audima

December 16, 2011

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Post Mortem for Bluetooth Hearing Aid *HAB-1*

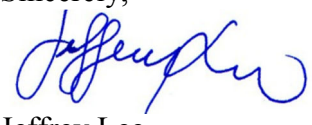
Dear Dr. Rawicz,

After four busy months, the engineers at Audima Inc. have finally completed the first prototype of the Audima HAB-1 Bluetooth hearing aid. Enclosed is the Post Mortem, describing the final modifications of design and implementation of our prototype.

In this document, the final state of our device will be covered in detail. Deviations from the original specifications as listed in our function and design specification documents will also be noted here. Future plans for the company and this line of hearing aid will also be briefly explained. The actual budget and timeline will also be compared with the original estimate for reflection purposes. Furthermore, personal experiences throughout the project will be discussed by each of the members on the team.

Audima Inc. consists of four individuals with Systems, Electronics, and Biomedical Engineering background: Jeffrey Lee, Kevin Wong, Eric Zhou, and Ali Pourghadiri. For further inquiries about our company and proposal, please contact Jeffrey Lee via e-mail at jal19@sfu.ca or by phone at (604)765-9428.

Sincerely,



Jeffrey Lee
Chief Executive Officer
Audima Inc.

Enclosure: Post Mortem for Bluetooth Hearing Aid HAB-1

Project Proposal for Bluetooth Hearing Aid *HAB-1*

Company Team
Jeffrey Lee
Kevin Wong
Eric Zhou
Ali Pourghadiri

Contact Person
Jeffrey Lee
jal19@sfu.ca

Submitted To
Dr. Andrew Rawicz – ENSC 440
Mike Sjoerdsma – ENSC 305
School of Engineering Science
Simon Fraser University

Issue Date
December 16, 2011

Table of Contents

List of Figures

List of Tables

Glossary

CEO	Chief Executive Officer
CFO	Chief Financial Officer
COO	Chief Operating Officer
CTO	Chief Technical Officer
HAB-1	Hearing Aid Bluetooth ver. 1
IC	Integrated Circuit
LED	Light Emitting Diode
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
SPDT	Single Pole Double Throw

1. Introduction

The Audima HAB-1 Bluetooth hearing aid is a small-integrated electronic device that amplifies both environmental sound and the sound from a cellular phone to enhance hearing for the hearing-impaired. This device was conceived as a means of assisting people with hearing loss to more conveniently communicate on their cellular devices without the use of wired accessories. The completed prototype will be discussed, outlining its final functions and designs as well as any deviations from the originally proposed plans. An analysis of the project budget and timeline will be included, as well as reflections from each member of the Audima Inc. team.

2. Current State of the Device

The device is composed of two main components: the hearing aid and the Bluetooth. Each component has its own switch to turn on and off, allowing them to be able to function independently of each other. A switch is used toggle between both components, controlling which one the user hears. A standard 3.7V battery is required to power the device. A red LED will light up when the hearing aid component is turned on, and a blue LED for the Bluetooth component. Since both components can be controlled independently of each other, both components can also be turned on at the same time, allowing the user to connect the device to his cellular phone even if the Bluetooth component is not actively in use. As a call comes through, the user can easily change to Bluetooth mode, seamlessly allowing him to quickly answer the phone through this device. Two microphones are used in the device: one for picking up all environmental sounds for the hearing aid, and the other for picking up the user's voice while speaking on the phone.

2.1 Hearing Aid

The hearing aid component is responsible for amplifying environmental sound and transmitting it to the user's eardrum. The PCB board of this component is assembled based on the schematic diagram shown below.

