ELECTRAUDIO

January 23, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Project Proposal for SoundSocket, an Innovative Audio Transmission Solution

Dear Dr. Rawicz,

The enclosed document contains the proposal for SoundSocket, a product that uses power lines to transmit audio signals. The objective is to create a device that will provide quality audio transmission utilizing existing power lines, effectively eliminating the need to set up alternative wiring schemes or rely on wireless communication.

The proposal provides an overview of the product. It includes background and motivation, design considerations, a preliminary budget, sources of information and funding, project scheduling, and a company profile. It also contains information regarding existing solutions and an analysis of the product market.

Electraudio was founded by five innovative and dedicated senior engineering students: Josh Ancill, Andy Cheng, Daman Dhillon, Kim Izmaylov, and Laura Wiggins. If there are any questions or concerns regarding the proposal, please feel free to contact us via email at kvi@sfu.ca.

Sincerely,

Kim Izmaylov

Kim Izmaylov
Electraudio

Enclosure: *Proposal for SoundSocket Power Line Audio System*

Proposal for **SoundSocket** Power Line Audio System

Josh Ancill
Andy Cheng
Daman Dhillon
Kim Izmaylov
Laura Wiggins

Executive Summary

> *"It's all about sound. It's that simple. Wireless is wireless, and it's digital. […] When digital first started, I swear I could hear the gap between the ones and the zeroes."* - Eddie Van Halen

Most people expose themselves to different forms of audio on everyday basis. And while analog was the only way to go a few decades ago, nowadays most audio is stored and transferred digitally. Evolution of electronics and signal processing has allowed the digital equipment to preserve the quality of the original recording to such an extent that it is virtually impossible to hear the difference. From smartphones to expensive home audio systems, most modern digital equipment offers virtually lossless playback capabilities.

While the quality goals were being achieved, wireless technologies offered further enhancements to the experience. Wireless speakers provide mobility, decrease the number of necessary wires and eliminates the need to have the source of audio nearby. However, with a vast and growing number of wireless devices, radio frequency interference quickly became a major performance degrading issue.

To avoid this problem, as well as to keep the frequency spectrum available, the audio transmission has to occur via other methods. At **Electraudio**, we found an existing method that is both elegant and efficient. Power line communications (PLC) can be utilized to transmit the audio via existing power lines of the building. The speakers would simply receive the audio straight from the power socket, eliminating a need for wires other than the power cable. This maintains some wireless characteristics without using up the wireless spectrum and causing interference issues.

Currently there is a poor choice of PLC based audio systems on the market. Some products are quite expensive and others are not readily available for purchase. At **Electraudio**, we are set to build a robust and affordable power line audio system. Our system will allow the user to simply plug the transmitter unit into a wall outlet and use any other outlet in the building as both sound and power source for the speaker units. This document proposes the development of such system and it describes major topics such as design overview, cost, planning and other important points.

Electraudio consists of five senior engineering students specialising in electronics, computer and systems engineering. Together we comprise a well-rounded team with a wide area of expertise in analog, digital and software design, as well as in administrative and organizational work. The prototype will be built using evaluation and interface boards as opposed to custom built printed circuit boards. This will be sufficient to demonstrate all the necessary functionality and it will also enable quick changes to the design, if necessary.

Table of Contents

Table of Figures

Introduction

Is Power Line Communication (PLC) better than Wireless Communication methods?

Growing number of wireless devices pose a constraint on the amount of equipment using wireless technologies as means of communication. In technology-dense areas, such as city centres or university campuses, interference might become an issue, degrading the performance of wireless devices. Various audio systems that use Wi-Fi or similar wireless technologies become increasingly vulnerable to interference, as high quality audio uses a considerable amount of bandwidth.

The objective of this project is to use method of Power Line Communication (PLC) to develop a device for audio systems which can transmit audio signal over power line thus avoiding problems associated with Wi-Fi audio systems. This device will used existing power (mains) lines since it doesn't require any other wiring than the usual power cable. It can be depicted as wireless as most audio components rely on power supply anyways. The transmitting part of the project includes input that will be an audio signal which will be modulated by the device and then will couple on to the power line. On the receiver side, the modulated signal is received and demodulated and then fed into speakers as output. Output received will be Stereophonic Sound for better quality.

