Jan 20, 2014

Andrew H. Rawicz
School of Engineering Science
Simon Fraser University
V5A 1S6

Re: ENSC440 Project Proposal --- SoundHub: Wireless Speaker Module

Dear Dr. Rawicz:

In regards to the course requirements of ENSC 305W/440W, enclosed to this letter is Arimus Audio's *Proposal for SoundHub: Wireless Speaker Module*. The objective of this project is to design and implement a home wireless audio solution to a speaker system that enables music streaming over a WiFi network.

The following documentation outlines the current availability of wireless speaker solutions in the consumer market, and our design in comparison. In addition, an overview of the product design, estimated budget, project schedule, team description, and references will be provided. We will also explore features and improvements that our product can achieve using modern WiFi standards.

Arimus Audio consists of 5 senior engineering students: Sherman Siu, Scott Malfesi, George Chang, Dongkai Miao, and David Yin. Their concentrations include an aggregation of computer engineering, electronics engineering, and engineering physics. If you have any questions or concerns regarding this proposal or the SoundHub device, please contact our CEO Sherman Siu at arimus.audio@gmail.com.

Sincerely,

Sherman Siu
CEO
Arimus Audio

Arimus Audio

PROJECT PROPOSAL

WIRELESS SPEAKER MODULE

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Submitted to : Dr. Andrew Rawicz
Steve Whitmore
School of Engineering Science
Simon Fraser University

Issued date : Jan 20, 2014
Revision : 1.1

Executive Summary

Music is timeless - regardless of which day and age, music is the unified language of the soul where it needs neither words nor pictures to communicate emotion. Yet while music itself is timeless, the way we make music and the devices we use to listen to it are evolving. In just the last fifty years, the world has witnessed the birth of digital audio. And since then we've advanced through many storage mediums, the vinyl, the cassette, the CD, mp3 players and so on. Technology has evolved to the level where we bring music with us wherever we go, in devices that fit in the palm of our hands.

However, while today's mobile devices are extremely capable, we are limited by the way they share audio. The current acoustic capabilities of a phone or tablet simply yield a subpar music experience because of speaker design and compromise. In general, a speaker dock would provide better audio quality than a phone, and a surround sound system would be better than the speaker dock. When the need to share arises, typically we dock or attach cables to our mobile devices. In doing so, we relinquish mobility.

Our goal at Arimus Audio is to offer a seamless solution, a way for content to be shared while breaking the acoustic constraints of a mobile device. With this ideal in mind, we came up with the SoundHub. The SoundHub is a low cost wireless speaker module that connects your personal device to the sound systems around you. It provides you mobility, yet retaining real-time control of features such as volume and song selection. No cables, no constraints. Minimalism.

"Technology is at its best, at its most empowering, when it simply disappears."
– Sir Jony Ive

With RoomFlow™, the music would flow with you as you move around the house. We want our users to be immersed in their music without having to worry about where it is playing. At Arimus Audio we understand that music is a core part of everyday life, and being able to enjoy your music the way you want means a great deal to us. Thus, we offer the freedom to stream from any set of pre-existing speakers of your choice. No matter if it is a 7.1 surround sound system, a dock or even a small computer speaker, SoundHub will integrate them all into a wireless home audio system.

Arimus Audio intends to perform research, design, implement and troubleshoot two versions of the SoundHub within three and a half months, with a budget of approximately $1000 CAD. Given additional time and resources, enhancements and software features may be added to further enrich the product.

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1.0 Introduction

The SoundHub is the next revolutionary step in wireless speaker technology. Designed to be sleek and discreet, it allows existing speaker docks to attain wireless freedom by streaming music from other devices to it. Furthermore by utilizing modern WiFi protocols, multiple speakers connected to separate SoundHub devices can be streamed to at the same time. With SoundHub, rooms or entire homes can have access to streamed audio content, with full control through your handheld devices or computers.

With user-friendliness in mind, the SoundHub requires minimal setup and has intuitive user controls. The setup requires the SoundHub to be connected to the speakers intended for streaming and will use the same WiFi network as the device to be streamed from. Once connected to the network, music streaming from a device can be performed through a music playing application to the SoundHub and streamed through the connected speaker system.

