Team SilentRave High Level Design

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1. Introduction

As headphone use has become more prevalent with the advent of mobile music players, a culture of isolation has emerged. We propose a solution to reincorporate the environment back into the listening experience. The group members are Tom Blanford, Eric Nolan, Michael Sizemore, Sara Taylor, and Mark Wurzelbacher.

2. Problem Description

When a user wears headphones to listen to music, he often times tries to perform other tasks simultaneously. Walking to class, going for a run, or even holding a conversation are just a few examples. Current high-end ear bud headphones can create a comfortable sense of isolation to optimize the music experience, but they do not adjust for changes in the environment. When a person runs with an iPod, he still needs to turn the volume up when the environment gets louder (for example, a train passes or you run past a power plant). In other cases, a person must take the ear buds out when someone talks to him (for instance, when a flight attendant requests a meal preference, or a friend says hello when walking by). When walking to class, an individual may also want to simultaneously listen to music and have a conversation, forcing him to leave one ear bud out.

In all these cases a user is either forced to constantly adjust the volume on the iPod (which is cumbersome, especially when running), or compromise the listening experience by removing one or more ear buds (which is an annoying, especially with high-quality isolating ear buds). With the removal of one ear bud, only half of the stereo music is heard, which may completely cut out the vocals or other critical musical aspects, destroying the song's musical intent. Some headphones incorporate a single microphone to facilitate phone calls or pass through audio from the environment, but the user must physically turn the microphone. Furthermore, these headphones still fail to incorporate the sounds of the outside world in a way that mimics the real environment.

3. Proposed Solution

In order to automatically adjust the sound you hear through your ear buds, we propose creating a small device to interface between your sound source that would sense the external environment and adjust the sound accordingly. You could specify your preferred aural environment (music only, occasional conversation, music and environment), and let the device take care of the rest. If you only wanted to hear your music when running, the device would sense the increase in environmental noise and boost the volume of your music to compensate. If you wanted to walk down the street and hear both the sounds of your music and the sounds of the city, the device would pick up the sounds of the environment as you would hear them yourself (in stereo, without the rumble of wind and microphone noise) and mix this with your music. If you wanted to only hear the outside world when someone was talking to you (say, the flight attendant), the device would sense these occasions and lower the volume of your music and mix in your environment.

4. System Requirements

The functional system will demonstrate three modes, each with different features:

- Conversation mode: the device will play music normally until a voice is detected. The device will then lower the volume of the music and mix in the sound picked up by the microphones to allow you to hear someone talking to you.
- Running mode: the device will play music normally until it senses that the environmental noise has increased passed a given threshold. At this point the device will increase the volume of your music (with dynamic compression to prevent distortion and clipping) to compensate for the increased ambient noise.
- Ambient mode (Safe Running mode): the device will continuously mix in environmental sound with your music.

In all cases where the device is mixing in sound picked up by the microphones, the device will:

- Process the external sound through a stereo enhancement algorithm to simulate natural stereo imaging.
- Compress and limit the external sound to prevent overloading and protect your ears (e.g. if someone yelled into one of the microphones).
- Equalize the external sound to seem natural and comfortable through your headphones.

Additional features:

- Alert the user when battery power is low.
- Allow the music to be played through headphones when the device is off (or in the case of device failure).
- Display the current operating mode to the user. This will be portrayed by LEDs.
- Allow the user to select how much the external environment will be integrated into his music. This adjustment will be made by up/down or increase/decrease buttons on the device.

The device structure:

- The device will be added directly to the iPod. Ideally, the unit will be combined into a sort of iPod cover or case.
- Marketed as a combined case and headphone set, the increased size and weight of an external unit will be less of a drawback to the qualities of the modified headphones. The size and weight of the device will be minimized as much as possible to avoid bulkiness and improve aesthetics.
- Since the device is a separate unit, no installation process is required. The customer can easily plug the device into his ipod, and the device is ready to be used as if he were using unmodified headphones.

