Wireless Controlled Guitar Pedal

Team 22 - William Newman, Marco Palella, Chris Scheurer
ECE 445 Project Proposal 2 - Spring 2020
TA: David Null

1 Introduction

1.1 Objective

Performing live at a concert often requires musicians to move around constantly on stage. Whether it be to crowd surf, mosh, or just to move to the rhythm of the music they're playing, the actions of a musician on stage can make or break a performance. Traditionally, guitars are connected to sound equipment, using pedal boards to control effects like distortion, echo, reverb, filtering, etc. [1]. Pedals are typically daisy chained together, and contain control knobs to adjust different parameters on each pedal [2]. This means that if the musician wants to make real-time adjustments, they need to be standing near the pedal and are forced to adjust parameters with their feet. There are existing devices on the market that allow for the modulation of certain effect parameters wirelessly, however, there are no devices on the market that allow a guitar player to remotely control several effect parameters on a pedal [3].

This pedal would be desired by musicians because it will increase the musical freedom of the musician on stage. Being able to adjust signals live from a device that is mounted directly onto a guitar is something that a lot of musicians are moving towards. For example, Matt Belleny, the lead guitarist of Muse has incorporated a MIDI X-Y control pad into his guitar so that he can modulate his guitar during performances [4]. Music is moving in a direction that combines acoustic and digital elements, which would make a guitar-mounted controller very appealing to musicians

Our solution to this problem is to create a transmitter unit that can be placed on the guitar. This device will be able to turn effect(s) on/off, and will have several potentiometers to give the user control over effect elements. The transmitter will communicate with a receiver unit that will take an analog guitar input, apply the effect/process the audio data digitally based on parameters coming from the transmitter, and then convert it back into an analog output. This receiver can be daisy chained to a guitar pedal board and is set up exactly like any other guitar pedal.

1.2 Background

Guitar pedals are widely used to manipulate the sound coming from a guitar during live performances. Typically, pedals are switched on with a button or a large potentiometer that can be moved with your foot, and they have knobs that adjust different parameters of the effect. Guitar pedals typically adjust the dynamics of the guitar, filter the guitar, or add reverb/echo to the guitar.

While performing, guitarists are often limited in their ability to move around because they must remain close enough to their guitar pedal board to operate the effects. We aim to alleviate this problem by exporting the operation of a digital guitar pedal to a wireless controller mounted to the guitar. Another ECE 445 team previously attempted to solve this problem in the Spring semester of 2003. However, their design (while functional) introduced several other issues [5]. Briefly put, their system operated on Radio Frequency (RF) and transmitted the guitar signal wirelessly. The reason RF transmission is a problem is because RF is open to any RF receiver such as a "walkie talkie" (commonly used by venue personnel), which means that instead of the guitarist's "sick" guitar solo, the crowd may be hearing the security guards talking about their after-show plans. Although transmitting the guitar's signal/sound over RF frees up the guitarist's movement, the guitar will be entirely removed from the audio mix if the RF signal is interrupted. If the guitar output is fed to the receiver and the wireless signal is interrupted, it will not impact the audio feed at all; the user will just be unable to make live adjustments.

The solution to these problems, which we will implement, will be to convert RF to Bluetooth and to have the audio from the guitar still be transmitted via cable instead of being transmitted wirelessly. This reliance on the cord still restricts the guitarist's movement; however, it is significantly easier to obtain and use a longer cord, and the guitarist's freedom of movement is still greatly expanded.

