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February 06, 2012

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

Re: ENSC 440 Functional Specification for Multifunction Intelligent Headphone System

Dear Dr. Rawicz,

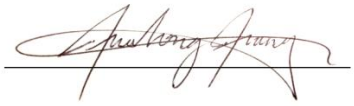
Enclosed is a functional specification which describes the features of the Multifunction Intelligent Headphone System. The project is designed and implemented with a system that will detect the surrounding environment in real time and process this information to the user. Some of the main features we are designing are word recognition, sound recognition, and voice recognition if time permits.

Our functional specification outlines the high-level requirements and consideration of the intelligent system's functionality. This specification will be used by all team members in the integration and testing stages. Targets are outlined in this specification for all members to ensure a minimum acceptable performance.

Our company, Sound Tec Inc., consists of five talented and innovative students from the School of Engineering Science at Simon Fraser University: Leo Jiang, Simranjit Sidu, Frank Zhu, Xiao Peng He and Afrin Chowdhury. We believe this team is capable of accomplishing the proposed tasks in a timely fashion.

If you have any questions about our functional specification, please do not hesitate to contact us via phone at 778-855-4037 or email at jhj1@sfu.ca.

Sincerely,



Leo Jiang
Chief Executive Officer
Sound Tech Inc.

Enclosure: *Functional Specification for Sound Tech Inc. Multifunction Intelligent Headphone System*

Functional Specification:

Multifunction Intelligent Headphone System

PROJECT TEAM

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SUBMITTED TO

Dr. Andrew Rawicz – ENSC 440
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ISSUED DATE

February 06, 2012

EXECUTIVE SUMMARY

The headphones in today's market provide great comfort and high-quality sound. These high-end headphones are completely noise proof. They not only eliminate noise, but also bring a lot of issues. These headphones can be very inconvenient to use when communicating with other people. They also bring danger to pedestrian users. Recent studies have shown that the number of injuries and deaths related to people using headphone on the street had increased. The multifunction intelligent headphones system will provide user the comfort, sound quality and more safety.

The device will have three modes: word, sound, and voice recognition modes. In word recognition mode, the system will tune the volume up and down by detecting the keyword 'up' or 'down'. In sound recognition mode, the system will interrupt the headphone volume system and warn the user when danger sound is detected in the surrounding environment. In voice recognition mode, the system will inform the user who is calling their name.

In this report, we have outlined the detailed modeling of our multifunctional intelligent headphone system. We have also provided detailed technical and physical requirements of the end product. The team will follow all the requirements towards the end of the project.

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GLOSSARY

MIHS	Multifunction Intelligent Headphone System
CPU	Central Data Processing Unit
SMVR	SmartVR Voice Recognition
NCH	Noise Cancelling Headphone

1. INTRODUCTION

The Multifunction Intelligent Headphone System (MIHS) is a noise cancelling headphone that provides users great comfort, high sound quality, as well as safety. While providing a high quality of sound to the user, the MHIS will capture all the analog readings around the user, analyze them, and inform the user in the case of danger.

The headphone system will be equipped with a high-performance Arduino microcontroller board, which is used to decode the analog reading. The headphone has three modes: word, sound, and voice recognition modes. The headphone system will behave accordingly to the different modes. In word mode recognition mode, the MIHS tunes the volume according to the word command. In sound recognition mode, the MIHS will interrupt the headphone and signal the user when danger sound is detected. In voice mode, the MIHS will auto adjust the volume for the user upon recognizing certain voices.

The detailed requirements for the MHIS are described in this functional specification.

1.1 Scope

This document describes the functional requirement for the Multifunction Intelligent Headphone System. It provides a detailed description of the required functionality for a proof-of-concept model and details the prototype system for reproduction. This document also provides a development test plan that will be used by the design engineers of Sound Tech Inc. during the testing, implementation, and testing of the device.

1.2 Intended Audience

The functional specifications are intended for all members of the Sound Tech Inc. team to track the project progress and to be used as reference during the development of the device. The team will use this document to ensure all the design functions have been implemented, and are working as in the proposed design.

