Vacuum Tube Amplifier Basics

Second Edition

EJ Jurich

A basic primer on vacuum tube amplifier design and construction

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Vacuum Tube Amplifier Basics, Second Edition by EJ Jurich
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TABLE OF CONTENTS

About This Book

Vacuum tube amplifiers have a sound unique to the characteristics of vacuum tube amplification. When comparing amplifier specifications, vacuum tube or solid state, keep in mind that the amplifier is not the last link. Actual system performance is dependent on other factors such as room acoustics and box & cone speaker systems that introduce distortion, depending on volume levels, up to 10%. What really matters is what sounds good. Beyond the realm of equipment test results, it is an area more appropriately left to the field of psychoacoustics. Regardless of equipment specifications, sound reproduction preference is a matter of the listener's perception.

With basic design knowledge, the hobbyist can design and build vacuum tube audio amplifiers that perform well. Besides taking pride in something that you built, you will have something that is not your typical throw-away electronics. Although there are calculations involved, do not let the math scare you. Most of the formulas used in this book are simple based on Ohms Law. Calculations presented in this book are explained with examples and can be performed on a standard twelve-digit calculator with a square root key. The information in this book is concise with the electronics hobbyist in mind.

As a first time builder, a lower power Class A amplifier that uses a reasonably simple circuit configuration may be the best project to choose. The process of designing and building a working two-channel (stereo) amplifier is presented in steps; with each step the necessary circuit information is explained with examples. To get an idea of the building process of a vacuum tube amplifier, start at page 116, chassis fabrication. With the use of a commercially available metal chassis, drilling and punching holes to produce a traditional fabricated chassis is demonstrated. An example of the design and build of a stereo Class A amplifier starts at page 127.

Use the technical sections, pages 3 through page 112, as a reference guide. It is necessary to be able to solder and follow circuit diagrams. A basic primer on soldering starts on page 8. Reading circuit diagrams is found on page 12.

EJ Jurich

Safety Concerns

While taking measurements or testing a live chassis, stay alert and pay attention to what you are doing. When working on an open chassis that is powered on, never rest your hands on the chassis. Never pick up an open chassis with it plugged in or powered on. In most cases, it is your hands that will get caught by a voltage and cause your muscles to lock up and are unable to let go. If you ever find your hands locked and unable to let go of a chassis, your only option may be to swing your body and fling the chassis out of your hands. The best policy is to assume there is voltage even if the chassis is off and unplugged. Use common sense, don't be careless.

Discharging Capacitors

For filtering capacitors in high voltage circuits of 700VDC or less, capacitors are discharged as shown.

DISCHARGING A CAPACITOR

Use a clip lead (jumper wire with clips) and a resistor to drain current from a capacitor. This can be done while a capacitor is in a circuit.

Capacitors are discharged while the equipment is 'unplugged' from AC power. Use a clip lead long enough to reach all the filtering capacitors.

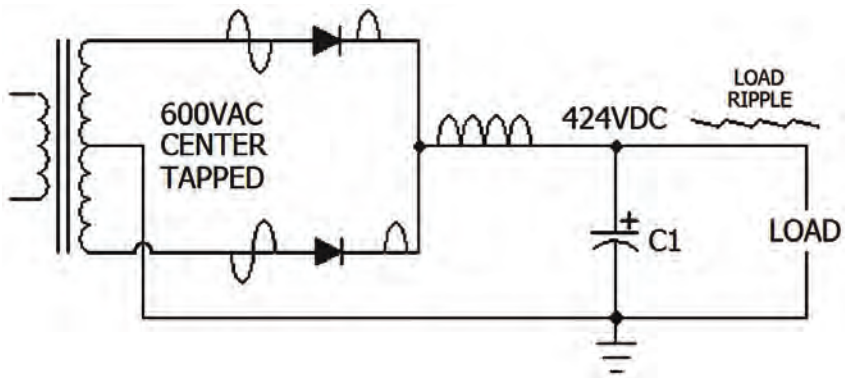
In a circuit, most filtering capacitors have one terminal or lead connected to ground. One end of a clip lead is connected to ground with the other end of the clip lead connected to a 1K (1,000) ohm 10 watt wirewound resistor.

With one hand, using the resistor as a probe, carefully touch the resistor to filter capacitor connections. Keep your other hand away from the chassis. Capacitors should discharge in a second or two. The resistor limits current flow, eliminating any spark. Verify that capacitors are discharged by checking with a DC voltmeter. Be aware that after discharging a capacitor, there may still be residual voltage of less than 20 volts. This is normal and should be safe to handle.

Load Effect on Filtering

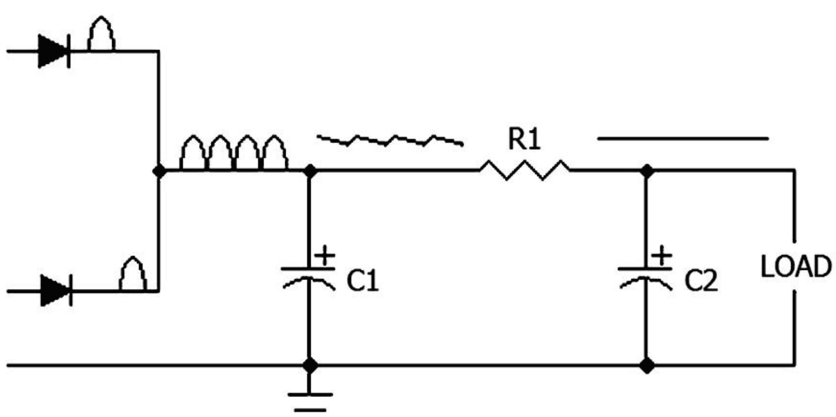
Any load placed on the power supply is also a load placed on the filtering capacitor. When a load is placed on the capacitor, it will discharge the capacitor between pulses. The effect of the load discharging the capacitor produces an AC ripple effect on the DC voltage. A 60 Hz AC primary voltage will cause a 120 Hz ripple in the DC voltage, Figure 5.

