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Prototype of Temperature Control For Cold Chamber Using Fuzzy Based on Microcontroller

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Abstract

Cold Chamber is a small cold room in a cooling system as a storage place for cold air before the air is flowed to the object to be cooled. A cooling system will be greatly influenced by temperature lowering sources. To be able to provide optimal results in a cooling system, it requires a cold chamber whose temperature can be controlled automatically. To be able to control the temperature, a tool is needed. So that the tool can control the temperature, the tool needs a sensor that can read the temperature in the cold chamber, namely DS18B20. This sensor works by reading the temperature of the environment and then sending it to the microcontroller. To control the temperature, the microcontroller will send commands to the fan which functions as a sender of cold air to the cold chamber, and a pump which functions to drain water on the hot side of the cooling element. The cold air source in this tool comes from Peltier TEC1-12706. The reading result and the desired temperature setting will be displayed on the LCD. If the actual temperature is greater than the desired temperature, the fan will blow more cold air into the cold chamber and the pump will flow water faster. If the actual temperature is less than the desired temperature, the fan will stop blowing and the pump will slow down the flow of water. With this tool, it will be easier to adjust the temperature in a cooling system.

Keywords: *Cold Chamber, DS18B20, Peltier, TEC1-12706*

1. Introduction

Every single electronic, mechanical, and mechatronics devices have a safety standard and operation efficiency. One of the most affected factors is the working temperature. Each device has a specified upper and lower threshold of working temperature to work optimally and efficiently and reduce the risk of damage. A Device failure caused by temperature occupies the highest position at 55% based on the US air force survey therefore thermal management is on electronic devices that cannot be ignored[1]. In the operation of each device, a cooling system is needed that can keep the device at a safe temperature according to predetermined specifications.

One of a couple of ways to build a cooling system is to use a thermoelectric. These thermoelectric devices have hot and cold sides. Peltier TEC1-12706 has ΔT about $25℃ - 50℃$ between hot and cold sides[2]. The differentiation temperature between hot and cold side, it depends on the voltage value and current value. Thus, to obtain a very low temperature on the cold side, the temperature on the hot side must be as suppressive as possible.

The small heatsink and fan will be attached to the Peltier cold side. This cold side will be placed in the cold chamber. The heatsink will spread the cold air, the fan will blow the cold air to fill the cold chamber. On the other side, a water block and a big heatsink with a fan will be attached to the Peltier hot side. The electric pump will be used to drain the coolant over the water block. This loop will increase the temperature of the coolant, so the heatsink that is attached to the water block will spread the heat. To optimize the heat spread, the fan that is attached to the heatsink will be controlled by a microcontroller.

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In this cooling system, the sensor device DS18B20 will be used to log the temperature of the cold chamber. This sensor device will send the log data to the microcontroller. The log data will be processed using fuzzy. The output of these processes will be sent to motor driver L298N to control the speed of the fan on the Peltier hot side.

2. Research Methodology

2.1. Fuzzy Logic

Fuzzy logic is an appropriate way to map an input space into an output space. This technique uses mathematical fuzzy set theory. Fuzzy logic is related to uncertainty that has become human nature. The fuzzy logic theory was built with the principles of set theory [3]. Fuzzy logic itself is understood as a rule-based decision-making process that aims to solve problems, where the system is difficult to model or there are ambiguity and ambiguity. That is why Fuzzy Logic is also referred to as fuzzy or cryptic logic because fuzzy logic captures uncertain information into logical values that must be taken into account. Fuzzy logic is defined by logical equations rather than complex differential equations and comes from thinking that identifies and takes advantage of the grayness between two extremes [4].

2.2. Peltier TEC1-12706

A thermoelectric cooler is a cooling device that uses the Peltier element in the system as a heat pump. The Peltier effect occurs when two different metals are connected and the two ends of the metal are maintained at different temperatures, besides that there will be other phenomena that will occur in two metals, namely the joule effect, the Fourier effect, the Peltier effect, and the Thomson effect [5].

