November 20, 2011

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

Re: ENSC 440 Design Specifications for Bluetooth Hearing Aid *HAB-1*

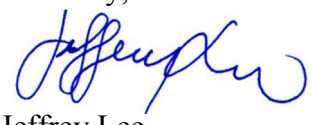
Dear Dr. Rawicz,

Please find enclosed the design specifications for the Audima HAB-1 Bluetooth hearing aid. Our device will increase the convenience for people hard of hearing while interacting with external devices, particularly cellular phones. Not only will the device eliminate the use of any wires and cables, but will also make the connection process hassle-free and as easy as the flick of a switch.

The design specifications provide a set of low-level requirements for the HAB-1. It will describe the methods implemented in its design, as well as the choices made to achieve the desired outcomes. Our objectives and requirements are laid out throughout the document to ensure the development progresses smoothly.

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

Sincerely,



Jeffrey Lee
Chief Executive Officer
Audima Inc.

Enclosure: Proposal for Bluetooth Hearing Aid HAB-1

Project Proposal for Bluetooth Hearing Aid *HAB-1*

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Issue Date
November 20, 2011

Executive Summary

At the turn of the 21st century, technology has taken another big leap forward and engineers are driven by a few key factors, two of which are fashion and convenience. In today's society, size matters. Everything must be miniaturized, and the smaller it is, the better. On top of that, everything must be connected wirelessly. Long, dangling wires and cables are a thing of the past, and society today dictates that devices today should be free of these annoyances.

One large boom in these past few years is the Bluetooth headset. In an effort to promote safe driving while still allowing drivers to talk on their cellphones, a slew of smaller, sleeker Bluetooth headsets have appeared on the market, allowing users to constantly hang a device off their ear yet still look fashionable. However, people with hearing deficiencies don't have these privileges. While hearing aids are becoming smaller and less conspicuous, they still utilize primitive ways of connecting to external devices such as cellular phones.

The Audima HAB-1 combines both a hearing aid with a Bluetooth headset, allowing hearing deficient people to easily and wirelessly connect their hearing aids to their cellular phones and other Bluetooth-enabled devices. This document will outline the design specifications of how this device is to be made. It consists primarily of two components: the hearing aid and the Bluetooth. Its integration is achieved mainly with a switch that connects the two, allowing the user to easily switch between the two components. Other push buttons will also be included in the interface for control over each component individually.

The information and specifications listed in this document serve as the baseline requirements for the prototype of the HAB-1, and will also touch on further iterations of the prototype and the retail version of the product. Not only do these specifications justify the design choices made by our team of engineers, but also serve as a means of ensuring that all the proposed requirements have been met.

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Glossary

ENSC	Engineering Science
HAB-1	Hearing Aid Bluetooth ver. 1
LED	Light Emitting Diode
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
SPDT	Single Pole Double Throw
QA	Quality Assurance

1. Introduction

The Audima HAB-1 is a revolutionary hearing aid. Not only will it be a hearing aid in its traditional sense – amplifying sound for people with hearing deficiencies – but it will also be able to connect to electronic devices using Bluetooth technology, without the use of any wires at all. The Bluetooth signal can be turned on or off independently of the hearing aid device to reduce energy consumption when the user doesn't need Bluetooth connectivity. In the situation where both hearing aid and Bluetooth are powered on simultaneously, the user can easily switch between the two, so he can, for example, talk on the phone and hear only the other person's voice clearly, without the distraction of all other noises being amplified by the hearing aid circuitry.

Our vision is to create a hearing aid that allows hearing deficient people to be able to interact in our technologically evolving society at the same pace everyone else can.

1.1 Scope

This document outlines the design requirements that the Audima HAB-1 must meet. The documented design specifications will fully describe the specifications required of the prototype, and to some extent explain further iterations of the prototype and the retail version of the product.

Alongside the HAB-1's functional specifications, this document will explain and describe clearly the methods used to create the prototype as specified.

1.2 Intended Audience

The design specification is intended for use by members of Audima Inc. and board members of ENSC 305 and ENSC 440. Its purpose is to act as a guide for all teams and executives working on this project, so the product can be developed as proposed in a timely manner.

The document can be used as a technical guide for developers to follow while designing, building, and implementing the prototype. QA technicians can follow the test criteria listed in the document to ensure that all the proposed specifications are met without flaws.

Additionally, ENSC 350 and ENSC 440 board members can also refer to the document to ensure the prototype was designed as proposed.