This system gives a sense of wireless communication as users do not have to deal with wiring setup for their systems. This device for audio systems is promising, considering the efforts needed to setup wired audio systems and the issues of interference in audio systems using Wi-Fi, especially in public places like music concerts and parties halls assuming they have proper a wiring system (separate circuits for the 3 different phases of electric power that comes to the home to reduce the load on each wire, most common in Germany, where this system will not work).

This Proposal document provides an overview of our product, the scope of the product which includes the risks and benefits, our company's details, and project planning which includes details about various milestones and deadlines related to them. This document also discusses costs associated with our product and its development. It also provides an explanation about possible design solutions and possible alternatives based on various constraints, related to design, budget and time required in each solution.

System Overview

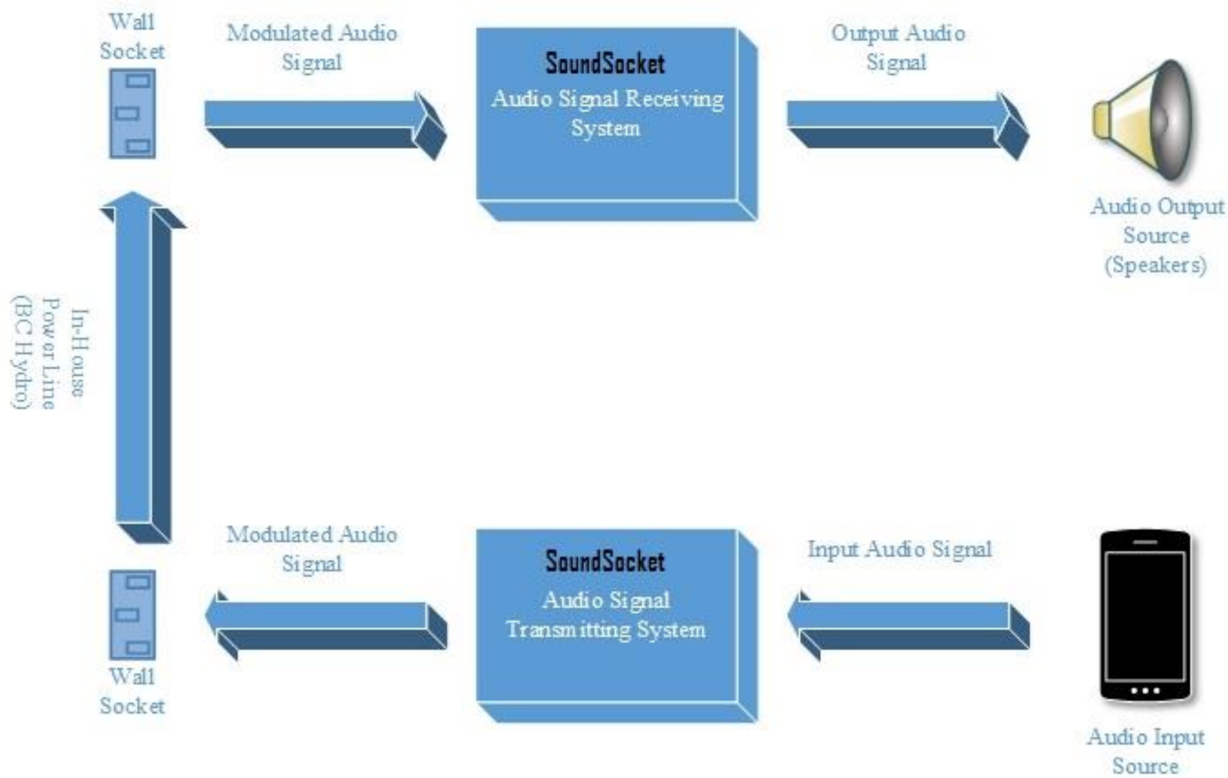

Figure 1: System Overview

Figure 1 illustrates the overview of our product. Note that one unit of SoundSocket system can act both as Transmitting or Receiving System. The sound signal from an audio input source will be fed into a SoundSocket. Once it's connected to the power outlet, it will start broadcasting music onto the power line. At that point, other SoundSockets can be plugged into various outlets in the building. Once the speakers are connected, CD quality audio will be played through them.

