Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú

UNIVERSITAT POLITÈCNICA DE CATALUNYA

EPS - PROJECT

TITLE:

THE AUTONOMOUS ACOUSTIC BUOY

STUDENTS:
DANIEL BENITO
UBEYDULLAH ISIK
SCOTT NELSON
STEFAN SCHARNER
KAMILA WOJCIECHOWSKA
PRISCILLA WOLF

SUPERVISORS: JOAN.V CASTELL, MICHEL ANDRÉ AND JORDI SEGALAS.

DATE: 12/06/09

TITLE: THE AUTONOMOUS ACOUSTIC BOUY

FAMILY NAME: BENITO **FIRST NAME: DANIEL**

HOME UNIVERSITY: TECHNICAL UNIVERSITY OF CATALONIA (EPSEVG)

SPECIALITY: ELECTRONICS ENGINEERING

FAMILY NAME: ISIK **FIRST NAME: UBEYDULLAH**

HOME UNIVERSITY: DUMLUPINAR UNIVERSITY

SPECIALITY: CERAMICS ENGINEERING

FAMILY NAME: NELSON **FIRST NAME: SCOTT**

HOME UNIVERSITY: SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

SPECIALITY: ELECTRICAL ENGINEERING

FAMILY NAME: SCHARNER **FIRST NAME: STEFAN**

HOME UNIVERSITY: UNIVERSITY OF APPLIED SCIENCE OLDENBURG/OSTFRIESLAND/WILHELMSHAVEN

SPECIALITY: MECHANICAL ENGINEERING

FAMILY NAME: WOJCIECHOWSKA **FIRST NAME: KAMILA**

HOME UNIVERSITY: TECHNICAL UNIVERSITY OF LODZ

SPECIALITY: COMPUTER SCIENCE

FAMILY NAME: WOLF **FIRST NAME: PRISCILLA**

HOME UNIVERSITY: THE HAGUE UNIVERSITY OF APPLIED SCIENCE

SPECIALITY: INTERNATIONAL MARKETING

Abstract

The purpose of this project is to design an Autonomous Acoustic Buoy (AAB) for the Laboratori d'Aplicacions Bioacústiques (LAB) and the Universitat Politècnica de Catalunya (UPC). The project is composed of five sub-projects: the Marketing Project, the Mechanical Design Project, the Electronics Project, the Computer Science Project, and the Wireless Communication and Power Supply Project. The Marketing Project created a leaflet for the AAB. The Mechanical Design Project has modelled the buoy using a computer aided design program. The Electronic Project has designed a programmable filtering circuit. The Computer Science Project has developed software for a single board computer called: the Hercules Board. The Wireless Communication and Power Supply Project has examined wireless communication and power supply solutions. All of the work done for the AAB Project is presented in this report and is addressed to both the LAB and the UPC.

Key words: Autonomous, Acoustic, Buoy, CAD, Wireless Communication, Filter and Leaflet

Contents

1 ABB Project Introduction

1 AAB Project Introduction

Due to the need to measure and control the correlation between human activity and presence of marine mammals in the marine environment the Autonomous Acoustic Buoy (AAB) is being developed. The task of the AAB is to record and sample acoustic signals from the marine environment and to deliver them to a research centre were they can be analyzed.

The project was started by previous European Project Semester students. This year the objectives of the project are to build upon and improve the already existing components.

The team working on the project consists of students coming from different countries and having different fields of study. Tasks were delegated to each student based on each student's academic backgrounds. These tasks along with the students working on each are shown below:

Marketing Project

Priscilla Wolf (International Marketing)

- Develop the marketing leaflet as a marketing tool for the buoy.

Mechanics Design Project

Stefan Scharner (Mechanical Engineering)

- Draw the computer aided design and simulate the behaviour of the buoy in a marine environment.

Electronics Project
Daniel Benito (Electronics Engineering) **and Scott Nelson** (Electrical Engineering)

- Design, simulate and manufacture a new circuit board with a programmable gain and cut-off frequency.

Computer Science Project

Kamila Wojciechowska (Computer Science)

- Provide software that will support the newly introduced functionalities.

Power Supply and Wireless Communications Project

Ubeydullah Isik (Ceramics Engineering)

- Verify the possibility to use wireless communication.
- Verify existing power supply solutions.

2 Marketing

2 Marketing

2.1 Goals and Aims of the Marketing Project

The Laboratori d'Aplicacions Bioacústiques (LAB) desires to sell the technique of the AAB to other companies. The LAB wants to market the AAB to the windmill, shipping, offshore oil/gas exploration and production industries. The goals of this project have been changed from the originals goals. The original goals where the following:

- Collect and maintain the project documentation
- Write a marketing plan for the AAB

The first goal still stands but the second goal does not. This change is because some restrictions whit contacting other organizations existed and therefore the ability to execute a good marketing research plan was not possible. Without marketing research , a marketing plan would be based on insufficient information and therefore is not useful. For these reasons new objectives were set.

The new goal is to develop a leaflet. This leaflet will be eventually used as a tool to market the technique of the AAB into the offshore windmill, shipping, military and offshore oil/gas exploration and production industry. To successfully develop the leaflet different steps were taken. These steps all have their own goals and aims. The different steps on the development of the leaflet are described below.

2.1.1 Understanding the Purpose of the AAB

To be able to create a leaflet, the main subject must be clear. This need creates the need to understand what exactly the AAB is and what exactly the AAB does.

2.1.2 Understanding the Characteristics and Goals of the Laboratori d'Aplicacions Bioacústiques

The second step is to understand the characteristics and goals of the LAB. This goal is set up to get an impression on what kind of organization the LAB is and how they work. Understanding the vision, mission, objectives and background of the LAB is necessary. These impressions are important to take in account while creating the leaflet.

2.1.3 Understanding How Bioacoustics Work

The next step is to understand how bioacoustics work. Knowing the background of the subject is very important while developing a leaflet. This knowledge makes creating a text which is accurate easier.

2.1.4 Understanding Noise Pollution Produced by the Windmill, Shipping, Military, Offshore Oil/Gas Exploration and Production Industries

This step is important because the effects of noise pollution made by these industries are the selling points of the leaflet. By fully understanding these effects, a better and unique selling point is created.

2.1.5 Understanding How the AAB Can Benefit the Windmill, Shipping, Military, Offshore Oil/Gas Exploration and Production Industries

The next step in this research is to understand how the AAB can benefit these above described industries. If the benefit is not clear, a good persuasive text cannot be written.

2.1.6 Understanding How to Work with Adobe Photoshop

Working with a professional program which is designed to modify images is necessary to create nice images for the leaflet. The most popular program for this need is Adobe Photoshop. Learning how to work with Adobe Photoshop is needed to be able to modify images.

2.1.7 Understanding How to Work with Adobe Indesign

Adobe Indesign is a program the can be used to design leaflets. Learning how to use this professional program is needed to be able to design a good leaflet. When using this program the leaflet will look nice and professional.

2.2 Method

The set goals and the methods to accomplish these goals are all different. In this section of the report, the different methods are described for each goal.

2.2.1 Understanding the Purpose of the AAB

To fully understand what the AAB is, a meeting was held among the group members and the staff of the LAB. Each person with his or her specialty explained how the different parts of the buoy functions. The second step was to understand what the purpose of the AAB is. The purpose of the buoy was also researched on the Sons de Mar website.

2.2.2 Understanding the Characteristics and Goals of the Laboratori d'Aplicacions Bioacústiques

To get the needed information, a meeting with the director, Michel André, was held. Also the Sons de Mar website was used to gain more information about the characteristics and goals of the LAB.

2.2.3 Understanding How Bioacoustics Work

To fulfil this goal, research on the internet was conducted.

2.2.4 Understanding Noise Pollution Produced by the Windmill, Shipping, Military, Offshore Oil/Gas Exploration and Production Industries

For this goal, research on the internet was also conducted.

2.2.5 Understanding How the AAB can Benefit the Windmill, Military, Shipping, Offshore Oil/Gas Exploration and Production Industries

Internet research was done to fulfil this goal. Also a meeting with Michel André was held to discuss how the AAB can benefit these industries.

2.2.6 Understanding How to Work with Adobe Photoshop

To be able to work with Photoshop, first Photoshop was downloaded and installed. Next, a few tutorials where completed to get more familiar with the program.

2.2.7 Understanding How to Work with Adobe Indesign

To be able to work with Adobe Indesign, the program was first downloaded and installed. Next, a few tutorials where completed to get more familiar with the program.

2.3 Results

During the development of the leaflet much research was done. This research brought produced a large amount of information. The results of the different parts of the research are described separately.

2.3.1 The Autonomous Acoustic Buoy

The research on the purpose of the AAB showed that the AAB is a buoy that receives sounds from Cetaceans. This sound is received with a hydrophone. The hydrophone is a microphone which will pick up acoustic energy underwater. The hydrophone will not only pick up the sounds from the Cetaceans, but also sounds from other animals and activities in sea. However the sounds from the Cetaceans are the only sound of interest. Therefore the received sounds need to be filtered and amplified. This filtering and amplifying of the signal is done by the Programmable Filtering Circuit (PFC). After passing through the PFC, the signals are sent to the Hercules Board to be sampled.

The Hercules Board is a computer which is also installed in the AAB. The Hercules Board controls the gain and cut-off frequencies of the Programmable Filtering Circuit. Furthermore the Hercules Board will sample and send the recorded signals to a nearby by computer using a wireless internet connection. These received signals can now be received and studied. **¡Error! No se encuentra el origen de la referencia.** shows the basic block diagram of the AAB [1].

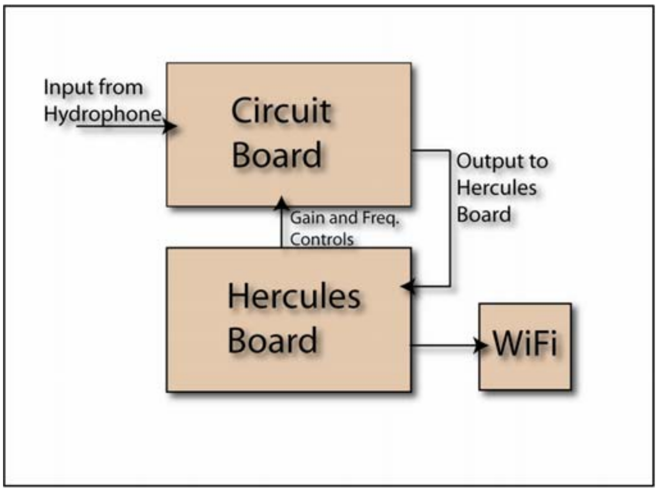

Figure 1 Basic Block Diagram of the AAB

2.3.2 The Purpose of the Autonomous Acoustic Buoy

The AAB is designed to study the effects of unnatural acoustics in the marine environment. These manmade or anthropogenic noises are made by shipping, offshore oil/gas exploration and production, industrial and military sonar, experimental acoustic sources, underwater explosives, other underwater civil engineering activities, airborne noise and windmill parks in the sea. These anthropogenic noises have increased in the last hundred years and now are at the highest levels ever experienced during the ten million years of modern order Cetacean evolution. Cetaceans use acoustic signals to communicate with each other. Cetaceans cannot catch up with these noise changes made by humans and are not able to develop their auditory apparatus for the loud sounds. Cetaceans are the bio-indicators of the acoustic balance in the oceans. The Cetaceans use acoustic signals to communicate where food sources are, to warn each other, to maintain the group and also to orientate, so naturally their ability to communicate with each other is important. Anthropogenic noises cause irregularities in the natural marine environment and may cause disorientation, stress, behaviour changes, infertility, internal bleeding and even death in Cetaceans. The LAB believes that, by researching and understanding how the Cetaceans communicate and live, the LAB can develop sustainable solutions for the human activities in the marine environment. This research can be done with the help AAB project. The AAB can receive, filter, sample and send acoustic signals. These signals can be used for research. The LAB can investigate how the anthropogenic sounds affect the Cetaceans. When the LAB fully understands these effects, they will research sustainable solutions for the human activities in the marine environment [1, 2].

2.3.3 The Laboratori d'Aplicacions Bioacústiques

The LAB (see Figure 2) is the mastermind behind the AAB project. The LAB was established in 1997 by Michel André. At that time the LAB was located on the Canary Islands. The LAB started out as a research group to study the impacts of acoustic pollution from human activities. In the year 2003 the Spanish Ministry of science gave the LAB the opportunity to work together with the Universitat Politècnica de Catalunya (UPC). The LAB took this opportunity and moved to Vilanova I La Geltrú in 2003. At that time the LAB became more of a laboratory instead of a research group. With the cooperation of the UPC and the Centre Tecnològic de Vilanova I La Geltrú (CTVG), the LAB started the Sons de Mar. Sons de Mar is an interface aimed at the promotion of research. The defining and controlling the impact of acoustic pollution, without impeding on the advances of human activities, constitutes a scientific challenge and carries an important responsibility to society. This is the challenge that the LAB has been faced with in its research for the last 12 years. The LAB holds a multi-disciplinary approach where the mathematical and physical sciences converge with biology and biotechnological engineering, with the objective of integrating models that describe the natural physiological processes of sound production and reception, as well as the development of passive technologies that allow the exploration of the sea without introducing noise pollution. [1,2,3].

Figure 2 LAB Logo

2.3.3.1 Vision

The vision of the LAB is as followed: In the future there will be no noise pollution in the marine environment. [1].

2.3.3.2 Mission

The mission of the LAB is to develop solutions for any kind of noise pollution. [1].

2.3.3.3 Objective

The objective of the LAB is as followed: To understand the impact of sounds in marine environments and to create solutions for noise pollution. [1].

2.3.3.4 Culture

The culture of the LAB is a mixture between the personal culture and the task culture.
This mixture means that the aim stands first. Authority finds its origin in expertise and knowledge. Within the task culture, action can rapidly be taken and with space for improvisation. Rules and processes that hinder the work are not welcome. Furthermore the social aspects are very important. A large amount of attention is given to the develop talents and ideas. The atmosphere present is that the company is for the people, and not the other way around. People work for the LAB because they care about the LAB and they feel that they can really make a difference. [1,2,3].

2.3.3.5 Structure

The culture of the LAB is very open and friendly. This culture also shows in the structure of the LAB. Michel André is the director and the overall boss. Other researchers work under and with him. These researchers have different degrees and specialties. Many of the employees are even students. Nevertheless, all these people work together without any kind of a hierarchy. According to Michel André, everybody is equal on the work floor. This equality makes for a nice and friendly work environment in which great ideas can be developed. [1,2,3].

2.3.3.6 Funding

Research requires not only a lot of time, but also a lot of money. The LAB receives money from different parties. First of all, the LAB gets money from its clients for whom it does research for. Also the LAB gets funding from the Spanish Ministry of Science. Furthermore the LAB gets money from private funding. This makes the LAB especially different from other laboratories because the LAB does not have to rely on funding from big clients, which makes its research and outcomes completely independent [1,2,3].

2.3.4 Bioacoustics

During the research on how bioacoustics work, the following results where found on the characteristics and differences between bioacoustics under and above water.

2.3.4.1 Characteristics of Bioacoustics

Bioacoustics are mechanical energy. To be more precise, bioacoustics are vibrations that move by causing pressure differences. However, though the ocean is almost impenetrable by light, the ocean is almost transparent for sounds. In the oceans many natural sounds like; wind, waves, rain and sounds of animal activities exist. However, unnatural sounds which made by humans exist. These sounds are called anthropogenic sounds. A few examples in which anthropogenic sounds are produced in the oceans are; shipping, sonar and windmills. All of these sounds, both anthropogenic and natural exist in the form of sound waves. Every sound wave is different in form, length, intensity and pitch. Each of the characteristics has effects on how far the sound can travel. The lower the pitch is, the further the sound can travel. [3,4,5]

2.3.4.2 Differences Between Underwater and Above Water Bioacoustics r

Sound properties underwater are totally different than the ones above water. Sound above water can travel 340 meters per second. Sounds underwater can travel 4.5 times further per second than sounds above water. On average sounds underwater cover a distance of 1500 meters per second. The speeds of the sound depends on the following characteristic of the water; depth, temperature and salt value. The intensity of sounds underwater is also different from the ones above water. The intensity of sound is measured in decibels (dB). The dB scale is logarithmic and describes with a relative number the pressure differences which sound waves produce. To have a comparable number of the intensities of sound underwater, one can reduce the number of dBs measured above water by 62 dB. Still the intensity of these two sounds is difficult to compare because the hearing mechanism of animals underwater and above are hugely different. [3,4,5]

2.3.4.3 Different Types of Sounds

Acoustic sources can be divided into two groups. The first group is continues sounds. An example of such acoustics is sounds produced by windmill parks. The second group consists out of short signals. An example short acoustic signals is sounds produced by explosions. Along with continuous and short sounds, background sounds exist. Back ground sounds are a product of all the acoustic signals together.[3,4,5]

Furthermore, acoustic signals sources in the marine environment can be divided into natural and unnatural. Natural acoustic signals are produced by physical and biological processes. A few examples of these natural signals are; wind, rain and communication sounds between marine mammals and fish. The unnatural sounds in the marine environment are linked to the activities made by humans. An example of an unnatural sound source is shipping. [3,4,5]

2.3.4.4 Acoustic Signals Used by Marine Mammals

The circumstances of the marine environment make situations that are hard for marine mammals to see in. These circumstances are because sunlight does not reach very deep and also the mod and plankton create a difficult seeing environment. Due to the fact that low visibility exists in deep waters, hearing is the most important sense of the marine mammals. The mammals use their hearing for many purposes such as navigation, communication and the search of food. [3,4,5]

2.3.5 Understanding Noise Pollution Produced by the Windmill, Shipping, Military, Offshore Oil/Gas Exploration and Production Industries

During the research of understanding noise pollution produced by the windmill, shipping, military, offshore oil/gas exploration and production industries the following results were found. The anthropogenic sounds made by these above described industries can have many negative effects on the marine mammals. All these anthropogenic sounds have a different effect on the marine environment depending on the source, the frequency, the duration, of the sound and the natural conditions at that time.

The continuous anthropogenic noises can cause habitat exclusion to the marine mammals. These continuous acoustic signals however will probably not cause any hearing damage, because the sounds can be heard at a large distance and because the marine mammals can keep at a great distance from the sound. The short anthropogenic noises are even worse than the continuous noises. These short noises are unexpected and so marine mammals can not stay at a safe distance to protect their hearing. Unexpected noises can therefore cause internal bleeding in the hearing organs. These internal bleedings can cause the mammals to become disorientated, to go ashore or to even die.

Both the short and the continuous acoustic signals can cause communication problems for the marine mammals. Hierarchy can become less clear and therefore fights between male mammals occur more often. All this fighting causes male mammals to expel too much energy and they no longer have the energy to reproduce. Also the noise pollution can cause communication problems between the calf and the mother. The calf can lose his or her mother and die because the calf needs the mother to survive the first for couple of years of his or her life. Furthermore groups can fall apart because of the communication problems caused by the noise pollution. This problem is a serious problem for warning and hunting activities. Also the noise pollution can cause stress. This stress can then manifest itself by causing infertility and infection diseases. [3,4,5,6,7,8,9]

2.3.5.1 Windmill Parks

The construction of windmill parks increases the shipping problems. Also the piling of foundation is associated with very high noise levels. The sound of the pile is short, but because piling takes along time, the sound will be for a period of time continuous. This will lead to habitat exclusion. An active windmill park produces approximately a 150 dB noise level. Also an active windmill park produces a continuous sound which causes possible habitat exclusion. [3,4,5,6,7,8,9]

2.3.5.2 Shipping

Shipping causes the most noise pollution to the marine environment. The noises are produced by the motor, sonar systems, depth sounders, etc. Most ships produce noise under the 1 kHz range. The exact range depends on how big and how old the ship is. The bigger and the older the ship is, the more noise it will produce. The sounds made by ships are continuous and so the mammals will avoid the shipping lane areas. The problem is that ships are not only in the busy shipping lanes, but they are practically everywhere in the marine environment. The exact numbers of dB levels produced by every military activity can be found in Appendix 1: *The different sound sources with their frequency*. [3,4,5,6,7,8,9]

2.3.5.3 Military

Noise pollution made by the military industry comes from three main sources which are: shipping, sonar and explosions. Also shipping can be divided into two parts: above water and underwater. The ships above water produce the same amount of noise as is described in the “shipping” section of the report. The underwater ships are submarines. The submarines are normally very quite but they produce sonar that sends short and loud signals. The fact that these signals are short and therefore unexpected can cause hearing damage in the marine mammals. The explosions which the military industry makes are also short and unexpected. These explosions can also cause hearing problems. The exact numbers of dB levels produced by every military activity can be found in Appendix 1: *The different sound sources with their frequency*. [3,4,5,6,7,8,9]

2.3.5.4 Offshore Oil/Gas Exploration

The construction of offshore oil/gas platforms increases the shipping problems. Also the piling the foundation is associated with very high noise levels. The sound of the pile is short, but because piling takes a long time, the sound will be for a period of time continuous. These sounds will lead to habitat exclusion. Also when searching for gas/oil, signals with a high frequency and high intensity are sent to the surface. These signals are sent every 6-20 seconds to certain routes. This research on where the oil/gas is can take months and is therefore continuous. This research can cause temporary habitat exclusion [3,4,5,6,7,8,9].

2.3.6 Understanding How the AAB Can Benefit the Windmill, Military, Shipping, Offshore Oil/Gas Exploration and Production Industries

Understanding the link between natural and anthropogenic processes is essential for predicting the magnitude and impact of future changes of the natural balance of the oceans. The recent introduction of anthropogenic sound sources has increased the overall noise budget of the oceans that is now experiencing the highest levels of the history of the Earth. These levels are threatening the natural balance of the seas and their continuous presence is not yet regulated. Because they almost exclusively rely on sounds for living, Cetaceans represent the bio-indicators of the acoustic degradation of the oceans. By understanding how Cetaceans perceive their environment, technological developments can be implemented to favor sustainable human marine activities. The outcome therefore can benefit the windmill, military, shipping, offshore oil/gas exploration and production industries in the future. Sustainable solutions will not only be good for the environment, but also for the reputation of these industries [1,2].

2.3.7 Understanding How to Work with Adobe Photoshop

Adobe Photoshop is now well known and can be used to edit images.

2.3.8 Understanding How to Work with Adobe Indesign

Adobe Indesign is now well known and can be used to create leaflets.

2.3.9 The Leaflet

The result of all the research done during the EPS, is a leaflet. The leaflet can be found in appendix 2: *The Leaflet*. The design was matched to the leaflet in which the LAB already has. Also the colour used is matched to the logo. The different shades of blue along with the water ripples give the feeling of the marine environment. The images of wavy lines represent the acoustic signals received by the AAB. Furthermore the image of the AAB Buoy is shown. Due to the limitations of time, a picture of the AAB in a marine environment was not taken. This picture will be taken later and added to the leaflet.

The text of the leaflet is set up to persuade organizations in the windmill, military, shipping, offshore oil/gas exploration and production industries to buy the AAB. First the introduction describes the need of knowing what the effects of human activities in the marine environment are. After that, the AAB is described as a solution in the research to develop sustainable solutions for the human activities in marine environments. This description is followed by an explanation of what the AAB is. Then the text stresses how the outcome of the research done by the AAB can be interesting for the windmill, military, shipping, offshore oil/gas exploration and production industries. To end the text, readers are invited to contact the LAB.

