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Senior Design Proposal

1. Introduction

1.1 Objective

Current music playback devices are increasing in size to meet the demand for larger and larger screen sizes. Phones are now averaging with a screen size of 5.5 inch and increasing each year[1]. The weight of these devices is rather large, the result of using metals and glass to give users a 'premium feel' and increasing battery size to maximize the charge life of the device. These factors are integral to making good smart devices; however, they also lead to bulky/inconvenient device profiles for physical activity, especially for exercises like running and rock climbing.

Our proposed solution is a clip-on wireless music player that is capable of storing and playing the user's music through wireless headphones via bluetooth. It will be lightweight and convenient to wear while exercising (clipped onto shirts or joggers). Our device will be simple and affordable. It will use micro-usb to transfer mp3 files on the device and play them via bluetooth.

1.2 Background

Spotify, Amazon, and Apple all attempted to create such a device, but failed to create a smooth user experience. Most branded company approaches are restricted to proprietary software when transfering music, when the job can easily be done through mp3. Also, lots of devices still include a headphone jack or could only transfer music files via bluetooth 4.0 (25 Mb/sec)[2] which takes an inconvenient amount of time. Lastly, most of these devices are priced at 80+ dollars. These factors make these products less appealing to consumers, and prevent some consumers from buying these products.

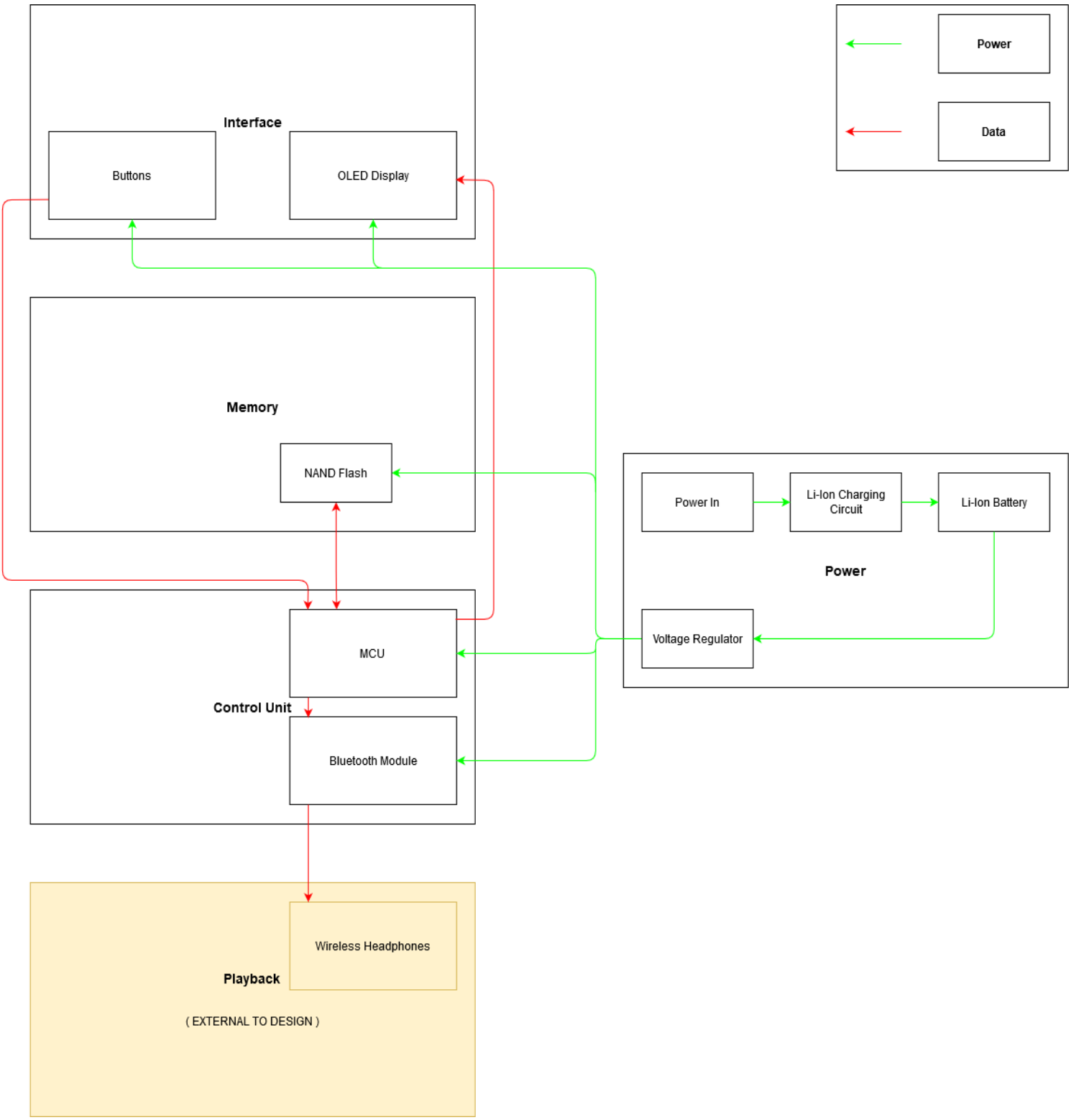
Our device will be paired with wireless headphones when playing music for workout convenience. It will be compatible with mp3 music files that will be transmitted to the device through micro-usb instead of bluetooth, as this approach is much faster. It will be a simple and affordable device that replaces your phone during workouts.