2. System Specification

The Audima HAB-1 is a next-generation hearing aid device, which combines both the general amplification in a hearing aid with Bluetooth technology, allowing it to connect wirelessly with Bluetooth-enabled devices such as most modern cellular phones. A switch will be implemented to make the two components work in conjunction, making the HAB-1 function as one device. The user will also have the option of freely controlling the volume independently in both hearing aid and Bluetooth modes.

3. Overall System Design

The Audima HAB-1 system consists of two components: the hearing aid and the Bluetooth. The hearing aid component is responsible for gathering sound in the surrounding environment and converting the sound to electrical impulses. The component then amplifies and transforms the impulses back to sound waves before transmitting them to the user's ear [1]. The Bluetooth component is responsible for detecting activity from a Bluetooth-compatible cell phone using a Voice Activity Sensor, modeling and eradicating background noise, and amplifying speech using Digital Signal Processing algorithms which enhance the quality of the audio [2]. These components are to be powered by a rechargeable lithium polymer battery which supplies 3.7 volts with a current of 15 mA. Each component can be turned on and off independently using a dedicated button for each, and there is also a volume control which provides a maximum resistance of 10 kΩ. The figure shown below is the concept design of what the retail version of the HAB-1 could look like.

Figure 1 – Concept Design of the Audima HAB-1[3]

3.1 Integration

Our device consists of two main components, a hearing aid unit and a Bluetooth unit.

The hearing aid unit captures environmental sounds using a microphone, amplifies the signal, and sends the resulting signal to a speaker. It has a power button, an LED to indicate the operating state, and a volume control. The Bluetooth unit sends and receives audio signals to and from a cellular phone via radio transmissions. It has a power button, two LEDs to indicate modes of operation, and a volume control.

Each component uses its own microphone, but they both share a common 3.7V rechargeable battery and speaker. The battery is connected to both components at all times so that they can be used simultaneously. Unlike the battery, the speaker can only be connected to one component at any given time. Because of this, we have implemented a single pole double throw (SPDT) switch that selects either the output signal from the Bluetooth unit or the output signal from the hearing aid unit. By default, the volume of the Bluetooth headset is too low compared to the volume of the hearing aid; therefore we must add a simple amplifier to the analog output of the Bluetooth unit to match the hearing aid's volume. The design is illustrated in the diagram below.

