For my Physics 398 semester project, I built a lap steel guitar from "scratch". When taking this approach to building a guitar, or any instrument for that matter, there are an infinite amount of design questions, both functional and cosmetic, that arise. For that reason, I decided to find an existing lap steel that I particularly liked and use it as a guide for construction. I ended up choosing a 1946 Fender Deluxe for my template. Many of the design questions were now answered for me, but some new ones arose as a result of me not being able to exactly replicate various elements of the Deluxe.

Having chosen the style for my guitar there were many specific design choices to be made. What kind of wood should I use for the body? Should I use tuning machines that go through the headstock or mount on top? What should I use for the nut? How am I going to design the fret board? What kind of pickup and bridge should I use? Should I attach the strings to a tailpiece or mount them through the body? Where do I want the knobs and output jack? Needless to say there were many issues to address. First off, I started researching online about different woods for guitars and on the Hawaiian Steel Guitar Association's website I found this description of Honduras Mahogany...a Gibson EH-150 full, mellow midrange to slightly bass sound... which sounded pretty good to me, so Honduras Mahogany it was. I ordered a 30" x 7 1/4" x 1 3/4" piece from www.rockler.com, which cost me about $45. I traced out Professor Errede's '64 Deluxe onto graph paper and laid out where I proposed to put the controls, pickup, etc. To make the guitar as resonant as possible, I chose to use tuning machines that mounted through the headstock of the guitar and to run the strings through the body below the bridge. The next step was to take the wood home and fabricate the body. I cut out my traced diagram, taped it to the wood, and traced the proposed body shape onto the wood. Given the size of the wood and the size of the tools at my disposal, some modifications to the original plan were made. Instead of having the tone and volume controls on opposite sides of the guitar, like the Deluxe, I ended up putting them next to one another, requiring only one cavity to be routed out for the two potentiometers. This required modifying the original body shape on the side with the controls, but the guitar body ended up with a cool, asymmetrical shape, while still keeping the look of the Deluxe.

With the heavy wood working done, I now turned to the wood finishing process. I did a massive amount of sanding, cleaned up the cavities I bored for the electronics, and made a recessed lip for the back cavity so I could screw a cover plate over it. My first intention was to try and do a three tone sunburst finish. I did a lot of research on the subject and thought I might be able to pull it off, so I got three different shades of stain and gave it a shot. It turned out to not work at all, and I guess the lesson I learned if anyone else wants to try it, is that you need extreme contrast between the shades of stain you are using. My wood was naturally so dark that the

lightest stain I bought still looked pretty dark. I decided just to go with the darkest stain I bought which is called "deep walnut". After applying a few coats, I polyurethaned the guitar to protect the wood and started working on the electric components.

The proposed circuit for my guitar(see diagrams at end) was just a basic one pickup, one volume control, and one tone control setup. For this I needed two potentiometers, which are just variable resistors, a telecaster style bridge pickup, two capacitors, one for volume and one for tone, and an output jack. The potentiometers are the knobs used for controlling the volume and tone. The pots I bought have a resistance of 500 K ohms. I chose to buy the extra long shaft pots from Stewart MacDonald because they were going to be mounted through the wood rather than a control plate and the wood has, by necessity, a much greater thickness than a control plate. I also purchased my pickup from StewMac. It is a Wilkinson, single-coil, telecaster style bridge pickup with a copper shielded and taped coil, brass booster plate, and raised non-staggered pole pieces. It is potted in wax to cut down on microphonic feedback from vibrations. StewMac's website(www.stewmac.com) says that it has a DC Resistance of 5.9K ohms and does not specify what the pole pieces are made of. We did some of our own testing on the pickup. We found it to have a DC Resistance of 6.16K ohms, an inductance of 1.88H at 120Hz, and an inductance of 2.61H at 1.0K Hz. We measured the magnetic field of each pole piece in an effort to discover what material they were made of. All 6 pole pieces had B-Fields of 1000 Gauss give or take 150 Gauss, which led to the conclusion that the pickups must be made of Alnico 5 to have such strong magnetic fields. The small sections of the magnetized strings directly above the pole pieces start to vibrate when plucked and an electric current is induced into the circuit directly proportional to the frequency and amplitude of the string's motion. This signal is then output to some sort of amplifier to boost it to a level that can drive a speaker. The resonant frequency of the circuit is given by the equation $f=1/\sqrt{(LC)}$ where L is the inductance and C is the capacitance. This is where the .05 F capacitor for the tone control comes into play. The tone potentiometer varies how much capacitance the circuit has. When the capacitance is increased, the peak resonant frequency of the guitar lowers, and it plays with a more bassy sound. When the capacitance is decreased, the guitar has a brighter, more trebly sound. Just adding a cable to plug in the guitar adds enough capacitance to change the tone of the guitar. Also, when the volume is turned down very low, not much voltage gets past the volume potentiometer and the circuit starts to act like a low pass filter, attenuating the high frequencies. This can be fixed by a well know trick of putting a small capacitor(100pF in my case) across the leads of the volume control pot. When the capacitance of this capacitor and the cable are close, the volume control high frequency roll-off is eliminated. I used a recessed, telecaster style cup, also from StewMac, to