1.3 High Level Requirements

- The device must be able to play as many songs users can listen to in a workout or run session.
- The device must have enough battery life to last a workout or run.
- The device must be light enough so it will not interfere with workouts or runs, and small enough so the user can carry it without annoyance.

2. Design

2.1 Block Diagram



2.2 Physical Design

The device's weight and size are important factors in its design, as it needs to be comfortable to wear while exercising. These factors are very important when choosing components, as minimization of the PCB profile is crucial to reducing size and weight.

2.3 Functional Overview

The design can be broken down into four distinct blocks, each with a different role in facilitating audio storage and playback. These blocks include a power supply, data storage, user interface, and a control unit. The power supply is responsible for charging and managing a lithium ion battery, and supplying the proper voltages to all components in the design. The data storage block handles the audio data storage, using a NAND flash IC to allow the MCU to access the audio data as needed for playback. The user interface block encompasses all user input via buttons, and all machine feedback through the OLED display. The MCU is responsible for accessing data from memory, processing it, and communicating the audio to the Bluetooth module in order to facilitate playback via the paired bluetooth device. Additionally, the MCU also manages playback and handle user input from the buttons, and interface with the display module.

2.4.1 Power

Block Requirement: The power block is responsible for supplying power to all the components in the device, must last at least 3 hours and prevent overcharging.

Lithium Ion Charging Circuit:
The lithium ion charging circuit will receive power from the USB input to the device, and manage the charging process of the battery to prevent damage to the battery, and ensure longevity of the device's charge life.

Battery:
We will be powering our device with a Lithium Ion Polymer Battery as they are the established standard for safety and size. There are some safety considerations, which we will cover in the Safety section, but Lithium Ion batteries are the best option available to us. The option we are currently considering is rated at 3.7V at 500mAh, a reasonable amount of power for a system as small as ours. This option is expected to easily meet the power demands of our device for more than the duration of average use.

Voltage Regulator:
This module takes in the battery voltage, and supplies 3.3V to all components on the board.

2.4.2 Interface

Block Requirement: Buttons must change the playback state of the music (rewind, fast-forward, volume changes). Display must show relevant information.

Buttons:
Buttons will act as the user's medium for changing the playback state of the device. We will have separate buttons for changing the volume of the music and pausing/rewinding/skipping through music, as well as powering and pairing the device. By mapping different combinations/timings of pressing buttons, we could simplify the design and have the same functionality while reducing the number of buttons, thereby reducing the size.

OLED Display:
The display will be a small monochrome OLED, interfacing with the MCU via I^2C, allowing for pairing information to be displayed to the user when setting up the bluetooth connection to a pair of wireless headphones. The display will be small, and should use as little power as possible (this is why a monochrome OLED display will be used, as power will only be consumed for illuminated pixels).

2.4.3 Memory

Block Requirement: Must be capable of storing the minimum requirement of 2 GB of data, to store a sizable amount of playback audio to last an entire workout session.

NAND Flash:
The NAND flash will be used to store the audio files for later playback, with fast read times, and a small footprint.

2.4.4 Control Unit

Block Requirement: MCU must communicate and relay instructions to various components on the device in accordance with button inputs.

