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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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.

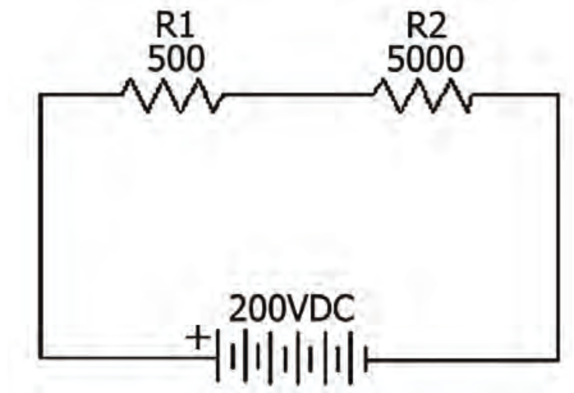
With one hand, using the resistor as a probe, carefully touch the resistor to filter capacitor connections. Keep your other hand away from the chassis. Capacitors should discharge in a second or two. The resistor limits current flow, eliminating any spark. Verify that capacitors are discharged by checking 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.

In Figure 1, we have a 500-ohm and 5000-ohm resistor in series connected across a 200V battery supply. Using Ohm's Law, we calculate the current in the circuit with I = E / R.

R = R1 + R2 = 5,500

I = E / R = 200 / 5,500 = 0.036 amps (0.0363636 rounded off)

Figure 1



Using a formula for watts, we can find how many watts are dissipated from each resistor. Since we know the current and resistance, we use $P = I^2 X R$.

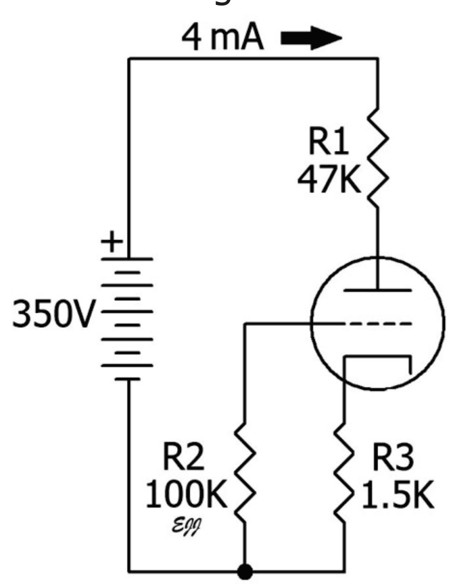
$P = I^2 X R$	R1 Dissipation
(square the current first)	0.0013 X 500 = 0.65 Watts
0.036 X 0.036 = 0.0013	R2 Dissipation
(0.001296 rounded off)	0.0013 X 5000 = 6.5 Watts

Even though current flow is the same, the higher resistance dissipates more power in the form of heat. R1 would need to be rated at least one watt and R2 at least seven watts. Good engineering practice would dictate adding some safety factors by increasing the wattage rating some. For instance, R1 rated two watts and R2 rated ten watts.

Figure 2 is similar to Figure 1 except we have a vacuum tube load. We already know the supply voltage is 350 volts and current in the circuit is 4 mA. We only need to calculate the power that is dissipated by R1, R2 and R3.

The functions of a vacuum tube will be explained later. All you need to know is that R2 has no current flow, so it can be rated at 1/2 watts. In order to be used in an Ohms Law power formula, current must be in amperes (amps). 4 mA = 0.004 amps.

Figure 2



Inductors and Transformers

Inductors are coils of wire wound in even flat layers with several layers of windings on top of each other; the number of turns or layers depends on the inductors application. Current through an electrical conductor induces an electromotive force in the conductor setting up a field around the conductor. Inductance is a property of a conductor which opposes any change in current through the conductor. There are two basic types of inductors, air core and iron core. Air core inductors are wound on a coil form with nothing but air within the coil form. Iron core inductors are wound on an iron core. Adding iron to the core increases inductance. Air core inductors are primarily used for RF work. Iron core inductors are used for audio and power supply applications.

Inductive Reactance

When AC current flows through an inductor, a back or counter-force is developed opposing any change in the initial current. This property of an inductor causes it to have opposition or impedance to a change in current. The measure of impedance of an inductor to AC current is known as inductive reactance. Iron core inductors called chokes are used in power supply circuits. The inductive reactance of a choke opposes the AC component of the DC, filtering out a large portion of the AC component from the DC.

Inductive Coupling

When one inductor is placed next to another inductor and the first inductor has AC current passing through it, the first inductor produces a varying magnetic field that cuts through the second inductor, inducing an AC current in the second inductor. This is the basis of how a transformer works.

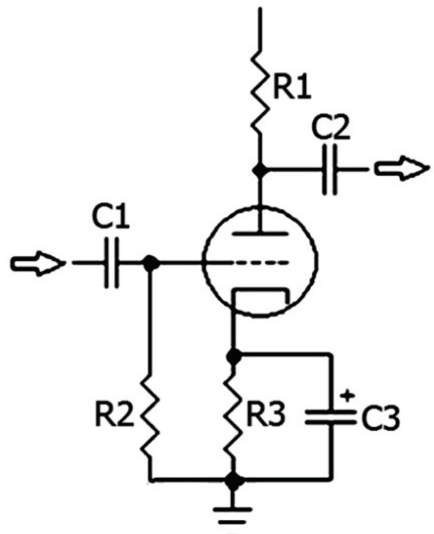
Transformers

A transformer is made up of two or more inductors wound on the same iron core. AC current is fed to the input inductor called the primary winding. The alternating current creates a magnetic field and the primary AC current is induced into the other transformer inductors called secondary windings.

Cathode Bypass Capacitor

A cathode bypass capacitor is a capacitor connected across the cathode resistor of a vacuum tube. Cathode bypass capacitors are used only in self-bias circuits where resistance in the cathode circuit is sufficiently high to make the cathode a few volts positive.

Figure 1A



In Figure 1A, C3 is the cathode bypass capacitor. Capacitors used to bypass the cathode are usually electrolytic types with values in the range of 10 uF to 100 uF or higher. Voltage rating can range from 25VDC to 100VDC depending on the voltage at the cathode. The bypass capacitor serves as an AC bypass. The cathode biasing resistor R3 is used to develop bias voltage on the cathode. The C3 capacitor is used to regulate the current flow through the bias resistor by giving the AC signal a direct path to ground.