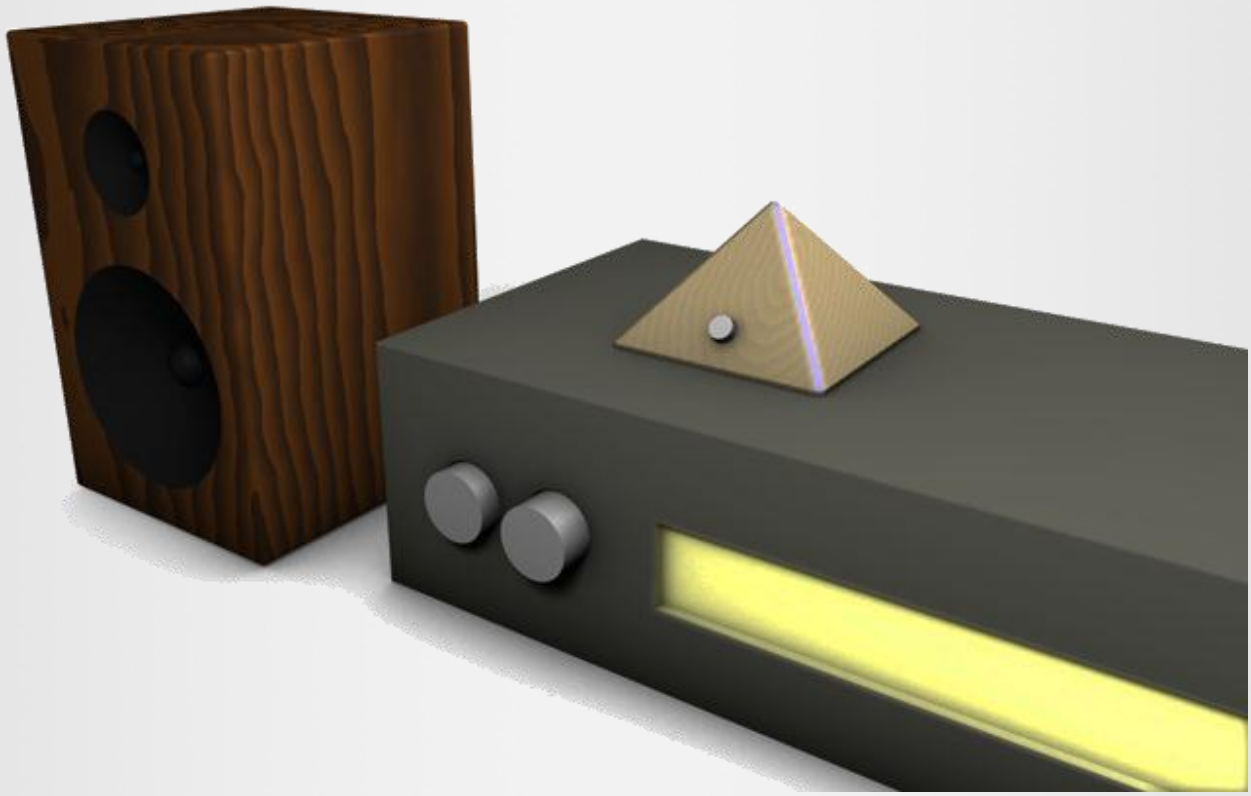

Figure 1: Artist's Rendering of SoundHub

The goal is to produce a slim and discreet speaker attachment that will allow music streaming through WiFi, while maintaining a price point much lower than existing competition. This product will allow users to gain the benefits of wireless streaming without having to upgrade their entire audio system.

This proposal will outline the following:

- The SoundHub product and its features
- Current market competition
- Risks and benefits with certain implementations and features
- Project scheduling, budget and funding
- The Arimus Audio team profile

2.0 Product Summary

2.1 Feature Set

Included in the SoundHub are a number of breakthrough innovations and features. These features are all focused on enhancing the user experience. At its core the SoundHub represents a rethinking on how users should be able to experience their music in their homes. We focused on creating a device which would free users from the confines that tether them in the current paradigm. SoundHub eliminates the need of messy wires in traditional solutions and brings mobility back to the free flowing elegance of music into your home. Starting from the idea of affordable wireless music without sacrificing quality, we expanded to create an audio solution without spatial limitations. This idea led to the creation of RoomFlow™ technology which allows music to flow between rooms without worry about connecting and disconnecting devices. It would be hypocritical to free the user from the mess of cords but not allow them to pick their input device of choice and which speaker system they want to pair with the SoundHub. All of these features meld together into a unified liberating user experience.

2.1.1 Quality Wireless Music

As people who genuinely enjoy music, the idea of reducing music quality to achieve wireless freedom was out of the question. Using the home WiFi network, we transfer the music at 16 bit quality and decode it using a high quality DAC and amplifier. The SoundHub will not be the limitation factor in your sound system.

2.1.2 SoundHub Array

SoundHub is designed to be a full house solution. When music is broadcasted over the WiFi network, each of the SoundHub devices on the network will be able to receive the signal and stream to all speakers in unison. It is designed so that each SoundHub can be assigned to different rooms playing by themselves, or with multiple SoundHub devices in the same room which play together. The devices in the same room can be configured to split up the left and right channels to create a greater soundstage. The SoundHub array will also allow for multiple people to enjoy their own music in different rooms. This breaks the boundaries in how music is presented and enhances the users' music listening experience.

2.1.3 RoomFlow™

The RoomFlow™ feature allows the SoundHub to detect the proximity of the mobile device to the SoundHub itself, and adjust its volume level accordingly. With this information the SoundHub is able to only have the speakers playing in the room the user is currently in. When life starts taking the user into another room, the music will simply flow with them. Unlike other solutions, RoomFlow™, with its remarkable degree of precision, can intelligently transition the music from one SoundHub to another using dynamic volume, composing a nearly seamless experience that is truly amazing. With an array of SoundHubs, RoomFlow™ can create a truly immersive listening experience that incorporates all of your speakers, creating a versatile full house audio solution. RoomFlow™ takes the convenience of making a speaker wireless to a whole new level. Users will never have to miss out on the music they are enjoying.

2.1.4 Line Through

If the users' speakers are wired to another setup (ie. computer speakers, TV sound system), the SoundHub supports a line through that would allow the user to toggle between wireless streaming, and their original wired configuration. To do so, the user is required to flip a switch on the SoundHub, rather than unplugging cables from their setup. This gives versatility to our product and allows the users to enjoy the best of SoundHub with no compromises.

2.1.5 Ecosystem Versatility

One of the biggest features of the SoundHub is how flexible it can be when trying to fit into the users existing ecosystem of devices. The SoundHub outputs line level audio which can be directed into the speakers or amplifiers that the users already own. This versatility makes the SoundHub compatible with any size of speakers. The music you love most on the speakers you are most familiar with. Additionally the SoundHub will support standards available on iOS and Android devices, so users will be able to use the mobile device of their choice.

