

Early Tornado Detection

Jacob Bertrand, Madison Likins, Jacob Nichols, Maxwell Niemeyer

Oklahoma State University College of Engineering, Architecture, and Technology

MAE 4344 Spring 2016

5/4/16

CONTENTS

1	Introduction	4
1.1	Problem Statement	4
1.2	Motivation.....	4
1.3	Final Design	5
2	Work Completed	6
2.1	Research of Alternative Sources	6
2.2	Torch Assembly	6
2.3	Microcontroller	9
2.4	Operating the Valve	10
2.5	Testing.....	12
2.5.1	Test Arrangement	12
2.5.2	Results.....	13
3	Final Design	16
3.1	Evaluation of Final Design.....	16
3.2	Final Micro-Controller Design.	16
3.2.1	Coding the microcontroller	16
3.2.2	Assembling the microcontroller system	16
3.3	Improvements and Future Work	17
3.3.1	Micro-Controller Improvements.....	17
3.3.2	Testing Improvements	18
3.3.3	Torch Improvements.....	18
4	Budget and Timeline	18
4.1	Updated Budget.....	18
4.2	Microcontroller Budget.....	19
4.3	Final Progress Report	19
4.3.1	Jacob Bertrand Completed Hours	19
4.3.2	Madison Likins Completed Hours	19
4.3.3	Maxwell Niemeyer Completed Hours.....	20
4.3.4	Jacob Nichols Completed Hours	20
5	Appendix	20
6	References	20

<blank page>

1 INTRODUCTION

1.1 PROBLEM STATEMENT

The purpose of this project is to develop a controllable infrasonic source that can be used as a research tool for the early detection of tornadoes. The torch, using a propane source, will pulse at varying time intervals to create a desired frequency between 0.5 to 5 Hz. A microcontroller will be used to set the desired frequency and send an electrical current to the solenoid valve in order to control the opening and closing of that valve. The sponsor requests a controllable flame size, an ignition switch, and a pilot flame that stays lit when in use. The torch will need a feedback system to ensure the flame stays lit for the duration of the test. The feedback system should also help maintain the frequency by accounting for delays during flame production. Figure 1 is an example of the type of propane torch requested by the sponsor.



Figure 1: Example Propane Torch [1]

1.2 MOTIVATION

The main motivation surrounding this project is the lack of improvement on tornado warning lead time and the high number of false alarms. Figure 2 displays a plateau of tornado warning lead time. This plateau spurred the recent interest in early tornado detection which led to the development of this research project. The ultimate goal of the research project is to improve tornado warning lead time and decrease false alarm rates; a better lead time can prevent thousands of deaths and injuries; fewer false alarms increase awareness to the severity of storms. The development of the propane torch will aid in simulating a tornadic infrasonic source. Information from the propane torch can then be used to develop new technology to detect tornadoes early and prevent deaths and injuries.

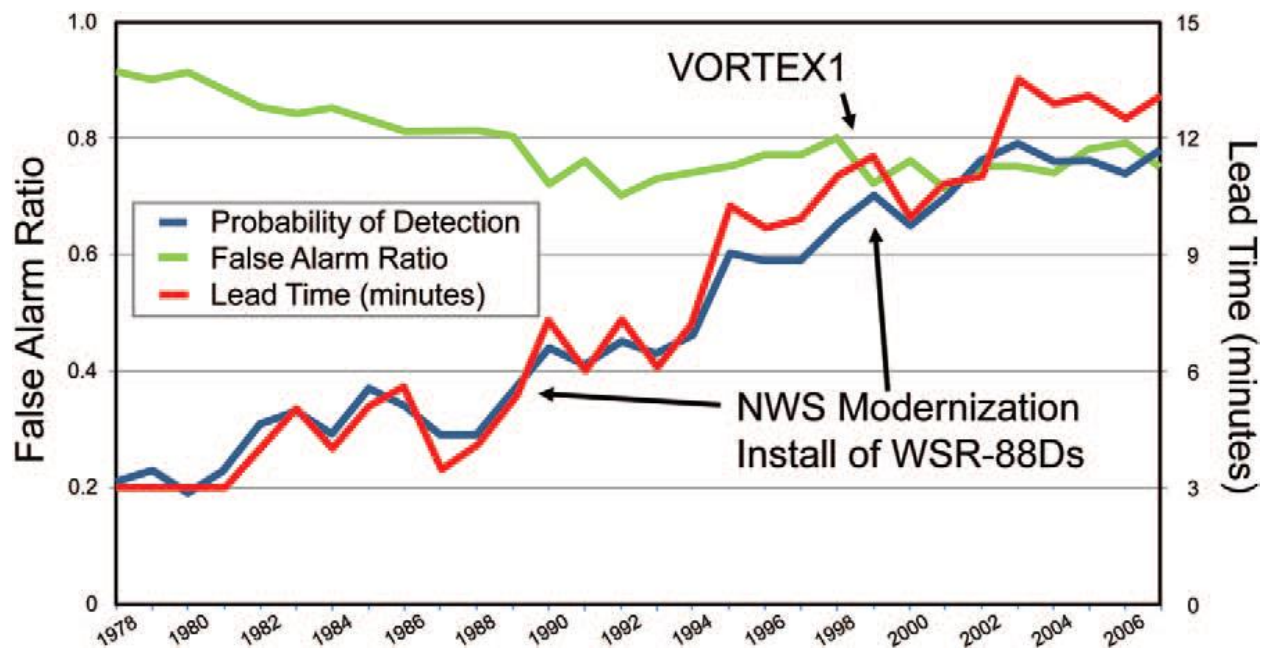


Figure 2: Plateau of Lead Time for Tornado Detection [2]

1.3 FINAL DESIGN

Figure 3 shows the final propane torch assembly. The black box holds the microcontroller circuit, which has been soldered. The spark plug is also integrated into the box for easy access.