This is considered bypassing or eliminating the effect of the AC input signal on the cathode; the input signal flows through the capacitor to ground. Without the bypass capacitor, the input signal would be present at the cathode, causing bias voltage to vary with the input signal.

Sometimes, in the case of push-pull or balanced circuits, a pair of tubes driven by identical signals may share a common unbypassed cathode resistor. The cathodes are connected together using a single cathode resistor without a bypass capacitor. Then, differences in tube conduction are balanced by bias variations that tend to reduce distortion.

Capacitors and Heat

When wiring components, it is often convenient to place the output tube bypass capacitor over the cathode resistor. However, it is important that the bypass capacitor is not touching the cathode resistor. Heat from the cathode resistor can shorten the life of the bypass capacitor.

Power Supplies

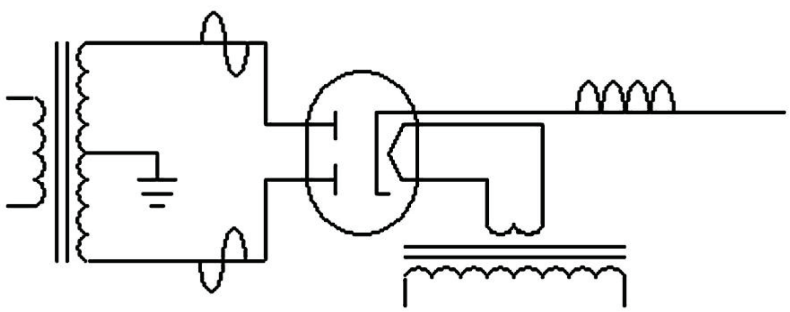
The Rectifier

Amplifying vacuum tubes requires a positive DC voltage to operate. A rectifier circuit is needed to convert AC to DC. The most common rectifier circuits used in vacuum tube amplifiers are of the full wave type. A full wave rectifier rectifies both the positive and negative halves of the AC voltage. A power transformer with a center tap provides the AC voltage. Full wave rectification using a center-tapped transformer requires two diodes.

Vacuum Tube Rectifier

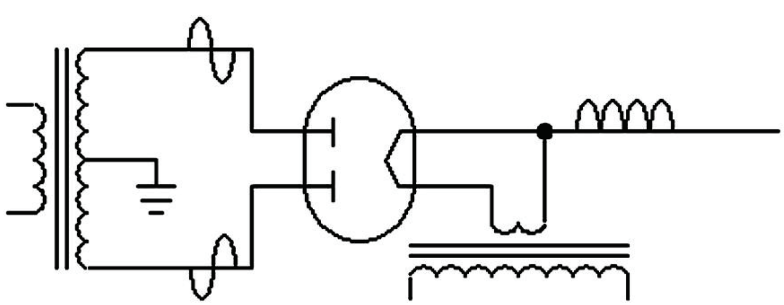
A full wave vacuum tube rectifier has two AC connections (called plates or anodes) and one DC out connection, the cathode. Each plate has current flow with the cathode and is, in effect, a diode. The transformer winding supplies each plate AC voltage that is 180 degrees out of phase referenced to the center tap; the center tap is negative common ground. The rectifier rectifies both halves of the waveform with the current load split between each half of the winding. The cathode output is made up of positive pulses from both plates.

Figure 1



Some rectifier tubes do not have a physical cathode, but instead use the filament as the cathode.

Figure 2



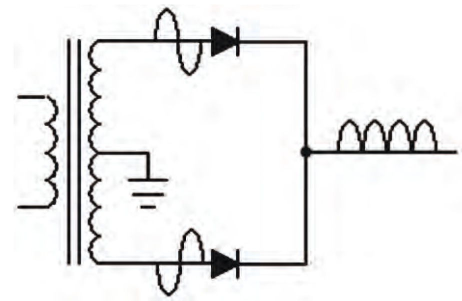
The AC voltage to be rectified is half the value of a transformer's rated voltage. For example, a 600-volt center-tapped transformer actually provides 300 volts of AC voltage to be rectified. This is why most transformers have a dual rating. For example, 600VCT, 300-0-300. VCT = voltage center-tapped.

Although rectifier tubes may look vintage, they do not provide a solid B+ voltage as they tend to sag under a heavy load. The internal resistance of a vacuum tube rectifier is fairly high. As the current load on the tube increases, the output DC voltage decreases. Rectifier tubes have a slight delay before voltage is produced.

Solid State Rectifier

Solid state rectifiers do not have high internal resistance and will provide a more steady DC voltage output over a wide range of current loads. When using solid state rectifiers, the high voltage will be significantly higher until the amplifier tubes warm up and start drawing current from the transformer.

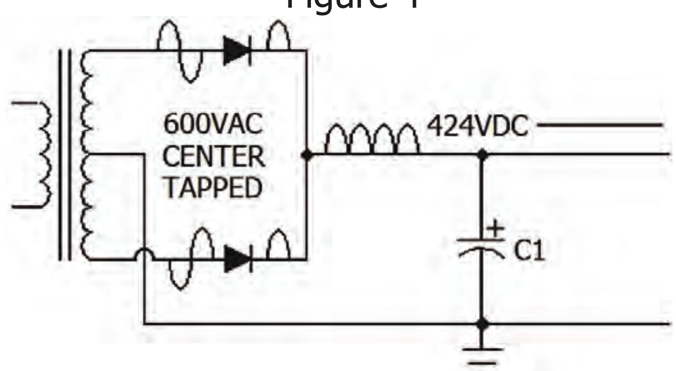
Figure 3
Solid State Rectifier



Filtering

Figure 3 shows a full wave rectifier circuit using a center-tapped transformer. The windings on each side of the center tap feed the rectifier diodes the AC voltage 180 degrees out of phase; each rectifier rectifying half the AC cycle. The outputs of the rectifiers are connected together, resulting in a series of positive pulses. In order for these pulses to be useful, we need to smooth them out. This is done by filtering with a capacitor C1 placed on the rectifier output, Figure 4.

Figure 4



In a no-load condition, the positive pulses charge the capacitor to the peak value of the AC voltage and the capacitor holds the charge, essentially smoothing out the pulses.

