Purdue ECE Senior Design Semester Report
(Team Section)

Course Number and Title	ECE 47700 *Digital Systems Senior Design Project*
Semester / Year	Spring 2020
Advisors	Prof. Meyer and Todd Wild
Team Number	8
Project Title	AudioBeamer

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Carson Tabachka	Computer Engineering	Android Development, Bluetooth LE, Digital Signal Processing	May 2020
Calvin Walter Heintzelman	Computer Engineering	Bluetooth LE, Power Management Integrated Circuit	May 2020
Aditya Thagarthi Arun	Computer Engineering	BLE(UART), Codec interfacing , audio knowledge	May 2020
Aditya Biala	Electrical Engineering	Digital Signal Processing, Hardware Design, Audio Firmware	May 2020

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Provide a general description of the product to be delivered by this design project.

The Audiobeamer is a portable, inexpensive guitar signal processing device. This first iteration of the device will offer equalization for high, middle, and low frequencies as well as echo and reverb features. These features will be controlled by an Android App which communicates with the Audiobeamer over Bluetooth Low Energy.

(b) What is the purpose of this product? For whom is it intended?

This product uses an analog signal from an electric guitar as an input and outputs an analog signal for use with a guitar amplifier. The device is intended for use by guitar players, but future iterations of the product could be expanded to other electric instruments. This product, being portable and battery powered, can be ideal for guitar players who travel or take their instrument to a friend's house with whom they play. This device is not meant to be the highest, audiophile quality, meaning that the device is intended more for casual players or those who do not want to invest a large amount of money into the hobby.

(c) Describe how the engineering design process used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

The project was designed modularly, such that each modular section of the project was determined to work on its own before being used with other modules of the project. Each module was tested with relevant inputs, either as they would be input in practice or generated by another device, and outputs were measured and compared to expected results. This

meant using an oscilloscope to analyze communication protocols before interfacing with the microcontroller. Only after the communication protocol was observed to be working correctly on the microcontroller and the peripheral would the two be directly interfaced. Other data which could not be measured by an oscilloscope, such as data sent from the RN4020, which sends Bluetooth Low Energy data to the microcontroller via UART, was read on the microcontroller in debug mode. This data could be interpreted in debug mode by watching relevant variables and adjusting the approach to handling this data in the firmware with respect to how the data was received.

(d) Describe the design constraints, and resulting specifications, incorporated into your product (list a minimum of 3).

An important design constraint was the desire to have the product operate with low energy consumption and be powered by a battery. This choice led to the selection of the MSP430 for our microcontroller because of its capabilities for consuming minimal power. This also led to the choice of using Bluetooth Low Energy to control the device, as the reduced energy requirement compared to standard Bluetooth would decrease the overall energy requirements of the product. Another constraint on our project was the desire for it to be portable. Portability led to the desire to have the device controlled by an Android App rather than being controlled directly by inputs on the device. Choosing to control the device by an App means the device itself does not need to have interfacing options available on the device itself. These interfacing options (buttons, dials, etc.) would have used more space and made the product less portable. Another constraint was the desire to allow for various sources for analog input. The first iteration of this product is intended to be used with an electric guitar over a 6.35mm aux cable. This is the size selected for the input port of the device. In future iterations of the product, this could also be used as an input for bass guitars or other electric instruments. This should mean that the device is able to be used by a wide range of electric guitar players with materials they would already have at their disposal.

(e) Describe how each of the following factors influenced your design specifications and constraints.

Public Health, Safety, and Welfare: The most important piece of our project with respect to health and safety is the use of a Lithium Ion battery. These batteries have the potential to emit toxic fumes, start fires, or explode. In order to protect against this, the charging circuit for the battery is prepared to stop charging the battery once fully charged as to not overcharge the battery. The final product would also contain proper warnings about protecting against the worst of potential problems with batteries. This includes avoiding heat, smothering fires, and contacting the fire department at the sign of a problem.