The working principle of the thermoelectric cooler is based on the Peltier effect, when DC current has flowed to a Peltier element which consists of several pairs of p-type semiconductor cells (semiconductors that have a lower energy level) and n-type (semiconductors with a higher energy level), it will cause one side of the Peltier element cools (heat is absorbed) and the other side becomes hot (heat is released), as shown in Figure 2, the side of the Peltier element becomes the hot or cold side depending on the direction of the electric current [5].

Figure 1. Peltier TEC1-12706

2.3. NodeMCU

NodeMCU is an open-source firmware and development kit that helps to prototype the IoT product with Lua Script. NodeMCU is an Arduino like device. Its main component is ESP8266. It has Programmable pins. It has built-in WiFi. It can get power through a micro-USB port. Its cost is low. It can be programmed through multiple programming environments.

ESP8266 NodeMCU requires 2.5V to 3.6V Operating Voltage, Onboard 3.3V- 600mA regulator, 80mA Operating Current, 20µA Current during Sleep Mode. Power to the ESP8266 NodeMCU is supplied via the on-board Micro USB connector. ESP8266

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NodeMCU is equipped with 32 Kb RAM, 80 Kb DRAM, and 200 Kb Flash Memory. ESP8266 NodeMCU has Pin D0 to Pin D10 Digital Pins, 12 PWM Pins, A0 Analog Pin. It has 5 Ground Pins, 3 number of 3.3 V Pins, 1 Vin Pin for adding 1 external supply of +5V which is not connected to USB. The ESP8266 NodeMCU has a total of 17 GPIO pins. These pins can be assigned to all sorts of peripheral duties, including one 10-bit ADC channel, Two No. of UART interface which is used to load code serially, four PWM pins for dimming LEDs or controlling motors, SPI and I2C interface to hook up all sorts of sensors and peripherals, I2S interface for adding sound to project. ESP8266 has a pin multiplexing feature (Multiple peripherals multiplexed on a single GPIO pin). Meaning a single GPIO pin can act as PWM/UART/SPI. NodeMCU has an RST button to Reset the ESP8266 chip, one FLASH button to Download new programs and one Blue LED that is user-programmable [6].

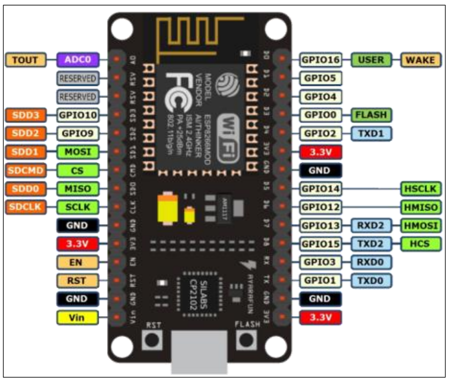

Figure 2. NodeMCU V3 Pinout

2.4. Sensor DS18B20

The DS18B20 is the latest digital temperature sensor series from Maxim IC (previously made by Dallas Semiconductor, then developed by Maxim Integrated Products). This sensor is capable of reading temperatures with an accuracy of 9 to 12-bit, range -55 ° C to 125 ° C with accuracy (+/- 0.5 ° C). Each sensor produced has a unique 64-bit code embedded on each chip, allowing the use of a large number of sensors via a single wire (single wire data bus / 1-wire protocol). As a reference and supporting information, this sensor has the following main features:

a) The interface uses only one cable as communication (using Unique 1-Wire protocol)
b) Each sensor has a unique 64-bit identifier code embedded in the onboard ROM
c) A multidrop capability which simplifies distributed temperature sensing applications
d) Does not require additional components
e) Power can also be fed through the data path. The power range is 3.0V to 5.5V
f) Can measure temperatures ranging from -55 ° C to + 125 ° C
g) Has an accuracy of +/- 0.5 ℃ over a range of -10 ℃ to +85 ℃
h) Sensor resolution can be selected from 9 to 12 bits
i) Can convert temperature data to 12-bit digital words in just 750 milliseconds (maximum)
j) Has an adjustable (non-volatile) alarm configuration
k) Can be used for alarm search feature and sensor address whose temperature is outside the limit (temperature alarm condition)
l) Its use can be in a thermostatic control environment, industrial systems, household products, thermometers, or any system that requires a temperature reading.