Figure 5

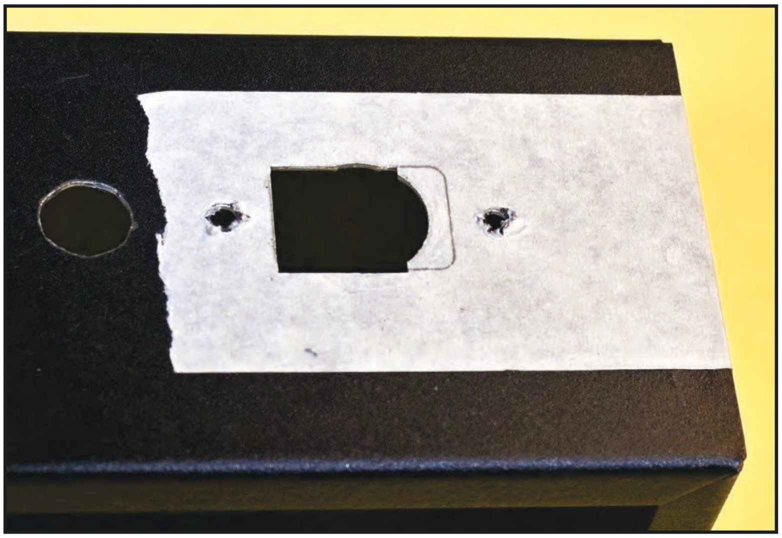


Increasing the value of C1 capacitance will reduce ripple, but will also increase current surge when the amplifier is turned on as the capacitor initially charges. In order to reduce ripple without having a large power-up current surge, more filtering circuits are required.

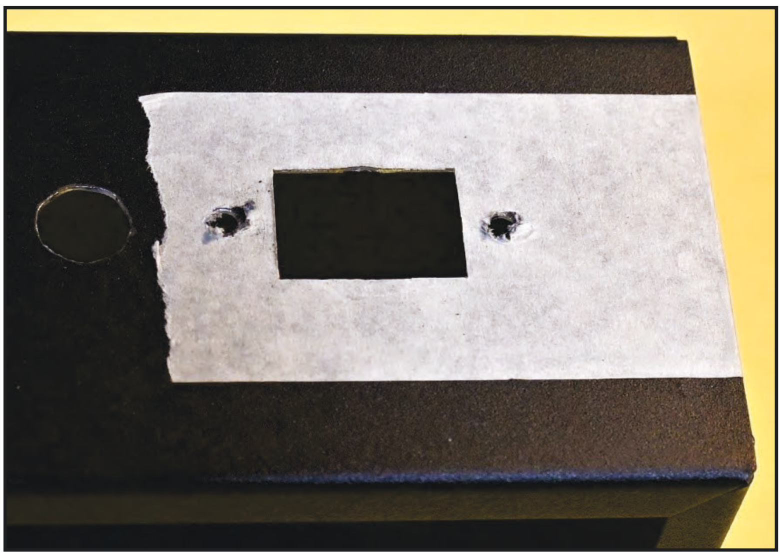
Figure 6



In Figure 6, adding R1 plus a second capacitor will reduce ripple. R1 limits current, allowing the value of C2 to be very large without causing excessive power-on current surge. Because R1 is limiting current, the load at C2 will cause a voltage drop across R1 with a reduction of DC voltage at C2.



The left side of the rectangle punched out. The 3/4-inch square punch is then aligned to punch out the right side of the rectangle.



A file is used to touch up the hole to fit the AC power cord connector.

The back side of the chassis ready for the rear panel plates.

