Recipe #1: Blues Monster

For this project I have developed a new circuit design, inspired heavily by what many guitarists have considered to be the greatest guitar amplifier ever made. The amp I'm talking about is the tweed covered Fender Bassman. The Bassman model that uses the 5F6A circuit was only made from 1958 to 1960. Since that time this amplifier has often been used by amplifier manufacturers as a reference point in their designs, from which they have added their own variations and enhancements. One famous example is the JTM45 made by Marshall, which is close to being completely identical to the 5F6A Bassman. With only minor changes, this amplifier evolved into the equally famous Marshall Super Lead 100 watt amplifier, model # 1959, made famous in the late 60's by guitar players like Jimi Hendrix, Eric Clapton, Pete Townsend, and many others. Another example was made by Traynor in their Bassmaster YBA-1. These amplifiers belong to the same "family" as the Fender 5F6A Bassman, as they share the same circuit topology, and are nearly identical in their circuit design.

While designing this project, my idea was to create an amplifier that fits sonically into the same family as the 5F6A Bassman and the JTM45, while using non-traditional new old stock (NOS) vacuum tubes. The desire to design this amplifier around obscure NOS vacuum tubes was attractive to me for two reasons primarily, those being quality and cost. My motivation for building this design was for the challenge, because it hasn't been done before, and also because I wanted to assess the viability of the design by building a prototype and tweaking it to sound great.

The issue of cost was a significant one, as it always is, and so the reason for choosing the tubes that I did was first of all because they were functionally equivalent and well suited for the circuit, as well as for their plentiful availability combined with a non-existent market demand which makes them very cheap. The other consideration was the quality that was implied due to the fact that they were NOS American made vacuum tubes. This is important not from a standpoint of nationalistic pride so much as it is simply a fact that vacuum tube manufacturing today is a bit of a lost art, where as

NOS tubes constructed during the cold war were subject to higher standards especially in military use, but also in the broader commercial market.

In some respects the amplifier design offered here is radically different from the 5F6A and JTM45 designs, however it does follow the same circuit topology. In place of using 12AX7 tubes it uses 4AV6s for the preamp, the EQ, and the phase inverter sections. In place of using 5881s or 6L6s for the power amplifier, it uses 6BG6-GAs. 12AX7s are dual high mu triodes, with each triode having an amplification factor of 100. The 4AV6 tube is a dual diode high mu triode, in which the triode section is electronically equivalent to one of the triodes in a 12AX7. So where ever a triode is needed in the circuit, a 4AV6 is used, which means using more tubes than either a Bassman or JTM45. To purchase NOS 12AX7s, you will spend anywhere from $20 up to $200 per tube! 4AV6s can be purchased for $1 each.

The other obscure choice that I made was to use the 6BG6-GAs for the power tubes. I have used 6BG6-GAs successfully in other amplifiers and it is partly for this reason that I decided to use them here. The 5881 tubes have a maximum plate dissipation of 23 watts. I chose the 6BG6-GA instead because it was close, with a maximum plate dissipation of 20 watts. NOS 5881s cost anywhere from $25 to $100 each. 6BG6-GAs can be purchased for $4 each for the industry standard version. There is also a (rare?) special 35 watt version of this tube that is available, but using that would require a different output transformer than the one used for this project. The special 35

watt version is undocumented and I don't know how many exist, so I don't think it's a good idea to design this project around them.

Preamp tubes can last a long time, 10 years or more, depending on use. They are low power devices and sometimes last over 20 years. Power tubes are current amplifiers and will deteriorate more rapidly. Replacing power tubes might be necessary every couple of years or more, depending on frequency of use and how heavily they have been stressed. The decision to use these obscure vacuum tubes results in significant savings , both initially and over the life of the amplifier, and for this reason I feel justified in designing an amplifier around these obscure tubes.

Other points of departure...

There are a few other ideas incorporated into this amplifier that are a departure from the traditional configuration of a 5F6A or JTM45 circuit. In each case they are augmentations, which is to say they add more sonic options, without eliminating the ability to select a configuration that is in conformity with the standard circuit configuration for the 5F6A. The one exception to this is the use of a solid state rectifier, as opposed to using a tube rectifier. I understand that the use of a tube rectifier will cause a voltage sag on the B+ supply, depending on variations of the load due to the frequency content of the signal being amplified. This should have a subtle affect on tone, but I think the main difference is in terms of the "feel" between the player's fingers and the responsiveness of the amp. Tube rectifiers are not the only way to introduce sag in the B+ supply. In this design I have chosen to use a sag resistor, which in combination with the low capacitance power filter and a saggy choke transformer provides enough compression and "saggy-ness."

