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Physics 498
Final Report
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Mesa Boogie Mark I

INTRODUCTION:

When I learned that there would be a final project in PHYS 498, I decided fairly quickly that I wanted to do something that would not only allow me to learn about the theoretical physics of instruments and music, but also to help better understand how tools and equipment involved actually work. Basically, I wanted to physically build something, in addition to learning the less tactile physics. Despite knowing that it would be difficult and time consuming, I decided to build a tube amplifier, specifically the Mesa Boogie Mark I. I did this because I thought I could learn a lot about circuits/electronics, and also because I thought it would be a neat accomplishment to end my undergraduate career with.

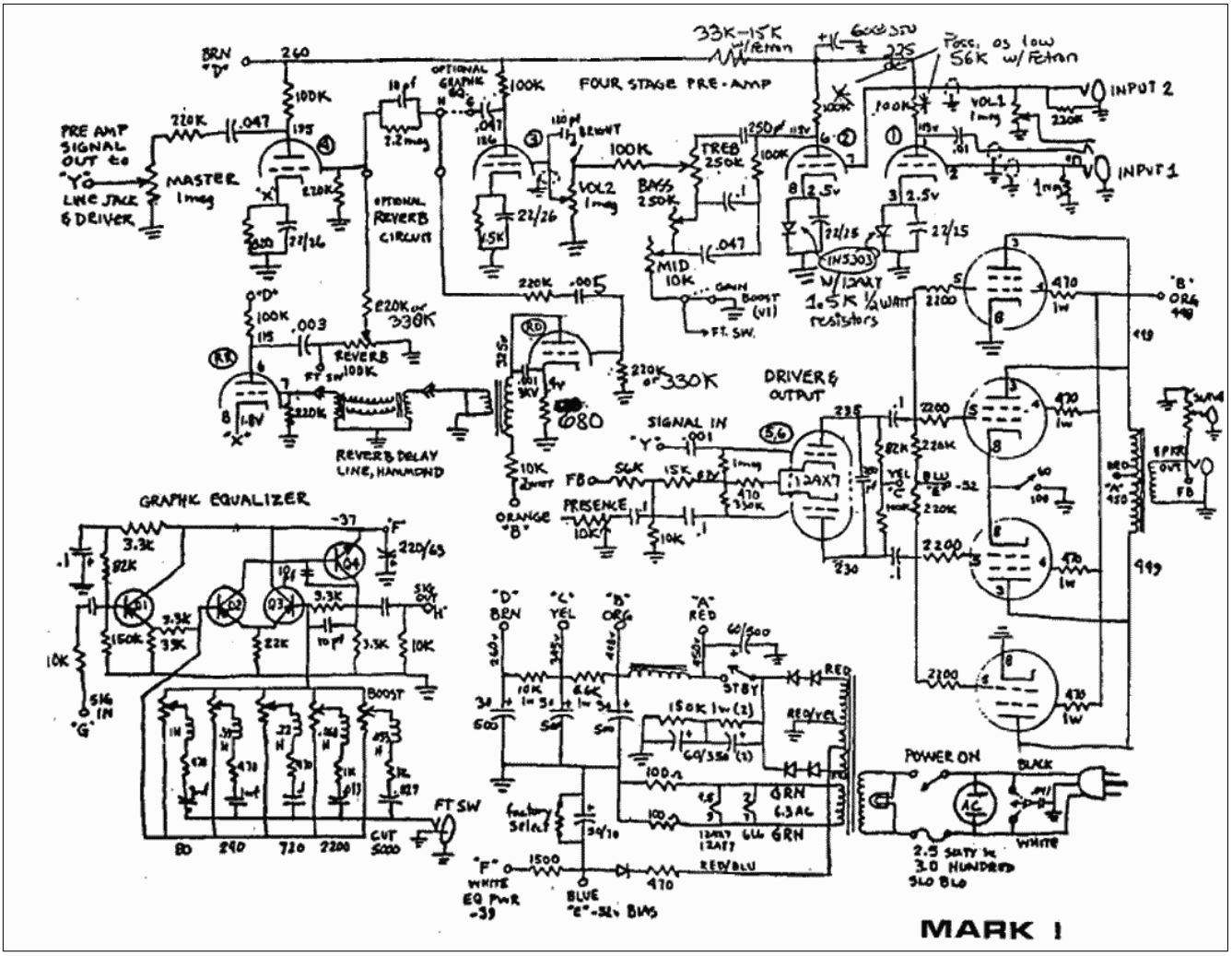
HISTORY OF THE MARK I:

The original Mark I was actually a modified Fender Princeton amp, and was made in 1969. Since most of the original Mark I's were all custom made, there wasn't really a standard set for the amp, and the reverb and graphic equalizer were in some and not others. The basic idea of the amp was that the second input had the classic clean Fender sound, and the main input had an extra stage of gain which gave it the “boogie” sound, as described by Carlos Santana. The Mark I was reissued as the Son of Boogie after the Mark II was released and reissued again as the Mark I in the 2000's.