Power of Device:

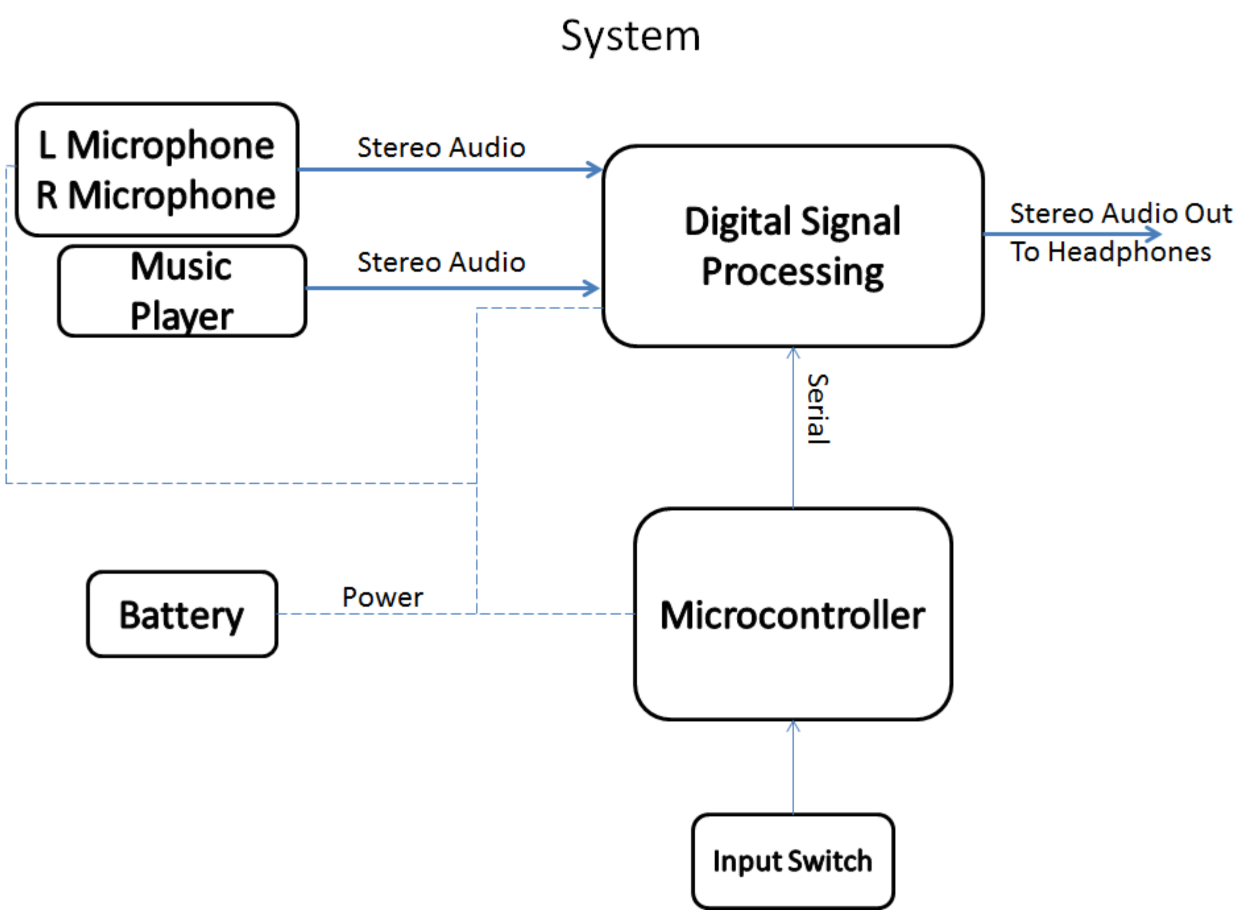
- The device will not draw power from the iPod and instead be externally powered by a battery.
- The device will use a 9 Volt battery for the prototype.
- In testing, a power supply may be sufficient and utilized.