2.1.6 Unique Industrial Design

The SoundHub has been meticulously designed and crafted to stand out from the crowd. The unique pyramid structure gives plenty of room below the PCB board for a heat sink and plenty of room above for the WiFi antenna. Its size is discreet enough that it can be tucked away. However with this design, you do not have to be embarrassed of having it out for the world to see. As shown in Figure 2, the body is planned to be made with bookmatched wood panels. In one of the front beveled edges we are embedded a status light so you can tell at a glance if the SoundHub is connected to your network or playing music.

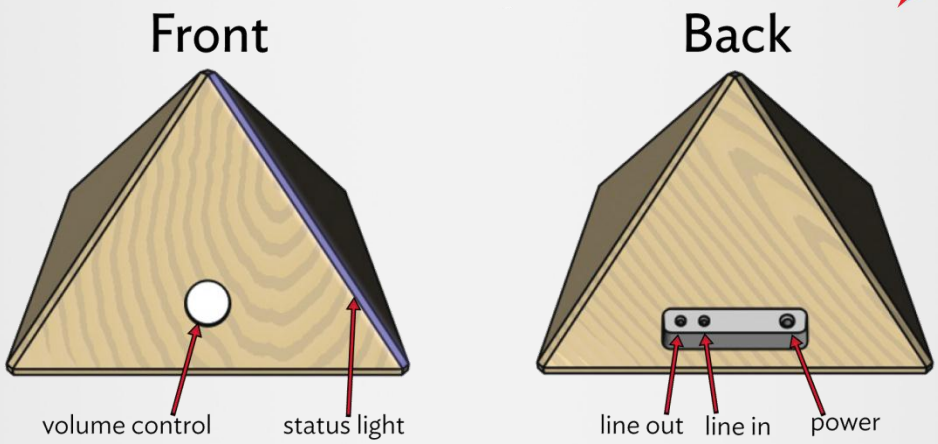

Figure 2: Front and Back View with Major Features Labeled

2.2 System Overview

The SoundHub consists of a CPU, running an embedded Linux kernel and custom firmware. There are two main peripherals off of the CPU: a WiFi module, and a DAC. The CPU will communicate with the mobile devices using the WiFi module. It will also decode the audio stream and pass it through the DAC to produce an analog signal. Off of the DAC there is also a power amplifier circuit so the SoundHub can drive larger speakers. Figure 3 shows the layout of the SoundHub and its components.

We plan on leveraging open standards and open source projects for as much of SoundHub as we can. This way we do not have to reinvent known solutions resulting in a faster development cycle.

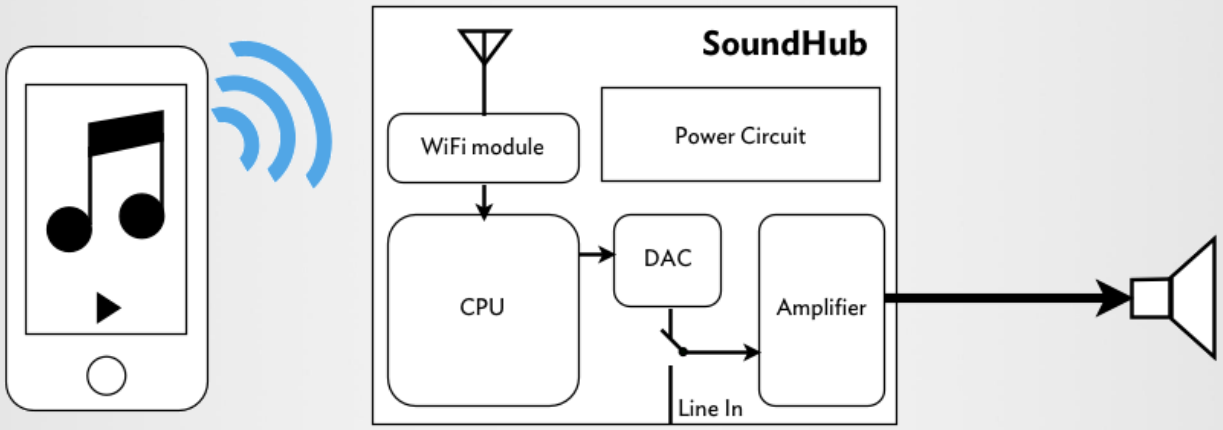

Figure 3: Internal Layout

2.3 Protocols

Considerations for different platforms and support for protocols has been made to ensure that SoundHub can be compatible with existing mobile devices in the market. Different platforms have been researched and considered for the implementation of SoundHub and its features. WICED™ (Wireless Internet Connectivity for Embedded Devices) from Broadcom[1] has been considered for its broad range of application utilizing WiFi, and Bluetooth on a dedicated chip. The downside of this will be the addition of a specified module and component locked to a single manufacturer.

Another platform that was recently announced by Qualcomm as a competitor to Apple's AirPlay™ called AllPlay™ is a more suitable choice[2]. The AllPlay™ Platform gives developers a cross platform SDK that allows interoperability between different devices. AllPlay™ is also a specialized platform built to target wireless streaming and supports audio streaming from online streaming content providers. This platform will allow the SoundHub the potential to expand its support and functionality[3].

2.4 Market Strategy

The wireless speaker market is set for explosive growth over the next few years. Only recently has the technology gotten to the point where high quality music is able to be streamed easily and reliably. This coupled with demand driven by the rise in popularity of smartphones is pushing the loudspeaker market to a forecasted $6.1 billion by 2018[4].