PLANNING AND DESIGN:

The beginning of this entire process consisted of a lot of research of not only the Mark I, but also tube amplifiers in general. Before starting anything on this project, I knew very little about how exactly tube amplifiers worked, and it was essential that I know the basics before I began to construct anything. Books, and music/amp message boards helped a lot as I got both the “official” and “unofficial” thoughts and ideas on building amplifiers.

The next step was to start the planning process of the Mark I itself. The first thing I needed was a schematic. Because of the handmade nature of the original Mark I's, there wasn't an official schematic, and in fact I found a couple different ones on the internet and in some books. For the most part they were all very similar, although there were some differences. However, it was fairly clear that there was one schematic that seemed to be used the most often, and seemed to be the most complete as well. Here is the schematic that I used:

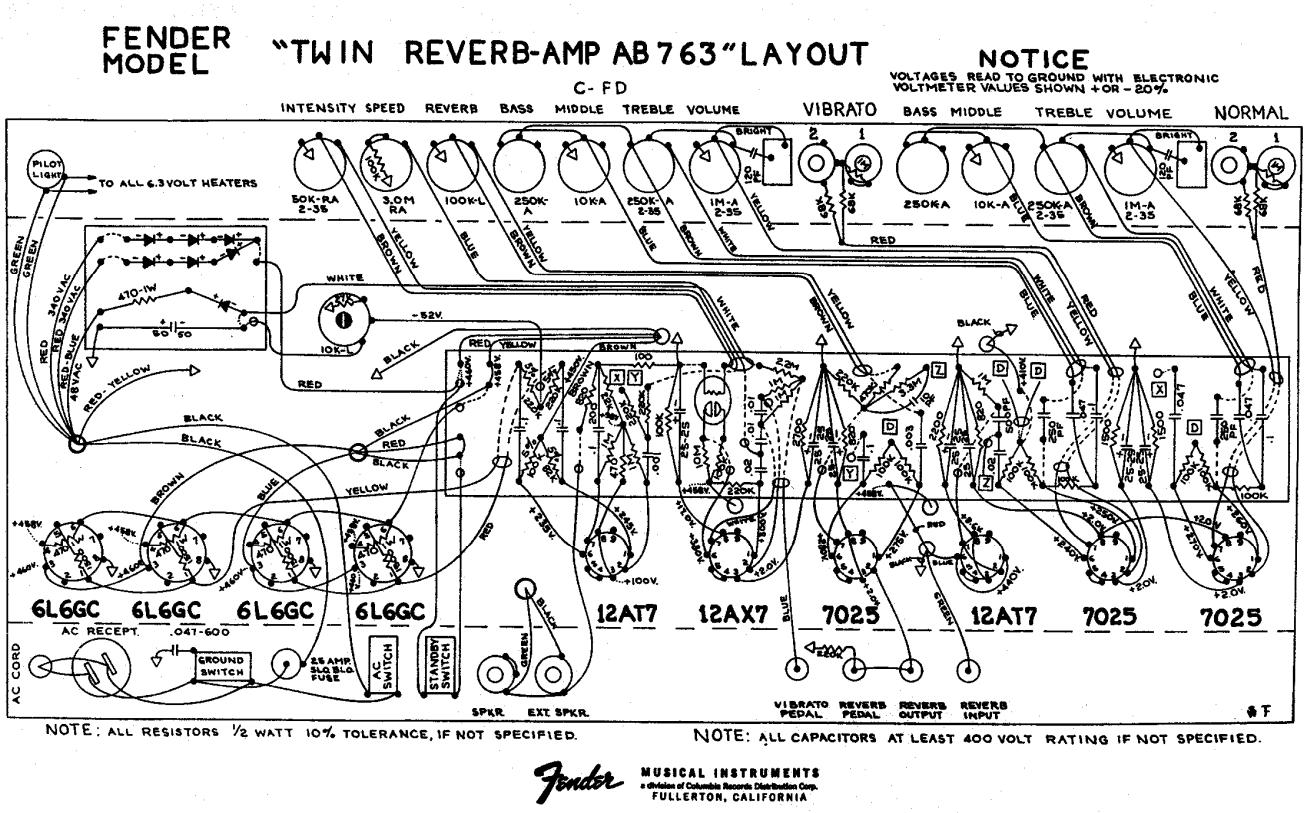


After settling on this schematic, I began to study it and take notes on what parts I would need. While I understood most of the basics, there were a lot of notational things I didn't know, as I wasn't used to reading a circuit schematic. Thankfully, Professor Errede went over the schematic with me and helped me understand it. This was one of the points were I was very lucky to have his help, because by the end of the project, the actual physics piece of paper looked completely different with all the marking and notes on it, something I never would have been able to do by myself.

After understanding the general design, I had to begin ordering the parts. All of my parts came from either Mojotone, Antique Electronics, Mouser, or Professor Errede. One early decision I had to make was whether I wanted 60 watt or 100 watt transformers. Since it was going to be a pretty big amp already, I decided to go with the 100 watt Marshall replacement transformers, which I got from Antique Electronics. There were some really nice transformers for around $120 a piece, but I went with the somewhat cheaper ones at about $80 a piece. I did this because I realized it was going to be fairly expensive for the whole project, so I needed to find places to cut back on spending. However, I didn't want to get cheap parts that would need to be replaced, so in some instances I spent a little more and in some a little less where I could. Overall I tried to aim for reliable parts, but nothing too fancy. I should note here that I decided not to included the reverb or graphic equalizer, and I did this to save money as well as to keep things simpler since this was my first time building something as demanding as an amplifier. With that in mind, the design called for two preamp tubes and one phase inverter, all of which were 12AX7's. I also needed four power tubes, and I used a matched quad of 6L6GC's. Because of the number of power tubes and the size of the transformers, I needed a fairly large

