ME1049 Project: Design of Cooling System in an IT Infrastructure and Data Center,

Christopher Jin
Pittsburgh Institute
Sichuan University
Chengdu, China
LIJ33@pitt.edu

Ian Li
Pittsburgh Institute
Sichuan University
Chengdu, China
XIL249@pitt.edu

Stanford Xue
Pittsburgh Institute
Sichuan University
Chengdu, China
RUX27@pitt.edu

Edward Shen
Pittsburgh Institute
Sichuan University
Chengdu, China
2018141521060@stu.scu.edu.cn

***Abstract*—In order to cooling an IT infrastructure and data center, a system that can determine the cooling rate is designed based on the temperature and the human's presence. a small-scale version of the cooling system is built at first. By calibrating the PT 100 temperature sensor, the actual environmental temperature can be measured and use that as the decisive factor of the motor speed by determine the PWM rate. Besides, the infrared photoelectric sensor is used to detect the existence of the human. By analyzing the performance of the testing version, the things that need to be improved in the future are concluded and listed at the end.**

***Keywords*—Cooling system, PT 100 temperature sensor, motor speed, Infrared Photoelectric Sensor, Triode, PWM**

I. Introduction

The working of IT infrastructure and data center shown in Figure 1 generates heat and increases the environmental temperature. However, the upper limit of the working temperature of a normal IC circuit is around 100. Whether the cooling system performs well affects the stability of the IT center. Therefore, a cooling system with a motor that helps the heat dissipation should be designed. Also, to save energy consumption, the speed of the motor should relate to the temperature. Considering human activities' requirements, the temperature should also be low enough to provide a good environment for humans.

Fig. 1. IT data center.

II. Theory

A. PT 100 Resistance Temperature Detector (RTD)

1) RTD: An RTD (Resistance Temperature Detector) is a sensor whose resistance changes as its temperature changes. The resistance increases as the temperature of the sensor increases [1]. The resistance vs temperature relationship is well known and is repeatable over time. An RTD is a passive device. It does not produce an output on its own [2]. External electronic devices are used to measure the resistance of the sensor by passing a small electrical current through the sensor to generate a voltage. Typically $1\ \mathrm{mA}$ or less measuring current, $5\ \mathrm{mA}$ maximum without the risk of self-heating [3].

2) PT 100 RTD: The PT 100 RTD as shown in Figure 2 is one of the most accurate temperature sensors. Not only does it provide good accuracy, it also provides excellent stability and repeatability [4]. Most OMEGA standard PT 100 RTD comply with DIN-IEC Class B. PT 100 RTD are also relatively immune to electrical noise and therefore well suited for temperature measurement in industrial environments, especially around motors, generators and other high voltage equipment [5].

Fig. 2. PT 100 RTD.

3) Theory equation for the temperature: The PT 100 RTD has an impedance of $100\ \Omega$ at $0°\mathrm{C}$ and roughly 0.385 of resistance change per $1°\mathrm{C}$ change in temperature. The resistance is $18.51\ \Omega$ at $-200°\mathrm{C}$ and $390.48\ \Omega$ at $850°\mathrm{C}$. So the relationship between temperature and resistance is shown in Figure 3.

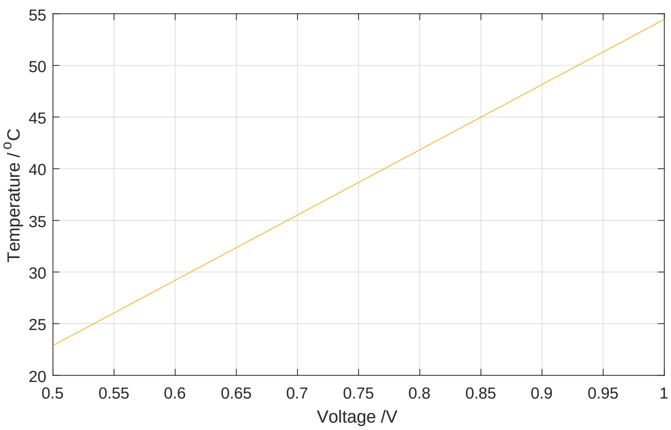

Fig. 3. PT-100 RTD Resistance vs. Temperature.

