by placing the object at a medium distance. As shown in the Display Image of the left sensor distance reading, the ultrasonic sensor successfully read the object distance as 28.8 cm (equivalent to 11.0 inches). Because this value is above the 16 cm threshold, the system automatically interprets that no cup is detected on that side, causing the indicator LED to turn red and the buzzer to activate as a marker. This result proves that the system is capable of accurately distinguishing between the 'cup present' and 'no cup' conditions based on changes in object distance.

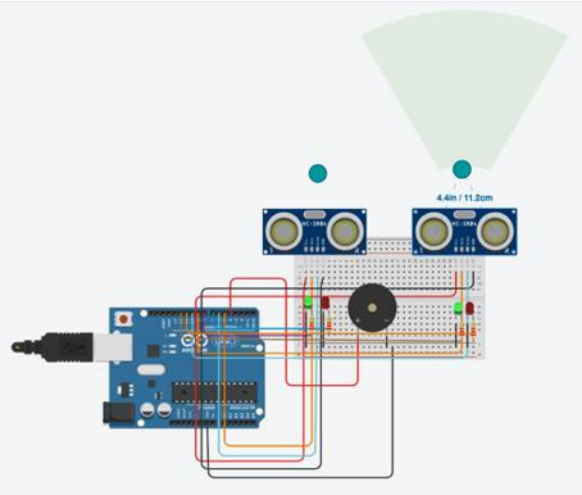

Figure 5. Image of the near-distance reading display, left and right

In the next test, the object was brought closer to the ultrasonic sensor until it reached a distance of 11.2 cm. As shown in the Right Left Close Distance Reading Display Image, the system successfully captured the distance value and displayed it through the Serial Monitor. Because the distance of 11.2 cm is below the threshold of 16 cm, the system assumes that there is a cup on that side. This proves that the detection algorithm works accurately, where the green LED will activate as an indicator that the cup has been successfully detected. This result complements the previous test in Figure 4.6 (distance 28.8 cm), which shows that the system is able to clearly distinguish between the 'cup present' and 'no cup' conditions based on the difference in object distance.

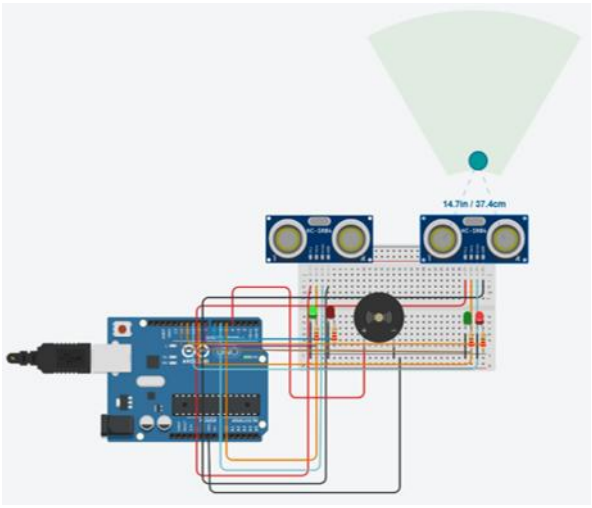

Figure 6. Image Display of Right Sensor Distance Reading

The final test was conducted by placing the object at a relatively far distance from the sensor, namely 37.4 cm. As shown in the right sensor distance reading image, the ultrasonic sensor successfully read the object's distance and displayed it through the Serial Monitor. Since the distance of 37.4 cm is above the 16 cm threshold, the system indicates that no cup is detected on that side. This condition reinforces the findings in Figure 4.6 (28.8 cm), both of which indicate that the red LED will light up and the buzzer will activate as a warning. Thus, from the three distance variations tested (Figures 4.6, 4.7, and 4.8), the system has proven consistent in classifying the presence of the cup based on the object's distance from the sensor.

Direct Test Results

After the simulation is declared successful, the system is implemented on real hardware (production equipment) for direct testing. This testing aims to verify that the system functions well under real conditions in the production environment.

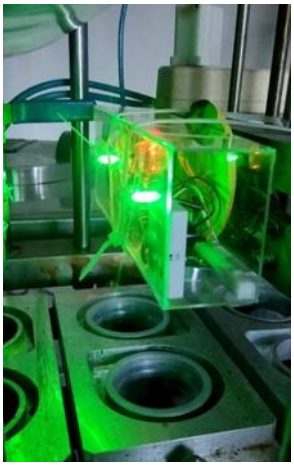

Figure 7. Image of the Right and Left Cup Detection System

Before conducting functional testing, the written program code is first verified through compilation on the Arduino IDE. The image of the Right and Left Cup Detection System shows that the right and left sensors of the system detect a cup on those sides. This proves that the detection algorithm works correctly, where the green LED will activate as an indicator that the cup has been successfully detected.

