Low Cost Electronic Algae Detection

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Abstract

The detection of harmful algae blooms (HABs) has caused problems for areas relying on Lake Erie for water. Improper detection led to the 2014 Water Crisis for Toledo, Ohio and surrounding areas. Since then, new detection methods have been developed but are too costly to be applied across much of Lake Erie. Present in this paper is a low-cost method for remote detection of algae. This project's purpose was to design and fabricate a mass producible detector to be used by health officials and assist in further research and relief efforts along Lake Erie. The detector is comprised of four sensors, chlorophyll, turbidity, conductivity, and color. The sensors work together to take and verify readings of algae.

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The detection of harmful algae blooms (HABs) has caused problems for areas relying on Lake Erie for water. Improper detection led to the 2014 Water Crisis for Toledo, Ohio and surrounding areas. Since then, new detection methods have been developed but are too costly to be applied across much of Lake Erie. Present in this paper is a low-cost method for remote detection of algae. This project's purpose was to design and fabricate a mass producible detector to be used by health officials and assist in further research and relief efforts along Lake Erie. The detector is comprised of four sensors, chlorophyll, turbidity, conductivity, and color. The sensors work together to take and verify readings of algae.

I. Introduction:

Cytobacteria also known as blue-green algae has been forming harmful algae blooms (HABs) in Lake Erie for years. These HABs have been killing fish, stopping water activities on the Lake, and put drinking water at risk. In 2014 a HAB made its way to the water intake pipe for Toledo, Ohio and surrounding areas, leaving them without drinkable water for several days. This water crisis was made worse as it caught the affected areas off guard. The city was caught off guard do to, “mishmash of testing methods and a lack of certainty over steps to be taken, even when drawing samples,” explains the Toledo Blade, on August 5th describing part of the cause for the crisis [1].

After the algae crisis, accurate methods for detecting algae were developed. There are two main methods of testing for algae. First, is using sensors to evaluate the water, these sensors have various types and forms from handheld sensors used from boats to buoys that float in the lake. The second way of detecting algae and the more accurate way is chemical tests in labs, but this is slower process as samples must be collected and taken to a lab to undergo testing[2].

Even though accurate ways of detecting algae have been found, the possibility being caught off guard without or in the midst of preparation for a water crisis is still possible. Most of the detectors in Lake Erie are being used for research and lab testing and sample collection takes time can be hindered by weather. This leaves areas relying on Lake Erie for water susceptible, these detectors cost thousands of dollars per unit are not practical for mass production use on Lake Erie. Lab tests use expensive chemicals along with the added time needed for sample collection, along with the tests themselves shortens the window of preparation.

The purpose of this research is to create a viable low cost remote electronic algae detector, that can be deployed across Lake Erie and other bodies of water affected by HABs. Using the data collected to visualize the growth and path of the HAB to predict where it will go next in attempts to increase the time for preparations before the HAB reaches the water intake pipe. Also having the information accessible to let further research and relief efforts coordinate with the detectors to assist them if possible.

