GNG 1103

Design Project User and Product Manual

Submitted by:

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Table 1. Acronyms

Acronym	Definition
SGD18	IP18 Specific Gravity Device
HC-SR04	Ultrasonic Sensor

1 Introduction

This user manual is a technical document laying out all the necessary information to setup, understand, implement, operate, troubleshoot, and maintain the c(SGD18). The SGD18 is a brewery intended instrument designed to be operated in a 1 ½ inch inline wort system. This document is intended for the owners and operators of the SGD18. The SGD18 is the rightful physical and intellectual property of IP18 (Benjamin Zinck, Aiden Charette, Ali Gohar, Evan Aguiar-Winter and Gilles Tang).

This User and Product Manual (UPM) provides the information necessary for users to effectively use the IP18 Specific Gravity Device (SGD18) and for prototype documentation.

2 Overview

The SGD18 was designed to meet the user needs of Shane Clarke (Co-owner of Beyond the Pale). The brewing industry is costly, consequently, most small breweries must use devices that are inefficient due to budget restrictions. In Shane's case, he uses a handheld hydrometer to measure the specific gravity of the wort in his brewing process. This method is extremely inefficient, wasting crucial time, in addition to significant amounts of beer. Consequently, Shane is seeking a way to automate this process, in turn saving him time and money. Furthermore, he will be able to brew more consistent beer, in addition to monitoring the specific gravity at a glance.

The user requires a device that automatically measures the specific gravity of the wort in the brewing process. In addition, it needs to: Display Specific Gravity with short intervals, remains as a closed system, be easy to maintain, provides time logs, stores data long term, fits within the set budget, offers wireless control, provides data in table form and is available to graph.

Our product offers the benefit of ultrasonic sensors, as well as compact and detachable components for simple and efficient cleaning/miniatous. By taking advantage of the multiple reading per second capabilities of the ultrasonic sensors, the SG18 can collect and log data at a more efficient rate than the competition. This provides more accurate tables and graphs, in turn offering more consistency to the beer-making process. Furthermore, this product offers ease of use with regards to maintenance and cleaning that no other product offers. It's robust construction and hand tightened clamps allow for a simple and easy install and uninstall.

The SGD18 is a device that offers an automated specific gravity reading for the brewing process. It displays data in a table format using Microsoft Excel and can translate said data into a graph. It is powered by an Arduino Uno microcontroller and receives readings via the use of a HC-SR04 ultrasonic sensor. It is constructed of ABS and PLA plastics and held together by steel handheld hardware. It is an inline pipe design, featuring a pipe and a clamp for the microcontroller. The clamp is detachable for maintenance and cleaning. The device drawings data from the sensor and transmitting it to a computer where it is stored and graphed.

2.1 Conventions

When an action is required, is indicated by the keyword “Action”.

2.2 Cautions & Warnings

Before using the SGD18, you should understand the limitations and risks associated. This device May cause irreversible water damage to electrical components and IP18 is not responsible for any damage the SGD18 may cause to your personal property. Before using or modifying the SGD18, pleases contact one of our representatives (contact can be found below) to request permission. This is also applicable if you wish to copy any martial or designs found in this document.

3 Getting started

This portion of the user manual demonstrates user concerns, how to build SGD18, how to access SGD18, how to navigate the device, and how to dismantle it.

3.1 User Access Considerations

This device was specifically designed for the measurement of the specific gravity of a fluid in an enclosed piped system. This entails that this device is only reliable under circumstances where a fluid is consistently flowing through a piped system and that there are no external factors, like air bubbles, that can influence the data gathered by the device. The device is entirely food grade, and the sensor will need direct contact with the desired measuring fluid. This system links directly to a piping system, and is designed to measure the specific gravity of a fluid as it passes through. Flowing water does not affect the outcome, so a piped system is required.

This product was created with the goal of manufacturing a device that automatically measures the specific gravity of the wort in the brewing process, however, this system is capable of measuring any fluid in a closed enclosure with reasonable accuracy. It is compact, portable, and easily cleanable. So long as the environment in question has a closed piping system, and a fluid with unknown specific gravity, the product will do the task.