Existing solutions

There are very few products that provide power line audio transmission. The most common examples are IOGEAR's Powerline Stereo Audio System and Simple Audio's Roomplayer:

Figure 2: IOGEAR Power line Stereo System

IOGEAR's system is a legacy product and isn't readily available for sale on the internet. Related products include network power line adapters which can be used as a basis for building a power line audio network. However, this requires significant skills and/or other specific equipment as the audio source has to be interfaced to these adapters. IOGEAR's system actually consists of a specialized audio adapter and a separate audio station to increase the functionality. Extra features include iPod docking capabilities and remote control.

Figure 3: Simple Audio Roomplayer

Simple Audio's Roomplayer offers extended functionality such as multiple line outputs (for different standards), a digital output and a dedicated subwoofer output. It also capable of interfacing with computers and creating user profiles. However, it is only available for sale in Great Britain. Prices start at $740 and online ordering is available through Amazon UK.

To summarize, existing systems are either expensive or not readily available for purchase. The immediate market consists of wireless audio users looking for solutions to interference issues, as well as potential buyers looking for an efficient and elegant audio system. With growing number of wireless devices, we believe that the demand for interference-free systems with wireless characteristics will increase. Other markets may include concert venues looking to reduce the amount of cabling or lecture halls that require high quality audio.

Possible Design Solutions

We first came up with the goal of doing easy to set up "wireless" speakers which would receive a selection of audio channels at CD quality, which means 16 bit samples at a sample rate of at least 44.1 kHz. We propose targeting a minimum of two 48 kHz audio channels at 16 bits/sample.

2.4 GHz Wireless Communications

When exploring possible solutions to the problem we first explored the use of 2.4 GHz Wi-Fi technology however the issues of increasing 2.4 GHz spectrum use may cause interference problems, especially in the case of a concert hall where many people will be using their mobile devices. There is also the issue of range and security when broadcasting over the air.

Power Line Communication

We arrived at the idea for communicating over the power line after the realization that most speakers will be plugged into the wall at some point and the wiring will be pre-existing and can allow for greater range than wireless communication and the ability to communicate through thick walls.

We investigated three methods of doing the modulation required to get the needed data rates.

- Amplitude Shift Keying (ASK): Simple digital narrowband modulation technique modulating the digital data on the amplitude of a carrier. Low data rates, not suitable for CD quality audio.
- Frequency Shit Keying (FSK): Another narrowband modulation technique modulating the digital data in the frequency of the carrier. Low data rates, not suitable for CD quality audio.
- Orthogonal Frequency Division Multiplexing (OFDM): Wideband modulation technique which splits the digital data into multiple sub-carriers orthogonal to each other to prevent inter-channel interference. High data rates, suitable for CD quality audio.

With the modulation technique determined we need to determine the plan for implementation.

The ideal solution we researched appears to be an Analog Front End evaluation board from Texas Instruments combined with an FPGA implementation of the OFDM transceiver. The high cost of the evaluation board makes the risk of damage a costly mistake, something we will need to be very careful with in testing/integration.

As a fallback plan if we experience significant issues in the implementation of the power line we have purchased Homeplug adapters, an off the shelf component which communicates over power line. We would be able to communicate with the adapter via Ethernet from our FPGA. The software and some of the VHDL will be compatible with both our primary plan and our fallback plan so that work will not have to be duplicated.