Global Factors: Global factors played heavily into the process of developing this product. The global outbreak of the corona virus looms over this project at every moment. In early stages, this meant that ICs and passive components required to complete the project were going to be more expensive than they otherwise would be. This also meant that when orders were placed, more components would be ordered than necessary out of fear of losing access to those suppliers.

Cultural Factors: The forms and particularities of music change from culture to culture. This project is explicitly centered on guitars, but that selection was somewhat arbitrarily chosen based on the culture in which we live. We enjoy music with guitars and some of us enjoy playing the guitar based in part on our culture. There is no real reason our project could not be generalized to any instrument capable of electric analog output. In a different cultural context, this project could be tailored to the needs of that context.

Social Factors: It is not uncommon for a guitar player to want to bring their instrument to a place outside their home, where they can play along with their friends. This desire for

communal playtime is one driving force behind the portability requirement for the product. If the player wants to bring a device with them that can alter the sound of their instrument, they should be able to do so without being encumbered by the size of the device. The goal with our device was portability and ease of use.

Environmental Factors: One goal for our project was to use little energy to operate the product. In order to accomplish this, a microcontroller with low energy options was selected. In addition, we chose to use Bluetooth Low Energy rather than traditional Bluetooth for controlling the digital signal process. This protocol sends data only when there is an update to a variable. This reduces the number of messages sent and the amount of energy consumed. Finally, we also chose to power the device with a rechargeable battery. Batteries in landfills can leak and contaminate water supplies. Using a single battery which would be recharged would reduce the number of batteries used by our product and therefore reduce the number of batteries in landfills.

Economic Factors: It was our intention in this project to create a low-cost product for guitar signal manipulation. In practice this meant potentially sacrificing audio quality for cost. We opted to use 16-bit resolution as well as 32.25kHz sampling rate. We believe this to be a good compromise between cost, processing power, and audio quality.

(f) Describe the appropriate engineering standards incorporated into the creation of your product.

The RN4020 which was used for Bluetooth Low Energy uses “fully certified Bluetooth version 4.1.” The RN4020 is also RoHS compliant and certified by FCC, IC, CE, and QDID. We are also using a 6.35 mm audio jack for audio output which is standardized across almost all electric guitars. We are also using serial communication standards for transmitting data between our microcontroller and its peripherals. This includes I2C, I2S, and UART.

(g) Describe the final status of your product.

The project currently has all relevant circuits built. For the battery this include a charging circuit, PMIC for measuring capacity, and a voltage regulator. These devices can charge the battery, step the voltage to 3.3V, and send battery capacity to the MSP430 and adjust an LED accordingly. For the RN4020 Bluetooth low energy peripheral, there is a UART connection which transmits messages from an Android App to the microcontroller. These messages are parsed in an interrupt and values controlling the operations of the digital signal processing are adjusted accordingly. The digital signal processing manipulates the input signal by separating high, middle, and low frequencies and adjusting the amplitude based on the user input from the Android App. Additionally, the digital signal processing can add an echo or distortion. We also have an audio codec working to transfer audio signals between devices.

(h) Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

Early on, the project was divided by four major components which all would need to be completed but could be completed independently of each other. Each of the four team members were assigned to the two major components which they were either best equipped to handle or most interested in. These major components were then prioritized based on the order in which the components would be used temporally in normal operation of the product. Each of these components were broken into smaller steps or goals leading to the final completion of that component. Each pair of two people would establish timelines to reach goals and complete that component such that they can continue work on the other component

to which they were assigned in a timely fashion. These dates were determined first in person and as quarantine become the norm, over group phone calls or messages.

(i) Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audiences for whom these materials were intended.

The final version of our product would have a short manual for proper use of the device. The device operates in an intuitive and simple way, but instructions can be helpful none the less. This would include marking the output and input on the device, instructions for installing the Android App, instructions for operating the Android App, proper instructions for caring for the battery, as well as instructions to find proper places to recycle the product if the user is done enjoying it. The product is intended for guitar players which is not necessarily exclusively an adult audience nor an English-speaking audience. While most adults should find operation of the device simple, a guide for younger players or the parents of players, who do not play themselves, may find instructions useful. Unfortunately, this information would be limited to the English language.