Output Tube To Speaker

Coupling a power tube to a speaker usually involves the use of an output transformer. The tubes themselves are resistive and not inductive. However, the output transformer is inductive. There is a lot going on between the output tube, the output transformer and the speaker that affects the overall sound that is heard. In the next few pages, coupling a vacuum tube to a speaker is briefly discussed.

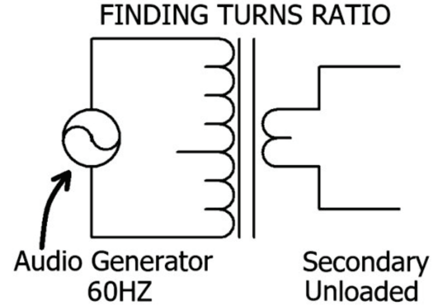
Impedance

Output transformers are used for coupling the plate resistance of the output tube to a speaker. An output transformer has no impedance by itself; it reflects the impedance load on the secondary back to the primary. The primary impedance can be determined by the ratio of the number of primary coil turns to the number of secondary coil turns. The following is a method to approximate this ratio without knowing the actual number of coil turns.

The transformer that was used for this example has a 3,300 ohm primary. You can approximate the turns ratio by applying an AC signal to the transformer primary. Any frequency from 50 Hz to 500 Hz can be used. The AC signal is applied across the entire primary. The secondary should be unloaded. A digital voltmeter is preferred for measurements.

Figure 1

FINDING TURNS RATIO



Using an audio generator to generate a test signal removes the risk of shock that might be encountered trying to tap voltage off a transformer powered by the AC mains. Use of a digital AC voltmeter will provide sufficient accuracy. Set the AC primary signal to a convenient reference level, if possible, 5 volts up to 10 volts. Measure the AC signal voltage across the primary. Also measure the AC signal voltage across the secondary. The ratio is determined by dividing the primary voltage by the secondary voltage.
If you measure 5 volts across the primary and 0.257 volts across an 8 ohm secondary, 5 / 0.257 = 19.5, the turns ratio is 19.5 to 1 (19.5 : 1).

The primary impedance would then be, $Z = (\&ratio^{2})\ \mathrm{X}\ (R)$.

• Chassis Fabrication

The following several pages are an example of the traditional fabrication of an amplifier chassis using a commercially manufactured blank chassis.

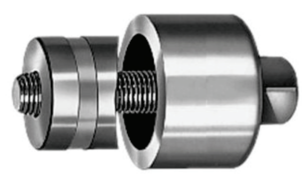
The chassis and wiring layout used in the following amplifier project is by the author. This layout is used to allow placement of the filter choke inductor and all filter capacitors inside the chassis. Doing so provides a sleeker look to the amplifier by keeping ugly parts inside the chassis. Careful placement of parts inside a chassis uses less surface area on the chassis' top side, allowing a smaller chassis size to be used.

For vacuum tube components, you will usually need at least a two-inch-high chassis; a three-inch-high chassis might be preferred depending on the largest component going inside the chassis. It's best to mount heavy components in a corner or along the edge of a chassis where the chassis has better support.

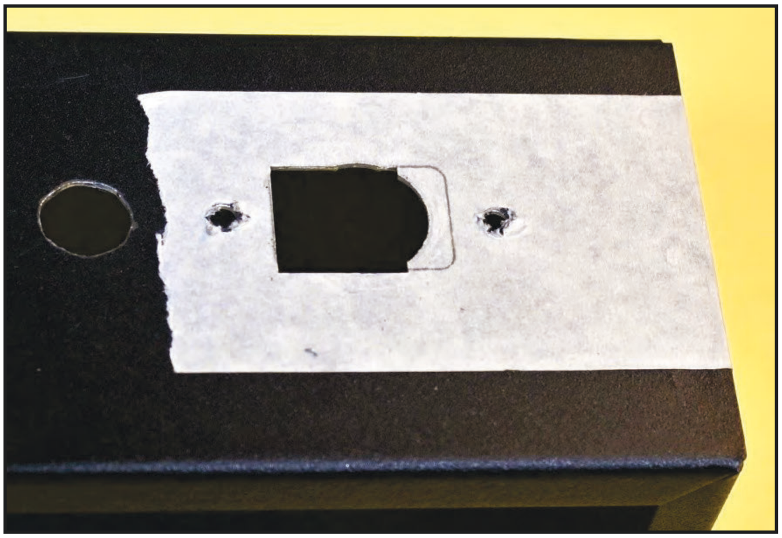
Suggested Tools

For a more professional-looking chassis, in addition to your regular tools, the following tools are recommended.

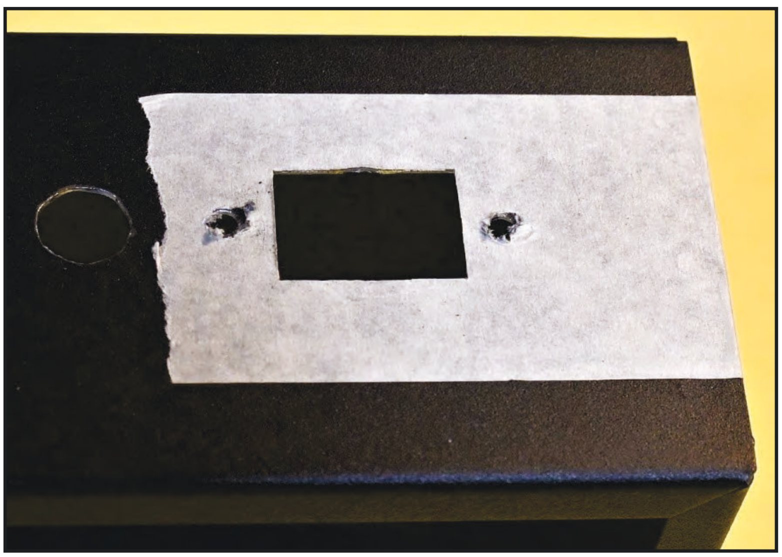
Chassis Punch (hole punch)
Best for
Making tube socket and large holes.
Maxium thickness 18 guage steel.



Tapered Reamer
Allows reaming holes bigger
to an exact size up to 1/2-inch.
Hole may need deburring.