A majority of our competitors are using the wireless feature as a selling point to convince consumers to purchase an entirely new audio system. Of the competitors which are taking this strategy, there is a strong divide between quality and price. At the lower end of the price spectrum, the devices are primarily Bluetooth dongles which range in price from $20-$40. Some notable examples include the Belkin Bluetooth Receiver[5] and the Logitech Wireless Speaker Adaptor[6]. The latest AD2P Bluetooth audio streaming protocol has brought the quality level of these systems to a point where these systems are starting to be competitive. The Bluetooth systems excel in their ease of pairing and at low power and portable situations. However the sound quality of these systems cannot match other streaming protocols, the range is fairly short, and you are limited in streaming to one device only.

At the higher end of the price spectrum the devices often use WiFi, or other higher bandwidth methods of streaming. These devices target high end home theatre systems and often include features such as built in amplifier, preamp stages, multiple input and outputs and internet radios. Some examples of these devices include the Cambridge Audio Minx XI[7] and the Sono Connect:Amp[8]. The extra quality and features of these systems comes at a steep price. These devices can cost up to $900 per unit, resulting huge gap in both price and performance between basic and premium wireless streaming devices.

Our aim is to fill this gap with a high quality WiFi connected device, at a price point low enough for the consumer to purchase multiple units. As the results, our users could join the wireless revolution while keeping their existing audio systems, and also have a greater experience while enjoy RoomFlow™ as their home solution.

3.0 Project Planning

This proposal plan only deals with the first stage of our product, the Proof of Concept phase. After we have completed this phase and demonstrated the value of the SoundHub we can move onto the Refining and Marketing Phase and then finally the Manufacturing and Distribution Phase.

3.1 Scope: Proof of Concept Phase

We plan on producing the following deliverables:

- Firmware functional on all SoundHub protoboards and developer evaluation boards
- 3 SoundHub hardware implementations on protoboards
- 1 enclosure

If time permitting, we will produce the following:

- Dedicated app for playback
- RoomFlow™ feature
- 3 SoundHub custom manufactured PCBs (potentially replacing the protoboards)

As a start-up company there are risks and benefits associated with attempting each of these deliverables, with monetary cost and time being limited resources. The evaluation board is a prime example: Our project incurs significant costs but allows firmware and hardware development in parallel. This development would separate firmware from hardware bugs to allow for easier debugging.

Our team has chosen to perform a hardware implementation on a protoboard with wire routing to separate chips and components on external daughter cards. Potentially, the CPU and/or WiFi chips required for our design may be Ball Grid Array (BGA) type and cannot be soldered by hand without special lab equipment. Hence we expect to route signals from these chips to our protoboard design. A custom manufactured PCB was considered in the early stages of the project, but is now categorized as a stretch goal for the following reasons:

- Order processing and shipping can take 5-10 business days
- Further delays to the package could occur at Canadian customs (most PCB manufacturing is in the United States)
- Hardware Design with a CPU and WiFi chip proves too complex for a scheduled development period of 5 working weeks
- Reduced troubleshooting time on custom equipment may result in a nonoperational hardware implementation
- High costs for board manufacturing ($100 to $200, not including parts)

The Arimus Audio team has also considered providing front-end iOS/Android apps to streamline the use of the SoundHub device and add extra control. As we are using established streaming protocols which are available in apps on these platforms this is not necessary for proof of concept. Instead this will be a long term stretch goal.

The construction of an enclosure requires some team members to gain experience utilizing machine shop tools. However, when marketing a potential product, a slick tangible design goes a far way in creating credibility. Several team members will be signing up for shop training to pick up the skills need to make an enclosure for the SoundHub device. Materials for an enclosure can be collected with relative ease.

The RoomFlow™ feature has also been designated as a stretch goal. Our team is currently analysing the features and limits of the Broadcom WiFi BCM4329 chip on the developer evaluation board and developing a proximity detection system. It is still too early in the development stages to gauge the feasibility of implementing this feature.

Each of these deliverables has tradeoffs to consider, these tradeoffs will need to be re-evaluated as the project continues to ensure that the project stays on schedule and within the budget.

3.2 Schedule Timeline

A simplified timeline for the SoundHub Proof of Concept phase has been shown below in Figure 4. The phase follows twelve major milestone deadlines, shown in Figure 5. To fulfill these milestones over the three and a half month period, the timeline has been broken into the following stages:

- Pre-Course Planning
- Project Initiation, Document Drafting
- Streaming Development
- Hardware Design
- System Integration and Testing

Documentation and presentations are expected to be a continuous task throughout the project.

	Task Name	Duration	Start	Finish
1	Pre-Course Planning	146 days	Mon 6/17/13	Sun 1/5/14
2	Project Initiation, Document Drafting	31 days	Mon 1/6/14	Mon 2/17/14
3	Streaming Development	33 days	Thu 1/16/14	Sun 3/2/14
4	Hardware Design	26 days	Mon 1/20/14	Sun 2/23/14
5	System Integration and Testing	31 days	Mon 3/3/14	Mon 4/14/14