(j) Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

The audience for our final presentation is the course staff for the project and potentially other students who are also developing projects in this course. The audience will be generally knowledgeable of computer engineering related terms. Some aspects of digital signal processing, music, or other niche aspects of our project that do not apply to all projects are not expected to be known by the audience prior to the presentation. This audience will also be a virtual audience which changes the medium for interaction with the audience. We will not be physically present with the audience and therefore specific questions about aspects of the project that might otherwise require physical inspect will be mediated by the virtual.

Purdue ECE Senior Design Semester Report
(Individual Reflections Section)

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2020
Advisors	Prof. Meyer and Todd Wild
Team Number	8
Project Title	AudioBeamer

Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Carson Tabachka	Computer Engineering	Android Development, Bluetooth LE, Digital Signal Processing	May 2020

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(a) Describe your personal contributions to the project.

In the early stages of the project, I worked to build an idea of what the project will be. In doing so, I did much research on several components which would be used throughout the project. The first major component on which I worked was the Android App and Bluetooth Low Energy (BLE). For this component, Calvin and I designed an Android App using Android Studio. The App consists of a connection button and five sliders for controlling digital signal processing parameters (equalization, reverb and distortion). This app would be required to communicate with an RN4020 using Bluetooth Low Energy. The RN4020 was programmed via UART to operate as a peripheral, meaning it would advertise itself to any central BLE devices. Additionally, the RN4020 was renamed to “audiobeamer” so the app would know which device to find. The passcode was also disabled, as the final audiobeamer product would not have an easy method of displaying the pin. Once the connection was established between the RN4020 and the Android App, a GATT server was set up in the Android App. This server hosts a service containing five characteristics. These characteristics represent the five values for low, middle, high, reverb, and distortion. When a slider moves, the corresponding variable changes to the new value and the corresponding characteristic is updated. This updated characteristic value is sent over the BLE connection. Then on the MSP430, I set up a buffer into which the received BLE messages would be stored. When a new message is received, the normal operation of the program pauses while the message is parsed. The updated value’s ID value is found in the message, the updated value is found and converted from hex characters to integer values. The corresponding variable in the MSP430’s program is updated to match the received value. The second major component on which I worked was the digital signal processing (DSP). The selected MSP430FR5994 has a low energy accelerator (LEA) which can process digital signals much faster than the MSP430 itself. There is a library of certain functions which will run over the LEA. These functions where used throughout the DSP process. The input signal is filtered with three bandpass filters for low, high, and mid frequencies. These filter results are scaled by their corresponding values from the Android App and then summed to a final equalization result. After this, the echo and reverb values are added to the result.

(b) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

My understanding of C, which was used to program the MSP430, was built in CS159 and ECE264. My understanding of Java, which was used to program the Android App, was built in ECE30862. My understanding of the Butterworth filters used in the digital signal processing was built in ECE202. My understanding of the communication protocols, such as UART, were built in ECE362. While not directly a topic touched on, ECE463 was a helpful background for understanding Bluetooth Low Energy. I built my understanding of the various tools used in lab, like the oscilloscope, function generators etc. in ECE207 and ECE208.

(c) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

The three major topics on which I acquired new knowledge were Android App development, Bluetooth Low Energy, and digital signal processing. For each of these topics, the process of building knowledge started by doing research and taking notes on the subject. Once I had a comfortable understanding of the concepts, I began preliminary implementation. Inevitably, my understanding of the concepts would not be complete after the initial research, and this preliminary implementation would be a useful means of determining where my understanding is lacking. After this, I would step away from the implementation and return to research to build a fuller understanding of the concept. This cycle would repeat throughout development. In each iteration of the cycle, my understanding of the concept would become more complete and more refined.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

This project requires teamwork. Learning to work effectively in our team of four was helpful throughout development. First, methods of communication, data sharing, and project collaboration were established. With this, we had established modes of contacting each other and sharing useful aspects of the project such as code or homework assignments. Effective communications are incredibly important to complete this project. Next, sections of the project were delegated early on. This delegation was incredibly useful. Knowing which aspects of the project each person is responsible for allowed us early on to begin research into those topics. Early research allowed us to build a deeper understanding of our respective topics, which we would then share with each other. With this method, we not only cover the full range of topics involved in the project, but also collectively build a deeper understanding of those topics. Finally, as the project progressed, we established deadlines which would be useful milestones. These milestones helped to establish which aspects of the project would be complete by which dates. Establishing these deadlines kept the project moving ahead on track to be completed by the final date.