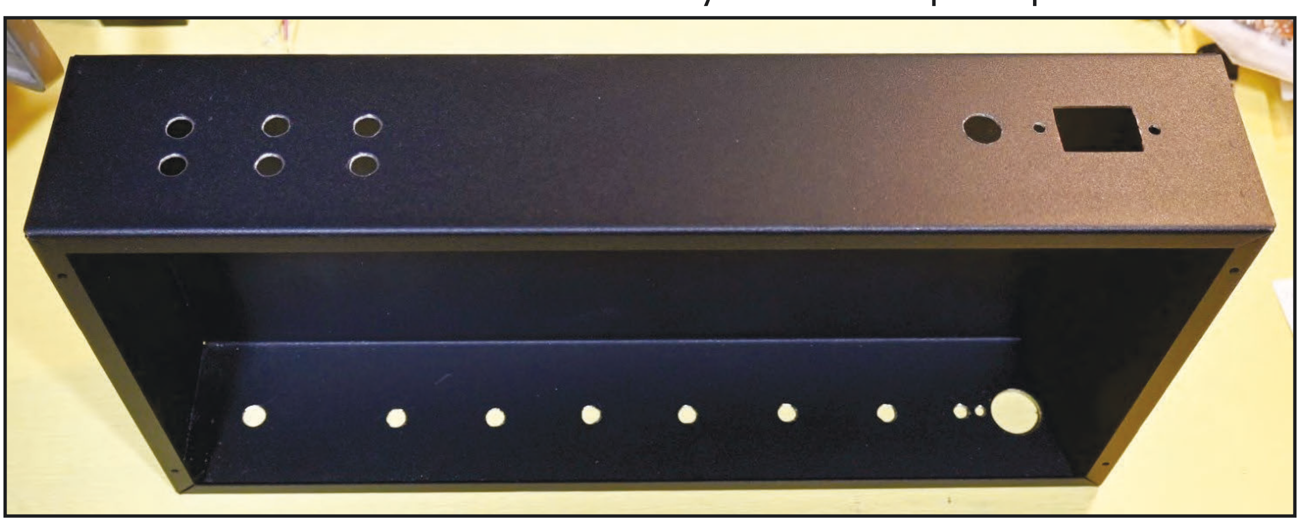


The left side of the rectangle punched out. The 3/4-inch square punch is then aligned to punch out the right side of the rectangle.



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.



Cold Filament Current Surge

The resistance of a 6L6GC filament is 7 ohms when hot (6.3 volts applied). However, the resistance before voltage is applied is only .8 ohms. When voltage is applied to the filament, for a brief moment, the filament draws 7.9 amps. Besides the two output tubes, there are two 6SN7 tubes each with a cold filament resistance of 5.0 ohms (1.3 amps each) and two 12AX7 tubes each with a cold filament resistance of 8 ohms (.79 amps each)[1].

The cold filament total current load.

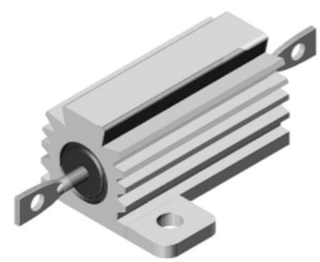
7.9 + 7.9 + 1.3 + 1.3 + .79 + .79 = 19.98 amps.

$P = I^2 \times R = (19.98 \times 19.98) \times 0.025 = 399 \times 0.025 = 9.98$ watts

This means that R5 and R6 will each dissipate 9.98 watts until the filaments warm up. R5 and R6 should be rated at least ten watts to handle the filament voltage turn-on current surge.

A possible choice would be a 0.025 ohms 12.5 watt Dale part number RH010R0250FE02 resistor with solder terminals. This type of resistor is intended to be mounted on a heat sink. The high current surge is very short with continuous current only dissipating .324 watts. A small aluminum heat sink will be fine.

Figure 6



Heat Sink For R5 and R6

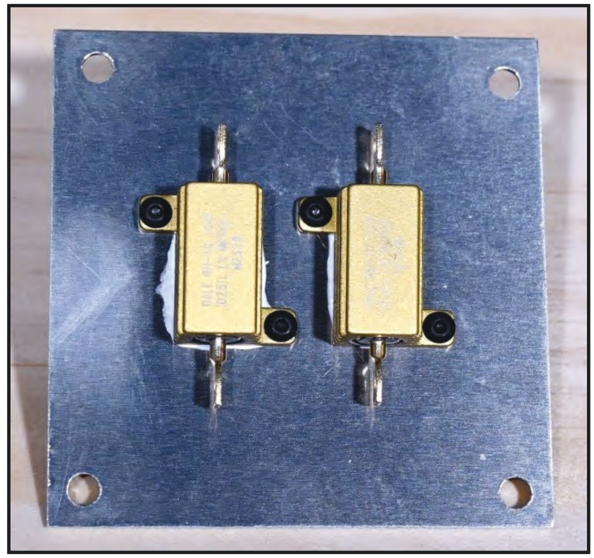
A small heat sink is fabricated from a piece of bare aluminum. The amount of heat dissipated from R5 and R6 is very small after the initial turn-on surge. A 2 1/2 inch by 2 1/2 inch piece cut off from a small aluminum chassis bottom plate is sufficient. The aluminum is 0.047 inches thick.

Both resistors are mounted on the heat sink, creating an assembly. The mounting holes for the resistors are small, requiring #2 screw hardware. As an assembly, R5 and R6 will be easier to install inside the chassis. Four holes in the corners are clearance holes for 6-32 screws. Heat sink compound is applied to the heat sink before mounting the resistors. See Figure 7.

[1] The cold resistance is measured across the filament pins of a vacuum tube with an ohm meter (no voltage applied). To measure, tubes are removed from their socket. The hot resistance of a filament is found by using ohms law, R = E / I, filament voltage divided by the filament current. For example, a 6L6GC filament, R = 6.3V / .9A = 7 ohms.