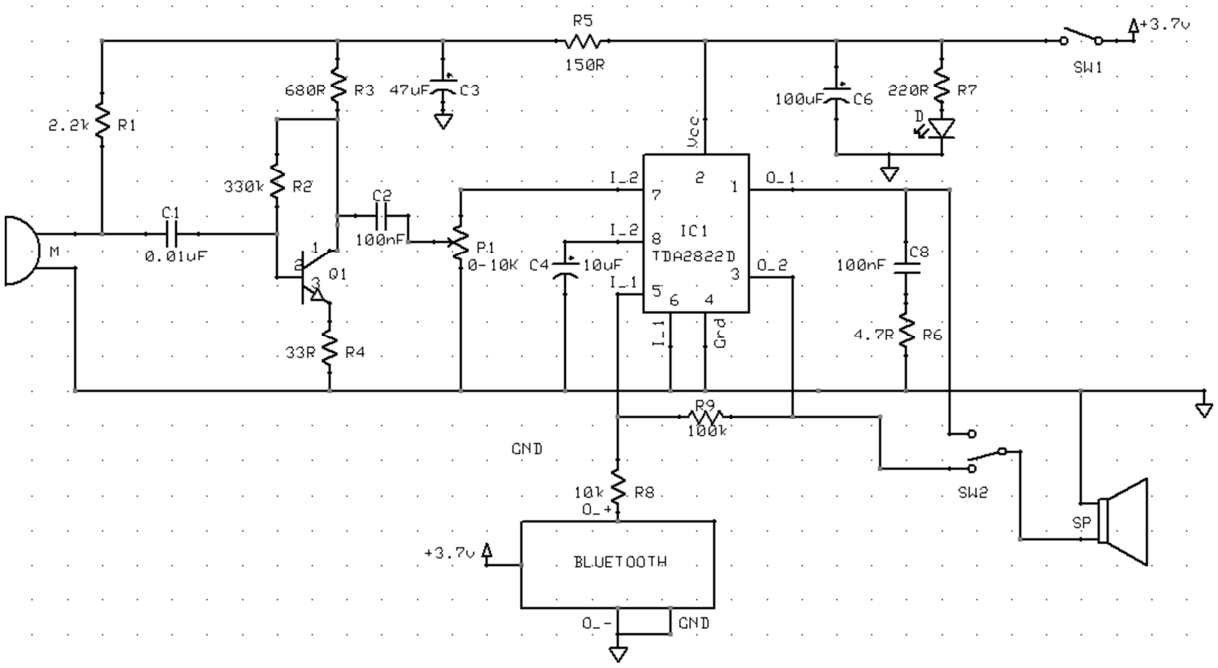


Figure 1: HAB-1 System Electronic Schematic Diagram

As figure 1 shows, transistor Q1 and its associated components form the audio signal preamplifier for the acoustic signals picked up by the condenser microphone, M, and converts them into corresponding electrical signals. The audio output from the preamplifier stage is fed to the input of the medium-power amplifier circuit via capacitor C2 and volume control P1.
The medium-power amplifier section is wired around the popular audio amplifier IC TDA2822D. Here the IC is wired in bridge configuration to drive the speaker earphone through switch-mode SW2. The output of the amplifier for hearing aid component transmits from PIN 1 to the speaker earphone through the switch SW2. If the switch SW2 is set at hearing aid mode, the speaker provides the amplified environmental sound to the user's ear. Red LED (D) indicates the power status. The audio output of this circuit is 10 to 15mW and the quiescent current drain is below 1 mA.

2.2 Bluetooth

The Bluetooth component is responsible for providing the sound output from a cell-phone to the user's ear. In the Audima HAB-1, the Bluetooth headset used is the Jabra BT2043. Its battery can withstand 8 hours of talk time and 10 days of standby time, and its signal range is 10 metres. This model has only one button which is used for powering up the Bluetooth headset component. A blue LED will turn on to indicate that the Bluetooth has been powered on. Once the mode is changed to Bluetooth mode using the switch SW2, as shown in figure 1, and the Bluetooth headset component is paired with the user's cell phone, the sound output from Bluetooth headset is transmitted to the second input of the audio amplifier IC TDA2822D at PIN 5. The amplified sound output is then sent from PIN 3 to the speaker earphone through the switch SW2.

2.3 User Interface

The device consists of two switches, one button, a volume control, and one red and one blue LED light. One of the switches, labeled M and O, powers the hearing aid. M stands for the device being on and O stands for the opposite of that. Another switch, labeled H and B, is responsible to change modes between hearing aid and Bluetooth headset components. There is also a separate button to independently power on and off the Bluetooth component of the device. The volume control increases and decreases the gain of the device. The red LED light turns on when the hearing aid is powered up and turns off otherwise. Likewise, the blue LED indicates the power status of the Bluetooth.