1.3 Physical description

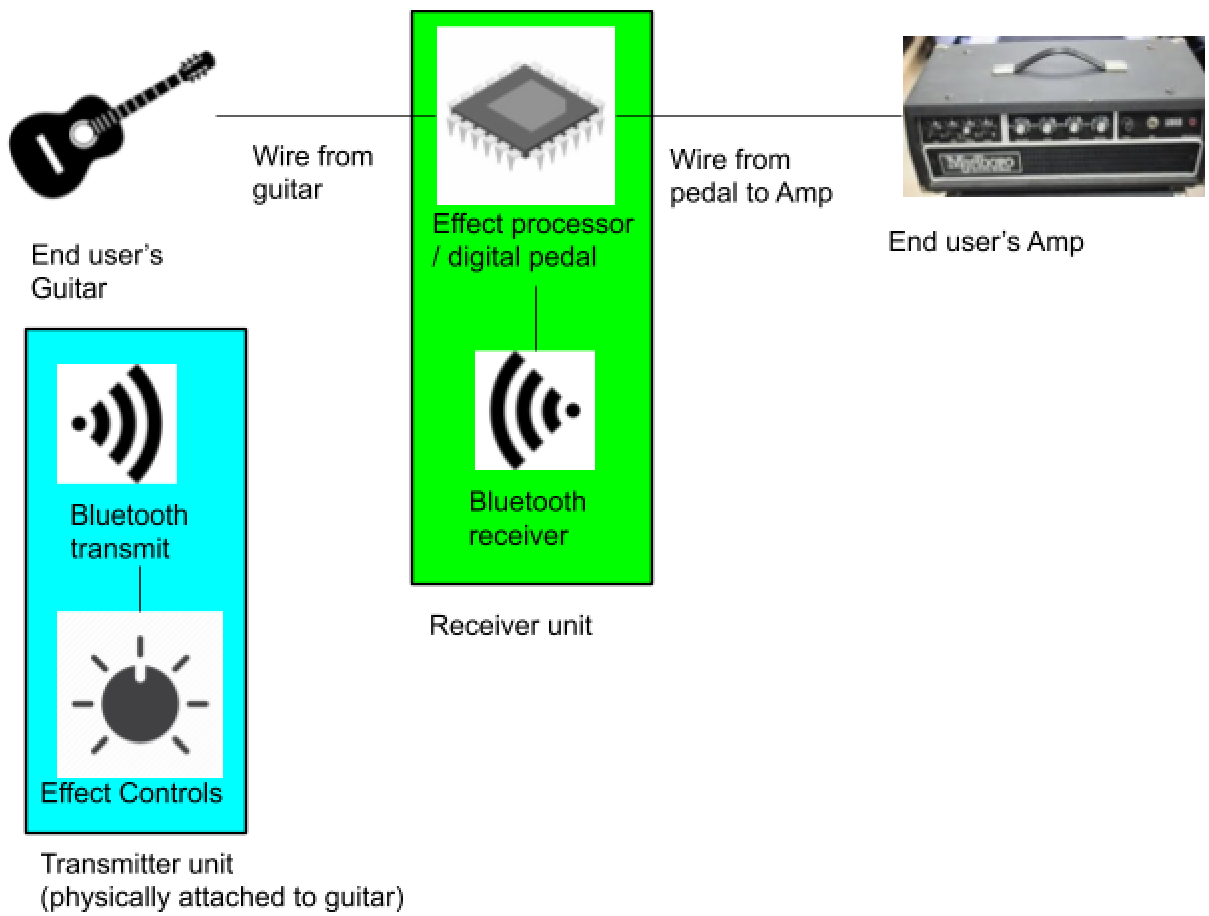

Figure 1. Physical layout

Figure 1 represents the physical layout of the wireless guitar pedal. The transmitter physically attaches to the guitar through some means, preferably some type of clamps so it is removable. The transmitter has the controls for the associated pedal built into it and operable by the end user. The settings imposed by the controls are then wirelessly sent to the digital pedal where they are fed into the effect's algorithm and modify how the effect sounds. The guitar's pickup connects to the pedal the same as any other pedal through a wire with male quarter inch jacks on both ends, the pedal to Amp connection is the same.