B. Infrared Photoelectric Sensor

A photoelectric sensor emits a light beam (visible or infrared) from its light-emitting element.A reflective-type photoelectric sensor is used to detect the light beam reflected from the target.A thrubeam type sensor is used to measure the change in light quantity caused by the target crossing the optical axis [6]. The fundamental principles is shown in Figure 4.

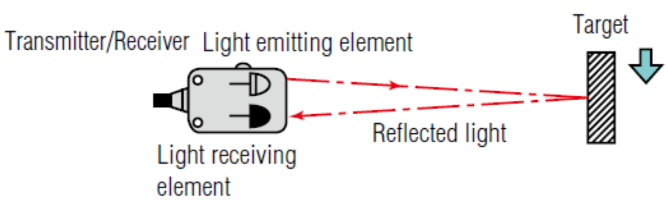

Fig. 4. Fundamental Principles of Infrared Photoelectric Sensor.

C. Triode (Transistors)

A triode as shown in Figure 5 is an electronic amplifying vacuum tube (or valve in British English) consisting of three electrodes inside an evacuated glass envelope: a heated filament or cathode, a grid, and a plate (anode). Its invention founded the electronics age, making possible amplified radio technology and long-distance telephony [7].

The change of the collector current is β times of the change of the base current, that is, the current change is amplified by β times, If we add a changing small signal between the base and emitter, it will cause a change in the base current I_b. After the change is amplified, it leads to a big change I_c. If the collector current I_c flows through a resistor R, according to the voltage calculation formula $U = RI$, the voltage on the resistor will change greatly. We take out the voltage on the resistor and get the amplified voltage signal.

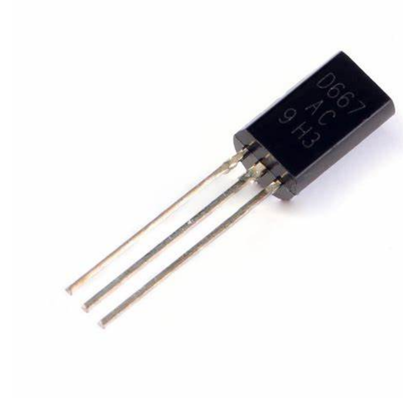

Fig. 5. Triode (Transistors).

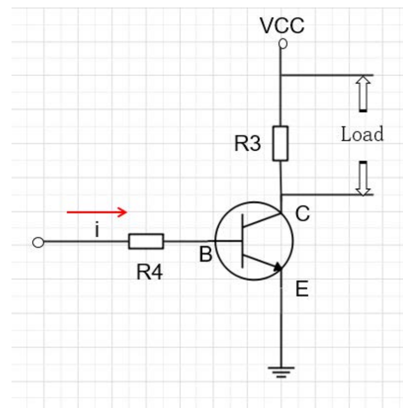

Fig. 6. Triode with DC motor connection.

D. Pulse-Width Modulation (PWM) Signal Generation

Pulse width modulation (PWM) is a modulation technique that generates variable-width pulses to represent the amplitude of an analog input signal. The output switching transistor is on more of the time for a high-amplitude signal and off more of the time for a low-amplitude signal. The digital nature (fully on or off) of the PWM circuit is less costly to fabricate than an analog circuit that does not drift over time.The wave graph of PWN is shown in Figure 7.

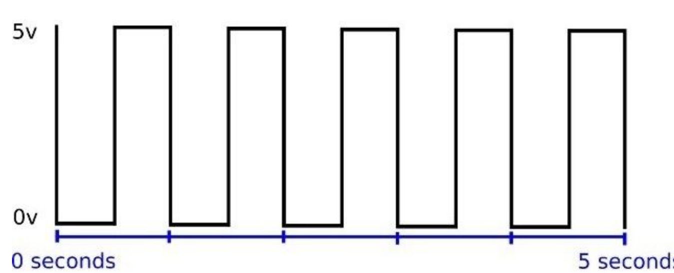

Fig. 7. Wave Graph Pulse-Width Modulation (PWM) Signal Generation.