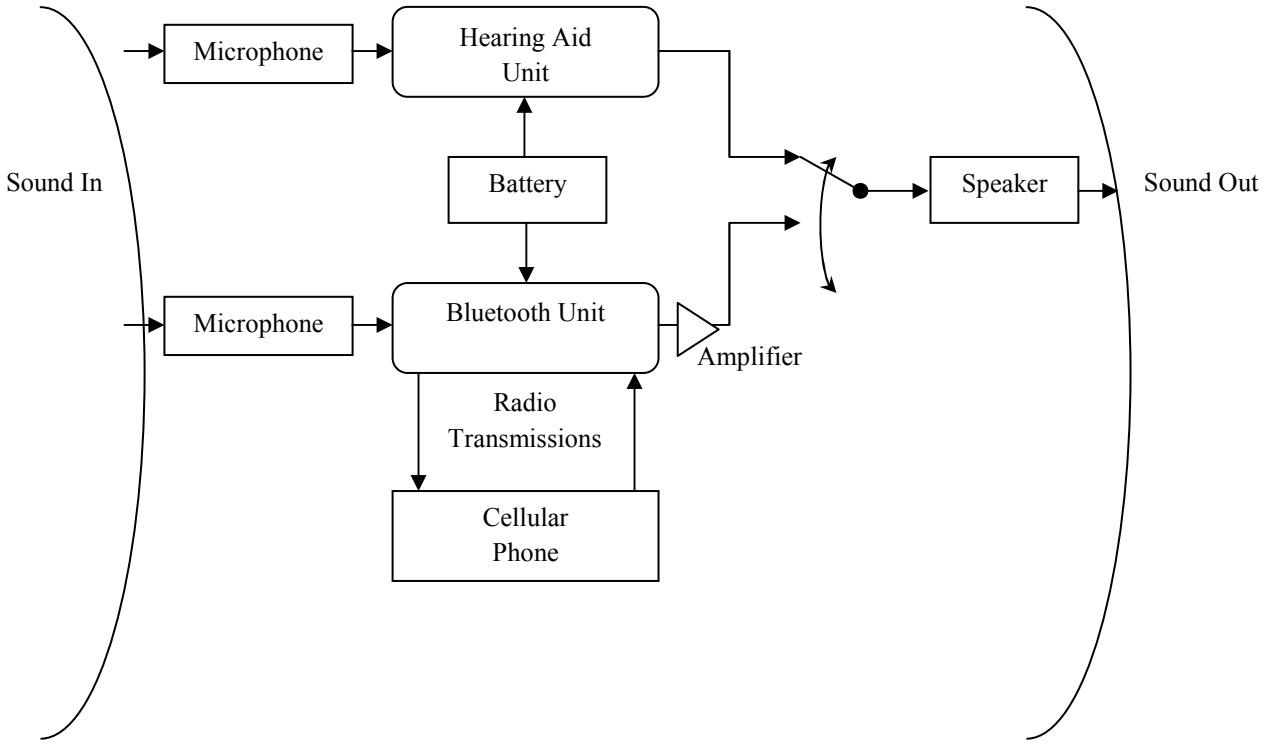

Figure 2 – HAB-1 Integration Design

3.1.1 SPDT Switch

The SPDT switch is a key component in the integration between the existing Bluetooth component and the hearing aid circuit. It is a 2-input, 1-output switch, allowing seamless transition between two different modes. Rather than acting as a conventional on/off switch, the SPDT switch connects one of the two components, while disconnecting the other. This then allows for both Bluetooth and hearing aid components to be powered on at the same time, but allows the user to easily choose only one to be active at any given time.

Such a switch is necessary for our design due to the nature of a Bluetooth connection. While it is theoretically possible for a user to turn on the Bluetooth signal every time a phone call comes in, this method is not always smooth and therefore comprises user safety, especially if the user is operating a vehicle. There will always be a short delay between the powering on of the Bluetooth signal and the pairing up with the cellular phone. In some odd cases, a connection may not even be made.

However, if the Bluetooth signal is turned on and confirmed to have paired successfully with the cellphone beforehand, all the hassle can be avoided. Now, when a call is received on the phone, the user knows his hearing aid is already connected to the phone, and all he needs to do is flick the switch to change the output to the Bluetooth signal, allowing him to talk comfortably and safely on his phone.

4. Hearing Aid Unit

The hearing aid component is considered to be an electroacoustic device and is designed to amplify and transmit the sound waves from the surrounding environment to the user's ear. The figures shown below are the schematic diagram of the component and the corresponding PCB layout. It contains an analog amplifier, a switch, an LED light, and some resistors and capacitors.

