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Lighter as flame control and temperature control in milk pasteurization system

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Abstract: Milk pasteurization involves heating milk at a specific temperature below its boiling point as a method to keep the resulting dairy product retaining the shape and taste characteristics of fresh milk. In several experiments, the use of fuzzy control systems has been tested to regulate the temperature in the milk pasteurization process and to time the ignition of the stove flame. However, this fuzzy approach still causes the system to give an unstable response and irregular stove flame. In order to study milk pasteurization, the Low Temperature Long Time (LTLT) method is used which is implemented automatically through a PID control system. This method serves to maintain nutritional quality by keeping the pasteurization temperature at a setpoint of 62°C. This control involves the use of servo actuators and electric lighters that are automatically regulated with the help of flame sensors. The flame sensor detects the presence of flame and ensures that the flame remains lit throughout the pasteurization process. At the end of the process, the flame sensor plays a role in breaking the flame by setting a certain threshold. This sensor operates within 10 CM of the flame source and will produce an analog output with a maximum value of 4000 when the flame is lit. When the flame is extinguished, the analog output of the sensor will reach a value of 4095. Testing of the milk pasteurization automation system is given a value for each PID resulting from the value of Kp = 31.8, Ki = 115.6, Kd = 4.4 and obtained a rise time value of 0.39 minutes, 0.61%, settling min of 60.88, and settling max of 62.38.

Keywords: DS18B20 sensors, lighter, milk, pasteurization, PIDs

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Introduction

To meet the community's nutritional needs for proper nutrition, it is undeniable that milk is one of the elements the community needs. In general, milk is essential as a source of animal protein for human health and growth due to its high nutritional content. Almost all the substances contained in milk are needed by humans, including proteins: fats, carbohydrates, minerals, and vitamins [1]. Animal protein processed products have better nutritional value than protein products from plants (vegetables) [2]. Milk also contains antibodies called immunoglobulins, which are good for the immune system of a growing child [3]. During the productive age of humans 15-65 years, the need for cow's milk encourages rapid growth and strengthens bones, preventing osteoporosis in old age. Osteoporosis is a disease characterized by low bone mass and structural damage to bone tissue, causing bone fragility and increasing the risk of fractures. Bone tissue is formed during puberty, so milk is very suitable for consumption during puberty [4]. The milk's nutrients include protein, calcium, vitamin A, vitamin B, vitamin D, amino acids, calories, fat, phosphorus, iodine, zinc, iron, copper, magnesium, vitamin E, and thiamine [5]. Milk contains high nutrition, which contains water (87.5%), carbohydrates (4.5%), fat (3.6%), protein (3.4%), and minerals (0.75%).

So that lactic acid bacteria do not attack and contaminate, it is necessary to do processing so that the milk does not spoil quickly. Although cow's milk has high nutritional value, it is susceptible to bacteria which causes cow's milk to have a short shelf life and spoil easily. One way to optimize milk is to use pasteurization and heating to prevent damage to the milk. Pasteurization of milk is a way of preserving milk by heating it to a certain temperature below the boiling point of milk so that the processed product retains its shape and taste of fresh milk [6]. In several experiments, a fuzzy control system has been applied to regulate milk temperature in the pasteurizer and stove lighter with a timer. However, the fuzzy method still causes the system response to be unstable, and the flame of the stove lighter is uncertain [7].

Previous research [8] showed a model of an automatic milk pasteurization system with the ultimate goal of controlling the temperature value on the output side, (t), in such a way that the output value is at the LTLT pasteurization temperature, namely at a temperature of $y(t) \approx 64$ °C. The servo motor is a load (plant) that functions as a regulator of the size of the flame in the heating furnace to increase or decrease the milk temperature. In that study, there was no flame sensor so the system could not know the on and off of the fire in the heating system. Whereas in this research a flame sensor is added to detect the flame in the heating system. With the flame sensor when the condition must cool the temperature of the milk the fire on the heater must be turned off by turning the servo to the minimum position and the flame sensor is used to detect the extinguishing of the fire. And vice versa if from the position of the fire extinguished the PID control system wants to raise the temperature then the heating system must be turned on. The step taken to turn on the heating fire is to rotate the servo to open the gas and then light the fire with a match when lighting the fire a flame sensor is used to detect the success of the match in lighting the fire. If the fire is detected to be unlit, it must light the match again until the fire is confirmed to be lit. That is the novelty of this system compared to the system from previous research.