Figure 7

Figure 8

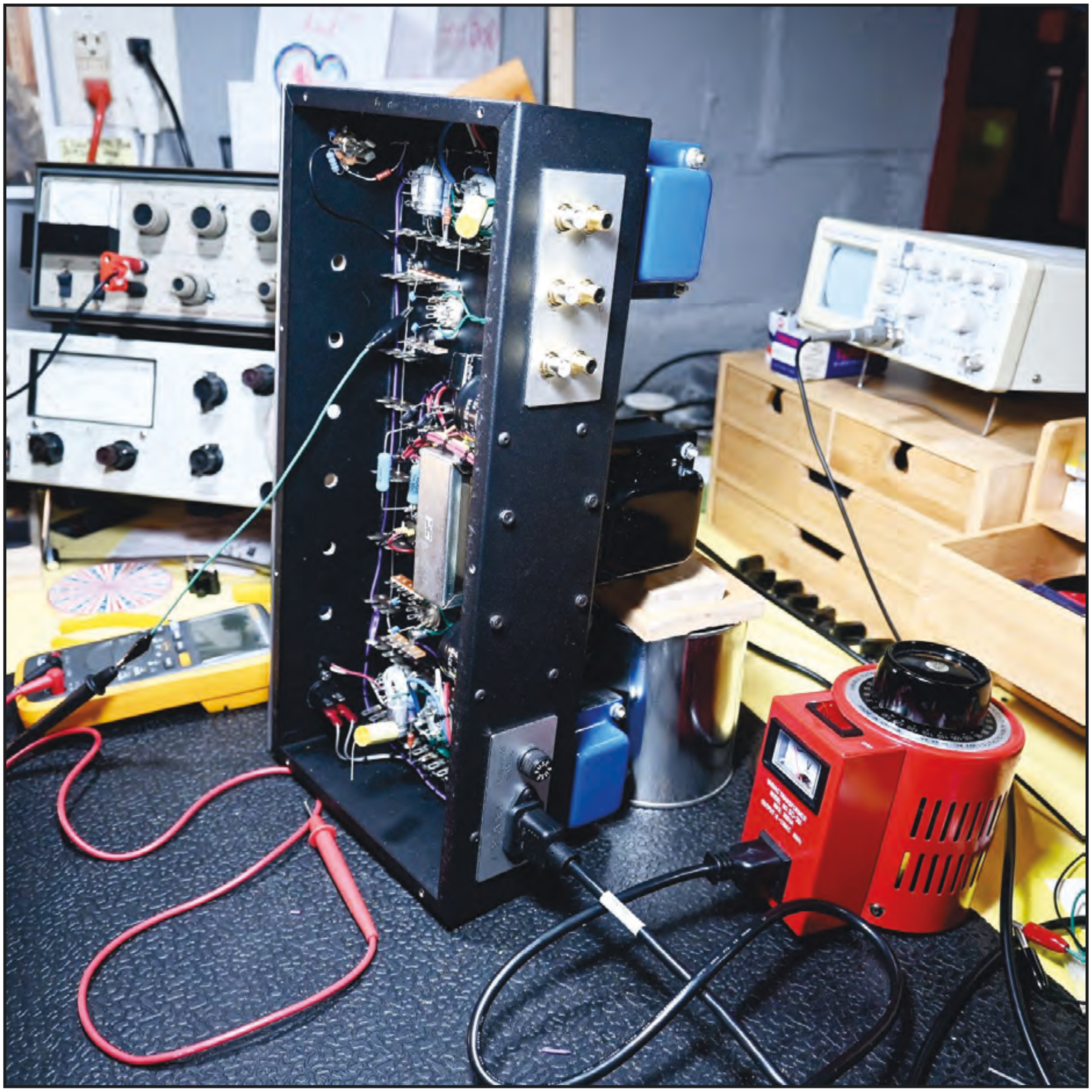


Both resistors are mounted on the heat sink assembly as shown in Figure 8. The assembly will be centered on the back side of the chassis. It will occupy what would normally be wasted space next to the filter choke. The filter choke will also be inside the chassis under the power transformer.

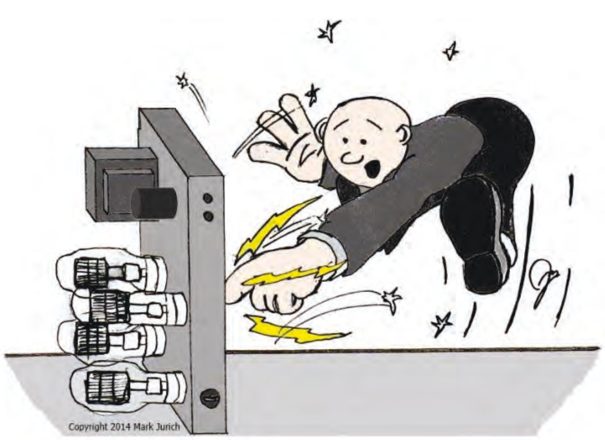
A traditional chassis layout will be used for this project. The traditional layout with components mounted on the top and inside the chassis with all controls on the front panel helps to keep the amplifier dimensions down to a more convenient size.

To get an idea of the required chassis size, all the major amplifier components were placed on a flat surface as they would be on a chassis. Capacitor and resistor wiring between tube sockets was taken into account. Terminal strips are provided for tie points. The 8-pin tube sockets used are a ceramic type with a separate mounting ring that allows mounting the socket from inside the chassis or on top of the chassis. The tube socket mounting rings are a perfect fit for terminal strip mounting tabs. Terminal strips are also mounted using the 12AX7 9-pin socket mounting screws. Using socket mounting screws for terminal strips reduces the number of visible screws on top of the chassis. It also keeps wiring as short as possible to reduce the chance of noise or AC hum pickup.