Proposed Design Solution

We propose building a system which allows a user to send audio from one location to another with minimal setup or extra wires. We intend to have our solution communicate over the pre-existing power lines built into all modern buildings. This will allow audio inputs and speakers to be placed anywhere within a building assuming the building is all on the same electrical circuit. This saves the user from having to run additional wiring or deal with the headaches of wireless communication. One connection provides both power and audio data. The plan is for a user to plug in one of SoundSocket into the power outlet and connect one or more audio sources to its input. In other rooms the user plugs in one or more SoundSockets and connects a sound system or simple powered speakers to the output.

Our goal is to achieve multi-channel CD quality audio transmission over the power line with a digital control mechanism to select which audio source goes to which audio output. To achieve this goal we will be building a digital system in a FPGA (DE2-70) consisting of a microprocessor (Nios II) audio controller, and an Orthogonal Frequency Division Multiplexer (OFDM) transceiver in VHDL. We need to use an advanced transceiver to be able to obtain the data rates required for CD quality audio transmission in the potentially noisy environment of power distribution networks. The other solutions we investigated such as Frequency Shift Keying (FSK) would not provide the data rates needed for the audio quality desired in the home.

We additionally require an Analog Front End (AFE) to convert the digital signals to the analog domain and modulate the output to a high frequency carrier for transmission over the power line. This involves high speed Digital to Analog Converters (DAC) and high speed Analog to Digital Converters (ADC) and a frequency multiplier/mixer. An evaluation board made by Texas Instruments (TI) is available and a good fit for our design. Finally we will require some kind of coupling/isolation circuitry to transmit the data and protect our circuit.