1.3 Classification

Throughout this document, the following convention will be used to denote functional requirements for the Multifunction Intelligent Headphone System:

[R#-p] – Functional requirement description, where '#' is the required number in this function specification and 'p' is the priority of the functional requirement. The priority levels are:

I Proof of concept prototype only
II Proof of concept prototype and final product
III Final product only

2. SYSTEM REQUIREMENTS

The overall function of MIHS is outlined below in the following sections. We specified general, physical, electrical, safety standards, and performance requirements. In order to prioritize our product, we must fulfill some basic requirements and list as more as features. Within the short period of time, we will realize necessary requirements step by step.

2.1 System Overview

The headphone system has four main components: the noise detection board, microcontroller board, volume controller and the noise cancelling headphone. The four main components will be implemented on the MIHS as shown in the following block diagram.

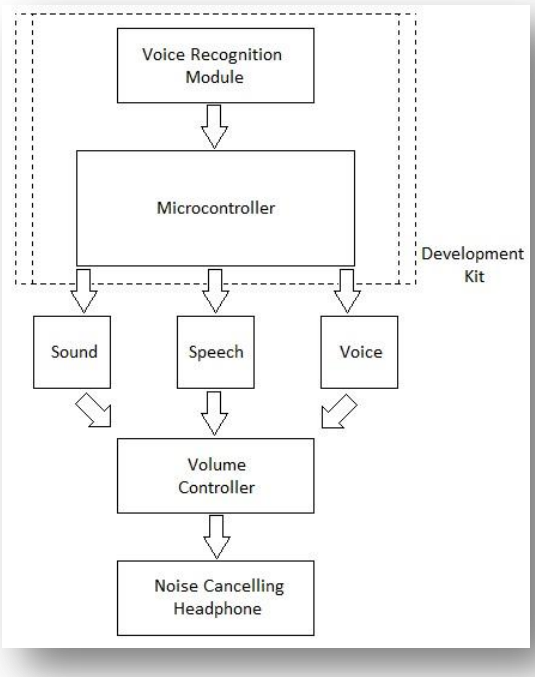

Figure 1: Structure of MIHS

Development Kit consists of Voice Recognition module and microcontroller. The Voice Recognition module as noise detection board will detect sound or noise from outside. After detecting the sound, it will send signal output to the microcontroller. Then, the microcontroller board will select different modes such as sound, speech, voice; and send command to volume controller. Lastly, volume controller will perform certain actions such as turn down the volume or mute it.

In our project, we are going to work with the Development Kit. The process of the development kit is shown in figure 2.

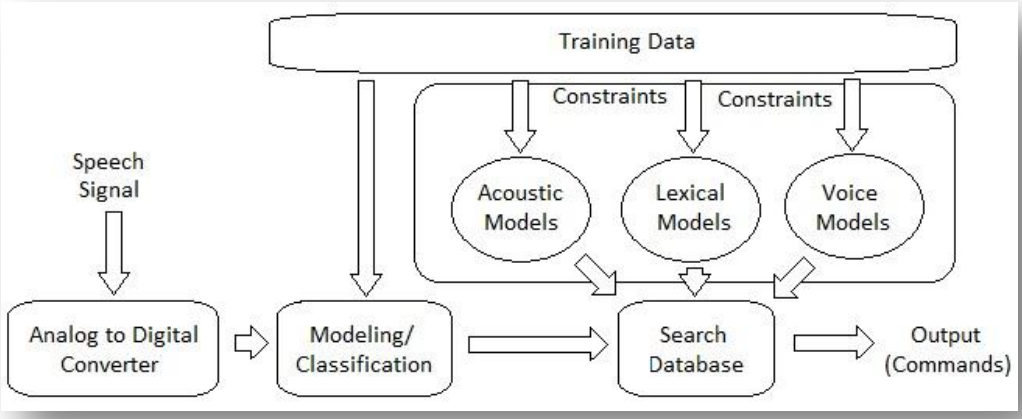

Figure 2: Process of Development Kit

In the development kit design, Training data will be divided into three parts: Acoustic models, Lexical models and Voice models. Each of the models will have specific operation in database. When SmartVR detect any speech signal through the microphone, it will convert that speech to digital data and will classify that data by searching in the database. If the speech data matches in the training database, then the system will operate and outputs the action.