Figure 3: Final propane torch assembly

2 WORK COMPLETED

2.1 RESEARCH OF ALTERNATIVE SOURCES

While waiting for parts to come in, different options for making an infrasonic device were explored. The first idea, come up with by Dr. Delahoussaye, was to implement a kick drum to create the pressure wave. The idea was that if the drum was operated at the infrasonic frequency, less than 20 Hz, that the pressure waves would be the source of the infrasonic noise. A pillow inside the drum would be used to dampen the vibration of the drum head to try and reduce extra noise to get a clearer signal. The

Another idea was to modify the torch to fit a horn, similar to a trombone bell or another instrument, to amplify the sound.

Both of these ideas were turned down by Dr. Elbing for the following reasons. A square wave is desired, where there is a constant pressure wave followed by a zero pressure wave. A drum would develop a sinusoidal wave with a peak instead of constant pressure. The bell on the end of the torch would result in a directional wave where an omnidirectional wave is desired. The bell would also vibrate at its natural frequency creating more noise when testing.

It was necessary to come up with a backup idea in the case that the torch ends up not being a good source of infrasonic sound. Dr. Elbing mentioned that a Rotary Subwoofer might make a good alternative so this was researched.

A rotary subwoofer is essentially a fan that has blades able to tilt while rotating. When the blades tilt, there is a pressure spike created in the room (usually used for wall-shaking bass in home theaters). The issue with this setup is that there is only one manufacturer of rotary subwoofers. This company, Eminent Technology, charges a premium for the setup. Just the parts cost over \$14,000 [2]. This, of course, is well outside of the budget for a senior design project.

It would be possible to build a rotary subwoofer at low cost using RC helicopter rotor assemblies. The issue that arises however is that the blades would most likely not provide enough air flow to achieve the pressure differences desired. New blades would have to be constructed at the Design Manufacture Lab and the hub would have to be modified to accept several more blades and to also allow the assembly to tilt quickly enough to create pressure waves at up to 20 Hz.

2.2 TORCH ASSEMBLY

Table 1, under section 4.1, shows a list of the materials that were purchased and used to assemble the torch (excluding the micro-controller). Figure 4 is a system diagram depicting how the major components will connect. Figures 5-7 are photos of the assembled torch and its important components. To operate the torch, the user must ensure that both the mainline and pilot line needle valves are completely closed; when both valves are closed the propane tank can be fully opened. The next step is to light the pilot light. In order to do so, begin by slowly opening the needle valve a quarter. Then the user will push the piezoelectric switch. The switch usually takes between 1 to 5 tries before it ignites the pilot light. The microcontroller can now be signaled to actuate. Once the valve begins to actuate the user will slowly open the mainline needle valve until the desired flame length has been met. To turn the torch off, close the propane tank, then both needles valves, and finally close the solenoid valve.