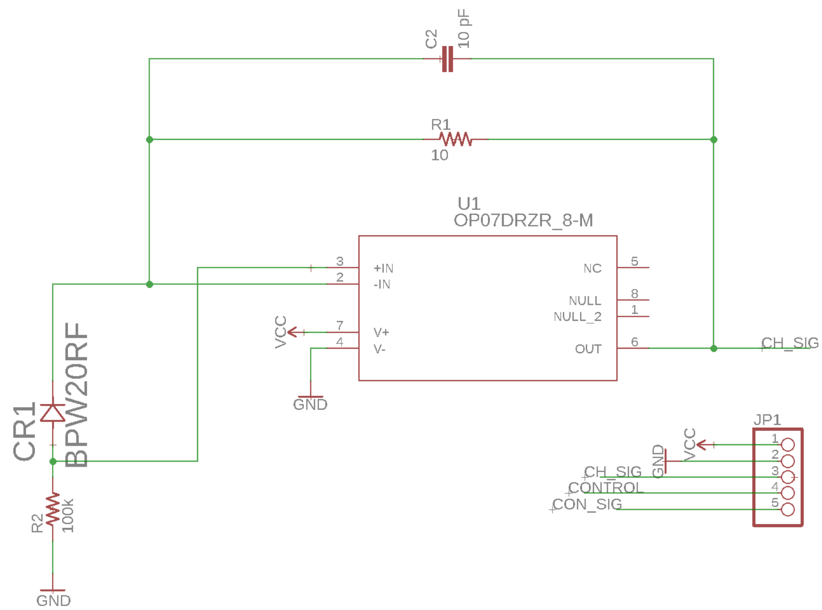
II. Methods

Chlorophyll Sensor

For accurate detection of algae originally, a phosphorus sensor was seen to give the best result, but there was no cost-effective way of implementing it. Instead a chlorophyll sensor was used for a quantitative measurement. To reduce costs, a custom-made chlorophyll sensor based off a design from Thomas Leeuw at The University of Maine was chosen. His chlorophyll sensor uses fluorometry to detect algae using a blue LED with a wavelength around 440 nm to irritate the chlorophyll in the algae. A photodiode then reads the irritated through a filter to negate the excitation light [3].

The schematic (figure 1) for the chlorophyll sensor used a VAOL-3MSBY2 diffused blue LED with a wavelength of 470 nm to irritate the chlorophyll. A Rosco Roscolux Red #19 (fire) filter to block out the excitation light from the BPW20RF photodiode. Both the blue LED and the photodiode were positioned at 45-degree angles as suggested in Leeuw's design, though the convex lens was not needed to focus the photodiode as the BPW20RF's focus was appropriate for the small distance that was needed for the detector on its own [3].

Figure 1: Schematic for the photodiode of the chlorophyll sensor



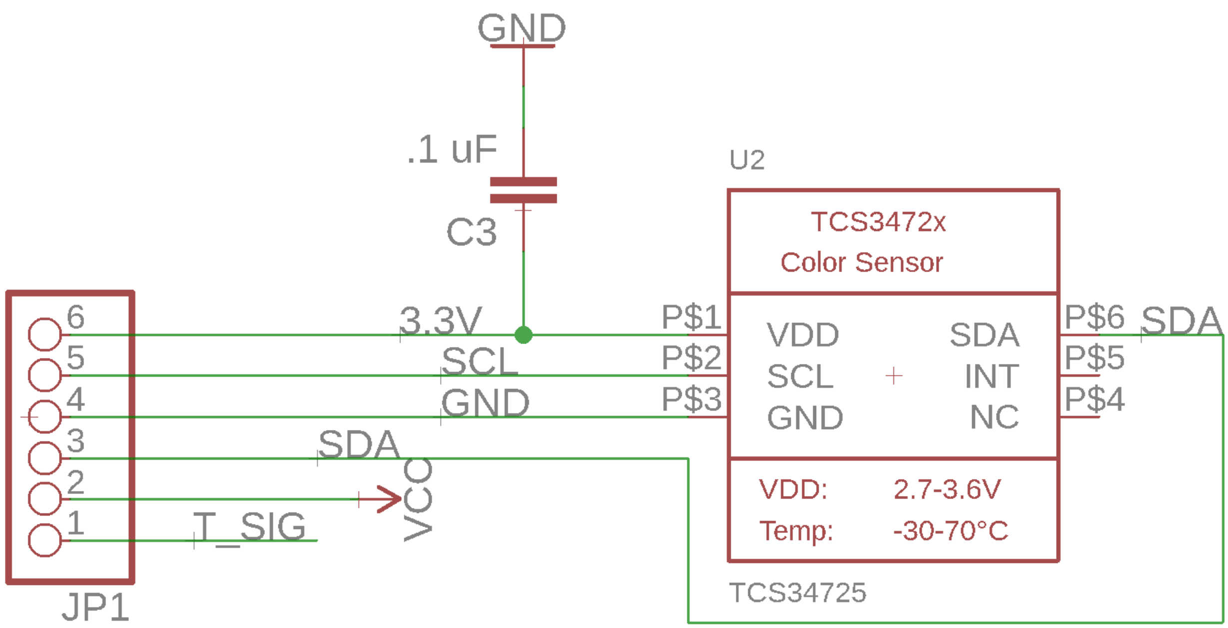
When testing the custom board, the photodiode had consistency issues and as such was replaced with the SparkFun luminosity sensor TSL2561, the luminosity sensor's photodiodes were used in place of the BPW20RF.