3.2 Accessing/setting-up the System

Following the procedures provided in the “Building the System” step, you should have the entirety of the case clamped firmly to your desired pipe. You should also have the Arduino UNO inserted into the protective case, and wired into the HC-SR04 correctly. If you are unsure how this is done, please refer back to the “Building the System” step. Once you have configured the device, you can now begin accessing your system testing.

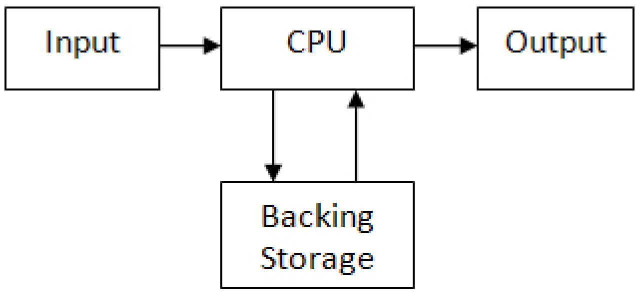
To begin testing your system, the first thing you'll want to do is turn on your Arduino. In order to do so, you will need to first plug your Arduino into an external source of electricity using the USB port. (Please refer to the “Turning on the system” portion for a more in-depth guide or if you are having any issues with starting the Arduino UNO). Once the Arduino is online, please open and access the device responsible for running your code, and open the Arduino IDE application. Once this application opens, it is best to run a test trial. Input the provided code on the large white canvas and press upload. If an error occurs, ensure you have the correct USB port selected in the “Select Board” banner. (The code to run the SGD18 is located in the “Getting Started” section.) Once you have received the results, start a test run to ensure the Arduino UNO is online and operating efficiently. Be sure you have calibrated your system properly, accounting for any change in distance, and inputting the bulk modulus for your fluid. If the distance is even slightly off the entire data reception can be off-put. The distance is measured in CM, be sure to calibrate ahead of your first practice test. If you are unsure of what your fluids bulk modulus may be, a number of fluids bulk modulus are available online, if your fluid is more unique a pressurized chamber may be needed to discover your fluids bulk modulus. (More on this topic in the “Configuration Considerations” section. Once your system is calibrated, insert your speaker into the pipe system with tap water and, if possible, run a test. What you should be seeing right now is the specific gravity of water (1 g/cm^3), it will be automatically displayed on the serial monitor.

If there appear to be any issues, ensure you have the case set up properly, Arduino UNO powered and wired correctly, and that the code displayed in the Arduino IDE is identical to the one provided. If issues continue to persist, please refer to the “Trouble Shooting & Support” section

3.3 System Organization & Navigation/ Configuration Considerations

The main component of this device is the Arduino UNO, it controls and monitors the specific gravity of the system. It gathers that data from the results it receives from the ultra-sonic sensor.

The sensor lets out a frequency and measures the amount of time it takes for that sound to emit and echo back to a separate sensor. It then relays that new information and converts it into specific gravity, and keeps track of and displays it on Excel for your faculty need. It is stored over time in case of any need for backtracking.



3.4 Exiting the System

First, turn off Arduino IDE and unplug your usb from the power source and the Arduino UNO. Now that the Arduino is disconnected, remove the ultrasonic measuring from the pipe system, be sure not to damage the wiring or open interface at the back of the sensor. Once the measuring device is removed, unfasten the bolts holding the clamp to the pipe and remove the entirety of the device. The device has now been removed, however, be sure to maintain the system using the methods provided in the "Maintenance" section.

4 Using the System

4.1 Turning on the system

4.1.1 Step 1 Setup

Action: To turn on the specific gravity device, plug it to a source of electricity via the Arduino USB port type B (see Fig 4.2.1) and watch that the LED diode on the Arduino turns on (see Fig 4.2.2), if it is not on then the device is not properly powered and will not function.