2.4 Conclusion and Recommendations

The purpose of the AAB is now known. Also the technique of the AAB is now described in an more easy manner. This description was written so everyone, even someone without any technical background can understand how the AAB works. Furthermore the company behind the idea of the AAB is fully explained. Moreover the knowledge about how acoustic signals work was obtained. Furthermore how noise pollution is made by the windmill, shipping, offshore oil/gas exploration and production industries and the possible effects of these industries on the marine environment is clear. Also Adobe Photoshop and Adobe Indesign were learned. These obtained skills were then applied to design the leaflet. At this moment only a picture of the AAB in a marine environment needs to be at to the leaflet. Also a market research on how the AAB can benefit the windmill, military, shipping, offshore oil/gas exploration and production industries is recommended. Furthermore a good marketing can then be written, to market the AAB in the best way.

3 Mechanical Design Project

3 Mechanical Design Project

3.1 Statement of Mechanical Design Objective

The objective of the mechanical design project was to redraw an already existing buoy and to calculate the behaviour of the buoy with Computer Aided Design (CAD).

3.2 Software Research

In the beginning, the software needed for drawing and simulating the buoy was not clear so the software package that best suits the job was researched. Once a program was chosen the team members needed to learn how to use the software.

An opportunity arose to use free software or proprietary CAD software. After checking the different available free software packages and their abilities to draw the buoy and calculate the behaviours of the buoy, the decision fell to proprietary CAD software.

The main reasons for this decision are that this software is available at the UPC and also support for the understanding of this type of software is available from students and professors. On the other hand, the free software packages are not able to interact with programs used for simulating forces relating to towing the buoy and thus cannot complete the task. Also personal support for this free software is not available.

A final decision was made that SolidWorks is the software package that best suits the tasks that need to be completed. SolidWorks is a program that has a reputation for being an easy use when compared to other CAD software.

3.3 Changes in the Team

The task was originally designed for two persons. During the first month the second team member realized that the task was beyond his abilities. So after five weeks he decided to change the team sand to work with the Power Supply and Wireless Communication Project on the 20th of April. Waiting for him to solve the task together led to a delay. Having only one team member doing a task designed for two persons vastly lowered the work efficiency.

3.4 Working in SolidWorks

To get familiar with the program, the first SolidWorks tutorials were completed. These tutorials are designed to show the main function and most common tools for CAD drawings. The result of the first tutorial is a pressure plate, as shown in Figure 3.

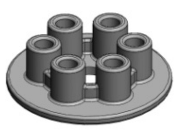

Figure 3 Pressuere Plate from SolidWorks Tutorial

Afterwards single parts of the buoy were drawn such as the top plate, back plate, shaft with rips, and mast. Additional help was needed to further the drawings. This help came from Joaquim Perramon Saura, a student who is very familiar with SolidWorks. He explained how to use different planes.

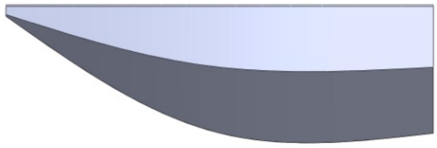

Figure 4 First Sketch with Shape Similar to the Buoy

This help led to the ability to draw a shape similar to the buoy as presented in Figure 4. The model consisted of three planes, front, middle and back plane. The middle and back plane have the same measurements. The front plane has a 12cm x 12cm cross section and the backplane has a maximal horizontal cross section of 115cm and a maximal vertical cross section of 72cm. Unfortunately this shape did not fit the exact shape of the buoy. This shape caused problems in the following steps. To overcome these problems support from a professor was needed. Although this professor is not familiar with SolidWorks, he gave some advice about construction principles and helped with the understanding in how CAD software works and interprets sketches.

Figure 5 shows the next stage of the buoy drawings. Now the buoy consists of five planes: one with the measurements of the front plane, three with the measurements of the back plan and one with a measurement between the back and front plane. The third back plane is placed in the middle between back and mid plane. The plane between the front and mid plane is placed to ensure that SolidWorks interprets the lines that connect the planes and build the surface correctly. In this stage the main extensions to the buoy were added too. Therefore the help of Saura was needed again in order to know how the extensions are fixed to the buoy body [1].

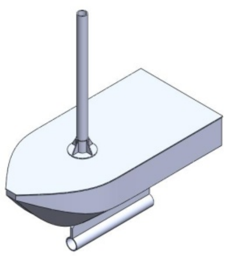

Figure 5 Sketch of the Buoy with First Extensions

After drawing the buoy with the mast and counterweight, a need arose to redraw the buoy from the very beginning.

To draw the buoy precisely, exact measures of each part from the buoy had to be taken. While drawing the buoy with precise measurements, several problems appeared.

Two main problems existed. The first problem was that the sketches of fixed extensions, (the attachments for the towing and the rips at the mast shaft), could not be converted from two-dimensional (2D) objects to three-dimensional (3D) objects. The second problem was occurred when drawing an extension which is not perpendicular or parallel to the main model. The first problem is caused because the attachments are drawn on another model. While making the sketches to 3D objects, intersections prevented the 2D sketches from becoming 3D objects. The rip tool is a special tool for these problems that SolidWorks has for this problem. This tool does not work very well and it became a problem because sometimes it worked and sometimes it did not. The solution came from Alejandro Arabas, a student at the Centre Tecnologic Vilanova i la Geltru, while solving the second problem. The sketches which were not perpendicular or parallel had to be 3D also. He used the Extruded Boss feature for making 3D objects from the 2D sketches of the extensions [2,3].

The main task for the second problem was to generate a plane with the correct angle. The solution for this problem was to generate a plane at the position where the extensions were supposed to be and to change the angle of the plane using the Reference Geometry feature.

Alejandro also explained how to assemble all of the different parts. At this point finishing the buoy was no longer a problem.

The parts which had to be assembled were the mast, the counter weight, the counter weight cap, the rubber layer, the metal storage room cover, the screws and the nuts.

All SolidWorks technical drawings are available in Appendix 3: *Buoy Measurements from SolidWorks.*

3.5 Simulations Software Package

When the buoy was finished the model needed to be transferred to another program. SolidWorks can save the model in various file formats. The choice fell to the CATIA file format. CATIA is one of the most popular CAD programs. Afterwards the model could be transferred to a simulations software package. The choice fell to the GiD software package because of its abilities in Finite Elements Method (FEM) and Computational Fluid Dynamics (CFD) calculations and also GiD. Also GiD is able to read the CATIA file format [4,5].

The buoy has to be pre-processed by making a meshed sketch of the buoy. Meshing means that the model has to be divided in small triangles (see Figure 6). The result is a meshed of small triangles. The full assembled drawing of the buoy had some intersections, so making a meshed sketch was not possible. Supervisor Joan Vincent suggested using a different drawing, which has less assembly parts, so the metal cover, screws, nuts and counter weight cap were erased. Also the counter weight was changed from an assembly part into a fixed extension of the buoy body.

Figure 6 Sketch of the Buoy with First Extensions

This design of buoy can be meshed by GiD simulations software package. The following steps will be done with Tydn. The Tydn software package is an add-on for GiD to simulate CFD based problems. The meshed model is the basis for the simulation of the buoy [6,7,8].

3.6. Conclusions

The main work of the project consisted of learning the abilities to draw the buoy in a CAD program. Due to the help of a professor and the students, the problems that arose while drawing the buoy could be solved. Due to the events mentioned in section 3.3 fulfilling the full task within the given time was not possible. To ensure the safety for the buoy, the buoy should be simulated to its balance weight, ideal weight distribution and maximal load to ensure the buoy will not sink. Also the velocity caused by wind and waves needs to be simulated along with the anchor and towing effects to ensure that the buoy will not get lost. The work done in the Mechanical Design Project along with the future simulations will help further the research the can be done with the AAB.

4 Electrical Design

4 Electrical Design

4.1 Statement of Programmable Filtering Circuit Objective

The objective for the design of the Programmable Filtering Circuit as stated in the project proposal presentation is to create a prototype circuit that has programmable gains and programmable cut-off frequencies that are controlled with the Hercules Board. The Programmable Filtering Circuit also needs to be able to work autonomously without the help of the Hercules Board [1].

These objectives entail the Programmable Filtering Circuit to have the following components and characteristics:

- A differential input amplifier to amplify the hydrophone signal
- A high pass filter to eliminate any unwanted low frequencies
- A programmable low pass filter
- An anti-noise filter to clean the signal
- An analog output amplifier to send the signal to headphones
- An output amplifier to send the signal to the Hercules Board to be sampled.
- The ability to have programmable gains.
- The ability to be controlled by the Hercules Board
- The ability to amplify and filter signals autonomously

4.2 Design Research

To ensure that a design that best fits the needs of the circuit design goals, five design options were researched. All five design options, along with explanations and discussion on the advantages and disadvantages of each, are available in Appendix 4: Design Research. The final design (See Figure 7) is the design that best fits the objectives and goals of the project.

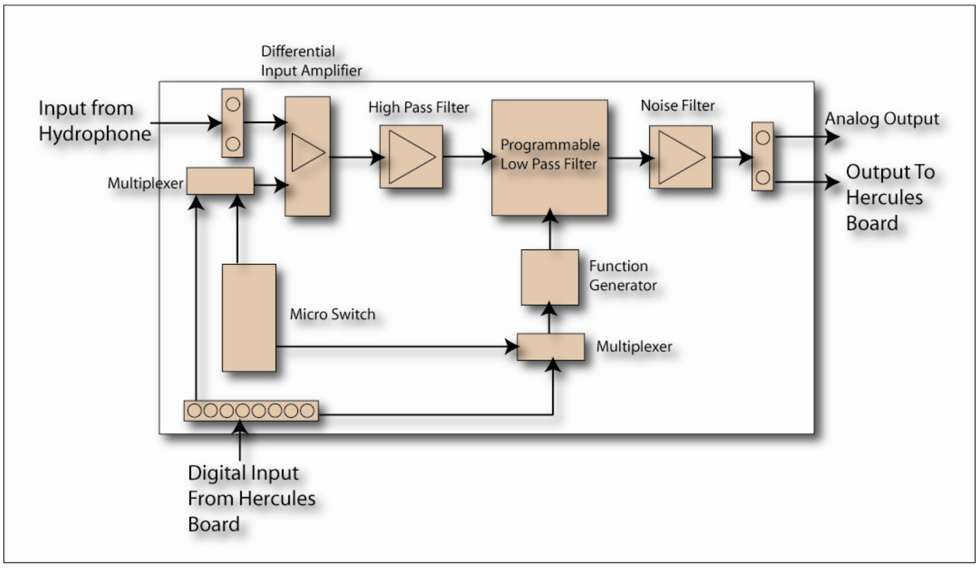

Figure 7 Block Diagram for the Final Design.

4.2.1 Final Design Explanation

In the final design, the signal from the hydrophone is first amplified with a differential input amplifier and then passes through the high pass filter where all frequencies less than 10 kHz are eliminated. Next the signal is filtered with a programmable low pass filter where all frequencies above the set cut-off frequency are eliminated. After the programmable low pass filter, the signal is cleaned with the 200 kHz anti-noise low pass filter and then amplified again with both an analog output amplifier and a Hercules Board output amplifier.

To make the input amplifier programmable, a differential input multiplexer along with a set of resistors was attached to the input amplifier. The digital output from the Hercules Board controls the differential multiplexer allowing for five different the five different input gains of 0 dB, 10 dB, 20 dB, 30 dB and 40 dB.

The cut-off frequency of the programmable low pass filter is controlled by a clock signal. To create a clock signal to control this filter, a multiplexer attached to a oscillator is added to the circuit. The oscillator is then attached to a multiplexer coupled to a set of resistors in order to make the system programmable. This multiplexer is attached to the digital output from the Hercules Board and allows for eight different frequencies from the clock and in return allowing for eight different cut-off frequency options of 5 kHz, 10 kHz, 20 kHz, 40 kHz, 60 kHz, 80 kHz, 100 kHz and 120 kHz.

Both the high pass and anti-noise low pass filters were designed using Texas Instruments FilterPro software [2]. Also, both output amplifiers are basic non-inverting operational amplifiers design with variable resistors which allow for the ability to manually fine tune to output gains. The output amplifiers allow for an output gain in the range of 0 dB to 40 dB.

4.2.2 Final Design Integrated Circuit Components

The design components had one condition to be chosen. All integrated circuits needed to use plastic encapsulation, the dual in-line package (*DIP*). Allow easier placement components.

4.2.2.1 Input Amplifier

The INA111 instrumental amplifier (see **¡Error! No se encuentra el origen de la referencia.**) was the differential input amplifier chosen because it has high speed and impedance input.
The INA11 has an extended bandwidth (2MHz at minimum gain) and the gain can be set from 1 to 1000 with a single external resistor.
Buying the INA111 is cheaper than building a differential amplifier with to operational amplifiers such as the LT1364 Dual [3]. Also the INA111 meets all the specifications needed for the input amplifier [4].

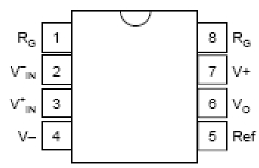

Figure 8 INA111

4.2.2.2 Input Multiplexer

The DG409 differential multiplexer (see Figure 9) was chosen to select the different set resistances in order to modify the input gain. The DG409 insures stability when working with the differential input amplifier. The DG409 has four differential channels and one enable function allowing for five different inputs gain inputs. The DG409 also has fast switching abilities, a low internal resistances and meets all of the requirements [5].

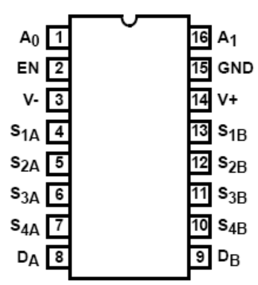

Figure 9 DG409DJZ

4.2.2.3 High Pass Filter, Anti-Noise Low Pass Filter and Analog Outputs

TLE2072IP (see Figure 10) was chosen for high pass filter, anti-noise low pass filter and the analog outputs. The TLE2072IP has a 10 Mhz bandwidth and is inexpensive [6].

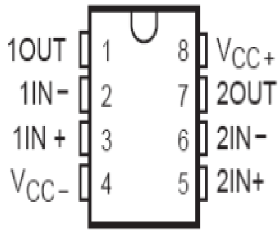

Figure 10 TLE2072IP

4.2.2.4 Programmable Low Pass Filter

LTC1064-2 Programmable Low Pass Filter (see Figure 11) was chosen because the LTC1064-2 Programmable Low Pass Filter has a wide range of cut-off frequencies which are controlled by varying clock frequencies Other important features were the 140 KHz maximum corner frequency which covers all the needed of cut-off frequencies. The LTC1064 is a low noise, high frequency and 8th order Butterworth low pass filter. These features insure a fast response in the signal cutting process [7].

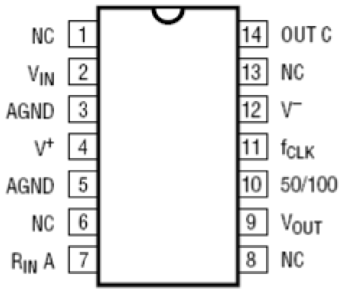

Figure 11 LTC1064-2

4.2.2.5 Clock Generator

LTC6908-2 clock generator (See Figure 12) was chosen for its frequency range which runs from 50 kHz to 10 MHz. The output signal is controlled by one external resistor. This characteristic allows the LTC6908-2 to be programmed with a analog multiplexer [8].

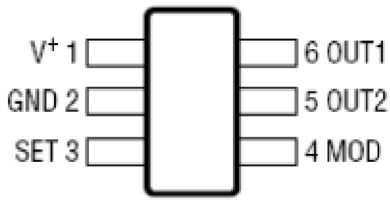

Figure 12 LTC6908

4.2.2.6 Analog Multiplexer

The MC14051B Analog Multiplexer (see Figure 13) was chosen because it has low internal impedance values making it the closer to an ideal multiplexer. The MC14051B has three inputs for the control of its eight switches and a single input. The eight external resistors set the frequency to the clock generator. Also this low internal impedance multiplexer is inexpensive [9].

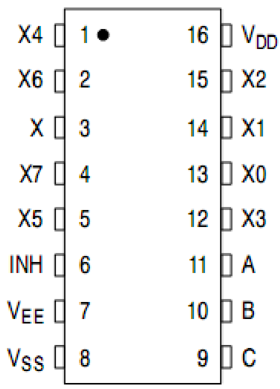

Figure 13 MC14051B

4.2.3 Final Design Passive Components

4.2.3.1 High Pass Filter

The High Pass Filter was designed using Texas Instruments Filter Pro Software (See Figure 14) [2].The filter design is a fourth order Sallen-Key Butterworth filter specified to have a cut-off frequency of 10 Hz. A Butterworth filter, as compared to a Chebyshev, Elliptic, or Bessel, was chosen because Butterworth filters have a relatively steep transition region and exhibit no rippling in pass band. A fourth order filter was chosen because this high order will ensure a steeper transition region. Both of these characteristics meet the needs filter design requirements. A screen shot of the design in Filter Pro is available in Appendix 5: *Filter Designs from FilterPro*.

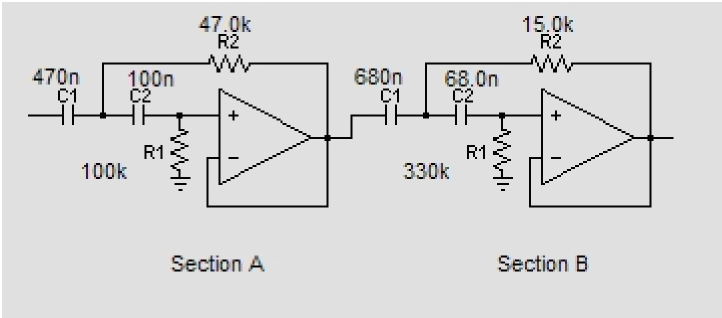

Figure 14 High Pass filter design using Filter Pro

The resistance and capacitance for the filters values are directly based on this design (See Table 1).

RESISTORS $(k\Omega)$	CAPACITORS (ρF)
100.00	470
47.00	100
15.00	680
330	68

Table 1: Passive Components used to Design the High Pass Filter

4.2.3.2 Low Pass Anti-Noise Filter

The High Pass Filter was designed us Texas Instruments Filter Pro Software (See Figure 15) [2]. The filter design is a fourth order Sallen-Key Butterworth filter specified to have a cut-off frequency of 200 kHz. These design characteristics were chosen for the same reasons explained for the high-pass filter. A screen shot of the design in Filter Pro is available in Appendix 5: *Filter Designs from FilterPro.*

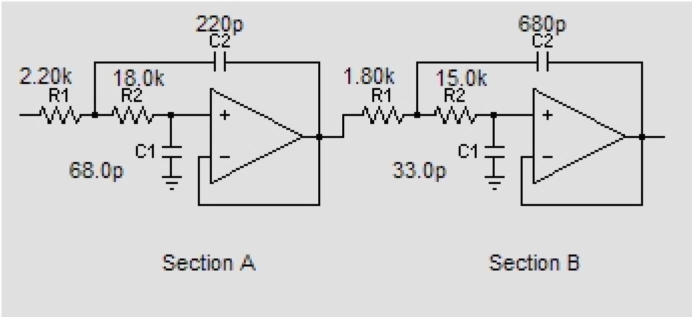

Figure 15 Passive Components Used to Design the Low Pass Anti-Noise Filter

The resistance and capacitance values are directly based on this design (See Table 2)

RESISTORS ($k\Omega$)	CAPACITORS (ρF)
2.20	220.00
18.00	68.00
1.80	33.00
15.0	680.00

Table 2: Passive Components Used to Design the Low Pass Anti-Noise Filter.

4.2.3.3 Programmable Gain

Resistance calculations to control the input gain with the differential multiplexer were based on these formulas:

$G_{dB} = 20log_{10}(G_{v/v}) \quad \Rightarrow \quad G_{v/v} = 10^{G_{dB/20}}$ ($G_{dB}/G_{v/v}$ relationship)

$G_{v/v} = 1 + \frac{50\ k\Omega}{R_G} \quad \Rightarrow \quad R_G = \frac{50k\Omega}{G_{v/v}-1}$ ($G_{v/v}/R_G$ relationship from the INA111 datasheet [4]).

$$\therefore \quad R_G = \frac{50\ k\Omega}{10^{G_{dB/20}} - 1}$$

Internal Resistance of Differential Multiplexer = 120 $k\Omega$ [5]

$$\therefore \quad R_T = \frac{50\ k\Omega}{10^{G_{dB/20}} - 1} - \ 120\ k\Omega$$

All of the original math work for these equations is available in Appendix 6: *Passive Component Math.*

Table 3 shows the calculated resistances based on the desired input gains.

$G_{dB}\ (dB)$	$Gv_{/v}\ (V/_V)$	$R_G(k\Omega)$	$R_T\ (k\Omega)$
0	1.00	∝	∝
10	3.16	23.00	22.90
20	10.00	5.55	5.43
30	31.62	1.63	1.51
40	100.00	0.51	0.39

Table 3 :Calculated Resistance Values Based on Desired Gains

With the the needed resistance values known, actual resistors with values clostest to the values needed were chosen. These values along with the expected gains based on these values are shown in table 4.

$R_{Actual}\ (k\Omega)$	$Gv_{/v\ Expected}\ (V/_V)$	$G_{dB\ Expected}\ (dB)$
∞	1.00	0.00
24.00	3.09	9.78
5.62	9.90	19.91
1.47	35.01	30.89
0.39	128.55	42.18

Table 4 : Expected Gains Based on Actual Resistance Values

4.2.3.4 Programmable Low Pas Filter

The LTC1064-2 Data Sheet (See Figure 16) suggests the use of Schottky diodes and capacitors to protect from transient supply reversal. The passive components used are directly abased this suggestion (See Table 5) [7].

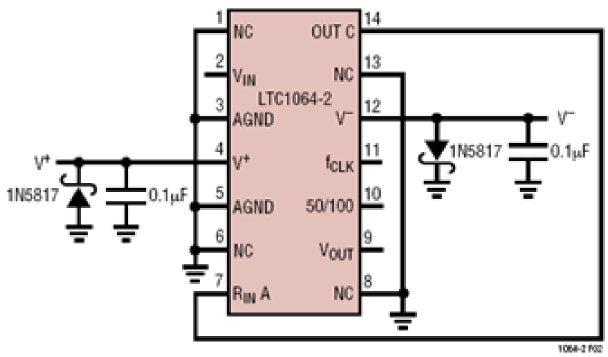

Figure 16 Using Diodes to Protect from Transient Supply Reversal

Capacitors (μF)	Schottky Diodes
2 × .1	2 × 1N5817

Table 5: Passive Components Used to Protect from Transient Supply Reversal

4.2.3.5 Oscillator and Multiplexer

The Oscillator's Data Sheet defines the f_{Out} / R_{Set} relation with the following equation [8]:

$$f_{Out} = \frac{(10 \text{ MHz})(10 \text{ k}\Omega)}{R_{Set}}$$

The LTC1064-2 Datasheets defines the $f_{Out}/f_{Cut-off}$ ratio to be $50:1$ [7]. Thus the following equation was derived:

$$\therefore R_{Set} = \frac{(10 \text{ MHz})(10 \text{ k}\Omega)}{50(f_{Out})}$$

All of the original math work for these equations is available in Appendix 6: *Passive Component Math.*

The resistances used to control the output frequency of the oscillator which in return controls the cut-off frequency of the programmable low pass filter, along with the corresponding frequencies are shown in Table 6.

$f_{Cut-off}$ (kHz)	f_{Out} (MHz)	R_{Set} $(k\Omega)$
5.00	0.25	400.00
10.00	0.50	200.00
20.00	1.00	100.00
40.00	2.00	50.00
60.00	3.00	33.33
80.00	4.00	25.00
100.00	5.00	20.00
120.00	6.00	16.67

Table 6: R_{Set} for the Oscillator Based on f_{Out} (MHz) and $f_{Cut-off}$ (kHz).

Based on the needed resistance values, actual resistance values were chosen. Table 7 shows the expected frequencies associated with the actual resistance values used.