The chlorophyll sensor had two flaws with this design, ambient light and high turbidity [3]. To resolve these issues the sensor was put at the bottom of the detector in a narrow channel to minimize the ambient light that could get to the photodiode. A turbidity sensor was added to check for errors due to high turbidity. A reference ambient reading was also taken each time before the LED was turned on and the result subtracted from it.

Turbidity and Color Sensors

The turbidity sensor was comprised of a white LED on one side of the detector shining through the water to a TCS347x color sensor. Using the clear photodiodes on the TCS347x a turbidity reading was taken. After the turbidity reading was taken a raw color reading would also be taken. The color sensor gives a qualitative measurement of the algae allowing for a simple visual of the strong algae concentration to be displayed along with the readings taken.

Figure 2: Schematic for turbidity and color sensor

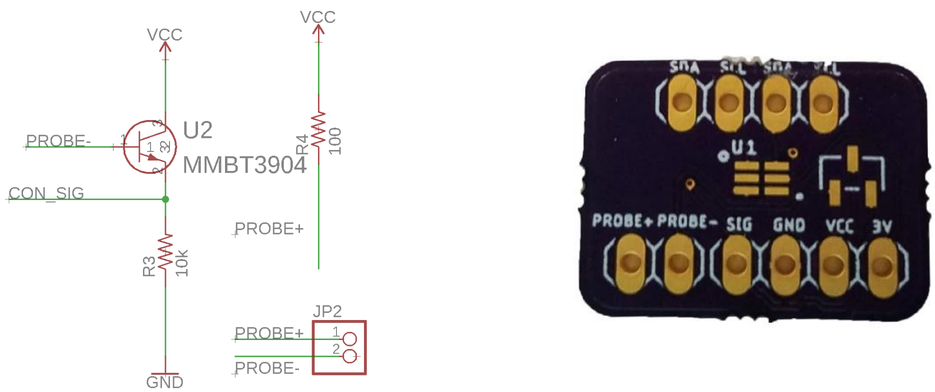


The TCS347x shares a flaw with the chlorophyll sensor of ambient light. To resolve this the sensor was place at the bottom of the detector taking readings through a narrow channel to minimize ambient light. A reference ambient reading was also taken each time before the LED was turned on and the result subtracted from it.

Conductivity Sensor:

A conductivity sensor was added to the detector as a simple non-optical sensor for detection of algae. If algae are present the water should have a mid-range conductivity value [4]. The conductivity sensor is comprised of a transistor and two wires functioning as probes.

Figure 3: Left conductivity schematic, right conductivity board



3D Printed Housing

For making a custom cost-effective housing 3D printing was chosen. For it, a Fusion3 FDM (fused deposition modeling) 3D printer was used. First attempt at printing the housing was out of standard PLA (polylactic acid) filament. The PLA housing had two flaws to it. First, the top to the housing was too malleable and would bend when screwed on preventing a proper watertight seal from being achieved. Second, in water testing PLA failed as water pushed its way through the air gap in between the layers of the print.

The same housing was then printed in ABS (acrylonitrile butadiene styrene) filament, a more durable filament. The top did not bend like the PLA but cracked instead still preventing a proper watertight seal. Water testing failed again, as water still pushed its way through the air gap between layers of the print. The housing was printed a third time in PETG (Polyethylene Terephthalate Glycol) filament, a sturdy filament like ABS, but more flexible. With the PETG housing a proper watertight seal was formed, though the water testing the PETG was still susceptible to water leaking in between the air gap.