For this reason, referring to the data presented, the researcher wants to improve this milk pasteurization system by applying PID control and flame sensor, to achieve a more stable control level. In its application concept, PID control works in a fairly simple way, where the error value is used as system feedback to determine the next control value.

Methodology

Pasteurization

Pasteurization is a high-temperature heating system designed to kill bacteria, microbes, and some microorganisms while minimizing damage to proteins. There are two pasteurization methods, namely Low-Temperature Long Time (LTLT) at 62°C for 30 minutes and High-Temperature Short Time (HTST) at 72°C for 15 seconds. The next pasteurization process is a cooling process with a temperature of 4°C to extend the shelf life of the milk. In the pasteurization of milk, pasteurization is used to destroy pathogenic microorganisms [8].

Proportional Integral Derivative Control (PID Control)

PID (Proportional Integral Derivative) is a regulatory system used to control an instrument system by utilizing feedback from the system. The PID controller consists of three main components namely Proportional, Integral, and Derivative. These three components can work together or separately, depending on the desired response of the device. In designing a PID control system, the goal is to adjust the parameters P, I, or D so that the system output response to a particular input is as desired. PID is usually used in closed-loop control systems as shown in Figure 1.

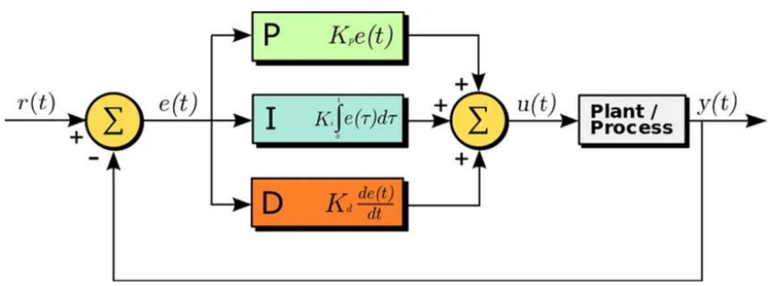


Figure 1. PID Control System

The PID controller equation is:

$$r(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \tag{1}$$

Description:
Kp = Proportional gain, tuning parameters
Ki = Integral Gain, tuning parameters
Kd = Derivative Gain, tuning parameters
e = Error
t = time
τ = Variabel integrasi; nilainya diambil dari waktu nol sampai *t*.

Ziegler-Nichols Method

The Ziegler-Nichols method consists of the first method and the second method. The first method has two parameters, namely L and T, then is used to find the values of Kp, Ki, and Kd. These two parameters are obtained from the inflection point of the S curve, which is obtained from the tangents to the x and y axes. The second method also has two parameters, namely Ku and Tu. Ku is the critical value of Kp when the system is properly oscillating. Tu is the distance between the crests of the wave in seconds. The equations for finding Kp, Ki, and Kd values based on L and T parameter values are shown in Table 1. The equations for finding Kp, Ki, and Kd values based on Ku and Tu parameter values are shown in Table 2 [9].

Table 1. Kp, Ti, and Td values based on L and T values

Controller	Kp	Ti	Td
P	T/L	∞	0
PI	0.9 T/L	L/0.3	0
PID	1.2 T/L	2L	0.5L

Table 2. Kp, Ti, and Td values based on Ku and Tu values

Controller	Kp	Ti	Td
P	Ku/2	-	-
PI	2Ku/5	4Tu/5	-
PID	3Ku/5	Tu/2	3Tu/25

ESP32 DEVKIT V1

The ESP32 module is a compact prototyping microcontroller that can be easily programmed through the Arduino IDE. This module was introduced and developed by Espressive Systems. The ESP32 chip has been equipped with a WiFi module that supports the development of Internet of Things (IoT) applications. One of the application systems is ESP32. The ESP32 DEVKIT V1 has two 32-bit processor cores that make it more advanced compared to the ESP8266 series. The advantage of the ESP32 DEVKIT V1 microcontroller is a low-cost, low-power, system-integrated microcontroller chip with Bluetooth dual mode and power-saving features that make the ESP32 DEVKIT V1 microcontroller compatible with mobile devices [10].

DS18B20 Temperature Sensor

DS18B20 is a type of temperature sensor that produces a digital signal as its output. One of the advantages of this sensor is its high level of accuracy, reaching 0.5°C over a temperature range of -10°C to +85°C. Temperature sensors generally require an Analog-to-Digital Converter (ADC) and several port pins on the microcontroller to communicate, but the DS18B20 does not depend on ADC and only requires one cable to connect to the microcontroller. The ground and Vdd pins are connected to Vcc, while the DQ pin is connected to the microcontroller I/O pins. The data output is digital data with an accuracy value of 0.5°C [11].

