Wireless Magnetic Pickup with Effects

Team 19 - Dylan Ouart and Wilson Ngai
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TA: Daniel Frei

1. Introduction

1.1 Objective

Acoustic guitars are an ancient instrument. They have been around for nearly 4000 years, and there are theories that suspect it was developed based on the lute or ancient Greek kithara [1]. Despite being such an old instrument, they continue to be widely used today. As time moved on, people began to want louder guitars, and began to explore electric amplification. The first electric guitar was made around 1931 by George Beauchamp and Adolph Rickenbacker [2]. This brings us to the modern age. The problem is that many acoustic guitars are not built with the capability to transmit their signal to an amplifier to make it louder. The ones that do have this capability are generally more expensive than ones that do not. For example, a Fender CD-60S is priced at $199.99, but essentially the same model with a pickup, the CD-60SCE, is priced at $299.99 [3]. Vintage acoustic guitars also do not have this capability. It also is desirable to put effects on the sound of the guitar. This can be done with various pedals or one multi-effect pedal. These pedals can also be relatively expensive, with prices ranging from around $50 to about $1500 [4].

Our goal is to create a cost efficient wireless pickup that does not damage the body of the guitar while at the same time being able to create guitar sound effects. We will use a magnetic pickup which will then send the audio signals to the effects module and from there will be sent to the RF transmitter and then be sent to the receiver into the amp.

1.2 Background

There are 4 basic types of pickups used in an acoustic guitar: undersaddle, magnetic, contact, and microphones or blended systems. Many of these systems require modifications to the guitar itself. This is undesirable if someone does not wish drill holes, cut holes, etc. in their guitar [5]. There is a product that solves this solution but it costs about $200 [6]. This product, however, does not incorporate effects. There are other products out there are simply a pickup. From personal experience these pickups do not work very well due to the quiet output of the amplifier. The amplifier had to be turned up extremely loud before there was noticeable difference in volume.

Our pickup should be as affordable as possible. Ideally the product would be less than $100. This will make it a economical option for somebody who wishes electrify their acoustic guitar but does not want to spend the money on an integrated system. It will also greatly reduce the cost of adding effects to the sound of the guitar.

1.3 High Level Requirements

- System must be as affordable as possible. This should be ideally less than $100.
- Sound output should be a clear sounding signal with little to no noticeable distortion in the sound.
- The device should be able to be easily installed and removed from any acoustic guitar sound hole without damaging the guitar.

2. Design

Our device will consist of 4 sections: the power supply, magnetic pickup, control unit, and RF circuits. The power supply will provide the necessary voltages to bias the pre-amplification module and power any IC chips needed for the effects and transmission circuit. The magnetic pickup will sense the signal from the guitar strings and send it to the pre-amplification stage to increase the voltage. The control unit will house the pre-amplification stage, the effects, and the user interface so the user can choose the desired effect. The RF circuits will transmit and receive the information from the pickup.