III. Procedure

The procedures of the experiment is shown clearly in Figure 8.

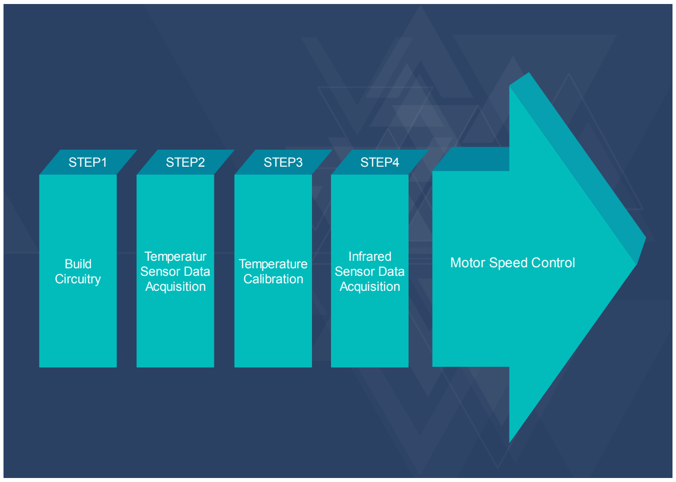

Fig. 8. Experimental Procedure.

A. Build Circuitry

The circuitry on the bread board is set up. The result is shown in Figure 9.

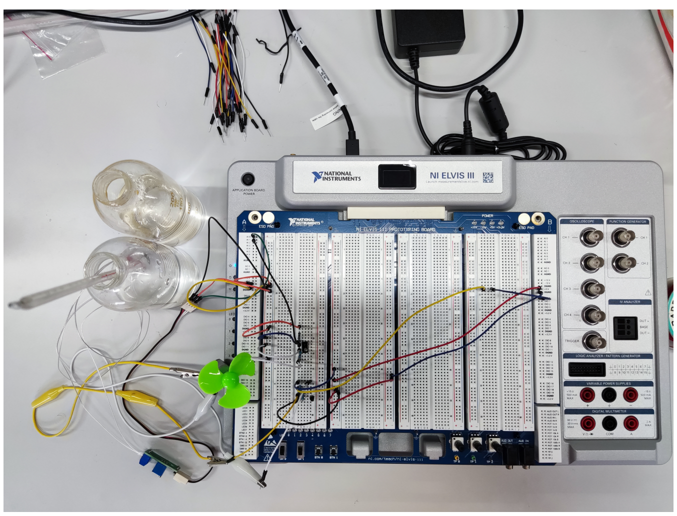

Fig. 9. Circuitry Built in Experiment.

The circuitry are divided into two parts–the temperature measuring one is plugged in A row of I/Os and the circuitry controlling the motor is connected with B row of I/Os in order to reduce the Reduce the influence of motor rotation on the output voltage of temperature measuring circuit.

B. Temperature Sensor Data Acquisition and Temperature Calibration

In this part, a set of temperatures of water by thermometer and their corresponding voltages need to be measured on LabVIEW, from which the fitting curve is drawn and the relationship between voltage and temperature is getten as shown in Figure. The result is shown in Figure 12.

Depend on Equation shown in Figure 12, the program is set up as shown in Figure 10.

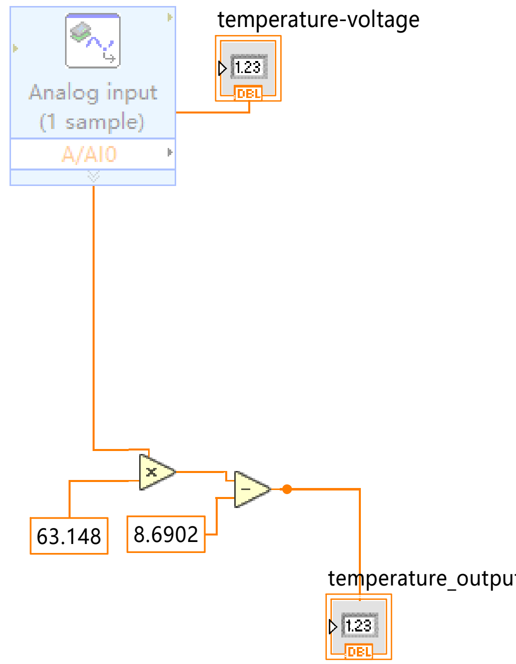

Fig. 10. LabVIEW Program for Temperature Measurement.