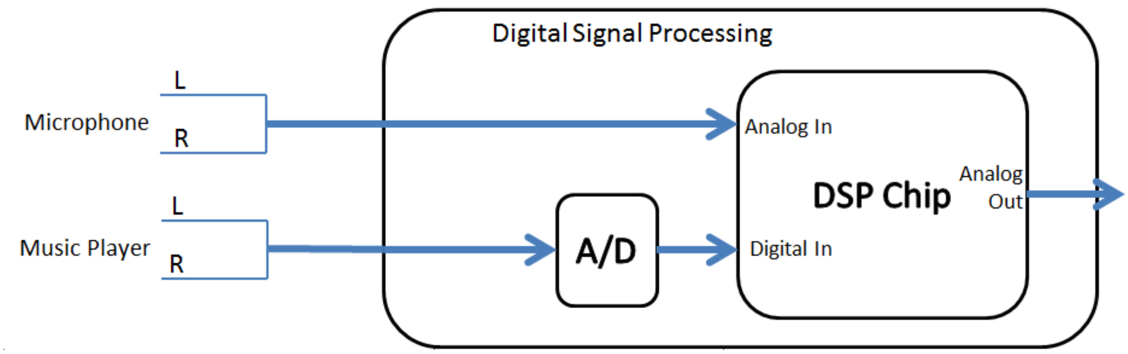
Safety Concerns:

- The current and voltage will be run at very low levels that the user should not be concerned with.

5. System Design

5.1 Overall System





5.2 Subsystem and Interface Requirements:

<u>Microcontroller:</u>

- 4-way switch for bypass, Conversation, Running, and Ambient modes
- Takes input from external rocker switch that determines the sensitivity of the program to the external audio environment.
    - Conversation Mode: Sensitivity to audio in useful human speech range (300Hz-3.5kHz)
    - Running Mode: Sensitivity to broadband audio (20Hz-20kHz)
    - Ambient Mode: Sensitivity to broadband audio (20Hz-20kHz)
    - N.B. Sensitivity may correspond positively or negatively with overall mix depending on mode
    - Bypass Mode: rocker switch has no effect
- Serial communication interface with DSP

<u>Digital Signal Processor:</u>

- 2 stereo audio inputs
    - Music player and headphones
- Serial input from microcontroller with processing directions
- Stereo imaging from microphone inputs
- Mix microphone and music signals according to program directions
- Stereo output that includes imaging

<u>External Memory</u>

- I^2C port for communication with microcrontroller
- Electronically programmable (EEPROM)
- Store DSP programs for use

5.3 Future Enhancement Requirements

- 2-way communication between DSP and iPod: This modification would allow for the elimination of the microcontroller. No external buttons would be needed to select the environment type or modify the extent to which the environment will be combined with the user's music. The controlling processes could be performed by an application run through the iPod or iPhone.

6. High Level Design Decisions

Digital Signal Processor

The system will use the Analog Devices SigmaDSP ADAU1701 processor because the system requires four audio inputs (two microphones, and a stereo signal from the music player). The SigmaDSP devices are low power and capable of being run off of a battery, and can process up to 28 bit word lengths. The ADCs in SigmaDSP chips can sample at up to 192 kHz with 24 bit word lengths - a resolution great enough to ensure that the user's audio quality will not be compromised by the device in most situations. The ADAU is the only SigmaDSP model to feature two ADCs and two DACs, as well as the capability for an additional two channels of digital audio input. This specific model meets the need for four analog inputs (when supplemented with an external ADC) and a stereo analog output while requiring only one additional chip (the external ADC) working in parallel. This model also provides 24 dB of internal gain headroom to allow a wide dynamic range for effective volume boosting in certain modes.

External ADC

The AD1871 ADC is capable of sampling up to 96 kHz (per channel) and 16, 20, or 24 bit word lengths over an I^2S interface - directly compatible with the SigmaDSP processor. It also has 105 dB of dynamic range and is capable of working at low voltages (less than 5 V). This device provides easy integration with the DSP and comparable audio capability to the ADCs internal to the DSP.

