Head Bangers: Concussion Sensor

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1 Introduction

Concussions seriously affect athletes with injuries sustaining a lifetime. Despite these long lasting injuries, concussions still occur frequently. In one year, there are 1.7 to 3.0 million concussions recorded in sports. A majority of these concussions occur in sports with athletes wearing helmets, such as football, hockey, and lacrosse. These sports are commonly played as students. As a result, student athletes are more prone to concussions with traumatic brain injuries than any other athlete. Even more worryingly, an estimated 5 in 10 concussions go unreported. Because coaches, trainers, and doctors do not have numerical data to diagnose a concussion when it happens, serious injuries are often overlooked, allowing athletes to continue to play. For example, Tua Tagovailoa suffered two serious head injuries in a row. The public saw Tagovailoa possibly seriously injure himself as he was stumbling off the field with the first concussion. Yet, a week later Tagovailoa was cleared to play again and was hit in the head again. Instead of stumbling, he started clenching his hands in response to a most likely brain stem injury that could have been prevented with definitive data on his head injury status the first time. Tagovailoa is one example of the serious injuries that can occur from concussions.

2 Problem Statement and Proposed Solution

Concussions are a major problem at all levels of athletics in the U.S. Around 1.6-3.8 million sports and recreation related concussions occur in the U.S. annually. In contact sports in specific, concussions are even more common: for football alone, in any given season, 10% of all college players and 20% of high school players sustain some sort of head injury. When not reported, a concussion will not get the treatment it needs, and it is possible that another concussion could occur. This is known as Second Impact Syndrome - and can lead to permanent brain damage or even death. Also, even multiple concussions even when given time to heal can lead to long term health complications like chronic traumatic encephalopathy, otherwise known as CTE - a degenerative brain disease that can cause memory loss, depression, anxiety, and even death.

A major issue in the reporting of concussions is that it largely depends on self reporting from the athlete in question. Oftentimes an athlete will not report symptoms in order to stay in the game, or due to them not understanding the symptoms they are experiencing. This can result in the previously mentioned Second Impact Syndrome. Concussion sensing systems have been developed in the recent past, however they often cost in the hundreds of dollars. This makes these products feasible for college and professional football teams with large budgets, however not for high school teams where many of these injuries still occur.

Our proposed solution is a low-cost concussion sensing system that will be housed in a headband under the helmet. This means that although the initial emphasis will be on football, it could have potential applications in other contact sports as well such as hockey. The system will revolve around a central wireless communication device and microcontroller, as well as peripheral accelerometers and pressure sensors. The accelerometers and pressure sensors will be used to measure the jerking of the head that causes concussions. This data will be reported in real time

3 System Requirements

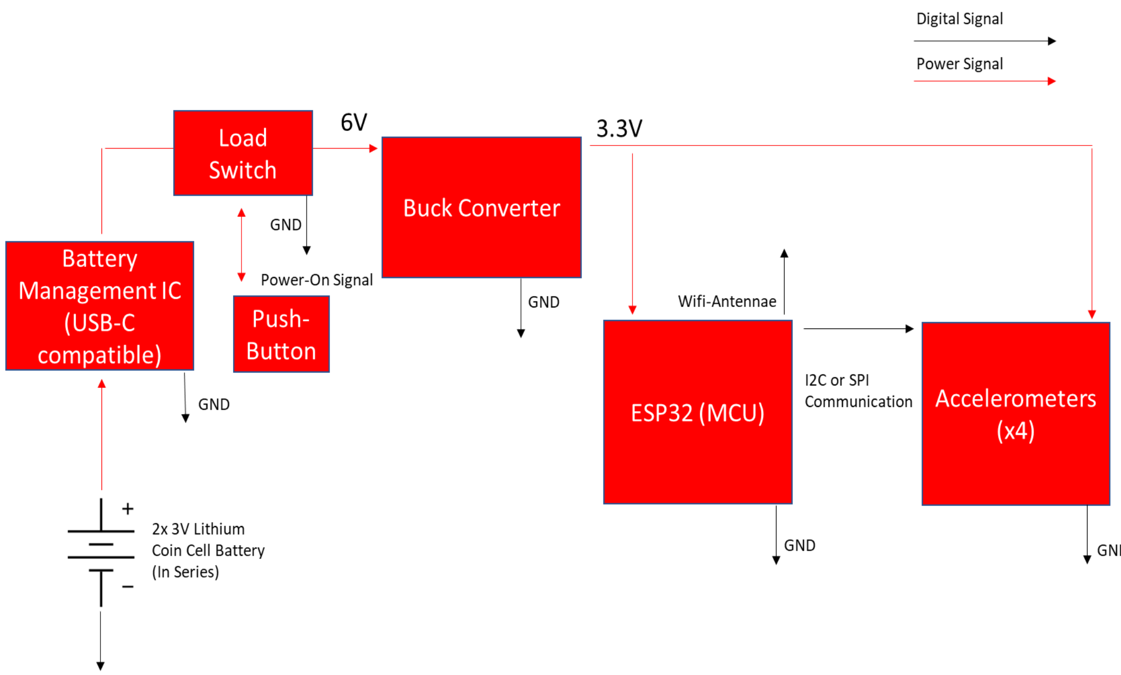
The concussion detector needs to gather data, receive data, and determine if a player has been hit in such a way that it may cause a concussion. The system needs multiple accelerometers surrounding the head, batteries, and a microcontroller to do this. It also needs wireless communication capability to communicate with coaches or trainers off the field about a possible concussion hit. The system needs to determine if a possible concussion has occurred based on the strength of the hit and the player’s previous concussion history. Another requirement for the system is battery life. The batteries need to last at least a couple of hours to endure through a sports game, as well as be rechargeable. We are considering two small 3V coin cells, which are lightweight and can lay flat against the head. Two of these batteries in series can produce 6V to charge the device.