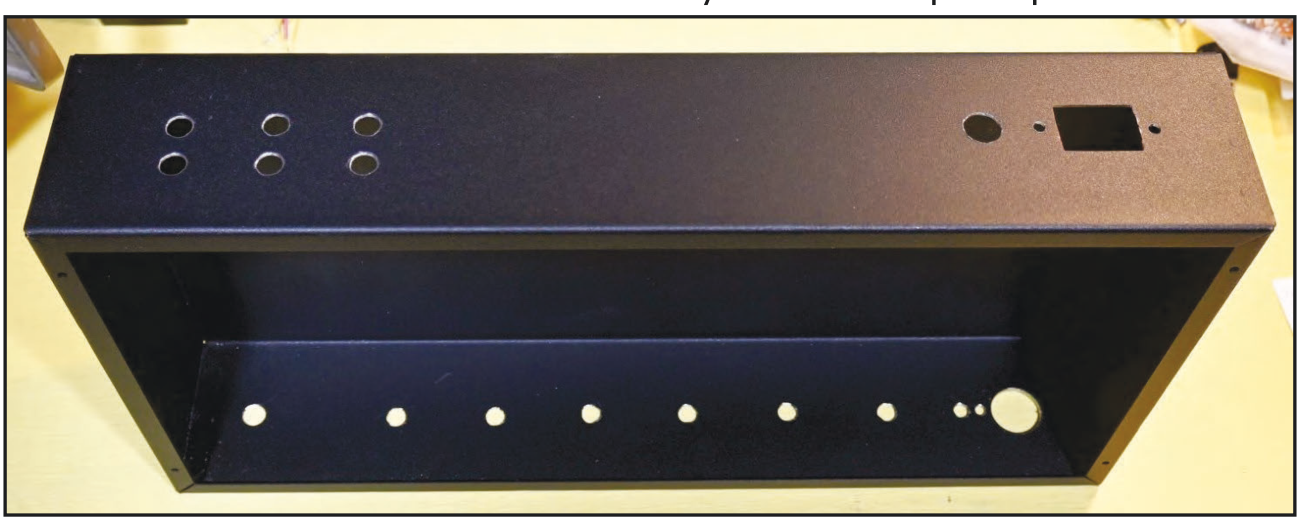


Figure 7

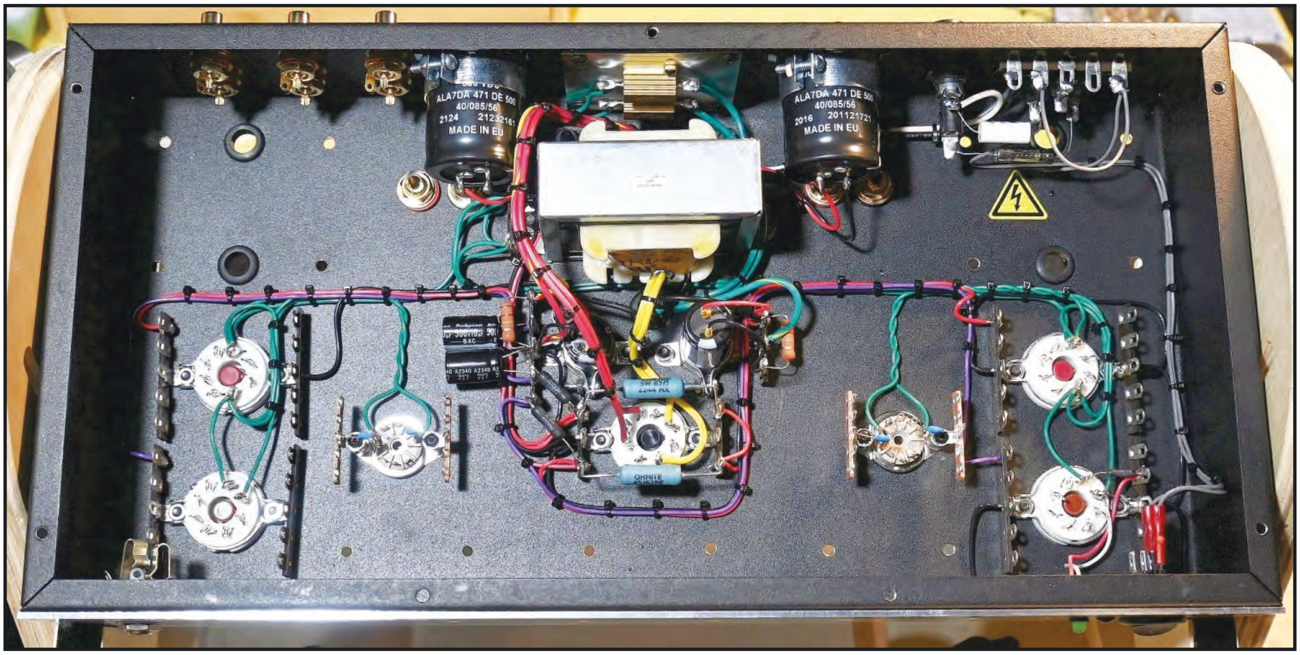
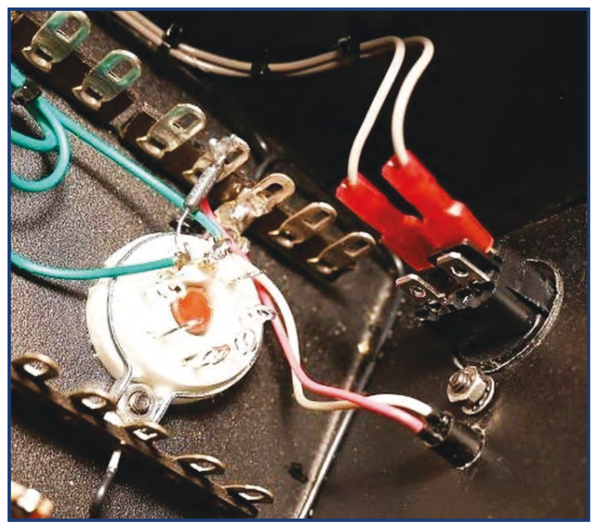


Figure 8



In some cases, power switch terminals should not be soldered; soldering may damage the switch. Switch datasheets should be consulted before attempting to solder switch terminals. The power switch used for this project could not be soldered. Instead, insulated push-on female terminal connectors are used. In this case, Panduit #DNF18-187FIB-3K. A terminal crimp tool must be used.