4.1.2 Step 2 Receiving data

Action: If the device is connected to a laptop, the data can be accessed in two ways. The first method would be to open the Arduino IDE, the specific gravity will be automatically displayed in the serial monitor.

4.1.3 Step 3 Excel (optional)

Action: The second way to stream the data would be via excel, make sure you have excel downloaded on your computer before proceeding. Refer to section 3 for proper excel setup.

4.2 <Given Function/Feature>

The specific gravity device can be plugged in via Arduino USB type B and streams data directly to the connected computer.

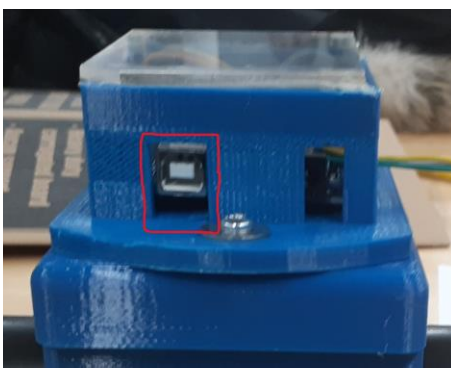


Fig 4.2.1

It also sports an LED which turns on when the Arduino is powered.

Fig 4.2.2

5 Troubleshooting & Support

During our testing procedures we identified a few errors that might occur with the device.

Due to time restraints, we were not able to eliminate these errors, so below we describe the errors that may occur and how to resolve and troubleshoot them.

5.1 Error Messages or Behaviors

During use if the specific gravity seems to be abnormal, make sure to calibrate the device. Device calibration procedures are listed in section 3. If the specific gravity values being displayed are “0.000” or “INF”, make sure HC-SR04 is plugged into the Arduino board. If so, make sure all wires are in place in the Arduino board. Namely, gnd to gnd (black wire), 5v to VCC (red wire), Pin 13 to trig, Pin 7 to echo. If excel datasheet is not displaying values as should, make sure excel is setup properly and the device is connected to excel. For further details on that please refer to section 3.

5.2 Special Considerations

In special circumstances, if the device displays abnormal specific gravity values, or returns “0.00” or “INF”, even after troubleshooting procedures, a new ultrasonic sensor may be required. Please get inContact with support, for details on how to order a new sensor. To replace the sensor, remove the sensor from its housing by gently pulling on it from the sides. Please make sure not to pull from the wiring, as it could damage the clip and new wiring would be required. To install the new sensor simply push it back in the housing, and push the clip back on making sure all the wires are plugged in the right order, as described in section 5.1.

5.3 Maintenance

Proper maintenance of the device is crucial for its accuracy and life time. The ultrasonic sensor should be removed and cleaned before every new brew. Simply remove the sensor and clean the mesh in the front with any non-fibrous material. Inspect for any visual damage, in case there is broken pieces, or corrosion a new sensor may be required. Please contact the support team for details on ordering a new sensor. Make sure to calibrate the sensor before use. The case for the SGD18 is built in a way to make it very low maintenance. But it is recommended to remove the components from the case, every six months and are dusted off to ensure no electronic component fails. To clean the components, make sure an electronics safe product is used, compressed air can also be used.

5.4 Support

In case any errors occur that are not listed above, or the errors are not resolved after all the troubleshooting procedures. Please get in contact with one of our team members whose contact information's are listed below. For Technical support please contact

Ali Gohar – Agoha014@uottawa.ca

Aidan Charette - aidcharette@gmail.com

Please make sure to include the error you are encountering, when and how did the error start occurring, the troubleshooting steps that you have performed and any other information that is relevant to the issue. We will try our best to get back to you as soon as possible.

For details on how to order new sensors please contact:

Evan Aguiar-Winter - Eagui048@uottawa.ca

For any other information please contact:

Benjamin Zinck – bzinc076@uottawa.ca

Gilles Tang - htang098@uottawa.ca

6 Product Documentation

6.1 Instructions

6.1.1 Step 1:

3D print the top and bottom parts of the pipe clamp and the Arduino case using the files provided.