chassis. Luckily, the chassis of a Fender Twin Reverb fit the bill for my amp almost perfectly, and I got a pre-drilled one from Mojotone for a fairly decent price, in addition to the main fiberboard, the diode board, and the capacitor board. All the potentiometers were CTS, and most of the resistors and capacitors I got from Mouser. Besides that, the rest of the miscellaneous parts I ordered from the various websites listed above.

While the parts were coming in, I still needed to design the layout of my amp. Unfortunately I can't provide my actual layout. However, I was very lucky and saved once again by the Twin Reverb as the layout of that amp and mine were very similar and almost identical in some places. I was unaware of this, but Professor Errede gave me a copy of the Twin Reverb layout, which I used very closely in my own design. Here is the Twin Reverb layout that I used:



When designing the circuit, there were many places were modifications could have been made. For the most part I tried to stay as true to the schematic as I could so that the amp would be as close to the actual thing as possible. Although there were a few instances where things needed to be changed, such as using two watt flame resistant metal oxide resistors on the capacitor pan on off the power tubes for safety, adding in two extra diodes to the diode board, and using 1N5302 current regulating diodes in the preamp rather than 1N5303's (they were too difficult to acquire). Once I had all, or at least most of the parts, and the circuit was designed, I was ready to start the physical building process.

CONSTRUCTION:

The first thing I did layout some of the bigger pieces, such as the transformers, fiberboards, and tube sockets, to see if they lined up with the holes that had already been drilled into the chassis. The preamp tube sockets fit just fine, but pretty much everything other than that didn't. The power tube sockets I got were too small, the transformers, the choke and the main fiberboard didn't match the holes at all, and there was no place for the diode board. After marking where the necessary holes needed to be, I went to machine shop in the ESB and drilled through the chassis. After the chassis

was prepped, I mounted the transformers, the choke, the potentiometers, the preamp tube sockets, the input/output jacks, the power/standby switches, the power cord, the fuse, and the pilot light assembly onto the chassis. It was important to drill the holes in the chassis before doing any of the mounting not only because it provided more space but also because it is very important not to get any metal shavings into things such as the potentiometers and tube sockets, as that can cause a lot of problems.