You could add a GZ34/5AR4 tube rectifier to this amplifier, and I have included an alternate schematic for doing this, but it will require a 5V/3A filament transformer, and installing an extra octal socket. There should be room for this on the chassis. One option for doing this, is to select a different power transformer that includes a 5 volt tap for the rectifier tube and delivers 6.3 volts to the filaments of all the tubes. In this case you would use 6AV6 triodes instead of 4AV6 triodes, and these cost three times as much at the moment, but they are still relatively inexpensive compared to 12AX7s.

Another design departure from a 5F6A circuit is the use of a high mu amplifier in the first gain stage. The Fender Bassman used a 12AY7 at this point, which had an amplification factor of 40. A Marshall JTM45 also used a 12AY7 here, but their JMP50 used a 12AX7 in this position. I am using a 4AV6 with an amplification factor of 100. My idea is to install a three position "voicing" switch that in one position emulates the response of a 12AY7 by cutting the gain of the 4AV6 in half.

Another option is for the amp user to pull the 4AV6 and use a 4AT6 instead in the normal channel's first gain stage. The 4AT6 has a lower amplification factor of 70 (like each triode in a 12AT7) rather than an amplification factor of 100 (like each triode in a 12AX7). So the gain reduction switch can alternate between mu = 35 and 70 with a

4AT6, or between mu =50 and 100 with a 4AV6. In the second position the mu = 100. In the third position a different voice is selected.

The 5F6A Bassman includes four input jacks, two bright, and two normal. For the Blues Monster design, the chassis will have enough room to add a voicing switch for each of the two channels. One possible modification idea is to add a couple of “three-way” switches (offering three “voices”) for both the normal channel and the bright channel of the first gain stage (comprised of two 4AV6s in parallel), which offers more possibilities than the original circuit, but also includes the original voicing as well.

Another design departure is the addition of a feedback selector switch on the back panel which can select between a 5F6A value, a JTM45 value, and a feedback disengaged selection.

I've made it as easy as a single click of a button to place your order for the "Blues Monster" kit. Just visit the Dragonfly Amplification website. If you would prefer to shop around instead, here are the places that I use to source parts for tube amp projects. There are many other electronics stores online, but the prices that I have researched are pretty competitive.

Mouser.com -	http://www.mouser.com/
Antique Electronic Supply -	http://www.tubesandmore.com/
ESRC Electron Tube Supplier-	http://www.esrcvacuumtubes.com/

Some parts are only available for ordering through the Dragonfly Amplification website, because they are custom designs and are made to order.

Chassis - Blues Monster
Custom Power Transformer
Custom Output Transformer

Project Schematics:

Let's take a look at the schematic diagram for the Blues Monster amplifier. One advantage of this ebook format is that schematics and layout diagrams have been created in vector graphics format, which means that the full size schematic can be viewed, magnified, and scrolled through on your computer monitor without losing resolution at each magnification. One difficulty with these large documents lies within the fact that they don't lend themselves easily to printing. For this reason, the schematics have also been broken down and shown in the following pages so that it makes them easier to print them, but also easier to understand the different functional sections of the amplifier circuit in a modular way.

Before Assembly:

Before we start bolting things together and firing up the soldering iron, the first thing we need to do is to take an inventory of the parts on hand and make sure they match the parts list. Once you have determined that you have all the parts necessary for the project, you should also make sure you have a good workspace for building the amplifier. You won't be completing the project in one session, and so depending on your situation, you might want to be able to isolate, lock, or otherwise close off the work area, for safety and so that everything is undisturbed when you return to it.

While the amplifier project is in progress, let others who share the same living space know that the amplifier can be extremely dangerous to touch and that it is hands off. If curious children (or adults) were to poke around the amplifier when you are away, you want to be sure they can't hurt themselves, so you should remove the power cord (so they can't turn the amplifier on) and discharge the filter caps (always, so that if hands reach inside the chassis, nothing is energized) at least until you have the amplifier chassis permanently mounted inside a cabinet.

One element not offered as a part of the kit at this time, is the cabinet to house the amplifier itself. While I am looking into finding a manufacturer for offering this in the future, I will name a few companies (at the end of this chapter) that will build these for you. Another alternative is to build your own amp and speaker cabinets, and so these DIY projects are included in this ebook as well. The speaker cabinet for this project needs to be equipped with speakers that can handle at least 40 watts.

In addition to following the 19 steps of this assembly procedure, you will also want to refer frequently to the schematic and the layout diagrams. The layout diagram shows every electrical connection to be made in the assembly of this amplifier, and should be the most comprehensive reference for how things go together in this amp. The components that are portrayed in the layout diagram are not exactly to scale, but are shown to give you an idea of where things are placed relative to each other. The chassis for this project will give further indication of parts placement based on where the precut and predrilled work has been done. The schematic is electrically exact and is the best reference for understanding how the circuit works, but does not indicate the position of the components generally.