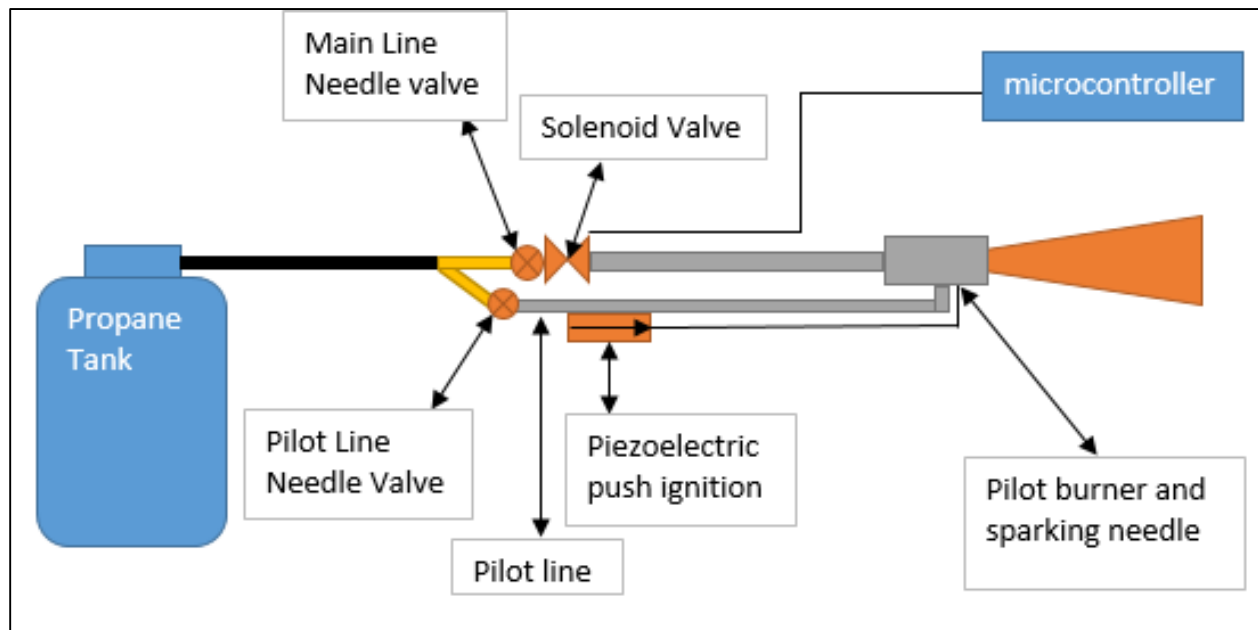


Figure 4: Torch configuration



Figure 5: Assembled propane torch system



Figure 6: Torch nozzle inside view of mounted sparking needles and pilot burner

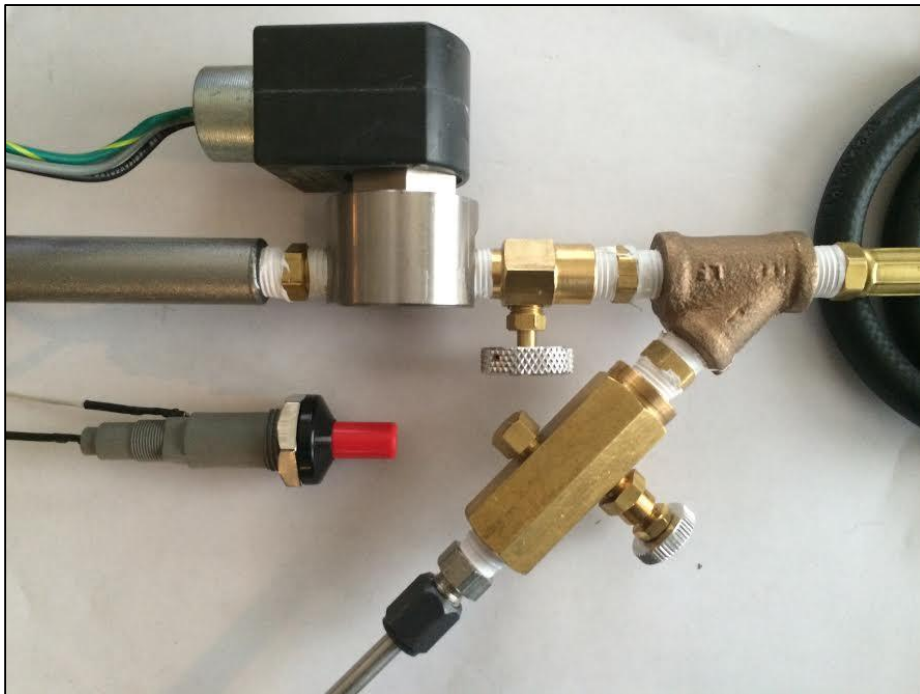


Figure 7: propane torch valve assembly

2.3 MICROCONTROLLER

A micro-controller system is going to be created in order to control the frequency of the fuel valve and the flame the torch produces. Currently, an Arduino Uno has been selected as the prototype microcontroller for its high affordability and versatile capabilities. Figure 8 shows the basic circuit diagram showing how the microcontroller works with the valve. The valve requires 24 volts to operate, so a Mosfet transistor will be used where the 5 volts from the Arduino will act as a signal voltage on the gate side of the transistor to begin to power the solenoid valve on the drain side of the resistor from a 24 V power source. A HC-05 blue-tooth module has been selected so that the Arduino can use serial communication through wireless blue-tooth. This will allow the torch operator to completely control the torch system from a computer at a safe distance. A complete parts list is shown in Table 2 under section 4.2 with the corresponding prices for each part.

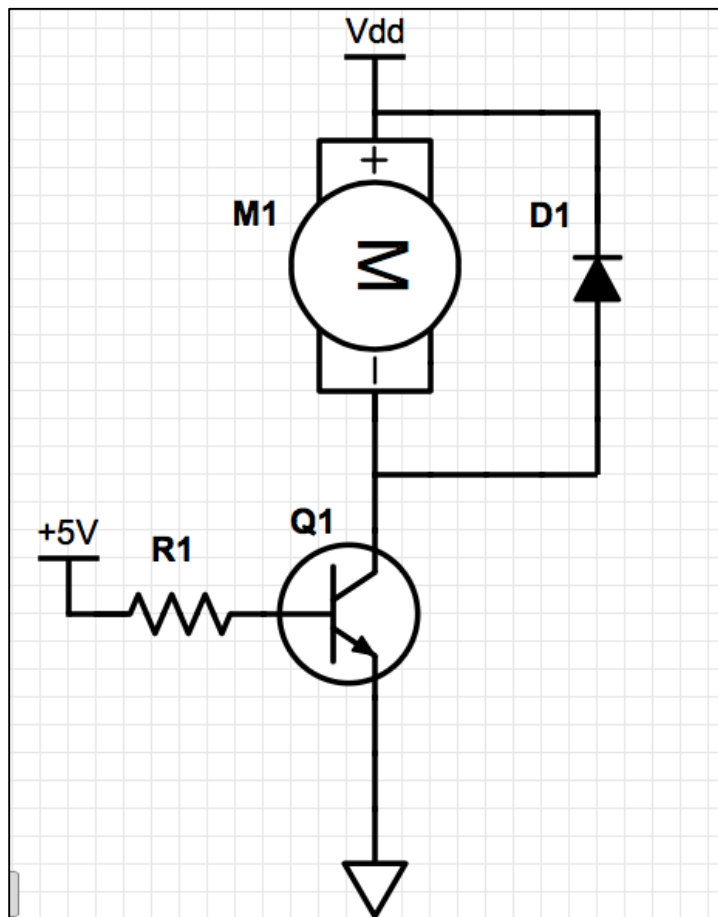


Figure 8: Circuit diagram for the solenoid valve. The +5v comes from the Arduino and the drainage voltage Vdd comes from a rechargeable 24 volt power supply. M1 is the solenoid valve, D1 is a power diode, and Q1 is a Mosfet transistor.

2.4 OPERATING THE VALVE

In order to operate the valve using Bluetooth, the operator must turn on the switch and button on the project box attached to the torch, then pair up with the HC-05 Bluetooth module. This can typically be done by turning on Bluetooth on the device that will control the valve and searching for devices as shown in Figure 9. The HC-05 module will show up in the searchable devices, the operator will select this device and pair with it by using the password 1234.

