P1 Builder's Guide
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Warning: Do not attempt to build this amp unless you know how to work safely with the dangerous voltages present in a tube amp.

1 Introduction

This guide will help you build the AX84 P1 tube guitar amplifier. It is oriented towards someone who knows a little about electronics but is new to do-it-yourself amps. It outlines a simple path to getting a decent quality amp built. Detailed technical information on the AX84 P1 can be found on the AX84 website at www.ax84.com.

There are many different opinions about the choice of components and construction techniques for guitar amps. The advice given here is but one possible way to build an amp.

The major steps in building the P1 are:

- Getting the parts
- Laying out the chassis
- Drilling the chassis
- Assembling the amp
- Troubleshooting any problems
- Building a cabinet

2 Getting the Parts

2.1 Suppliers

Guitar amps contain many uncommon parts such as tubes, tube sockets, transformers and a metal chassis. Fortunately there are vendors that specialize in tube amplifier parts. The Links page on the AX84 website contains a list of websites of vendors of guitar amp parts. Browse the websites to narrow it down to one or two vendors that have the parts you need.

For the more common parts such as resistors, capacitors, switches, jacks, etc. you can either use a guitar amp parts supplier or a general electronics components supplier such as Mouser, Digi-Key or Radio Shack. Both Mouser and Digi-Key have websites where you can order parts online. These sites have downloadable catalogs or you can request that a catalog be sent to you through the mail.

The P1 Bill of Materials lists of all of the parts that appear in the schematic. Appendix A contains a list of the additional parts you might need to build the amp. Get all of the parts listed in the Bill of Materials and Appendix A and you should have everything you need.

2.2 Resistors and Potentiometers

There are many different types of resistors available. Carbon composition, metal film, and metal oxide are types commonly used in amplifiers. Carbon composition resistors were traditionally used. Metal film and metal oxide resistors are a good choice because they are quieter, less flammable and more stable than carbon resistors. Make sure the resistors you use are the proper wattage and are rated for the voltages they will be subjected to.

For the potentiometers use ½ or ¼ watt carbon potentiometers. The Xicon 24mm potentiometers from Mouser are a popular inexpensive choice. CTS potentiometers are also popular but are more expensive. Note that potentiometers come in linear or logarithmic (also called audio) taper.

2.3 Capacitors

There are three basic types of capacitors used in amps – electrolytic, film and ceramic/mica capacitors.

Electrolytic capacitors are used where high capacitance and high voltage capacitors are needed. They are polarized. They are identified in the schematic as a capacitor with a plus sign showing the polarity. Care must be taken to install them with the right polarity. Usually the package has an identifying mark that indicates the positive or negative terminal (e.g. an arrow with minus signs that point to the negative terminal).

Electrolytic capacitors come in axial or radial packages. Use whichever package is most convenient. The larger electrolytic capacitors used in the power supply are also available as "can" capacitors containing multiple capacitors in a single package. Using can capacitors results in a more compact layout. However, they are more expensive and can be more difficult to work with since they require the drilling of some large holes in the chassis.

For capacitors in the .001 to 1 microfarad range use polyester or polypropylene film capacitors. The Xicon line of polyester film capacitors from Mouser is a popular choice. Others prefer Sprague "Orange Drop" polyester film capacitors.

Ceramic disc or silver mica capacitors can be used for the small capacitors in the tone stack. Ceramic disc capacitors are cheaper and more easily obtained. Some people feel silver mica capacitors sound better.

If you can't find the exact capacitor you need you can usually substitute a part with a capacitance within 10% of the desired value and a voltage rating greater than or equal to the specified voltage rating.

2.4 Switches and wire

Use standard UL approved switches with a 125V/3A rating for the Power and Standby switches.

Use 20 or 22 gauge insulated solid wire with a 600V rating. It is good to get a variety colors so you can color code your wiring.

2.5 Output Transformer

The Aikens/Delft output transformer specified in the schematic is a custom transformer. In the US it is available from Obsolete Electronics at www.obsoleteelectronics.com. If you are outside the US contact Stephen Delft at flying.kiwi@paradise.net.nz for information on pricing and availability.

A Hammond 125E universal output transformer can be substituted for the custom transformer. This transformer is readily available from many guitar amp parts vendors. It can be configured for a variety of primary and secondary impedances by selecting the appropriate secondary output pair. The transformer comes with a chart showing the available combinations. For the P1 use the secondary pair that gives you a 4.2K primary impedance. For example, if you have an 8 ohm speaker use pins 2 and 6. The brown and blue wires go to the B+ and EL84 plate. The red center tap wire is unused and should be insulated to prevent shock.

2.6 Power Transformer

The BOM calls for a Hammond 269EX power transformer, but any transformer with secondary outputs of 190-0-190 @ 65mA and 6.3V @ 2A can be used. A Hammond 369EX can be used if you're in a country that does not have 120V mains. The 369EX is a universal version of the 269EX that handles a variety of primary voltages.