Figure 9

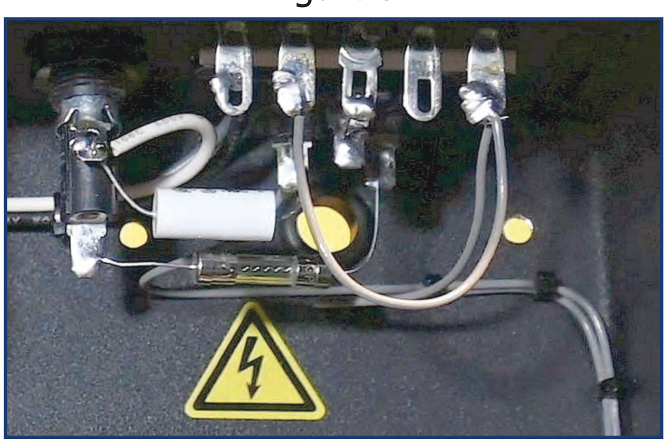
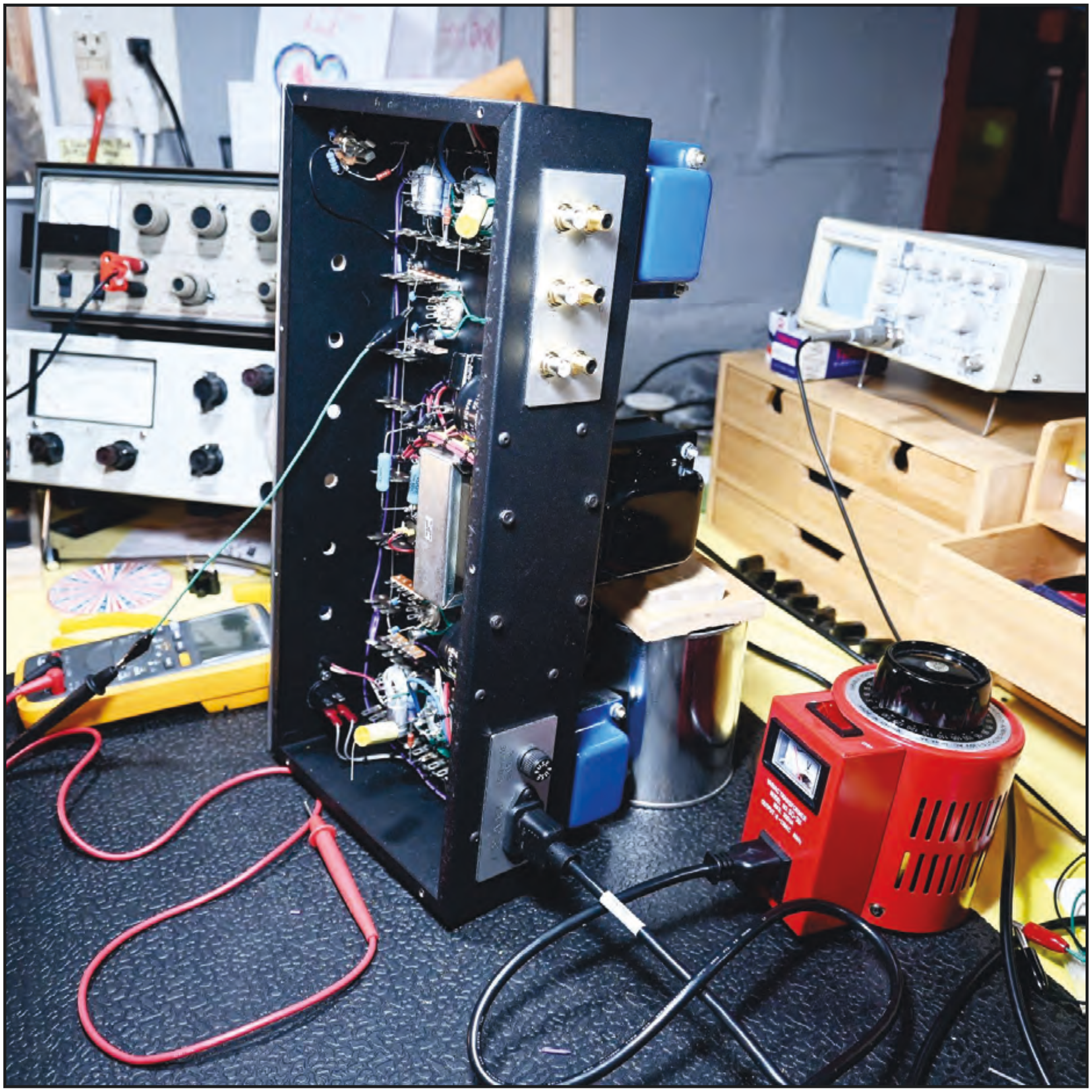
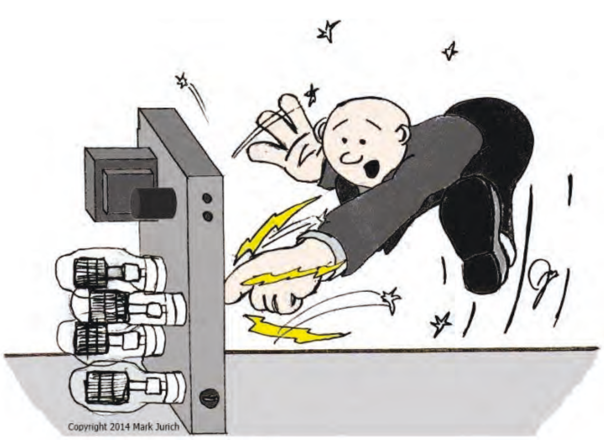


Figure 9 shows the J1 jumper wire used to select either 115 to 120VAC operation (terminal 1 from the left) or 120 to 125VAC operation (terminal 2 from the left). You may also notice a fuse in series with the main fuse. This is a 5-amp fast blow fuse not shown on the circuit diagram. This is added by the author for safety.