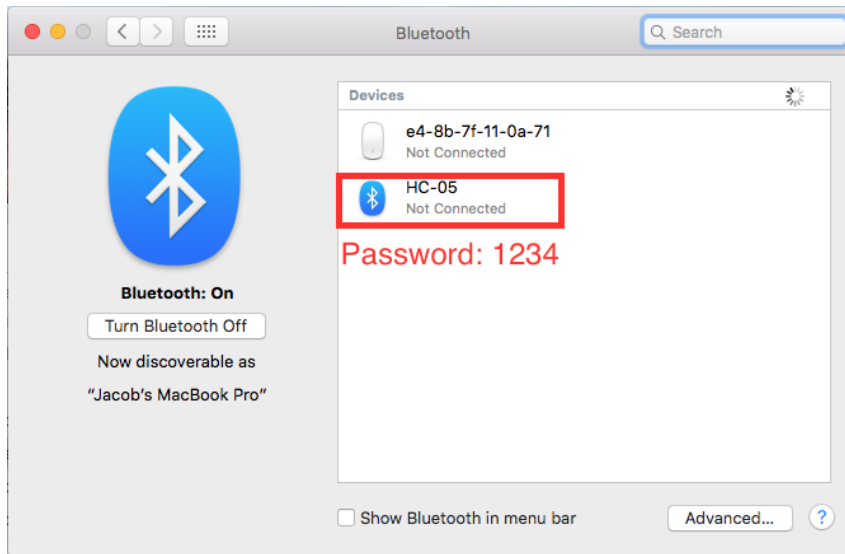


Figure 9: Bluetooth Devices options. HC-05 will be listed as a connected device.

Once the HC-05 module is paired with computer, the operator will then open up the Arduino editor program as shown in Figure 10. In this window, the user can create different codes for the Arduino to operate, however, the code is already written and stored on the Arduino, so there is no need to write any code, the Arduino program is being used merely as a medium of communication.



Figure 10: Arduino Program. This will be used to send data to the valve.

In order to establish communication between the computer and the Arduino, the user will go to *Tools* and then make sure the board tab reads “*Arduino/Genuino Uno*” and that the port that is selected reads “*HC-05-Dev B*”. Figure 11 shows the steps to selecting the correct port for communication.



Figure 11: Port selection for communication is selected

When the correct port for communication is selected. The serial monitor is then ready to send and receive data to the solenoid valve. To open up the serial monitor, select the icon on the upper right hand of the Arduino editor window. This icon (Figure 12) will open another window that will allow you to send frequencies for the valve to operate wirelessly.

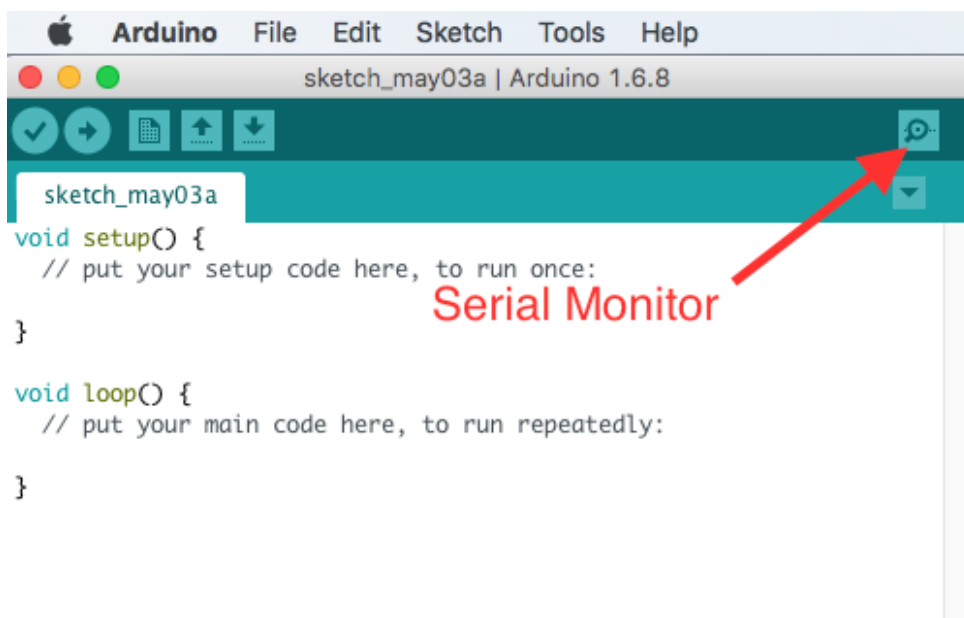


Figure 12: Opening the serial monitor for communication

With the serial monitor open, the operator will then send the frequency they want the valve to operate at through the input bar at the top of the monitor and click send or enter. The valve will then begin to actuate at that frequency then send back data to the monitor confirming the frequency of its actuation as shown in Figure 13. In order to turn off the valve, the operator simply sends a value of 0. If the serial monitor is receiving different symbols or odd messages, make sure the baud rate selected in the monitor is 9600. The code in the Arduino is hard coded to work on a baud rate of 9600, any other communication rate will cause errors in the monitor.

