FORTRESS SYSTEMS LIMITED

November 3, 2008

Dr. Andrew Rawicz and Mr. Mike Sjoerdsma

School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 305/440 Design Specification for the Sound Sense Vibe

Dear Dr. Rawicz and Mr. Sjoerdsma,

The attached document, *Design Specification for the Sound Sense Vibe*, outlines the design plans for our product currently in development for Ensc 440. The purpose of this document is to provide an overview of the design plans required to satisfy the functional specifications proposed previously. The document concentrates on the design specifications required to satisfy the proof-of-concept functional requirements, however some prototype/final product design plans are discussed. Please note that the design specification is a living document and may be modified/improved during the implementation phase.

Fortress Systems Ltd is comprised of 3 talented, motivated and driven Engineering students: Patrick Beaulieu, Mike Saad and Johnson Lam. If there are any questions or concerns about this document, please contact me by e-mail at ckl10@sfu.ca.

Sincerely,

Johnson Lam

President and CEO
Fortress Systems Ltd

Enclosure: *Design Specification for the Sound Sense Vibe*

FORTRESS SYSTEMS LIMITED

Design Specification

Sound Sense Vibe

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Submitted to: Dr. Andrew Rawicz – ENSC 440
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Issued date: November 3, 2008

Revision: 1.0

Executive Summary

The Sound Sense Vibe will be designed to allow the deaf to tactilely experience sound. Audio occurring around the user will be passed on via vibrations that will allow them to determine the position and the strength of sounds occurring. This will allow the user to be more aware of their environment and even improve their safety.

Fortress Systems Ltd is currently building a proof-of-concept version of the Sound Sense Vibe. The design specifications discussed herein apply mostly to this proof-of-concept phase, though some final product design considerations will also be discussed. These design specifications explain how Fortress Systems plans to create a product that satisfies the functional requirements detailed in *Functional Specification for the Sound Sense Vibe* [1].

The design specifications outlined in this document will detail our implementation plans for the Hardware, Software, Interface and Industrial Design (form factor) of the Sound Sense Vibe. Once the plans for input capture, processing and output are detailed the development process will have a roadmap to follow. A vision of the form factor of the final product will also help when imagining its every day use. By having these feasible design plans, the completed proof-of-concept device should meet its functional requirements.

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Glossary

A/D:	Analog to Digital signal converter, necessary for signal processing
BEMF:	Back Electromotive Force; caused by electric motor feedback
HMI:	Human to Machine Interface
LED:	Light Emitting Diode, light used as a user notification device
Microcontroller:	A computer system on a chip including I/Os
Nyquist Frequency:	Minimum frequency at which a signal must be sampled to avoid losing any high frequency information
PCB:	Printed Circuit Board; The base of most electronics systems
PWM:	Pulse-Width Modulation; method of delivering varying power to a DC motor
Unidirectional Microphone:	Sound input device that will only register sound from one direction

1. Introduction

1.1. Document Scope

This document describes the design specifications of both the proof of concept and prototyping/final product stages of the Sound Sense Vibe. These specifications make up the basis of this document, and this document will guide the product development. It is important to remember that this document will be treated as a living document, meaning that if, during development, a design specification is found to be unnecessary or must be modified this document, in turn, will be modified. This living document concept is important because the ability to dynamically adapt product plans during the development phase will allow adaptation to new information, encouraging the creation of the best product possible.

1.2. Intended Audience

This document is intended for two distinct audiences. The first, developers, will use the document for design decisions, planning and verification. The second intended audience, the management team and stakeholders, will use the document to gauge development plans and progress. It is important to note that a basic understanding of certain software and hardware concepts will be required for full comprehension of the design plans discussed.

2. Overall System Design

In general, the Sound Sense Vibe is a passive sound detection device; it requires the external input of audible sound at any of its 3 microphones. The input signal will be amplified and processed by a microcontroller program to determine the vibrational output. The feedback system will use the tactile sensory system of the user's arm.

2.1. High-level System Design

To help explain the overall design, Figure 1 below shows high-level system operation.