In the layout diagram, the portrayal of the wire routing is often optimized for an organized and easily readable diagram, when in actual practice the wire routing is direct between connected points.

Required parts:

(5x) 1/4 inch mono jacks, normally closed type
(2x) chassis mount fuse sockets
(1x) package of 3 amp slo-blow fuses
(1x) package of 500 mA slo-blow fuses
(2x) SPST switches
(1x) 6.3 VAC Jewel Indicator Lamp (and chassis mounting assembly)
(6x) 4AV6 vacuum tubes
(6x) 7 pin ceramic tube sockets, 7 pin miniature
(2x) 6BG6-GA vacuum tubes (the industry standard 20 watt version)
(2x) octal ceramic tube sockets
(2x) ceramic plate caps, size = medium
(1x) spool of black teflon coated stranded hook-up wire, XX gauge (for filaments)
(1x) spool of green teflon coated stranded hook-up wire, XX gauge (for 6.3 VAC filaments)
(1x) spool of blue teflon coated stranded hook-up wire, XX gauge (for 4.2 VAC filaments)
(1x) spool of red stranded hook-up wire, XX gauge
(1x) spool of blue stranded hook-up wire, XX gauge
(1x) spool of green stranded hook-up wire, XX gauge
(3x) 1M Ω logarithmic potentiometer (for Volume 1, Volume 2, and Bass tone controls)
(1x) 250K Ω logarithmic potentiometer (for Treble tone control)
(1x) 25K Ω logarithmic potentiometer (50K Ω is optional, for Middle tone control)
(1x) 25K Ω linear potentiometer (for internal Bias range control, pcb mount)
(1x) 5K Ω linear potentiometer (for Presence control)
(1x) Output Transformer, identifier code = 45W001OT (Edcor Custom OT)
(1x) Choke, identifier code = 45W001CT (Hammond 194B)
(1x) Power Transformer, identifier code = 40W001PT (Edcor Custom PT)
(1x) Filament Transformer, identifier code = 45W001FT (Hammond 167Q6)
(1x) chassis
(6x) rotary control knobs

(6x) 1N4007 diodes
(1x) UF10004 diode
(1x) capacitor mounting clamp (one and three eighths inch diameter)
(1x) capacitor mounting clamp (one and a half inch diameter)

All resistors rated at 1/4 watt unless otherwise specified:

R1 = 68K Ω
R2 = 68K Ω
R3 = 1M Ω
R4 = 68K Ω
R5 = 68K Ω
R6 = 1M Ω
R7 = 2.7K Ω
R8 = 1.64K Ω
R9 = 270K Ω
R10 = 270K Ω
R11 = 820 Ω
R12 = 100K Ω
R13 = 56K Ω
R14 = 27K Ω
R15 = 1M Ω
R16 = 10K Ω
R17 = 1M Ω
R18 = 470 Ω
R19 = 220K Ω
R20 = 220K Ω
R21 = 470 Ω / 1W
R22 = 470 Ω / 1W
R23 = 20 - 100 Ω / 10W
R24 = 150K Ω (value to be determined)
R25 = 15k Ω
R26 = 56K Ω
R27 = (value to be determined) / 10W
R28 = 4.7K Ω / 1W
R29 = 10K Ω / 1W
R30 = 100K Ω
R31 = 100K Ω
R32 = 100K Ω
R33 = 82K Ω
R34 = 100K Ω
R35 = 1 Ω /5W (1%)
R36 = 1 Ω /5W (1%)

All capacitors rated at 400 volts unless otherwise specified:

C1 = .02 µf / 400 v
C2 = .0001 µf / 400 v
C3 = .68 µf / 6v
C4 = .02 µf / 400 v
C5 = 250 µf / 6 v
C6 = .00025 µf / 400 v
C7 = .02 µf / 400 v
C8 = .02 µf / 400 v
C9 = .02 µf / 400 v
C10 = .1 µf / 200 v
C11 = .1 µf / 200 v
C12 = 47 pf / 400 v
C13 = .1 µf / 400 v
C14 = .1 µf /400 v
C15 = .05 µf / 600 v
C16 = 10 µf / 160 v
C17 = 10 µf / 160 v
C18 = 50 µf / 1000 v
C19 = 20 µf / 1000 v
C20 = 20 µf / 500 v
C21 = 8.2 µf / 630 v

The first part of the amplifier assembly involves installing each of the components that mount to the front, rear, and top of the amplifier chassis. After this, and after the turret board has been installed, then the final wiring between the various components can be completed. The chassis has been predrilled and powder-coated with the control markings silk-screened on the front and the rear. It is a good idea to use masking tape to cover those parts of the chassis that you would like to avoid scratching during the assembly process. Inside the chassis it doesn't matter so much if scratches occur, but you will at least want to protect the front and rear control markings.