6.1.2 Step 2:

Drill 4 vertical hole through the clamp with a drill bit the same size of the 4 bolts you will use to fix the clamp. Ensure that the holes do not pass by where the pipe will be.

6.1.3 Step 3:

Secure the Arduino case to the top of the pipe clamp by drilling in 2 screws on each side of the cases flange, make sure there is a washer between the screws and the case flange when you do this.

6.1.4 Step 4:

Put the Arduino in the Arduino case and connect it to the ultrasonic sensor via this wire array:

6.1.5 Step 5:

Put plexiglass over the Arduino case and secure it, make sure to secure the clamp with 4 bolts and nuts.

6.1.6 BOM (Bill of Materials)

Material:	Price (CAD):	Link
3D printer filament	$0.47/g	https://makerstore.ca/shop/ols/products/onyx-per-cm3
Ultrasonic distance sensor	$20.69	https://www.amazon.ca/DAOKI-HY-

		SR05-Ultrasonic-Distance-Detection/dp/B08XLKN5C5/ref=sr_1_3_sspa?gclid=CjwKCAiA0JKfBhBIEiwAPhZXDzHYo4gX6NhjSeemdLDhlpeWdFJUbR7YkLuodnbLTd-pweKtHiRusRoC470QAvD_BwE&hvadid=595961483019&hvdev=c&hvlocphy=9000668&hvnetw=g&hvqmt=e&hvrand=17066737634070379410&hvtargid=kwd-297531272153&hydadcr=1506_13492350&keywords=ultrasonic+distance&qid=1675968683&sr=8-3-spons&psc=1&spLa=Z

		W5jcnlwdGVkUXVhbGlmaWVyPUFITFMzT1FWUVJUR0YmZW5jcnlwdGVkSWQ9QTA0Nzg5OTYyQjUwOEFYMElQVE9GJmVuY3J5cHRlZEFkSWQ9QTAxNTQyNjcyMUoyMElONlhEV01FJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
Arduino Uno	$17	Maker Space
Excel	$159	-
Male/female jumper wires x4	$12.69	https://www.amazon.ca/IZOKEE-240pcs-Solderless-Breadboard-Arduino/dp/B08151TQHG/ref=sr_1_5?crid=3ES6QPDPYKMU5&keywor

		ds=jumper+wires&qid=1675969568&sprefix=jumper+%2Caps%2C183&sr=8-5
Bolts x4	$0.50	Hardware Store
Nuts x4	$0.50	Hardware Store
Screw x2	$0.50	Hardware Store
Washer x2	$0.50	Hardware Store
USB type A cable	C$1.70	https://makerstore.ca/shop/ols/products/usb-type-a-to-usb-typeb-cable-3ft
Plexiglass	$8	https://makerstore.ca/shop/ols/products/acrylic-12-inch-x-24-inch
Arduino IDE	$0	
Onshape	$0	https://cad.onshape.com/documents/78f764f5700bfa6ed95d623d/w/db01223695c3412fb43baba9/e/952e3fa3a1f134af6930bf3f?renderMode=0

		&uiState=63e54ad36471 804987b82acb

6.2 Desing considerations

6.2.1 Materials

There was not much of a choice for the materials used for the prototype, its main components were 3D printed and as such, the prototype was mainly composed of plastic and no other materials were tested although an aluminum clamp and a hard rubber Arduino case would have been ideally provided, we would have had the time and money to machine those components.

6.2.2 Code

Most of the code was outsourced from opensource, it would have taken much longer to make the whole code from scratch and it would not be as efficient as somebody with more coding knowledge with Arduino. The premise of the code however is quite simple as it measures the time it takes to transmit and receive an ultrasound and then to use that value to find specific gravity with the help of a few other variables and the last bit of the code graphs it onto Excel.

6.2.3 Math

The math equations were found online but manipulated by us so that we could achieve the desired result, distance and bulk modulus must be adjusted for the system. We had to "settle" to manually input bulk modulus but in a future design we would need another system to input it or a different approach on the math.