$R_{Set\,(Actual)}\ (k\Omega)$	$f_{Out\ Expected}(MHz)$	$f_{Cut-off\ Expected}\ (kHz)$
390.00	0.26	5.13
200.00	0.50	10.00
100.00	1.00	20.00k
51.00	1.96	39.22
33.00	3.03	60.60
24.00	4.16	83.34
20.00	5.00	100.00
16.00	6. 2	125.00

Table 7: f_{Out} (MHz) and $f_{Cut-off}$ (kHz) Based on $R_{Set\,(Actual)}$ for the Oscillator.

4.2.3.6 Output Amplifiers

Non-Inverting operational amplifiers were used for the output amplifiers. In order to be able to fine tune the output amplifiers a variable resistor is used. Resistance values were based on the following equation. A derivation of this equation is available in Appendix 6: *Passive Component Math.*

$$Gv_{/v} = \frac{R_{Var}}{R_{Fixed}} + 1$$

Let $R_{Fixed} = 1\ k\Omega$ and $\boldsymbol{G_{dB}}\ (\boldsymbol{dB})$ vary from $10\ \boldsymbol{dBs}$ to $40\ \boldsymbol{dBs}$.

Table 8 shows the range of $\boldsymbol{R_{Var}}$ needed to produce the desired gains.

$G_{dB}\ (dB)$	$Gv_{/v}\ (V/V)$	$R_{Var}\ (k\Omega)$
0	1.00	0
10	3.16	2.16
20	10.00	9
30	31.62	30.62
40	100.00	99

Table 8: R_{Var} Based on Varying R_{Var} and $Gv_{/v}$

Table 9 shows the passive components needed for both the Hercules Board output amplifier and the analog output amplifier.

Fixed Resistors $(k\Omega)$	Variable Resistors $(k\Omega)$
2 × 1	2 × 1N5817

Table 9: Supply List for the Output Amplifiers

4.2.3.7 Additional passive components

Capacitors were coupled to each integrated circuit to protect each integrated circuit from the $\pm 12\ V$ power supply. A list of these capacitors used is shown in table 10.

CAPACITORS (nF)
16 X 10.00

Table 10: Capacitors Used for Supply Protection

Also capacitors were connected to each voltage regulator for power supply protection. A list of these capacitors is shown in table 11.

CAPACITORS (μF)
2 X 100
2 X 1

Table 11: Capacitors For Voltage Regulator Protection

Resistors were couple to ground at each digital input to protect from current leakage when a micro-switch is in place. A list of these resistors is shown in Table 12.

RESISTORS $(\boldsymbol{k\Omega})$
6 x 2.5

Table 12: Resistors Used to Protect from Current Leakage

4.3 Simulation

The circuit schematic was drawn in using Orcad 16.2. Simulations of the of the High-Pass, Anti Noise Low Pass, Input Amplifier, and Output Amplifiers were created to ensure the designs would work correctly (See Figure 17). Neither the programmable low pass filter nor the oscillator was simulated because these components were not available in PSpice libraries of Orcad 16.2.Every simulation is available in Appendix 6: *Orcad Simulations and Schematics.*

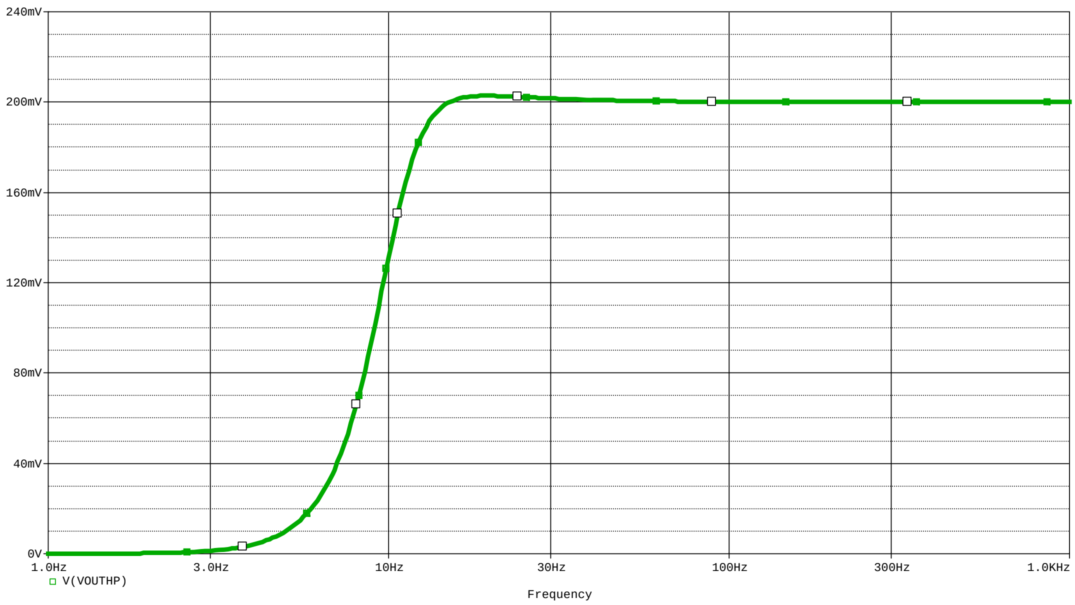

Figure 17 High Pass Filter Simulation using Orcad 16.2

After individual components were simulated, the entire circuit schematic was drawn. Due to complications with the Orcad 16.2 software and lack of sufficient tutorials, the circuit schematic was then transferred to Protel DXP 2004. The schematic drawn with Orcad 16.2 is available in Appendix 6: *Orcad Simulations and Schematics.*The schematic drawn with Protel DXP 2004 is available in Appendix 7: *Protel Schematics and PCB Designs*.

4.4 Fabrication

The final PCB design was created in using Protel DXP 2004 software (See Figure 18) using a tutorial from Glenn Mercier [10]. More information about the PCB design in Protel DXP 2004 is available in Appendix 7: *Protel Schematics and PCB Designs*

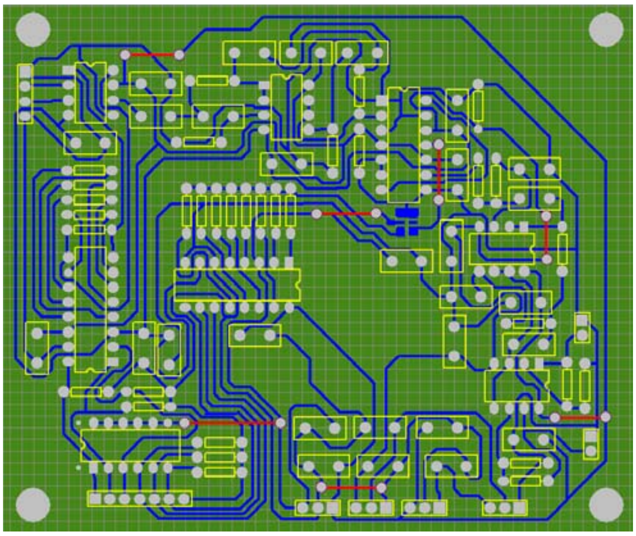

Figure 18 Printed Circuit Board Design from Protel DXP 2004.

The design from Protel DXP 2004 LPK was converted to LPKF CAM format. This LPKF CAM software allowed for the LPKF milling machine to physically create the PCB (See Figure 19)

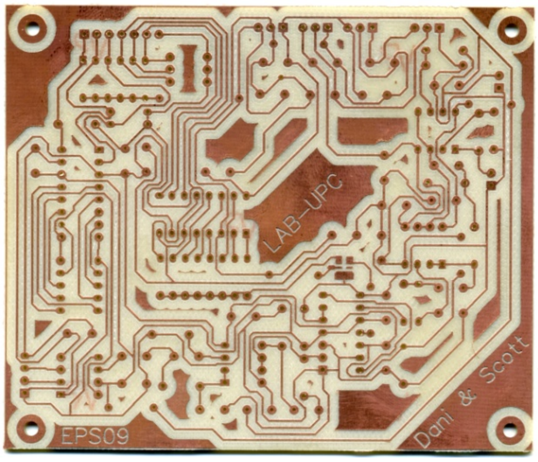

Figure 19 PCB made with LPKF automatic milling machine.

After the board was printed, each component was hand soldered to the board (See Figure 20).

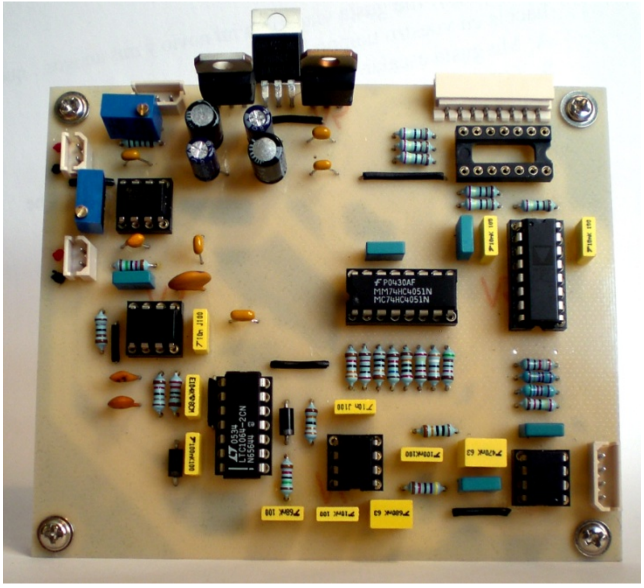

Figure 20 Completed Programmable Filtering Circuit

4.5 Programmable Filtering Circuit Tests

While testing the board, a misconnection in the PCB design of the board was discovered. Unfortunately, this misconnection broke the oscillator. Also an error in the differential multiplexer placement broke the differential input multiplexer. Thus, testing was done under the following conditions:

- A function generator was used to simulate the clock signal from oscillator.
- Wire jumpers were used in the place of the differential multiplexer.
- A 200.00 mV Peak-to-Peak differential input signal from a function generator was used to simulate the input signal from the hydrophone.

4.5.1 Test 1: Component Gains

Gains were recorded at each amplifying and filtering component across the board at minimum, medium, and maximum input gains with the corresponding cut-off frequencies as shown in table 13.

Level	Input G_{dB} (dB)	$f_{Cut-off}$ (MHz)
Minimum	0.00	5.00
Medium	20.00	60.00
Maximum	40.00	120.00

Table 13: Input Gain Levels with Corresponding C-Off Frequencies

Table 14 shows that the signal's gain remains relatively constant throughout the entire circuit board. All data points and calculations for this test can be found in Appendix 8: *Programmable Filtering Circuit Test Results*.

Component	Min. $G_{dB}\ (dB)$	Med. $G_{dB}\ (dB)$	Max. $G_{dB}\ (dB)$
Input Amplifier	2.61	19.60	35.64
High Pass Filter	2.67	19.60	35.49
Prog. Low Pass Filter	-0.18	18.74	35.42
Anti-Noise Filter	-0.04	18.74	35.12
Output Amplifier	-0.72	18.74	35.17

Table 14 : Component Gains at Varying Input Gain Levels

4.5.2 Test 2: Gain v. Input Frequency

Figure 21 shows the output gain with each set input gain at all frequencies. All gains remain relatively constant all frequencies with slight attenuation at higher frequencies. This attenuation was expected based on information from the LTC64-2 datasheet [7]. Also the input gain of 40 dBs only produces a 35 dB gain. This loss of gain is attributed to limitation set by the having a 12 V power supply. All data points and calculation associated with this test are available in Appendix 8: *Programmable Filtering Circuit Test Results*.

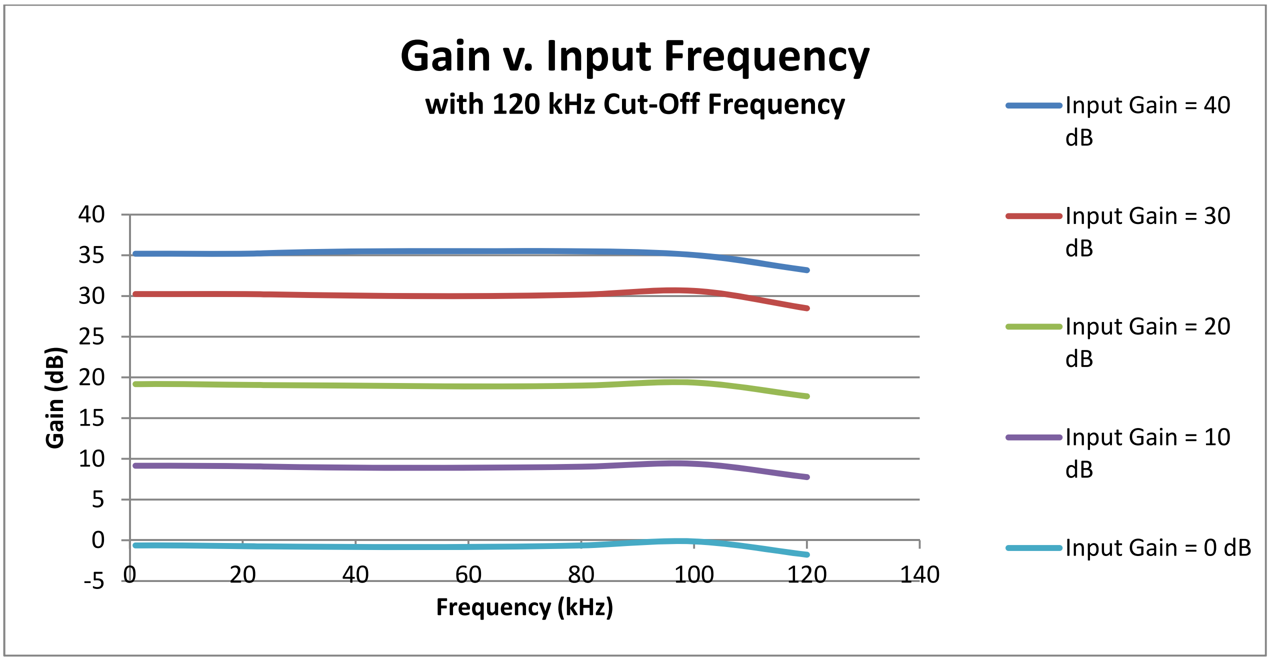

Figure 21 : Gain v. Input Frequency with Varying Input Gains.

4.5.3 Test 3: Frequency Response

The frequency response was measured at four different cut-off frequencies. The result produced the desired frequency response. Figure 22 shows that frequency with 5 kHz cut-off frequency produces a steep transition region. All data points and calculations for this test, along with additional graphs can be found in Appendix 8: *Programmable Filtering Circuit Test Results*.

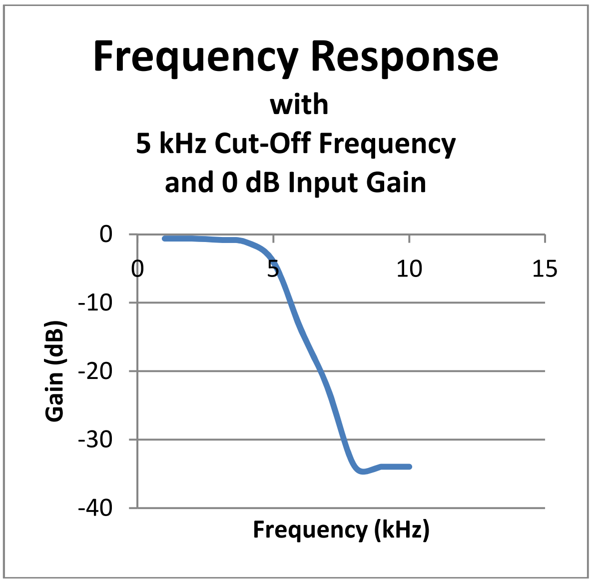

Figure 22 : Frequency response with a 5 kHz Cut-Off Frequency

Figure 23 shows that with a 120 kHz cut-off frequency transition region is slightly longer with a -3 dB gain of about 135 kHz.

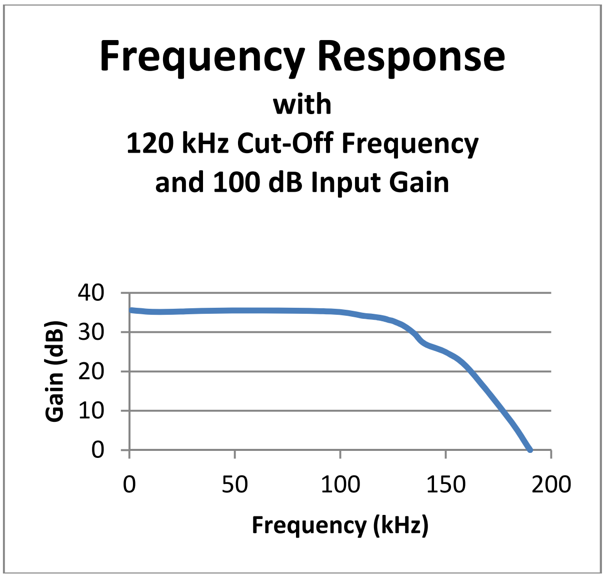

Figure 23 : Frequency response with a 120 kHz

4.6 Error Analysis

The purpose of this error analysis is to discuss ways in which the prototype circuit board can be improved.

Many connections tracks between the components can be routed in a more efficient manner. Also, also the tracks connecting the oscillator were incorrectly routed. The tracks were manually rerouted with solder for testing purposes. Also a wire is attached to where the output of the oscillator was located so that the clock signal of the oscillator could be simulate.

The position of the differential resistors and the –8 V voltage regulator needs to be changed so they better fit on the board (See Figure 24). Also the digital connection port needs to be changed so that it does not face upwards. The change will allow the circuit to better fit into the buoy. The resistor controlling the clock output from oscillator that sets the 120 kHz cut-off frequency can be changed to make the actual cut-off frequency closer to 120 kHz.

Complete tests need to be conducted with both the oscillator and the input amplifier attached to the board. These tests should then be analyzed to insure that the circuit has all the capabilities needed.

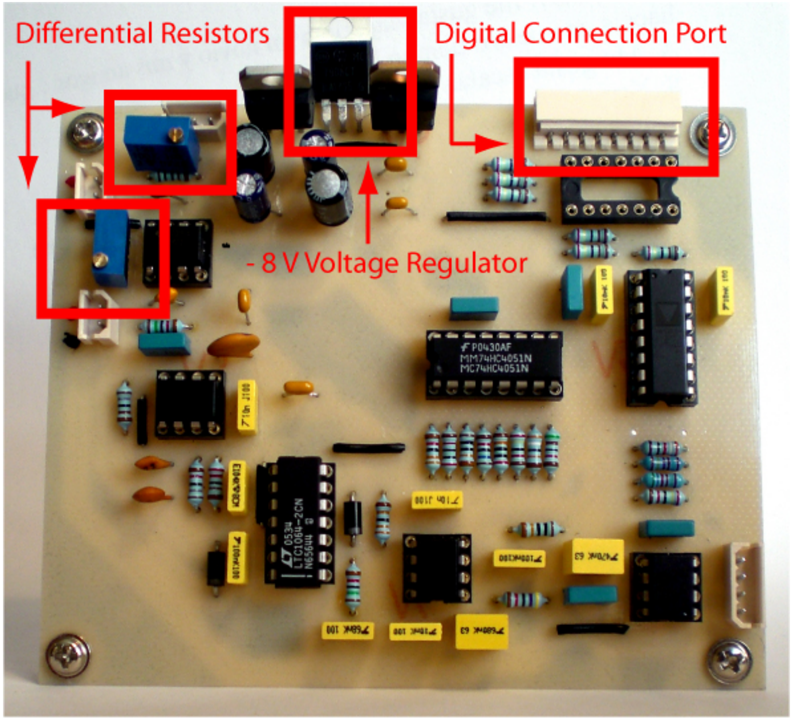

Figure 24 PCB Errors

4.7 Conclusion and Recommendations

A design for the Programmable Filtering Created was created in order to best meet the needs of assigned objective for the Programmable Filter Circuit. The design was tested with simulations and a prototype circuit was fabricated and tested. The test results show that the circuit works in a manner that meets the needs of the objective. The fabrication and testing of the board also reveal certain aspects of the overall design that can be improved. With these improvements, the need for other tests arises. These additional tests that will help expand the overall understanding of the capabilities of the Programmable Filter Circuit. The theory behind, progress, processes, tests and errors analysis of the design of the Programmable Filter circuit have been recorded. These records will help further the design of both the Programmable Filtering Circuit and the Autonomous Acoustic Buoy as a whole.

5 Computer Software Design

5 Computer Software Design

5.1. Introduction

The operation of the buoy is controlled by a single board computer called Hercules Board (HB). The application run on this computer is responsible for controlling the operation of the Programmable Filtering Circuit (PFC) and handling the data flow between the buoy and an external computer. On the external computer, graphical interface is provided for the user. With this application the user selects the parameters and time of recording. The values selected by the user are stored in the configuration file. This file is sent from the external computer to the HB to set up and start the acquisition process. During the recording, the files with raw data are stored on the HB. Once the acquisition process is completed, the files can be downloaded to the external computer with the help of the user interface application.

5.2 Goals and Aims

The goal of the programming part done this year in the AAB project was to further develop the existing source code of both applications in order to:

- Provide control over the newly designed and developed Programmable Filtering Circuit.
- Extend the functionality of the buoy with two selectable parameters: gain and cut-off frequency.
- Enhance the stability of the existing code and fix any faulty behaviour of the program run on the HB.
- Enhance the user interface.

The most important programming goal was to provide control over the newly designed and developed circuit board. The PFC design is similar to the previously completed circuit board but includes programmable devices enabling different configuration settings for filtering the signals. Therefore, a connection enabling the data flow from the Hercules board to the PFC had to be added.

Necessary changes had to be introduced to the application run on the HB as well as the user interface to allow for selection and operation with different gain and cut-off frequency values.

Throughout the whole project upgrades were made when noticing any faulty behaviour of the program. Parts of the previously existing code were rewritten in order to improve the stability of the application and the general quality of the source code.

The user interface was redesigned to enhance its functionality, facilitate further development and minimize the risk of errors.

5.3 Software

5.3.1 Providing Control Over the Newly Designed and Developed Programmable Filtering Circuit.

The main upgrade from the previously existing design is that the PFC is programmable. The aim was to provide a selection of different gains and cut-off frequencies. Providing this functionality creates the need to investigate ways to translate the options chosen by the user into the signal that can control the hardware. Several possibilities were available to complete this task. They differed in respect to the hardware design as well as HB outputs used. The user manual of the HB clearly showed that the HB can provide digital output. Furthermore, the user manual showed a possibility to obtain a pulse width modulated signal from the board [1] However, testing was needed to find out if the signal produced by the board is continuous or only a pulse. Obtaining a pulse signal in the testing process would mean that the circuit needs additional memory.

To test the exact behaviour of the HB a testing circuit board was prepared (See Figure 25). The test circuit was connected to the digital output of the HB with a fifty-conductor ribbon cable. Eight red light emitting diodes (LEDs) were connected to eight lines of the digital output and one yellow LED was connected to the pulse width modulation output.