2.2 General Requirements

[R1-II] The MIHS should be used in noisy environments (such as on the street, bus etc.).

[R2-III] All circuits should fit inside the MIHS.

[R3-III] The retail price of the MIHS should not be over $600 CAD.

[R4-III] The MIHS must be simple to maintain.

2.3 Physical Requirements

[R5-III] The size of the MIHS shall not exceed 10.9 x 3.5 x 7.5 inches.

[R6-II] The total weight of the MIHS shall be approximately 350g.

[R7-II] The MIHS cable length should be around 1.3 meters.

[R8-III] The internal circuits should be connected to external devices.

[R9-III] The MIHS should not control by pushbutton.

2.4 Electrical Requirements

[R10-III] The MIHS shall be powered by battery in a range of 8V to 11V.

[R11-III] The MIHS should operate reliably within a temperature range of 0°C to 70°C.

[R12-III] The operating current of power supply should be 11mA.

[R13-II] The Advanced driver of MIHS shall be designed for precise audio clarity.

2.5 Mechanical Requirements

[R14-III] Operation buttons shall be placed on the top of the MIHS.

[R15-II] Power button shall be placed away from the operation buttons.

[R16-III] The device shall be easily unassembled with the use of screwdrivers.

2.6 Safety Requirements

[R17-III] All electrical components must be enclosed inside the MIHS.

[R18-II] All electrical components should not cause any harmful interference.

[R19-III] The MIHS should never output any unwanted loud sound.

2.7 Performance Requirements

[R20-III] Voice recognition of MIHS (inform the user of incoming call).

[R21-III] Sound recognition of MIHS (when danger is around user, system will automatically mute).

[R22-III] Speech recognition of MIHS (when someone talks to user, volume will automatically tune down).

[R23-II] The MIHS shall be well-defined syntax for grammar representation.

2.8 Usability Requirements

[R24-II] The MIHS shall be used by human beings.

[R25-II] The MIHS shall be easy to turn off and on by user's command (voice).

[R26-II] The MIHS shall be automatically tune down and up by detecting outside noise level.

[R27-II] The MIHS shall be easily adjusted to fit different sizes.

[R28-II] The MIHS shall have power indicator LED to indicate when the user needs to replace batteries.

3. CENTRAL DATA PROCESSING UNIT REQUIREMENTS

In our project we are planning to achieve three different use cases. The design and requirements of the central data processing unit (CPU) will depend upon the case, which will require the most processing. The highest use case we had considered is voice recognition. Voice recognition deals with analysis of the linguistic content of a speech signal. So, we need a decent central processing unit.

Some of the requirements are as follows:

3.1 General Requirements

[R29-II] The CPU chip should be able to capture and process the voice data in real time.

[R30-II] The CPU chip should have ports for capturing the audio data and communicate with the SMVR module.

[R31-II] The CPU chip should have some memory to load the heavy algorithm for voice recognition.

[R32-II] The CPU chip should have fast processing speed and better energy efficiency.

[R33-II] The CPU chip should be capable of working effectively in all weathers.

3.2 Physical Requirements

[R34-II] The CPU chip should be light in weight and small in size.

[R35-II] The CPU chip should be available in different size and style to custom fit different headphones.

3.3 Electrical Requirements

[R36-II] The CPU chip should be easy to interface with SMVR module.

[R37-II] The CPU chip should be able to use same power supply as SMVR module.

[R38-II] The CPU chip should have proper power protection and shielding from static charges.

3.4 Mechanical Requirements

[R39-II] The base of the CPU chip should have material to support the screws for proper holding with headphones.

[R40-II] The base of the CPU chip should be shock proof and strong enough to handle forces arising from everyday headphone handling.

3.5 Reliability and Durability

[R41-II] The CPU chip should be able to perform all the voice recognition algorithms effectively. The results should be consistent.