mount the output jack and the circuit was complete.

The next thing to address was what to use for the nut. The headstock of the Deluxe is covered with a steel plate which is bent back over itself and notched to be used for the nut. This was not an easy design to emulate so something else needed to be done. The first plan was to obtain a steel rod whose diameter was the same size as the bridge height so the strings wood be parallel to the neck, have it grooved for the strings, and attach it to the wood somehow. This also proved to be difficult. The solution turned out to be a pleasant surprise. I was at Menard's buying woodworking tools and ran across a package of Stanley inside corner braces for a wooden box. I bought them and flattened one so it could be screwed down evenly on a flat surface. The bump that was left in it was the same height as the bridge so I had my solution. I grooved out notches for the strings using a dremel which work reasonably well, but a couple of the notches were too deep and when the open strings vibrate, the string comes into contact with the lower portion of the nut, causing it to sound somewhat like a sitar. Luckily, the braces were very cheap and this problem is easy to fix.

Now that I had the nut in place, I could measure the approximate scale length of my guitar, use it as a guide to make the fretboard, and fine tune the intonation using the individual adjustable bridge saddles. My measured scale length was 22 3/4". Scale length is defined as the distance from the bridge to the nut, the length of string between its endpoints. Modern day guitars as use the tempered 12 note scale. This means that the interval is the same between each note. Maintaining constant interval distance between notes requires a logarithmic function, Fret Location x = L/2^(x/12) where L is the scale length, the location of the nut (fret 0) is L and the location of the bridge is 0(see chart at end). So I did some brute force mathematical calculations and figured out all of the correct fret locations. Unlike a standard guitar where you push the string down, making it contact the fret wire, to play a desired note, a steel guitar is played using a rounded bar of steel which acts as a single movable fret at the player's disposal. The string never comes in contact with the neck of the guitar which allows for quite a bit of flexibility when it comes to designing the fretboard. I decided to wood burn the frets using my soldering iron. I measured and laid out each fret on both sides and in the middle of the neck to ensure they would be perpendicular to the neck. I then placed masking tape guides around each fret and went to work burning them in. This turned out to work extremely well, and gives the guitar a very unique look. As an homage to the fretboard of the '46 Deluxe, I burned in the same Roman Numeral fret markers and tapered the upper frets similar manner.

All that was left to do at this point was to string up the guitar, properly intonate it, and start jamming. For a steel guitar, heavy strings are desirable so I bought a set of .011 gauge D'Addario round wound strings. When

a guitar is properly intonated, the note at the 12th fret is exactly one octave higher than the open string. So I plugged in to an electronic tuner, tuned the open strings and adjusted the bridge saddles for each string so that the guitar was in tune across the 12th fret. One thing I realized while doing this and am realizing more and more as I've been playing the guitar, is that the note that is played at any given location is also dependent on how hard you press down so you really just have to use the fretboard as a semi-rough guide and trust your ear.

With all of this done, it became and still is now the time to reap the benefits of my work, and play my guitar like crazy. It has a great sound and I am shocked, amazed, and pumped about how it turned out. I'm big on having things that aren't the most popular or widespread, and other than Professor Errede, I don't know anyone, especially my age, who owns a lap steel. It's an awesome feeling showing the guitar off to friends and having them ask where I got it, and then coming back with that I built it from a solid block of wood. It wasn't a super cheap undertaking, but many of the decisons I made were in the interest of quality rather than cost. The one place I did skimp was on the pickup and that ended up sounding great. The guitar is still a playable work in progress; I plan on replacing the nut and the cover for the back cavity, but I now feel confident that I would be able to diagnose and address any problems that come up with it or my other guitars for that matter. All in all, it was a very interesting, challenging, and rewarding project.