3. Deviation from Proposed System

3.1 System

The Audima HAB-1 was able to satisfy most of the system requirements. However, there were a few deviations from the proposed specifications. Requirement [R15-I][1] was not satisfied because the SPDT switch and the volume control have no feedback. Requirement [R17-II][1] was not satisfied because programming beeping sounds would require more expensive hardware. Requirement [R19-III][1] was not satisfied because we did not submit our device for FDA approval. Finally, our device does not beep when the battery requires charging or when modes are changing.

3.2 Hearing Aid

The hearing aid unit that we created was able to satisfy all the requirements specified, although the sound quality could be improved. Nevertheless, it fulfilled its purpose in amplifying environmental sound and transmitting the sound to the user's ear. The buttons were also fully functional and worked as intended.

3.3 Bluetooth

After rigorous testing of our Bluetooth unit, we can confidently say that all our Bluetooth requirements have been satisfied. We tested the Bluetooth's compatibility, connectivity, stability, and range with various phones, and it proved successful in every case.

3.4 User Interface

For the user interface, we were not as successful in satisfying our requirements. Requirement [R47-II][1] was not satisfied for the hearing aid unit because the battery level is actually indicated by the intensity of the LED. We realized that making the LED flash would require programming and more expensive hardware, so we decided to sacrifice some usability for cost reduction. Requirement [R49-II][1] was not satisfied because instead of using two dedicated buttons for volume control, we used a thumbwheel adjuster. The last deviation involves [R51-II][1]. Our device ended up weighing around 30g instead of 20g.

4. Future Improvements of System

4.1 Hearing Aid

We have many plans for the improvement of the hearing aid in our production line of Bluetooth hearing aids at Audima Inc. Primarily, all hearing aids will utilize digital technology. Digital hearing aids are quickly becoming the norm in the market, as they provide much higher clarity than analog hearing aids by converting sound waves into electrical pulses rather than electrical waves. Our devices will then have much better signal-to-noise ratios as the digital technology will filter and isolate background noise, amplifying only important signals such as speech. Moreover, the user will be able to choose between different listening modes, such as conversation, loud environment, and headphone modes. This will accommodate for different environments, and the hearing aid will adjust to give the user the best clarity possible in any environment.

4.2 Feedback Noise Control

Feedback noise is a problem that the engineers at Audima Inc. take very seriously. We want to ensure that the user has the most comfortable listening experience possible, and feedback is first and foremost one our list to cut. In comparison with our prototype, much of the feedback noise will be reduced in the conversion from analog to digital technology. Frequency modulation will then be implemented, selectively passing certain ranges of frequency and blocking unwanted ones. Additionally, with the help of a professionally made case as well as a custom ear mold for each user, the speaker and microphone will each be sealed apart from each other, further reducing feedback noise.

4.3 Battery Life

Battery life is another important factor that will be dealt with in the early stages of future production. The primary option is to replace the rechargeable battery in our prototype with a high capacity disposable battery, since disposable batteries normally have a much higher capacity than rechargeable batteries. Another option is to find a higher capacity rechargeable battery.

5. Project Budget

The following table shows the comparison of estimated cost, actual cost and the deviation incurred during the project. The estimated cost to build HAB-1 is $175, but unfortunately to do previously unforeseen circumstances, the actual cost came to $284.70, resulting in us going $109.70 over budget.

Table 1: Audima HAB-1 Budget

Parts	Estimate Cost	Actual Cost	Deviation
PCB	$50	$125.79	-$75.79
Bluetooth	$105	$56.87	+$48.13
Breadboard Components	Free	Free	$0.00
Surface Mount Components	$20	$85.04	-$65.04
Soldering Tools	Free	$17	-$17.00
Total Cost	**$175**	**$284.70**	**-$109.70**

PCB: The PCB boards cost only $50 as we expected, but we neglected to factor in shipping costs and taxes. Since the boards are manufactured in Portland, shipping costs and customs taxes added another $75.79 on top of the $50 for the boards.

Bluetooth: Audima engineers donated their old Bluetooth headsets for research purposes, allowing us to spend less than we originally expected.

Surface Mount Components: The original estimate only included the cost of components for one device. However, to ensure that we had enough components in case of accidents or component failures, we ordered four sets of surface mount components.

Soldering Tools: We were not able to borrow all the surface soldering tools we needed from Fred, so we had to purchase a flux pen, soldering wick and some thin wires.