Figure 23



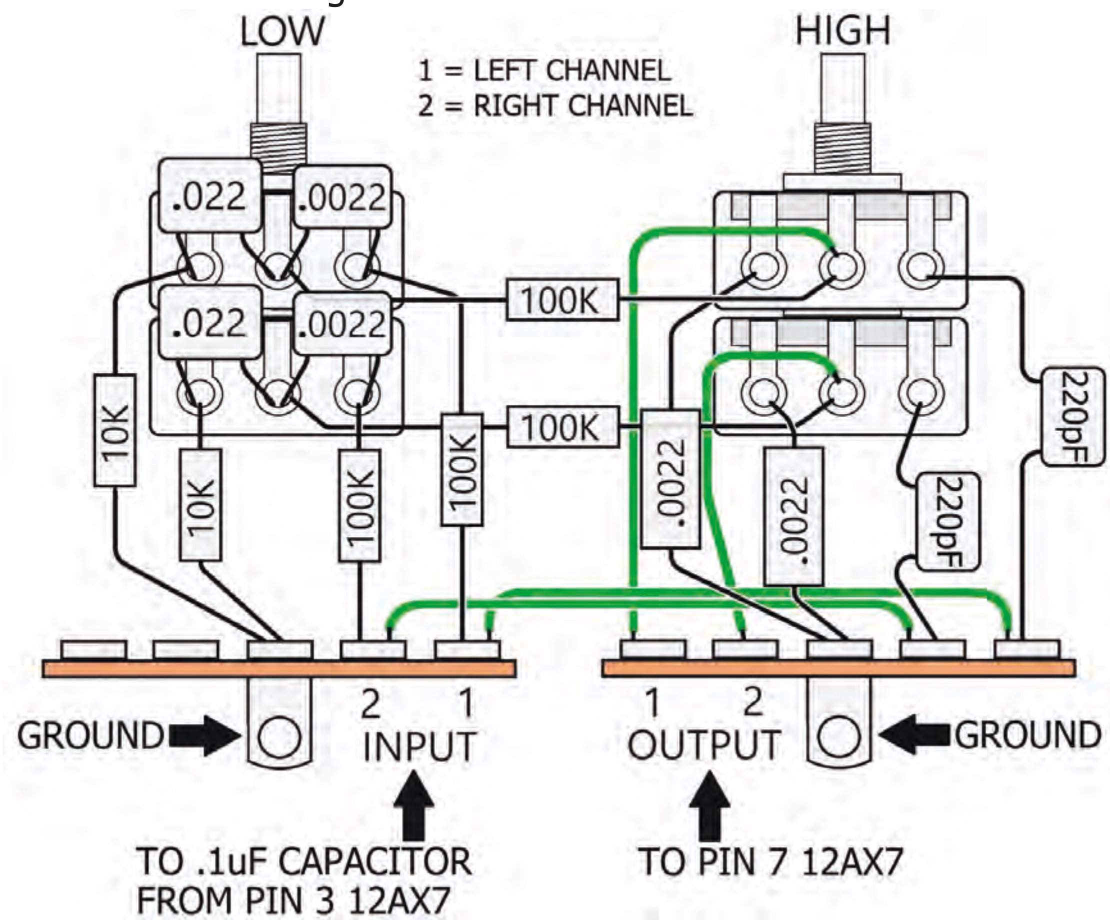
Voltage Readings



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. Never rest either hand on the chassis.

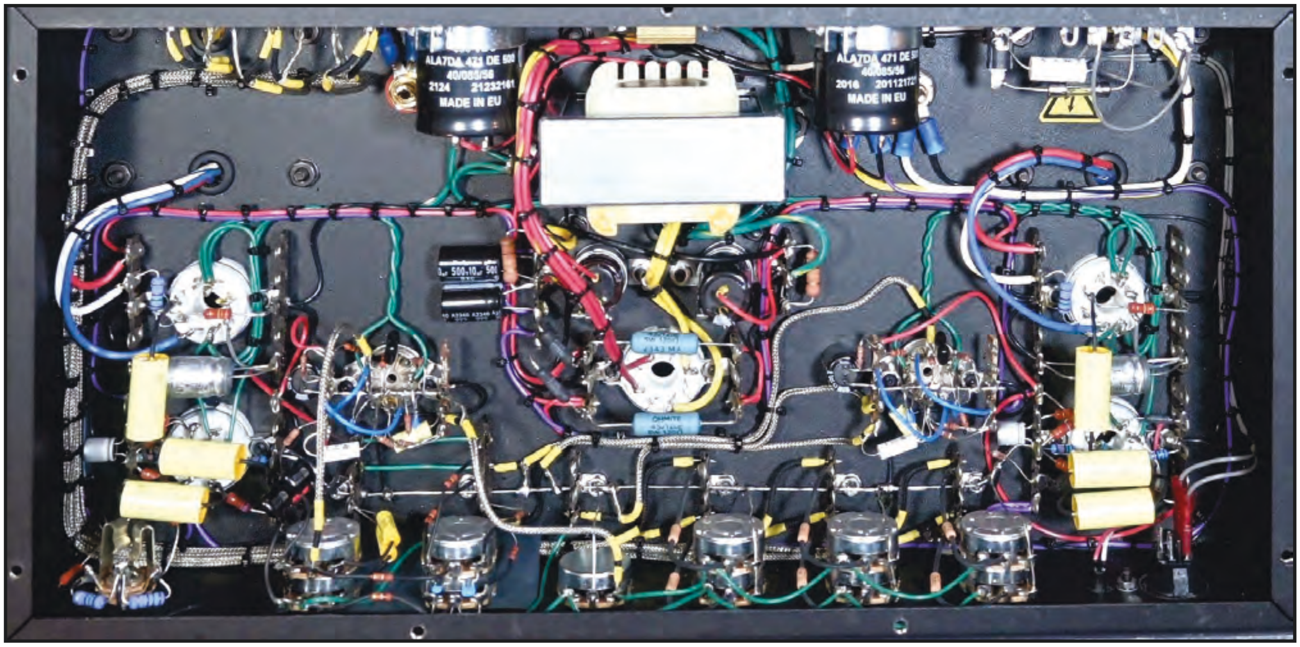
The tone control potentiometers can be pre-wired on the bench. The wiring layout in Figure 35 illustrates how the tone control potentiometers are wired. This layout should eliminate any confusion as to how the controls are wired. There is some flexibility in how the terminal strip connections are made. 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.

Figure 47, the amplifier completely wired.

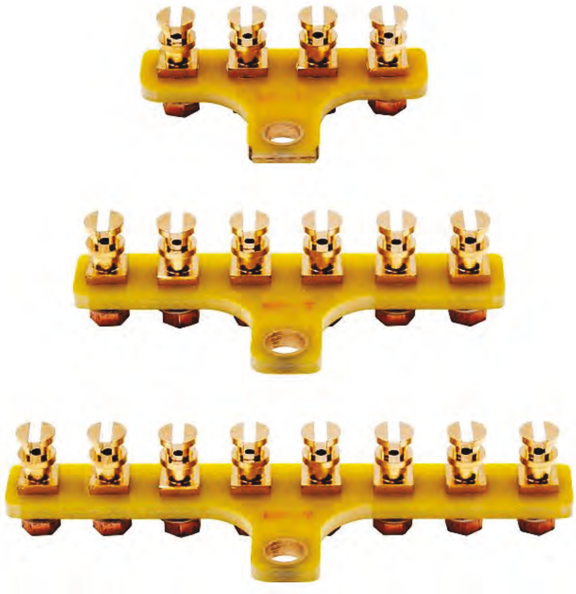


Notes:

The amplifier was built using some components that were on hand, including the power transformer, filter choke, output transformers and chassis. The engraved plates were custom-made for this project.