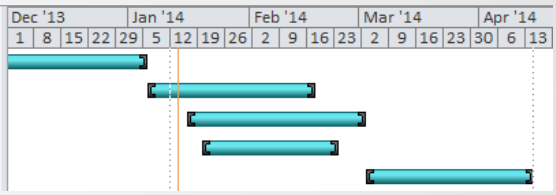

Figure 4: Simplified GANTT Chart

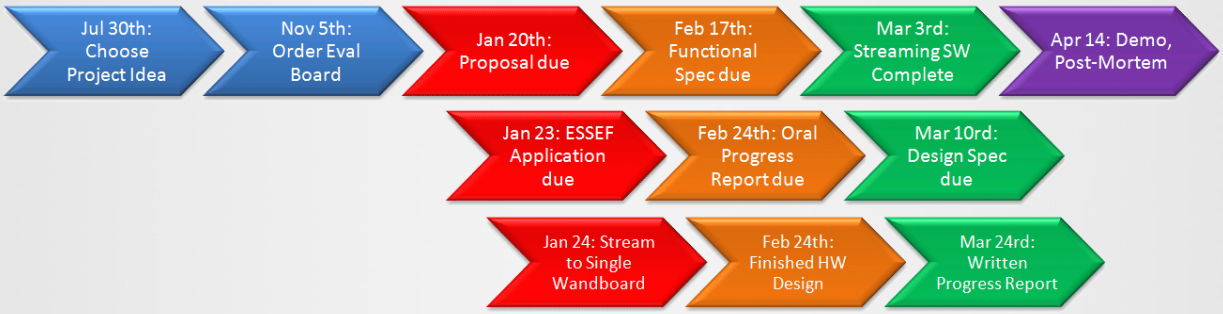

Figure 5: Milestone Chart

3.2.1 Pre-course Planning

Pre-course covers the development of the project idea, drafting the proposal, identifying key strengths of team members, and forming the company. This includes voting on a company name, and designing a company logo. Identifying the market competition, and research into wireless standards, open-source software, and SDKs are also during this period. Additional tasks include identifying sources of funding in advance, and begin designing document skeletons and templates for future use in milestone submissions and presentations. The GANTT chart is designed in this phase to streamline the rest of the project.

3.2.2 Project Initiation, Document Drafting

The project scope is further defined during this stage where benefits and risks of deliverables are analyzed before proceeding forward. Development platforms and PCB design software will be setup in preparation for the next stages of the project.

This stage is documentation heavy, as the Proposal and Functional Specification must be drafted within a relatively short period of time. As parts of the Proposal were previously written during the Pre-Course Planning stage, revisions will be made to ensure the document is up to date. Applications to fund the project such as the ESSEF fund, and the Wighton fund are completed here. *(See Section 5.1 for further details)*

3.2.3 Streaming Development

The firmware streaming functionality of the project is developed on the evaluation boards throughout this stage. This begins shortly after the Project Initiation, and continues throughout late January and February until the custom PCB is received in early March. It is expected that streaming to single device will be completed before on to multi-device streaming. The RoomFlow feature is also developed during this stage, if time-permitting.

3.2.4 Hardware Design

Hardware design of the SoundHub protoboard is done concurrently with the Streaming Development stage. Research on suitable ICs and components will be done in parallel with schematics. If a custom manufactured PCB is planned, a hard deadline has been set for the second last week of February for a finished layout design and to order the custom PCB. With completed hardware in early March, this ensures the team has sufficient time for integration and testing.

3.2.5 System Integration and Testing

During this stage the two subsystems, PCB hardware and firmware are integrated together into a final conceptual model. Integration and testing are to be iteratively implemented to ensure all of the SoundHub features are working and robust. These tasks are performed until the project end in mid-April along with the completion of the Project Demo, and Post-Mortem.

3.3 GANTT Chart

See Appendix A for the full GANTT Chart detailing the progression of the SoundHub project.

4.0 Budget

Over the 4 month schedule we plan to deliver a software proof of concept demonstrated on the Evaluation boards, and an in-house custom designed SoundHub PCB. All of the components are being carefully weighed against the alternatives to yield optimal performance while keeping costs down. Table 1 outlines our preliminary budget estimates for completing the Proof of Concept phase of the SoundHub. The category *Minor Components*, includes parts such as resistors, capacitors and connectors and *Miscellaneous* includes any uncategorized expenses. We have set aside approximately 15% and 20% (of the Subtotal) for *Shipping Costs* and *Contingency* respectively. If a custom manufactured PCB run occurs, we expect an additional cost of approximately $150.

Table 1: Estimated Budget

Item	Quantity	Price Each ($)
Eval Boards	2	150
DAC	3	7
AMP	3	5
Microprocessor	3	10
WiFi RF chip	3	5
Power Supply	3	30
Enclosure	1	50
Minor Components	3	50
Test Speakers	2	20
Miscellaneous		50
	Sub Total	761
Shipping Costs	~15%	114
Contingency	~20%	152
	TOTAL:	**$1027**
Note: **With custom PCB run** (+$150)	TOTAL:	$1177

4.1 Funding

The SoundHub conceptual model is expected to require significantly more capital than a production model due to the research and development costs. We expect this figure to decrease substantially when the mass production occurs. All project expenditures are constantly documented to ensure accuracy when reporting costs and figures.

The Arimus Audio team will be applying to both the Engineering Science Student Endowment Fund[9] as well as Wighton Engineering Development Fund[10]. In order to acquire funding from these sources, a PowerPoint presentation and a project proposal will be prepared and presented to the funding sponsors. Requests for parts sponsorship such as microprocessors from Texas Instruments, and Wolfson Microelectronics DACs are also in progress.

Arimus Audio has also considered placing our product and concept on Kickstarter to potentially generate funds. A requirement for starting on Kickstarter is that we can provide a proof of concept video to grab the attention of the public sponsors. We will use the funds to research, produce, and manufacture more SoundHub devices and potentially ship them to our customers. The team only considers an application to Kickstarter near the end of our project cycle, where a working proof of concept can be demonstrated.