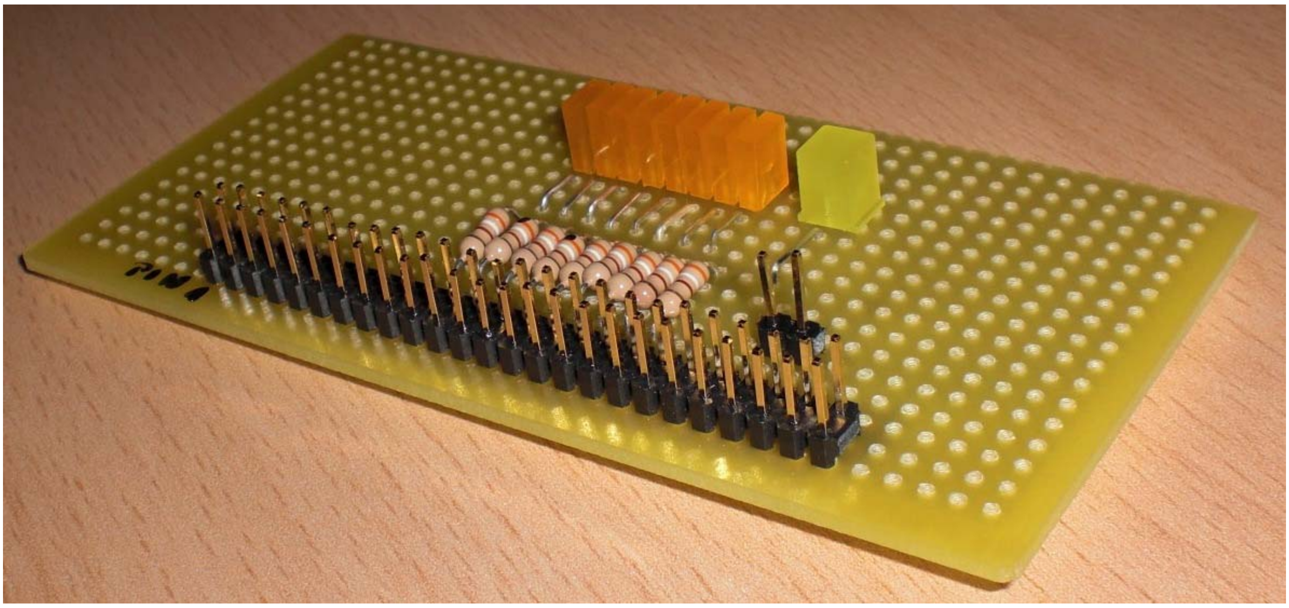

Figure 25 Testing board

Test software was written. The programs were based on the demos included in the HB development package [2]. During this process configuration and control values of the HB were examined. Testing the digital output proved that the signal is continuous. Testing the pulse modulation showed the HB can work as a source of a frequency clock in the range of 250 KHz – 6 MHz. The testing proved that these signals can be sent independently of each other and the operation of the board is not disrupted. However, further testing with the oscilloscope showed that the signal presents high interference starting around 4 MHz and up and thus making the pulse with modulation output unusable for the purpose at hand. As a result of this research and testing, eight lines from the digital output of the HB were chosen to provide control over the PFC. An algorithm was written to translate the decimal values selected by the user into the binary values used for the control lines.

5.3.2 Extending the Functionality of the Buoy with Two Selectable Parameters: Gain and Cut-Off Frequency.

The necessary changes had to be made in both applications used: in the program run in the buoy and the user interface run on external computer. In the part run on HB the parser function was upgraded to read and store the two additional parameters. The sending of control values was implemented using the function of the Application Programming Interface (API) [3] of the HB and the source code of the test program. Once the parser successfully completes reading of the configuration file and obtains what values of gain and cut-off frequency the user wants to use, the program passes these values to the digital output of the board. The possibility to set the values for two additional parameters (gain and cut-off frequency) was added in the user interface and the creation of the configuration file was altered accordingly.

5.3.3 Enhancing the Stability of the Existing Code and Fixing Any Faulty Behaviour of the Program Run on the HB.

A new parser function was written to help the application handle different configuration files and to provide for a more reliable and flexible code. The previously existing parser responsible for reading the configuration file relied on the sequence of the parameters in the configuration file. However, the configuration file has a human readable format and includes labels with the name of the parameters. Therefore, the parser should try to find the right label and after that read the value from the file, instead of relying on the sequence of parameters. After writing the new version of the parser, the test program was written. The program was debugged and tested against reading different configuration files.

To provide higher performance and stability of the software the checking of the return value of the *fopen() [4]* function was introduced.

Problems that occurred while running the application with in-line parameters were fixed. The no-sleep mode was upgraded to enable immediate recording without analysis of the values in the configuration file.

The paths where the files are created and stored were parameterized and the structure of the catalogues was redesigned.

5.3.4 Enhancing the User Interface.

The source code of the graphical user interface was analyzed. Besides the possibility to select the value of the gain and cut-off frequency, a number of upgrades was introduced to user interface.

The possibility to set the path, were the user wants the acquired data to be stored, was introduced.

In order to minimize the risk of creating an invalid configuration file the structure and components of the user interface were edited. Sliders and checkboxes were introduced for the parameters which can be given only predefined values. Moreover, for the parameters with no predefined values default values were inserted in the text fields. For the calendar the default value was set to current day to minimize the risk of creating a configuration file with an incorrect starting time.

However, due to the character of the parameters, a possibility to create a configuration file cannot be fully eliminated. Therefore, a prompt informing the user about the mistakes was added.

The layout of the application was redesigned to make it more clear and functional (See Figures 26 & 27). The source code was upgraded to facilitate any further development for example addition of more parameters.

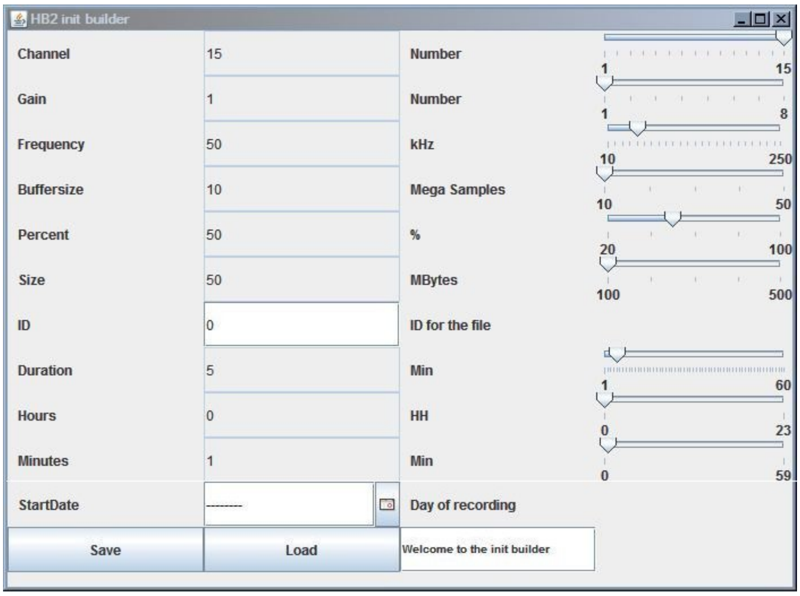

Figure 26 Primary layout of the user interface

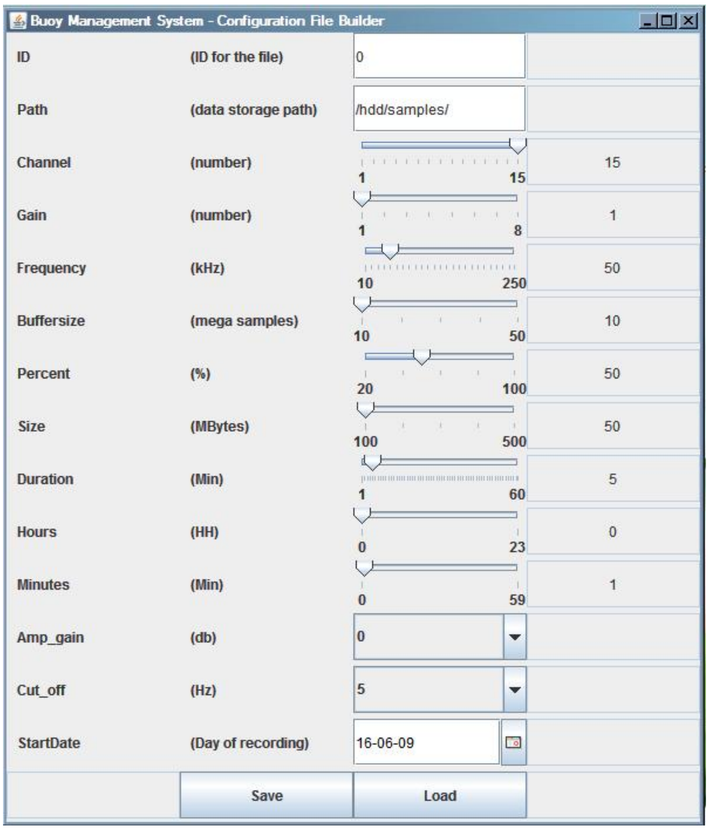

Figure 27 Final layout of the user interface.

5.4 Conclusion and Recommendations

The programming objectives set up in the beginning were met in the course of the project as the required functionality and upgrades of the software were provided. Unfortunately, due to the delays and problems in the development of the PFC, the components of the buoy were not put together and tested properly. Therefore it is highly recommended that the whole system is set up and tested so that any possible faulty behaviour of the program can be eliminated.

Special attention should be put to test:

- Operation of the buoy with the newly designed circuit board.
- Data acquisition process.
- Data storage on the Hercules Board.
- Sending acquired data to the external computer.
- Assessment of the quality of the acquired data.

6 Power Supply and Wireless Communication

6 Power Supply and Wireless Communication

The goal of the Power Supply and Wireless Communication Project in for the AAB is to use a Wi-Fi wireless connection instead of a cable connection and to make a battery box which can provide a power supply for devices in the buoy.

Figure 28 Wi-Fi Router

Wireless communication is the transfer of information over a distance without the use of electrical conductors or wires. The distances involved may be short (a few meters as in television remote control) or long (thousands or millions of kilometres for radio communications). Wireless is good choice for the places where the cables are sufficient. Data communication between Wi-Fi routers which are devices that allow for the sending and taking of data without cables has made by using a Wi-Fi system (See Figure 28) [1]. One of the Wi-Fi routers translates data, which comes from the Hercules Board in the form radio waves. The Wi-Fi router which takes this data translates these radio waves to data and gives the opportunity to use this data.

6.1 Wireless Connection

6.1.1 Setting Up a Wireless Communication Between WI-FI Routers

Connections between Wi-Fi routers can be different for different types of Wi-Fi routers. Generally, a Wi-Fi router connects to a computer and the reset button is pushed for 10-15 seconds to get the factory settings. After that, the Wi-Fi router installs in a main page of Wi-Fi router by using the common Internet Protocol (IP) address of the Wi-Fi routers which differs by brand of Wi-Fi routers. At this moment, a change of name for the connection or password can be created. Also changing the IP address of this router is necessary. To make a Point-To-Point (PTP) connection, a Media Access Control (MAC) address, which changes by every single Wi-Fi router, is used. In this situation, when making a PTP connection, a Mac address is written to the Wi-Fi routers which need to be connected.[1]

Figure 29 Location Wi-Fi Test

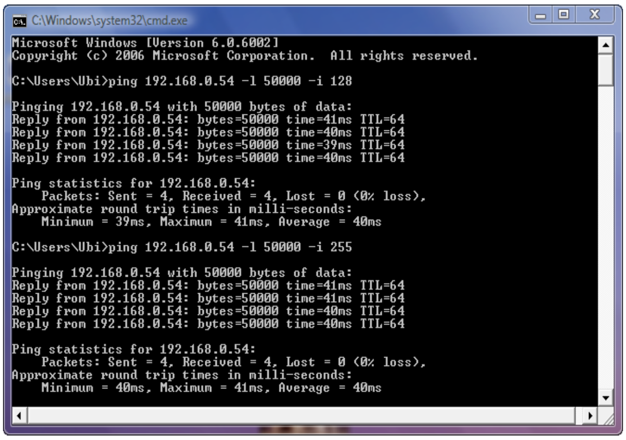

Figure 30 Results of the WI-FI Test

6.1.2 Testing Wireless Connection

A ping was sent for testing the Wi-Fi connection (see figure 29 and 30)[3]. If the package is sent sent and received, the wireless connection is good. The data sending and taking quality depends on the distance between Wi-Fi routers, the variety of Wi-Fi routers, the antennas, and barriers which are between Wi-Fi routers (walls etc.) and the abundance of the devices which use same frequency. Also a few programs which can calculate the quality of Wi-Fi connection exist. These programs calculate the speed of Wi-Fi communication by sending and downloading data.

6.2 Power Supply

Figure 31 Battery Box

The battery box (see Figure 31) made by student during the 2008 EPS has six different outlets. Every outlet has a different duty: an outlet for the Hercules Board, the Wi-Fi router, the alarm, the analog output, for recharging the first battery and the recharging the second battery.

6.2.1 Reducing Voltage

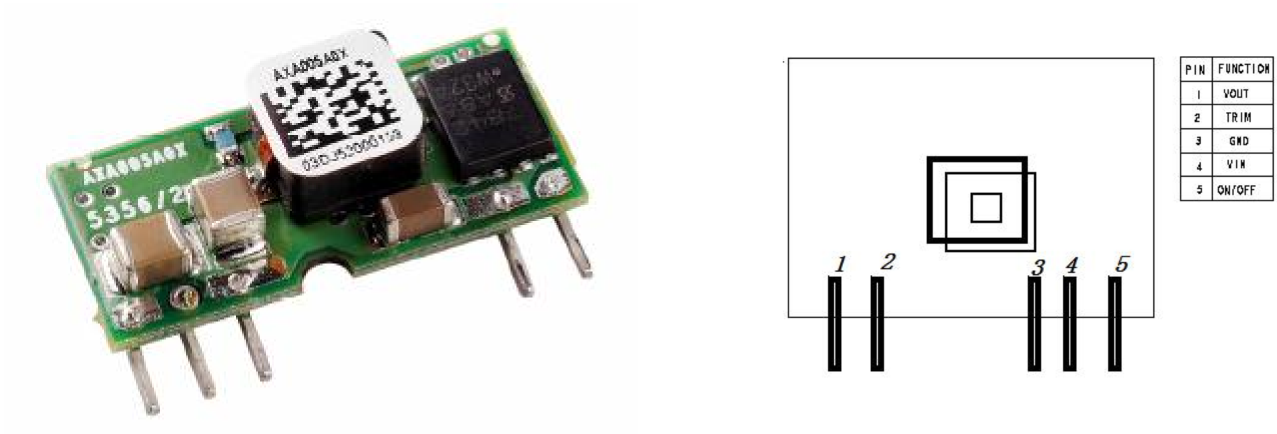

Figure 32 DC-DC down voltage converter switched voltage regulator and function of pins

The Hercules Board, Wi-Fi routers and hydrophone are using electric power but the voltages are different for each device. Originally the battery box was only provided a 12 V output, but the Wi-Fi router works with 5 V. Reducing to voltage from 12 V to 5 V was necessary. A DC-DC down voltage converter switched voltage regulator made this possible. Also using power pins is important to give different voltages for different devices (See Figure 32) [3].

6.2.2 Testing the Battery Box

A digital voltmeter was used for testing the battery voltage and the cables. The battery life depends on many conditions: the data sending rate of the Wi-Fi routers, the Hercules Board, the battery charge time etc.

6.3 Conclusion and Recommendations

Wireless communication between two computers was established by making PTP connections with Wi-Fi routers. Also the Wi-Fi connection was tested by sending pings from different locations in a harbour. The battery box was updated to provide both a 12 V and 5 V output. The battery box was tested with Wi-Fi routers. Further wireless communications tests at further distances at sea should now be conducted. Also testing the battery life should be done. These tests, along with the work done, will help further the progress of the AAB.

7 ABB Project Conclusion

7 AAB Project Conclusion

Design progress has been made with the AAB Project for the 2009 EPS. The Marketing Project created a leaflet to help market the AAB. The Mechanical Design Project has drawn the AAB using CAD software and prepared these technical drawings for simulation. The Electronic Project has built the Programmable Filtering Circuit and conducted tests to help ensure that the circuit can work properly. The Computer Science Project has written code that allows an external computer to communicate with AAB. The Power Supply and Wireless Communication Project has explored wireless communication solutions and provided a battery to power the AAB. All work done in the AAB Project for the 2009 EPS will help the LAB further research involving the protection of marine animals and the marine environment.

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8 Bibliography

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8.5 Wireless Communications and power Supply

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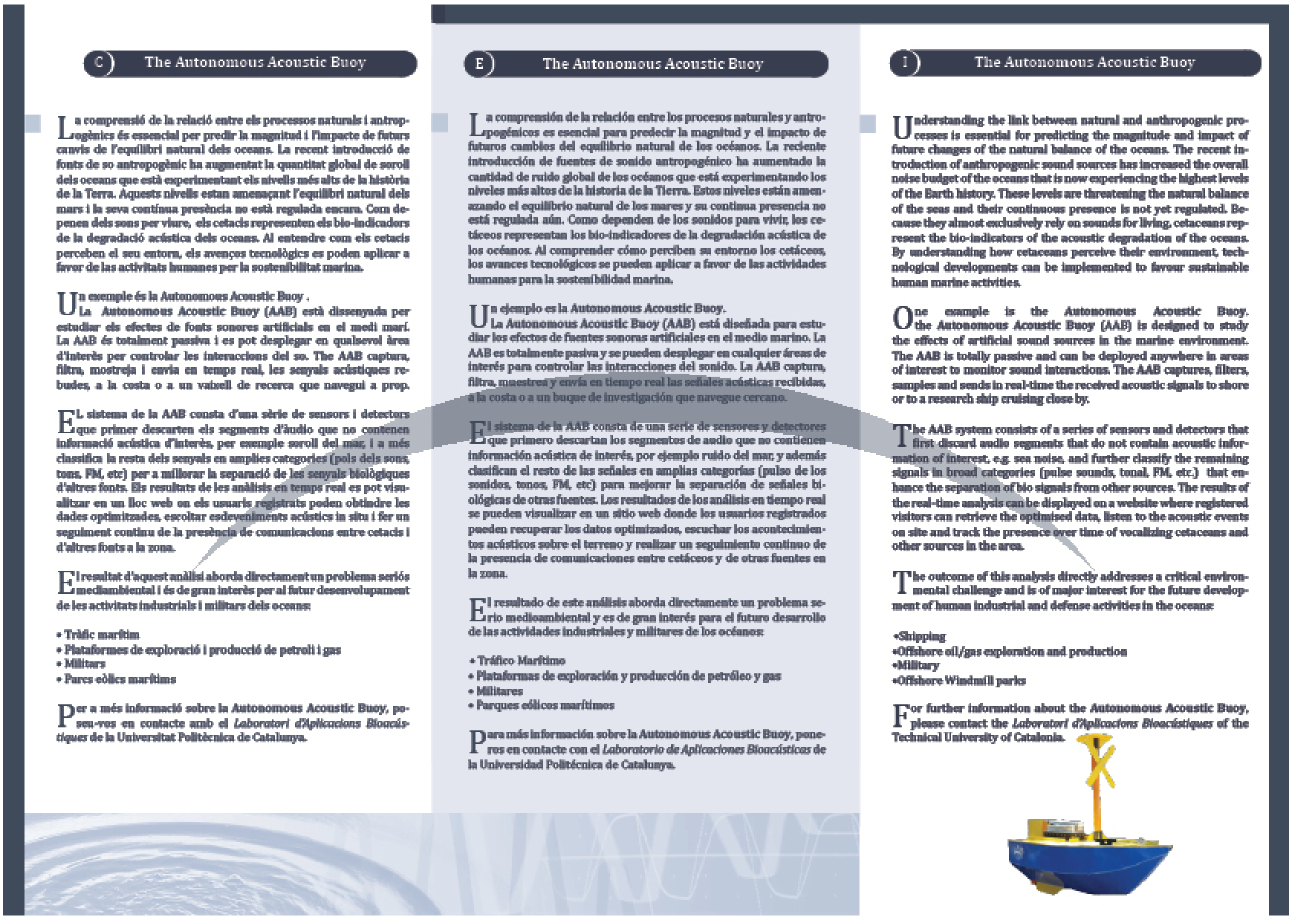
Appendix

Appendix 1: The different sound sources with their frequency

Sound source	Frequency (kHz
53C Sonar	2,6-3,3
56 Sonar	6,8- 8,2
Search and Patrol	2- 57
mine and obstacle avoidance	25-200
Weapon mounted sonar	15- 200
Surveillance Towed Array Sensor System Low frequency Sonar	0,1- 0,5
submarine communication system	5- 11
Explosions	0,47- 7,07
650cc Jet ski	0,8- 50
Fishing boat	0,25- 1
Net-dragging fisher	0,1
Tug with empty barge	0,037- 5,0
Tug with full barge	1,0- 5,0
Work boat (34 meters)	0,63
Tanker (135 meters)	0,43
Tanker (179 meters)	0,06
Super tanker (266 meters)	0,008
Super tanker (340 meters)	0,007
Container ship (219 meters)	0,033
Container ship (274 meters)	0,008
Freighter ship (135 meters)	0,041

Appendix 2: The Leaflet

Figure 29 The Outside Of The Leaflet



C) The Autonomous Acoustic Buoy

La comprensió de la relació entre els processos naturals i antropogènics és essencial per predir la magnitud i l'impacte de futurs canvis de l'equilibri natural dels oceans. La recent introducció de fonts de so antropogènic ha augmentat la quantitat global de soroll dels oceans que està experimentant els nivells més alts de la història de la Terra. Aquests nivells estan amenaçant l'equilibri natural dels mars i la seva contínua presència no està regulada encara. Com depenen dels sons per viure, els cetacis representen els bio-indicadors de la degradació acústica dels oceans. Al entendre com els cetacis perceben el seu entorn, els avenços tecnològics es poden aplicar a favor de las activitats humanes per la sostenibilitat marina.

Un exemple és la Autonomous Acoustic Buoy .
La Autonomous Acoustic Buoy (AAB) està dissenyada per estudiar els efectes de fonts sonores artificials en el medi marí. La AAB és totalment passiva i es pot desplegar en qualsevol àrea d'interès per controlar les interaccions del so. The AAB captura, filtra, mostreja i envia en temps real, les senyals acústiques rebudes, a la costa o a un vaixell de recerca que navegui a prop.

EL sistema de la AAB consta d'una sèrie de sensors i detectors que primer descarten els segments d'àudio que no contenen informació acústica d'interès, per exemple soroll del mar, i a més classifica la resta dels senyals en amplies categories (pols dels sons, tons, FM, etc) per a millorar la separació de les senyals biològiques d'altres fonts. Els resultats de les anàlisis en temps real es pot visualitzar en un lloc web on els usuaris registrats poden obtindre les dades optimitzades, escoltar esdeveniments acústics in situ i fer un seguiment continu de la presència de comunicacions entre cetacis i d'altres fonts a la zona.

El resultat d'aquest anàlisi aborda directament un problema seriós mediambiental i és de gran interès per al futur desenvolupament de les activitats industrials i militars dels oceans:

• Tràfic marítim
• Plataformes de exploració i producció de petroli i gas
• Militars
• Parcs eòlics marítims

Per a més informació sobre la Autonomous Acoustic Buoy, poseu-vos en contacte amb el *Laboratori d'Aplicacions Bioacústiques* de la Universitat Politècnica de Catalunya.

E) The Autonomous Acoustic Buoy

La comprensión de la relación entre los procesos naturales y antropogénicos es esencial para predecir la magnitud y el impacto de futuros cambios del equilibrio natural de los océanos. La reciente introducción de fuentes de sonido antropogénico ha aumentado la cantidad de ruido global de los océanos que está experimentando los niveles más altos de la historia de la Tierra. Estos niveles están amenazando el equilibrio natural de los mares y su continua presencia no está regulada aún. Como dependen de los sonidos para vivir, los cetáceos representan los bio-indicadores de la degradación acústica de los océanos. Al comprender cómo perciben su entorno los cetáceos, los avances tecnológicos se pueden aplicar a favor de las actividades humanas para la sostenibilidad marina.

Un ejemplo es la Autonomous Acoustic Buoy.
La Autonomous Acoustic Buoy (AAB) está diseñada para estudiar los efectos de fuentes sonoras artificiales en el medio marino. La AAB es totalmente pasiva y se pueden desplegar en cualquier áreas de interés para controlar las interacciones del sonido. La AAB captura, filtra, muestrea y envía en tiempo real las señales acústicas recibidas, a la costa o a un buque de investigación que navegue cercano.