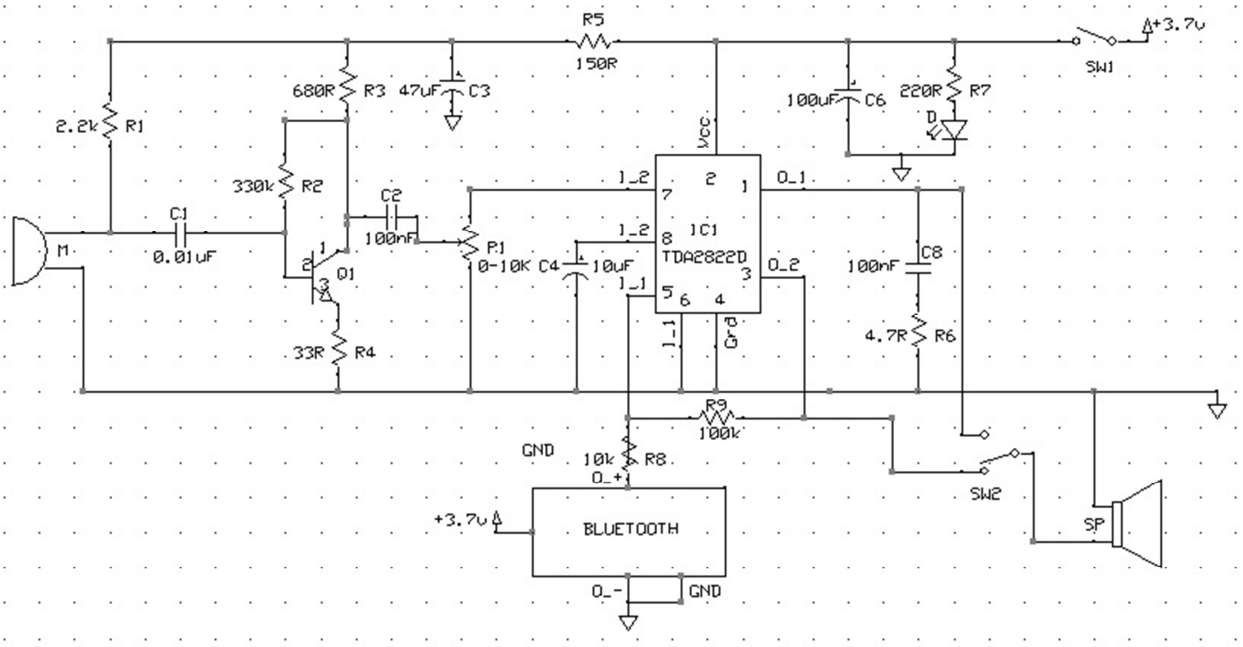

Figure 3 – HAB-1 System Electronic Schematic Diagram

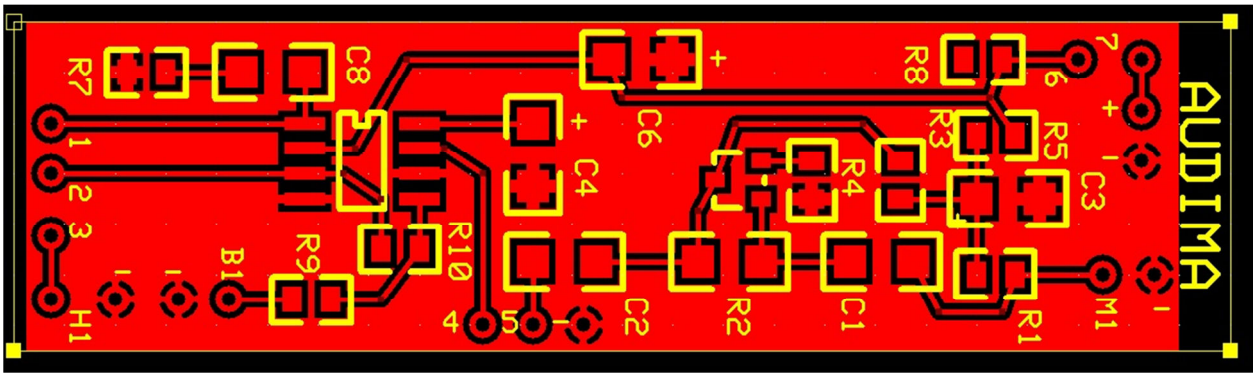

Figure 4 – HAB-1 System Electronic PCB Layout

As figure 3 shows, transistor Q1 and its associated components form the audio signal preamplifier for the acoustic signals picked up by the condenser microphone, M, and converts them into corresponding electrical signals. Resistor R5 and capacitor C3 decouple the power supply of the preamplifier stage. Resistor R1 biases the internal circuit of the low-voltage condenser microphone to allow it to function properly. The audio output from the preamplifier stage is fed to the input of the medium-power amplifier circuit via capacitor C2 and volume control P1.

The medium-power amplifier section is wired around popular audio amplifier IC TDA2822D. This IC, specially designed for portable low-power applications, is readily available in 8-pin mini DIP packages. Here the IC is wired in bridge configuration to drive the speaker earphone. Red LED (D) indicates the power status. Resistor R8 limits the operating current of D1. The audio output of this circuit is 10 to 15mW and the quiescent current drain is below 1 mA. The main parts of the circuit which are important in the component are the transistor, Q1, and the audio amplifier IC TDA2822D.

4.1 Transistor

The type of the transistor used for the hearing aid component is BC847. It is an NPN Epitaxial silicon transistor supplying low voltage and current.

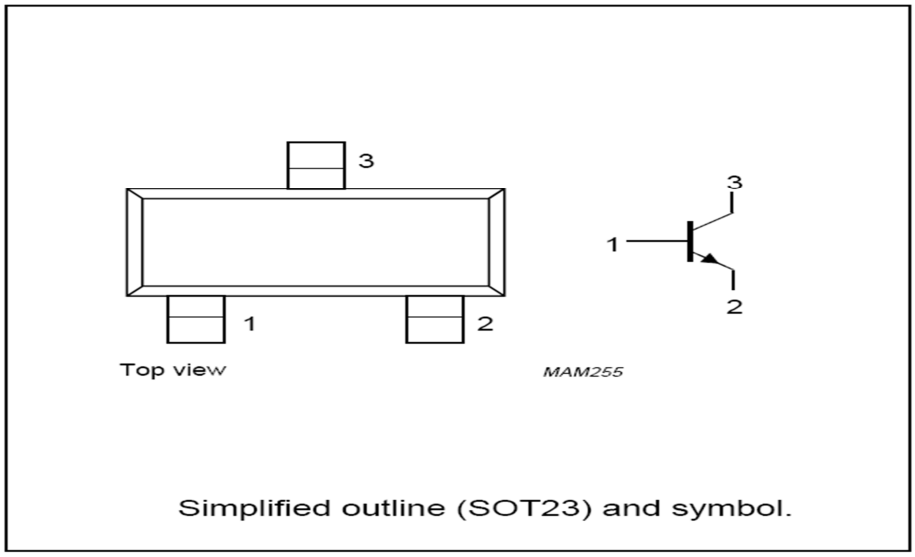

Figure 5 – Transistor BC847 Outline and Symbol [4]