Figure 23



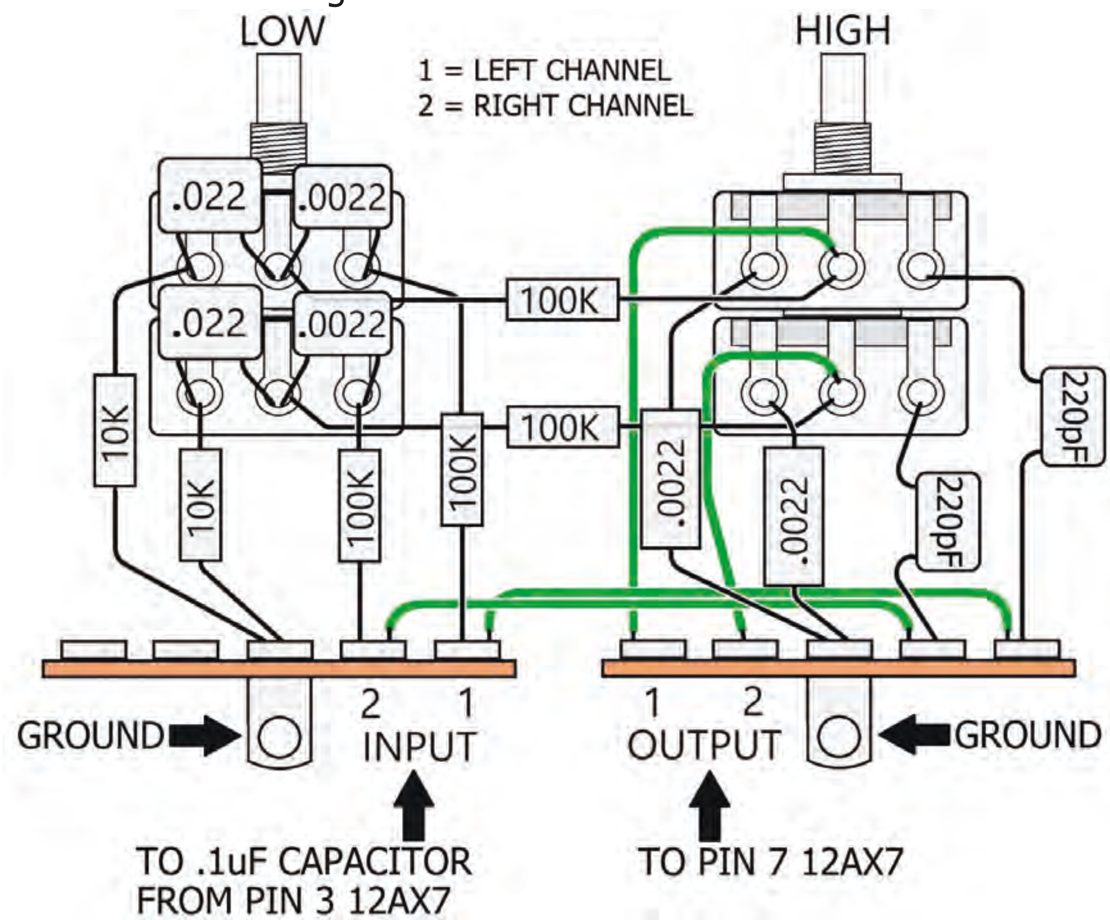
Voltage Readings



When taking voltage readings, be extra careful where you put your fingers. This is especially true when taking readings with no load on a power supply. Connect your voltmeter negative test probe to ground using a clip lead. This allows taking measurements with just one hand. <u>Never rest either hand on the chassis</u>.

The tone control potentiometers can be pre-wired on the bench. The wiring layout in Figure 35 illustrates how the tone control potentiometers are wired. This layout should eliminate any confusion as to how the controls are wired. There is some flexibility in how the terminal strip connections are made. The terminal strip connections do not have to be laid out exactly as shown in Figure 35. Just be sure that the 100K resistors are connected to the 220 pF capacitors at a terminal strip near the tone controls.