1.4 High Level Requirements

- If a 1V peak to peak analog sine wave is inputted to the receiver, the receiver's output must be an identical signal that has a latency less than 13 ms with an SNR greater than 20dB
- Bluetooth transmitter must be able to send 12-bit digital potentiometer values to the bluetooth receiver at a distance of 10 feet
- Receiver microcontroller must be able to process audio data (data from the guitar) at a sampling rate of at least 48 kHz and a bit resolution of 16-bits

2 Design

Our design is going to consist of two major systems, a transmitter module and a receiver module. These modules will communicate with one another using a bluetooth transmitter and receiver, and will be powered independently from one another this will make it possible for the user to travel freely.

The transmitter module will be mounted on the guitar and powered by an on board battery. It will have a potentiometer module that a user can interact with, along with a power light and switch. The first submodule is the power module, which will supply a voltage drop across the potentiometers, along with regulating power to other modules on the board. The voltage drop across each potentiometer will be converted into a digital signal by an ADC, sent into a microprocessor, which will communicate data and control commands to an onboard bluetooth module. There will also be an on board oscillator to ensure that the transmitter is synchronized with the receiver.

The receiver module will be a separate device that will be connected to the guitar data line like a guitar pedal (ie. the line from the guitar is the input, and the output is either connected to an amp or other pedals). This module will be powered by a 9V supply, and will have an LED to verify that power is being supplied to the device. The analog input will be converted into digital data and sent to a microcontroller via an I2S data line. This data will be processed by the microcontroller based on parameters I2S data being transmitted to the bluetooth receiver. The processed digital data is then converted back into an analog signal with a DAC.