Flame Sensor

A flame sensor is a device that detects the presence of flame and smoke using an infrared transducer. It can detect wavelengths between 760 nm to 1100 nm, which is used to identify flames. The structure of this sensor consists of four important pins: VCC, GND, AO (Analog Output), and DO (Digital Output). The AO pin is responsible for providing an analog output that can give an indication of the position or direction of the flame, as it has a reading angle of 60°. This sensor has 5 LEDs (Light Emitting Diode) which are useful as detection indicators. The flame sensor is a sensor that can detect fire and change its representation to an analog quantity. The parameter measured by the flame sensor is temperature, while the temperature measured by the flame sensor is the wavelength of light [12].

MG995 Servos

A servo motor is an electromechanical component designed as an actuator in a system. It generates torque and speed based on the applied electric current and voltage. Servo motors are commonly used in closed control systems, which allow setting the speed and acceleration of the motor with a high degree of accuracy. In contrast to DC motors, servo motors do not move continuously. They only move at a certain angle and stop at that angle. There are two types of servo motors, namely standard servo motors and continuous servo motors. A continuous servo motor can move a full 360^{O}, but a normal servo motor can only move half a turn, ie. 180^{O} [13].

DC Motors

A direct current motor (Direct Current) is a device that converts electrical energy into kinetic energy or motion. DC motor speed is around 3000 to 8000 RPM (revolutions per minute) with an operating voltage of about 1.5 to 24 volts. A DC motor uses the concept of an electromagnet for its motion [14].

Relay

A relay is an electrical device that functions as an electrically operated switch. This component consists of two main parts, namely the electromagnet coil and mechanical (a set of switch contacts). The working principle of the relay is to move the switch contacts through an electromagnet so that a small electric current can control the flow of electricity that has a higher voltage.

LCD (Liquid Crystal Display) 16x2

LCD (Liquid Crystal Display) is a display device that uses liquid crystal as its main element, which is capable of displaying characters and images. Inside the LCD there is a microcontroller in charge of controlling the display of characters on the screen. LCD screens have been used in various fields, such as electronic devices such as televisions, calculators, or computer screens. LCD applications use a dot matrix LCD with a 2x16 character count. The LCD screen functions as a display device which is then used to indicate the working status of a tool [15].

System Block Diagram

Figure 2 below is a hardware design with input in the form of DS18B20 temperature sensor values and Flame Sensor. The input will be displayed through the LCD (Liquid Crystal Disk) and then processed by the ESP32 DEVKIT V1 microcontroller system and sent a command to the servo as an actuator on the gas stove to light the stove using an electric lighter through a relay so that heating occurs.

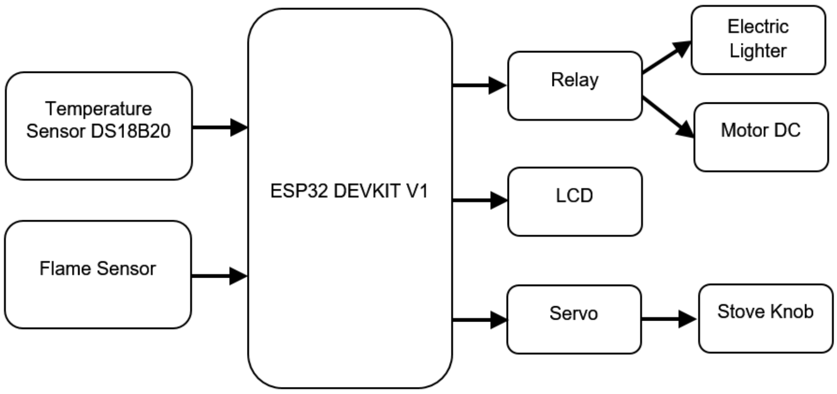


Figure 2. System Block Diagram

DS18B20 Temperature Sensor Design

Figure 3 below is a DS18B20 temperature sensor design used to read temperature values in the range of -10 to +85 degrees Celsius. This sensor can work with serial communication with one data line and one ground or what is commonly called one wire. In the DS18B20 sensor, there are 3 pins used, namely the data signal line, ground, and 5 Volt VCC power supply line. VCC and signal data pins are connected to the ESP32 DEVKIT V1 microcontroller, but a pull-up resistor of 4.7k is added.