El sistema de la AAB consta de una serie de sensores y detectores que primero descartan los segmentos de audio que no contienen información acústica de interés, por ejemplo ruido del mar, y además clasifican el resto de las señales en amplias categorías (pulso de los sonidos, tonos, FM, etc) para mejorar la separación de señales biológicas de otras fuentes. Los resultados de los análisis en tiempo real se pueden visualizar en un sitio web donde los usuarios registrados pueden recuperar los datos optimizados, escuchar los acontecimientos acústicos sobre el terreno y realizar un seguimiento continuo de la presencia de comunicaciones entre cetáceos y de otras fuentes en la zona.

El resultado de este análisis aborda directamente un problema serio medioambiental y es de gran interés para el futuro desarrollo de las actividades industriales y militares de los océanos:

• Tráfico Marítimo
• Plataformas de exploración y producción de petróleo y gas
• Militares
• Parques eólicos marítimos

Para más información sobre la Autonomous Acoustic Buoy, poneros en contacte con el *Laboratorio de Aplicaciones Bioacústicas* de la Universidad Politécnica de Catalunya.

I) The Autonomous Acoustic Buoy

Understanding the link between natural and anthropogenic processes is essential for predicting the magnitude and impact of future changes of the natural balance of the oceans. The recent introduction of anthropogenic sound sources has increased the overall noise budget of the oceans that is now experiencing the highest levels of the Earth history. These levels are threatening the natural balance of the seas and their continuous presence is not yet regulated. Because they almost exclusively rely on sounds for living, cetaceans represent the bio-indicators of the acoustic degradation of the oceans. By understanding how cetaceans perceive their environment, technological developments can be implemented to favour sustainable human marine activities.

One example is the Autonomous Acoustic Buoy.
the Autonomous Acoustic Buoy (AAB) is designed to study the effects of artificial sound sources in the marine environment. The AAB is totally passive and can be deployed anywhere in areas of interest to monitor sound interactions. The AAB captures, filters, samples and sends in real-time the received acoustic signals to shore or to a research ship cruising close by.

The AAB system consists of a series of sensors and detectors that first discard audio segments that do not contain acoustic information of interest, e.g. sea noise, and further classify the remaining signals in broad categories (pulse sounds, tonal, FM, etc.) that enhance the separation of bio signals from other sources. The results of the real-time analysis can be displayed on a website where registered visitors can retrieve the optimised data, listen to the acoustic events on site and track the presence over time of vocalizing cetaceans and other sources in the area.

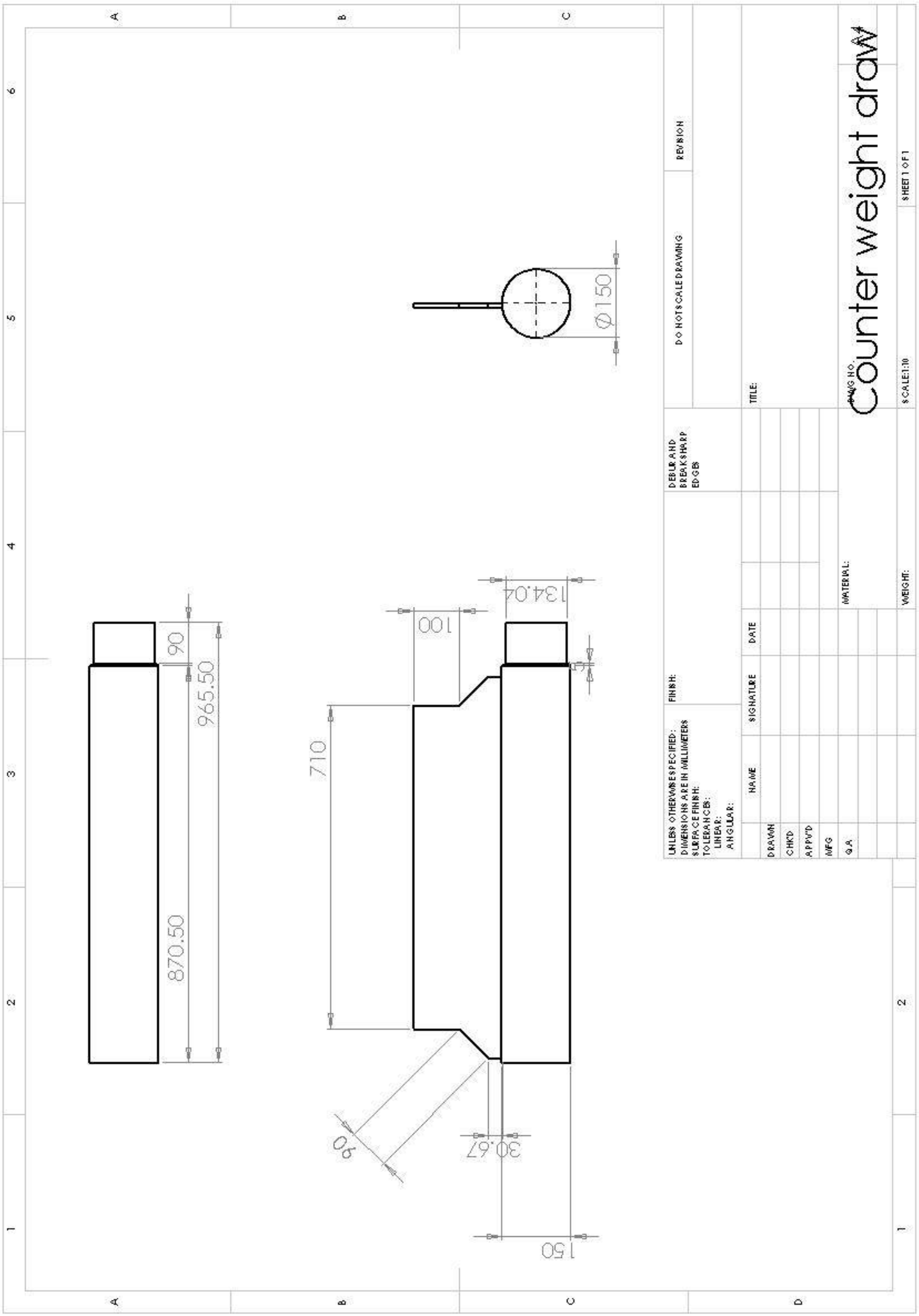
The outcome of this analysis directly addresses a critical environmental challenge and is of major interest for the future development of human industrial and defense activities in the oceans:

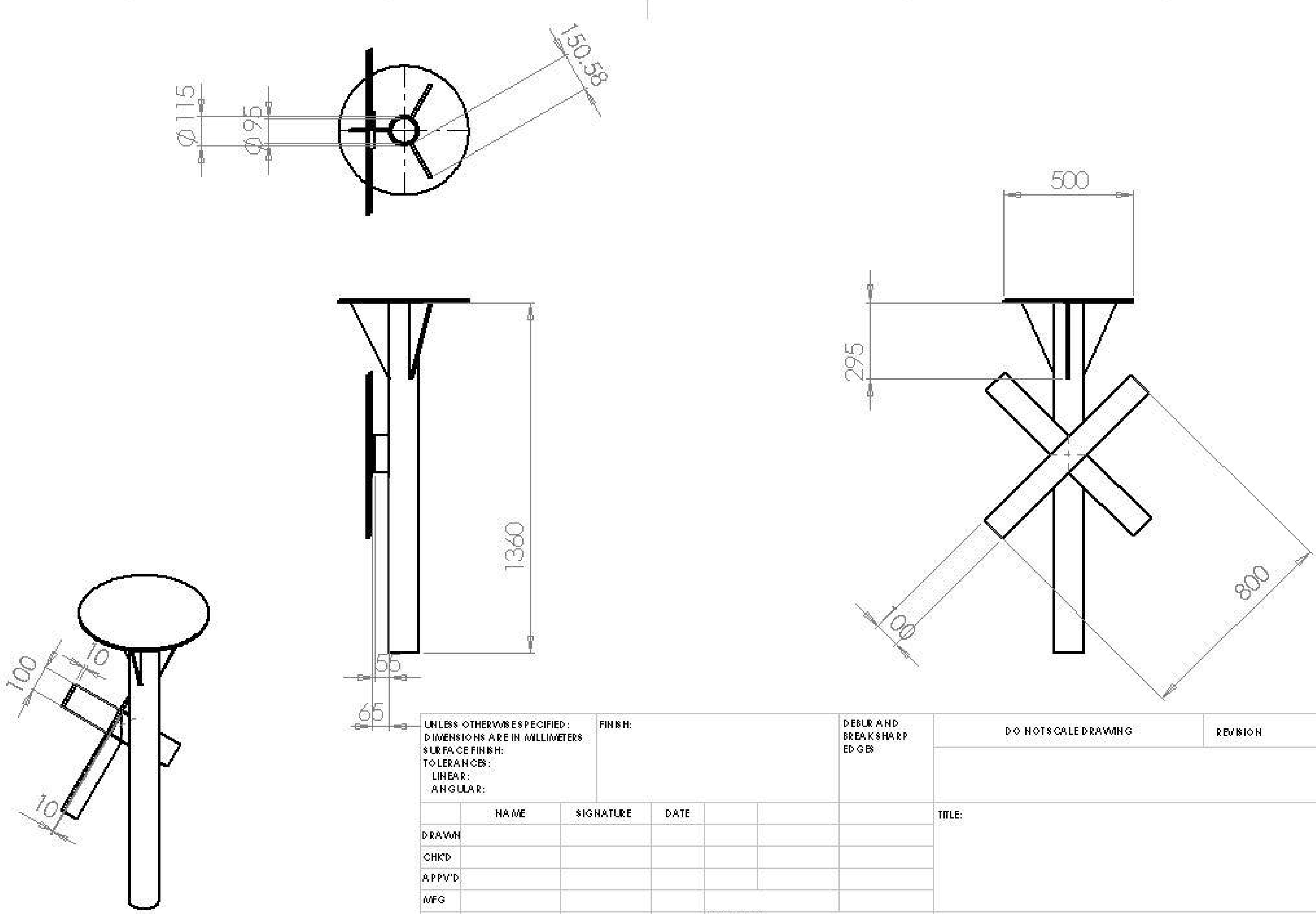
•Shipping
•Offshore oil/gas exploration and production
•Military
•Offshore Windmill parks

For further information about the Autonomous Acoustic Buoy, please contact the *Laboratori d'Aplicacions Bioacústiques* of the Technical University of Catalonia.

Figure 2: The Inside Of The Leaflet

Appendix 3: Buoy Measurements from SolidWorks





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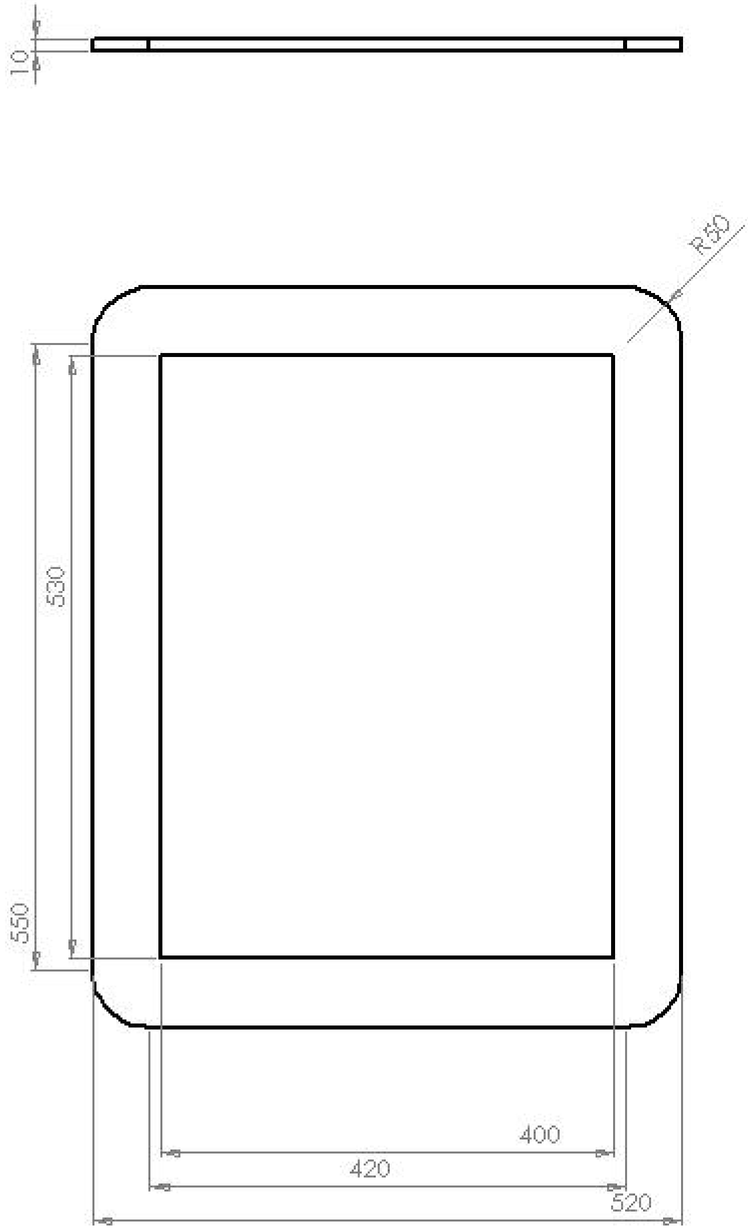
A3

boje2



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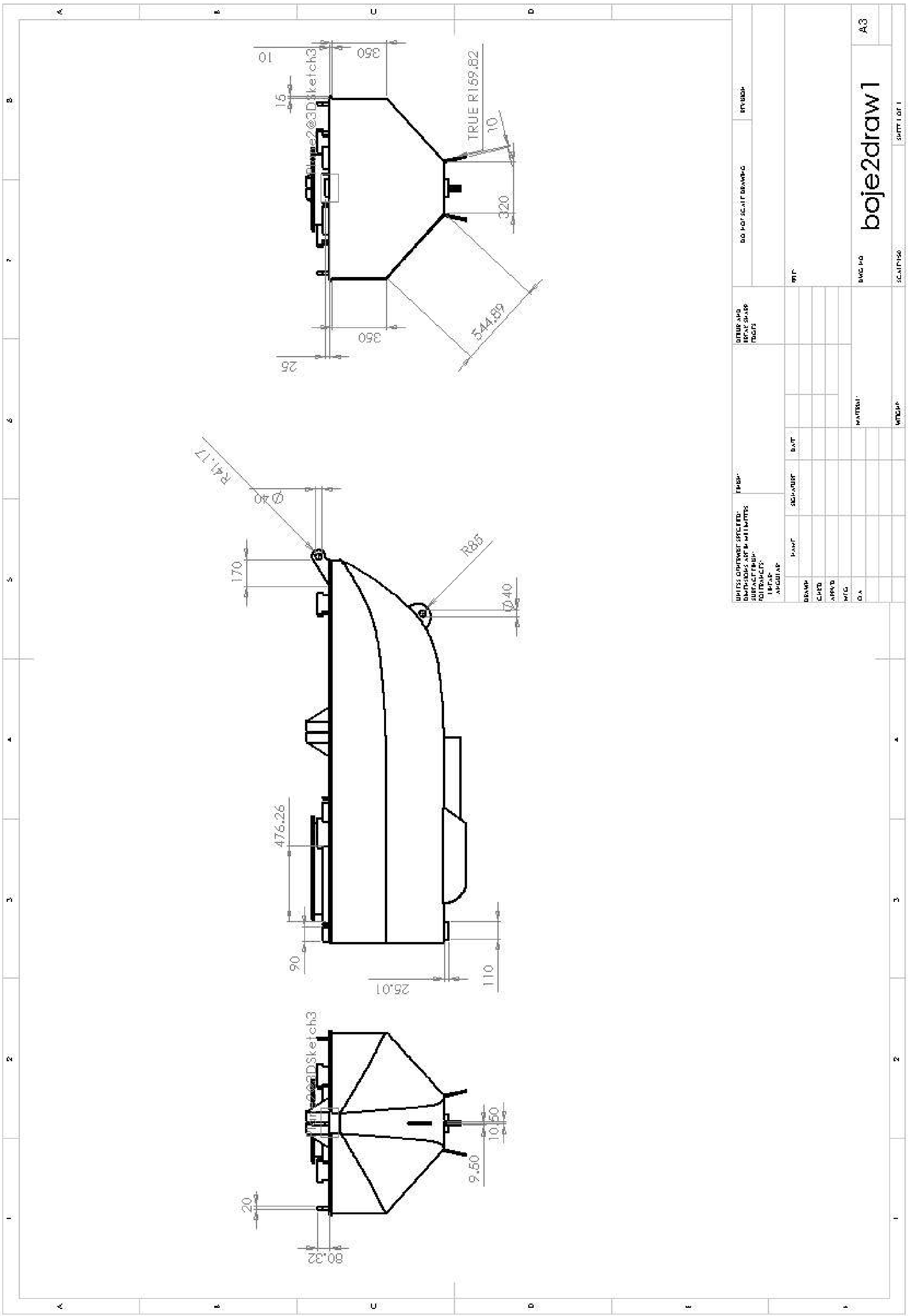
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TRUE R159.82
544.89
350
320
476.26
R85
R41.17
170
90
110
9.50
20
80.32

Appendix 4: Design Research

4.1. Design Research

To ensure that a design that best fits the needs of the circuit design goals, five design options were researched.

4.1.1. Design Option One

Option one assumes that an adequate clock signal for the Programmable Low Pass Filter cannot be generated by the Hercules Board, but a continuous digital output signal can.

The cut-off frequency is controlled with a Programmable Low Pass Filter. To create a clock signal to control this filter, a multiplexer along with a clock generator is added to the circuit. The clock needs a variable resistor to modify the frequency output. A multiplexer is used for a digital variable resistor, but the multiplexer only has eight outputs for the different resistance values. The multiplexer allows for eight different frequencies from the clock and in return allowing for eight different cut-off frequency options for the Programmable Low Pass Filter.

Also a micro switch will be added to the circuit so that the circuit can be manually controlled.

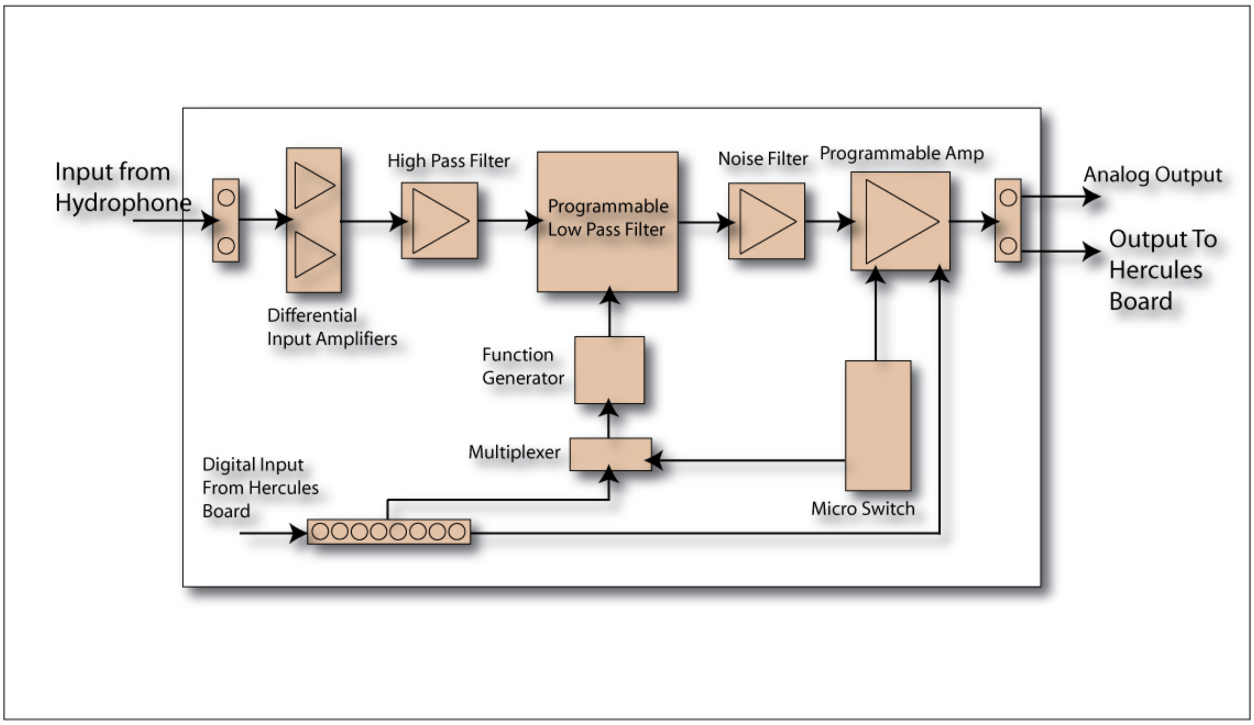

Figure 1: Basic block diagram for Design Option One

The advantage of this system is that both the Programmable Low Pass Filter and the Programmable Gain Amplifier can be controlled digitally with a six bit serial output from the Hercules Board. Another advantage of this option is that the circuit board is fully autonomous. This option simplifies the programming aspect for the Hercules Board, but complicates the Programmable Filtering Circuit as a whole because the multiplexer requires eight resistors.

Option one uses the following active components:

- **Input Amplifier -** INA111 Instrumental Amplifier.
- **High Pass Filter, Noise Filter and Analog Output Amplifier** - TLE2072IP Low Noise.
- **Programmable Low Pass Filter -** LTC1064-2CN Butt 8 order adjustable.
- **Programmable Gain Amplifier -** LTC6910 Digitally Controlled Gains.
- **Clock Generator** - LTC6908-2 Oscillator.
- **Multiplexer -** MM74HC4051N Analog Multiplexer.

4.1.2. Design Option Two

Option two is similar to the option one, but the option two assumes that the digital signal generated by the Hercules Board is not continuous. This discontinuous signal creates a need for digital memory to be added to the board as well.

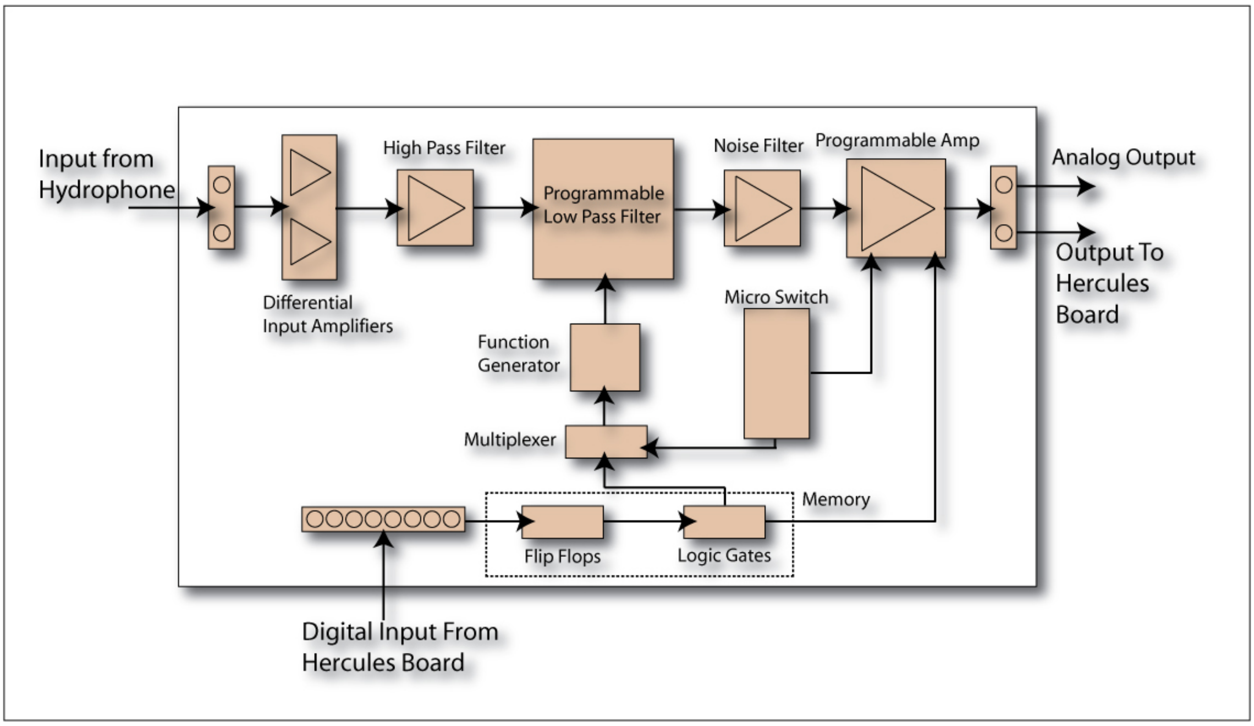

Figure 2: Basic block diagram for Option Two

All the advantages of the option two are the same as for option one. Option two has the disadvantage the additional digital logic memory.