6. Timeline

The following figures shows expected timeline and actual timeline of our project

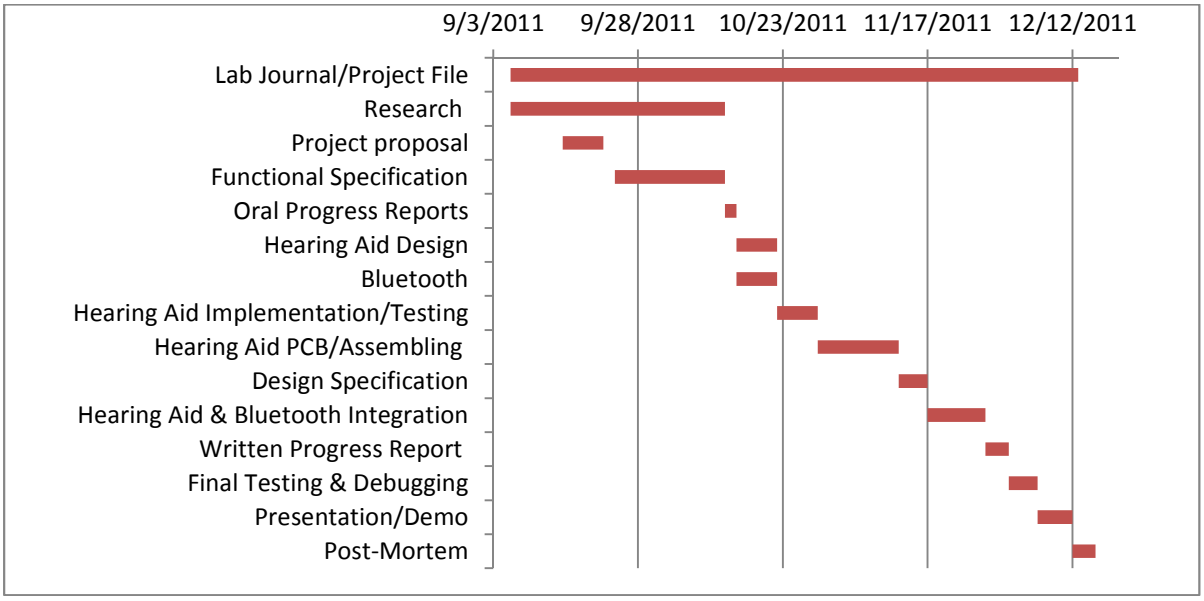


Figure 2: Estimate Project Timeline

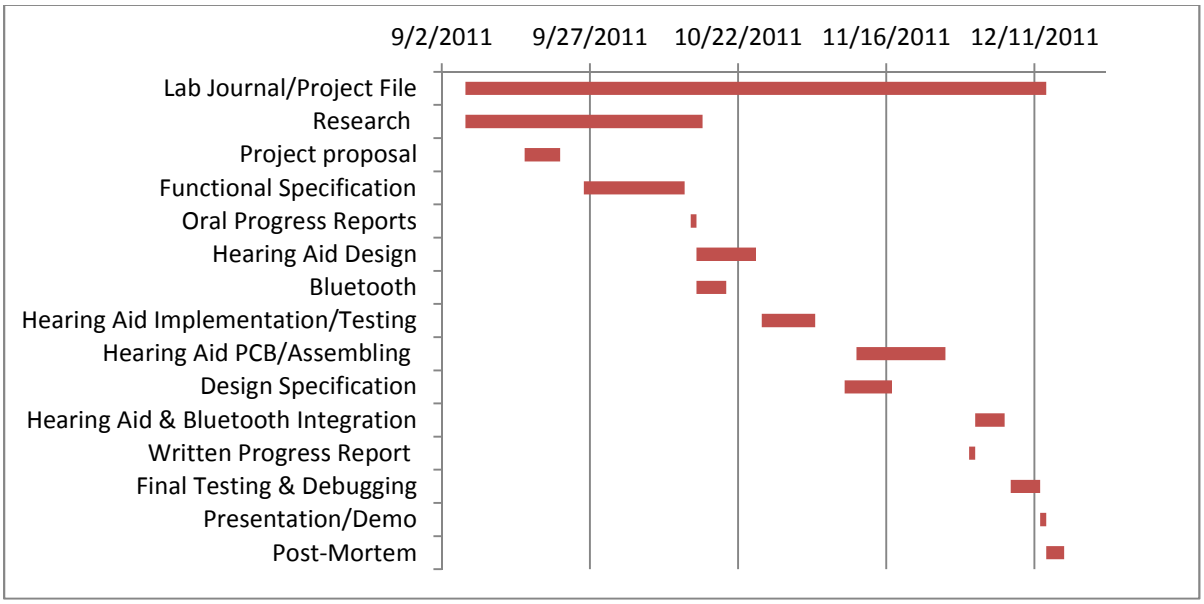


Figure 3: Actual Project Timeline

We completed the majority of the tasks before the proposed timeline. The only discrepancies between the two timelines are the time spent on developing and assembling the hearing aid and the integration of the hearing aid with the Bluetooth. We spent more time on developing the

hearing aid due to the complexity of the development and the lengthy testing process of the hearing aid. Assembling the hearing aid took longer than we expected because none of the group members had experience with PCB design, so the learning process took longer than originally planned. The integration between the hearing aid and Bluetooth also took longer than expected, as we required a few extra days to complete the integration circuit. However, despite the slight difference between the estimated time and the actual time spent on parts of the development stage, our team was still able to utilize all labour and resources efficiently to complete the prototype by the proposed date.

7. Team Dynamics

Audima Inc. consisted of four talented engineering students who worked comfortably and efficiently through the past 13 weeks to complete the Capstone Engineering Science project. Individual tasks were assigned throughout the project according to each member's unique skill set allowing us to easily monitor the progress of the project. Although tasks were split up separately, each member still worked together and provided support to each other when needed. Debates were encouraged and conflicts were always resolves in a professional manner. Meetings were held at least every week to allow us to talk through issues we had encountered the previous week, and assign tasks to be accomplished for the following week. Due to such efficient team dynamics, the team was able to complete the prototype by the proposed date.

7.1 CEO – Jeffrey Lee

I would first like to thank all of the engineers on the Audima Inc. team for being a group of hard working and amazing people to work with. As the CEO of the company and the project manager, I have been occupied with most of the administrative tasks as well as overseeing the project development on a whole. Not only was time management very important, but managing the relationships between each of the members of the team was equally important in my role. I learned many new interpersonal skills and different nuances in handling conflicts and assigning tasks to members without