As our contingency plan, the team at Arimus Audio has agreed to fund any outstanding costs within the team.

5.0 Company Organization

At Arimus Audio we believe in the life changing effects of quality design. We are focused on using innovative solutions to enhance the user experience. Arimus Audio was founded by five highly motivated and exceptionally skilled engineers from Simon Fraser University: Sherman Siu, Scott Malfesi, George Chang, David Yin, and Dongkai Miao.

Though this ambitious project we plan to manage the work using the AGILE development model. There will be weekly team meetings where we will discuss our latest deliverables ensure that we stay on schedule. Each individual's strengths have been analyzed and assigned a suitable role to optimally match those strengths.

Sherman Siu *- Chief Executive Officer*

Sherman Siu is a fifth year computer engineering student at Simon Fraser University. From his five work terms at Broadcom, he has gained industrial experience regarding the software quality assurance, and hardware modification/troubleshooting of the latest state of the art consumer products. He has been exposed to recent audio/video encoding algorithms in scripting environments as well as and various high end hardware testing equipment such as oscilloscope, power analyzer, and thermal camera devices. With a focus in computer science and embedded systems, he has a well-rounded set of hardware and software skills, and serves as a bridge for the team between the two areas. From participating in national engineering competitions, he has refined his presentation and communication ability and thus acts as the liaison for the team. Given free time, Sherman pursues projects in film and animation.

Scott Malfesi *- Chief Operations Officer*

Scott Malfesi is in his fifth year of an Engineering Physics program at SFU. He has co-op experience developing firmware for IP cameras at Avigilon and expanding the automated regression tests at MDA. At school, he has worked on a wide range of projects including designing an algorithm to analyze and segment pictures of embryos; developing the electronics of a biosensor with a PhD candidate; and recreating the game Duckhunt on a FPGA. Throughout his career, Scott has gained a strong understanding of real time embedded system design and a knack for analytically solving complex problems. As COO, Scott is in charge of the making sure that the day to day operations of the company are being taken care of and the project is on track. In development, Scott is taking lead of the operating system and driver work and taking a secondary position in developing the networking. His experience with embedded Linux and TCP/IP protocols garnered while working at Avigilon makes him qualified for the task. When not working on a personal or school project, Scott enjoys graphic design, listening to music, and drinking coffee.

George Chang *- Chief Information Officer*

George Chang is a 5th year Electronics Engineering student who specializes in both digital communications networking and multimedia compression methodology in our group. George has work experience in the academic research field and also for the industry, both in the field of modern communication protocols for wired and wireless applications. Throughout his career, he has completed many projects that highlight his software and hardware capabilities. Projects includes NTSC signal filter and decode circuitry, High Dynamic Range image processing, and as a member in the industry partnered project for implementing the RPKI-BGP security protocol. George has also personally worked with all of the executive members, on multiple occasions, and has developed outstanding teamwork and communication skills with the Arimus Audio group. As a CIO, George is responsible for providing various network topologies and setups as a networking and communication lead. In his spare time, he enjoys listening to Jazz music on his surround sound system and joining into the harmony with his saxophone.

Dongkai Miao *- Chief Technology Officer*

Dongkai Miao is a fifth year electronic engineering student at Simon Fraser University. At school, he studied a variety of engineering projects including reproduction of the classic Duckhunt game on a FPGA, designing a NTSC TV signal processing circuitry combined with a oscilloscope together as a luminance TV, and multimedia image rendering algorithms such as High Dynamic Range Imaging. In industry, he has worked on LTE communication hardware validation at BlackBerry as well as development and validation of a cutting edge raid controller at PMC-Sierra. These working experiences have helped him develop a solid set of hardware troubleshooting skills, leading him to become the hardware lead in Arimus Audio. As CTO, Dongkai is in charge of ensuring all the hardware technical issues are solved on time and establishing the test plan of the product. Aside from his technical ability, he is also a part-time comic maker.

David Yin *- Chief Financial Officer*

David Yin is currently in his fifth year at Simon Fraser University majoring in Engineering Physics, and has 125/158 credits hours to date. As a senior undergraduate student, David has completed three internships that involve academic research, industry processing, and project management in various engineering fields. His notable achievements include co-authoring a published research paper and developing testing methods on material fatigue analysis. He is also a sector coordinator of national account forum. Some of his expertise includes professional documentation, programming in C/ C++, and data analysis skills in MS Excel and MATLAB. David enjoys working with people from different places. He gained significant amount of experience in team communication and alignment while he was working in different teams in Vancouver, Toronto, and Beijing. As the CFO of the company, David is in charge of funding application, administrative duties, as well as supporting software development. David likes many kinds of popular music, and goes to karaoke frequently.

6.0 Conclusions

Starting off with a dream, an idea, a passion, we at Arimus Audio not only want to bring innovative products to our customers, but also want to achieve so much more. We strive to redefine how people listen to music and how music is played. The SoundHub is the convenient solution to wireless streaming in the home and will allow mobile freedom for its users.

In this proposal, we have outlined the overview of SoundHub and its promising features. A market research has been conducted and the result suggested that our solution to wireless audio streaming would make our product unique in both cost and performance, filling in the gap between low end Bluetooth speaker adapters and the high end home theatre systems existing on the market. From our GANTT chart construction and budget estimates, we can implement our product in a timely manner while updating our progress in the future months. We have adopted open source coding, allowing users to implement their own features and customizations to the SoundHub, opening up our product to all developers, audio enthusiast and also our valued customers.