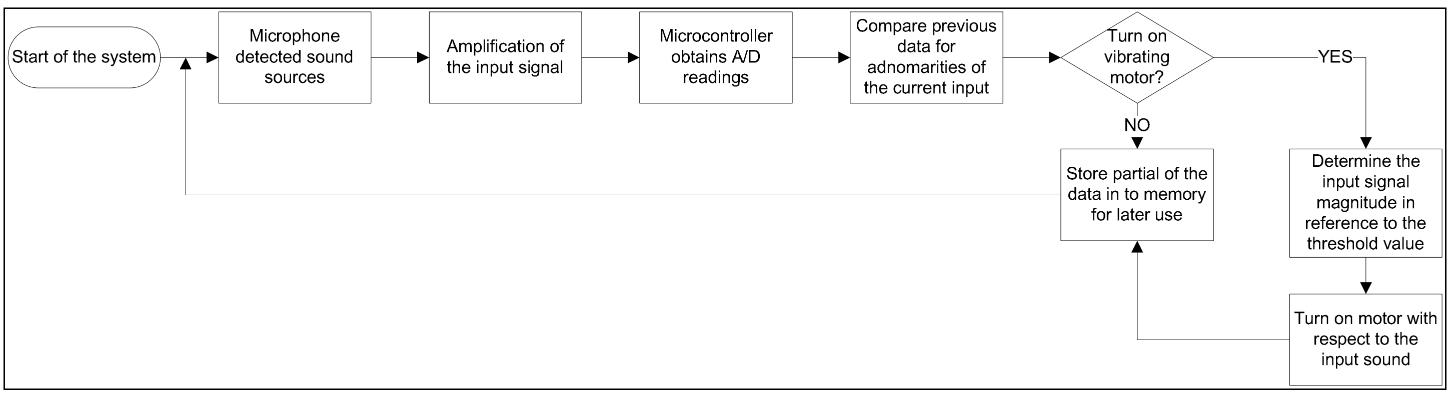

Figure 1: High-level System Flow Chart

As the above figure indicates, the input signals will be compared to the previous inputs to determine the need of turning on the vibrating motors to alert the user. In the event that there is no previous data for comparison, the default threshold values will be used.

2.2. Sensor Placement

As mentioned in the high-level system design section, an array of 3 microphones will be the sensors for this project. The following figure demonstrates the planned layout of the microphones.

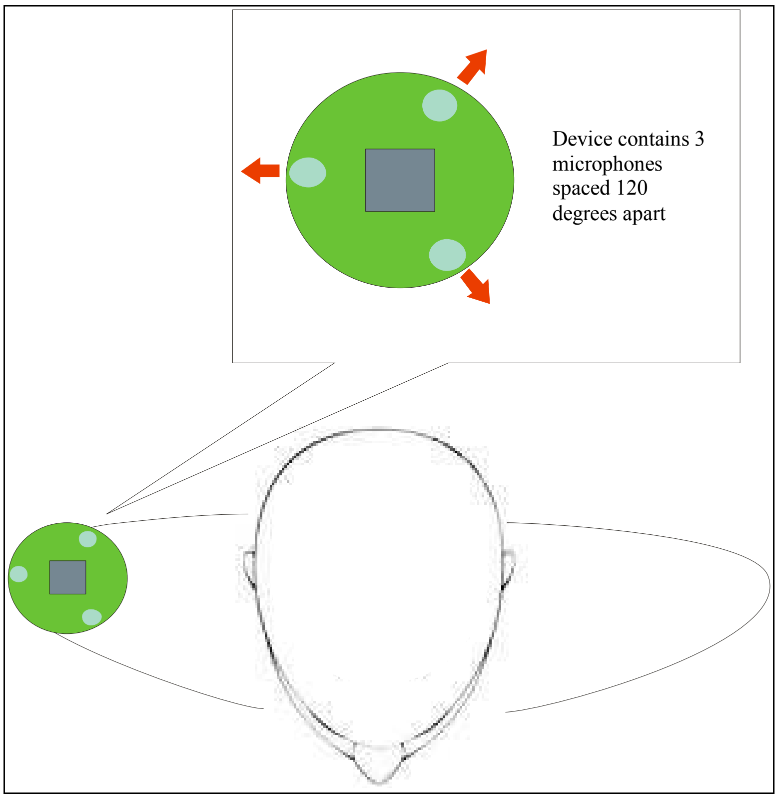

Figure 2: Microphone Placement and Orientation

We are using 3 discrete microphones to help determine the direction of the sound. We will use the 3 inputs to estimate 4 separate channels for our 4 vibrational motors. More information on the approximation method will be discussed in the *Signal Processing and Computation Software* section.