[R42-II] The CPU chip should be able to perform efficiently in large temperature range.

[R43-II] The CPU chip should not be prone to shocks and stress of everyday handling.

[R44-II] The CPU chip should never hang up. It should have proactive recovery mechanism.

3. 6 Safety Standards Requirements

[R45-II] The CPU chip should not over heat.

[R46-II] The CPU chip should not make loud noise and should be as quiet in operation as possible.

[R47-II] The CPU chip should never give any electric shock.

3.7 Performance

[R48-II] The CPU chip should be able to recognise voice in real time.

[R49-II] The CPU chip should be able to communicate with SMVR chip in real time.

[R50-II] The CPU chip should be able to support the multithreaded environment to parallels different processes.

After lots of research, we had decided to use Arduino processor. “Arduino is a popular open-source single-board microcontroller, descendant of the open-source Wiring platform, designed to make the process of using electronics in multidisciplinary projects more accessible. The hardware consists of a simple open hardware design for the Arduino board with an Atmel AVR processor and on-board input/output support. The software consists of a standard programming language compiler and the boot loader that runs on the board.” [1].

Some of the benefits of using Arduino will be decent processing power, cheaper in cost, different shapes to custom fit the headphones, great support for development by robot community.

4. SMARTVR CHIP REQUIREMENTS

The SmartVR also known as VoiceGP chip can quickly and easily develop voice and speech recognition. This technology is rich in features and has powerful mixed signal processor named sensory RSC- 4128. It has the capability of multi-language speaker independent (SI), speaker dependent (SD), and speaker verification (SV) speech recognition [2].

4.1 General Requirements

[R51-II] The weight of the SMVR chip should be under 25g.

[R52-II] The total dimension of SMVR chip is 42mm x 72mm.

[R53-III] The SMVR chip should fit inside the MIHS.

[R54-II] The memory capacity of SMVR chip should be at least 10MB.

[R55-II] The delay of SMVR chip's output signal must be lower than 100ms.

4.2 Physical Requirements

[R56-III] The SMVR chip should plug into the development board (CPU).

[R57-II] An External microphone must be connected with a source resistor value of 1.2kΩ.

[R58-II] The external microphone should have sensitivity of 38dB and Impedance of 2.2 kΩ.

[R59-II] The SMVR chip should be able to connect to external devices (CPU, memory etc.)

4.3 Electrical Requirements

[R60-II] The SMVR chip must be powered by battery in the range of 2.7V – 3.6V.

[R61-II] The circuit of SMVR chip should use resistive values range of 1kΩ, 10kΩ, 50kΩ, 100kΩ or 200kΩ.

[R62-II] The SMVR chip should operate reliably within a temperature range of 0°C to 70°C.

[R63-II] The operating current of power supply should be 11mA.

4.4 Mechanical Requirements

[R64-II] The base of the SMVR chip should have material to support the screws for proper holding with MIHS.

[R65-II] The base of the SMVR chip should be shock proof and strong enough to handle forces arising from everyday MIHS handling.

4.5 Reliability and Durability

[R66-II] The SMVR chip should be able to perform all the sound recognition algorithms effectively.

[R67-II] The SMVR chip should be able to perform efficiently in large temperature range.

[R68-II] The SMVR chip should not be prone to shocks and stress of everyday handling.

[R69-II] The SMVR chip should never hang up. It should have proactive recovery mechanism.

4.6 Safety Standards Requirements

[R70-II] The SMVR chip should not over heat.

[R71-II] The SMVR chip should never output any unwanted loud sound.

[R72-III] All electrical components of SMVR chip must be enclosed inside the MIHS.

[R73-II] All electrical components of SMVR chip should not cause any harmful interference.

4.7 Performance

[R74-II] The SMVR chip should be able to recognize up to 12 user commands.

[R75-II] The SMVR chip should be able to communicate with CPU in real time.

[R76-II] The SMVR chip should be well-defined syntax for grammar representation.