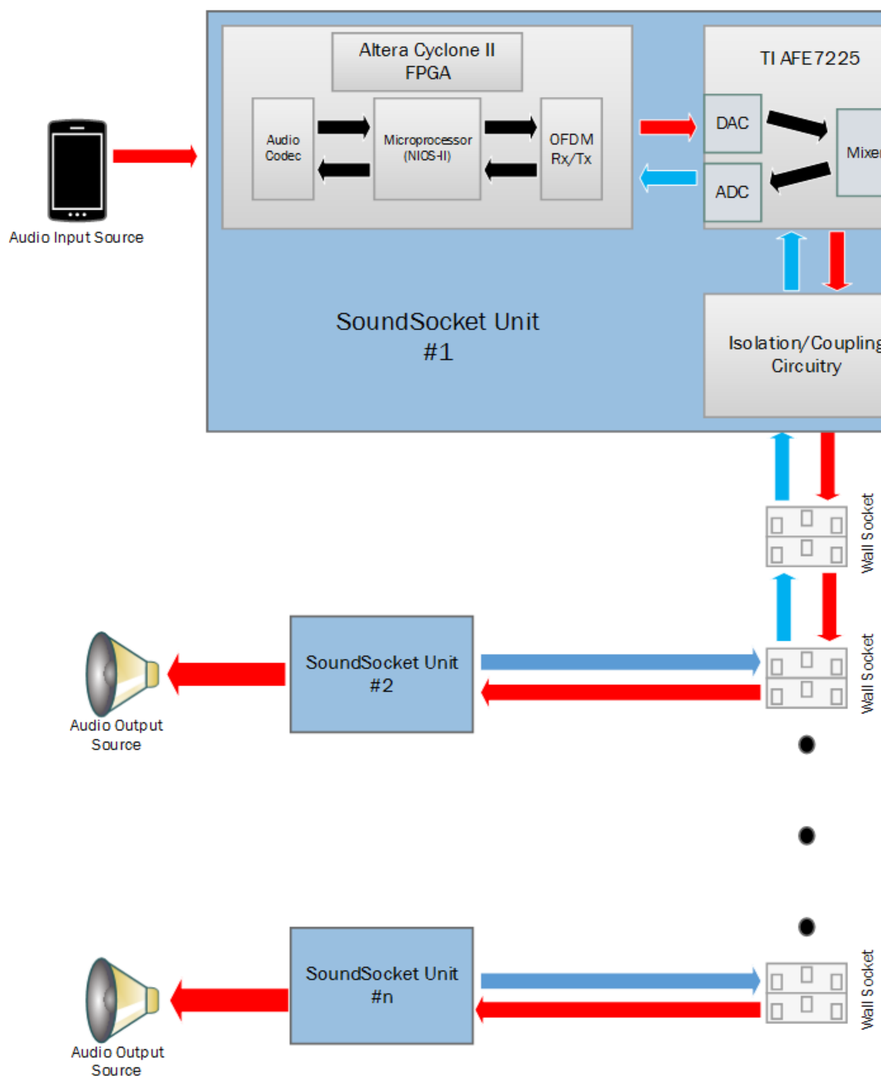

Figure 4: Proposed Design Solution

Constraints on our design include the desire for CD quality audio and multiple channels. We require a minimum of two channels for stereo however more channels will be targeted if channel bandwidth permits a higher data rate. Given the time constraints of the ENSC 440 we plan to only build the prototype using evaluation boards, off the shelf parts and an FPGA. Given more time we would like to design our own circuit with the individual IC's all on one board. Instead our focus will be on the theory of the design and the construction of a functional prototype.

Budget and Funding

Budget

The table below summarizes the breakdown of all the costs involved in prototyping our product, including shipping, tax, and customs if applicable. Some components with a cost of zero imply that it is loaned from the ESSEF Parts Library. This list aims to be final, but during development, our implementation may change and hence the parts as well. As a result, we went for the most cost effective models when selecting the equipment, especially ones with which our engineers were familiar working with. This effectively reduces development time and may allow us more time to further fine-tune the end solution to be simpler and cheaper to produce.

One issue we ran into is the relative costly AFE7225 evaluation boards. At such an early stage in development, we can't predict whether they will be used in the final prototype which means we could potentially be investing a large sum on a component that isn't considered 'final'. We're currently looking at alternatives which do not involve such a large upfront cost. Lastly, to cover for the costs of shipping and additional small supplies (resistors, wires, ICs) we may need along the way, we've added an item 'Miscellaneous'.

Table 1: Estimated Cost

Equipment List	**#**	**Estimated Unit Cost**
DE2-70 FPGA boards	2	$0
AFE7225 Evaluation module	2	$998
Miscellaneous		$100
Subtotal		**$1098**
+Tax(12%)		**$131.76**
Grand Total		**$1229.76**

Funding

The prototype will require significantly more time and money to produce versus the commercial counterpart. As such, we've reached out to a few sources of funds to help launch our development. One of which is the Engineering Science Student Endowment Fund. We are currently in the process of applying for the ESSEF fund, which we hope to acquire our target value through our presentation in front of their committee. Secondly, there is the Wighton Fund which we are also in the process of applying for. Aside from direct monetary funds, we've managed to incorporate some parts of the ESSEF Parts Database into our prototype design to save costs. As such, we pay only the $400 deposit required for the two DE2-FPGA boards.

Project Schedule

The schedule for our project is depicted in the following figures. The specified timings are subject to some adjustment. The Gantt chart in Figure 5 displays the timeline of the various tasks associated with the development of SoundSocket. This format provides a simple method of viewing the required tasks and keeping track of our progress.

Task Name	Duration	Start	Finish
Primary Research	35 days	Fri 14-01-03	Thu 14-02-20
Proposal	6 days	Thu 14-01-16	Thu 14-01-23
Sourcing/Ordering Parts	26 days	Mon 14-01-20	Sun 14-02-23
Functional Specification	18 days	Thu 14-01-23	Mon 14-02-17
Design Specification	27 days	Sat 14-02-01	Mon 14-03-10
Assmebling and Testing Modules	21 days	Mon 14-02-10	Mon 14-03-10
Integration and Prototype Testing	21 days	Mon 14-03-03	Mon 14-03-31
Debugging	13 days	Thu 14-03-13	Mon 14-03-31