MCU:
Because the uniqueness of the device lies in its small profile and affordability, the microcontroller we use will have to be low cost and power efficient. The K32 L2 (K32L2B31VLH0A) MCU, the chip we plan to use, meets these conditions. It also has native 2.0 USB hardware, simplifying the design process and ensuring that the device will handle USB communication. The K32 L2 has a sufficient amount of GPIO pins along with the required DMA to access the flash IC, as well as I^2C pins to handle communication with the remaining peripherals, such as the bluetooth module and a small monochrome OLED display.

Bluetooth Module:
The Bluetooth communication will be handled by a standalone Bluetooth module, interfacing with the MCU over either I^2C or UART, while still not consuming large amounts of power. The bluetooth communication will in all likelihood be drawing the largest amount of power, so selecting a power efficient module is key.

2.4.5 Playback (External)

Block Requirement: Wireless Earbuds must support bluetooth and be able to play music from the device.

Wireless Earbuds:
The wireless earbuds is the final product of the data from the device. There are a variety of earbuds available on the market, but as long as they support bluetooth they will be able to receive data from the device. We output music data into the earbuds using the A2DP bluetooth profile.

2.5 Risk Analysis

The flash memory is the biggest risk to the completion of the project. Without any storage, the device does not have any music to play and is therefore unable to operate. It is also the hardest component to get working, as we do not have as much experience working with memory as we do with the other subsystems. Managing the data storage will be a significant part of the challenge, as flash memory has unique quirks that make it challenging to work with at times. This is partly due to the difficulties and risks of damage to the device in cases of power failure/incomplete write operations. This can be addressed with limiting the amount of writes to memory, and taking measures to ensure that power failure will not occur while the device is writing to flash. This challenge also is mitigated by the simple fact that our device will be able to operate off battery power, and therefore will not typically operate under the risk of "sudden" power loss due to this fact.

Bluetooth communication could potentially be a blockade for our project. The aim is to have a standalone Bluetooth module that interacts with the MCU over either the I^2C or UART standard. Although the internal design sounds straightforward, it requires further research in the pairing process of the Bluetooth module and the external device. The pairing process could potentially be either programmed while the MCU is connected to the computer or using the device's interface (screen and buttons) to select the device we wish to pair it with.

3. Ethics and Safety

There are some safety concerns present in our device. Lithium-ion batteries have the potential to explode and cause fires under certain conditions like puncturing and overheating. In 2015, lithium batteries in hoverboards caused so many house fires that Amazon suspended their sales; e-cigarette batteries have combusted even when not in use; and the fire suppression system on airplanes is often inadequate at extinguishing lithium battery fires so captains must make emergency landings [3]. To prevent batteries from being exposed to these dangerous conditions, we will warn the user of the potential hazards and encase the battery and the device components in a puncture resistant housing. We could also monitor temperatures and suspend operation beyond a certain temperature threshold. Another common cause of lithium battery fires is overcharging. To prevent such a situation, we will ensure the device cannot charge beyond a certain voltage threshold. In order to prevent moisture from entering the device and causing short circuits, the casing will also have to adhere to IP67 guidelines.

When the user is operating the device while running, it is possible that he or she is not paying attention to his or her surroundings. When running on the streets, there is a possibility that the user is unable to hear incoming vehicles if the device is operating at a high enough volume. Although the runner is using the device to facilitate this situation, we believe the responsibility in this scenario lies with the user. This is a potential issue with every device with audio capabilities, but in the end, users do have a degree of responsibility when using any product. It is common practice to monitor one’s situation while listening to music in order to avoid accidents or injury.

References

[1] TechCrunch, ‘Smartphone Screens Find Their Sweet Spot,’ 2017. [Online]. Available: https://techcrunch.com/2017/05/31/phables-are-the-phuture/

[2] PCWorld, ‘Wi-Fi direct vs Bluetooth 4.0: A Battle for Supremacy,’ 2010. [Online]. Available: https://www.pcworld.com/article/208778/Wi_Fi_Direct_vs_Bluetooth_4_0_A_Battle_for_Supremacy.html

[3] Tufts EHS, ‘The Hazards of Lithium Batteries,’ 2016. [Online]. Available: https://viceprovost.tufts.edu//ehs/files/The-Hazards-of-Lithium-Batteries.pdf