The next step was to mount the components onto the three fiberboards. I followed my layout very closely, and took my time to make sure I didn't make any mistakes. As I was putting the pieces in place, I realized there were a couple of areas that I realized needed to be redesigned. This was particularly the case with the part between the master volume and the phase inverter and also the entire capacitor pan. For the most part, I tried to cram too many components into too small of a space, which was a simple mistake since I wasn't looking at the actual parts when I designed the circuit on paper. Professor Errede helped me especially with the capacitor board. I was having a hard time getting all the necessary parts on it, and what I ended up with on my own can only be described as hideous. He suggested that I move two of the electrolytic capacitors onto a very small fourth fiberboard next to the main one. I found an unnecessary resistor on the main fiberboard and moved a few other things around so that I was actually able to fit those two electrolytic capacitors on the main fiberboard As for the in general electrolytic capacitors he also told me that it was important for safety reasons to put covers over the leads. With everything in place, I clipped the leads on the underside of the fiberboards and then mounted the main fiberboard to the chassis along with the backingboard.

After a quick lesson in how to solder, I had never done it before, I started to connect the components of the main fiberboard to the preamp tubes. I learned that teflon wire was good more most connections, and coaxial wire was needed for most connections to and from the potentiometers. Coaxial wire is a little more difficult to work with, as it requires more effort to strip the extra shielding. I also found out that when soldering wire to the tube sockets, it is important to try and keep the wire leads as high as possible on the socket leads so that no solder gets into the socket itself, which can cause problems. After wiring up most of the simple stuff, Professor Errede helped me wire the input jacks and the bright switch, which would have been very difficult on my own, as the schematic and layout provide very little direction as to how to do it. Wiring the potentiometers and the input jacks required separating the hot wire and the coaxial shielding from one another in order to properly setup different star grounds. I suppose this is an appropriate time to talk about star grounding. This was something I never knew about before, but basically there are firewalls (lines of capacitors) in the circuit which essentially divide the circuit into areas that each get their own grounding wire, or star ground as they are called. It should be noted that this is separate from the earth ground, and all these different star grounds go to one spot near the power transformer. This is done to help eliminate 60 cycle hum from the circuit.

The capacitor and diode boards were then attached to the chassis, in which case the diode board needed have a corner cut off to fit between the bolts of the power transformer, and the holes of the backingboard needed to be enlarged to that the screws could fit to secure it. The diode board and the diodes themselves sit pretty close to the wall of the chassis, luckily where I placed it, it was far enough away that there wasn't a risk of an electrical arc from the diodes to the chassis. The professor told me that in some fender amps, they actually put an extra piece of fiberboard in between the chassis wall and the diode board to prevent this, but as I said, I did not run into this problem. At this point, I wired up the power/standby switched, the power cord, the capacitor/diode boards, the choke, most of the power/output transformer wires, and the power tube sockets, which required a little more work than the preamp sockets due to the several resistors and jumper wires that needed to go across the leads.

The next step was to wire up all the heaters across the power and preamp tube sockets. Professor Errede helped me twist two wires together which would be used for the connections. One wire would go across the 2 and 9 pins of the power and preamp tube sockets respectively and the other would go

across the 7 and 4/5 pins of the power and preamp tube sockets respectively. This was somewhat difficult to do because there were already a lot of things connected to the pins of the tube sockets, in addition, there were four wires in two pins that needed to be connected at each socket.

This is as far as I have gotten on this project. There are only a few more things to do such as the remaining transformer wire, soldering all the star grounds, the output jacks, and the final heater connections. Sometime after this projected is fully completed I will update this report.

CONCLUSION:

Unfortunately at the time that I am writing this, the amplifier is not done, so I cannot speak to how it actually sounds. However, it is almost complete and requires probably only a couple more hours to finish, so parts this report will be updated at a later date. However, I can still say that I learned a great deal through this whole process. I've learned about physics, but also circuit design/construction and tube amplifiers in general. While it wasn't explicitly stated in this report, it should be noted that Professor Errede helped guide me, correct my mistakes, and offered invaluable advice throughout the entire project. I would like to thank him for all the time and effort that he put into my project, especially since so much of it was outside of class, and I know there were many other things he was busy with. This never would have been possible for me without his help. With all that said, I would like to say that this has been one of the most rewarding experiences I've had in my college career, and hopefully this amplifier lasts me a long time so that I will never forget it. If you have the time and are willing to put in the work and are considering building a tube amplifier, then it's definitely something you should do.