University of Victoria
Engineering & Computer Science Co-op
Work Term Report
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PWM Temperature Control for Fuse Testing Device

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In partial fulfillment of the academic requirements of this co-op term

Supervisor's Approval: To be completed by Co-op Employer

This report will be handled by UVic Co-op staff and will be read by one assigned report marker who may be a co-op staff member within the Engineering and Computer Science Co-operative Education Program, or a UVic faculty member or teaching assistant. The report will be retained and available to the student or, subject to the student's right to appeal a grade, held for one year after which it will be deleted.

I approve the release of this report to the University of Victoria for evaluation purposes only.

Signature: ______ Position: Shop Manager Date: 04/22/22

Name (print): Dillon Retter E-Mail: dillon@industrialplankton.com

For (Company Name) Industrial Plankton

Branden Voss
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April 22, 2022

Kelly Stegman
Co-op Coordinator
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Dear Kelly Stegman,

As partial fulfillment of Work Term 3, please accept the following Work Term Report entitled 'PWM Temperature Control for Fuse Testing Device'.

The accompanying report is the result of work completed during my employment with Industrial Plankton for the Spring 2022 semester. Over the course of the semester, I have worked alongside a team of professionals to aid in design and manufacturing of Industrial Plankton's product line of bioreactors for aquaculture. My responsibility as a design and manufacturing engineer mandated that I participate in product design and the assembly process. The role that I took on required me to work with electrical systems on the Photobioreactor, contribute to general assembly and perform testing on various components. Furthermore, this work term presented the opportunity to design and develop a PWM temperature control system for a fuse testing device which is the topic of the subsequent Work Term Report. This report entails an evaluation of two solutions to be considered for implementation.

I am grateful to have been a part of Industrial Plankton's team and fortunate to have had the opportunity to develop in a production-oriented workplace. The skills and knowledge I have gained during my time working at Industrial Plankton has been instrumental to my development as an engineer. This work term has provided me with a first-hand account of engineering design and manufacturing in the real world. Moreover, my experience as a design and manufacturing engineer has been a vital component in my education as an Electrical Engineering student.

It was my pleasure to work under such a professional, yet enjoyable and encouraging group at Industrial Plankton. I owe the whole team a huge thank you for giving me the opportunity to work alongside them and for providing exemplary leadership and professionalism.

Sincerely,

Branden Voss
University of Victoria - Department of Electrical Engineering & Computer Science
4A Electrical Engineering Student - University of Victoria

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Summary

Industrial Plankton is made up of a team of professionals that work together in designing and manufacturing Industrial Plankton's product line of photobioreactors for aquaculture. Photobioreactors are equipped with supporting peripherals to promote the growth of algae within a 1250 litre tank.

The subsequent report is intended to address a method for testing fuses which have been implemented as a safety measure on the reactors' CO_2 solenoid. In the event a current supply does not allow the solenoid to close a fuse has been purposed to disconnect and effectively close the solenoid. Such a safety measure is important to limit the unintended release of harmful gases in the presence of an operator.

However, under the higher ambient temperatures the fuse may experience on the reactor it is necessary to test their functionality in a controlled environment. In response to this need two methods for implementing a temperature-controlled fuse testing device are presented in this report. Both designs will utilize the Arduino nano microcontroller, two 300W resistive heaters, and an IRLZ44N MOSFET. Distinctions between the two designs are found in their method for temperature sensing. Both an analog sensor method and a digital sensor method will be covered. As part of the process in determining the best option to proceed with, it is important to compare the ability and features of each design.

Glossary

PBR	Photobioreactor.
PWM	Pulse width modulation.
Arduino Nano	Microcontroller that uses Arduino architecture and has both analog and digital I/O capability.
MOSFET	Metal-oxide field effect transistor.
PTC	Positive temperature coefficient. A variable resistor that increases in electrical resistance with increasing ambient temperature.
DS18B20	Digital temperature sensor.
ADC	Analog to digital converter.
DAC	Digital to analog converter.

1. Introduction

Industrial Plankton both designs and manufactures a product line of Photobioreactors (PBR). PBRs are 1250 litre tank with supporting peripherals designed to optimize the growth of algae for use in aquaculture. A photobioreactor is depicted below in figure 1. One such support system is the ability to regulate CO_2 levels in the water as a necessary component to promote algae growth. On board Industrial Plankton's Photobioreactor, a solenoid is used as a valve to regulate these CO_2 levels inside the tank. However, in the event the solenoid does not close, a fuse is wired in as a safety measure and will trip under the current demands of the open solenoid after a certain duration of time. Furthermore, temperatures ambient to the fuse may reach approximately 60°C and therefore a means to test the operation of these fuses at such a temperature is required in order to mitigate safety hazards.