2.3. Actuator Placement

Spatially correlated with the input microphone array, an array of vibrating motors is also implemented into this project. The motor vibrating duration and vibrating strength will be determined by the strength of the current input signal in respect to the threshold values.

The duration and strength of the vibrating motors will be covered in the *Output Signal Conditioning* section.

2.4. Electrical System

The device electronics will require a 5V and a 12V DC as power source. The 5V source is for logical device such as microcontroller, memory, microphone circuit, LEDs and vibrating motors. The 12V source is for the microphone input signal amplification circuit. Protection such as diodes will be used to protect the motor driver from causing damage and the 5V and 12V DC power will be delivered from voltage regulators.

2.5. Noise Considerations

This project is very sensitive to noise due the nature of microphones; careful layout of each component should reduce the input noise. We will use shielded cables for microphones and reduce any redundant wiring as much as possible to prevent interference. The PCB layout may have 2 separate pieces distanced apart; this will effectively isolate the interference with the microphones when the vibrating motors are in operation.

2.6. Safety Considerations

Safety is a major concern for any electrical device. In order to provide a robust device, circuit protection is inevitable. We will apply heat sinks along with thermal past to all voltage regulators to dissipate heat and the thermal paste will increase the surface contact between the voltage regulators and heat sinks to achieve better silent cooling. All external wiring will use heat shrink-wrap as protective insulation to prevent against short circuits and wearing.

2.7. Power Supply

A 12V DC 5A power supply is sufficient to drive the device. This calculation is based on the current power requirement of the individual components and includes headroom for further development of the device. A 120V AC to 12V DC power adapter would be ideal for this proof-of-concept device because this will allow us the use of any wall socket.

3. Input Signal Conditioning Unit

Signal processing is essential in the project because noise filtering is required for the microphone input. This section will discuss the input signal conditioning process of the project in both hardware and software.

3.1. Analog Signal Amplification

Signals generated from a microphone are extremely difficult to be used directly for A/D sampling with a microcontroller. A better approach would be to implement a microphone pre-amplifier circuit to clean out possible noise and amplify the microphone signals. For this project we chose an off the shelf single channel pre-amplifier kit from CANKIT[2]. We will reverse engineer the original circuit to create a triple channel pre-amplifier kit (one for each microphone) for our project. We expect to create a triple channel pre-amplifier kit with at least 0.7Vp-p output on each channel. The pre-amp output will then be amplified to achieve the 0-5V swing required of our ADC.

3.2. Analog Filtering

To reduce the computation load (of digital filtering) on the microcontroller, an analog filter with level shifting is desired. The analog filter should be a bandpass filter to remove non-human audible frequencies such as less than 60Hz or greater than 17Khz. Level shifting on voltages is needed for the microcontroller's ADC. For example, if the signal from the microphone is -1 to +1 V then we need to level shift the voltages to 0V to +5V for the microcontroller. For this task, we will use an op-amp circuit due to its simple implementation.

3.3 A/D Converter

Using the three ADC channels on the microcontroller, the microphones can pass audio to the controller at a sampling rate of 22.7uS (44 kHz). This sampling frequency is required to sample the input at well over the Nyquist frequency of human hearing limits. This sampling rate can be controlled by the timer interrupt of the A/D converter sub systems within the microcontroller to ensure accurate A/D conversion readings. The 3 channel A/D results will be read as a linear operation; whenever the result is ready the main program will take the data away from A/D system for computation.

4. Output Signal Conditioning

Even though the outputs of the microcontroller are capable of driving the vibrating motors directly, this is not safe in a practical design. The inductive load of motors will cause undesirable effects on our circuit. This section will provide information about our approach and design to solve this problem.