The amplifier fits on a shelf next to a turntable. A chassis of the same width, but deeper, would have provided more room in the chassis for wiring and still fit on the shelf; something to keep in mind when laying out a chassis.

Figure 48



Standard size turret strips, also known as terminal boards, were not used for this project. Besides taking up a lot of room, turret strips spread out wiring, providing more chance of hum and noise pickup. You might consider using small turret strips like those shown in Figure 48. They mount next to a tube socket using the screws that secure the tube socket. Close to the style of traditional terminal strips, they keep components near the tube socket.

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

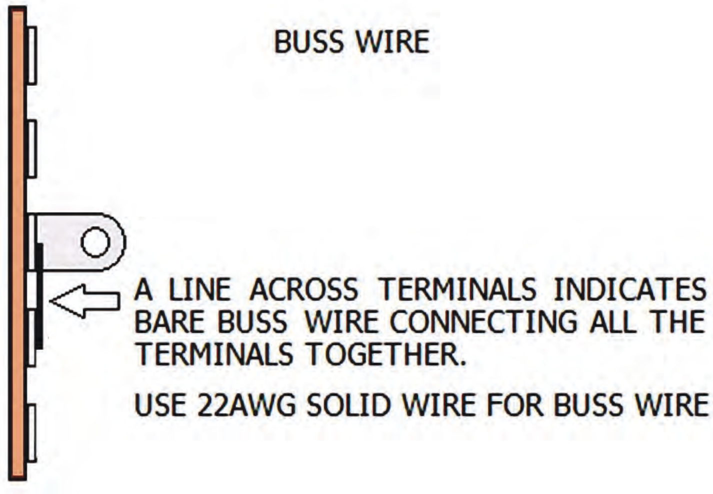
First-time project builders will find working with an aluminum chassis to be far easier than a steel chassis. Besides aluminum being easier to drill and punch holes, aluminum is a better conductor than steel. However, for projects that include heavy transformers, the 30-watt monoblock amplifier, for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

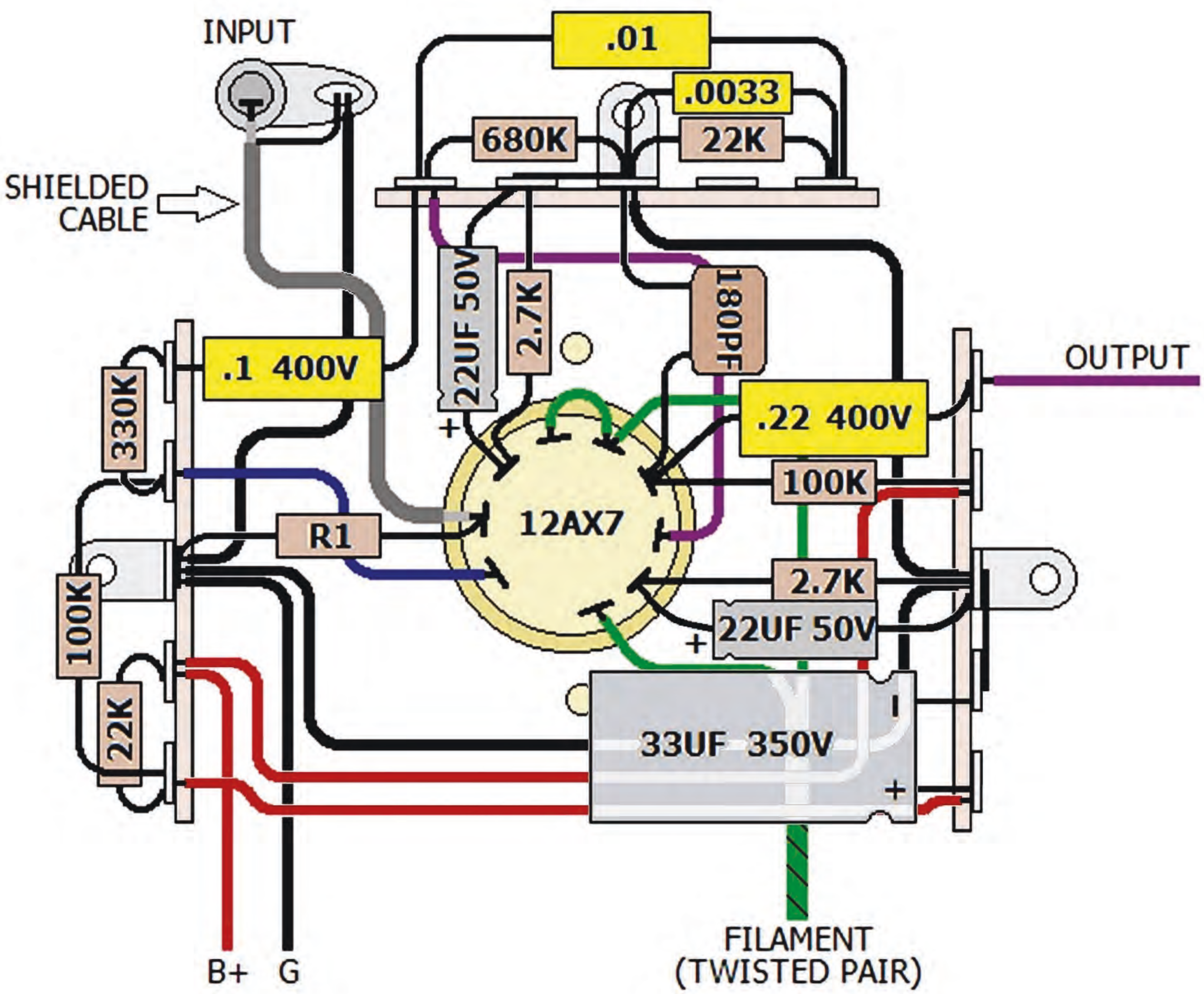
Soldering is much easier on a chassis with plenty of room. You can get an idea of the size of chassis you need by laying out the parts on a table, positioning transformers and tube sockets. When laying out the chassis for drilling, you should not place sensitive pre-amplifier stages or inputs near the 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