(e) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product's impact in each of these four contexts?

Our product is intended to be battery powered with little energy consumption. Electronic components generally can have a negative environmental impact. The product process and the disposal process are especially likely to create environmental pollutants. However, the product is intended to consume a small amount of energy and has a rechargeable battery. The choice of a rechargeable battery over replaceable batteries was taken, in part, to reduce the number of battery waste from the device. The economic impact is likely to be small. The product is intended to be low cost, hopefully increasing access to an otherwise potentially expensive experience. In the broader society or global context, more guitar effects devices in circulation could increase interest in guitar playing or music generally.

Purdue ECE Senior Design Semester Report
(Individual Reflections Section)

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2020
Advisors	Prof. Meyer and Todd Wild
Team Number	8
Project Title	AudioBeamer

Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Calvin Walter Heintzelman	Computer Engineering	Bluetooth LE, Power Management Integrated Circuit	May 2020

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(f) Describe your personal contributions to the project.

I primarily contributed to the project by creating/designing the application for an Android phone. I also helped set up the communication with the Bluetooth chip and the Android App and the communication with the Bluetooth chip and the MSP430FR5994. Earlier in the semester, I also helped decide on which devices we were going to use for the project, including the microcontroller, Bluetooth chip, and power management integrated circuit. Lastly, I did all the circuitry and coding for the STC3100 and MSP430FR5994 for all power management integrated circuit operations.

While working with the Android App, I did all of the coding behind the UX/UI design, including sliders for adjusting values for equalization, distortion, and reverb. I also did much of the coding to get the Android App to connect and bind to the Bluetooth module by having it search for the correct name and only connect to that specific name (I believe it was “audiobeamer”). The app then sends information from the sliders whenever they are changed to another value.

I have also tested programming the STC3100 (the power management integrated circuit) with an Analog Discovery 2 device. After correctly sending a receiving the necessary information, I went on to test programming the STC3100 with the MSP430FR5994. This included wiring and significantly more coding than with the Analog Discovery 2 device. I programmed I2C communication between the MSP430FR5994 and the STC3100 by using TX and RX buffers to write to control registers in the STC3100 and then read from the appropriate registers in the STC3100 to return those values to the MSP430FR5994. The MSP430FR5994 would then use that information to determine if that battery level was low and if so, the MSP430FR5994 would light up and LED indicator.

(g) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

I have always been interested in coding for both hardware and software. By being primarily involved in two main components of the project (getting the Bluetooth and PMIC modules to work), I was able to satisfy both of my interests. I enjoyed programming the microcontroller in ECE 362 with Rick and I felt like my work with the PMIC was somewhat of an extension of that. I also felt like my work with the Bluetooth modules in the Android App developer IDE software was similar to using external libraries that I have used in other projects, like an XML interpreter or NumPy, or SciPy.

(h) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

To work on this project, I had to become familiar with coding techniques and libraries for both android app development and the MSP430FR5994. I did this by reading through the documentation and tutorials for both using a “try, test, and repeat if necessary” strategy. I also accessed several help forums and even posted on a couple of them to help me work my way through this project. Now I feel much more comfortable programming Bluetooth modules for Android apps and working with the MSP430FR5994, especially with its I2C communication protocols.

(i) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

I have an ethical responsibility to not let our Bluetooth module interfere with other Bluetooth capable devices. To do this, I assured that our Bluetooth app would strictly only connect and/or bind to our Bluetooth low energy device. I did this (with the help of Carson) by ensuring that the Android app would only connect and/or bind to a device labeled “audiobeamer”. I also believe I have a professional responsibility to do my expected part in this project for my team members as to not put unnecessary stress on their part. This also translates to good practices in any workplace so that I do not put extra work on those who do not deserve it.