Figure 1: Industrial Plankton's Photobioreactor [1]

3. Discussion

In response to this need for a method to test fuses under certain conditions, two circuit concepts were developed. Both designs will utilize the Arduino nano microcontroller, two 300W resistive heaters, and an IRLZ44N MOSFET. The important distinctions between the two designs reside in their method for temperature sensing. The first concept will make use of analog sensor made from a voltage divider configuration between an NTC and a 922Ω resistor. Alternatively, the second design will use a DS18B20 digital temperature sensor. The purpose of this report is to compare the two previously mentioned solutions for a temperature control system used in fuse testing.

Before discussing the two methods separately, it is important to explain the functionality that is common between them. In both designs the Arduino Nano will output a signal to an IRLZ44N MOSFET which is used as a switch for controlling the duty cycle of the input signal to the heaters. When the Arduino signals the MOSFET closed current will flow from a 24V power supply, through the resistive heaters causing heat to be generated. Conversely, when the Arduino does not output a signal, the MOSFET will be open. If the MOSFET is open no current will flow through the heaters and thus, no heat will be generated. By switching the on/off state of the MOSFET the amount of heat output can be controlled. Effectively, in an enclosure this will allow for accurate ambient temperature regulation.

The following subsections of this report will cover two different methods for temperature sensing. The first is an analog method and the second is a digital method. Both designs are described in detail for your understanding.

3.1 Option 1: Analog Temperature Sensor

The analog temperature sensor consists of a negative temperature coefficient (PTC) thermistor and a 922Ω resistor in series between a 5V source and ground as displayed in figure below. The PTC is a variable resistor that increases in electrical resistance with increasing ambient temperature [2]. This configuration creates a voltage divider network in which the voltage drop across the thermistor can be measured as it changes with changing temperature. The Arduino nano contains a 10-bit ADC which will interpret this voltage reading as a value within 0 – 1023 ($2^{10} = 1024$ steps) [2]. From here, software will be used to correlate these readings with ambient temperature in order to properly control the heaters and achieve a desired temperature.

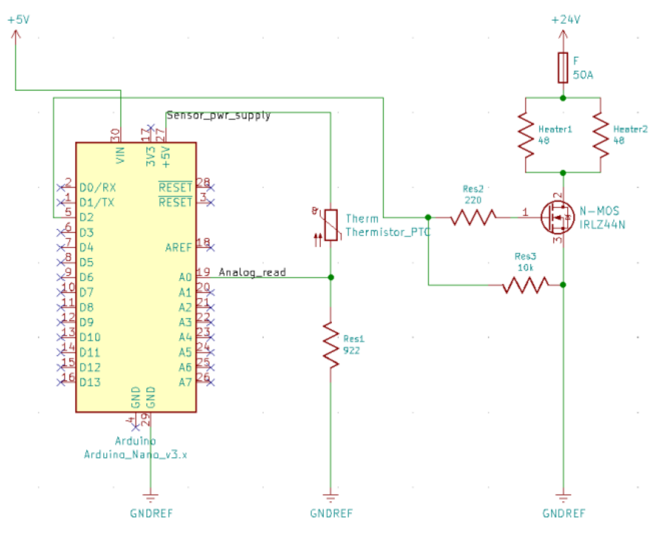

Figure 2: Analog Temperature Sensor

One significant drawback of this design is its accuracy in specific temperature ranges. When the thermistor has a 0V drop across it, it is reading the minimum temperature it is rated for, its electrical resistance is also at a minimum and this will correlate to a ADC reading of 0. Under this condition, it is ideal that the entirety of the 5V supply will be dropped across 922Ω resistor. Similarily, when the PTC experiences the maximum temperature, it can detect the electrical resistance will be increased to its max and approximately all of the 5V will be dropped across it. The scope of this project requires a specific temperature range between room temperature and 60℃. Therefore, only a fraction of the 0 – 1023 ADC resolution will be used and as a consequence, the accuracy of this method will suffer. Pros and cons of this design are considered in the table below.

Table 1: Pros and Cons of Option 1

Pros		Cons	
Criteria	Explanation	Criteria	Explanation
Software	Design is simple and easily implemented in software [4]	Accuracy	Specific temperature ranges do not utilize full range of ADC
Low Cost	PTC thermistor is a cost effective device to use (<$1.00) [2]	Functionality	ADC values do not vary enough according to ambient temperature

3.2 Option 2: Digital Temperature Sensor

The digital design for temperature sensing utilizes the DS18B20 sensor. This device has an on-board DAC and is compatible with the Arduino Nano using a single digital pin. DS18B20 can give up to 12 bits of precision and is usable in the temperature range of -55 to 125℃ with a ± 0.5℃ accuracy from -10 to 85℃ [3]. The schematic below shows how this system would be implemented. The sensor is compatible with the 3V or 5V input capabilities of the Nano [3].