4.1. Pulse-Width Modulation (PWM)

A common way to drive a low voltage DC motor is the PWM method. This method provides excellent power and speed control to a DC motor that is interfaced to a microcontroller. By applying a fixed frequency (eg. 1Khz) and by altering the bandwidth area of the positive and negative waves, the net power delivered to the motor can be adjusted. The figure below shows how the waveforms change under the different power delivery levels.

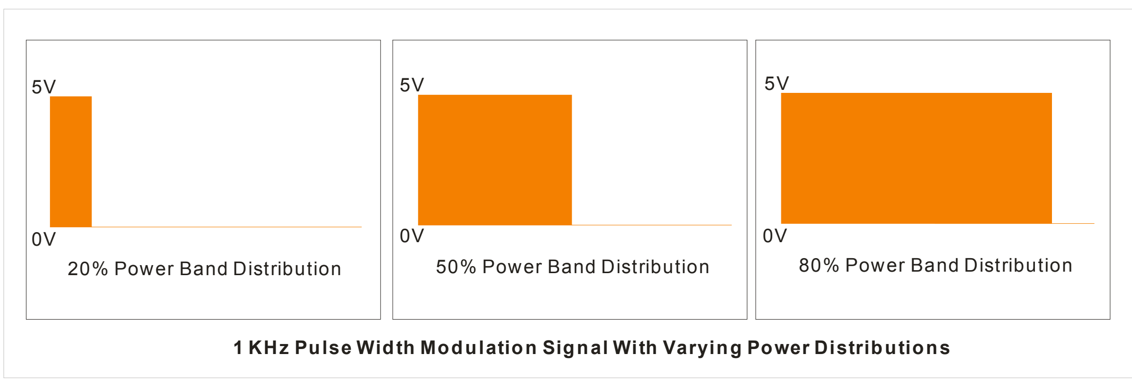

Figure 3: PWM Power Distributions

4.2. Motor Drivers

If the motor requires an external power source to drive it, a single PNP or NPN transistor with proper protection is sufficient. The following figure shows a very common motor driving circuit.

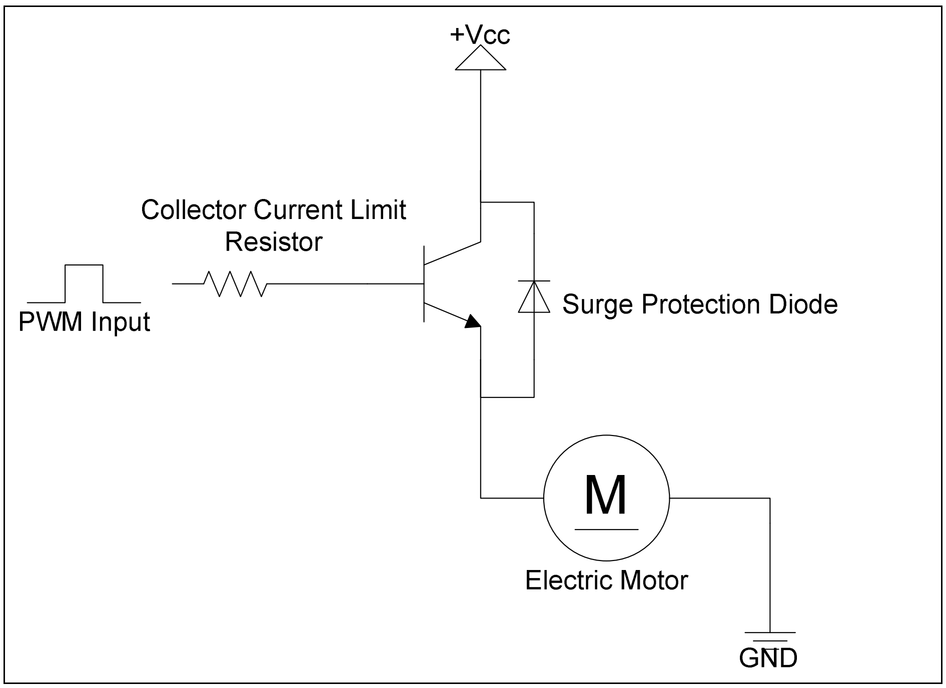

Figure 4: PWM Motor Driver Schematic

The resistor in the schematic is to prevent the motor drawing from too much current from the power source. The diode is used to protect the transistor from damage if the motor is generating voltage spikes during its operation. These voltage spikes are the phenomenon of BEMF (Back EMF) when the motor is behaving as a power generator that over volts the voltage supply source under excessive speed. Improper handling of this situation will shorten the lifespan of both motor driver and the motor.