In attempts to waterproof the housing both conformal coating and polyurethane were tried to stop the water from pushing through the air gap. They were tried on all three housing, but only slowed down the leakage. The pressure on the housing from the water was still too great and forced its way in through the air gap. A fourth housing was made, but this time a different method of 3D printing was used. A Formlabs Form 2 SLA (stereolithography apparatus) 3D printer was used. SLA is a different form of printing, having a laser etch the print into a pool or resin layer by layer making a more durable and detailed print than FDM printing. The SLA housing was able to get an airtight seal on top and did not have water leaking in through the air gap.

V: Results

The detector was deployed in a control pond at the Lake Erie Center on July 16th. The detector acquired three days of successful readings before it became waterlogged. The seals around the plexiglass at the bottom of the detector started to decay due to water interacting with the outer wall of the print.

Figure 4: Graphs of conductivity, spectral (chlorophyll), and turbidity

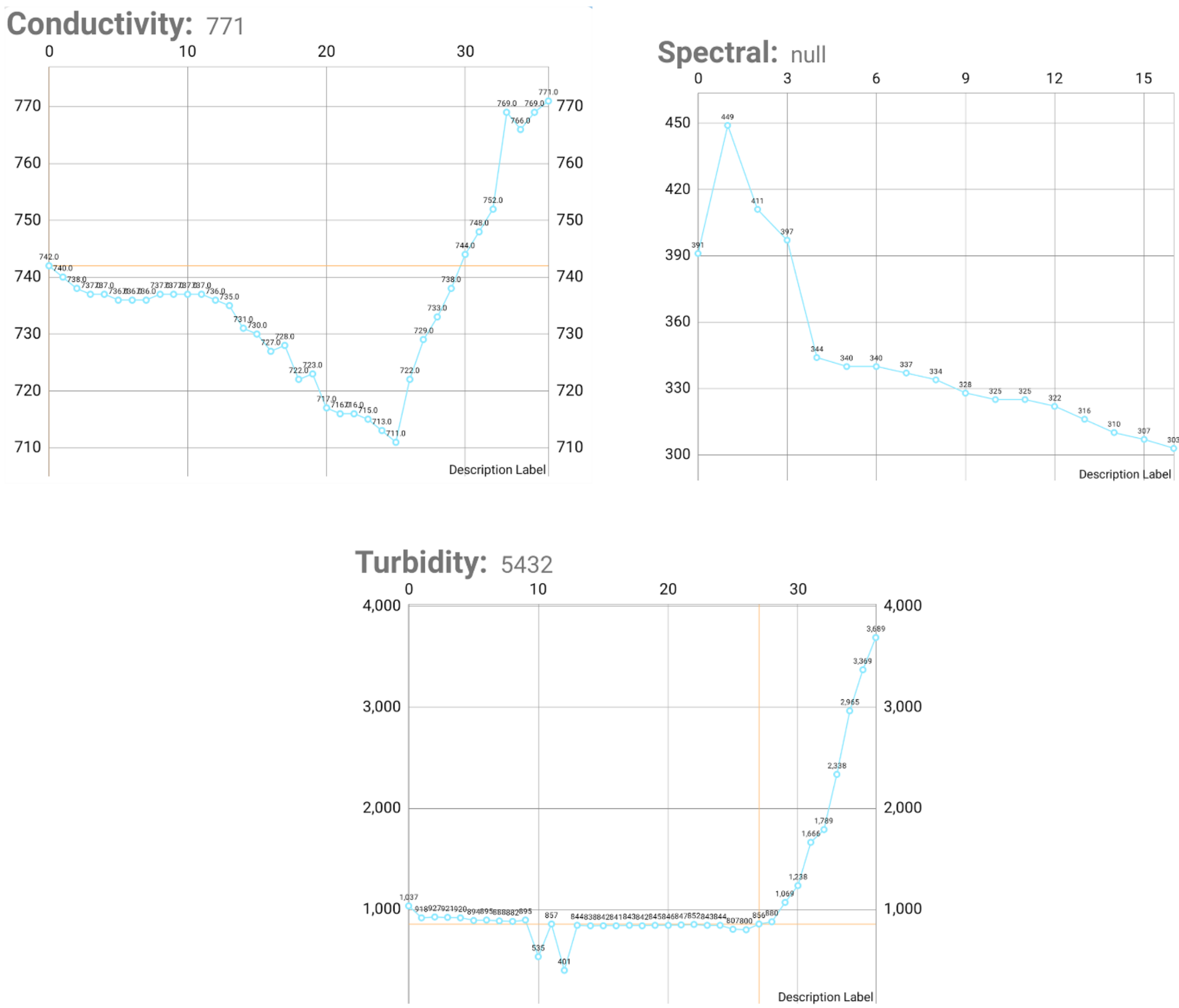


Figure 4 shows the graphs of the readings that were taken every 30 minutes over the course of 3 days. The small dip in the conductivity and the dip in the turbidity graphs are caused by rain washing surrounding sediments into the pond. This demonstrates the detector's capabilities of functioning in different weather scenarios. Though some improvements could be made as the chlorophyll (spectral) graph has less data points as some readings failed due to oversaturation of light when the sun was directly above the detector. The attempts to shield the chlorophyll sensor from the ambient light from the sun were not successful and need to be improved.

IV. Discussion

The detector has potential of being a viable low cost remote algae detector after some improvements have been made. In the future the housing will either need to have a better watertight seal around the plexiglass or have the housing made of an alternative material to 3D print. Utilizing SLA printing made the housing significantly more watertight, however more investigation into using UV cured prints is