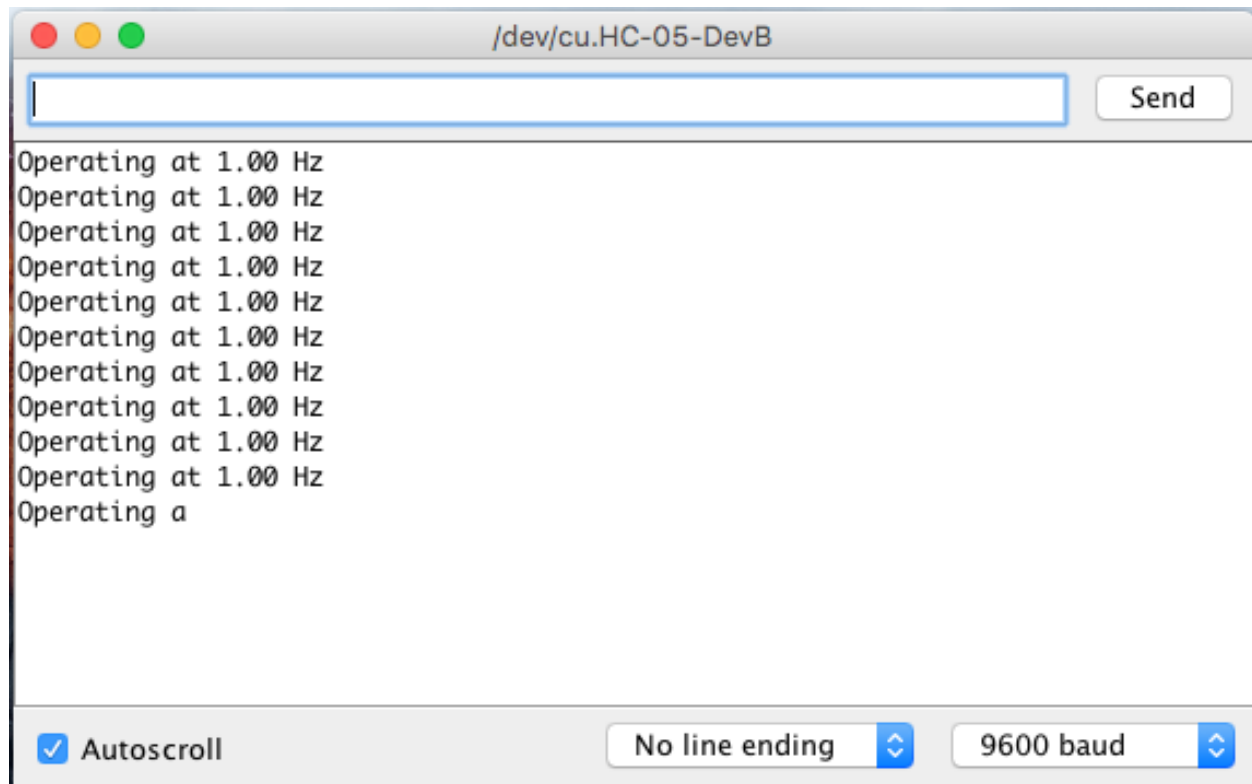


Figure 13: Sending data to the solenoid valve using the serial monitor.

2.5 TESTING

All testing took place in the garage area of the DML. Conditions in the garage are similar to those outside but with limited wind noise. The frequencies tested were 1, 2, 3, 4, and 5 Hz. Each test ran for two minutes. The data was recording using an infrasonic microphone that was connected to the program, Amaseis. Amaseis converts pressure waves into a voltage output. This data was saved and ran through an FFT program developed by Arnesha Threatt on Matlab.

2.5.1 Test Arrangement

Figure 14 shows the arrangement of each test. Every test had identical arrangements. The propane torch was held by a team member, around 2 feet off the ground. The microphone was placed on the ground, 2 feet away from the propane torch. The microphone can be interchanged with any infrasonic

microphone. The frequency of the torch can be controlled through any Bluetooth enabled device, or wired through a USB port of computer.

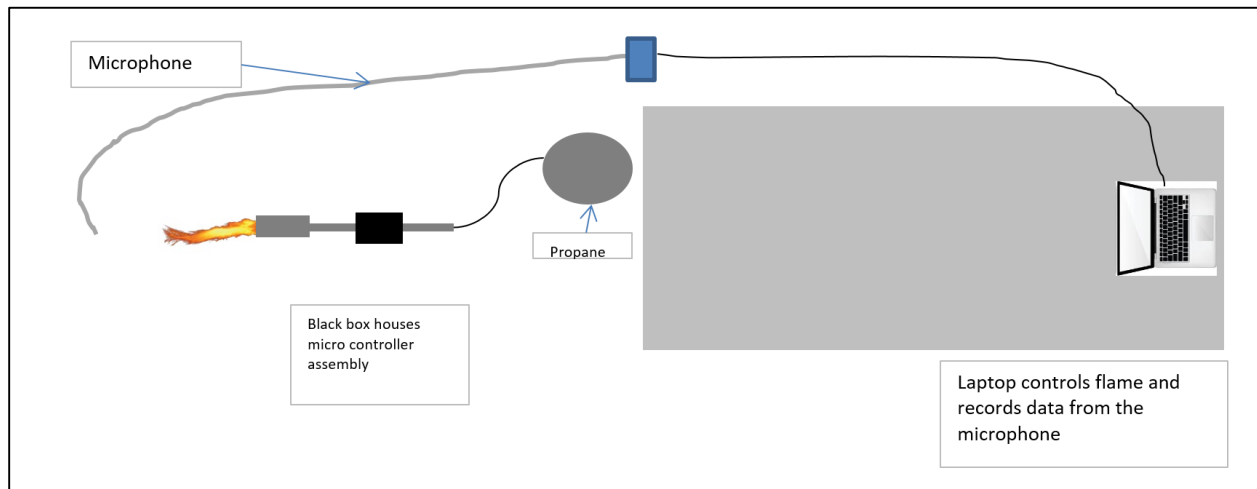


Figure 14: Testing schematic

2.5.2 Results

Figures 15-19 show the results for each test. The black line represents the frequency at which we were testing.

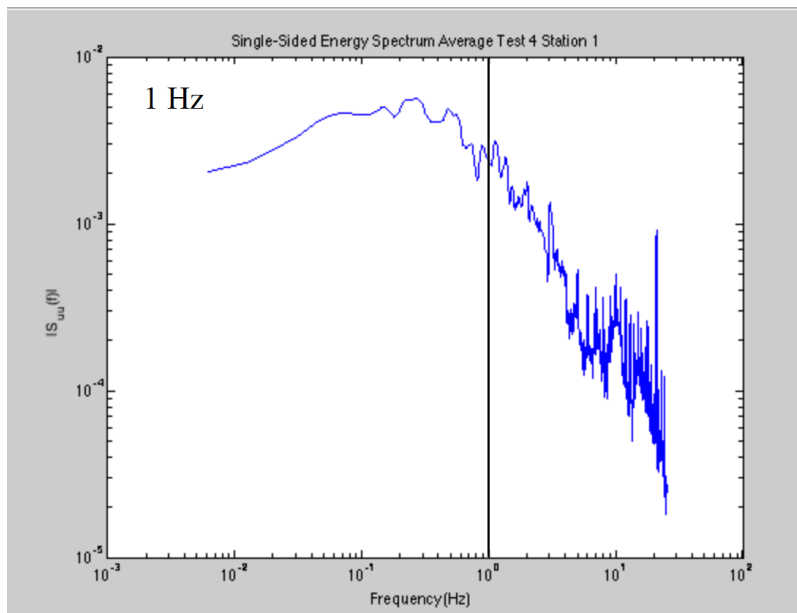


Figure 15: Frequency spectrum for 1 Hz test

For 1 Hz, there is not spike on the frequency spectrum at the 1 Hz mark. This means the microphone was unable to detect the propane torch pulsing. The spike is most likely not seen due to the high amount of noise in the surrounding area while the frequency is so low. A lower frequency is harder to make louder, so it is likely that the torch did not produce a strong enough signal at 1 Hz.