2.1 Block diagrams

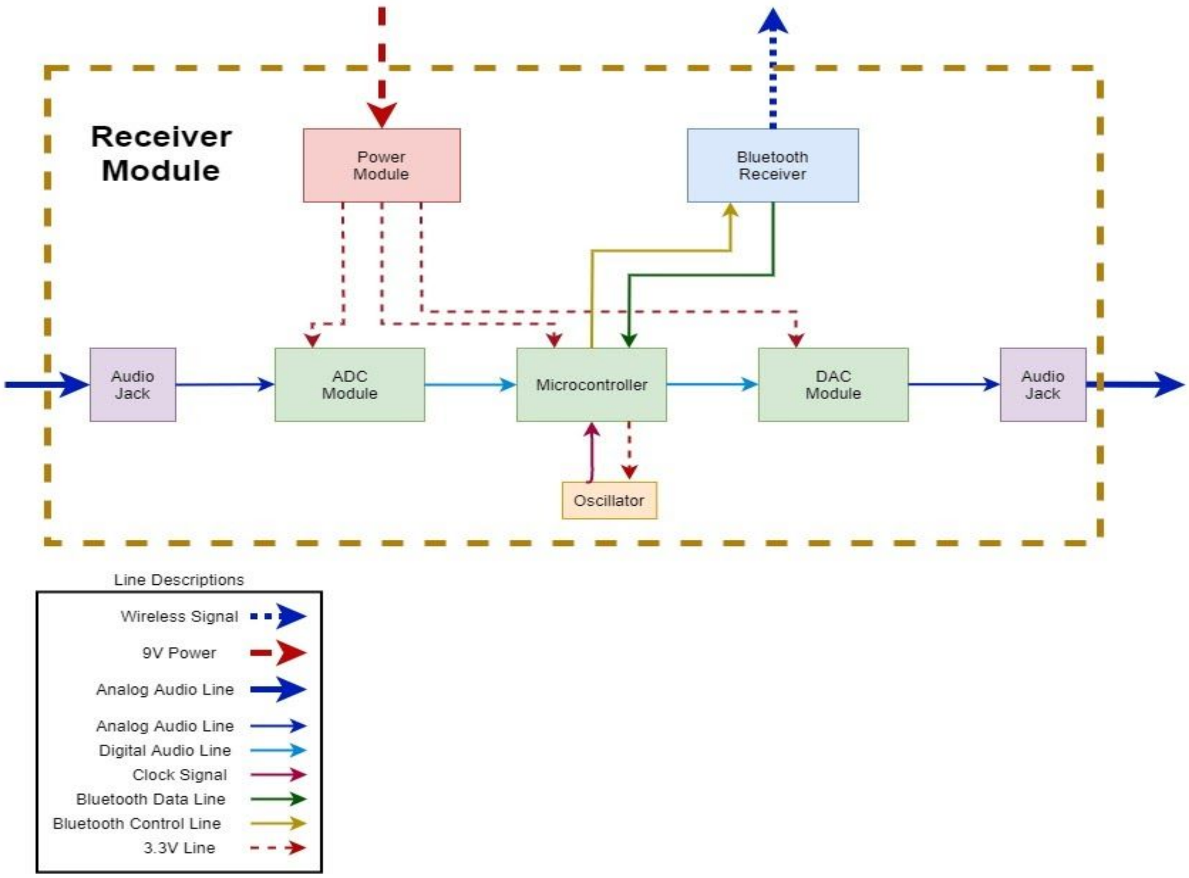

Figure 2. Block Diagram of Receiver Module

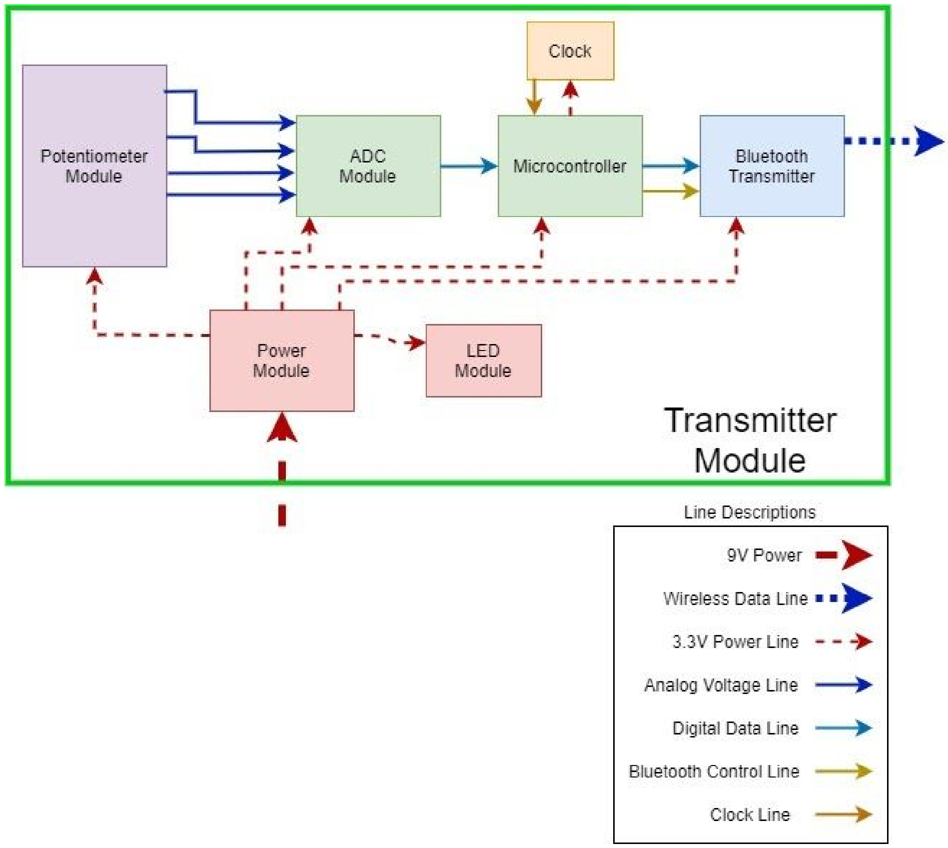

Figure 3. Block Diagram of Transmitter Module

2.2 Receiver Module

The receiver module acts as the pedal portion of the design. This module will have the means to wirelessly receive data from the transmitter module, and will also be in charge of processing the guitar signal.

2.2.1 Power Module

This module will be in charge of stepping down the 9V voltage of the power source to 3.3V. This is a voltage that devices on the board can be powered with. Additionally, the power module will protect ICs from voltage/current fluctuations and act as a buffer between the power supply and on-board electronics.