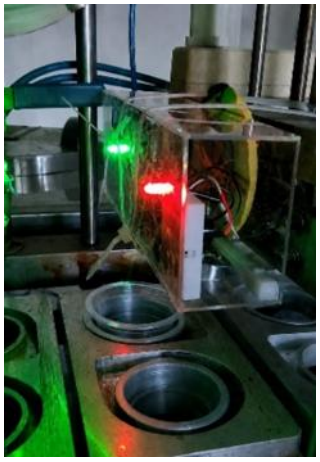

Figure 8. Image of the Left Cup Detection System

The system consistently outputs a value of 1 during the observation period. This value of 1 indicates that during the testing, the sensor detects the presence of an object (cup) or certain active conditions without experiencing unwanted status changes (fluctuations). This result proves that the program runs stably and there are no reading errors that cause the system to stop or respond unpredictably. the system automatically interprets that no cup is detected on that side, causing the indicator LED to turn red and the buzzer to activate as a marker. This result proves that the system is capable of accurately distinguishing between the 'cup present' and 'no cup' conditions.

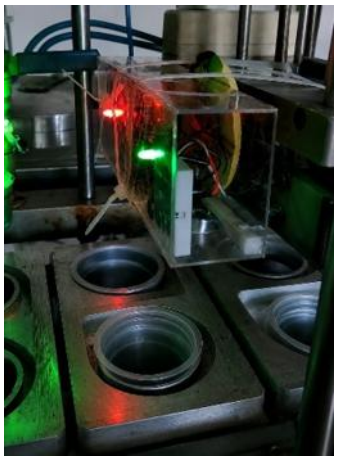

Figure 9. Image of the Right Cup Detection System

Before conducting the side detection scenario testing, the program code was first verified through compilation on the Arduino IDE. Image of the Right Cup Detection System After the program was uploaded, a simulation was conducted where the left side detected the cup and the right side did not. The result was that the system successfully turned on the Green LED on the left, the Red LED on the right, and activated the buzzer, proving that the program logic was functioning according to specifications.

System Test Results

System testing was conducted using the Black Box Testing method to ensure that every function operates as expected.

Table 4. Black Box Testing Results

No	Features Tested	Test Input	Testing Steps	Expected Output	Results
1	Cup Detection Available	Cup in front of the sensor	Run the system	The green LED is on; the buzzer is off	succeed
2	Cup Detection Not Available	The cup is taken from the sensor.	Run the system	The red LED is on, and the buzzer is active	succeed
3	Left-Side Detection	The cup is only on the left side	Run the system	Left green LED, right red LED	succeed
4	Right-Side Detection	The cup is only on the right side	Run the system	Green LED on the right, red LED on the left	succeed
5	Response Time	Change the cup position	Record the response time.	< 1 second	succeed
6	Threshold Calibration	Distance range: 0–50 cm	Compare readings	With an accuracy of ±0.03 cm	succeed

Test results show that all system features are functioning properly. Detection accuracy reached 100% with a response time of less than one second, proving that the system is capable of providing effective early warnings.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on research ranging from needs analysis to implementation, a cup availability monitoring system based on an Arduino microcontroller was successfully developed and implemented at the Luru Barokah MSME. This system replaces the error-prone manual method with a real-time automated system, integrating an HC-SR04 ultrasonic sensor, an Arduino Uno R3, a buzzer, and red and green LEDs.

Using C/C++ programming logic in the Arduino IDE, the system continuously reads the distance and compares it to the calibrated threshold value of 16 cm. The results of the implementation show:

1. 100% detection accuracy
2. Fast response time of less than one second
3. Effective visual and audio indicators assist the operator

This system is a reliable and easy-to-implement appropriate technology solution for MSMEs, proven to improve operational efficiency and reduce production bottlenecks.

Recommendation

Based on the research findings, several recommendations for further development are presented:

1. Development of Additional Features: Addition of a feature to automatically count the number of cups used via a load cell or infrared sensor, as well as an LCD display showing real-time cup availability information.
2. Hardware Maintenance: Routinely clean the ultrasonic sensors of dust and dirt, check the jumper cable connections, and use a protective housing to shield against water splashes and vibrations.
3. Testing Under Various Conditions: Further testing under different environmental conditions (extreme temperatures, high humidity) and at a larger production scale to determine the system's durability and adaptability.

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May this research contribute to the advancement of science and technology, particularly in the application of microcontroller-based monitoring systems in MSMEs.

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