(j) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

Our product could have an economic impact by providing more money for electronic devices in the music industries, especially those involved with electric guitars. Our product could have an environmental impact if those who use our products do not discard them appropriately or if our product is mass produced at the expense of environmental resources. Our product could have a societal impact because it could potentially help guitar players ease into digital signal processing by introducing them to it in a fun and easy way. Our product could have a global impact by making digital signal processing among guitar players far more ubiquitous across the globe, perhaps even creating more guitar players indirectly when those who see the use of our product want to join in on the fun.

Our economic impact would be considered by looking at the price of each individual component and at the unit as a whole and then deciding where costs could be cut, allowing the manufacturer(s) to make more money in selling these. Our environmental impact would be considered by looking into the environmental cost/footprint that each of our devices have and trying to minimize this by finding alternative products and/or providing disposal instructions for our product for its end of life. Our societal impact would be considered by seeing how the music industry has shifted after our product has been released to the product by considering how culture behind playing guitar, the total number of people playing guitars, and the number of people playing electric versus acoustic guitars have all changed since the release of our product. Lastly, our global impact would be considered by seeing how global industries and cultures behind playing electric guitar and digital signal processing for electric guitars has changed since the release of our product, assuring that this product can be purchased/accessed in all appropriate areas of the world.

Purdue ECE Senior Design Semester Report
(Individual Reflections Section)

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Semester / Year	Spring 2020
Advisors	Prof. Meyer and Todd Wild
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Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Aditya Thagarthi Arun	Computer Engineering	BLE(UART), Codec interfacing, audio knowledge	May 2020

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(k) Describe your personal contributions to the project.

In the very initial stages of the project Aditya B and I brainstormed the basic idea on what our project will be based on. We decided that it would have something to do with audio, a guitar audio processor to be more specific. After suggesting our idea to the course staff, we were told to make some changes, and we evolved our idea to incorporate the changes suggested.

During the beginning of the semester I worked on finding the various parts required for our project. A Major part I helped find was the RN4020 module. I made efforts of getting the UART between our BLE module and the MCU. I also helped with testing the BLE module in the later stages of the semester.

The next thing I worked on was getting the mode control for our codec to work. A challenge I faced here was that our MCU only supports 8-bit MCU, but the codec required 16 bit SPI for it to be programmed. I found a workaround for this problem using some tricks with the clock. We later decided that the mode control for the codec was not essential/necessary for the operation of our project, so we omitted this.

Finally, I worked on the I2S communication between the MCU and the codec. My implementation used SPI because our microcontroller does not have native support for I2S. The implementation involved the use of SPI along with DMA for a continuous clock and data stream which are essential in I2S communication.

(l) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

The knowledge and skills I gained with ECE362 were immensely helpful in the senior design project. A deep understanding of communication protocol taught in 362 were the building blocks to this project. It was also helpful that my project in 362 involved audio (a keyboard synthesizer to be exact). Additionally, the lab techniques taught in ECE207 were needless to say very helpful. The C programming knowledge I gained in 264 and 368 helped me craft embedded C programs.

(m) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

I gained majority of the new knowledge by looking up issues on the internet. I also read the data sheets and user guides for the components I was working with to get a comprehensive understanding of what was to be done. I2S was a major new topic I was exposed to. I used the various TI forums and TI documents to learn about this protocol. I used the several code examples provided by TI on our MSP430FR5994 MCU to get an understanding of how to approach software related problems. The course staff were also very helpful in helping me make progress in this course.

(n) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

We set up our communication and code repositories very early on. This helped us communicate, share important resources and code easily. It was very important for us to learn how to improve the way we interacted communicated with our teammates as the semester progressed. The roles were established early on and this helped us decide our professional responsibilities in the team (ex: hardware, software, firmware etc). The establishment of roles also allowed us to do learn more in that area and helped us focus our efforts. This made us get a deeper understanding of the subjects we were focusing on. As the semester moved along, we established deadlines, and this allowed us to make progress in a timely manner. This also helped us decide the priority of various parts that needed to be completed.