This transistor dissipates a total power of 250 mW, which proves that it transmits low voltage and current. As shown in figures 3 and 5, the base of the transistor, marked “1” in figure 5, receives the acoustic signal from the microphone and converts it into electrical pulses. Once

converted, the audio output – in the form of electrical signals – transmits from the collector side of the transistor, marked “3” in figure 5, to the audio amplifier. For the reason of conversion to an electrical signal, the stage in which the transistor resides is known as the audio signal preamplifier.

4.2 Audio Amplifier

The type of the audio amplifier used for the hearing aid component is TDA2822D. It is a monolithic integrated circuit in 8 lead (SO-8) packages. A diagram of the part is shown below.

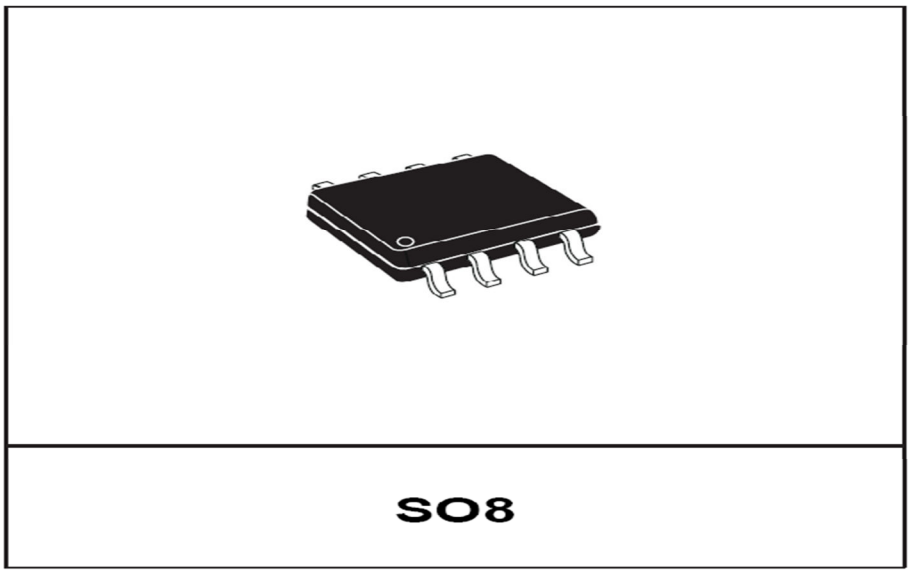

Figure 6 – Audio Amplifier TDA2822D [5]

The pin assignment of the audio amplifier is also shown below.

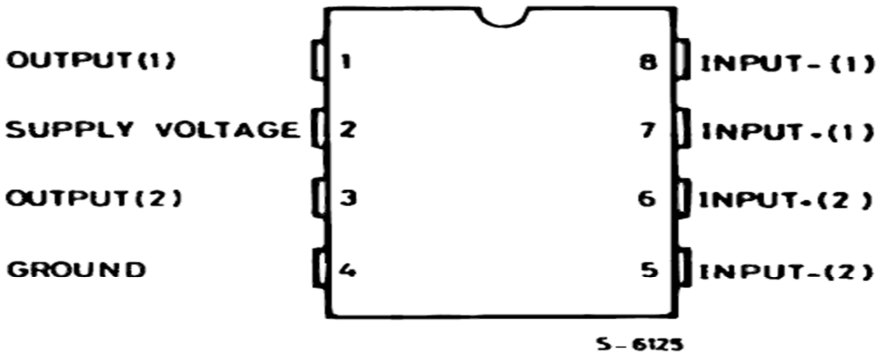

Figure 7 – Audio Amplifier TD2822D Pin Assignment [6]

The audio amplifier can supply voltage to a maximum of 15 volts, and generate a peak current of 1 A. The total power dissipation is 0.5 Watts. As shown in both figures 3 and 7, the voltage generated after the switch SW is closed is sent to pin 2 on the audio amplifier. The audio output from the transistor, Q1, passes through capacitor, C2, and the volume control, P1, to reach to pin 7, input(1), on the audio amplifier. The audio input is amplified and converted back to sound waves before transmitting through the output pin of the audio amplifier. The audio output that leaves from pin 1, output (1), is transmitted to the speaker earphone.