Microphones

The Panasonic WM-55A103 Electret Condenser Microphones are small and low-profile, suitable for attaching to earbud headphones. They have two connections that can be easily soldered by hand to make assembly of prototypes simple. They can be biased with low voltage, 1.5 VDC. The frequency response of the microphones is flat except for a low frequency roll off, preferable for stereo-enhancement processing because of the inherent increase in low frequency sensitivity.

Microcontroller

The PIC24FJ64GA002-I/SO microcontroller from Microchip is electronically programmable and has two available I^2C ports. Both the DSP and the external EEPROM memory are I^2C compatible and can communicate with the microcontroller over this interface. The chip is low power and offers several power modes. As the microcontroller will not be under constant use the lower power idle mode may be employed to reduce overall power consumption while the device is not in use. Multiple UART ports allow for information from the switch to be input to the controller as well as be used for status indicating LED's. The SOIC 300mil packaging will allow the best option for mounting the IC to the board.

External Memory

Additional external memory is required to store the programs needed for the DSP. The available built-in EEPROM memory found in microcontrollers is insufficient for the storage of these programs. The 24AA64-I/MS has 64 Kb of non-volatile memory which should provide more than sufficient capacity for the files needed. The device shall communicate with the microcontroller over the compatible I^2C interface. The short read/write cycle of 5 ms should reduce delays in the system during changes in operating modes. The MSOP packaging will allow the chip to be mounted onto the fabricated board.

Headphone Decisions

The system will work when integrated into any set of headphones because the audio processing is not dependent on the frequency response or sensitivity of the headphones. The effects of using the device will be more noticeable (but also more desired) in headphones with significant isolation from external environments. The audio processing will consist of dynamic processing and equalization of the microphones. Therefore, a pair of headphones that sounds "good" to a user without the system will still sound "good" in the same way with the system. Given that the microphones must be integrated into the housing on the headphones, and that each headset will use a specialized connector (not the standard ⅛" connection), this system must be designed around a particular set of headphones in order to use them.

7. Open Questions

How effective will the system be in utilizing power? What is the battery lifetime? Is this lifetime long enough to be convenient for the user?

How will the system be packaged so as to minimize space and make the system convenient for the user?

How will the microphones and necessary cabling be mounted in each pair of headphones to conserve space and avoid damage to the headphone drivers?

Where will the system's memory be stored?
[The microcontroller will have an EEPROM to store the necessary data. -verify with Eric]

8. Major Component Costs

Table 1 depicts the expected costs for the major components of one system with the parts described in the "High Level Design Decisions" chapter.

Table 1. Major Component Costs	
Part	**Cost**
Sony Sport Clip-On Headphones	$15.75
Digital Signal Processor	$10.79
Microphones (2)	$4.20
Microcontroller	$3.66
Analog/Digital Converter	$10.83
External Memory	$0.42
Total	**$45.65**

The approximate total cost at this point, which accounts for miscellaneous parts and multiple units for the development process, is seen in the following table:

Table 2. Estimated Total Costs			
Part	**Number of Units**	**Cost per Part**	**Total Cost**
Sony Sport Clip-On Headphones	3	$15.75	$47.25
Digital Signal Processor	5	$10.79	$53.95
Development Board	1	$259.35	$259.35
Microphones	25	$2.10	$52.41
Apple Headphones	3	$29.00	$87.00
EP-3 Foam Ear Cushion	50	$0.59	$29.50
Microcontroller	1	$3.66	$3.66
Circuit Board	1	$50.00	$50.00
Duracell Coppertop Alkaline Batteries 9V	3	$9.99	$29.97
Analog/Digital Converter	1	$10.83	$10.83
External Memory	10	$0.42	$4.20
Total:			**$628.12**

9. Conclusions

The proposed solution should result in a device of a reasonable size which can be integrated into a case, arm band or separate module. Thus, with our solution as a small add-on, users will be able to listen to their audio of choice while having the option to remain a part of the external world or completely tune it out without constantly adjusting settings. The device gives its user significantly more control over their personal listening experience.

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