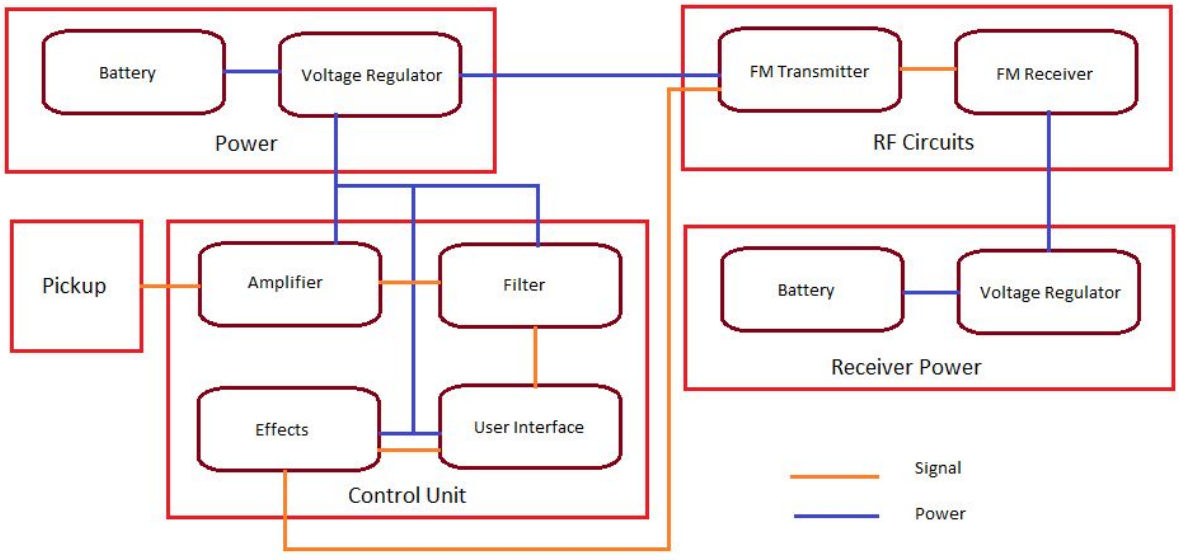

Figure 1: Block Diagram

The physical design of the device must be small enough to fit into the sound hole of an acoustic guitar. The diameter of the sound hole is approximately 4 inches. The strings sit approximately 0.5 inches above the face of the guitar. Since the device will be placed into the sound hole it can have a depth of about 1 inch. This should give us an appropriate volume to fit all necessary components into the casing. The pickup is placed toward the top of the device so the rest of the electrical components can be placed in the bottom. The Thickness of the device is to be approximately 1 inch with the curved section of the top view having a diameter of 4 inches.

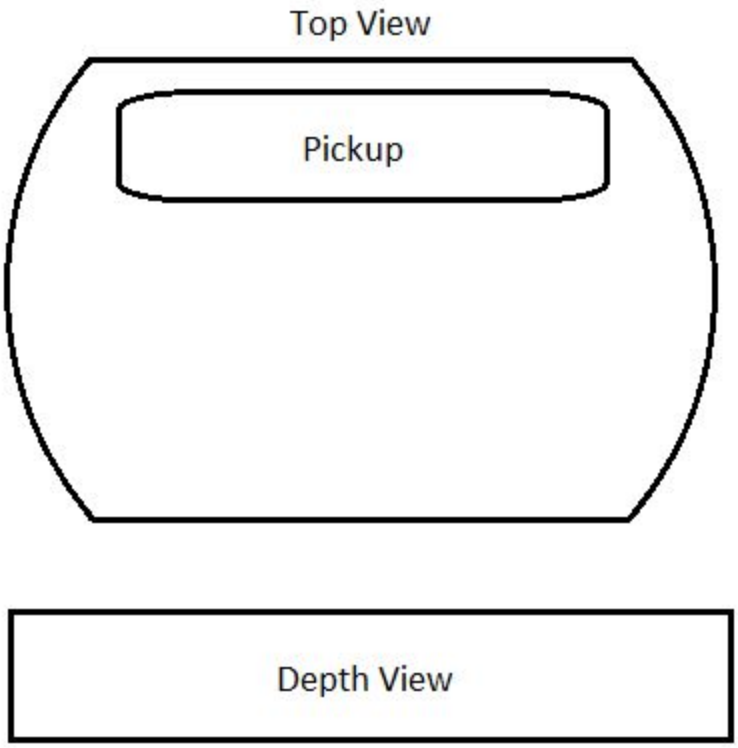

Figure 2: Physical Design

2.1 Power Supply

Our power supply will most likely be a 9 volt battery that will provide power to bias the pre-amplification module and power the effects and transmitter modules. The receiver power module will have the same function and requirements as the power module on the pickup.

2.1.1 Battery

We will use a 9 volt battery supply necessary power the device.
Requirement 1: Must be able to provide enough charge to power the device for at least 2 hours at full load.

2.1.2 Voltage Regulator

Common 9 volt battery voltages range from 7.4-9.6 volts. This module must be able to regulate the input voltage to a voltage of 7 volts to power the device.
Requirement 1: Regulate input voltage of 7.4-9.6 volts to 7 volts +/- 5%.

2.2 Magnetic Pickup

This module is what senses the vibrations of the guitar strings. It must be able to sense the signal and convert it into a voltage signal of the same frequency as the plucked string.
Requirement 1: Output signal from string with a voltage of amplitude greater than 150 mV.

2.3 Control Unit

The control unit will manipulate the signals generated by the pickup. It will first amplify the signal from its initial value to a value that is easier to sense. After the amplifying stage the signal will then go into the effects module where it will either receive no effect, be adjusted by an octave up or down, or have a flanger applied to it.