creating problems. On an interpersonal level, I feel that I've grown and matured a fair amount during these past 13 weeks with the group, and these are skills that will follow me for the rest of my life, in every job I will find, regardless of the field. Simply managing not only my own time, but as well as the time of others, has gradually become easier for me, and I can already see this skill being extremely beneficial to me.

On a business aspect, I realized (thanks to Dr. Andrew Rawicz) during our project demonstration that there are many factors – such as financial budgeting – that I have never previously thought of. The ways of thinking and managing a project, or even a company, is not something that is

taught in any engineering class, and I believe that as an engineering student, these are experiences that are definitely worth having to help me mature overall, not just in one specific field of study.

On a technical aspect, I've also grown in these past 13 weeks while overseeing and helping out with the research and development of the device. Although my role comprised mainly of the administrative tasks, simply being there to support my teammates in any way possible is already a great way for me to absorb and learn many new tricks. This is also the first project I've had in which specific documentation played such a large role, and I've probably learned and applied more different writing styles in this project than I have in anything else.

All in all, it has been a very rewarding semester, and I had the chance to work with some great engineers that I believe will be very successful in the future. What I had originally thought would be a grueling 13 weeks turned out to be very enjoyable, and I would love to continue to work on this project.

7.2 CTO – Ali Pourghadiri

Throughout this project, in the past 13 weeks, I have learned a lot technically and interpersonally. Our group consists of four talented individuals from SFU Engineering Science. For a semester-long project like this, it is impossible to work as a big group on every single components of the project. Therefore, we have split into two subgroups to work on the hearing aid component and the Bluetooth headset component separately. I was happy to be placed in the hearing aid subgroup, and most of my technical skills gained in this project were from working on the hearing aid component. Also, I was able to provide information resources regarding the hearing aids since I use hearing aids myself as I have a hearing loss. Besides, we worked on the documentations as a big group, and most of my interpersonal skills were learned from working with other people.