After then, the resistance temperature detector can show the correct temperature on VI directly.

C. Infrared Sensor Data Acquisition

In this part, the output of infrared sensor with human and without human conditions is measured, respectively. If the infrared sensor is blocked, which means the sensor detect someone here, the output is about 0.2. And if there is no people, the output of sensor is around 0.4. So the judge criteria is set as 0.3. If the output of the sensor is larger than 0.3, it recognizes the presence of human being.

D. Motor Speed Control

Based on different inspection situations, different control strategies are used to control the motor speed. The program is shown in Figure 11.

If the infrared sensor detects the presence of human, the motor rotate in maximum speed regardless of the temperature. If there is no people beside the infrared sensor, the motor speed changes with the reading of temperature sensor–the motor starts to work at $33°C$ and reaches the maximum speed at $45°C$.

IV. Summary of Results

A. Temperature Sensor Calibration

The result of calibration is shown in Figure 12 below. The voltage and the Temperature get from the PT 100 temperature

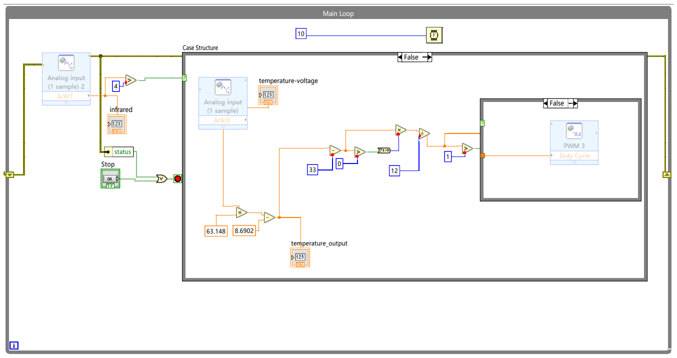

Fig. 11. Control Strategies to Control the Motor Speed.

sensor is a positive correlation. The calibration is done by adding some cold water to the hot water each time and recording the corresponding output voltage and the Temperature from the mercurial thermometer, shown in Figure 12. By MATLAB basic fitting, a yellow linear line matches the measured data effectively. The slope of the line indicates the changing rate of the Temperature per volt. Therefore, the water temperature can be calculated by multiplying the voltage output into the calibration equation as shown in Equation 1.

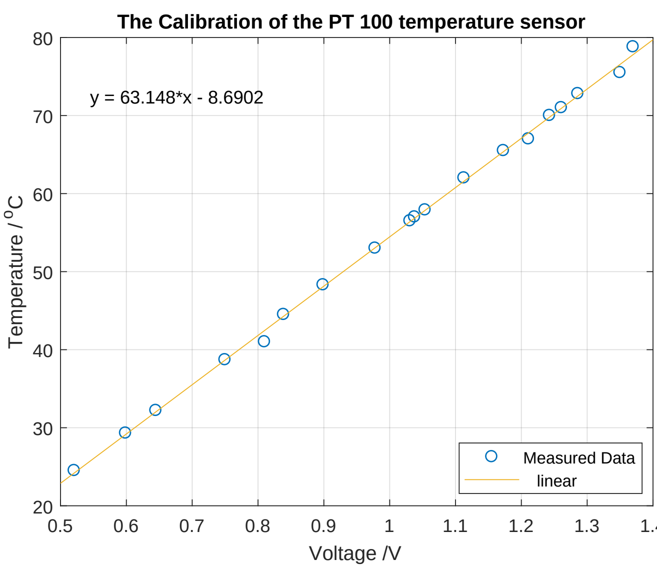

Fig. 12. The Calibration of the PT 100 temperature sensor.

$$T = \frac{\partial T_c}{\partial V_c} V_M + C \tag{1}$$

where $\frac{\partial T_c}{\partial V_c} = 63.148$ and $C = -8.690$.

