1. Introduction
   a. 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.
   
   b. 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.

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.

2.1 Amplifier
This module will consist of a common source amplifier in order to amplify the voltage signal. The overall gain of the amplifier should be around 6 to make the signal somewhat larger in order to make it a little louder at the guitar amp.

**Requirement 1:** Overall gain of $6 \pm 5\%$ must be achieved at the output.

**Verification 1:** Use the oscilloscope to display the input ac signal. Display the output signal in ac coupled mode to display only the ac component of the output. Check that the amplitude of the output is 6 times greater than that of the input.

**Requirement 2:** The output signal should be in phase with the input signal.

**Verification 2:** Use the oscilloscope to plot both the input voltage and the output voltage. The output voltage should be ac coupled. Then, use the measurement tool to measure the phase difference between the two signals.

2.2 Schematic and Simulation
The schematic and simulation in ltspice of the amplifier circuit is shown below. The input voltage is indicated in blue and the output voltage is shown in green. It can be observed that the output is larger than the input.

2.3 Calculation
In order to bias the transistor in saturation a voltage divider is used to obtain a gate voltage of 3.5V. The overall gain can be calculated once the drain and source resistances are known. Knowing the desired gain, some values of these resistances were iterated until the necessary gain was achieved. The calculations are shown below. The transistor used is the Fairchild 2N7002. All necessary values for the calculations are from the datasheet[8].

\[ V_{gs} = 2.5 \text{ V} \rightarrow V_g = 3.5 \text{ V} \rightarrow V_s = 1 \text{ V} \]
\[ 3.5 = 9 \frac{R_2}{R_2 + R_2} \rightarrow R_2 = 500k\Omega \rightarrow R_1 = 785.7k\Omega \]
\[ V_{ov} = 2.5 - 2.1 = 0.4V \]
\[ I_{ds} = \frac{V_{ov} \times gfs}{2} = 64mA \]
\[ R_d = \frac{7}{.064} = 110 \Omega \rightarrow R_s = \frac{1}{.064} = 15.625 \Omega \]
\[ A_v = \frac{gfs \times R_d}{T \times gfs \times R} = 5.867 \]

3. Safety

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 in an enclosure 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. Using an abs enclosure which has a glass transition temperature of 221°F.
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.
References


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