It's an outstanding component and is the cornerstone of many of the data logging and temperature-based control projects out there. The DS18B20 sensor has two types of cases, which are commonly circulating in the market, namely the ordinary casing and the waterproof case [7]. The DS18B20 sensor is used as in Figure 2.

Figure 3. DS18B20 Sensor Module

2.5. L298N Dual H-Bridge Controller

The L298N H-bridge IC shows in Fig. 3 that can allow controlling the speed and direction of two DC motors. This module can be used with motors that have a voltage of between 5 and 35V DC with peak current up to 2A. The module has two screw terminal blocks for the motor A and B, and another screw terminal block for the Ground pin, the VCC for the motor, and a 5V pin which can either be an input or output. Pin assignments for the L298N Dual H-Bridge Module are shown in table 1. The digital pin assign from HIGH to LOW or LOW to HIGH is used IN1 and IN2 on the L298N board to control the direction. And the controller output PWM signal is sent to ENA or ENB to control the position. The forward and reverse speed or position controlling for the motor has been done by using the PWM signal. Then using the analogWrite() function and send the PWM signal to the Enable pin of the L298N board, which drives the motor [8].

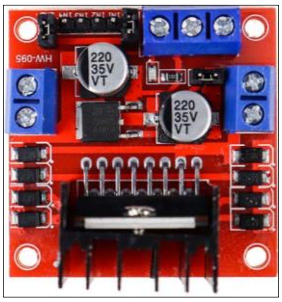

Figure 4. L298N Dual H-Bridge Controller Module

3. Results and Discussion

3.1. Fuzzy Set

The temperature control system in the cold chamber uses a DS18B20 sensor to read the temperature state in the cold chamber in realtime. If the temperature in the cold chamber is higher than the predetermined temperature threshold, the microcontroller will send a command to the Motor Driver L298N. The output generated from the L298N Motor Driver is a change in the exhaust fan rotation speed and the internal fan rotation speed. The temperature conditions in the cold chamber will be grouped into 3 (three) states, namely: low, mid, and high. To classify the sensor loggings, fuzzification will be carried out using the Tsukamoto method. The formation of a fuzzy set will group the input data into the above state. The fuzzy set in this temperature control system can be seen in Table 1 below.

Tabel 1. Fuzzy set

No	Variabel	Temperatur
1	Low	≤ 0℃

No	Variabel	Temperatur
2	Mid	0 – 5℃
3	High	≥ 5℃

The flow of the processes and relationships between components in this temperature control system is shown in Figure 5 below.

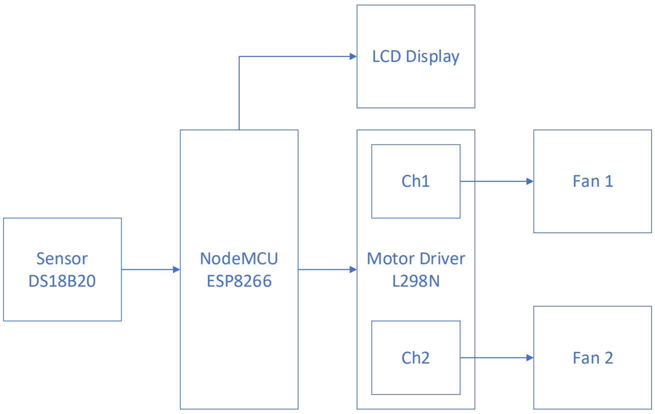

Figure 5. The flow of Processes and Components Relationship

3.2. Hardware Design

The hardware in this temperature control system consists of a Power Supply, Input Unit, Control Unit, and Output unit. The power supply functions to supply electrical power to all hardware used in the system. In this system, the main power supply unit will supply max 12V of voltages and 10A of currents. To supply power to hardware that needs 5V and 3.3V of voltages, the output voltages of the power supply will be step down using the LM2596 module. The input unit functions are used to get data from the environment being monitored. The control unit functions to manage data obtained from the unit input. The unit output functions to carry out commands given from the control unit. The hardware design and relationship are shown in Figure 6 below.