Arimus Audio sees seamless wireless streaming of content as the future in homes, and public spaces. We believe the SoundHub will address the needs of our target consumers, and function as a stepping stone to further innovation in the field of wireless multimedia.

Glossary

AD2P	A Bluetooth protocol for streaming music
Amplifier	An electronic device used to increase the amplitude of electrical signals
Android	A science fiction robot with human appearance; also a mobile operating system developed and open sourced by Google
Bandwidth	A range of frequencies used to transmit a signal
Bluetooth	A short range wireless communication protocol common to phones
BGA	Ball grid array; a type of surface-mount packaging for ICs
DAC	Digital to analog converter
Evaluation boards	A generic board which has common features so that an engineer can start to test their design
FPGA	Field Programmable Gate Array; a chip which contains configurable digital logic
Internet radio	An audio service transmitted over the internet
iOS	A Cisco router operating system; also an embedded operating system created by Apple to run on their phones and some music players
Line level	A specified strength to transmit analog sound between audio components
NTSC	National television system commission
PCB	Printed circuit board
RF	Radio frequency
RoomFlow	A proprietary algorithm developed by Arimus Audio which the SoundHub uses to detect the users position to play music only in the users space
RPKI-BGP	Resource public key infrastructure - border gateway protocol
SDK	Software development kit

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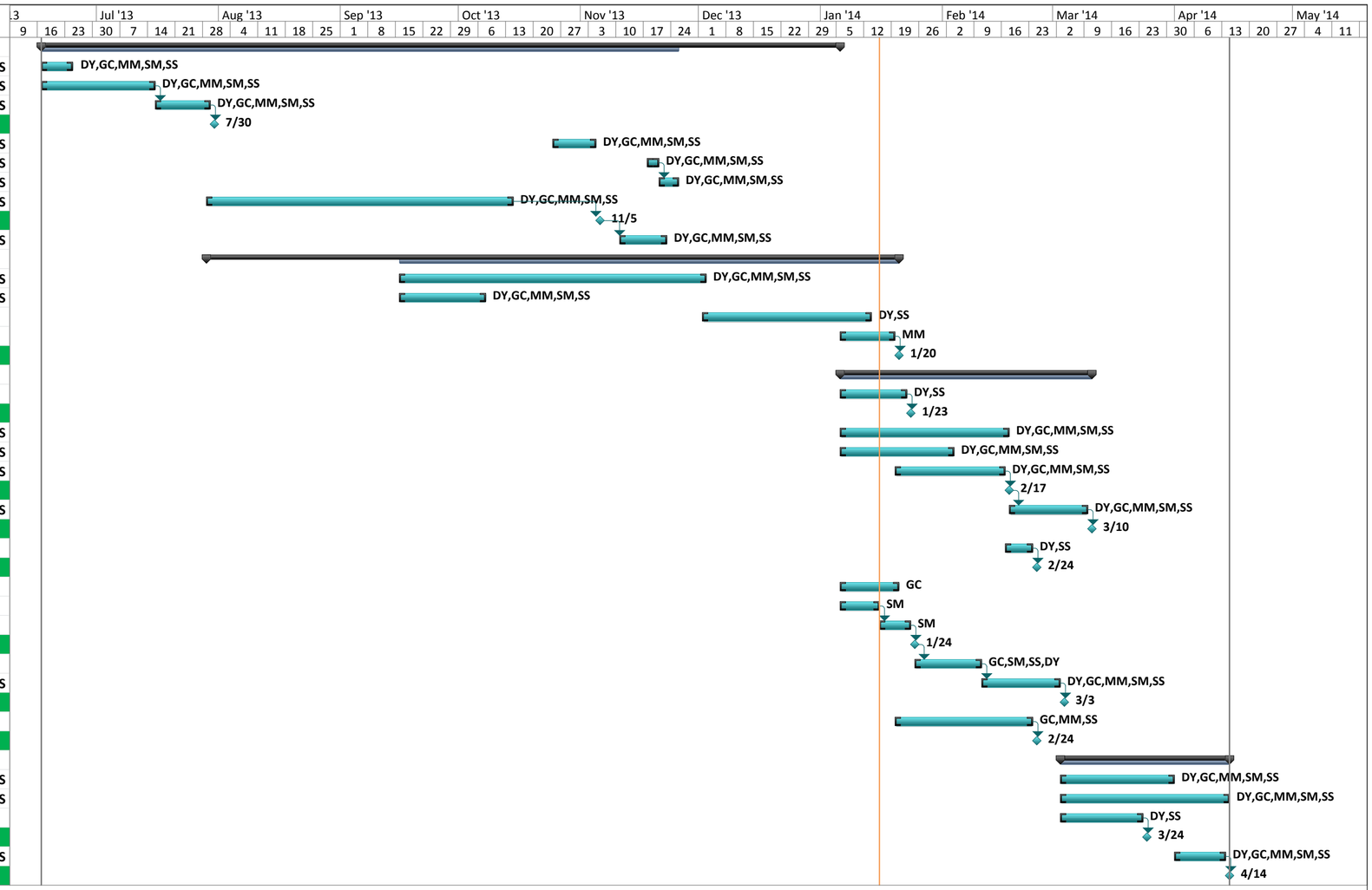
Appendix A