Step 1:

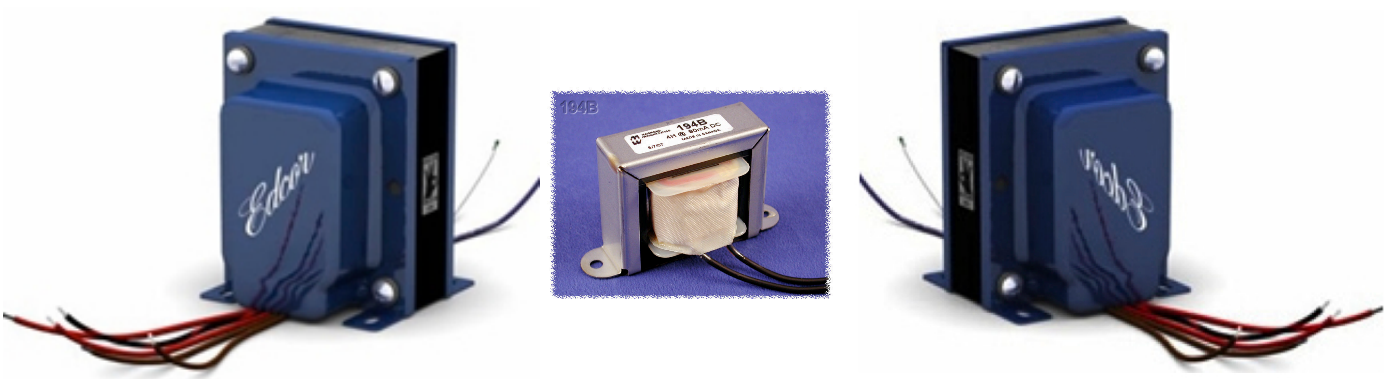
Mount the ceramic tube sockets first. The orientation of the tube sockets is important, because we want the filament pins to face the rear side of the chassis, as much as possible, so that these wires are kept low against the chassis and away from audio signal wires, as they are routed from the tube sockets straight back along the wall of the chassis, where they will turn and follow in the corner towards the power supply.

The ceramic tube sockets are inserted from beneath the chassis, with the bolts fed downwards from above. The nuts and lock-washers are tightened on the (interior) underside of the chassis deck. (Note: the octal tube socket shown below on the left has a metal mounting ring sitting on top of it, when in actual use the metal ring will be placed underneath the ceramic "lip" and inverted relative to the position shown).

Step 2:

Install rubber grommets into the "routing" holes that have been pre-drilled to allow the transformer leads to be fed through the top of the chassis. This will protect the insulation on the wires that are fed through these holes, preventing them from being cut open which would allow them to short-circuit against the chassis.

After the rubber grommets have been installed, install the power transformer, the output transformer, and the choke on the topside of the chassis. Make sure each transformer is oriented correctly. The power transformer primary leads should be fed through the hole closest to the front side of the chassis, and the secondary leads should be fed through the hole closest to the center of the chassis.



When installing the choke (inductor), it doesn’t matter which direction the current flows through it, as long as it matches up with the predrilled holes you should be okay.

The output transformer should be oriented so that secondary leads are fed through the hole closest to the rear side of the chassis. The output transformer’s laminations should be oriented perpendicular to the laminations of the power transformer, in order to avoid hum caused by the coupling of the magnetic fields of each transformer. After doing this, it can be helpful to label the transformer lead wires. You can use a black marker on some masking tape and just write what each lead is, the color code scheme that comes with the transformers gives you the information, but labeling the leads means you don’t have to look it up later.

Step 3:

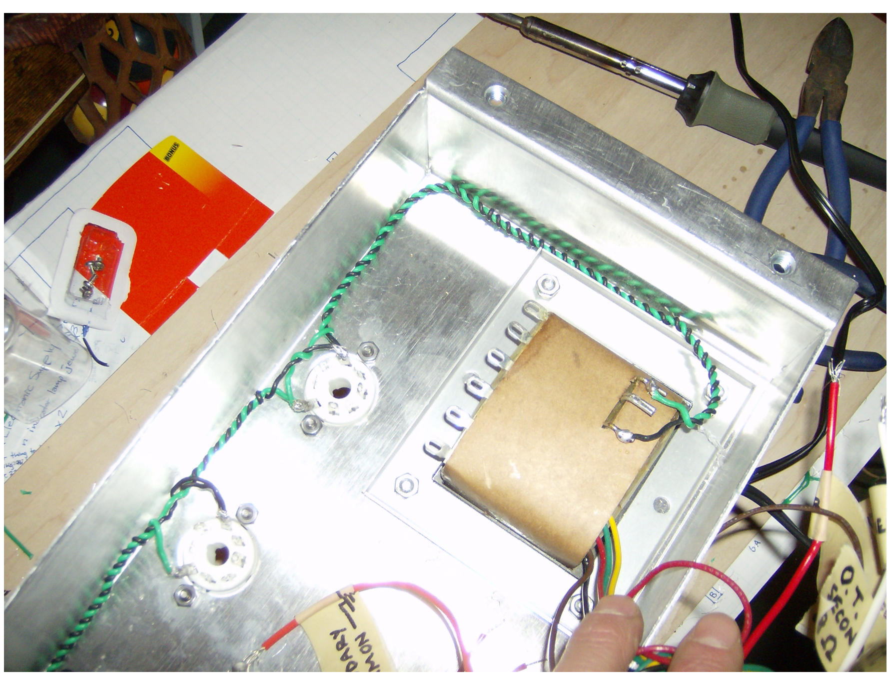
Install the chassis-mount filter capacitors, which are secured by the capacitor mounting brackets. When placing the capacitors inside their mounting brackets, make sure that the ground terminal of the capacitor is aligned with one of the mounting tabs on the capacitor mounting bracket. This will make it possible to easily connect the ground terminal to the ground lug which will be bolted to the chassis at this point.

Step 4:

Install the indicator lamp to the chassis.

Step 5:

Install the wiring for the filament supply connections. Since the filament supply will be using alternating currents there will be a 60 cycle per second pulsing magnetic field that can induce hum in the signal circuits, so it is important to reduce this noise by twisting the filament supply wires tightly together, in order to reduce this radiation. For this I would suggest using teflon coated wiring. The teflon wire is harder to work with but it holds it’s shape well after being twisted together. The other advantage is that you won’t have any trouble with accidentally melting away the insulation when soldering to tube pins.



There are two different filament supplies in this amplifier project. A small turret strip with 4 turrets is mounted on the underside of the chassis deck near the power transformer. The filament leads, from the power transformer secondaries, are connected to these turrets, and the twisted filament wires that connect to the vacuum tubes and the indicator lamp also connect to and originate at this turret board. The indicator lamp gets 6.3 volts AC, and the power tubes will use 6.3 volts AC, wired in parallel to each tube socket, for the filaments. This is depicted in the layout diagram using green and black wires, with connections to pins 2 & 7 on each 6BG6-GA tube. The preamp tubes will use 4.2 volts AC, wired in parallel to each tube socket, for their filaments. This is depicted in the layout diagram using blue and black wires, with connections to pins 3 & 4 on each 4AV6 tube.

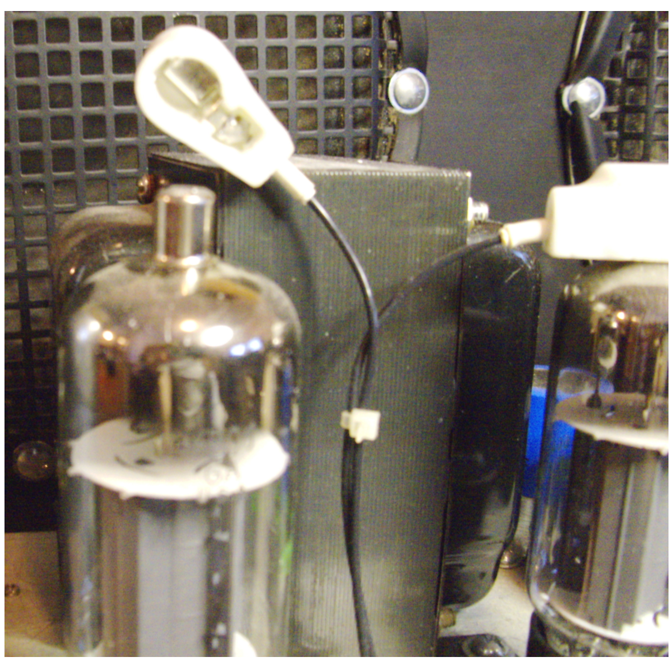
Step 6:

Install IEC connector, the On/Off switch, the On/Standby switch, the two Fuse holders. Connect the power transformer’s primaries to the On/Off switch and to one of the Fuse holders. All of the power transformer’s (secondary) ground connections should terminate at a ground lug that is mounted to one of the power transformer’s mounting bolts. Refer to the layout diagram for specific wiring details.



Step 7:

Connect the output transformer's primary connections. The center tap connects to point A of the (B+) high voltage line. The left and right sides of the output transformer's primaries connect to each of the two ceramic plate caps. Use the teflon coated wire for this, and use heat-shrink tubing as extra insulation at the plate cap end of the wire and also at the point where these wires will pass through the chassis deck. This will help provide some rigidity and also help to prevent the breakdown of the insulation at the points most susceptible to abrasion. When soldering the output transformer primary lead connections, be aware that there is a fifty/fifty chance you're wiring them up backwards. You'll find out if this is the case if the amplifier howls with feedback without any signal applied, when you first start it up. If that happens, you will disconnect the power, discharge the filter caps, then proceed to reverse those connections. You could use a pair of wires with alligator clips on them, to determine the correct polarity, and then solder it up later, after disconnecting the clips and discharging the filter caps again.