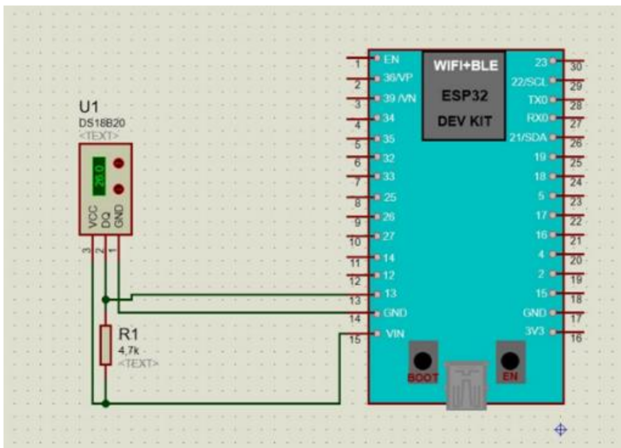


Figure 3. DS18B20 Temperature Sensor Design

Flame Sensor Design

The image below shows the design of the flame sensor circuit. This fire sensor has four pins, namely VCC, GND, AO (analog output), and DO (digital output). The AO pin can detect the location of the fire because the reading angle is 60°. The analog pin input voltage is 5V, and the digital pin is 3.3V. When the VCC voltage at the analog output of this sensor is less than 3.3V, the fire detection becomes unstable, and an error occurs at the output. In a milk pasteurization system, the analog output is used to set the threshold value on the stove fire. Figure 4 below describes the Fire Sensor Design.

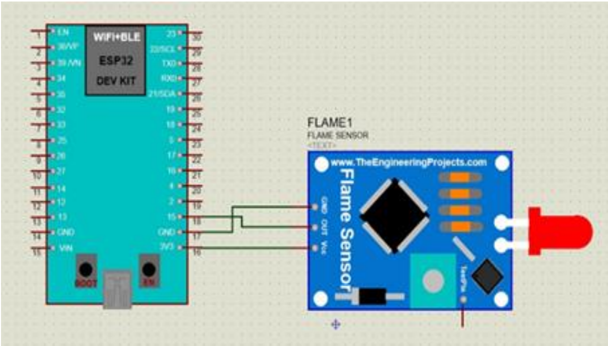
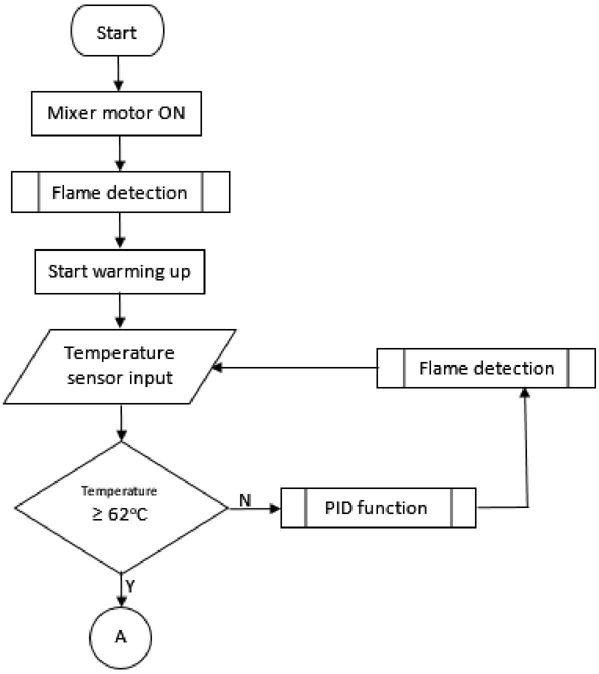