5. NOISE CANCELLING HEADPHONE REQUIREMENTS

In order to hear more detail of music in today's noisy world while artists and producers work hard in the studio perfecting their sound, a noise cancelling headphones (NCH) is required. Normal headphones are distinct from a NCH which combines the extra-large speaker driver, high power digital amplifier, and powered isolation technology.

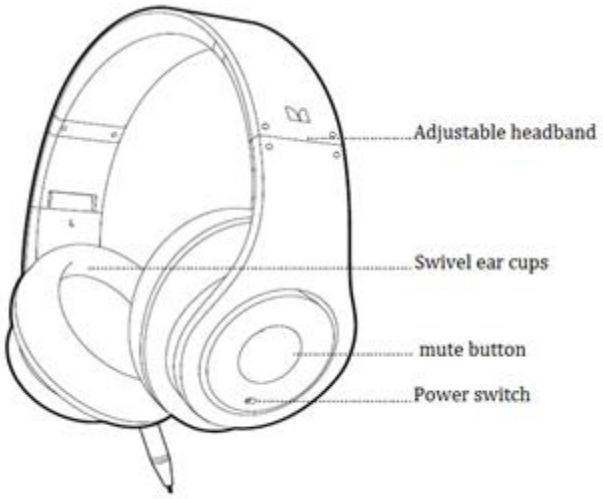

Figure 3: Noise Cancelling Headphones [3]

5.1 General Requirements

[R77-II] NCH combines the extra-large speaker driver, high power digital amplifier, and powered isolation technology.

[R78-II] The NCH can be used in most of the noise environment such as: on the street, on the bus, and on the plane.

5.2 Physical Requirements

[R79-II] The weight of NCH with batteries is between 250 grams to 300 grams.

[R80-II] The NCH cable length should around 1.3 meters.

5.3 Electrical Requirements

[R81-I] The Advanced driver of NCH is designed for precise audio clarity.

[R82-I] The Extra-large speaker drivers of NCH for super deep bass.

[R83-I] High powered digital amplifier of NCH plays music more loudly but without distortion.

[R84-I] Powered Isolation technology which is activated by two AAA batteries cuts external noise.

5.4 Safety Standards Requirements

[R85-I] It is unsafe to wear NCH during an activity or environment where you need to pay your full attention.

[R86-I] This decibel (dB) table compares some common sounds and shows how they rank in potential harm to hearing.

Table 1: Common sound comparison in decibel (dB) [4]

Sound	Noise Level (dB)	Effect
Whisper	30	Very quiet
Quiet Office	50-60	Comfortable hearing levels are below 60 dB
Vacuum Cleaner, Hair Dryer	70	Intrusive; interferes with telephone conversations
Food Blender	85 - 90	85 dB is the level at which hearing damage (8 hrs.) begins
Garbage Truck, Cement Mixer	100	No more than 15 minutes of unprotected exposure recommended for sounds between 90-100 dB
Power Saw, Drill/Jackhammer	110	Regular exposure to sound over 100 dB of more than 1 minute risks permanent hearing loss
Rock Concerts (varies)	110 - 140	Threshold of pain begins around 125dB

5.5 Usability

[R87-II] To mute audio, simply press and hold the mute button. To resume, release the mute button.

[R88-II] The headband of NCH should be adjusted to fit different sizes.

[R89-I] Power indicator LED will indicate when the user needs to replace batteries.

6. DIGITAL VOLUME CONTROL REQUIREMENTS

The digital volume control is constructed with an integrated circuit. The digital potentiometer replaces the mechanical potentiometers with digital precision. It has no moving parts to wear out, saves space, reduces heat, and communicates with a processor for flexible and automatic adjustment [5]. The volume control in this integrated circuit is controlled by a binary count up and count down.

6.1 General Requirements

[R90-III] The controller circuit should fit inside the headphone system.

[R91-II] The controller circuit should be controlled by binary count.

[R92-II] The controller circuit should introduce little to no noise to the system.

[R93-III] The weight of the controller should be under 15g.

6.2 Physical Requirements

[R94-II] The controller should not control by pushbutton.

[R95-II] The controller should connect to both the microcontroller and the headphone.

6.3 Electrical Requirements

[R96-II] The input signal for the circuit should not fall below -0.2 volts.