Requirement 1: Must be able to step down a 8-10V DC signal to 3.3V DC signal
Requirement 2: Must create an open circuit if above 10V DC, to prevent damage to system

2.2.2 Audio Jacks

The audio jack circuits will be used to connect the signal going through a TRS cable to the electronics on the board (ie. the ADC and DAC modules).

Requirement 1: When no signal is sent, must not create a signal due to noise
Requirement 2: When audio is sent through the jacks, and processing is turned off, the output of the jack circuit must not exceed an SNR of 20 dB

2.2.3 Bluetooth Receiver

The bluetooth receiver will be in charge of communicating wirelessly with the bluetooth transmitter on the transmitter module. This device will be in charge of pairing with the transmitter and receiving the digital voltage values of the potentiometer control knobs and sending that data to the microcontroller.

Requirement 1: Must be able to pair and receive data from the transmitter
Requirement 2: Must not introduce any complex noise to the signal, IE any noise introduced can be filtered out via linear filters

2.2.4 Microcontroller

The Microcontroller on the receiver is in charge of organizing the data being transmitted from the ADC and the bluetooth receiver. The data coming from the bluetooth receiver will be checked and then the processor will process the data coming from the ADC with the pedal effect, and then send the value to the DAC module. The microcontroller is also in charge of initializing the Bluetooth receiver.

Requirement 1: Must not change the signal when processing is disabled (IE output == input)
Requirement 2: Must have at least one (1) effect
Requirement 3: Must be able to control the I2S transfer protocol

2.2.5 Oscillator

This module is a clock that will be used to ensure that the transmitter microcontroller is in sync with the receiver microcontroller. There will be an identical module attached to the microcontroller on the receiver module.

Requirement 1: Must be able to provide a 50 khz clock consistently

2.2.6 DAC Module

This module is in charge of taking the processed digital I2S data coming from the microcontroller and converting it back to an analog signal to be sent out of the receiver via an audio jack.

Requirement 1: Must be able to convert a digital representation of a signal (sine, square,etc) into the appropriate analog signal
Requirement 2: Must not have an SNR less than 20 dB
Requirement 3: Must be able to communicate via I2S at a sample rate of 48 kHz and a bit depth of 16 bits

2.2.7 ADC Module

This module will be in charge of taking analog audio data from the audio jacks and converting it into an I2S data stream that will be sent to the microcontroller.

Requirement 1: Must be able to convert an analog representation of a signal (sine, square,etc) into the appropriate digital signal
Requirement 2: Must not have an SNR less than 20 dB
Requirement 3: Must be able to communicate via I2S at a sample rate of 48 kHz and a bit depth of 16 bits

2.3 Transmitter Module

The transmitter module will be the controller mounted onto a guitar. This device will send the voltage drop of several potentiometers to the receiver module via bluetooth. Each potentiometer voltage drop will control a parameter of the effect that the receiver is applying to the guitar audio.

2.3.1 Power Module

The power module is in charge of regulating the voltage drop of a 9 volt battery down to a 3.3V steady DC signal. This 3.3V line will be used to power several other submodules on the transmitter and it will supply a voltage drop across all the potentiometers. There will be a switch in this module that allows the user to turn the device on and off.

Requirement 1: Must be able to step down a 8-10V DC signal to 3.3V DC signal
Requirement 2: Must create an open circuit if above 10V DC, to prevent damage to system

2.3.2 ADC Module

The ADC Module will be in charge of converting the analog voltage values to a digital I2S data value that can be sent to the bluetooth transmitter. This will be the medium between the potentiometers and the Micocontroller. Because there are several inputs and 1 output channel, this ADC will need to be multi-channel.

Requirement 1: Must be able to convert an analog representation of a signal (sine, square,etc) into the appropriate digital signal
Requirement 2: Must not have an SNR less than 20 dB

Requirement 3: Must be able to communicate via I2S at a sample rate of 48 kHz and a bit depth of 16 bits

2.3.3 LED Module

This module will be used to convey that the transmitter is indeed on to the user.