From technical point of view, I have learned to work with surface mount circuits, and improve my knowledge on testing hearing aid component. For the first month and a half, I tried to study a simple hearing aid circuit by understanding the purpose of each components involved in that component. Since then, I have become familiar with different types of audio amplifiers and transistors that could help us to get a good result of hearing aid testing. With the help of my group mates, we were able finally able to choose the right audio amplifier and low-signal transistor which gave us the best and loudest sound output. This process also helped me learn about the technical specification documents and how they are formatted and written. When the PCBA board for hearing aid was ready, I was responsible for ordering the surface mount components required for that, and learning about the technical spec. documents had helped me to find and order the right parts. However, this process was a bit difficult for me when I had to

order the audio amplifier and transistor because the ones that we used previously for testing were all through holes, and their names are different if their package types are different, so I had to search for the right ones by looking at their technical specification documents and comparing with those of the ones we used for testing. I also had a chance to learn the soldering techniques on the PCBA board using the surface mount parts.

From the interpersonal perspective, I have learned various skills to work with a group of people. I have learned that communication is very important when working as a group. Even when we were split into two subgroups, we still scheduled to have meetings every week. Working as a group means lots of different opinions, and above all, it is very important to respect everyone's ideas and to come up with an idea which everyone agrees on. Planning ahead as a group is another main ingredient in succeeding in projects, and this is the main reason why our group met all the deadlines for documentations and completed the project in time. Group mates are always willing to help when we make a mistake or don't know about something. Personally, I feel lucky to work with my group. This is not a group just wanted to meet their academic purposes or to learn technical skills, but this is a group that is fun to work with and this led us amazing results and friendships.

7.3 CFO – Kevin Wong

Through completing this project course, I have learned a lot of invaluable skills in various different fields. Firstly, by being in charge of the Bluetooth unit, I learned about how devices communicate with each other through this networking method, its unique protocols and the advantages/disadvantages associated with this technology. Secondly, by designing the integrated circuit, I gain some important knowledge regarding lithium ion polymer batteries, such as designing protection circuitry to prevent explosions and how to step up/down the voltage. I also learned how to use different types of switches, microphones, and speakers, as well as the benefits of each type.

Thirdly, by being part of the soldering group, I learned how to solder surface mounts onto a PCB, and the purpose of all the equipment required (such as the wick, flux pen, etc). Fourthly, by being involved with the prototype testing, I learned a lot about audio feedback and various ways to solve it. I also learned about the current capacity of the lithium ion battery and how its voltage changes through its battery life. Fifthly, working in a group has helped me develop my team working and communication skills. By meeting every week, and updating each other on our individual progress, we were able to finish our project in time, and follow our scheduled timeline. It has also helped me understand how to partition the workload between the group members, and how to use the different strengths of each group member to our advantage. Lastly, by writing the documentation, I learned how to write in various styles directed at different types of audiences. It has also helped me refine my technical writing skills. In conclusion, this project course has really

opened my eyes to the real world applications of engineering. Not only did I gain some invaluable technical skills, I also learned how to work successfully in a group environment. Overall, it has been a very enjoyable and fulfilling semester.

7.4 COO – Eric Zhou

My initial roles in the project were to come up with the design for our hearing aid device and organizing meeting and record minutes for our group. In the first month, I did a lot of reading and research on hearing aid since I have never had any past experiences working with hearing aid. This allowed me to understand a totally different area. In the second month, I came up with the design for our analog hearing aid using two ICs and some other resistors and capacitors. This allowed me to practice the electrical circuit design knowledge which I learnt from ENSC 225 and 325. Then I built the circuit on the breadboard and spent a couple of days to test the functionality of the circuit. Unfortunately, the signal to noise ratio of the circuit was not ideal, so I had to modify the circuit a bit by varying the values for resistors and capacitors. This helped me to apply the circuit analysis skills I learnt from the textbooks. After I finished testing the circuit on the breadboard, I started to design the PCB layout of the finalized circuit. This is a very different challenge for me because I have never done any PCB layout before. Luckily, I was able to get a lot suggestions and helps from TA Jamal. Afterwards, I was able finish the PCB layout design and soldered all the surface mounts components on the manufactured PCB board.

Throughout this project, I learned not only the technical skills as I mentioned above. I also learned various soft skills. I learned how to work with other people in a group, and I learned how to deal with conflicts and debates in a professional manner among the group members. I learned how to budget and how to write proposal, functional specification and design specification.

8. References

[1] Audima Inc. (2011). *Functional Specifications for Bluetooth Hearing Aid HAB-1*. Simon Fraser University.