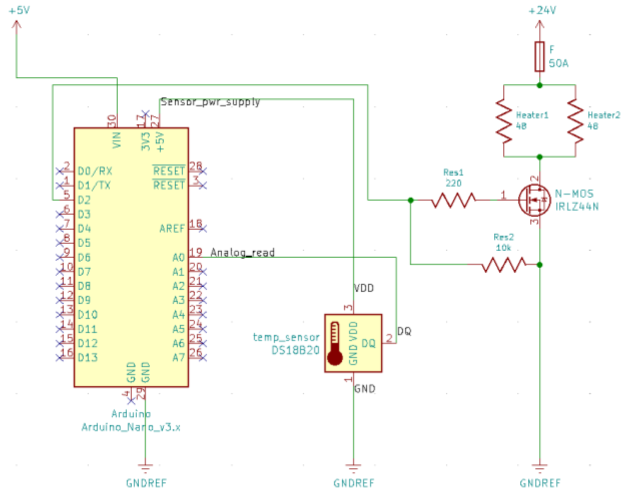

Figure 3: Digital Temperature Sensor

Though, in terms of hardware this method is easier to implement it can be complex when it comes to the software for parsing out the data communication because of the 1-wire data line [3]. The up and downsides of this method are presented in the following table.

Table 2: Pros and Cons of Option 2

Pros		Cons	
Criteria	Explanation	Criteria	Explanation
Accuracy	Temperature range of -55 to 125℃ with a ± 0.5℃ accuracy from -10 to 85℃ [3]	High Cost	The DS18B20 is more complex and thus more expensive than PTC (Approx. $10) [3]
Functionality	Highly compatible with Arduino [3]	Software	Requires more complex software to handle data communication [4]

4. Comparative Analysis

The research and design phase has led to the two previous; the analog sensor and the digital sensor. As part of the process in determining the best option to proceed with, it is important to compare the ability and features of each design. In summary, Table 3: Weighted Objectives Chart included in this section effectively highlights the key decision-making factors behind this project. Refer to Appendix A to better understand the criteria for Table 3.

4.1 Design Reliability and Functionality

Upon review it can be seen that each design provides a viable solution to the existing need for a PWM temperature control for fuse testing as previously outlined. Option 1, the analog temperature sensor implements a simpler approach when it comes to software and is a more cost-effective design to meet the objectives of this project. Option 1 utilizes a basic design that relies on a voltage divider, 922Ω resistor and a PTC thermistor to measure the voltage drop and correlate this measurement to a temperature reading through software. Unfortunately, this design is deficient in its accuracy as it relies on a small range of its resolution capability. Therefore, the change in the ADC reading will likely not be significant enough to control the PWM signal precisely.

Option 2 approaches the solution by measuring ambient temperature with the DS18B20 digital sensor. This solution provides a more accurate temperature reading and is less complex when it comes to hardware design and implementation. Despite being more expensive and computationally complex this solution provides compatibility and precision which is ultimately of higher value for this application.

Objective	Weight	Criteria	Analog		Digital	
			Score	Value	Score	Value
Accuracy	0.45	Will the system accurately measure temperature	2/5	0.4	4/5	1.6
Cost	0.25	Is the cost of the system reasonable for its purpose	5/5	1.25	2/5	0.5
Overall Score (out of 5)				**1.65**		**2.10**

Table 3: Weighted Objectives Chart

5. Conclusion

The comparison of the two temperature control methods determined that the digital sensor most effectively fits requirements of this project. Despite the additional cost of DS18B20 sensor compared to the PTC thermistor the benefits reveal this method as the most effective means of temperature control for testing fuses. The digital system presents an overall superior functionality to its competition. Notably, the DS18B20 supersedes its competition in precision of measurement, compatibility, and the ease of implementing it from a hardware standpoint. The lack of accuracy and capability of PTC thermistor method proves it to be unsatisfactory for the purpose of controlling temperature to test fuses.

6. Recommendation

This report recommends with confidence that the DS18B20 digital temperature sensor should be selected and implemented for use in fuse testing devices for PWM temperature control. Ultimately the functionality and capability of the DS18B20 should be prioritized over the cost effectiveness of the first option. This option effectively provides an accurate and reliable system for temperature control. Such a design will adequately meet the requirements for a temperature-controlled fuse testing device and as a result, mitigate CO_2 exposure risk to users.

Works Cited

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Appendix A - Weighted Objectives Chart Criteria

The following table outlines the criteria for scores from 1-5 on each objective covered in Table 3, the Weighted Objectives Chart of this report.

Objective	**1 - Poor**	**2 - Bad**	**3 - Average**	**4 - Good**	**5 - Excellent**
Accuracy	± 1.5℃	± 1.25℃	± 1℃	± 0.75℃	± 0.5℃
Cost	$10.00	$7.50	$5.00	$2.50	0.00$