Option two uses the following active components:

- **Input Amplifier -** INA111 Instrumental Amplifier.
- **High Pass Filter, Noise Filter and Analog Output Amplifier -** TLE2072IP Low Noise.
- **Programmable Low Pass Filter -** LTC1064-2CN Butt 8 order adjustable.
- **Programmable Gain Amplifier -** LTC6910 Digitally Controlled Gains.
- **Clock Generator** - LTC6908-2 Oscillator.
- **Multiplexer -** MM74HC4051N Analog Multiplexer.
- **Flip flop and Logic Gates.**

4.1.3. Design Option Three

Option three assumes that an adequate clock signal can be generated from the Hercules Board. This adequate signal will eliminate the multiplexer and oscillator, and the passive elements associated with each.

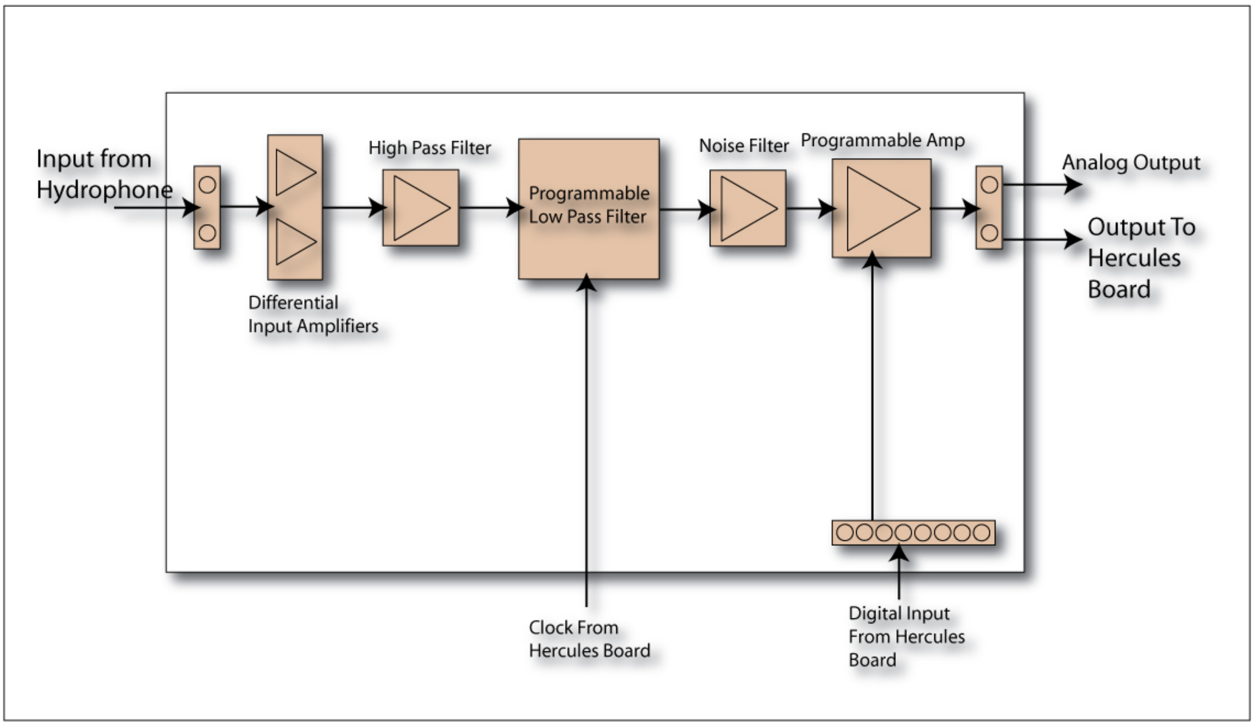

Figure 3: Basic block diagram for Design Option Three

The advantage of option three is that the circuit is greatly simplified, more stable and cheaper to build. A disadvantage is that the circuit is not controlled manually with a micro-switch.

Option Three uses the following active components:

- **Input Amplifier -** INA111 Instrumental Amplifier.
- **High Pass Filter, Noise Filter and Analog Output Amplifier -** TLE2072IP Low Noise.
- **Programmable Low Pass Filter -** LTC1064-2CN Butt 8 order adjustable.
- **Programmable Gain Amplifier -** LTC6910 Digitally Controlled Gains.

4.1.4. Design Option Four

Option four assumes that an adequate clock signal cannot be generated from the Hercules Board. A micro controller is used to generate a clock signal to control the Programmable Low Pass Filter and to control the Programmable Gain Amplifier.

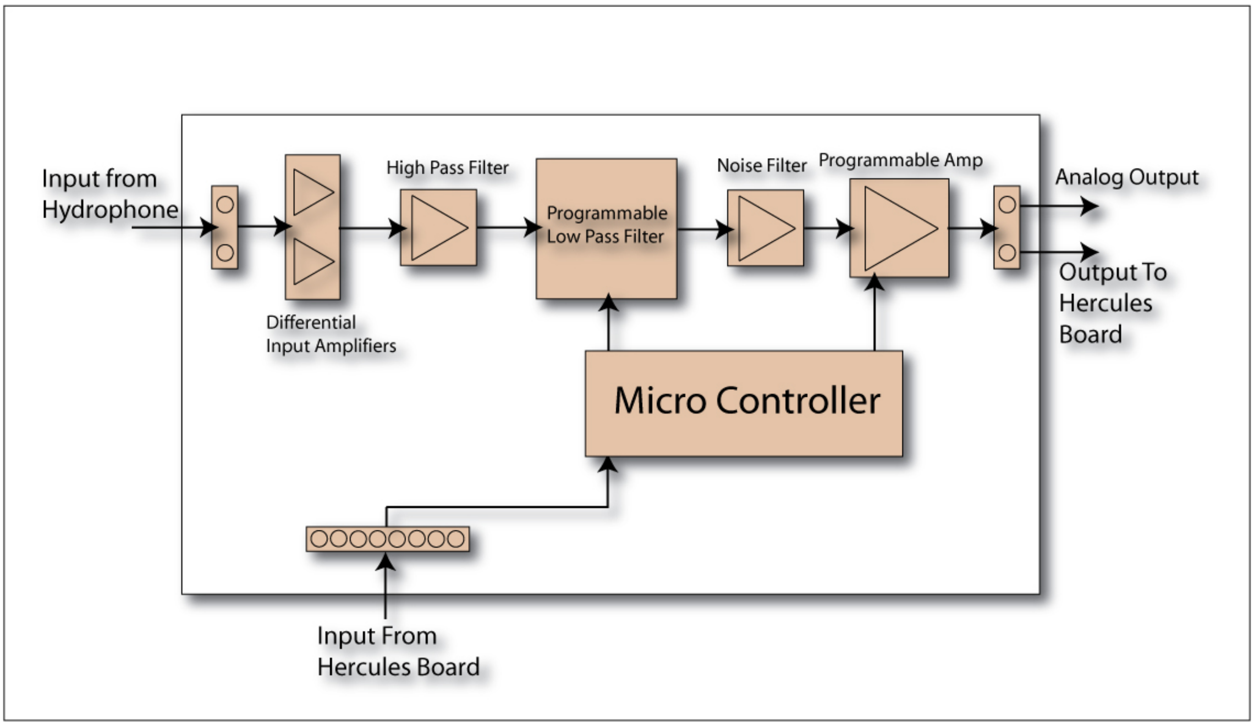

Figure 4: Basic block diagram for Design Option Four

The advantage of this option four is that the design simplifies the circuit by eliminating the multiplexer, clock generator, and memory components. Also communication between the Hercules Board and the Programmable Filtering Circuit will be bidirectional. Other advantages are a greater range of cut-off frequencies for the Programmable Low Pass Filter and the circuit is cheaper to build. A disadvantage of this circuit is that the circuit needs to rely on the Hercules Board and thus not making the circuit autonomous.

Option four uses the following active components:

- **Input Amplifier** - INA111 Instrumental Amplifier.
- **High Pass Filter, Noise Filter and Analog Output Amplifier** - TLE2072IP Low Noise.
- **Programmable Low Pass Filter -** LTC1064-2CN Butt 8 order adjustable.
- **Programmable Gain Amplifier -** LTC6910 Digitally Controlled Gains.
- **Micro-Controller** - PIC16F688 Flashed-Based, 8-Bit.

4.1.5. Design Option Five

Option five is similar to options one and two but option five removes the Programmable Gain Amplifier and replaces it with a multiplexer and a set of resisters attached to the Input Amplifier. This replacement is done because the Programmable Gain amplifier has only four pre-set gains. A multiplexer with a set of resistors allows for a digitally controlled gain that can be set by choosing specific resistors.

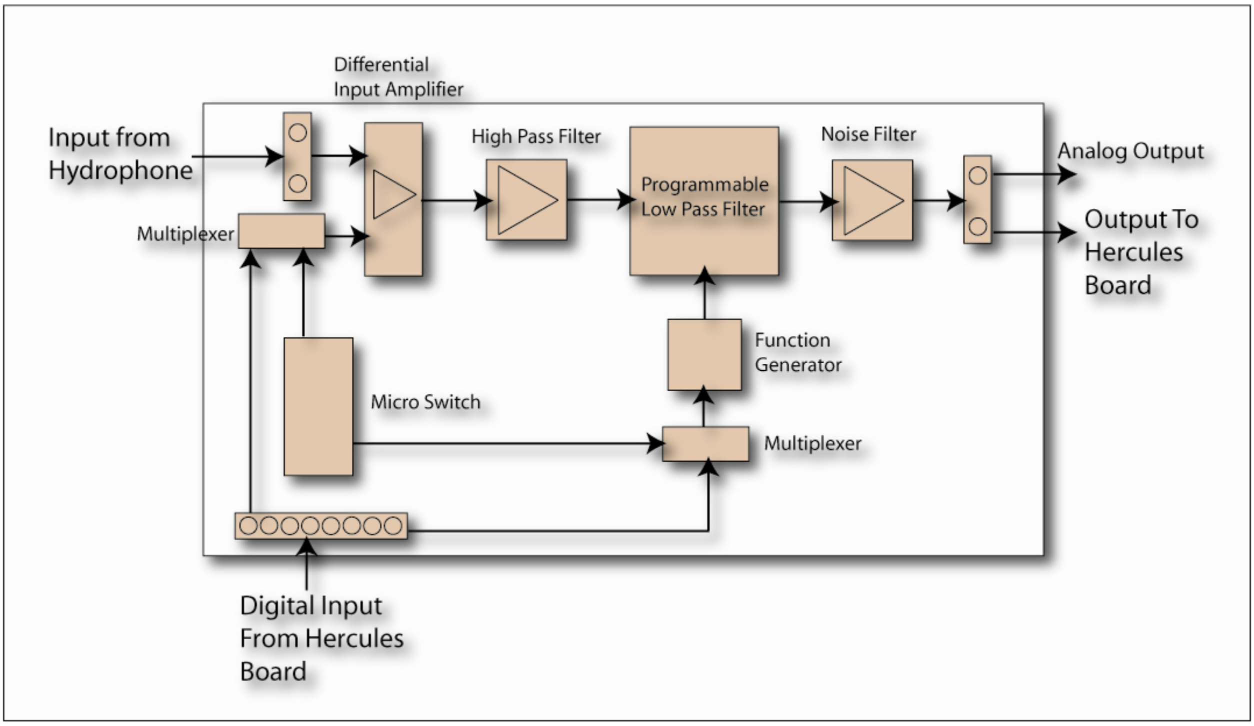

Figure 5: Basic block diagram for Design Option Five

The advantage of this option is the gain values can be set when building the board. Also complications due to soldering the Programmable Gain Amplifier are removed.

Option Five uses the following Components:

- **Input Amplifier -** INA111 Instrumental Amplifier.
- **High Pass Filter, Noise Filter and Analog Output Amplifier -** TLE2072IP Low Noise.
- **Programmable Low Pass Filter -** LTC1064-2CN Butt 8 order adjustable.
- **Clock Generator** - LTC6908-2 Oscillator.
- **Multiplexer -** MM74HC4051N Analog Multiplexer.
- **Differential Multiplexer -** DG409DJZ - 4CH.

Appendix 5: Filter designs from FilterPro

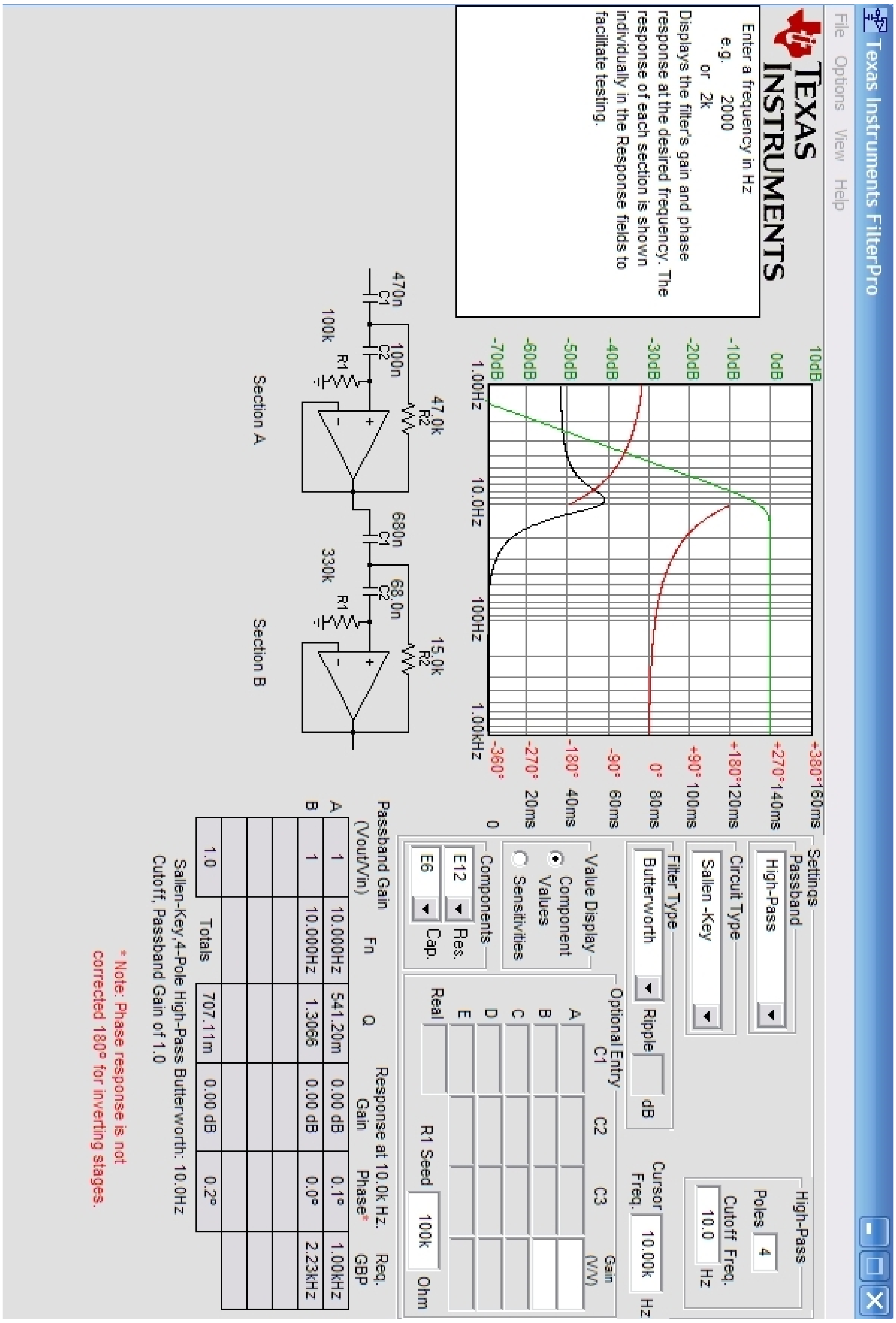

Figure 1 Screen shot from the high pass filter design

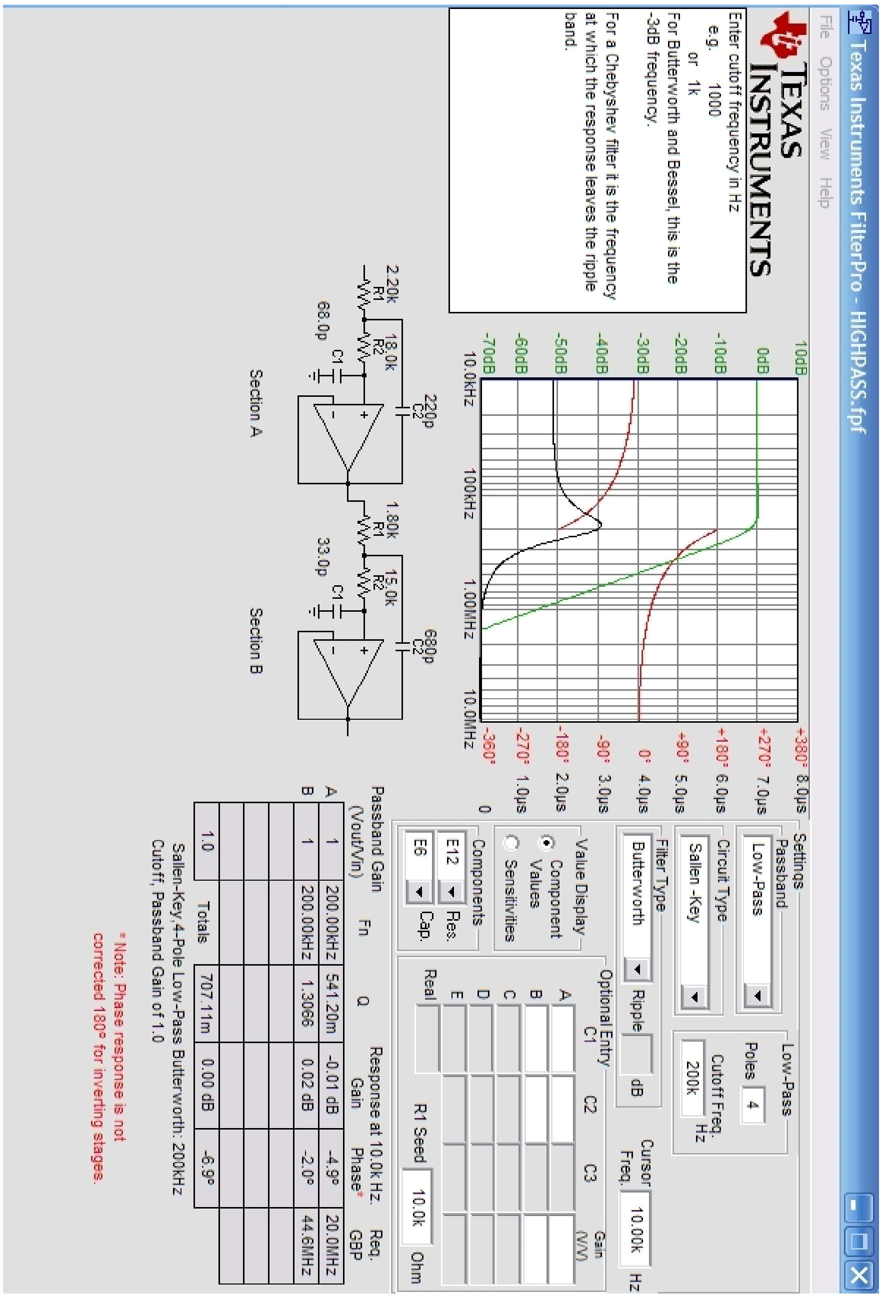

Figure 2 Screen shot from anti-noise filter design

Appendix 6: Orcad Simulations and Schematics

The following are the results from simulations ran with Orcad 16.2 of the input amplifier, output amplifiers, high pass filter and anti-noise. All Orcad files are available on the project CD.

6.1. Input Amplifier Simulation

Figure 1 shows the Input Amplifier Schematic used for the simulation.

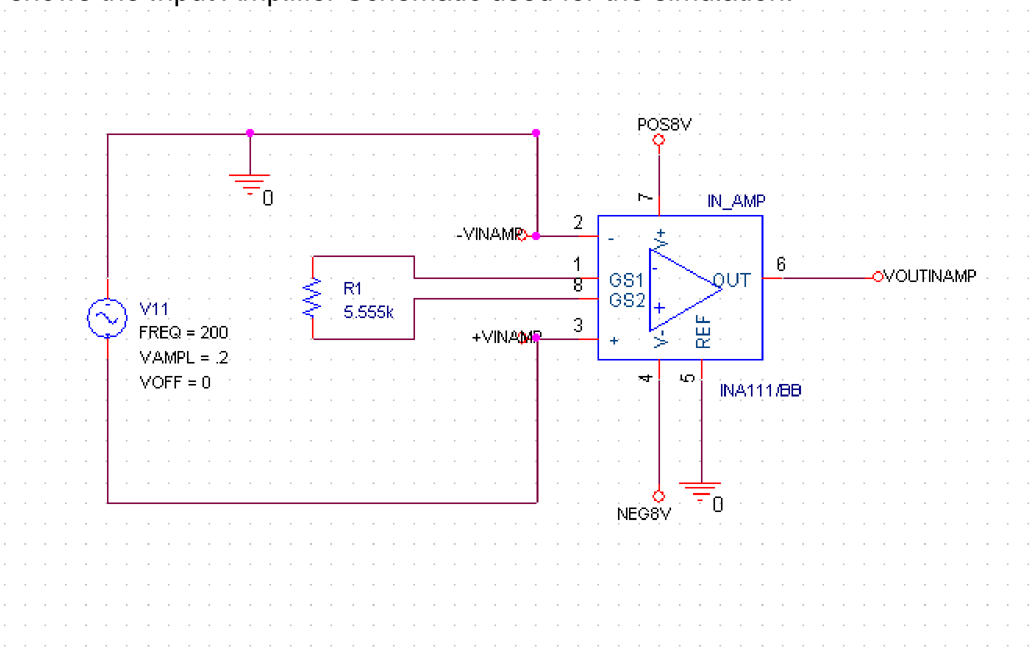

Figure 1: Input Amplifier Schematic drawn in Orcad 16.2

The transient analysis was run on the input amplifier showing that a 2 mV input signal was amplified to a 2 V output signal. This level of output amplification was the expected level with a 5.6 $k\Omega$ resistor in place. The transient analysis is shown in Figure 2.