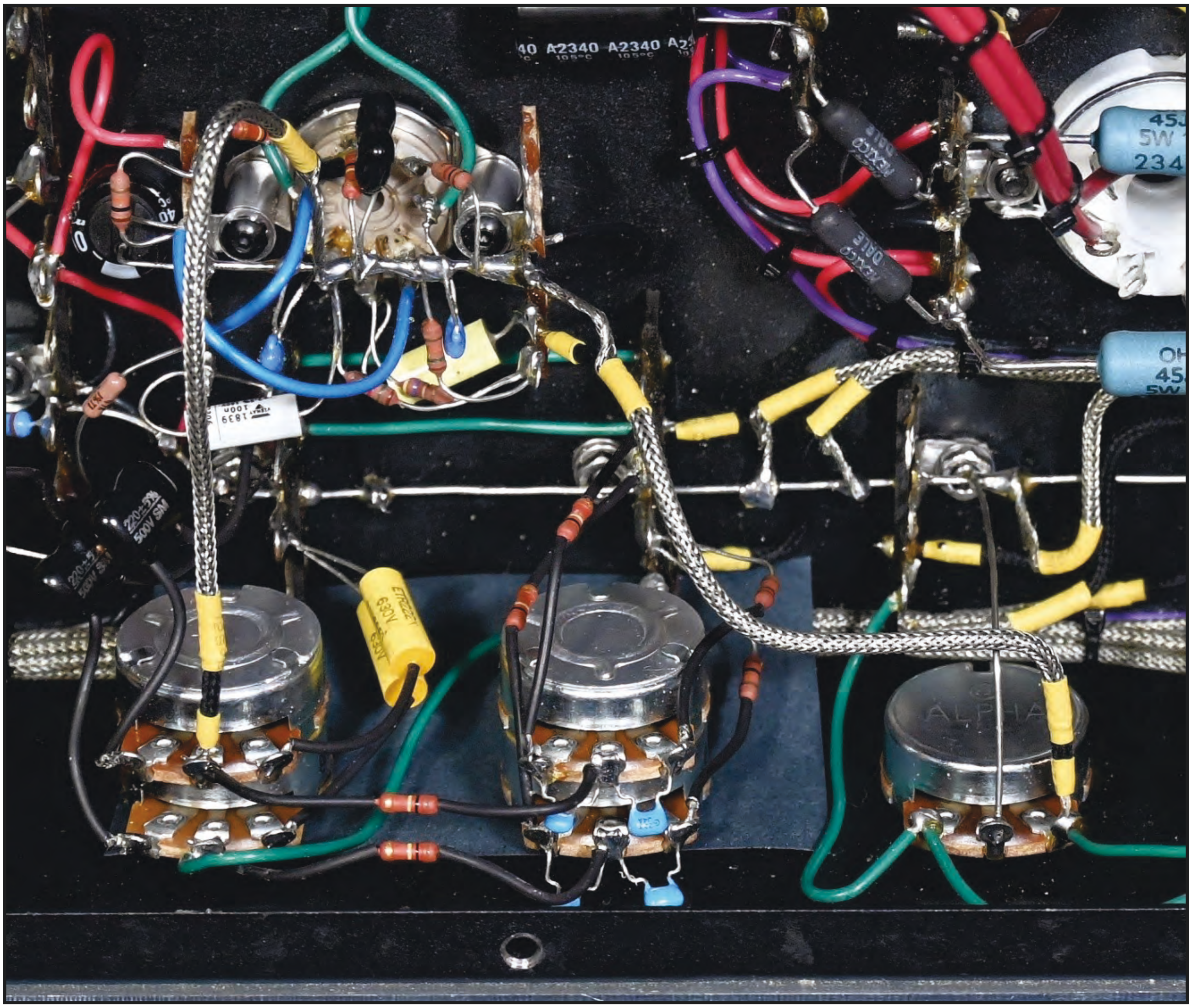
Figure 35 - Tone Control Circuit



R100K and C220 pF in Figure 34 are best located at pin 7 of the 12AX7s. The capacitors on the low-frequency tone control are multilayer ceramic-type capacitors with a C0G/NP0 dielectric. The 220 pF capacitors are silver mica types. The high frequency tone control .0022 uF capacitors are film type capacitors. The 100K and 10K resistors plus the 220 pF and .0022 uF capacitors require long leads. You might consider these components with leads that are at least 1 1/2 inches (3.8 centimeters) long. The resistors can be 1-watt or 2-watt metal film type.

In Figure 42, the 500K ohm level controls are wired for a mix buss resistance of about 167K ohms (500K / 3). When connected to the balance control, the mix buss resistance will be 167K in parallel with 250K, about 100K ohms with the balance control in the center of rotation.

Figure 43



The 20K-ohm resistors provide some isolation between inputs. Also, when a level control is set to the full off position, there is a 20K load placed on the input source rather than a dead short.

Metal film 2-watt 20K-ohm resistors are used. These resistors need to have long leads. The two-watt rating has heavier gauge leads that better hold the resistors in position. Dale brand resistors were used for the input resistors. Tubing is placed on the resistor leads to prevent circuit shorts.

Projects

Building From Scratch

The following sections provide circuit drawings including component values for a few projects. These projects will require component placement, drilling a chassis and soldering. All the projects use point-to-point wiring. If you are new at this, the best advice is to take your time and work carefully.

- Buffer Line Amplifier – Adjustable line amplifier with 25dB of gain. Page 195
- Turntable Pre-Amplifier – Magnetic turntable pickup pre-amplifier. Page 199
- 6V6GTA/6L6GC Monoblock Amplifier – Class A output. Page 205
- 6L6GC/KT66 30 Watt Monoblock Amplifier – Class AB push-pull. Page 210
- 6V6GTA/6L6GC Guitar Amplifier – Basic 5-Watt guitar amplifier. Page 220

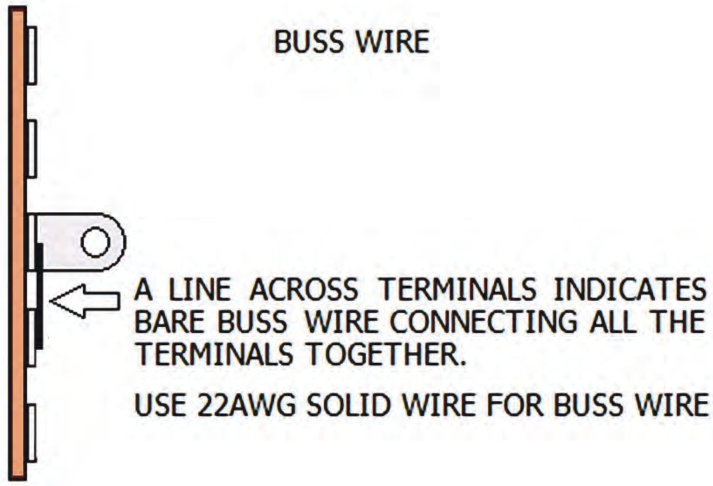
First-time project builders will find working with an aluminum chassis to be far easier than a steel chassis. Besides aluminum being easier to drill and punch holes, aluminum is a better conductor than steel. However, for projects that include heavy transformers, the 30-watt monoblock amplifier, for example, a steel chassis may be the better choice for strength.