Requirement 1: LEDs must be able to light up when being supplied with a 3.3V voltage.

2.3.4 Microcontroller

The Microcontroller on the transmitter is in charge of organizing data coming from the ADC module, and sending it to the bluetooth transmitter in I2S formatting. The Microcontroller will also be in charge of initializing the bluetooth transmitter when the transmitter module is powered on.

Requirement 1: Must be able to initialize the bluetooth transmitter
Requirement 2: Must be able to drive the I2S transfer protocol

2.3.5 Bluetooth Transmitter

The Bluetooth Transmitter is in charge of pairing with the bluetooth receiver on the receiver module and wirelessly streaming the potentiometer voltage data to the receiver.

Requirement 1: Must be able to pair and transmit data to the transmitter
Requirement 2: Must not introduce any complex noise to the signal, IE any noise introduced can be filtered out via linear filters

2.3.6 Oscillator Module

This module is a clock that will be used to ensure that the transmitter microcontroller is in sync with the receiver microcontroller. There will be an identical module attached to the microcontroller on the receiver module.

Requirement 1: Must be able to provide a 50 khz clock consistently

2.3.7 Potentiometer Control Module

The potentiometer module will act as a user interface for the musician on the guitar. It will consist of four linear potentiometers and a switch. Each potentiometer will have a 3.3V drop across, and the voltage output of each potentiometer will be what inevitably controls the parameters of the effect. The switch will also have a 3.3V drop across it, and if the switch is closed, the effect of the pedal will be audible in the audio stream.

Requirement 1: Must be accessible by the end user
Requirement 2: Must function in arbitrary configuration of voltages over potentiometers and switch configurations.

2.4 Risk Analysis

There are two major risks to completing this project. The first is a perfect or near perfect signal conversion. By changing the audio from analog to digital, processing, and then converting from digital to analog a significant amount of noise and not intended distortion can be created. The I2S data transfer protocol plus some digital filtering and smoothing solves this, but this processing is not trivial to properly set up. This risk is largely mitigated by several team members having experience dealing with this task, but it is still a risk to the project should new problems arise.

The second major issue is the introduction of the Bluetooth transmitter/ receiver as no one in our group has much experience configuring Bluetooth data transfer. From what we've found so far, communicating with the actual chips will be done with I2S which (as previously mentioned) we are familiar with. The exact type of data that has to be given to the bluetooth chips, however, is new territory for our group and could present significant challenges.

The block or interface that poses the greatest risk to successful completion of our project is the bluetooth transmitter. This is because of the fact that data must be sent serially, so we will be required to synchronize the serial data. Our receiver device needs to read data at the same rate the transmitter device is sending data. If there are only very small (less than or equal +/- 0.1 Hz) differences between the transmission and receive rates, our device can essentially correct itself because the next data set will not replace the old dataset before the next clock cycle. However, our device will not be able to correct for instances when the transmission rate and receive rate are largely different (any difference greater than +/- 0.1 Hz). This is because of the fact that our receiver device will either see a blank transmission or delete a transmission between clock cycles.

3 Ethics and Safety

After careful consideration, there are only a few ethical and safety concerns regarding the pursuit of this project. One potential safety/security risk that could be considered is the ability for the bluetooth communications between the transmitter and the receiver to be maliciously intercepted. A malicious attacker attempting to disturb a band/musician's performance could intercept and/or alter the data being sent to the receiver resulting in unwanted/bad sounding output from the amplifier. However, because this device only deals with guitar effect parameter data, a compromise in this data transmission would not be as detrimental as if other wireless bluetooth data was intercepted such as a classified document. Nevertheless, in this case, we will work to ensure that statement 9 of the IEEE Code of Ethics is satisfied, in the fact that we will work to ensure that there is no injury in reputation to any person or their property in the event that important data is not compromised from the use of our device [6]. In the event that our device's bluetooth transmissions are being tampered with, we can always switch the transmitter/receiver system off and continue to allow the guitarist to change effects manually.