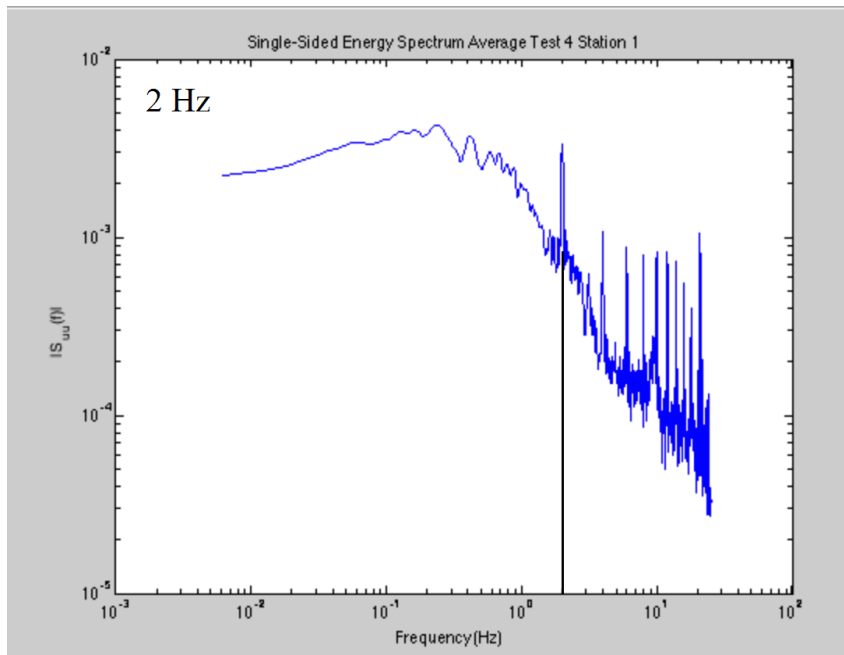


Figure 16: Frequency spectrum for 2 Hz test

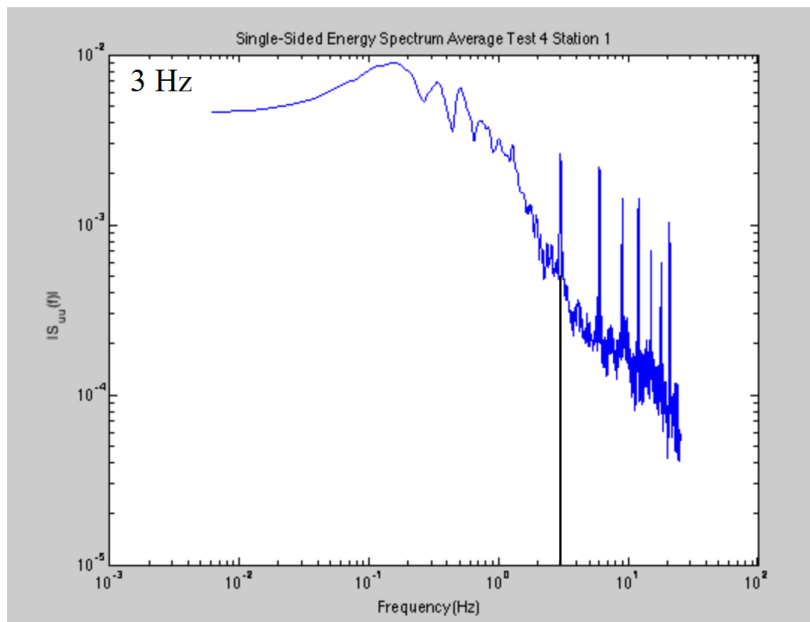


Figure 17: Frequency spectrum for 3 Hz test

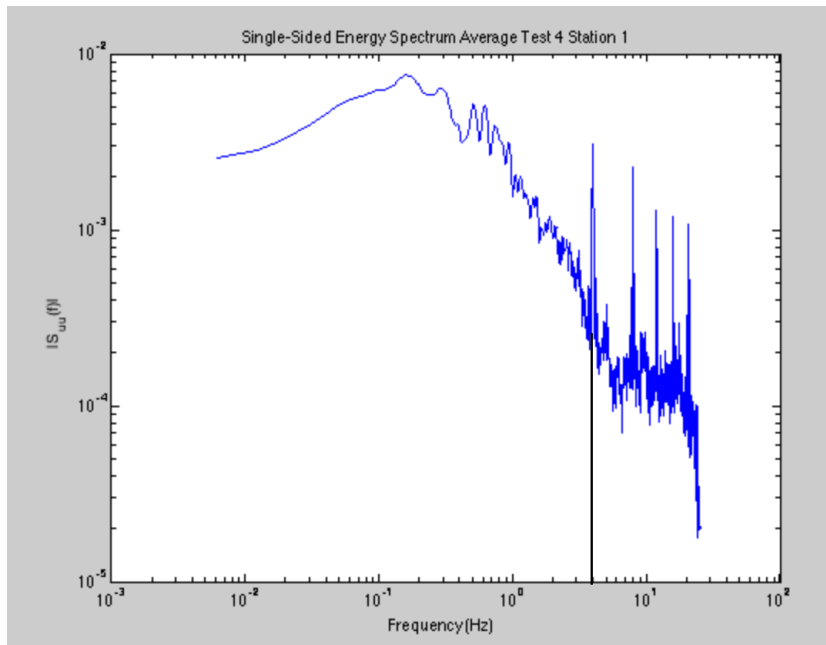


Figure 18: Frequency spectrum for 4 Hz test

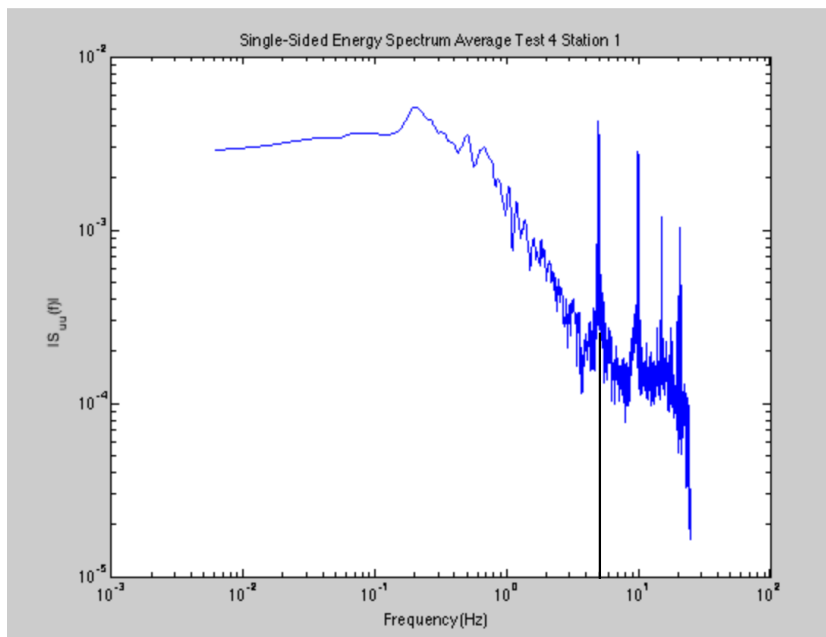


Figure 19: Frequency spectrum for 5 Hz test

The results for 2 through 5 Hz follow exactly what is expected for infrasonic sources. The first large spike occurs at the frequency tested, followed by harmonic spikes. These harmonics occur at intervals equal to the frequency tested. These results confirm that the microphone is picking up the propane torch signal, and the torch is pulsing at the desired frequency. Since the results match what is expected, it can be concluded that the propane torch is acting as proper infrasonic source.

3 FINAL DESIGN

3.1 EVALUATION OF FINAL DESIGN

Infrasonic noise is any sound between 0 and 20 Hz. As mentioned earlier in the paper, our goal is to be able to produce infrasonic noise between 0.5 and 5 Hz. From the testing section above, we can see that five tests were conducted 1,2,3,4 and 5 Hz. Results for all tests other than 1 hertz confirmed correct infrasonic noise being emitted. This gives us a viable operating range of 2 to 5Hz. It is hypothesized that the bad data for 1 Hz is due to the noise seen in the test results, or the inability for us to produce a long enough flame. The reason our design was not able to produce a large enough flame at frequencies of 1 Hz and below is due to an issue with the solenoid valve. When the valve is actuating at lower frequencies, the valve stays shut longer in between openings. The extended close time at lower frequencies allows for a greater pressure build up on the upstream side of the solenoid valve and the downstream side of the main line needle valve. When the solenoid valve sees a high enough differential pressure across its diaphragm, the solenoid valve will struggle to actuate. Because