2.3.1 Pre-amplification

This module will consist of a common source amplifier in order to amplify the voltage signal. This will most likely be a 2 stage amplifier with an overall gain of around 10. This will put the new output voltage at about 1.5 volts.
Requirement 1: Overall gain of 10 +/- 5% must be achieved at the output.
Requirement 2: The output voltage must be in phase with the input voltage.

2.3.2 Low Pass Filter

A low pass filter will be placed after the pre-amplification in order to filter out any high frequency noise associated with the signal. Since the highest frequency of a guitar is 1318.52 Hz all other frequencies can be filtered out.
Requirement 1: The filter must have a cutoff frequency of 1500 Hz to filter out high frequency noise.

2.3.3 Effects

This module will change the output audio signal of the sound to replicate octave changes and flanger.

Requirement 1: Frequency for an octave higher should be double whereas the frequency should be half the input frequency.
Requirement 2: Flanger signals should be identical

2.3.4 User Interface

The user interface will consist of a four way switch that will allow the user to choose between the available effects.
Requirement 1: Switch must be able to select between all effects available: no effect, octave up, octave down, reverb, and flanger.

2.4 RF Circuits

The RF circuits will handle the transmission and receiving of the sound signal. This signal must be as high quality as possible because the listener will be able to notice a difference in the original sound and the electric sound coming from the amplifier.

2.4.1 Transmitter

The transmitter is going to be an FM transmitter so the frequency will be modulating in order to encode the outgoing signal. The latency time of the system must be small otherwise a delay will be experienced when the device is in use.
Requirement 1: Encode the signal from the effects module onto a carrier wave of 2.7 GHz.
Requirement 2: Transmit the encoded signal to the receiver with a latency time of less than 10 ms.

2.4.2 Receiver

The receiver must be able to identify the signal transmitted to it from the transmitter. It must also be able to decode the FM signal and output the original signal to an amplifier.
Requirement 1: Decoded signal must match original signal amplitude +/- 5 %.
Requirement 2: Total latency time should be less than 10 ms so delay is not noticed.

2.5 Risk Analysis

The most risky block of the project is the RF module. This module is essential to the entire design coming together and working. If the RF does not work, the signal from the guitar will not be able to reach the amplifier and produce the sound. We need to design the transmitter and receiver in such a way that the integrity of the signal is preserved and is not lost. The speed of the entire system also needs to fast enough such that no delay is noticeable. This is the reason RF was chosen because of its speed.

Interference from internal components as well as outside sources is another concern. The magnets used could interfere with the RF circuitry. To combat this we plan to use a Faraday cage to block the interference from the magnetic field of the pickup. There could also be external interference on the signal that could cause it to distort the output. This would result in a poor output signal at the amplifier.

The FM signal is known for its high quality. This is very important when dealing with audio signals. If the signal is distorted at all it will be noticed. If the signal is distorted the device will again fail because the original signal was not preserved. There would be no point in having something that does preserve the original signal because the sound would not be what is expected from the guitar.

3. Safety and Ethics

There are a few potential safety hazards that can occur in use with our project. If the pickup shorts there is a possibility of burning the circuits and with the battery in the pickup it may explode. Using a PCB, will prevent the chances of a short happening. The 9-Volt battery could also become a hazard since the two positive and negative points are on the same side which means if they become shorted it could spark and cause a fire within the circuit and burn the guitar (and your hand). Using a 9 volt battery connector will prevent a short from happening. We will provide a casing for this battery to also prevent any chance of something piercing the battery. All safety concerns must be disclosed to the end user. We will address these safety concerns in accordance with #1 of the IEEE code of ethics which states "to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment" [7].

The dangers associated with the device should be relatively small. All necessary measures will be taken to ensure that injury will not occur when somebody is using the product. This aligns with #9 of the IEEE code of ethics which says "to avoid injuring others, their property,..." [7]. The location of the pickup puts it in close proximity with the person who is playing the guitar, so extra precautions will be taken to ensure the safety of the user.

Designing a magnetic pickup from the ground up could prove difficult. The differences in signals it will output could vary greatly from those of a professionally designed pickup. It is important that data is not faked no matter what the output may look like. This follows #3 and #7 of the IEEE code of ethics [7]. All data taken will be the real data no matter how noisy or bad it may be, if this problem occurs.

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