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**Pre-Course Planning**	**146 days**	**Mon 6/17/13**	**Sun 1/5/14**		
2	Team Recruitment	6 days	Mon 6/17/13	Mon 6/24/13		**DY,GC,MM,SM,SS**
3	Brainstorming Ideas	21 days	Mon 6/17/13	Mon 7/15/13		**DY,GC,MM,SM,SS**
4	Project Idea Debate and Voting	10 days	Tue 7/16/13	Mon 7/29/13	3	**DY,GC,MM,SM,SS**
5	**Milestone: Choose Project Idea**	**1 day**	**Tue 7/30/13**	**Tue 7/30/13**	**4**	
6	Company Name and Logo Design	7 days	Fri 10/25/13	Mon 11/4/13		**DY,GC,MM,SM,SS**
7	Determine Team Member Skillsets	3 days	Mon 11/18/13	Wed 11/20/13		**DY,GC,MM,SM,SS**
8	Designate Company Roles	3 days	Thu 11/21/13	Mon 11/25/13	7	**DY,GC,MM,SM,SS**
9	Research (Protocols, Eval Board, SW Solutions)	56 days	Mon 7/29/13	Mon 10/14/13		**DY,GC,MM,SM,SS**
10	**Milestone: Order Evaluation Board**	**1 day**	**Tue 11/5/13**	**Tue 11/5/13**	**9**	
11	Test Eval Board Functionality	10 days	Mon 11/11/13	Fri 11/22/13	10	**DY,GC,MM,SM,SS**
12	**Draft Proposal**	**126 days**	**Mon 7/29/13**	**Mon 1/20/14**		
13	Determine Project Scope and Feasibility	56 days	Mon 9/16/13	Mon 12/2/13		**DY,GC,MM,SM,SS**
14	Determine Prototype Budget	16 days	Mon 9/16/13	Mon 10/7/13		**DY,GC,MM,SM,SS**
15	Identify Sources of Funding	31 days	Mon 12/2/13	Mon 1/13/14		**DY,SS**
16	Final Revisions, Formatting, Letterhead	11 days	Mon 1/6/14	Sun 1/19/14		**MM**
17	**Milestone: Proposal due**	**1 day**	**Mon 1/20/14**	**Mon 1/20/14**	**16**	
18	**Project Initiation**	**46 days**	**Mon 1/6/14**	**Mon 3/10/14**		
19	Apply for Funding	13 days	Mon 1/6/14	Wed 1/22/14		**DY,SS**
20	**Milestone: ESSEF Applicaton due**	**1 day**	**Thu 1/23/14**	**Thu 1/23/14**	**19**	
21	Draft Functional Spec	31 days	Mon 1/6/14	Mon 2/17/14		**DY,GC,MM,SM,SS**
22	Determine Core Features	21 days	Mon 1/6/14	Mon 2/3/14		**DY,GC,MM,SM,SS**
23	Determine Stretch Goals and Feasibility	21 days	Mon 1/20/14	Sun 2/16/14		**DY,GC,MM,SM,SS**
24	**Milestone: Functional Specification due**	**1 day**	**Mon 2/17/14**	**Mon 2/17/14**	**23**	
25	Draft Design Spec	15 days	Tue 2/18/14	Sun 3/9/14	24	**DY,GC,MM,SM,SS**
26	**Milestone: Design Specification due**	**1 day**	**Mon 3/10/14**	**Mon 3/10/14**	**25**	
27	Prepare Oral Progress Report	6 days	Mon 2/17/14	Sun 2/23/14		**DY,SS**
28	**Milestone: Oral Progress Reports due**	**1 day**	**Mon 2/24/14**	**Mon 2/24/14**	**27**	
29	Research Platform for Development (SDK)	11 days	Mon 1/6/14	Mon 1/20/14		**GC**
30	Build Custom Image for Wandboard	8 days	Mon 1/6/14	Wed 1/15/14		**SM**
31	Streaming from Device to Single Wandboard	6 days	Thu 1/16/14	Thu 1/23/14	30	**SM**
32	**Milestone: Single Wandboard Streaming Complete**	**1 day**	**Fri 1/24/14**	**Fri 1/24/14**	**31**	
33	Streaming from Device to Dual Wandboard	12 days	Sat 1/25/14	Mon 2/10/14	32	**GC,SM,SS,DY**
34	Roomflow Feature Development	15 days	Tue 2/11/14	Sun 3/2/14	33	**DY,GC,MM,SM,SS**
35	**Milestone: Streaming SW Development Complete**	**1 day**	**Mon 3/3/14**	**Mon 3/3/14**	**34**	
36	Hardware Design and Fabrication	26 days	Mon 1/20/14	Sun 2/23/14		**GC,MM,SS**
37	**Milestone: Finished Hardware Design**	**1 day**	**Mon 2/24/14**	**Mon 2/24/14**	**36**	
38	**Integration and Testing**	**31 days**	**Mon 3/3/14**	**Mon 4/14/14**		
39	Hardware and Software Integration	21 days	Mon 3/3/14	Mon 3/31/14		**DY,GC,MM,SM,SS**
40	User Compliance Testing	31 days	Mon 3/3/14	Mon 4/14/14		**DY,GC,MM,SM,SS**
41	Draft Written Report	16 days	Mon 3/3/14	Sun 3/23/14		**DY,SS**
42	**Milestone: Written Progress Report due**	**1 day**	**Mon 3/24/14**	**Mon 3/24/14**	**41**	
43	Draft Demo Presentation/Documentation, Post-Mortem	10 days	Tue 4/1/14	Sun 4/13/14		**DY,GC,MM,SM,SS**
44	**Milestone: Demo, Eng Journal, Post-Mortem due**	**1 day**	**Mon 4/14/14**	**Mon 4/14/14**	**43**	



Project: Proposal_Main_GANTT
Date: Thu 1/16/14

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Progress