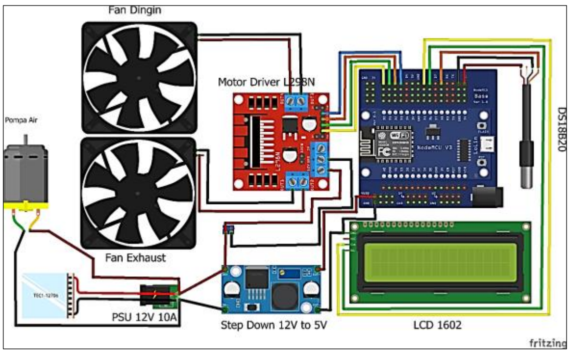

Figure 7. Hardware Design of Temperature Control System

3.3. Software Design

To make all the hardware working properly and the temperature control system running well, we have to embed some code of the program into the microcontroller. Before making the code of the program, we need to make a flowchart that visualizes the flow of the data in the processes. The program will divide into 3 (three) procedures. The first procedure is to get input from the sensor about the condition in the cold chamber. The second procedure is the fuzzy process. The third procedure is the output of the processes.

IF the status of the cold chamber is low, the microcontroller will send data to the motor driver to lowering the speed of the fan. If the status of the cold chamber is mid, the microcontroller will send data to the motor driver to spin the fan normally. If the status of the cold chamber is high, the microcontroller will send data to the motor driver to increase the speed of the fan.

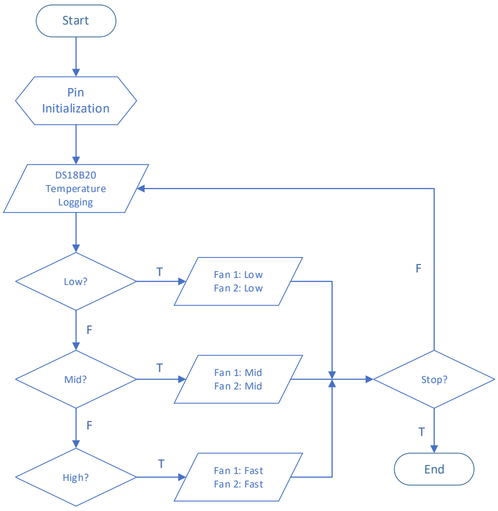

Figure 8. Flowchart of Coding Program

3.4. Test The System

After assembling all of the hardware and embedding the code of the program into the microcontroller, the next step is to test the system. The test will run in 10 minutes. Every change of temperature will be logged as described in Table 2 below.

Tabel 2. Test Run

Time	Temp	Status	Fan 1	Fan 2
00:00	29.8°C	High	25%	100%
01:00	18.7°C	High	25%	100%
02:00	7.2°C	High	25%	100%
03:00	2.9°C	Mid	50%	50%
04:00	1.4°C	Mid	50%	50%
05:00	0.5°C	Mid	50%	50%
06:00	0.1°C	Mid	50%	50%
07:00	-0.2°C	Low	100%	25%
08:00	-0.8°C	Low	100%	25%
09:00	-1.4°C	Low	100%	25%
10:00	-2.1°C	Low	100%	25%

4. Conclusion

Based on the 10 minutes test results and the conclusion of Temperature Control System For Cold Chamber is as follows:

a) DS18B20 sensor module sends the data to the microcontroller and displays it on LCD the actual temperature of the cold chamber.
b) The starting temperature of the cold chamber is 29.8°C and it decreases with time.
c) The Fan speed on the hot side of Peltier will be increased to the maximum value while the temperature status of the cold chamber is high. And it will be decreased if the temperature status of the cold chamber is mid or low.
d) The minimum temperature of the cold chamber can reach -2.1°C.

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