5. Signal Processing and Computation Software

Short and efficient programming is important in this project due to limited computational resources. Any redundant program instructions may seriously affect the performance of the device. The following sub sections will cover the parameters of the computation software in more detail.

5.1. Overview of the Computation

In general the computation algorithm is simply taking the average values of the input and comparing the result to the preset threshold. The magnitude difference of both values will be the actual magnitude that the vibrating motors will vibrate at. We will also implement an operation that will auto adjust the threshold values to make the device operates under a noisy environment. In the control software section these design parameters will be discussed in depth and should provide a better picture of the operation of the device.

5.2. Control Software

The control software is the heart of this project; all operations are closely related and must be properly timed in order to have the device working properly. There are different levels of system operations and the priorities for these systems are essential. The figure below shows the description of the system priorities and the components associated with them.

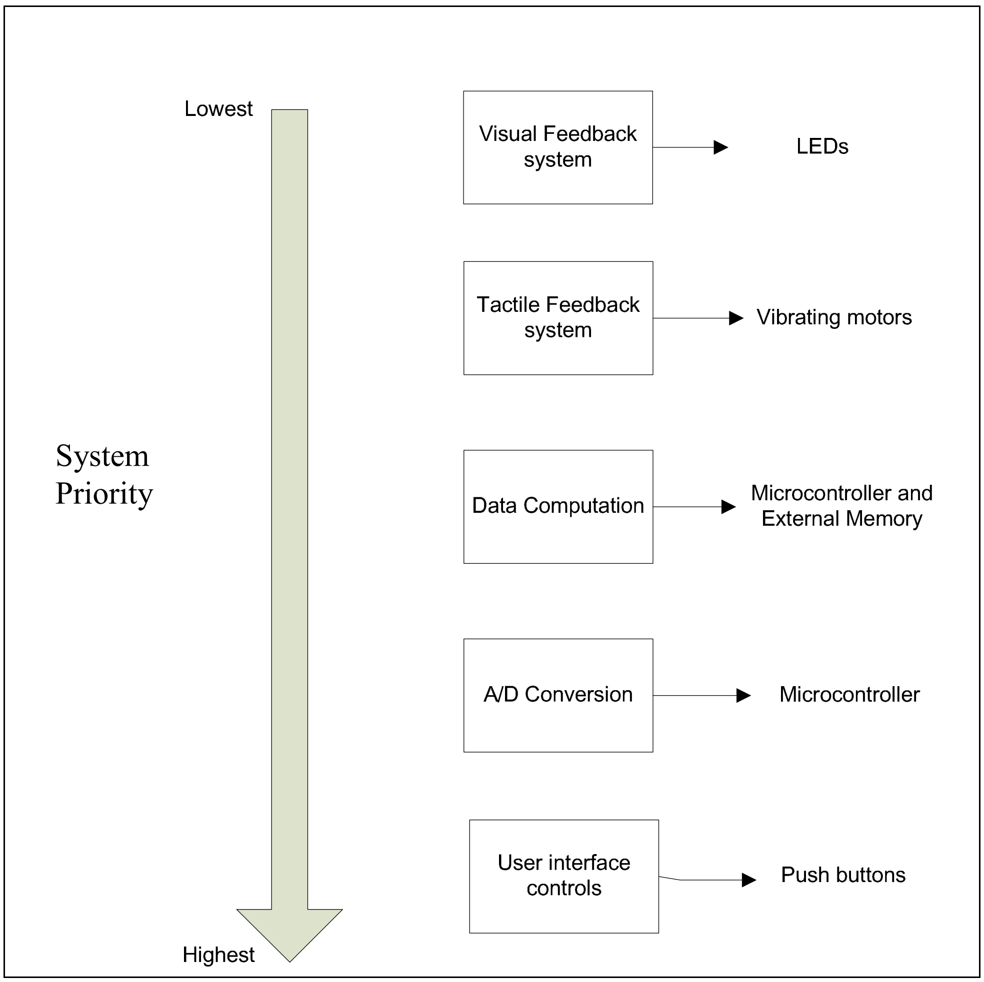

Figure 5: System Priorities

The majority of the systems mentioned above will operate as interrupt requests; this will increase the microcontroller's idle time such that it can react faster to the actual environment. The following topic will explain the full operation of the device and its decision making scheme.