[R97-II] The ds1869 chip should operate between 3V to 8V.

[R98-II] The circuit should use resistive values range of 10kΩ, 50kΩ, or 100kΩ.

[R99-II] The operating temperature should be -40°C to +85°C.

6.4 Safety Standards Requirements

[R100-III] All electrical components must be enclosed inside the headphone.

[R101-II] All electrical components should not cause any harmful interference.

[R102-III] The digital potentiometers should not exceed the maximum preset decibel of the headphone.

7. USER DOCUMENTATION

The user documentation is a manual that will be provided with Multifunction Intelligent Headphone. The users of the device will also be able to access this information online in case of damage or loss.

[R103-III] The user documentation shall be provided with detailed user manual and a quick start guide.

[R104-III] The installation manual shall be included in the Multi-function Intelligent Headphone system.

[R105-II] A step by step troubleshooting guide shall be incorporated into the instruction booklet.

[R106-III] Warranty terms and conditions, as well as all company contact information are to be made available to the user.

[R107-II] The user manual shall be written for an audience with minimal technical knowledge.

[R108-II] The quick start guide, user manual, and the installation guide will be provided in official languages of nations where products are distributed.

[R109-III] The user documentation shall be provided in the company website.

[R110-III] The user instruction manual must get updated regularly.

[R111-III] A regularly updated F.A.Q. Frequently Asked Questions, section will be available to the user via company website.

8. MARKET REQUIREMENTS

[R112-III] The MIHS should have durable packaging.

[R113-II] The MIHS should be flexible and cost-effective.

[R114-III] The MIHS ensures user's safety with warning system.

[R115-II] The MIHS design enables user to listen to the outside world without removing headphone.

[R116-II] User will enjoy the best listening experience from the MIHS design.

9. SYSTEM TEST PLAN

The development of headphone system will follow three in-depth test stages. The testing stages consist of testing the SmartVR board, testing the Arduino microcontroller, and finally testing the volume controller. After all modules are tested, the overall system will be integrated and tested in the normal scenario. Testing of the whole components will undergo extensive end-user trials to identify faults.

The MIHS is designed to meet all functional requirements listed in this document, so all the listed requirements in this document will be tested. However, the test procedure can vary from the scheduled steps in the development stage, and the new detailed test procedure will be determined by the practical situation. Still below the core requirements will be tested and included.

9.1 SmartVR Board

The SmartVR Board is the most crucial test as it detected outside noise. We satisfy all requirements of hardware, and test the various software involved in it.

- The desired sound and speech can be detected and recorded by the SMVR board.
- The sound and speech from the outside world could be recognized by SMVR board.
- The analog signal of sound and speech could be converted to digital signal.
- SMVR board is able to communicate with Arduino Microcontroller board.

9.2 Microcontroller Board

Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board [6].

- Arduino Microcontroller can receive the signal from SMVR successfully.
- The digital signal can be matched with the pre-programmed code.
- Sound recognition function works properly based on signal from SMVR.
- Speech recognition function works properly based on signal from SMVR.
- Voice recognition function works properly based on signal from SMVR.
- The output signal could reach volume controller successfully.

9.3 Volume Controller

We will choose DS1669 Digital Potentiometer as volume controller. The DS1669 can be controlled by either a mechanical–type contact closure input or a digital source input such as a CPU [7].

- The volume controller is able to control the volume of headphone.
- The volume controller could receive ‘order’ from microcontroller properly.
- The volume controller can implement the proper operation to headphone.

10. CONCLUSION

The functional specifications describe the requirements for our product, the Multifunction Intelligent Headphone System. We, at Sound Tech Inc. will strive hard to follow and stand by these requirements to bring out a robust product. The development of the product will be undertaken in two phases. In the first phase, the three main components (SMVR board, microcontroller board, and the volume controller) will be tested. After the three main components are tested we will enter phase 2, where a prototype meeting the primary specifications will be integrated and tested. We are expected to have a complete working prototype of the product ready by Mid-April 2012.

11. SOURCES AND REFERENCES

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