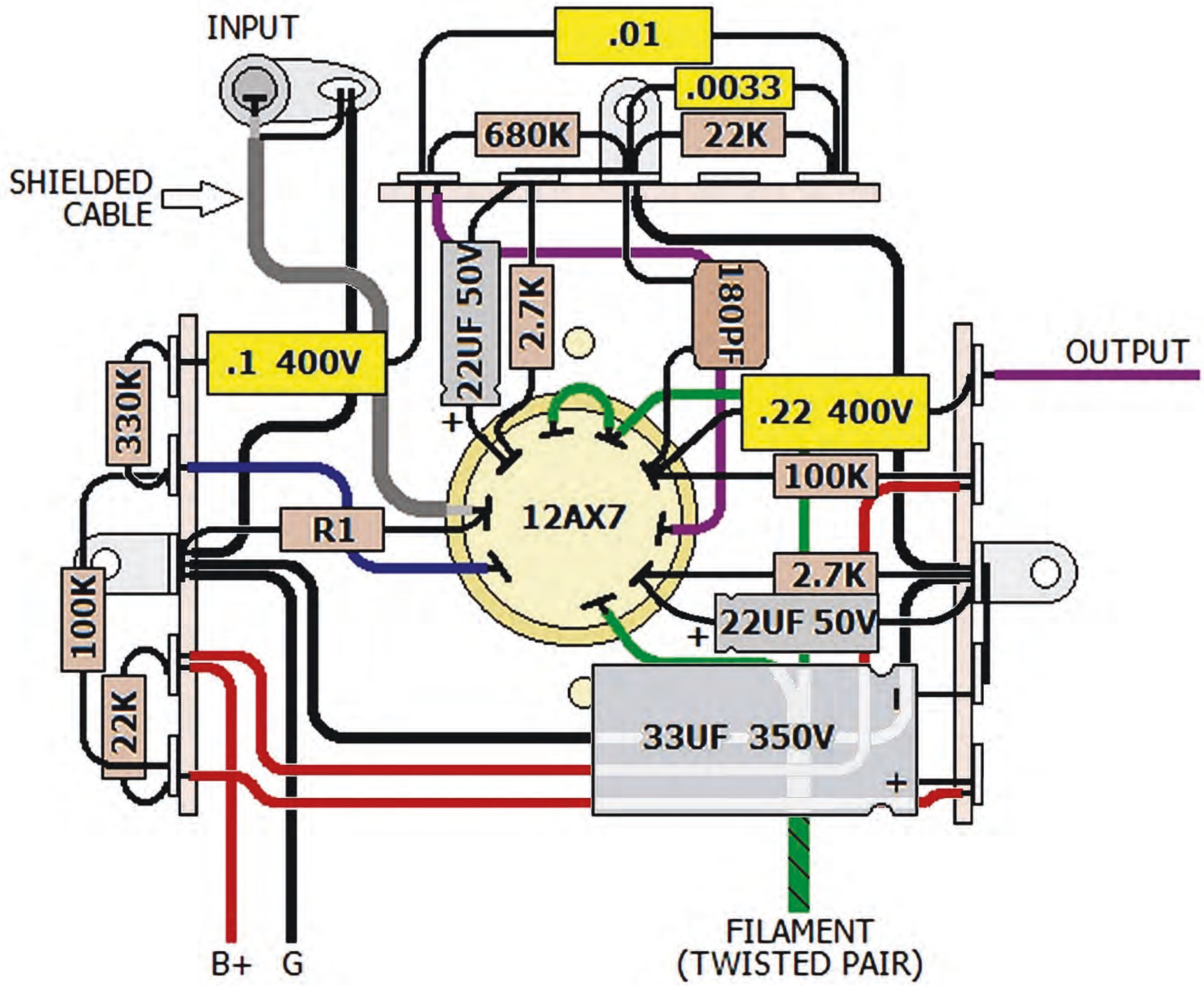
Soldering is much easier on a chassis with plenty of room. You can get an idea of the size of chassis you need by laying out the parts on a table, positioning transformers and tube sockets. When laying out the chassis for drilling, you should not place sensitive pre-amplifier stages or inputs near the power supply or primary AC wiring. This will help reduce hum pickup. Using top-mount tube sockets will help cover imperfect chassis socket holes, improving the appearance of the finished project.

It is a good idea to run all the wiring first, positioning wires against the chassis. Other components such as resistors and capacitors are positioned over the wiring. Do not solder terminals until all wires and components that go into a terminal are in place.

Do not keep a soldering iron on a tube socket terminal for too long. The molten solder may travel up into the pin contact area where the tube pins plug in, making it impossible to insert a tube. In the event you have solder travel into a tube socket pin contact, read how to clear solder out of tube socket pin contacts on the bottom of page 179.