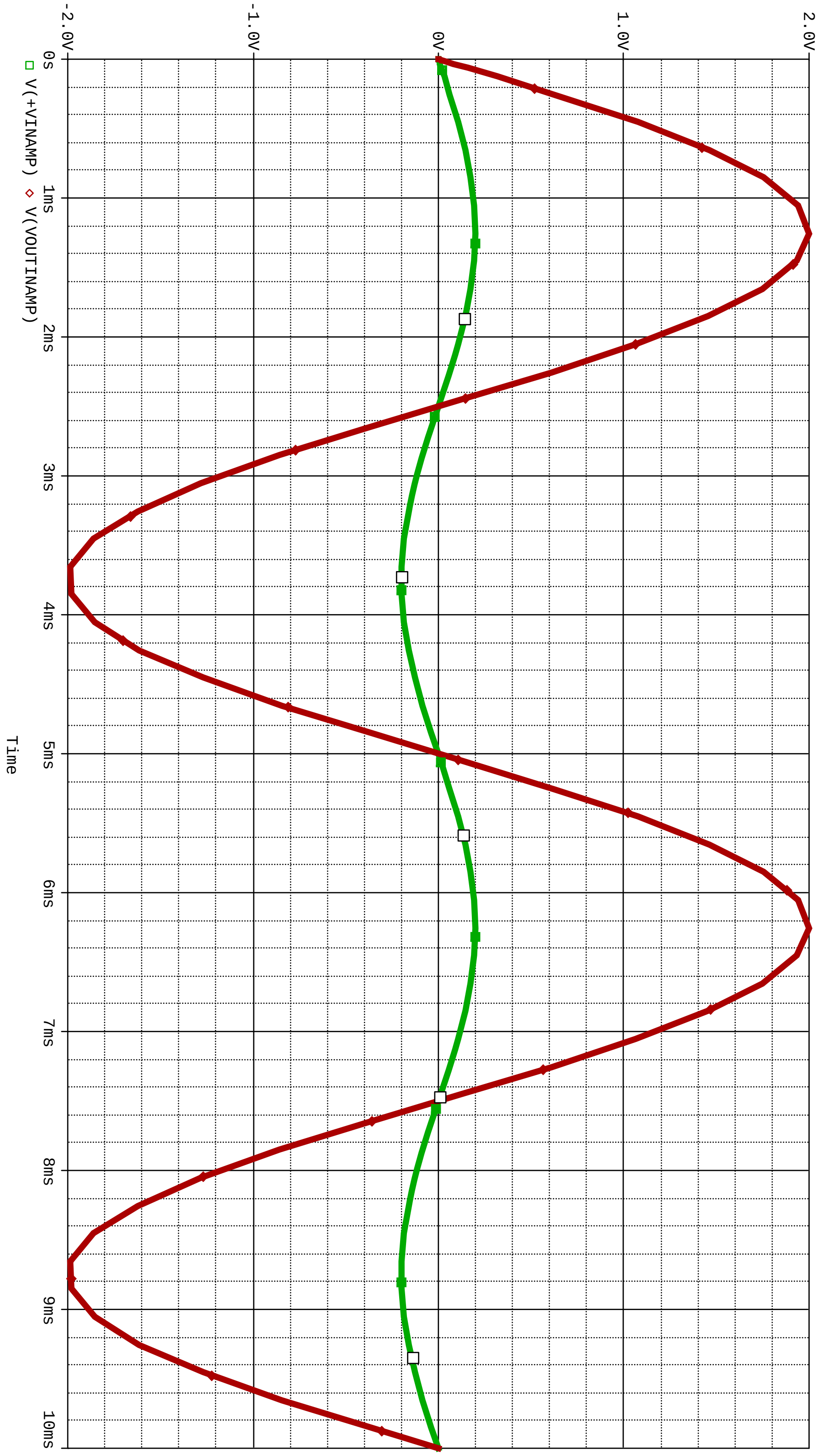

Figure 2: Transient response for the input amplifier from Oracad 16.2

6.2. Output Amplifier Simulation

Figure 3 shows the Output Amplifier (used for both the analog and Hercules Board outputs) schematic used for the simulation.

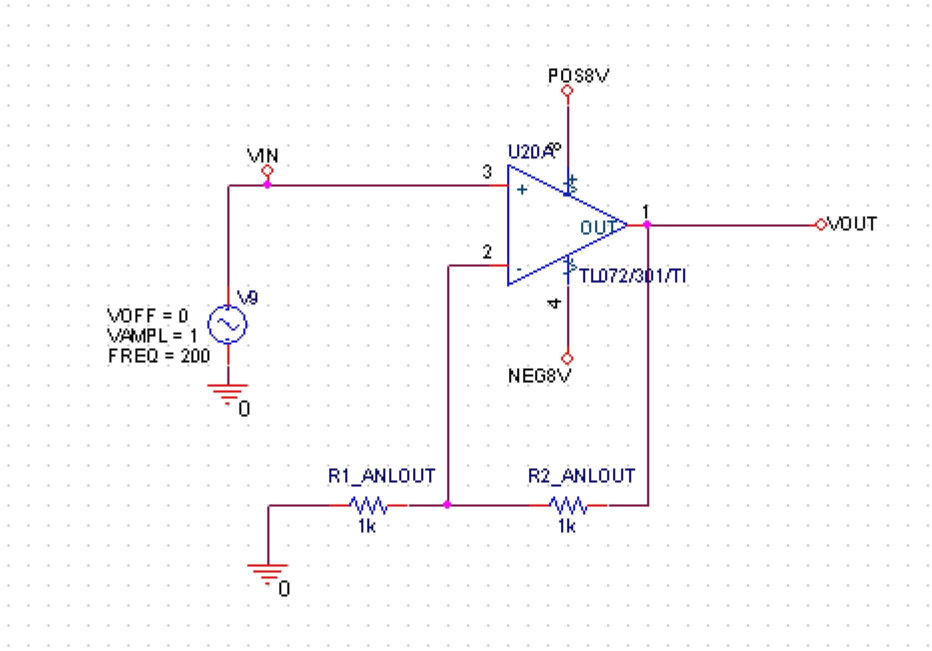

Figure 3: Output Amplifier Schematic drawn in Orcad 16.2

A transient analysis was run on the output amplifier showing that a 1 V input signal was amplified to a 2 V output signal. This level of output amplification was the expected level with the two 5.6 $k\Omega$ resistors in place. The transient analysis is shown in Figure 4.

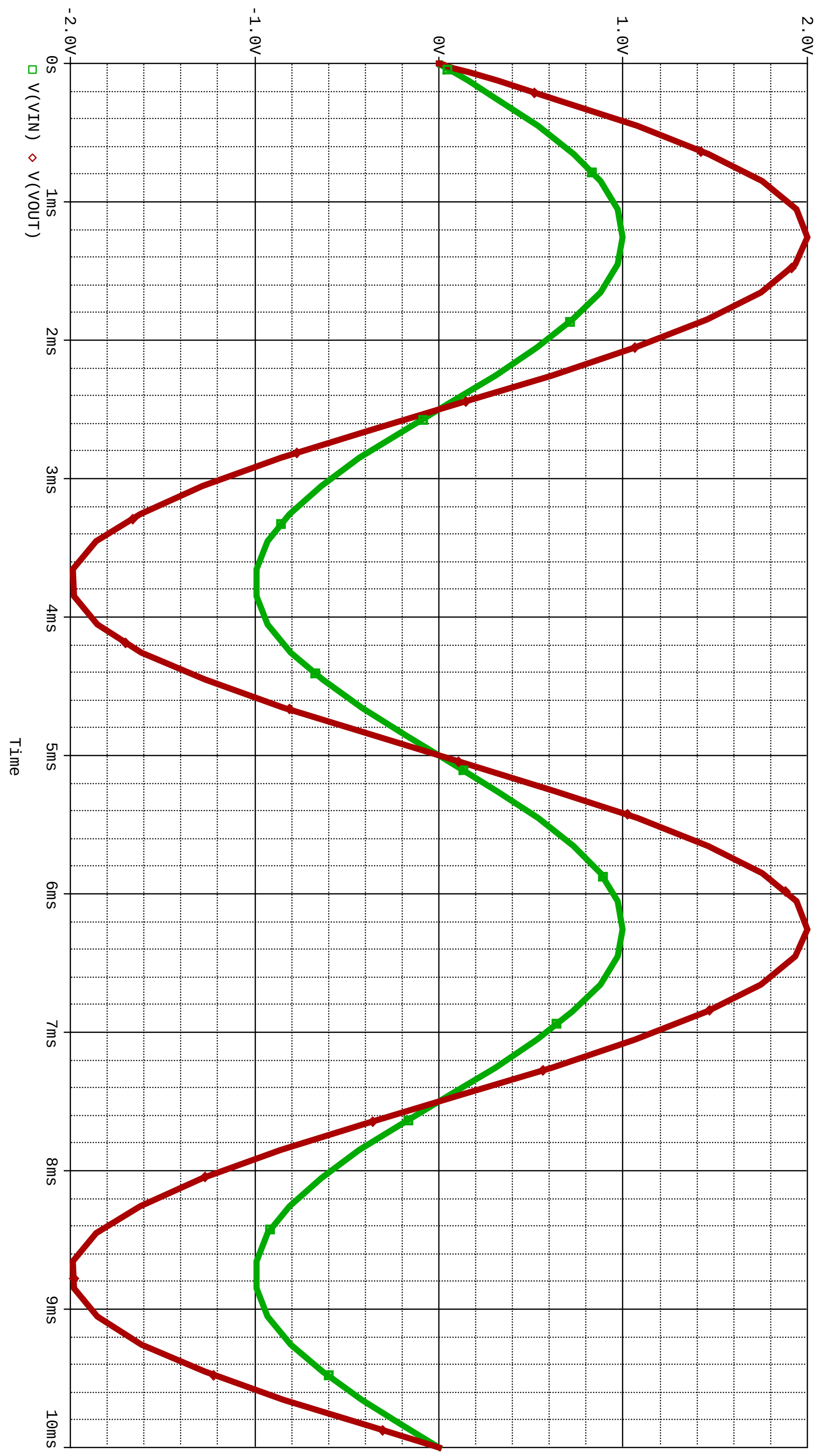

Figure 4: Transient response for the output amplifier from Oracad 16.2

6.3. High Pass Filter Simulation

Figure 5 shows the high pass filter schematic used for the simulation.

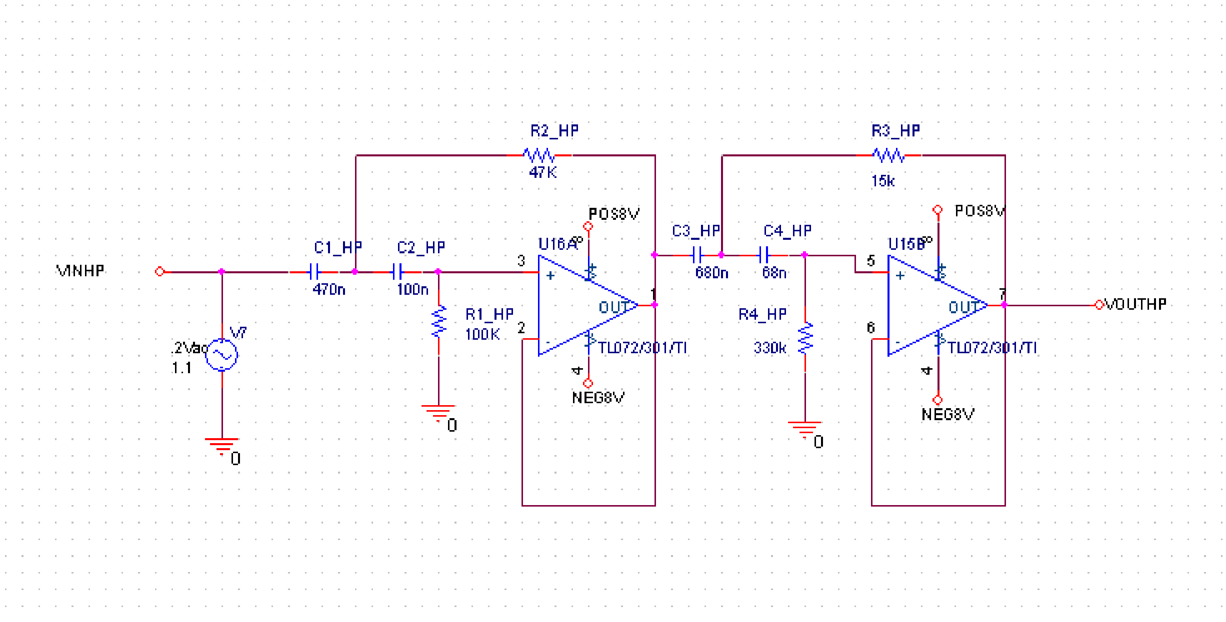

Figure 5: High Pass Filter Schematic drawn in Orcad 16.2

An AC sweep analysis was run on the high pass filter. The sweep revealed a cut-off frequency of 10 Hz. This cut-off frequency was the expected cut-off frequency. An AC sweep analysis is shown in Figure 6.

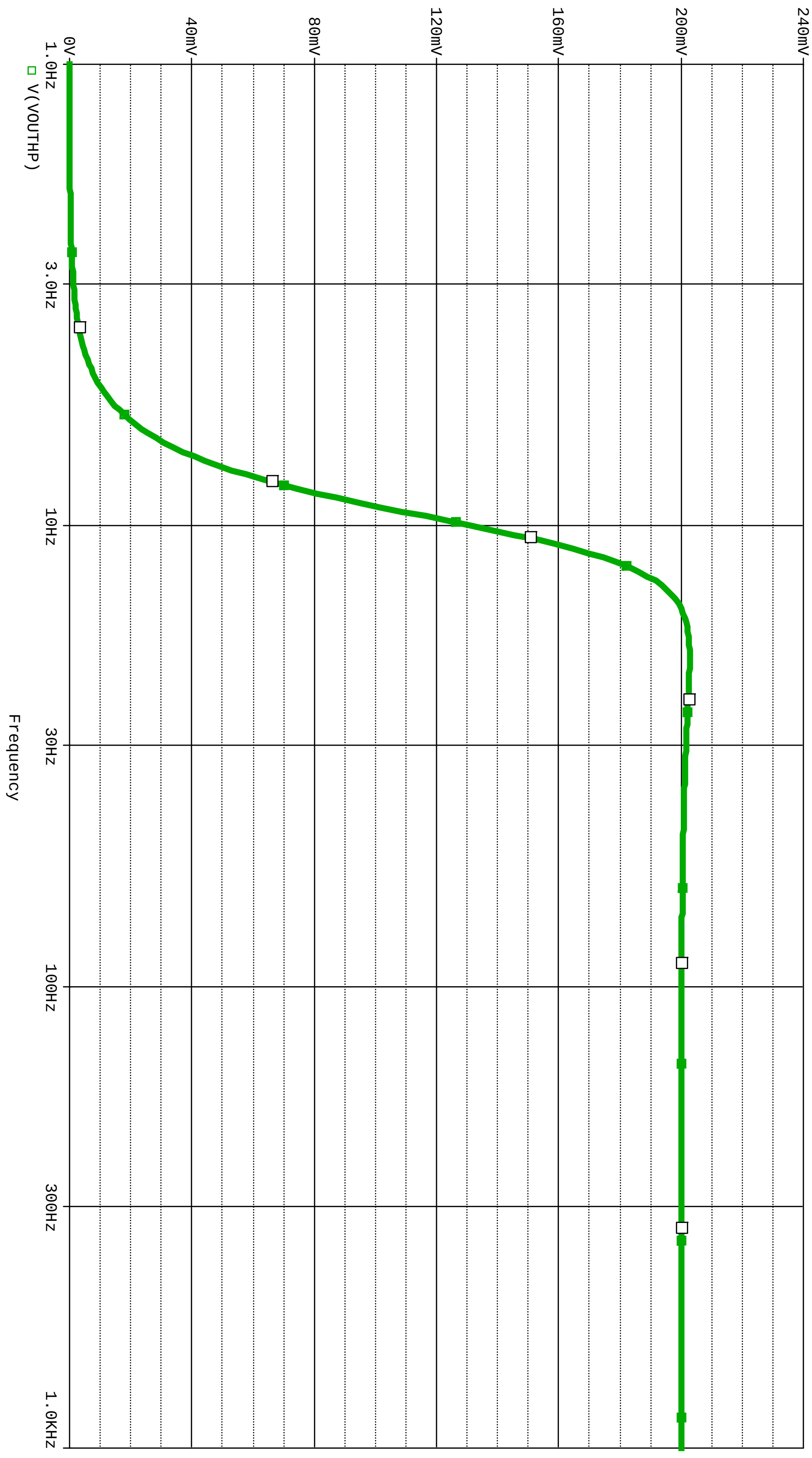

Figure 6: AC Sweep Analysis for the high pass filter from Oracad 16.2

6.4. Anti-Noise Low Pass Filter Simulation

Figure 7 shows the anti-noise low pass filter schematic used for the simulation.

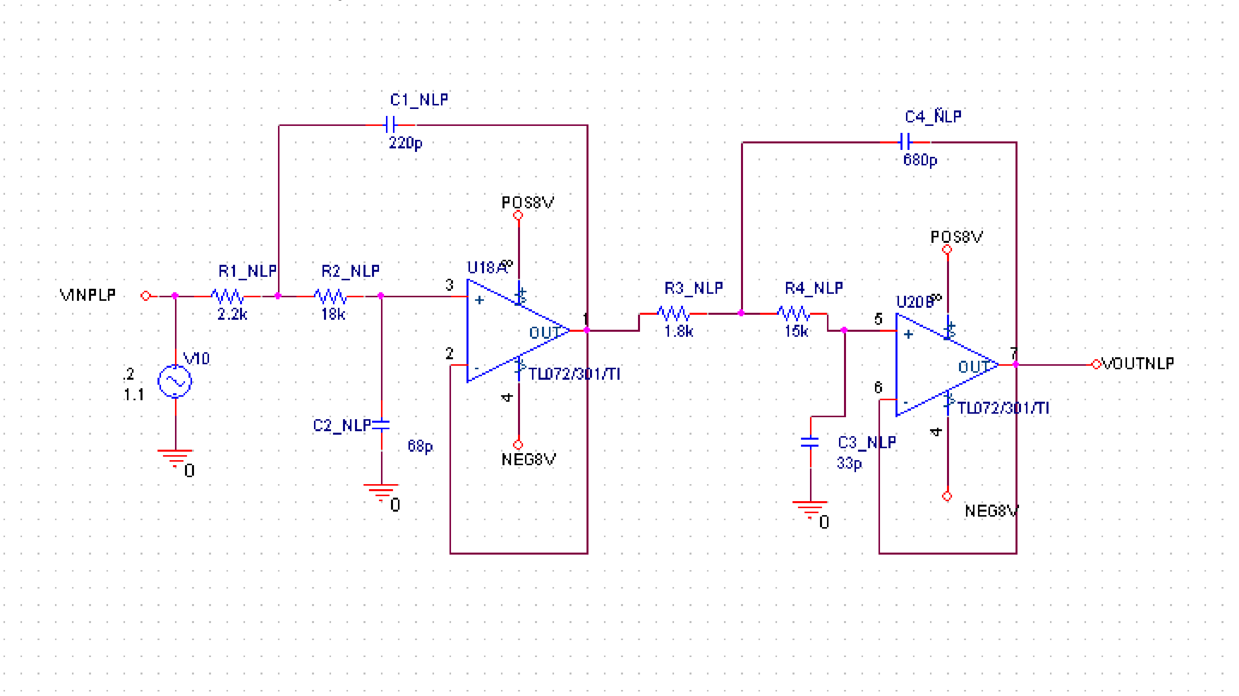

Figure 7: Anti-Noise Low Pass Filter Schematic drawn in Orcad 16.2

An AC sweep analysis was run on the anti-noise low pass filter. The sweep revealed a cut-off frequency of 200 Hz. This cut-off frequency was expected cut-off frequency. An AC sweep analysis is shown in Figure 8.

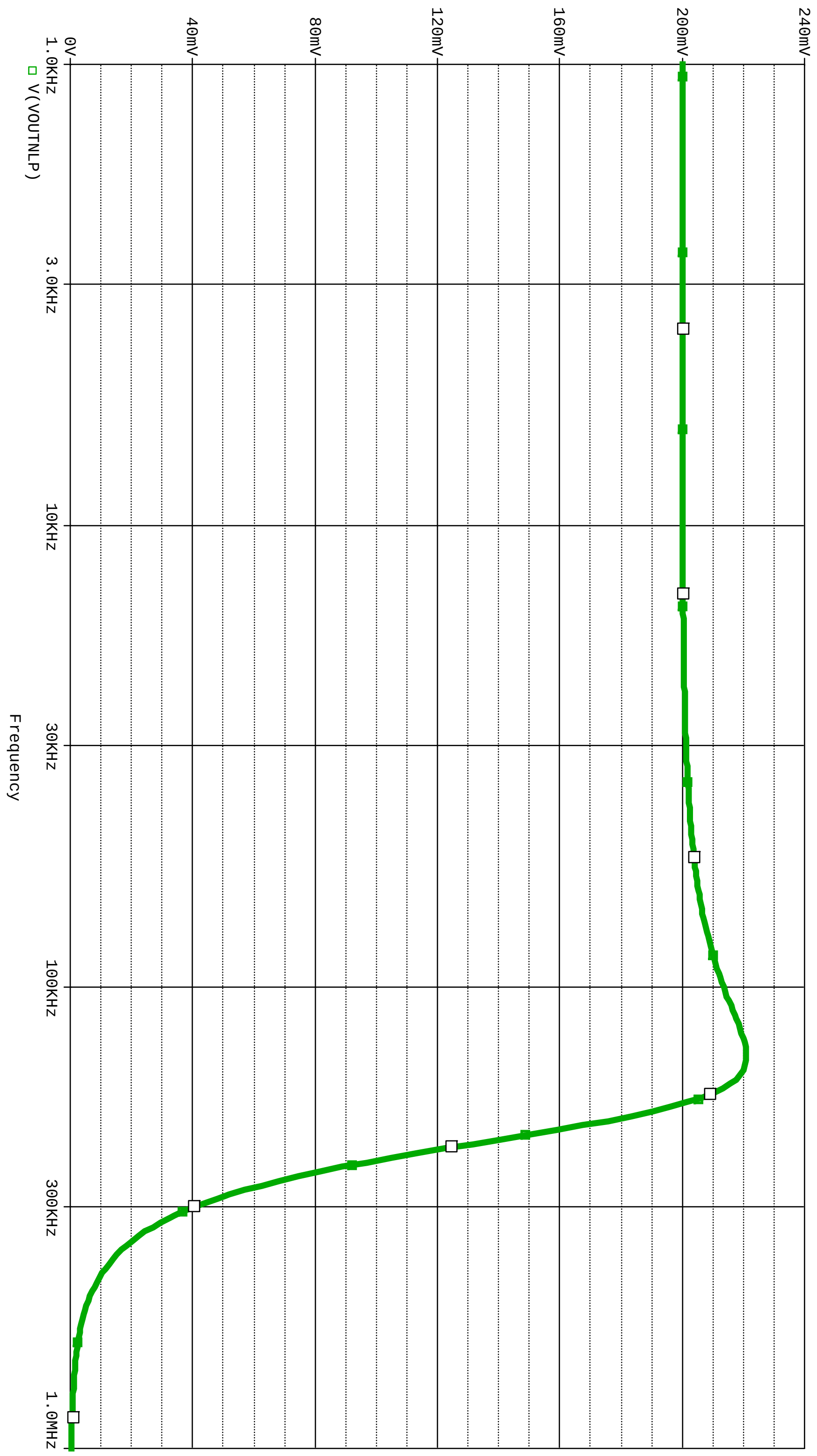

Figure 8: AC Sweep Analysis for the Anti-Noise Low Pass Filter from Oracad 16.2

Figure 9 shows the completed schematic with all components connected.