5.3. Main Process

This section will cover the full operation and decision making scheme that this device will undertake. A flow chart is provided below to give a better explanation.

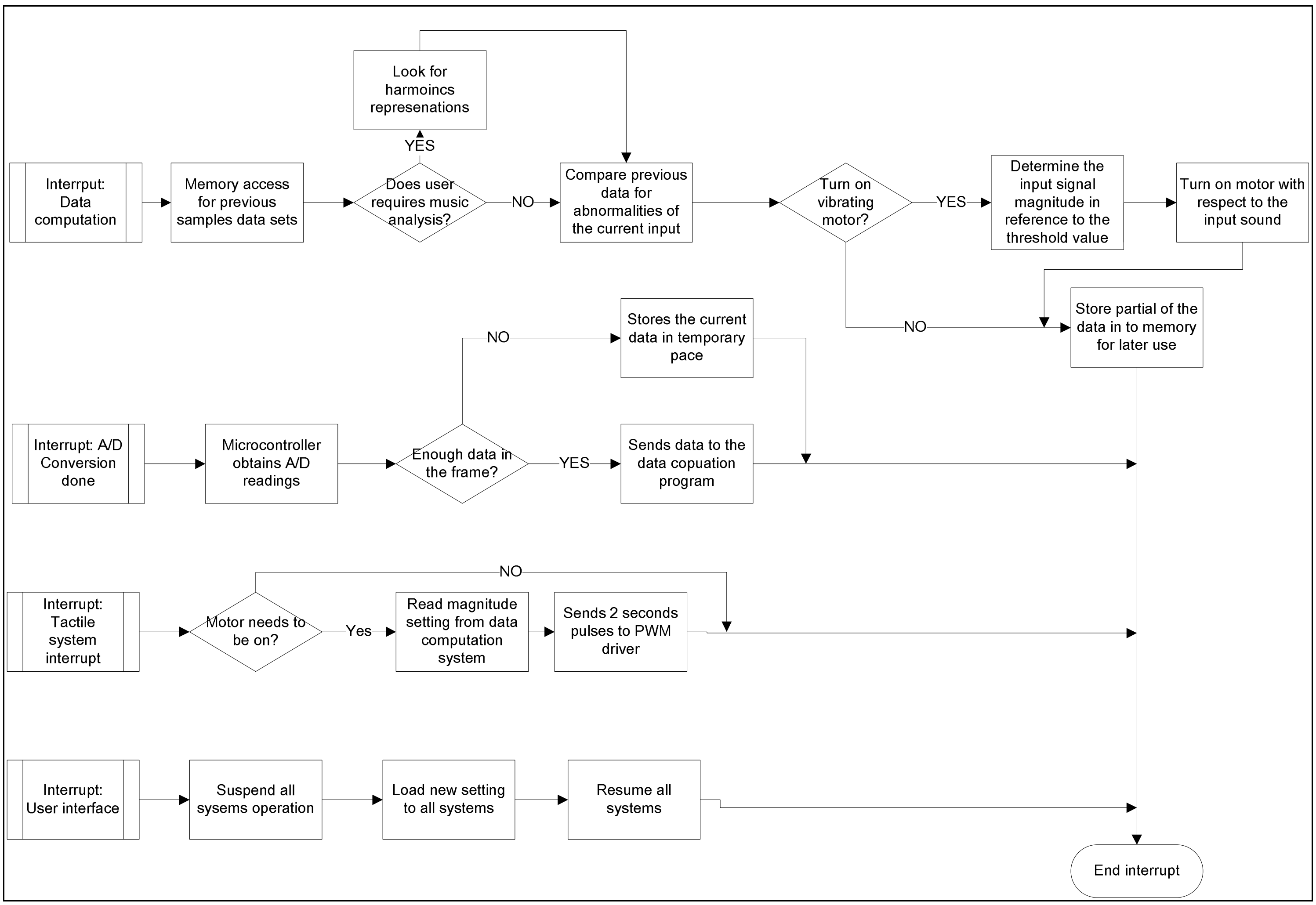

Figure 6: Interrupt Service Routine Block Diagram

6. Arm Attachment

Our current product plan is for the device to be on one of the user's arms. This is specifically designed for high portability and personal comfort during the user's everyday body movement. Attachment design specifics will be discussed in the following sub-sections.

6.1. Physical Design

After careful examination of the interaction between microphones and vibrating motors, we have decided to try to separate them as much as possible. The reason is because the amount of noise generated by the vibrating motors will distort heavily on the microphone input signals. The vibrations of the motors can be absorbed by human tissue. By isolating these two components with a small gap, the need for shielding can be avoided. The figure below shows a possible implementation for this arm attachment.