Figure 4. Flame Sensor Design

Overall System Flowchart



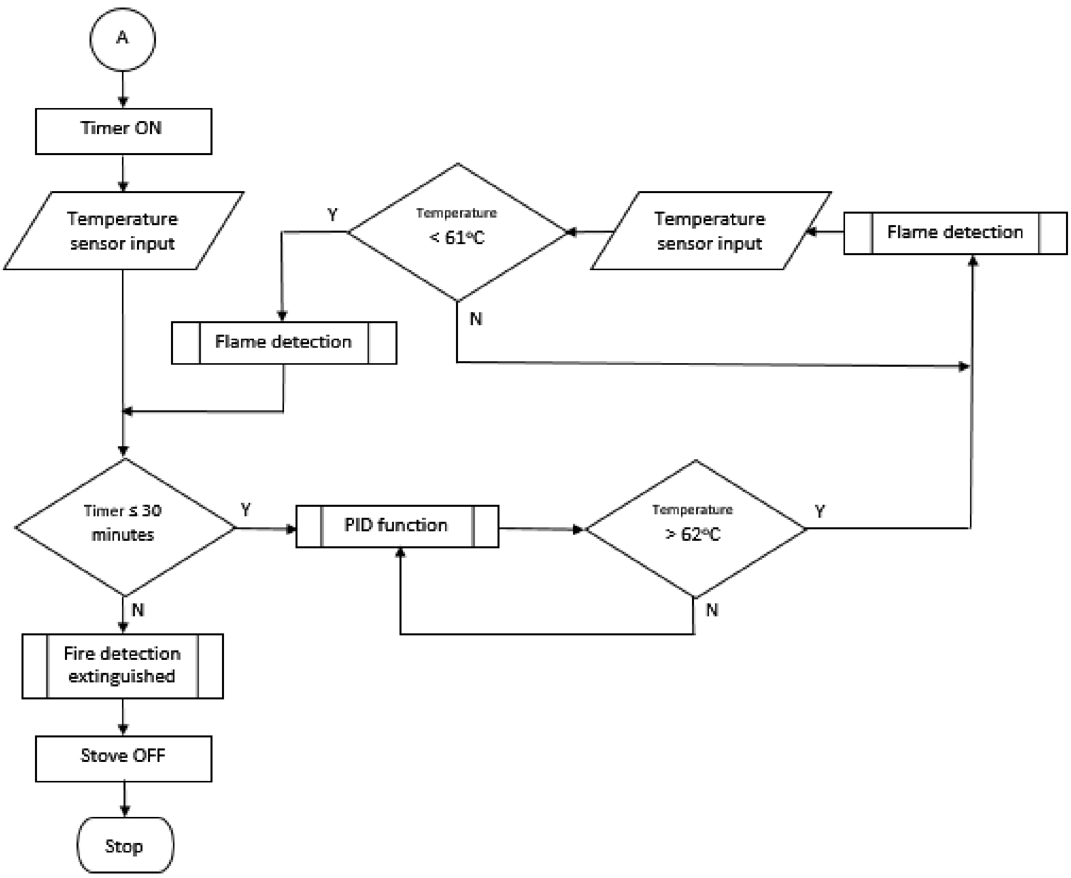


Figure 5. Overall System Flowchart

Judging from Figure 5 that has been presented, it can be explained that when the system is activated, the stirring motor will operate. After that, the lighter will be turned on to ignite the flame. The next process involves the flame sensor which will detect the presence of the flame. In the milk pasteurization stage, the temperature sensor detects the temperature of the milk being cooked. If the detected milk temperature value is still below 61 degrees Celsius, the microcontroller will control the flame level on the stove by moving the servo that regulates the flame control knob using PID logic. After the milk temperature reaches above 61 degrees Celsius, the timer on the stove will be activated to start the cooking process with a duration of 30 minutes. During this cooking stage, the temperature sensor continues to monitor to keep the temperature of the cooked milk stable, so that the milk can be cooked with the right consistency. The sensor instructs the microcontroller to control the flame intensity by moving the servo connected to the stove's flame control knob. After 30 minutes have passed, the timer will stop and the microcontroller will turn off the stove to end the milk pasteurization process.