Step 8:

Connect the output transformer's secondary connections. The secondaries include a 16Ω tap, an 8Ω tap, a 4Ω tap, and a ground tap. Refer to the layout diagram for the specific wiring details for this. The 16Ω tap connects to the impedance selector switch at the same point that the feedback wire does. From the impedance selector switch the signal line connects to the output jack which employs a safety load resistor. This will protect the output transformer from being damaged in case the amp is turned on without a speaker load connected. All tube amplifiers must only be turned on after first connecting a speaker load. All of the input and output jacks employed in this amplifier are of the "normally-closed" type, and are insulated from the chassis (by virtue of being the plastic type).

Step 9:

Install the input jacks.

Step 10:

Install the six potentiometers. Use a socket wrench with deep sockets to tighten the nuts on the potentiometers, instead of using an open ended-wrench. Either will work, but an open-ended wrench can slip and scratch the front side of the chassis.

Step 11:

Populate the turret board with all of the capacitors, resistors, and diodes that are shown on the turret board in the layout diagram. Also, install the bias range potentiometer on the turret board. All of these components will have their wires fit into the tops of each of their respective turrets, where they will be soldered in place. You will have to trim some of them so that they do not extend beyond the bottom of the turret board.

Step 12:

All that remains of the assembly now is the wiring between the various components mounted on the chassis and their connections to the turret board, in addition to connecting eight pairs of turrets to each other, using eight segments of wire. These eight segments of wire that connect pairs of turrets *can* be installed on the underside of the turret board, which makes for a neater appearance when all the wiring is completed, but makes it very hard to double check or revisit this work after everything is installed. If you keep this wiring on the topside of the board, then every solder point in the entire amplifier will be visible and accessible without having to remove or de-solder anything. I prefer the latter approach myself.

The first wire segments to install are those between the eight different pairs of turrets which can be seen in the layout diagram. All wires that connect to any turrets should be installed by wrapping them tightly and low around the base of the turrets, before soldering. In cases where multiple wires will be attached to the same turret, wrap them all first and then solder them together once. Also, try to orient the wires so that they are pointed along the path that they are intended to travel before you solder them in place.

After the first wire segments have been installed, the remaining wires to install will be the ones that leave the turret board to connect to the other components, like the tabs of the potentiometers, the tube pins, the standby switch, and etc. Refer to the layout diagram for the specific routing, but also place the turret board in the chassis on top of the standoffs where it will eventually be seated. While the turret board is sitting in it's final position, but not yet bolted in place, you can measure out the required lengths for each of the wires that leave the turret board. Give them an extra couple of inches more than you need before cutting them. This will be helpful later when you use wire ties to bundle some of the wires together, because you'll need some of the slack. Now you can solder those wires to each of their respective turrets before installing the turret board permanently on it's standoffs inside the chassis. You can remove the excess wire when you connect the other ends to their respective destinations.

The color coding of wire used in the layout diagram is employed to avoid confusion regarding what connects to what. While it is not absolutely critical, it is useful for remaining organized and can be helpful for troubleshooting and for tracing the circuit later on, even years later.

Step 13:

Install the ground wiring. The layout diagram shows the various points that need to be connected to chassis ground, but doesn't explain the strategy. There are two ground lugs secured by bolts to the chassis. One of these ground lugs is bolted to one corner of the power transformer, the other is bolted to one of the capacitor mounting clamps.

The ground path for the input jacks, the potentiometers, and two ground points on the right side of the turret board are all connected together and brought to the ground lug at the power transformer. The remaining three ground points on the turret board are connected to each other and brought to the ground lug at the power transformer also, by their own path. The ground connection from the IEC plug and the three ground wires from the power transformer's secondaries all converge at the ground lug at the power transformer. The ground points from the two power tubes, and from the two chassis mounted filter capacitors, and from the output jack, all converge at the ground lug bolted to the capacitor mounting clamp.

This is a variation on the star-ground strategy. The idea is to isolate the ground paths of the low current signal circuits from the higher current ground paths of the power supply circuits and the (current) power amplifier circuit.

Step 14:

Test the filament supply voltages.

At this point everything is wired up and soldering is complete. Take some time to double check your work. Trace the circuits against the layout diagram and against the schematic. Also make sure the solder joints have all been completed and look good. It is time to do the first stage of testing, which is to see if the filament supplies are working properly.