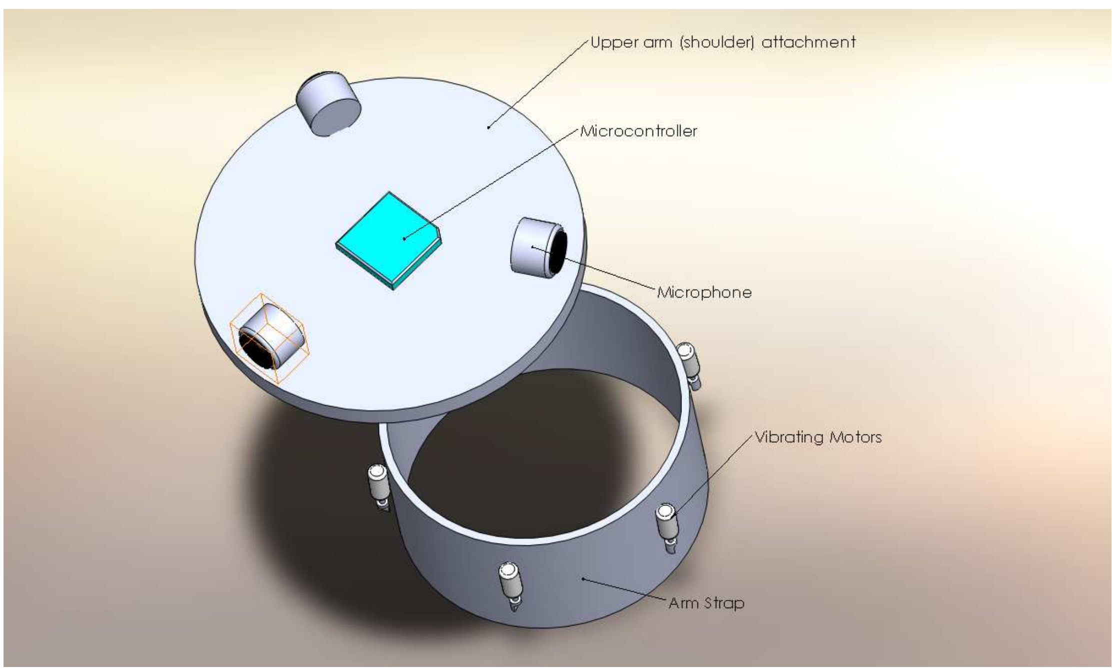

Figure 7: Possible Arm Attachment Implementation

6.2. Attachment Adjustment Mechanism

In the event the user wishes to adjust the arm attachment, there will be a Velcro strap for quick adjustment and removal of the arm attachment. To increase user comfort, soft rubber foam pads will be placed at the back of the arm attachment and around the Velcro.

7. User Interface Unit

A user interface (also known as, Human to Machine Interface, HMI) tells the user the current status of the device and allows the user to adjust the operation of the device to suit their personal needs. The following section will cover the role of the HMI.

7.1. User Interface Hardware

The interface hardware consists of 4 buttons and 4 LEDs. The figure below shows a possible implementation of the user interface layout.