6.3 Testing & Validation

The first test that was done was to see if the value given by the sensor would differ depending on what substance the ultrasonic sensor was in. We proved that it could get different reading in different substances by using it in air and watching how long it took to receive a reading against how long it took in water and sugar water. The distance between the fluid, the sensor bottom of the cup were left constant but the values changed depending on the substance which proved that the sensor could get different readings in different fluids and that it could work in water.

The next few tests were to see if the math worked to give the specific gravity of a substance in a cup and it did work however it did not work in a pipe no matter what we did. The final prototype was displayed and tested with cups. It was determined that what stopped it from working in the pipe was how the ultrasound was echoing in the pipe because it was hitting a very curved surface because of its size and the beam angle of the ultrasonic emitter.

7 Conclusions and Recommendations for Future Work

In constructing this device, it has been observed that the existing sensor proves quite inaccurate, in the future a focus should be the implementation of a significantly more accurate and waterproof sensor is required. After investing a large portion of the allocated budget into our design, IP18 observed the inaccuracy of the existing sensor, not to mention the non-waterproof construction. Consequently, we were forced to proceed with an inaccurate sensor, leaving readings inaccurate to an error of 30%.

Recommendations to render the product useable in a real brewery scenario reflect the need for a waterproof high accuracy sensor, food grade sealants and additionally, wireless connectivity. In addition to these necessary improvements, the case design could be improved, by relocating the sensor inside the clamp, sealing and hiding all wiring, implementing a backup battery power supply, implementing wireless connectivity, and finally attaching an external hard drive for long-term storage. Adding these luxuries render the device appropriate for use and worth Shane's wile. More features such as a temperature sensor or drop proof housings would also be ideal.

Ultimately, if given a longer timeframe, IP18 would focus on refining its physical appearance, and more importantly implementing and testing a high-fidelity waterproof sensor. Simply due to time and budgetary constraints, IP18 was forced to proceed with the best possible option, the HC-SR04. Unfortunately, this sensor is not industry implementable, therefore it is required that a better one is installed. Furthermore, IP18 also abandoned a battery backup, and wireless connectivity. In the future IP18 looks forward to seeing improvements and future developments to the SGD18 specific gravity device.

APPENDICES

8 APPENDIX I: Design Files

Table 2. Referenced Documents

Document Name	**Document Location and/or URL**	**Issuance Date**
Project Deliverable A-Team Contract	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/9/25
GNG1103 Deliver	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/1

able B		0/2
Gng 1103 B05-Deliverable C	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/10/09
Project Deliverable D GNG1103 Group18 Resubmission	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/10/16
Gng1103-Deliverable E	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/1

		0/23
Deliverable F Group 18	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/11/6
Deliverable G Group 18	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/11/13
GNG1103 Group - 18 - Deliverable H Prototype III	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/11/27

Deliverable J 15 min Presentation	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/11/15
Deliverable J Design Day presentation	https://drive.google.com/drive/folders/1oRVDytlphbOvr5iTtPd5zZreBJJJTxqX?usp=sharing	2022/11/15
Maker Repo	https://makerepo.com/AidanCharette/1331.gng1103-b4-ip18-specific-gravity-device	2022/11/17
The Portable Density	https://www.mt.com/int/en/home/products/Laboratory_Analytics_Browse/density-meter/portable-density-meter.html?cmp=sea_04010105&SE=GOOGLE&Campaign=MT_ANA-DERE_EN_CA&Adgroup=DE_Beer-wine-hydrometer_Phrase&bookedkeyword=%2Bbeer%20%2Bhydrometer&matchtype=b&adtext=619293025095&placement=&network=g&kclid=_k_Cj0KCQjw4omaBhDqARIsADXULuVb7Bp8AOMqfp1ueLF63v5wXiaaiOAgQtDWnsFlzvzCl4ZR1nR7UgcaAiXlEALw_wcB_k_&cq_src=google_ads&cq_cmp=260833586&cq_con=109676032524&cq_term=%2Bbeer%20%2Bhydrometer&cq_med=&cq_plac=&cq_net=g&cq_pos=&cq_plt=gp&gclid=Cj0KCQjw4omaBhDqARIsADXULuVb7Bp8AOMqfp1ueLF63v5wXiaaiOAgQtDWnsFlzvzCl4ZR1nR7UgcaAiXlEALw_wcB	N/A