Install the 3 amp fuse in the fuse holder connected to the IEC socket. Install the 500 milliamp fuse in the other fuse holder. Connect a speaker load to the output jack (this is not really necessary yet, but it doesn't hurt either). With no vacuum tubes installed, plug in the amplifier. Keep the standby switch in standby mode, and turn the power switch on. If there is any sparking, loud pops, or smoke - turn off the amplifier immediately.

Assuming everything is okay so far, you can make some test measurements. The safest technique for making test measurements is to connect your test probes with alligator clips to the test points, before turning on the power. Never put two hands into the chassis while it is energized, just use one hand to guide a probe and have the other probe positioned in advance (and secured with an alligator clip), before you turn on the power. This is most convenient for measuring DC voltages, but is the safest way to make any measurements in a “live” circuit.

Use your multimeter to measure the AC voltage for each filament supply. You should measure close to 6.3 volts AC between pins 2 & 7 on each of the power tubes. Or alternatively, with one lead connected to chassis ground, you should measure close to 3.15 volts AC on either pin 2 or pin 7.

Next, use the multimeter to measure the AC voltage to the preamp filaments. You should measure close to 4.2 volts AC between pins 3 & 4 on each of the six preamp tubes. Or alternatively, with one lead connected to chassis ground, you should measure close to 2.1 volts AC on either pin 3 or pin 4.

Once you are satisfied that the filament supplies are working properly, turn the power switch off. So far in the testing procedure, the standby switch has remained in standby mode. This means that the filter capacitors should not have been charged yet, assuming everything is wired properly. Let’s not make that assumption. It only takes a few seconds to discharge the filter capacitors, so go ahead and disconnect the power for a moment. Using a wire with alligator clips on either end, attach one alligator clip to a ground point on the chassis and touch the alligator clip on the other end to points A, B, C, and D on the turret board. Remove the wire with the alligator clips from the chassis. Now you know that the capacitors are discharged. This is a critical habit to get into, if you want to avoid a potentially lethal surprise.

Step 15:

Test the negative voltage bias supply.

Still with no vacuum tubes installed, reconnect the power cord. Before turning the power switch on again, (and also keeping the standby switch in standby mode) take this opportunity to clip in your test leads. Attach the black test lead to chassis ground. Attach the red test lead to the turret between resistors R19 and R20. Now you have your hands free. Set the multimeter to read DC voltage in the 100 volt range. Turn on the power switch. Using one hand with a very small regular screwdriver, adjust the bias range resistor fully clockwise and write down the voltage. Next, adjust the bias range resistor fully counter-clockwise and write down the voltage. Your meter should read between approximately - 30 and - 50 volts DC. It's okay if it's off a little at either end. Ideally the bias will be set in the middle of this range - otherwise resistor R24 may need to be adjusted by replacing it with a higher or lower value. Turn the power switch off. Repeat the filter capacitor discharge procedure.

Step 16:

Test the high voltage (B+) supply voltages.

At this point you should install all of the vacuum tubes. Make sure a speaker load is connected. Before turning on the power switch, connect your multimeter's black test lead to the chassis ground. Set the multimeter to read DC voltage in the 500 volt range. The first test is to make sure the filaments of all the tubes light up, keeping the amp in standby mode at first. Let the tubes warm up for a minute or two. You can measure the "no load" voltage at the output of the rectifier. This should read approximately 458 volts DC, plus or minus 5% depending on the AC service at your residence (or where ever you are while testing the amp). This is the highest voltage in the amplifier.

The remaining voltage tests will be with the standby switch set to "on". You should turn the volume knob down to very low, but not quite off. Before you turn the standby to "on", remember that there is a 50% chance that the output transformer's two primary leads could be wired in reverse, and if this is the case, the amplifier should howl and scream immediately and loudly. If this happens, you will have to power down, disconnect the power cord, discharge the filter capacitors, and then reverse the output transformer's primary connections, which luckily in this case, only means switching the plate caps from one power tube to the other (no new soldering required).

If, on the other hand, you throw the standby switch to the "on" position, and you don't hear loud screaming feedback, then the sound of silence is ideal with no signal applied. Keep in mind that the power tubes have not been properly biased yet, and could possibly heat up and begin to glow red. If you see this happen, turn off the amplifier.

There should be time to take your test readings before the power tubes have time to get red hot, even *if* they are biased too hot by default. Let’s take some test measurements.

With the red probe from your multimeter, using one hand, take a reading at the output of the rectifier and write it down. Because the power supply circuit is now powering a “load,” the voltage should be significantly lower than before. Next, take readings for points A, B, C, and D, and write them down. You should here some audible “pops” when your multimeter’s test leads touch each test point. These should read close to 432 volts DC, 430 volts DC, 385 volts DC, and 325 volts DC. The measured voltages could be higher or lower, because of variations in the AC service, but the relative changes in the voltages between these test points should be the proportional to these expected design center values. Point A could measure from 410 volts to 454 volts and be within 5% of design center values.