needed. The next step for the project would be to finish proper calibration or the sensors with side by side test with already calibrated sensors to make equations to take the arbitrary numbers generated by the readings and convert them into useable scientific measurements. Another step to be taken is a redesigning of the housing to block the chlorophyll sensor from getting oversaturated when the sun is directly above the detector.

Table 1: Budget for sensors and housing

Chlorophyll Sensor			
Parts	**Quantity**	**Price**	**Sub-Total**
Rosco Roscolux Red #19	1	$10.99	$10.99
SparkFun Luminosity Sensor TSL2561	1	$5.95	$5.94
VAOL-3MSBY2 Blue LED	1	$0.65	$0.65
		Total	$16.93
Color and Turbidity Sensor			
Parts	**Quantity**	**Price**	**Sub-Total**
White 3mm LED	1	$0.61	$0.61
TCS347	1	$4.53	$4.53
		Total	$5.14
Conductivity			
Parts	**Quantity**	**Price**	**Sub-Total**
Transistor	1	$0.19	$0.19

		Total	$0.19
Housing			
Parts	**Quantity**	**Price**	**Sub-Total**
200mL FormLab Resin	1	$30	$30
Conformal Coating	1	$12.83	$12.83
		Total	$42.83
	Total		$65.09

The price for the sensors and housing for the detector is $65 dollars. The unit cost of a single detector can be reduced by producing a large amount of the detectors, sharing things such as filter sheets.

V. Acknowledgment

Thanks go to the University of Toledo Department of Undergraduate Research for the opportunity and funding of this research, the Lake Erie Center for help with calibration of the sensors and use of the field testing pond, Maker Society for allowing their workshop to function as the lab for the research, the University of Toledo Department of Chemical Engineering for giving access to the 3D printers for the housing, and the University of Toledo Department of Arts and Letters for use of the laser cutter for the plexiglass.

VI. References

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[3] Leeuw, Thomas, et al. “In Situ Measurements of Phytoplankton Fluorescence Using Low C ost Electronics.” *MDPI*, 19 June 2013, doi:10.3390/s130607872.

[4] Osswald, Joana, et al. “Toxicology and Detection Methods of the Alkaloid Neurotoxin Produced by Cyanobacteria, Anatoxin-a.” *Environment International*, vol. 33, no. 8, 30 Jan. 2007, doi:10.1016/j.envint.2007.06.003.