PID System Flowchart

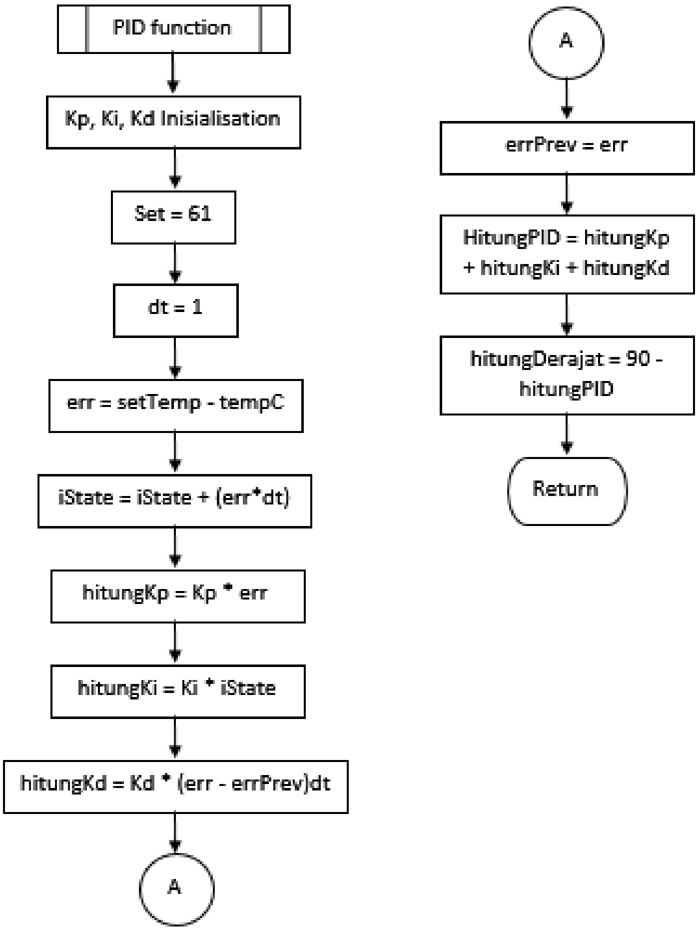


Figure 6. PID System Flowchart

The PID control stage is illustrated in Figure 6. At the start of the process, initial values are initialized for the Kp, Ki, and Kd parameters. The desired temperature setpoint is set at 62°C, and the variable dt representing the time change is set at a value of 6. Before the PID formula can be applied, calculations are performed for the integral error value stored in the variable 'iState'. Initially, the 'iState' value is initialized with zero, assuming that the integral process starts at time 0. The 'iState' value is updated by adding the previous 'iState' value with the latest error value (variable 'err'). The next step in the PID system is to calculate the PID value itself, by calculating the Kp, Ki, and Kd values separately. This calculation involves the following formulas: Kp = Kp * err, Ki = Ki * iState, and Kd = Kd * (err - errPrev)/dt.

Mechanical Design

This section describes the design of the installation of components consisting of a DS18B20 temperature sensor, flame sensor, servo motor, and DC motor, and the placement of the ESP32 DEVKIT V1 microcontroller so that it can run as desired. Figure 7 below is a mechanical design for the milk pasteurization system:

Figure 7. Mechanical Design of the System

Results and Discussions

Results

DS18B20 Temperature Sensor Test Results

This test is carried out to display sensor readings and process status on the pasteurization device. This test aims to ensure that the 16x2 LCD screen functions properly and is able to display data sent by the microcontroller during the process.

Table 3. DS18B20 sensor test results

No	DS18B20 Temperature Sensor (in degrees)	Digital Thermometer (in degrees)	Measurement Difference (in degrees)	Errors (in %)
1	29.95	29.41	0.54	1.84
2	30.76	30.70	0.06	0.20
3	31.21	31.40	0.19	0.61
4	36.21	35.20	1.01	2.87
5	30.61	29.80	0.81	2.72
6	31.85	31.00	0.85	2.74
7	30.13	30.80	0.67	2.18
8	30.13	29.50	0.63	2.14
9	33.31	33.60	0.29	0.86
10	32.82	32.10	0.72	2.24
11	32.82	32.60	0.22	0.67
12	34.76	34.60	0.16	0.46
13	38.61	38.10	0.51	1.34
14	40.81	40.80	0.01	0.02
15	43.39	43.30	0.09	0.21
16	45.82	45.10	0.72	1.60
17	47.81	47.00	0.81	1.72
18	49.89	49.60	0.29	0.58
19	53.89	52.80	1.09	2.06
20	56.20	56.50	0.30	0.53
21	57.41	57.50	0.09	0.16
22	59.20	59.10	0.10	0.17
23	62.39	61.80	0.59	0.95
24	63.17	63.60	0.43	0.68
25	61.14	61.20	0.06	0.10
26	60.95	60.80	0.15	0.25
27	60.70	60.50	0.20	0.33
28	60.39	59.50	0.89	1.50
29	60.01	60.50	0.49	0.81

No	DS18B20 Temperature Sensor (in degrees)	Digital Thermometer (in degrees)	Measurement Difference (in degrees)	Errors (in %)
30	59.76	59.50	0.26	0.44

Flame Sensor Test Results

The next step in the test is to check the performance of the flame sensor as a stove lighter detector in the milk pasteurization system. This test is intended to verify whether the flame sensor is able to detect the presence of fire through analog output and produce output data that can be displayed on the 16x2 LCD screen.