You can continue to test and write down your readings for other points in the amplifier, like the plate voltages for each tube for comparison against the ideal voltages displayed in the schematic diagram. If everything appears to be in the right ballpark, within plus or minus 5% of design center values, then it is time to bias the power tubes. If the voltage readings don’t look right, you should make sure that your AC service is between 115 VAC and 125 VAC before moving on. You can use a Variac to set the voltage to 120 VAC before it enters the amplifier in order to create the ideal electrical environment, so long as you have consistent line voltage.

Step 17:

Power Tube Biasing.

The power tubes in this amplifier have **1 Ω / 5 watt / 1%** value resistors wired between the cathodes and ground on each power tube. This allows for a useful technique for measuring the total current passing through each power tube, which is in turn useful for properly biasing the power tubes. Using the “70%” rule, each 6BG6-GA tube (rated for 23 watts plate dissipation) will be biased for approximately 70% of that value, or 16 watts per tube. This is just a guideline and is somewhat arbitrary. The power tubes can be biased either “hotter” or “colder” based on what sounds best, so long as the plates don’t melt or glow cherry red. Using a variation of Ohm’s law, volts x amps = watts. So for this amplifier we have a given plate voltage of 432 volts, and a given (desired) power output of 16 watts (per power tube), the required bias current is 16 W / 432 V = .037 Amps, or 37 mA. So 37 mA is the ideal current for each tube. (Actually this is plate current plus screen current, but it’s close enough to treat it as the plate current for the tube).

Now set your multimeter to read DC millivolts and connect the black test lead to chassis ground and the red test lead to pin 3 of first one and then the other power tube sockets. Since we have a desired target of 37 mA of current passing through each tube, and we have a special resistor with a known value of exactly 1 ohm, then we know that a precise measurement of 37 mV means we have our target current value. This is found using Ohm’s law again, E = I x R. 0.037 Volts = 0.037 Amps x 1 ohm. So if we get a reading of something like 32 mV, then we need to adjust the bias range potentiometer until we get a reading of 37 mV. It is worth noting that power tubes are not likely to match exactly, but so long as they read within 5 mV of each other they should be okay. In the case of a mismatch, adjust the bias to split the difference so that each is as close to 37 mA as the other. For example you could have one power tube biased at 35 mA and the other power tube biased at 39 mA and that would work. If the mismatch is greater, it would be better to substitute more tubes until a better match was found. As power tubes are “burned-in” their biasing will often need to be adjusted, so you should check them periodically.

Step 18:

If for any reason you are encountering problems and the amplifier is not functioning properly, don’t freak out, every problem is solvable. One good option, if you have been working for several hours, is to take a break and come back to it at another time, when you can approach the project again with less anxiety. Sometimes the solution is a simple one, and sometimes it is a combination of things that need to be discovered and corrected. There are standard trouble shooting procedures available that can be followed to help figure out what and where exactly the problem is. Double check your work, and take a look at the section on trouble-shooting at the end of this ebook.

Step 19:

At this point you should have a nicely working tube amplifier that is unique in design configuration, using vacuum tubes that have never before been employed in guitar amplifier service. Yet because this amplifier’s circuit topology is directly inspired by the family of amplifiers represented by the Fender Bassman 5F6A, the Marshall JTM 45, the Marshall JCM 50, and the Traynor Bassmaster YBA-1, there should be a noticeable resemblance between them in terms of sound, feel, and quality. The NOS vacuum tubes that this amplifier uses are among the cheapest and yet the highest quality of any vacuum tubes available today. Due to the relative ease of working with a point-to-point wired amplifier, and specifically by the use of a turret board, this amplifier was designed specifically to be an ideal platform for making custom modifications and tone “tweaks,” if so desired. If well cared for, this amplifier should easily last at least 50 years with frequent use and proper maintenance.

Thoughts on AC power service.

Measure the AC voltage from the wall socket that you are using. 120 volts AC is ideal, and this is the AC voltage that the amplifier was designed to operate at. However it’s okay if it is plus or minus 5% of this. That would be from 114 volts AC to 126 volts AC. If this operating voltage was reliable and consistent, then the amplifier can be “tuned” to operate at any one voltage within this range. By “tuned” I mean that the amplifier’s power tubes could be properly biased for a given set of operating conditions. In the real world the amplifier might be used in various locations, each with different AC service conditions, which can affect the sound of the amplifier. It’s just something to keep in mind, and is one reason to consider using a Variac to set the AC voltage at 120 VAC. If the AC line varies up or down by more than 3 volts within a short time range, I would recommend plugging in to a different and more reliable circuit.