of this problem, the main line needle valve opening has to be reduced more and more the longer the valve is shut in between openings to ensure full actuation. The reduction of the needle valve opening leads to smaller flame sizes, thus explaining the current designs inability to produce a large enough flame at lower frequencies. While tests were not performed at frequencies higher than 5 Hz, it is hypothesized that the torch will be able to function and produce reliable data up to 10 Hz; however, this is only hypothesized and more tests need to be conducted to confirm.

3.2 FINAL MICRO-CONTROLLER DESIGN.

3.2.1 Coding the microcontroller

The Codes to operate that the Arduino runs on are given in the information file. Essentially, there is a loop that constantly runs looking for data in the serial monitor, if the data sent is larger than 0, it will start actuating the valve at that frequency and then print the frequency that the valve is operating at in the serial monitor. If the value sent is a 0, this calls another function that will shut off the valve and then begin looking for incoming data again.

3.2.2 Assembling the microcontroller system

The entire circuitry to the system has been soldered to a permanent bread board. On this bread board, there are 3 resistors that make up a voltage divider for the TX to RX line. This voltage divider is needed because the TX and RX pins on the HC-05 Bluetooth module can only operate at 3.3 VDC. All three of the resistors are 100 kohm resistors that feed to the ground that is given from the Arduino. The transistor shares its ground pin with the voltage divider and solenoid valve. The jumper cable from pin 8 is soldered in place to give a 5 volt signal to the transistor so that the 24VDC power supply can begin to drain into the solenoid valve wires. The power diode helps relieve some of the residual power and current that would otherwise be loading the transistor. The circuit that is soldered in place is shown in Figure 20.