2.7 Speakers

Any 8" to 12" guitar speaker with a power rating of 10watts or more can be used. Good results have been reported with Mojo MP10R and Jensen Reissue C10Q speakers. A stereo speaker is not suitable for a guitar amp because it will not stand up to the transients produced by a guitar.

2.8 Chassis

There are three common amp configurations: a head, a combo amp with the chassis mounted horizontally and controls in front, or a combo amp with the chassis mounted vertically and controls on top. The AX84 Gallery contains examples of both kinds of combo amps.

The amp fits neatly on a 12x8x2 chassis if building a head or a horizontally mounted chassis. A 13x5x2 chassis can be used if building a vertically mounted chassis with the tubes along the back edge. You may want to use a 16x8x2 chassis to make the layout of the parts easier and leave room for future expansion.

Hammond has a line of steel and aluminum chassis that is very suitable for guitar amplifiers. Either a steel or aluminum chassis can be used. Steel is more durable and easier to paint but much harder to drill. Aluminum is fine for an amp the size of the P1.

2.9 Tubes

Among the new tubes that are easily obtained, people have reported good results with the EL84, 12AX7LPS and 12AX7WXT+ from Sovtek and the EL84 from JJ/Tesla. Power tubes are usually sold as matched pairs, but some vendors sell single tubes.

3 Laying out the chassis

Once you have all of the parts, you need to layout the chassis. Dave Sorlien’s AX84 jpegs in the Gallery section of the AX84 website is a good example of a layout using terminal strips on a 12x8x2” chassis.

This section describes some things to consider when laying out the chassis.

3.1 Physical layout

Make sure the jacks, sockets and pots mounted along the edge won't interfere with parts mounted on the underside of the chassis. Imagine how chassis will be mounted in the cabinet and make sure there is enough clearance for the speaker and mounting brackets.

3.2 Grounding

Amps traditionally use the chassis for signal ground. This is not the best choice since it can create ground loops and bad ground connections may develop over time. It is better to use star grounding in which all of the local grounds are collected at a single "star ground" point. With star grounding there is only one connection between the chassis and signal ground.

Here are some rules for laying out a star ground. More information on grounding can be found in the Tube Amp FAQ and the Tech Info page of Aiken Amplification (see the Links page on the AX84 website).

(1) Connect the power transformer center tap directly to the negative terminal of the first power supply filter cap then run a separate wire from the negative terminal to the star ground point.
(2) Collect the ground points of each tube and its associated resistors and capacitors to a local ground point that is not connected to the chassis. Run one wire to the star ground point from each collection.
(3) Run exactly one wire from the star ground point to chassis.
(4) Insulate the input and output jacks from the chassis.

The safety ground wire from the mains is separate from the signal ground. Run a wire from the AC ground to the chassis near where the AC power enters the chassis.

3.3 Insulated jacks

To insulate the input and output jacks either use plastic insulated jacks or metal jacks with insulating washers. Some people prefer the increased durability of metal jacks. Insulating a metal jack requires a shoulder washer with a 3/8" internal hole that fits a ½" panel hole.

3.4 Minimizing interference

To minimize coupling between the power transformer and output transformer orient them so their plates are at right angles. Place them at opposite ends of the chassis.

Keep the input stage wiring short and away from the output stages. This minimizes the possibility of oscillations caused by coupling of the output signal into the input.

Mount the grid resistors as physically close to the grid pins as possible.

Use a twisted pair of wires for the tube filament wiring. Route it away from AC lines and close to the chassis.

3.5 Wiring

The traditional method of constructing amps involved mounting the components on tagboard or fiberboard. This technique can be used for the P1 but it requires carefully laying out the board and mounting eyelets or terminal posts for the components. Boards and a staking tool for the terminal posts are available from some guitar amp suppliers.

Using terminal strips is a simpler method. They are easy to obtain and don't require any special tools. They result in a less compact layout compared to fiberboard.

Point to point wiring without the use of mounting strips can also be used. This is quick but it results in a messy layout that is hard to debug and modify.

4 Drilling the chassis

You will need an electric drill and a set of drill bits. The input jacks, pots, switches and screws require holes up to ½" in diameter. The 9-pin tube sockets require a ¾" or 7/8" diameter hole. A Unibit stepper bit that goes up to 7/8” can be used to drill all of the larger holes. It's available from most hardware or home improvement stores. Chassis punches (such as Greenlee punches) are cleaner and easier but are more expensive. A set of metal files is useful to clean up the holes after they are drilled.

If using a modular connector for the mains, it may be necessary to make a rectangular cutout.

The chassis will probably get scratched during the process of drilling it. If you plan to paint the chassis, do it after all of the holes are drilled.

Use grommets on the holes for the transformer leads so they don't fray and short to the chassis.