4.3 LED

The type of the LED used for the component is SML-211UT, a red light LED in the form of a surface mount package. The red LED is shown below.

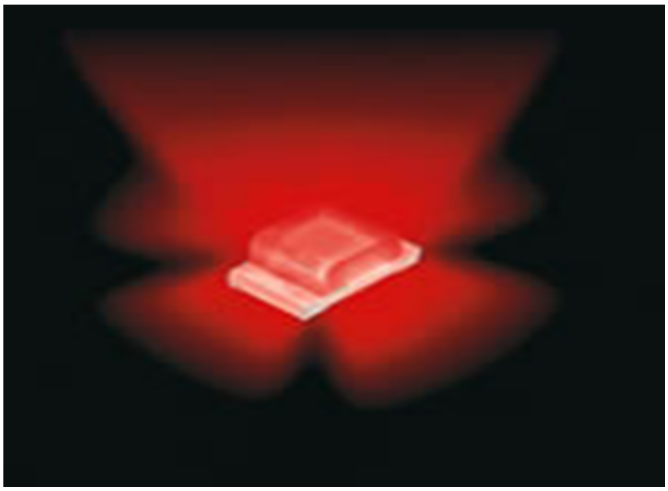

Figure 8 – Red Light LED SML-211UT [7]

This part generates a power dissipation of 44 mW. As shown in figure 3, the LED, marked “D”, is responsible for indicating the power status of the hearing aid component. When the hearing aid is powered off, the LED should be off as well. Otherwise, the LED should display a bright red light.

5. Existing Bluetooth Unit

5.1 Overview

For the Audima HAB-1, we will be integrating the hearing aid unit with the printed circuit board assembly (PCBA) with an existing Bluetooth headset available on the market. This will allow our device to utilize the predefined protocols programmed by the manufacturer of the Bluetooth headset to connect and communicate with cellular phones. At the time of this writing, we are using Sony Ericsson's HBH-PV705 Bluetooth headset, but we may decide to use another Bluetooth headset for final integration, depending on whether further space optimization is necessary.

5.2 Criteria

In order for our product to function as desired, we must choose a Bluetooth headset that fulfills the following criteria:

- It must be able to pair up with the majority of cellular phones available on the market
- It must be able to remember the device that it is paired up with even after the headset has been switched off.
- It must have one main power button.
- It must be easy to un-solder the speaker phone and battery from the PCBA.
- It must have a decent battery life (at least 5 hours of talk time and 1 week on standby).

The Bluetooth headset that we have chosen fulfills all of the above criteria. Additionally, it provides volume control and two LEDs to indicate battery level and modes of operation.

5.3 Sony Ericsson HBH-PV705

Sony Ericsson's HBH-PV705 Bluetooth headset has three main buttons: one for power, and two for volume control (volume up and volume down). To turn the headset on or off, the power button must be held for at least five seconds. This is to prevent the device from accidental power on or off. The headset also contains two LEDs (red and green). The LEDs are used to indicate battery level and mode of operation. The battery is a 3.7V 150mAh lithium ion polymer battery and it offers a whopping 12 hours of talk time and 13 days of standby. Furthermore, the soldering pads for the battery and speaker phone are quite distinct, making it easier to modify the PCBA. Like most Bluetooth headsets, the HBH-PV705 is of the Class 2 type, meaning that the maximum permitted power is 2.5mW and 4dBm, and the maximum range of the Bluetooth signal is approximately 10m. The original Bluetooth headset is shown below.

Figure 9 – Sony Ericsson HBH-PV705 Bluetooth Headset [8]

5.4 Modification for Integration

To integrate the Bluetooth headset's PCBA with the hearing aid unit, we had to make a few modifications. Firstly, a branch was added between the battery and the PCB so that the battery could power two separate devices (the other device being the hearing aid unit). We had to make sure that lithium ion battery could carry enough current to power both components. Secondly, the headset's speaker was replaced by a common speaker that connects to both the Bluetooth headset and the hearing aid through a SPDT switch. This allows the user to choose which unit to listen to. Lastly, because the audio gain of the Bluetooth headset is quite small compared to the gain of the hearing aid, we had to add a simple amplifier to the analog output of the Bluetooth headset. To match the approximate volume of the hearing aid, we set the gain of the amplifier to 10.

6. User Interface

6.1 Overview

The HAB-1 will have four main switches (or more specifically, two buttons, one slider, and one thumbwheel). The first button turns the hearing aid on and off, the second button turns the Bluetooth component on and off, the slider chooses the input for the speaker, and the thumbwheel adjusts the volume. There are also three LEDs, two of which are used to indicate the battery level and the Bluetooth's modes of operation, and the other is to indicate the operating state of the hearing aid. A diagram of our product is shown below.