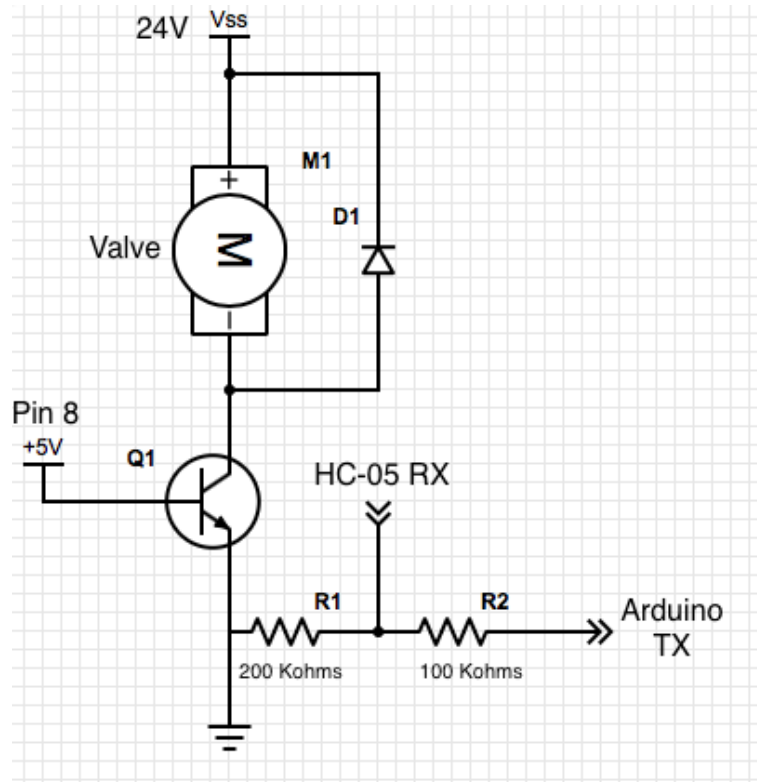


Figure 20: Circuit soldered to circuit board.

3.3 IMPROVEMENTS AND FUTURE WORK

3.3.1 Micro-Controller Improvements

While the system works and works well, there are still many areas of improvement. Attaching a proximity sensor at the end of the torch to create an emergency shut off system could be beneficial at lowering the safety risks attached to this research.

Another improvement that can and should be made is the sources of power for the microcontroller system. Currently, there are two sources of power, one 5 volt source powering the Arduino and Bluetooth, and one 24 Volt source powering the solenoid valve. The 24 volt source is created by attaching three 9 volt batteries in series and attaching a resistor to achieve 24 volts. In order to improve this system, it would be more efficient to have one single power source that powers both the solenoid valve and the micro-controller. This single power source would then only require one switch to turn on the torch valve assembly instead of two.

The last and final suggestion for an improvement would to implement a photo diode to help quantify the length of the flame that is being emitted from the torch. Currently, the torch has a hard time keeping the same length of flame at various frequencies, using a photo diode could help rectify that error and create more stable, reliable data.

3.3.2 Testing Improvements

One major improvement of testing would be to control access to the room in which testing is taking place. Loud noises, such as doors, can be picked up by the microphone and cause problems with the data. Another improvement would be to place the torch on a table, rather than hold it. Sudden changes in movement can also interfere with the data and cause undesired results.

3.3.3 Torch Improvements

As mentioned in 3.3.1, the torch functions as desired from ranges of 2 to 5 Hz, but fails to produce a large enough flame at frequencies less than 2 Hz to produce reliable data. To combat the issue with the larger differential pressure across the solenoid diaphragm at lower frequencies, it is suggested that a pressure regulator be placed upstream of the solenoid valve. The pressure regulator will be adjusted to achieve the maximum operable differential pressure across the solenoid valve to ensure actuation and maximum possible flame lengths at all frequencies of operation.

4 BUDGET AND TIMELINE

4.1 UPDATED BUDGET

Item	Quantity	Cost
Honeywell pilot burner	1	\$23.71
Piezo electric ignition	1	\$11.41
Red Dragon torch kit	1	\$47.39
Stainless Steel Solenoid Valve 1/4" npt	1	\$119.40
Stainless Steel Tubing 1/4" 3 foot	1	\$11.70
1/4" npt wye fitting	1	\$25.49
1/4" brass hex nipple	3	\$6.90
1/4" Compression to threaded fitting	1	\$11.66
1/4" needle valve brass	1	\$32.63
Shipping Cost		\$5.00
Total Cost		\$295.29

Table 1: Initial budget

4.2 MICROCONTROLLER BUDGET

Part	Cost
Resistors	\$8.99
Power Diode	\$1.55
Jumper Wire	\$6.87
Bread Board	\$3.38
Transistor	\$3.54
Arduino Uno	\$9.99
24v power supply	\$7.92
HC-05 Bluetooth Module	\$6.99
Serial to USB port drive	\$8.00
Mobile Power Bank	\$7.99
A to B USB cable	\$3.95
Total Cost	\$69.17

Table 2: Microcontroller budget

4.3 FINAL PROGRESS REPORT

Our team put in more time to the project after the final presentation. This section serves as our final progress report, covering April 20th-May 4th.

The team's test session revealed that the torch is functioning as expected. We had to go back to test a second time because the first time the proximity sensor was not functioning properly. The only issue is the pressure drop across the solenoid valve which we do not have time to fix. The recommendation is to install a pressure regulator to alleviate this problem. Much of the time spent by the team was troubleshooting the sensor and pressure issues.

Dr. Elbing was very pleased with our work and presentation. We will be showing him and Arnesha how to operate the torch this week.

The final report has been finished along with the log books.

4.3.1 Jacob Bertrand Completed Hours

Time for two weeks: **60 Hours**

Total: 160 Hours

4.3.2 Madison Likins Completed Hours

Time for two weeks: **70 Hours**

Total: 142 Hours

4.3.3 Maxwell Niemeyer Completed Hours

Time for two weeks: **60 Hours**

Total hours: 160

4.3.4 Jacob Nichols Completed Hours

Time for two weeks: **60 Hours**

Total: 162 hours

5 APPENDIX

$$Tx = Rx \frac{R2}{R1 + R2}$$

$$HC05 Tx = 3.3 \text{ volts} = 5 \frac{200}{100 + 200}$$

Equation 1: Voltage divider

6 REFERENCES

[1] Wurman, J, D Dowell, Y Richardson, P Markowski, E Rasmussen, D Burgess, L Wicker & HB Bluestein (2012) "The second verification of the origins of rotation in tornadoes experiment: VORTEX2," *Bulletin of the American Meteorological Society*, **93**(8), 1147-1170.

[2] Clarke Extended Propane Gas Roofing Roof Roofers Plumbers Torch, photograph, viewed 31 January 2016, http://ecx.images-amazon.com/images/I/41xnt0Jk0tL._SY300_.jpg

[3] <http://www.rotarywoofer.com/trw17pricing.html>