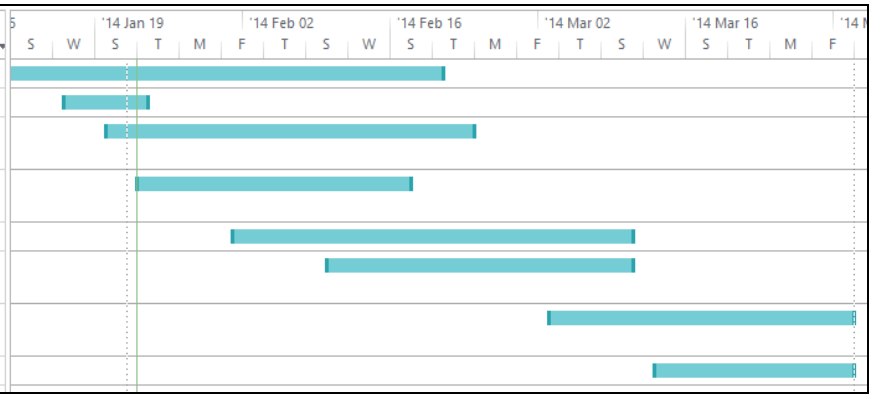

Figure 5: Gantt chart

The milestones associated with our project are shown in Figure 6. These milestones indicate the necessary completion dates for various aspects of the project.

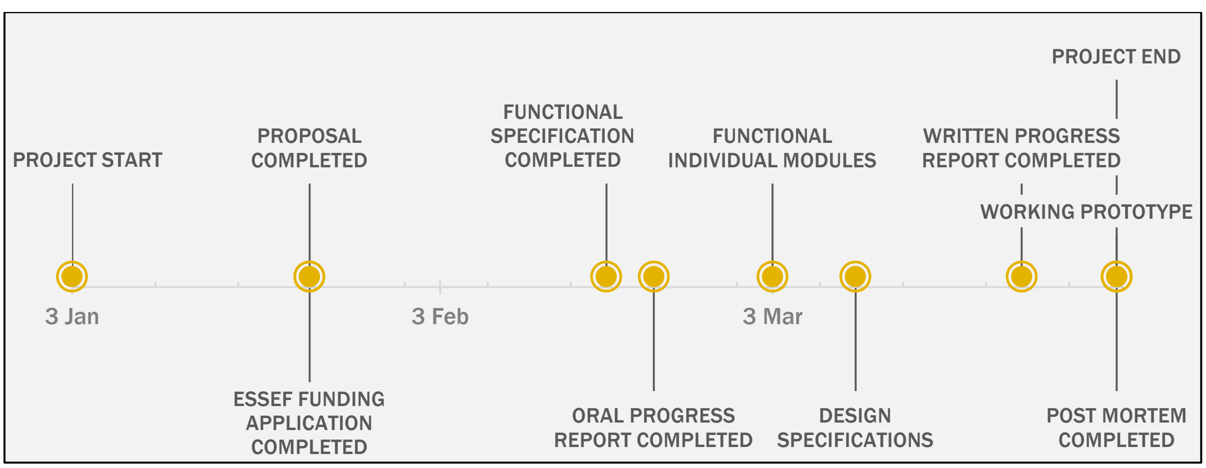

Figure 6: Milestones

Company Profile

Josh Ancill, Digital Electronics Engineer

Josh is a fifth year Electronics Engineering student at Simon Fraser University in his final year of study. Josh has completed two 8-month co-op positions, one at LightHaus Logic and the other at Nyce Control. He has experience with both software and hardware designs. Software languages include C, C++, python and bash. He enjoys working with digital designs on FPGAs and has experience with ASIC design. He has a passion for working with high quality video and audio systems and has been fascinated with the idea of data transmission over power lines. He is comfortable working alone but prefers to work in a team.

Andy Cheng, Digital Electronics Engineer

Andy Cheng is currently finishing his last semester at Simon Fraser University for his Electronics Engineering degree. He has completed three different co-ops: Muprime Technology, Ayogo Health, and North American EMC Certification Services. From there, he has picked up various software skills in web application and server development. Additionally, he also has had experience in writing automation programs for instruments used to perform electromagnetic compatibility and antenna calibration using LabView. Currently, he is working in a team to design a Computer Numerically Controlled (CNC) machine to be controlled by LabView through an FPGA.