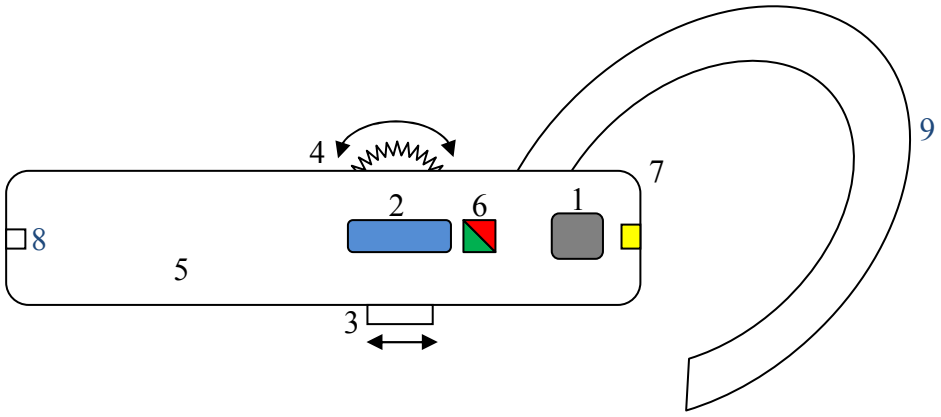

Figure 10 – Side View of the Audima HAB-1 Interface

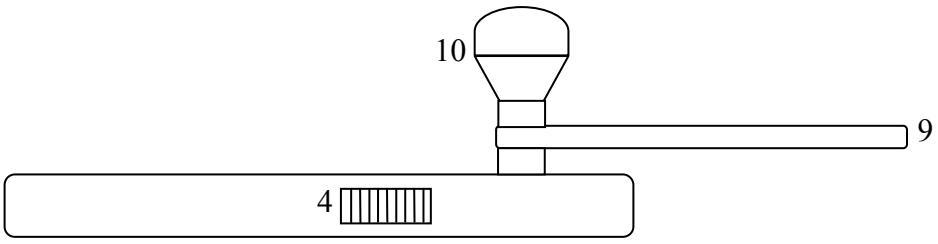

Figure 11 – Top View of the Audima HAB-1 Interface

Table 1 – List of Device Functions

Number	Function
1	Power Button for Hearing Aid
2	Power Button for Bluetooth
3	SPDT Switch
4	Volume Control for Hearing Aid
5	Volume Control for Bluetooth
6	LEDs for Bluetooth
7	LED for Hearing Aid
8	Microphone
9	Ear Hook
10	Speaker

6.2 Hearing Aid Functions

Table 2 – List of Hearing Aid-Specific Functions

Desired Outcome	Action
Power On/Off Hearing Aid	Press 1
Adjust Hearing Aid Volume	Turn 4

6.3 Bluetooth Functions

Table 3 – List of Bluetooth-Specific Functions

Desired Outcome	Action
Power On/Off Bluetooth	Press and hold 2 for at least five seconds
Adjust Bluetooth Volume	Press 5
Pair Device with Cellphone	Ensure headset is turned on Press and hold 5 (both buttons) LED 6 should flash green and red Headset becomes discoverable with 10m Passcode is 0000 LED 6 flashes green when successfully paired
Answer a Call	Press 2
End a Call	Press 2 (while in call)
Reject a Call	Press and hold 2 for two seconds
Mute/Unmute Microphone	Press 5 (both buttons)

6.4 General Functions

Table 4 – List of General Functions

Desired Outcome	Action
Switch Speaker Output	Slide 3
Recharge Battery	LED 6 flashes red: battery is low Plug charger into port near LED 7 If LED 6 is steady red, the headset is charging If LED 6 is steady green, the headset is fully charged

7. Testing Plan

7.1 Overview Testing

A test plan is created to ensure the functionality, quality, reliability and safety of the Audima HAB-1. The general approach to the testing plan initially consists of separately testing the individual components comprising of the Sony Ericsson HBH-PV705 Bluetooth headset and the hearing aid circuit. After individual testing passes the standard, tests to the integrated Bluetooth and hearing aid device are conducted. Finally, the end-users will be conducted to the trials of the final product.

7.2 Unit Testing

The purpose of unit test conduction is to ensure that each individual component works as expected and performs its tasks reliably before the device is integrated. Unit testing consists of the testing of the Bluetooth module and the hearing aid circuit. The steps to each component test are shown below, and all unit tests are conducted under normal lab environment.