Table 4. Testing Results of Flame Sensors (Flame Sensors)

Distance (in cm)	Flame sensor analog output	Description	Accuracy Percentage (in %)
10	3823	Succeed	100
	3547	Succeed	
	3623	Succeed	
	3551	Succeed	
	3509	Succeed	
15	3959	Fail	40
	4071	Fail	
	4027	Fail	
	4079	Succeed	
	3775	Succeed	
20	3791	Succeed	20
	4079	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
25	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
30	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
35	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
40	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	
45	4095	Fail	0
	4095	Fail	
	4095	Fail	

Distance (in cm)	Flame sensor analog output	Description	Accuracy Percentage (in %)
	4095	Fail	
	4095	Fail	
50	4095	Fail	0
	4095	Fail	
	4095	Fail	
	4095	Fail	
	4095	Fail	

Further testing was done with an approach where the flame sensor was placed in a fixed position at a distance of 10 CM from the stove flame. The results of the test were recorded as follows:

Table 5. Testing the Flame Sensor at a Distance of 10 cm

No	Time (in minutes)	Distance (in cm)	Value Analog Output	Description
1	01:00	10	3824	Succeed
2	02:00	10	3548	Succeed
3	03:00	10	3624	Succeed
4	04:00	10	3552	Succeed
5	05:00	10	3510	Succeed
6	06:00	10	3384	Succeed
7	07:00	10	3264	Succeed
8	08:00	10	3478	Succeed
9	09:00	10	3456	Succeed
10	10:00	10	3404	Succeed
11	11:00	10	3284	Succeed
12	12:00	10	3428	Succeed
13	13:00	10	3424	Succeed
14	14:00	10	3380	Succeed
15	15:00	10	3392	Succeed
16	16:00	10	3384	Succeed
17	17:00	10	3408	Succeed
18	18:00	10	3368	Succeed
19	19:00	10	3262	Succeed
20	20:00	10	3372	Succeed
21	21:00	10	3280	Succeed
22	22:00	10	3380	Succeed
23	23:00	10	3352	Succeed
24	24:00	10	3328	Succeed
25	25:00	10	3452	Succeed
26	26:00	10	3352	Succeed
27	27:00	10	3282	Succeed
28	28:00	10	3528	Succeed
29	29:00	10	3347	Succeed
30	30:00	10	3420	Succeed

MG995 Servo Trial Results

The following test results reflect the evaluation of the MG995 servo motor with rotation angle as a comparison applied as a stove knob control device in the temperature control system. This test is intended to assess whether the MG995 servo can function properly by displaying its output results through the 16x2 LCD screen.

Table 6. MG995 Servo Trial

No	Servo Degrees (in degrees)	Protractor (in degrees)	Measurement Difference (in degrees)	Accuracy Percentage
1	10	10	0	0 %
2	10	10	0	0 %
3	10	10.1	0.1	0.99 %
4	10	10	0	0 %
5	10	10	0	0 %
6	30	29.9	0.1	0.33 %
7	30	29	1	3.44 %
8	30	30	0	0 %
9	30	30	0	0 %
10	30	30	0	0 %
11	40	40	0	0 %
12	40	40	0	0 %
13	40	40	0	0 %
14	40	40	0	0 %
15	40	40	0	0%
16	45	45	0	0 %
17	45	45.1	0.1	0.22 %
18	45	45	0	0 %
19	45	45	0	0 %
20	45	45.1	0.1	0.22 %
21	60	60	0	0 %
22	60	60	0	0 %
23	60	60	0	0 %
24	60	60	0	0 %
25	60	60	0	0 %
26	90	90	0	0 %
27	90	90	0	0 %
28	90	90	0	0 %
29	90	90	0	0 %

Overall System Test Results

In this test, tests were carried out for the entire system that has been integrated on the ESP32 DEVKIT V1 Microcontroller. This test aims to test the function of the entire system which includes temperature settings, fire sensors, servo motors, electric lighters, and stirring motors in the context of milk pasteurization. In the milk pasteurization test, the Low Temperature Long Time (LTLT) method is used which requires the temperature to reach 62°C for 30 minutes during the pasteurization process. From the temperature value, it can be observed how the servo motor responds to reach the balance point by utilizing the Kp, Ki, and Kd parameters generated through the Ziegler-Nichols 2 method. In this test, Kp, Ki, and Kd have been given certain values, namely Kp = 31.8, Ki = 115.6, and Kd = 4.4. Furthermore, the test was conducted by setting the temperature at various different levels, with the temperature setpoint fixed at 61°C.