A safety concern is if we expect someone to fall or get hit in their head, we are concerned that the device could hurt someone. To help solve this issue, we might bulk order headbands and surround the electronic parts in soft materials to protect the user. As well as, because they are wearing it on their forehead, it could slip and blind them during a game. To prevent this, we might add grippers to grip the wearer's head to prevent slipping. Further, the weight on the head might weigh them down. However, we estimate the weight of the device to be around 100g at its completion, which is nearly undetectable to the average neck. Another safety concern is the risk of breaking the device and causing overheating. Having a hot device near someone's head is not safe by any means, so we need to make sure whatever encapsulates the device protects the skin from the heat. Finally, although this wouldn't technically hurt a user, a false reading during a game could cause inaction or an overreaction for someone who is not hurt. Although, currently inaction for hurt players is why we are making this device.

Taking into consideration what the concussion-detector must do and the safety concerns, the concussion-detector will be protected in soft materials inside the headband with grippers. The system will have the ability to be mounted in any helmet using pins. There will be a button on the microcontroller that will turn on the system. This button will be easily accessible and have a cover to protect it once the headband is in the helmet. Overall, the system must be lightweight in order to not add more weight to the helmets. Since the system is using low voltages, there are no major safety concerns and, thus, the design will be safe to use.

4 System Block Diagram

4.1 Overall System:



4.2 Subsystem 1 and Interface Requirements:

Subsystem 1 will be the power delivery system for the device. We plan on using 2 x 3V lithium coin cell batteries in series to deliver 6V to the overall system. A single 3V cell was not desirable because the minimum voltage to the ESP32 is 3V, and we wanted enough margin to power the MCU. The coin cells are also inexpensive and small so this is an easy fix. We plan on using a battery management IC to charge the cells with a USB-C interface. The overall system will also be turned on from a push button which toggles a load switch to the rest of the devices downstream. This will allow the device to retain maximum charge when not in use on the field. Finally, a buck converter will step down the voltage to 3.3V for the MCU and accelerometers.

4.3 Subsystem 2 and Interface Requirements:

Subsystem 2 will be the measurement and communication system for the accelerometer data. We plan on having 4 accelerometers placed around the headband to measure the jerking of the head at different angles. In order to preserve the battery, we may need to use accelerometers with the capability for threshold interrupts. This would work to transition the MCU from standby mode to active mode, and also to turn on the wifi module. Alternatively, if the MCU can run in active mode with sufficient battery life for the entire course of a football game, then all calculations could be done on the MCU itself, and the wifi module would be the only module toggled on and off. To communicate with the accelerometers, either I2C or SPI will be used. The wifi module will be used to communicate with a server on the sideline, where trained medical staff will monitor the signals.

4.4 Future Enhancement Requirements

In the future, we might like to add a physical helmet, instead of a headband that goes beneath the helmet. Helmets are expensive and not standardized across different sports. If we have the time, we would also like to design a more visually appealing app with more features, such as a record of concussion hits or a fully integrated live data for more than one player at a time. Finally, we would like to integrate optical imaging to locate neuron movement. This would provide a more accurate notice of a concussion.

5 High Level Design Decisions

The battery must be able to support the system’s requirement of powering the ESP32 and the different devices associated such as the accelerometers. The ESP 32 required a VDD of at least 3.3V meaning we need a battery which produces at least that much voltage without being heavy or taking up space. Coin cell batteries producing 3V in series can produce around 6V which can easily power our device after being stepped down, as well as any peripheral sensors. Coin cell batteries weigh around 2.4g each, meaning their additional weight is insignificant. As well as their physical design as we receive them are flat round objects the size of a coin which can easily lay flat comfortably to a human head.

The overall objective of the concussion-detection is to find out when a hit could lead to a potential concussion. The method this system is using to declare a concussion is when a head moves in excess, due to a hit. In the order to measure the head movement, accelerometers need to be placed around the head. Accelerometers are the best sensor for this use case because they are built to measure the change of velocity. The accelerometer also has to be small and lightweight in order to be placed around the head without any discomfort.

6 Open Questions

The following are open questions about the design and science of the concussion-detector:

1. How would the battery life affect the system?
2. What would the threshold for a concussion or a traumatic brain injury (TBI) be? Further, how does the individual’s physicalities affect their disposition to get a concussion?
3. Would potential hits break the system? If so, what is the threshold?
4. Will there be any communication interference with the helmet?
5. How would the accelerometers connect to the PCB without disturbing the user?

7 Major Component Costs

The major components that will need to be purchased are the microcontroller, helmet, and accelerometers. Below is a table of their costs.

Component	Price
Accelerometer (6)	$15.72
Headband Battery Management IC	$11.99
Buck-Converter	$6.99
Load Switch	$3.30
3V Coin-Cell Batteries	$9.99
Total:	$47.99

8 Conclusions

Concussions are an everyday occurrence in all levels of contact sports. They can have serious health consequences, and frequently go unreported. Existing concussion sensors are very expensive and can only be afforded by professional and collegiate sports programs. Our device provides a low-cost, versatile solution to this problem. The device consists of 6 accelerometers embedded within a headband that will interface with a microcontroller to alert when a possible concussion hit has occurred. Our system is broken down into a power delivery system and a measurement/communication system. Even though our system is planned out, we still have lingering questions about the physical tolerance of the device and possible communication interference from the helmet. We estimate that the total cost of our major components will be approximately $50.

9 References

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