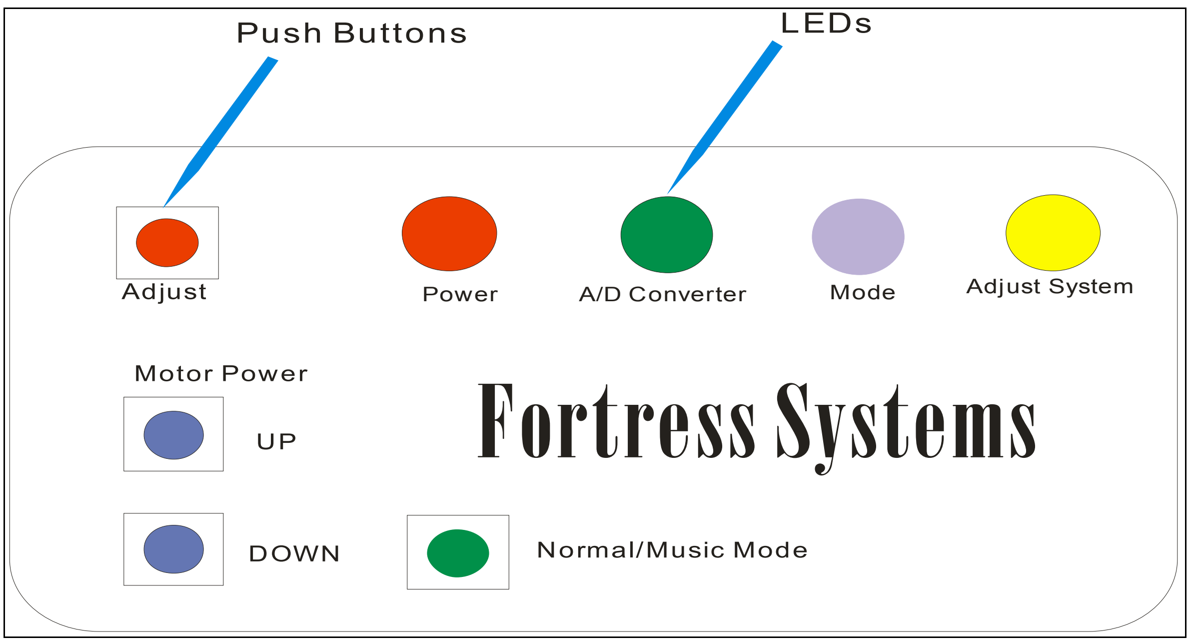

Figure 8: User Interface Layout

7.2 LED Display

The LEDs are indicators for the device operation; explanations of each LED are as follows:

- Power – the indicator of the device power and should be turned on for all times
- A/D – Indicates the microcontroller is reading signals from microphones

- Normal – User can set the device to Music mode to have the device differentiates music harmonics
- Adjust – This will suspend all operation of the device other than adjustment to motor vibration power

7.2 Button Identification

The 4 buttons will be implemented along with switch debouncer and each of their implementations are as follows:

- Button A – Enters/Exit Adjustment mode
- Button B/C – Turn the power of the vibrating motor UP/DOWN
- Button D – Enable/Disable Music Mode

7.3. User Interface Software

The software is triggered as the highest interrupt service routine within the controller. Then the service routine should read from a data port of the microcontroller and change the corresponding control flags within the software. Upon the exit of the service routine, the device will implement the new settings of the control flags.

8. Conclusion

The *Design Specification for the Sound Sense Vibe* document should be consistent with the functions listed in *Functional Specification for the Sound Sense Vibe*. By following the design specifications, most of the functional requirements will be met.

Now that the Sound Sense Vibe has a complete Design Specification, development can commence. Once development of our proof-of-concept device implementing the design discussed is complete, we can begin further planning and marketing in hopes of continuing on to complete a full prototype of the Sound Sense Vibe.

9. References

[1] Fortress Systems Ltd. 2008. *Functional Specification for the Sound Sense Vibe*. Burnaby, British Columbia.

[2] CK495 Electret Microphone Pre-Amp. Accessed: October 29, 2008. http://www.canakit.net