B. Motor Speed Control with Temperature and Human Presence

The Infrared Photoelectric Sensor is the determinant of the speed of the motor. When the infrared photoelectric sensor detects human presence, the PWM output reaches the maximum, and the engine works at the highest rate.

When no human around, the Temperature determines the PWM output of the program. In the range of $33°\text{C}$ and $45°\text{C}$, the motor speed changes linearly with the Temperature, as shown in Figure 13.

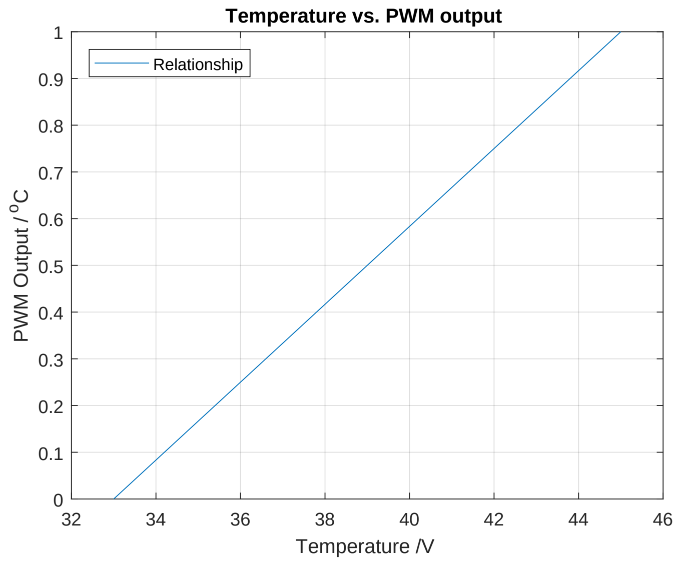

Fig. 13. Temperature vs. PWM output.

C. Experiment Result

1) The Human Presence detection done by the Infrared Photoelectric Sensor performs well and stable. Because the threshold value was set as a relatively large value, the distance between the block and sensor should be minimal, which does not match reality.
2) The temperature can be measured correctly when the motor doesn't work. However, once the motor works, the temperature sensor increases immediately to about $5°\text{C}$.
3) The speed of the motor increases with the Temperature well. However, in the beginning, when the PWM rate is low, the motor vibrates but won't work.
4) The device must be recalibrated each time when using it because the calibration will change.

V. Discussion

Our system is only a model of the cooling system. To equip this system in reality, the problems mention above must be solved, and some improvement must be made to fit the real situation.

Problems solution.

1) The program should upgrade since the motor doesn't need to work at full speed in lower temperatures.
2) The motor's working will influence the temperature sensor without a possible solution. Therefore, two devices working separately and communicating the data may be the only choice to ensure good performance.
3) Because of the motor's resistance, it will not work at low voltage. The motor speed is not linearly relating to

the PWM rate. Therefore, the speed of the motor and the PWM rate should be calibrated to make sure the PWM rate can control the speed precisely.

Realistic modification methods

1) In reality, the distance between the Infrared Photoelectric Sensor is much farther than the number set in the program. To measure the distance, the infrared sensor has to be calibrated and sets a proper distance.

VI. Conclusion

By designing the computer program, our group learns how to use Labview to program the conditioning control, acquire and send the data we need to the hardware. Besides, we also learn how to use the infrared sensor to measure the distance and use the acquired data to control the speed of the motor. The PWM rate is a new concept in this course, which is useful in controlling the speed of the motor. Therefore, by designing the relationship of the PWM rate and the motor, we understand the working principles of the PWM rate and the triode function. By result analysis, the problems are listed and need to be improved in the future. The model system has some differences from reality and needs to be optimized when applying to the real situation.

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We want to thank our professor of the course - Mechatronics, Qi Lu. Whenever we met the problem, he listened carefully to our problems and provided us with fantastic solutions with his strong professional knowledge and rich research results. After two semesters' study in his class, we have a systematic understanding of what mechanical engineering is. To be honest, we really enjoyed this course and cherished the time with Prof. Lu.

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