Table 7. Testing the Whole System

No	Temperature	Fire sensor analog results	State of the electric lighter	Stove state	Servo degree
1	62.19	4095	0	0	0 degrees
2	61.80	4095	0	0	0 degrees

No	Temperature	Fire sensor analog results	State of the electric lighter	Stove state	Servo degree
3	61.38	4095	0	0	0 degrees
4	60.88	3527	1	1	90 degrees
5	61.13	3875	0	0	90 degrees
6	62.38	4095	0	0	0 degrees
7	62.13	4095	0	0	0 degrees
8	61.80	4095	0	0	0 degrees
9	61.55	4095	0	0	0 degrees
10	61.34	4095	0	0	0 degrees
11	61.19	4095	0	0	0 degrees
12	61.13	4095	0	0	0 degrees
13	61.06	4095	0	0	0 degrees
14	60.94	4095	1	1	90 degrees
15	61.19	3356	0	1	90 degrees
16	61.50	3419	0	1	90 degrees
17	61.94	3650	0	1	90 degrees
18	62.00	4095	0	0	0 degrees
19	61.88	4095	0	0	0 degrees
20	61.55	4095	0	0	0 degrees
21	61.34	4095	0	0	0 degrees
22	61.13	4095	0	0	0 degrees
23	61.06	4095	0	0	0 degrees
24	60.88	4095	1	1	90 degrees
25	61.34	3231	0	1	90 degrees
26	61.50	3547	0	1	90 degrees
27	61.94	3854	0	1	90 degrees
28	62.00	4095	0	0	0 degrees
29	62.13	4095	0	0	0 degrees
30	61.88	3991	0	0	0 degrees

Information:

1. Electric lighter status = 0, which means the lighter does not work (does not ignite).
2. Stove status = 0, which means the stove is off.
3. Electric lighter status = 1, which means the lighter is working (igniting).
4. Stove status = 1, which means the stove is on.

Discussions

In the experiments shown in Table 3 using the DS18B20 temperature sensor and a thermometer for comparison, it can be seen that there is a difference in the value of 0.44°C and an average percentage error of about 0.01%. From the experimental results, it can be concluded that the DS18B20 sensor is reliable in the milk pasteurization control system.

From Table 4 listed above, it can be stated that the flame sensor test results show that the reading success rate is 100% at a distance of 10 CM. At a distance of 15 CM, the success rate is 40%, while at a distance of 20 CM, the success rate is 20%. However, for distances between 25 CM to 50 CM, the accuracy percentage reaches 0%, which indicates that at these distances, the analog output of the flame sensor cannot detect the presence of fire.

In Table 5 listed above, the test was carried out by placing the flame sensor in a fixed position at the same distance in each experiment, which is 10 CM from the stove flame. The results of the test showed a success percentage of 100%, where the flame sensor was able to detect the analog output value of the flame for 30 minutes.

Based on Table 6 above, it can be concluded that the average angle difference between the servo motor and the arc angle is about 0.04°, with an average error percentage of about 0.17%.

Table 7 shows the results of testing the milk pasteurization control system over 30 minutes by applying the Low-Temperature Long Time (LTLT) method. Data was taken at one-minute intervals to record the temperature values during the pasteurization operation. From the experiments on the milk pasteurization system for 30 minutes, the results were obtained for a rise time of about 0.39 minutes, less than 1% error value (overshoot) at a settling time of about 60.88, and a maximum settling value of 62.38.

Conclusion

The conclusions based on the research conducted are: (1) In the actuator test using the MG995 servo, the servo-operated well. When the temperature reaches the setpoint value of 62°C, the servo will rotate at an angle of 0°; (2) From testing the DS18B20 temperature sensor, the average measurement difference is 0.44°C and the average percentage error is 0.011%; (3) In testing the milk pasteurization automation system, the PID parameters that have been generated with values of Kp = 31.8, Ki = 115.6, and Kd = 4.4 are applied. The test results show a rise time value of 0.39 minutes, an overshoot percentage of 0.61%, a minimum settling time of 60.88, and a maximum settling time of 62.38; (4) In testing the activation of the stove using an electric lighter and flame sensor, the threshold value imposed in the range of 1000 to 4000 for the analog output is used to detect the flame at a fixed distance of 10 CM. The purpose of this test is to ensure that the stove ignites successfully at a percentage of 100% when the flame sensor detects the flame; (5) In testing the electric lighter and flame sensor, it can be concluded that the time required to light the stove when the electric lighter is on is 2 seconds, and when the stove is lit, the electric lighter will turn off within 1 second.

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