Meter		
Ultrasonic Hydrometer	https://www.cae.it/upload/products/pdf/ulm20/Ultrasonic_Hydrometer_ULM20.pdf	N/A
Project for ultrasonic piezo buzzer at 40 Khz along with power question	https://forum.arduino.cc/t/project-for-ultrasonic-piezo-buzzer-at-40khz-along-with-power-question/480573	2017/9/17
Ultrasonic pie	https://maker.pro/forums/threads/ultrasonic-piezo-buzzer.17208/	2003

zo buzzer		/8/15
Add Wi-Fi to Arduino Uno	https://create.arduino.cc/projecthub/imjeffparedes/add-wifi-to-arduino-uno-663b9e	2017/7/6
Using a Microphone with Arduino	https://www.aranacorp.com/en/using-a-microphone-with-arduino/#:~:text=The%20microphone%20requires%20low%20power,to%20adjust%20the%20microphone%20sensitivity	2020/10/2
A Sensitive DIY Ultrasonic Range	http://www.kerrywong.com/2011/01/22/a-sensitive-diy-ultrasonic-range-sensor/	2011/1/22

Sensor		
Ultrasonic sensor hc sr04 with Arduino tutorial	https://create.arduino.cc/projecthub/abdularbi17/ultrasonic-sensor-hc-sr04-with-arduino-tutorial-327ff6	2019/9/7
Measuring the Speed of Sound With Arduino Microcontroller and	https://www.instructables.com/Measuring-the-speed-of-sound-with-Arduino-microcon/	N/A

Ultrasonic Sensor		
Stream data from Arduino into excel	https://create.arduino.cc/projecthub/HackingSTEM/stream-data-from-arduino-into-excel-f1bede	2019/9/26