Another concern that comes to mind with a system like this is equipment damage. We would not want our device to cause an amplifier to be overdriven to the point of failure. However, after reading through several guitar forums [7], we have come to the conclusion that this will not be a problem. At its worst, an incredibly distorted signal would be simply that: a distorted signal. Guitar amplifiers are designed to handle a ton of feedback and distortion, unlike a standard public address speaker system. Because of this research, we have concluded that our device will be in total accordance with statement 3 from the IEEE Code of Ethics in the fact that the available data tells us honestly and realistically that an end user's guitar amp will not be damaged from the possibility of an immensely distorted signal. Our device will also be in accordance with statement 9 from the Code of Ethics in the fact that no injury of property will occur from the usage of our device.

Finally, in regards to environmental ethics, we will fully comply with statement 1 from the IEEE Code of Ethics by ethically designing our system and developing it with sustainability in mind [6]. For this reason, it is important to discuss and be aware of the resources required to manufacture the Integrated Circuits found in our design. Stanford University reported that, "it takes roughly 10 gallons of water to make a single computer chip" [8]. When developing our system, we will try to be conscientious of waste and try to minimize it throughout. Although, because of the fact that we are not actually building this system physically, environmental factors are not really an issue.

4 Resources

[1] Unknown Poster, "How are guitars hooked up to speakers at concerts?"Accessed: 1APR2020. [Online]. Available: https://www.reddit.com/r/Guitar/comments/1ta0nn/how_are_guitars_hooked_up_to_speakers_at_concerts/

[2] Hugo, Strymon, "Setting Up Your Effect Signal Channel" 29FEB2016. Accessed: 1APR2020. [Online]. Available: https://www.strymon.net/setting-up-your-effect-signal-chain/

[3] "Source Audio Hot Hand 3 Wireless Effects Controller Pedal," Accessed: 1APR2020. [Online]. Available: https://www.sweetwater.com/store/detail/HotHand3--source-audio-hot-hand-3-wireless-effects-controller-pedal?mrkgadid=3331289787&mrkgcl=28&mrkgen=gpla&mrkgbflag=0&mrkgcat=guitars&&acctid=21700000001645388&dskeywordid=92700046934877524&lid=92700046934877524&ds_s_kwgid=58700005283398557&ds_s_inventory_feed_id=97700000007215323&dsproductgroupid=373037010169&product_id=HotHand3&prodctry=US&prodlang=en&channel=online&storeid=%7bproduct_store_id%7d&device=c&network=g&matchtype=&locationid=%7bloc_phyiscal_ms%7d&creative=332063179833&targetid=pla-373037010169&campaignid=1709882817&gclid=EAIaIQobChMI3dPf4LPG6AIVWPfjBx12jAtEEAQYAyABEgLjcvD_BwE&gclsrc=aw.ds

[4] Dave Burrluck, "Manson Guitars MB-1 Standard Matt Bellamy Signature Guitar Review," 12APR2010. Accessed: 2APR2020. [Online]. Available: https://www.musicradar.com/reviews/guitars/manson-guitars-mb-1-standard-matt-bellamy-signature-guitar-241595

[5] J Miller, J Smith, E Bellas, "Wireless Guitar Unit," 12FEB2003. Accessed: 1APR2020. [Online]. Available: https://courses.grainger.illinois.edu/ece445/projects.asp

[6] “IEEE Code of Ethics,” *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 02-Apr-2020].

[7] *Can you overload/damage an amp with too much distortion?* [Online]. Available: https://www.soundonsound.com/forum/viewtopic.php?f=22&t=56495&p=507054&hilit=. [Accessed: 02-Apr-2020].

[8] *Can computer chip makers reduce environmental impact?* [Online]. Available: https://news.stanford.edu/pr/96/960605chipsenvir.html. [Accessed: 02-Apr-2020].