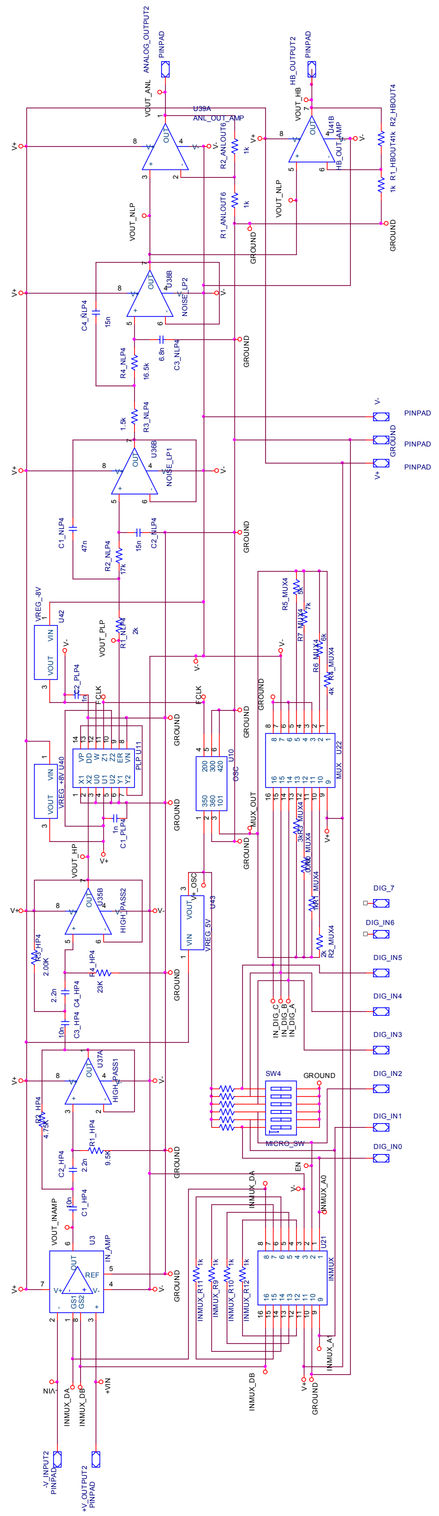

Figure 9: Final schematic drawn with Orcad 16.2

Appendix 7: and Printed Circuit Board Design from Protel

All Protel files used are available in the Protel folder on the AAB Project CD.
Figure 1: Shows the final schematic, including the track corrections associated with the oscillator.
Figure 2 shows the Printed Circuit Board Design, not including the track corrections associated with the oscillator.

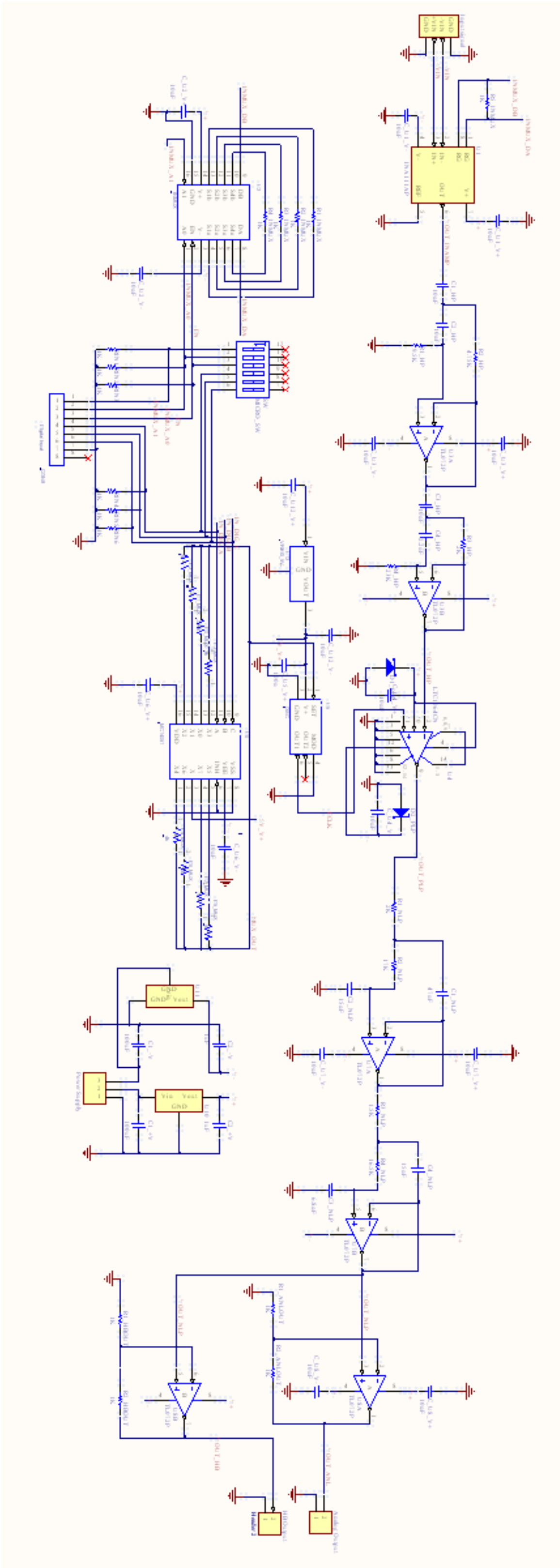

Figure 1: Schematic from Protel

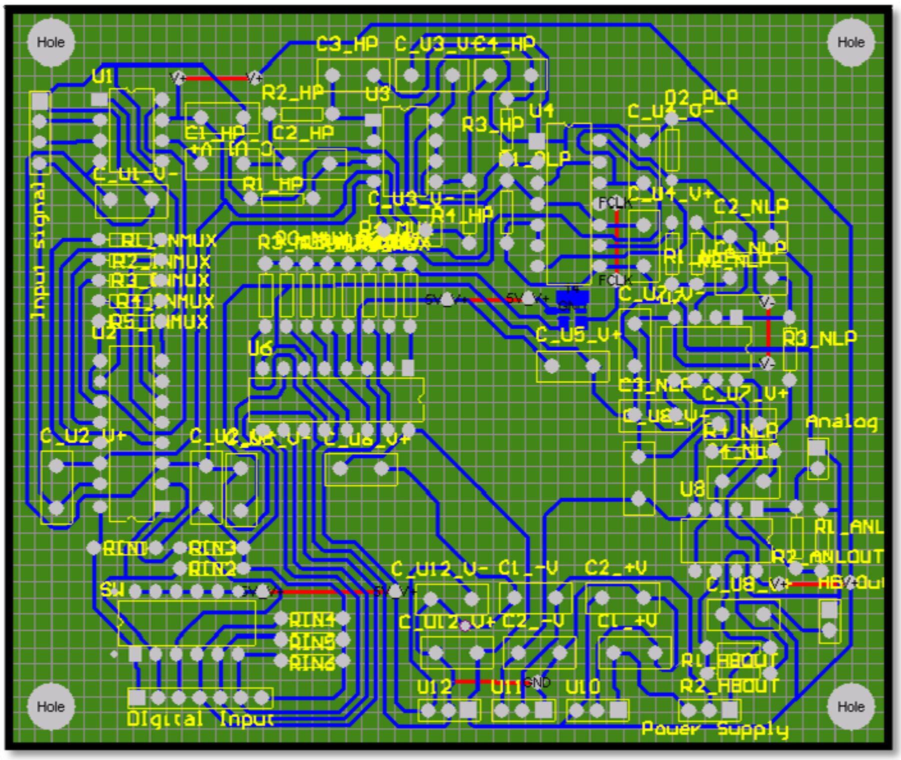

Figure 2: Printed Circuit Board Design from Protel

Appendix 8: Programmable Circuit Board Test Results

While testing the board, a misconnection in the PCB design of the board was discovered. Unfortunately, this misconnection broke the oscillator. Also an error in the differential multiplexer placement broke the differential input multiplexer. Thus, testing was done under the following conditions:

- A function generator was used to simulate the clock signal from oscillator.
- Wire jumpers were used in the place of the differential multiplexer.
- A 200.00 mV Peak-to-Peak differential input signal from a function generator was used to simulate the input signal from the hydrophone.

8.1. Test 1: Component Gains

Gains were recorded at each amplifying and filtering component across the board at minimum, medium, and maximum input gains with the corresponding cut-off frequencies as shown in table 1.

Level	Input G_{dB} (dB)	$f_{Cut-off}$ (MHz)
Minimum	0.00	5.00
Medium	20.00	60.00
Maximum	40.00	120.00

Table 1: Input gain levels with corresponding cut-off frequencies

Table 2 shows that the signal's gain remains relatively constant throughout the entire circuit board.

	Vin	0.2			0.2			0.2		
	Fin	1 KHz			40 KHz			100 KHz		
		Minimum			**Medium**			**Maximum**		
Tag	**Component**	**Vout (V)**	**Gain (V/V)**	**Gain (dB)**	**Vout (V)**	**Gain (V/V)**	**Gain (dB)**	**Vout (V)**	**Gain (V/V)**	**Gain (dB)**
U1	In.Amp	0.27	1.35	2.60667537	1.91	9.55	19.60006743	12.1	60.5	35.63510749
U3	HP	0.272	1.36	2.670778167	1.91	9.55	19.60006743	11.9	59.5	35.49033931
U4	PLP	0.196	0.98	-0.175478486	1.73	8.65	18.74032215	11.8	59	35.41704023
U7	Noise Filter	0.199	0.995	-0.043538385	1.73	8.65	18.74032215	11.4	57	35.11749711
U8	Out Amp	0.184	0.92	-0.724243453	1.73	8.65	18.74032215	11.4	57	35.11749711

Table 2: Component gains at varying input gain levels

8.2. Test 2: Gain v. Input Frequency

Figure 1 shows the output gain with each set input gain at all frequencies. All gains remain relatively constant all frequencies with slight attenuation at higher frequencies. This attenuation was expected base on information from the LTC64-2 datasheet. Also the input gain of 40 dBs only produces a 35 dB gain. This loss of gain is attributed to limitation set by the having a 12 V power supply. All data points and calculation associated with this test are available in Appendix *.

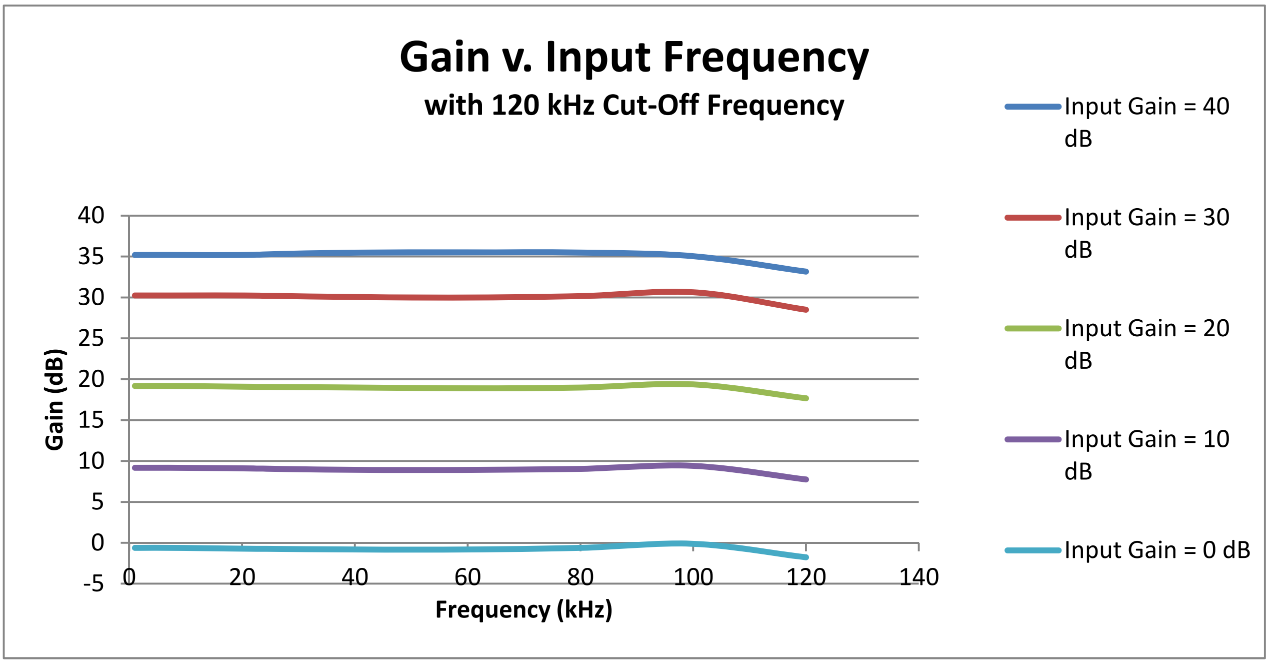

Figure 1: Gain v. Input Frequency with varying input gains

Tables 3, 4, 5 and 6 show the output gains at every cut-off frequency with varying input gains.

Frequency (KHZ)	Vout (V)	Gain (V/V)	Gain (dB)
1	0.186	0.93	-0.63034103
5	0.186	0.93	-0.63034103
10	0.186	0.93	-0.63034103
20	0.184	0.92	-0.72424345
40	0.182	0.91	-0.81917215
60	0.182	0.91	-0.81917215
80	0.186	0.93	-0.63034103
100	0.197	0.985	-0.13127539
120	0.163	0.815	-1.77684783

Table 3: Outputs gains with 0 dB input gain

Frequency (KHZ)2	Vout (V)	Gain (V/V)	Gain (dB)
1	0.574	2.87	9.157637935
5	0.574	2.87	9.157637935
10	0.574	2.87	9.157637935
20	0.57	2.85	9.0968972
40	0.558	2.79	8.912084065
63	0.558	2.79	8.912084065
82	0.566	2.83	9.03572871
100	0.59	2.95	9.39644032
122	0.488	2.44	7.747796527

Table 4: Outputs gains with 10 dB input gain

Frequency (KHZ)6	Vout (V)	Gain (V/V)	Gain (dB)
1	1.82	9.1	19.18082785
5	1.82	9.1	19.18082785
10	1.82	9.1	19.18082785
20	1.8	9	19.08485019
40	1.78	8.9	18.98780013
60	1.76	8.8	18.88965344
80	1.78	8.9	18.98780013
99	1.86	9.3	19.36965897
118	1.53	7.65	17.6732287
122	0.488	2.44	7.747796527

Table 5: Outputs gains with 20 dB input gain

Frequency (KHZ)9	Vout (V)	Gain (V/V)	Gain (dB)
1	6.5	32.5	30.23766722
5	6.5	32.5	30.23766722
10	6.5	32.5	30.23766722
20	6.5	32.5	30.23766722
40	6.36	31.8	30.0485424
60	6.32	31.6	29.99374165
80	6.44	32.2	30.15711743
100	6.8	34	30.62957834
120	5.32	26.6	28.49763273

Table 6: Outputs gains with 30 dB input gain

Frequency (KHZ)12	Vout (V)	Gain (V/V)	Gain (dB)
1	11.5	57.5	35.19335689
5	11.5	57.5	35.19335689
10	11.5	57.5	35.19335689
20	11.5	57.5	35.19335689
40	11.9	59.5	35.49033931
60	11.9	59.5	35.49033931
80	11.9	59.5	35.49033931
100	11.3	56.5	35.04096896
120	9.1	45.5	33.16022793

Table 7: Outputs gains with 40 dB input gain

8.3. Test 3: Frequency Responses

The frequency response was measured at four different cut-off frequencies. The result produced the desired frequency response. Figures 2, 3, 4 and 5 the frequency responses for various cut-off frequencies.

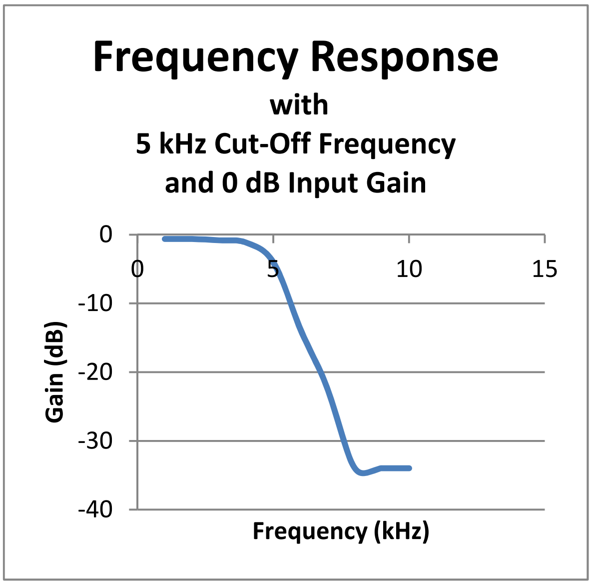

Figure 2: Frequency response with a 5 kHz cut-off frequency

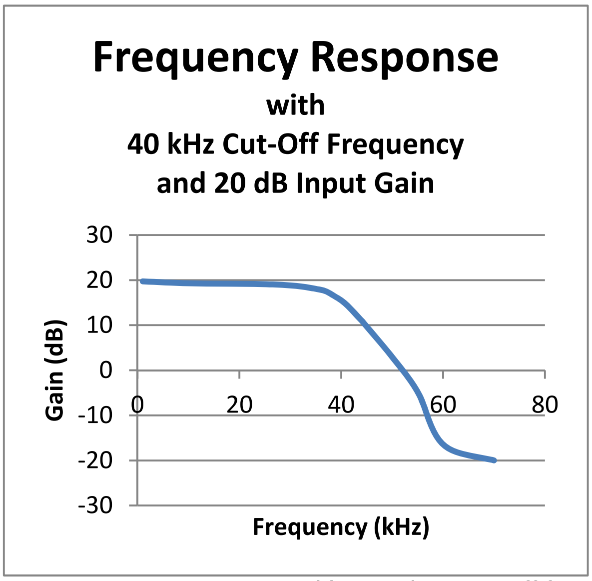

Figure 3: Frequency response with a 40 kHz cut-off frequency

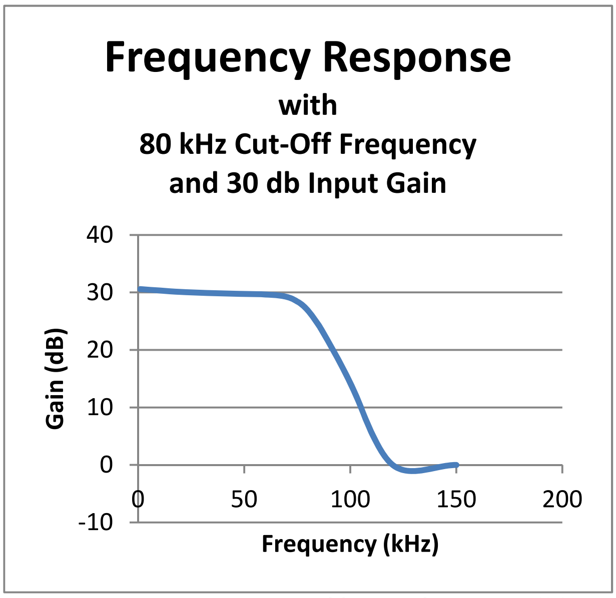

Figure 4: Frequency response with a 80 kHz cut-off frequency

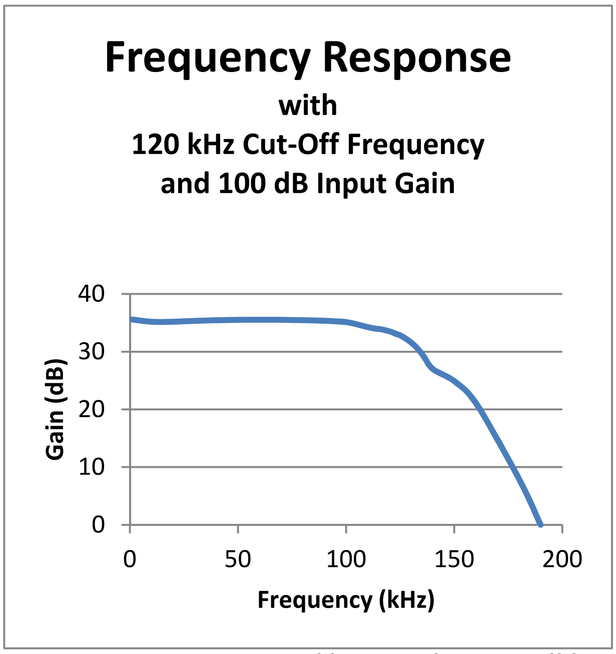

Figure 5: Frequency response with a 120 kHz cut-off frequency

Tables 8, 9, 10 and 11 shows that data points collected while testing.

Input Frequency	Vout	Gain (V/V)	Gain (dB)
1	0.186	0.93	-0.63034103
2	0.186	0.93	-0.63034103
3	0.182	0.91	-0.81917215
4	0.175	0.875	-1.15983894
5	0.126	0.63	-4.01318901
6	0.041	0.205	-13.7649228
7	0.015	0.075	-22.4987747
8	0.004	0.02	-33.9794001
9	0.004	0.02	-33.9794001
10	0.004	0.02	-33.9794001

Table 8: Data points with 5 kHz cut-off frequency

Input Frequency	Vout	Gain (V/V)	Gain (dB)
1	1.936	9.68	19.71751
10	1.84	9.2	19.27576
20	1.82	9.1	19.18083
30	1.75	8.75	18.84016
36	1.56	7.8	17.84189
37	1.5	7.5	17.50123
38	1.4	7	16.90196
39	1.29	6.45	16.19119
40	1.19	5.95	15.49034
41	1.07	5.35	14.56708
42	0.94	4.7	13.44196
43	0.815	4.075	12.20255
44	0.71	3.55	11.00457
45	0.61	3.05	9.685997
50	0.28	1.4	2.922561
55	0.115	0.575	-4.80664
60	0.03	0.15	-16.4782
70	0.02	0.1	-20

Table 9: Data points with 40 kHz cut-off frequency

Input Frequency	Vout	Gain (V/V)	Gain (dB)
1	6.77	33.85	30.59117
20	6.4	32	30.103
40	6.2	31	29.82723
60	6.08	30.4	29.65747
70	5.8	29	29.24796
76	5.16	25.8	28.23239
77	5	25	27.9588
78	4.8	24	27.60422
79	4.64	23.2	27.30976
80	4.44	22.2	26.92706
81	4.16	20.8	26.36127
82	3.96	19.8	25.9333
83	3.76	18.8	25.48316
84	3.52	17.6	24.91025
85	3.32	16.6	24.40216
90	2.32	11.6	21.28916
95	1.56	7.8	17.84189
100	1.04	5.2	14.32007
120	0.2	1	0
150	0.2	1	0

Table 10: Data points with 80 kHz cut-off frequency

Input Frequency	Vout	Gain (V/V)	Gain (dB)
1	12.03	60.15	35.58471
10	11.5	57.5	35.19336
20	11.5	57.5	35.19336
40	11.9	59.5	35.49034
60	11.9	59.5	35.49034
80	11.9	59.5	35.49034
100	11.4	57	35.1175
110	10.3	51.5	34.23614
117	9.84	49.2	33.8393
118	9.72	48.6	33.73273
119	9.64	48.2	33.66094
120	9.5	47.5	33.53387
121	9.38	46.9	33.42346
122	9.22	46.1	33.27402
123	9.04	45.2	33.10277
124	8.92	44.6	32.9867
125	8.76	43.8	32.82948
130	7.64	38.2	31.64127
135	6.1	30.5	29.686
140	4.5	22.5	27.04365
150	3.52	17.6	24.91025
160	2.28	11.4	21.1381
180	0.5	2.5	7.9588
190	0.2	1	0

Table 11: Data points with 120 kHz cut-off frequency