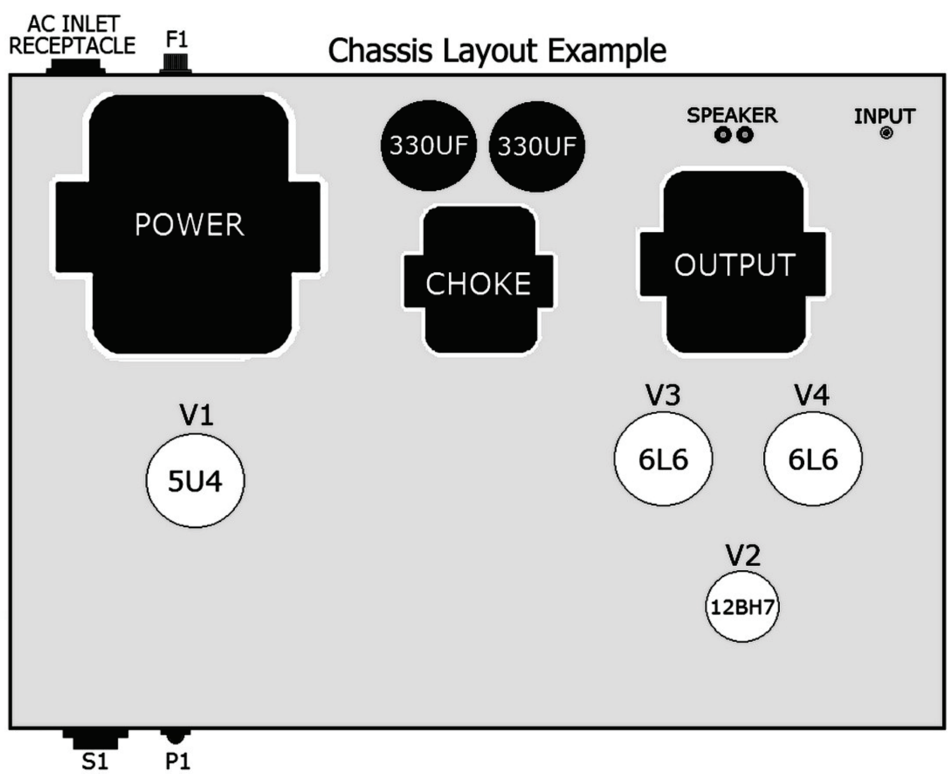


30-Watt 6L6GC/KT66 Monoblock

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.



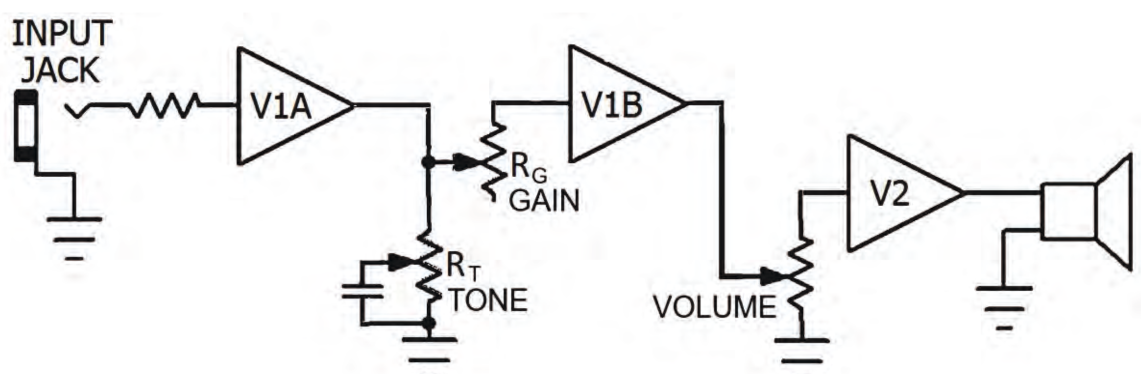
6V6GTA/6L6GC Basic Guitar Amplifier

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
© 2007
The Aerospace Corporation

Selecting Capacitors to Minimize Distortion in Audio Applications by
Zak Kaye
Texas Instruments Analog Design Journal
Published 2020

Classic Amplifier Kits
Allied Radio catalog 1957
Used as filler on page 44

Series RC circuit Impedance Calculator
mathforengineers.com

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

From Amazon book reviews

5.0 out of 5 stars

If you are wanting to build an Audio Tube Amp for your Stereo, this is the book!!

Reviewed in the United States on April 26, 2023

Verified Purchase

Finally, I found it, a book on building tube amplifiers and you do not need an advance degree in Calculus to understand the theory. Very clearly written in plain English and easy to understand.

Having worked as an electronic tech for the past 30 years, I can read and understand complex schematic. This book is fantastically easy to understand and if you are afraid of electrical schematics, the author has provide detail drawing of how the circuit is layout with component by component placement.

I have purchased several other books that spent page after page with charts telling me how a tube or a transistor will perform. That stuff puts me to sleep and those books are in a pile labelled I'll will never read them.

This book is totally different and so easy to understand. Another excellent thing about this book is, if the author is explaining how a portion of a circuit works, the drawing he is referring to is located in the same paragraph and not on the next page!! I really enjoyed reading this book and hopefully you will too.

5.0 out of 5 stars

What the title says

Reviewed in the United States on March 10, 2024

Verified Purchase

This is a good book for someone who has little knowledge of electric circuits and no knowledge of how tubes do what they do. I did not need the basic electricity information but the tube information is kept deliberately simple so as to not overwhelm the reader. I now know a lot more about tube circuits and how they work. I can now follow the signal path through a wiring diagram. There is also a section on basic amplifier construction. I would recommend Vacuum Tube Amplifier Basics to anyone wishing to learn a little bit about the nuts and bolts of these devices.

5.0 out of 5 stars

Excellent, mid / intermediate DIY amp builder resource.

Reviewed in the United States on February 11, 2018

Verified Purchase

Well written and concise, hobbyist DIY amp builders will learn something here. Supplement with other online video resources to nail down critical concepts and build your confidence to build a great tube amp - great stepping stone for beginner to intermediate level electronics enthusiasts with some amp building experience. Two thumbs up! Basics? Well, perhaps, but plenty of good material here to reinforce what you think you may already know. You know who you are!