Turntable Pre-Amplifier
Component layout guideline



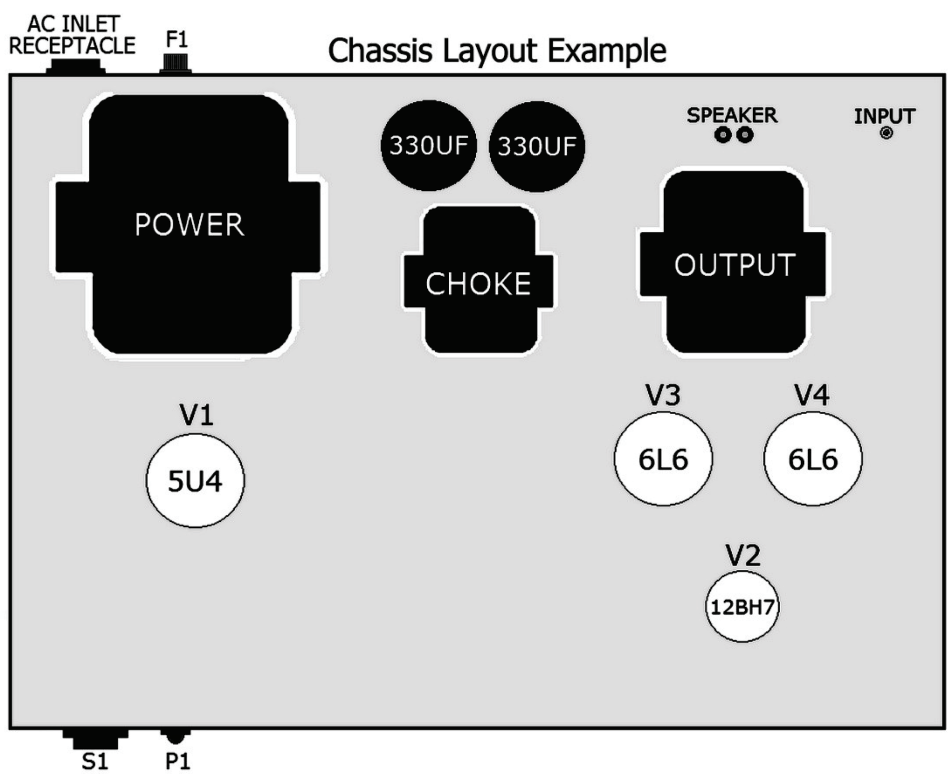


30-Watt 6L6GC/KT66 Monoblock

This project is a 30-watt single-channel power amplifier. Actual amplifier power output will vary depending on the type of output tubes used. This design uses cathode self-bias, eliminating any bias concerns, lending the amplifier to tube rolling. The power supply is designed to provide enough filament and high voltage power for operating various power tubes. Tubes that can be directly plugged in include the 6L6GC, KT66, 5881, 6CA7 (EL34), and 7581. The input/phase inverter can either be a 12AU7 or 12BH7. Voltage amplifier tubes such as the 12AX7 are not suitable for the input/phase inverter because of the output tube drive requirements. An audio control unit typically precedes a monoblock that can provide the two or three volts of audio required by the monoblock.

There are component layout drawings provided for the amplifier circuits that can be used as a guideline, or you can come up with your own layout. The component layout drawings are not to scale, use actual components as a template when machining chassis holes.

An 8-ohm output impedance is recommended. This is because of speaker load impedance variations reflected back to the output transformer primary. Read pages 100 through 105.



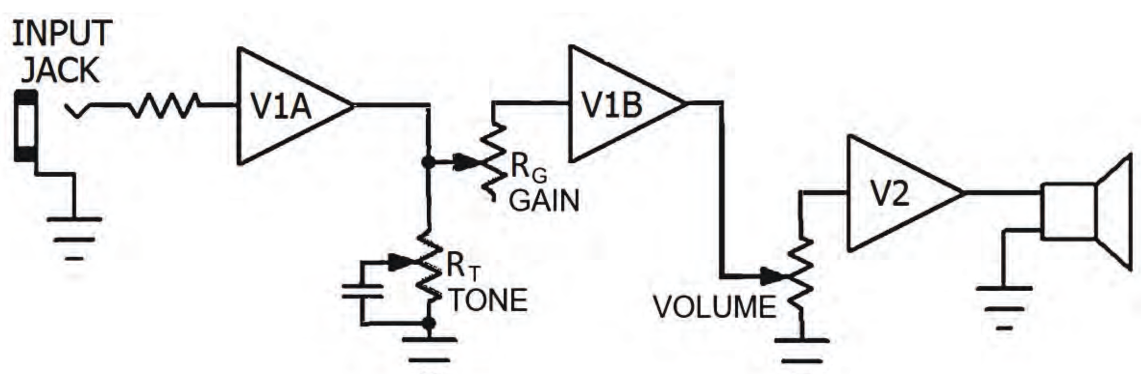
6V6GTA/6L6GC Basic Guitar Amplifier

Updated Dec 2024

A simple guitar amplifier with volume and tone controls. Output tubes that can be directly plugged in include the 6V6GTA, 6V6EH, 6V6S, 6L6GC, 5881 or 7581. The 6V6EH or 6V6S is a custom version of the standard 6V6GTA except with higher maximum voltages. Pre-amplifier tubes that can be directly plugged in include the 12AX7, 12AY7 and 12AT7.

Electric guitars sound best when played through a paper cone speaker that has a paper edge suspension, such as the Jensen™ line of guitar speakers. Besides the quality of sound, paper cone speakers with paper suspension are usually more efficient than full-range Hi-Fi type speakers; it takes less wattage to get more volume. When paired with a high-efficiency guitar speaker, five watts of amplifier power provide appreciable volume. Another advantage of this type of speaker is that they do not need to be in a sealed baffle. Mounting the speaker in an open back cabinet is fine.

Audio Path



Two level controls are used. A volume control is in front of the output tube and a gain control is in the pre-amplifier. The level control in front of the output tube is the master volume. The gain control in the pre-amplifier adjusts the pre-amplifier's gain level. Potentiometer R_T limits the pre-amplifier's low gain setting. R_T is also the tone control. Only the master volume can turn the audio level completely off. Using two level controls allows the option of driving the pre-amplifier hard while still having volume control.

The V2 output stage uses the volume potentiometer as a grid leak resistor.

Citations

Lead Free Solder
Preventing the Growth of Metal Whiskers
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Texas Instruments Analog Design Journal
Published 2020

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Integrated Stages
A process of linking the plates of consecutive stages
Previously used in the output stage of a Revere T-100 tape recorder

CrownAudio.com
Amplifier Power Required Calculator

RCA Receiving Tube Manuals
Graphs and data reference

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