(o) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product's impact in each of these four contexts?

Electronic products usually have a negative impact on the environment because of hazardous metal and non-biodegradables. Our product was designed to be as minimal as possible to minimize the negative effects on our environment. The use of a rechargeable battery also meant that the waste caused by the disposable batteries would be nil. Our product is meant for ease of use and convenience of having a guitar processor in a small package. It will enable people get together and play guitar in a fun manner. I cannot think of any economic impacts our product might have as it is designed to be a relatively low-cost device.

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Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Aditya Biala	EE	Digital Signal Processing, Hardware Design, Audio Firmware	May 2020

Individual Reflection: Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

(p) Describe your personal contributions to the project.

I was mainly responsible for hardware design in this project. This involved component selection, circuit design and prototyping all the individual subsystems. Additionally, I completed three iterations of PCB design using KiCAD keeping with the principles of RF & audio system design.
I also contributed with the development of the audio pipeline & writing audio firmware code, specifically with finding optimizations to use the I2S protocol with SPI. Additionally, I helped implement & design digital filters that were used for audio equalization.

(q) Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

Many contributions built on knowledge learnt in ECE362. ECE362 laid the foundation of firmware and microcontrollers and helped with the overall design and development of the project. Furthermore, the individual subsystems required knowledge from other classes as well as listed:
ECE202 – Filters
ECE301 & ECE306 – FFT, frequency domain analysis, signals
ECE305 – Transistor & semiconductor fundamentals
ECE264 & ECE368 – C programming & algorithms
ECE 207 & ECE208 – Usage of Lab equipment (oscilloscope, function generator etc.)

(r) Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

The first step I followed when I had to learn new information was to read texts on the internet to get a general understanding. In addition, I thoroughly read the data sheets of all the major components the team was using to understand how the device behaves. If the problem is more complex, I used Purdue Online Library to find a suitable textbook and read a few chapters to get a detailed understanding of the theory. If I was approaching a software problem, my first step was to look at example code and get the most basic implementation working with the microcontroller and then build on that knowledge. In addition, course staff were always available to provide a possible solution to my problems. As the semester moved

towards online learning, I also utilized YouTube videos to learn soldering tips and DSP fundamentals.

(s) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

Our project required efficient teamwork and coordination in a team with a diverse background, just like it may be in the workforce. As a member of this team I was responsible for giving an objective my maximum effort in a timely manner so that we progress as a team and complete a robustly designed project that meets all the requirements. As the hardware design lead, I was also responsible that the circuit is designed with safety in mind as the project should not be dangerous or cause harm to its user.
A major requirement was effective delegation and communication between team members and it really helped that the entire team got along with each other. In the start of the design phase, towards the end of the Fall 2019 semester, we figured out what each team member is strongest at and divided roles accordingly. This really helped our team become efficient with minimal issues along the way. Additionally, effective electronic communication channels were established along with version control so that all team members have access to project files and backups. Our team also followed a project management style (SCRUM) where we used shorter deadlines with smaller submodule objectives to work faster and gauge our progress better when compared to a large module with longer deadlines. All these factors combined allowed team members to quickly understand their responsibilities and allowed us to work effectively as a team, in a professional and ethical manner.

(t) Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product's impact in each of these four contexts?

In terms of environmental impact, our product is designed to draw a small amount of current (0.3A max) from a rechargeable battery. All our components are expected to last for at least 30 years according to the theory reliability analysis we conducted. Additionally, we are using a rechargeable battery which reduces the use of external reusable batteries which further reduces environmental impact.
The economic impact is likely to be small. We aim to provide a low cost, portable, easy to use substitute to a heavier, more expensive guitar amplifier. It is important to note that this product does not aim to replace the guitar amplifier but provide a reliable substitute. In the global context our product could gain popularity with novice musicians looking for a portable solution for guitar effects.