9 APPENDIX II: Other Appendices

Pictures and Figures of the project

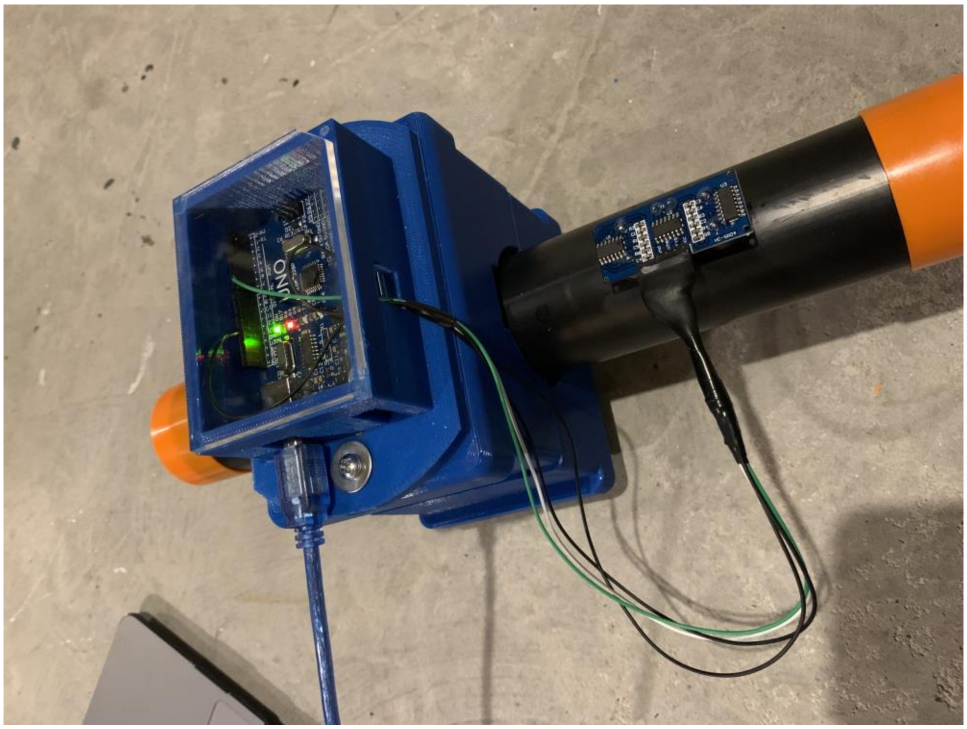


Figure 1: the final project with the sensor from Arduino, which don’t work that well in the pipe

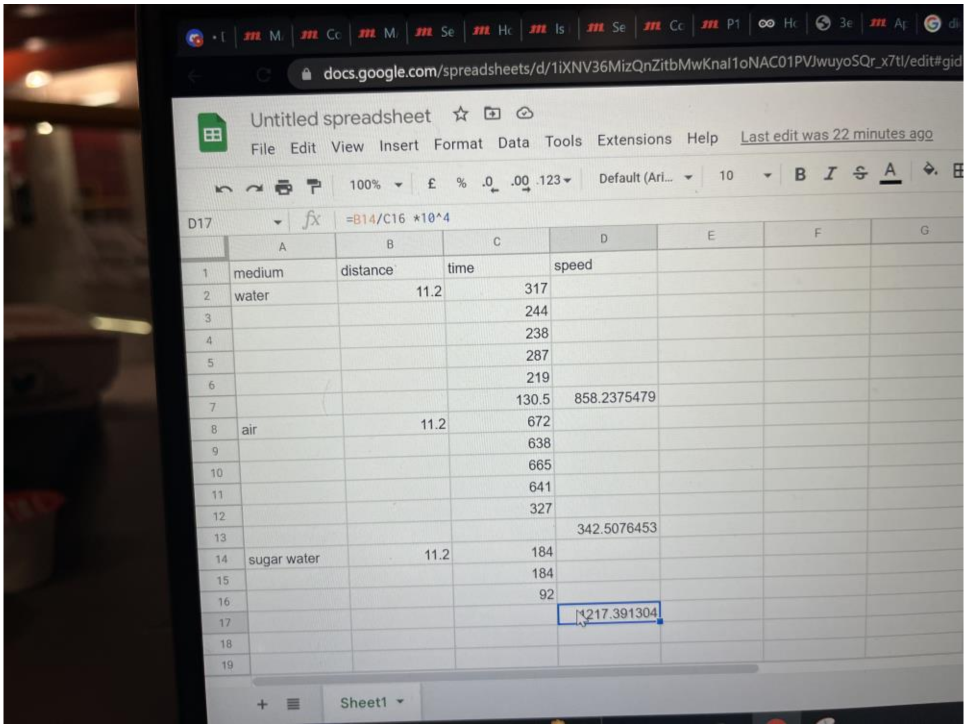


Figure 2: the reading from Prototype II we output it into Excel(automatically)