Sony Ericsson HBH-PV705 Bluetooth headset

Test Steps:

1. Connect the charger and charge the battery
2. Press and hold the power button for 5 seconds to power on the device
3. Press and hold both volume buttons (at the same time) for 5 seconds to make headset discoverable to cellular phones
4. Enable the cell phone's Bluetooth
5. Search for the headset through the cell phone's Bluetooth menu
6. Pair the cellphone with the headset
7. Receive a call with the cellphone.

8. Press the answer/end button on the headset to answer the call. Ensure the phone's audio output can be heard through the headset's earpiece
9. Changing the volume of the headset
10. End the call by pressing the answer/end button
11. Press and hold the power button for 5 seconds to power off the Bluetooth headset
12. Press and hold the power button for 5 seconds to power on the device once more
13. Allow the device to pair automatically with the cellphone
14. Power off the device

Expected results:

1. The battery charges
2. Headset turns on
3. Green LED flashes periodically to indicate the headset is on
4. Bluetooth headset becomes discoverable to all cellular phones with Bluetooth enabled, within 10m
5. Headset pairs successfully with cellphone
6. Headset accepts the call successfully and routes the phone's output audio to the headset earpiece
7. Volume can increase and decrease at will
8. Call can be ended successfully
9. Headset powers off properly
10. For every consequent powering on of the Bluetooth headset, as long as the phone's Bluetooth is enabled and is within 10m range of the headset, the two devices should pair automatically without having to search for the headset again on the phone

Hearing aid circuit

Test steps:

1. Assemble all the resistors, capacitors, transistors, etc. following the hearing aid schematic
2. Connect the hearing aid circuit to a 3.7V power supply or battery
3. Bring the speakerphone to your ear and speak with a normal tone
4. Slide the volume control back and forth
5. Turn the switch on and off

Expected results:

1. LED turns on
2. Voice is clearly amplified, without the need of purposely speaking directly into the microphone

3. Volume control changes the amplification of the sound
4. The circuit draws approximately 15mA of current
5. The device can be powered on and off with the switch

7.3 Integration Testing

The individual components will be integrated to form a complete device after all the unit tests are passed. With the complete system, the integration testing will be performed. The test steps and expected results are shown below

Test Steps:

1. Connect the Bluetooth and hearing aid with a SPDT switch
2. Connect the integrated system to a 3.7V power supply or battery
3. Power on both components
4. Pair the cellphone with the Bluetooth
5. Slide the switch to hearing aid mode
6. Speak with a normal tone
7. Receive a call with the cellphone
8. Slide the switch to Bluetooth mode
9. Speak with a normal tone
10. End the call
11. Slide the switch back to hearing aid mode
12. Speak with a normal tone
13. Power off all components

Expected Results:

1. Hearing aid and Bluetooth can both be simultaneously powered by a single 3.7V battery
2. While SPDT switch is in hearing aid mode, the amplified voice can be heard clearly through the speakerphone
3. While SPDT switch is in hearing aid mode, the phone audio output will not be heard through the speakerphone, even while a call is connected
4. While SPDT switch is in Bluetooth mode, the phone audio output will be heard through the speakerphone, only while a call is connected
5. While SPDT switch is in Bluetooth mode, environmental sounds are not heard through the speakerphone
6. Each component of the device can be powered on and off independently of each other, without affecting the other component

7.4 System Testing

Once the integration tests have passed, system testing will be conducted. The best way to test the device is by performing typical user scenario tests, and the users will not have detailed knowledge on how the device works, so the users' feedbacks will be unbiased after using the device and the engineers can modify the product accordingly.

Typical Usage Scenario

The device will be operated by a typical user in the following manner:

1. User presses the power on button for the hearing aid to power on the hearing aid. The red LED will turn on to indicate the hearing aid is powered on
2. The thumbwheel can be used to adjust the volume of the hearing aid to the user's preference
3. User presses the power on button for the Bluetooth when he decides to pair the HAB-1 with his cellphone (for example, before getting into and driving a car)
4. When the user's cellphone rings, or the user makes a call, the user slides the switch to "T" mode for Bluetooth use
5. After ending the call by pressing the answer/end call button, the user slides the switch back to "M" mode for regular hearing aid use
6. User powers off the Bluetooth after driving to conserve battery if he decides Bluetooth is no longer necessary

8. Conclusion

In this document, the proposed design solutions were presented to meet the functional specifications of the Audima HAB-1. Justifications were made for the engineers' design choices, and test plans were also included to ensure that the device operates as proposed. Goals for the development of the prototype were clearly specified, and the working prototype of the HAB-1 is expected to be available on December 14th.

9. References

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