Kim Izmaylov - Analog Electronics Engineer

Kim is a fifth year Electronics Engineering student at Simon Fraser University. His extensive musical experience is an important addition to the electronics and signal analysis courses he has been passionate about at SFU. Kim's relevant skills include analog circuit analysis and design, programming experience in C/C++ and basic prototype assembly. During a one year internship at Stemcell Technologies, he gained valuable hands on experience in experimenting and prototyping with OEM components. Besides his technical skills, organization and management is something that Kim have always involved in, given the opportunity.

Damandeep Singh Dhillon - Software/Hardware Engineer

I am fourth year Computer Engineering student at Simon Fraser University. I have 8 months of Coop work experience which include working Virtual Intelligence Inc. as Junior Software Engineer where I develop strong programming skills in C, C++ and Python. Second Coop Term include working in a research position at UBC Electrical and Computer Department polishing my skills in C# and working with Arduino Microcontroller Family. Beside software skills I do have experience working with FPGAs and working with lab equipments like oscilloscope, power supplies, function generators and digital meters. I do have good communication skills and work well with others.

Laura Wiggins – Systems Engineer

Laura Wiggins is currently in the final semester of study as a systems engineering student at Simon Fraser University. Through the completion of numerous courses, she has developed a very strong background designing and analyzing electronic, mechanical, and computer systems. Notable past projects include the control of a SCARA robotic arm manipulator, game development on an FPGA, and an air hockey playing mechanical device. Utilizing the skills obtained from her experience she can develop software in C, C++, create digital circuits using VHDL, and design and assemble analog electronic circuitry to aid in the development of SoundSocket.

Team Organization

Electraudio is proud to consist of members who feel comfortable and excited about their roles in this project. Having different areas of expertise, we have a clear sense of a common goal. The project involves analog and digital circuitry design as well as software development. **Electraudio** has just the right alloy of skills and experience to tackle this project. Task distribution happened naturally, based on personal interests and individual strengths. Kim will be working on the analog isolation/coupling circuitry as well as assisting with writing the software for audio processing. Besides that, he will be taking care of administrative and organizational aspects of the company. Josh will be working on the VHDL design of the OFDM transceiver and interfacing with the Analog Front End evaluation board. Andy will be working as a hardware engineer and apply the skills and knowledge on signal processing and FPGA development. He will also take care of the financial aspects of the project. Daman and Laura will be working on generating data packets from the sampled signal and transmitting them to the modulation stage. Daman will also be assisting Kim on isolation/coupling circuit development in the hardware section of the project. He will also be working on any miscellaneous problems that might occur during the development of the project.

As a team of students we have very similar schedules, which will allow us to meet for 8 hours per week or more. This will result in high quality of communication, efficiency and smoother integration in the final stages. The online communication will also be streamlined by using Google Hangouts and Document services as well as Dropbox cloud service. **Electraudio** engineers have successfully used these services in their previous projects.

Conclusion

SoundSocket is a product that aims to provide audio transmission in a way that eliminates many headaches that the current range of audio transmitting devices introduce. Wired devices are limited due to the range of the additional wiring it needs to connect the transmitter and speaker and or receiver. Wireless devices eliminate this problem but will always be prone to interference from other devices operating on the same frequency band which can affect the performance and reliability. **Electraudio** addresses these issues by using an already abundant resource: power lines. Although Power Line Communication has been around for a while since the 1990s, it has not been pushed for consumer applications until recent years. One such example is Power Line Adapters used in networking. SoundSocket as a solution provides audio transmission that possesses the advantage of range exhibited by a wireless counterpart, but with the reliability of a physical connection. **Electraudio** believes a product should be simple in design, easy to use and reliable; SoundSocket is built upon these principles.

The milestones have given an overview of the development process from design to prototype over the next four months, and **Electraudio** is determined to stay on schedule with scheduled weekly meetings to plan and discuss the current status of the project or to resolve any issues. As of this moment, our company has already began acquiring some equipment such as development boards and began doing various experiments to test the feasibility of our technical approaches. We believe **Electraudio** is on schedule to deliver a product that complies with industry standards.

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