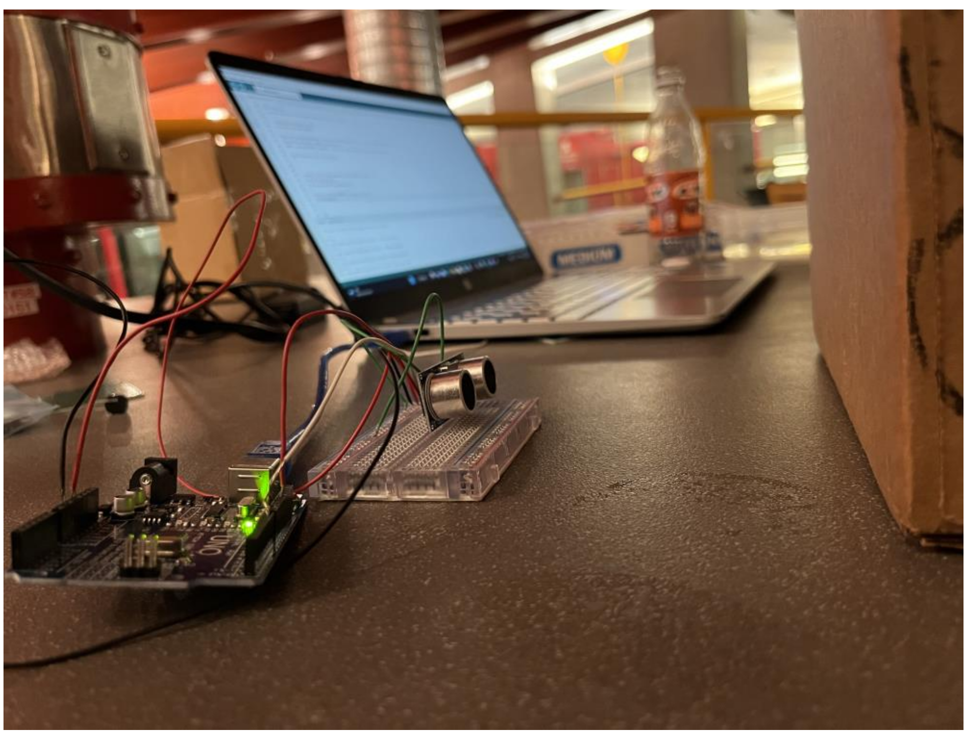


Figure 3: the setup of Prototype II

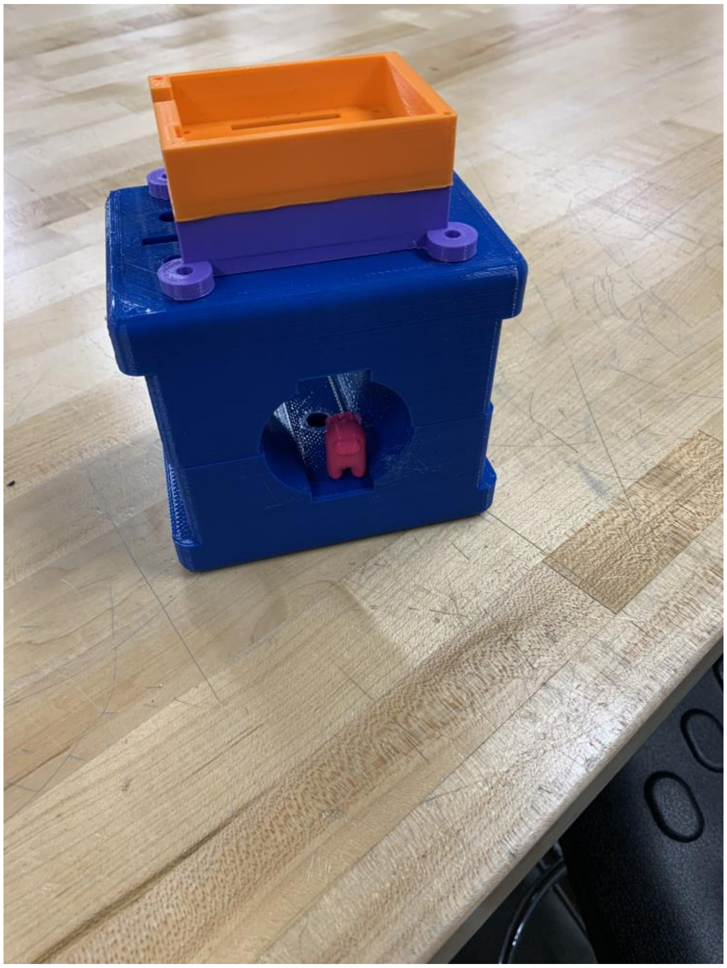


Figure 4: Initial look of the clamp that is going to clamp onto the pipe