5 Assembling the amp

5.1 Tools

To assemble the amp you need a 30 to 40W soldering iron, 60/40 rosin core solder, a wire stripper, a wire cutter and needle nose pliers. It is useful to have a stand for the soldering iron, a sponge to keep the tip clean, desolding wick material and clip leads.

You should also have a multimeter. Try to get a multimeter that measures capacitance. This lets you verify the value of your components before you install them.

5.2 Soldering

This section describes how to solder for those of you who have never soldered before. However, the best way to learn is to be shown by someone who knows how.

Soldering is accomplished by heating the components to be soldered and allowing the molten solder to flow onto them. Do not try to melt solder on the tip of the iron and transfer it to the solder joint. It doesn't work.

Follow these steps when soldering:

- Keep the tip of the soldering iron clean. If it's dirty, wipe it on a damp sponge to clean it.
- Melt some solder on the tip of the iron. The molten solder helps to efficiently transfer heat from the soldering iron to the component leads.
- Heat the leads to be soldered by touching it with the tip of the iron.
- Touch the solder to the leads. The solder should flow onto the leads. Avoid breathing the fumes.
- Removed the soldering iron and allow the solder joint to cool.

The solder joint should be clean and shiny. If it is dull looking it may be a "cold solder joint" which is not a good electrical connection. If a solder joint is suspect, heat it with the iron to reflow the solder.

5.3 Pin Numbering

The pins on a 9-pin tube socket are numbered 1 to 9 in a clockwise direction when viewed from the bottom. There is a gap between pins 1 and 9.

The pins on the potentiometers are numbered 1 to 3 from left to right when the shaft is facing towards you and the pins are at the top.

5.4 Final checkout

When you finish assembling the amp, double-check the wiring and the components. Apply power without the preamp or power tubes installed and check the filament and plate voltages on the tube sockets. The plate voltages will be slightly higher than the voltages listed on the schematic because there is no load present. If everything is okay, power off the amp, install the tubes and power on again.

6 Troubleshooting

The Amp Debugging FAQ (see the Links page on the AX84 website) contains some tips on debugging amps. Although it is oriented towards fixing broken amps rather than debugging newly constructed amps, the information is still very useful.

When debugging a newly built amp the first things to do are check the wiring, make sure the correct components are installed, and look for bad solder joints.

Use a voltmeter to check voltages and compare them with the voltages listed on the schematic. Remember that you can calculate current by measuring the voltage drop across a resistor and dividing by the resistance. An incorrect voltage or unusual current may give you a clue to the source of the problem. A low voltage often indicates that something is drawing more current than the power supply can handle and dragging down the voltage.

Probing with a non-conductive object such as a chopstick while the amp is powered on is a good way to find bad connections or problems with the way the wiring is laid out.

Remember that dangerous voltages are present when the amp is powered on. Always drain the filter caps and disconnect the mains before working on the amp.

Never operate the amp without a load or you will damage the output transformer. You can use an 8 ohm 15 watt power resistor as a dummy load in place of a speaker.

6.1 Hum

Hum is usually caused by AC line noise leaking into the filament wiring or input stages and getting amplified. Look for bad wiring or a bad ground.

6.2 Squealing/Feedback

Squealing usually occurs when there is coupling between the input and output stages. The positive feedback causes the amp to become an oscillator. Vary the volume and tone controls to see if it affects the oscillation. That will tell you if the coupling is occurring before or after the control. Sometimes the problem can be solved by minor changes to the wiring (moving output wires away from input wires, shortening excessively long wires, etc.). Using shielded wire on the input jack can sometimes help a hum or squealing problem.

7 Building a cabinet

The last step is designing and building a cabinet. There are lots of creative possibilities.

The cabinet should protect you from the high voltages and hot tubes. Make sure there is enough ventilation so that the amp doesn't overheat.

Traditionally cabinets were made out of solid pine with dovetail joints and covered with tweed cloth or Tolex. Speakers were mounted on a baffle made of 3/8" or ½" birch plywood. If you use plywood for your cabinet make sure it is void-free plywood to avoid rattling or unwanted resonances.

Many people choose a stained wood finish for their cabinets. It is not as durable as tweed or Tolex, but it is much easier.

8 Frequently asked questions

8.1 How much will it cost?

The major parts and their cost are:
- Output transformer $30
- Power transformer $30,
- Chassis $20
- Tubes $15-$20
- Speaker $30-$50
- Sockets, resistors, capacitors, pots, switches, jacks $50.

Note that this is more than it would probably cost to buy an amp.

8.2 How long does it take to build?

Planning the amp and getting all of the parts may take a few weeks. The drilling of the chassis and wiring can be done in a weekend.

8.3 What is FIL in the schematic and BOM?

It indicates the filament for the tubes and is not a separate part.

8.4 How do I add reverb, vibrato and other features to my amp?

You can check out other tube amp schematics to get an idea how these features are implemented. For reverb you need to an additional preamp tube and transformer. If this is your first amp it is best to keep it simple and not attempt too much.

Appendix A – Additional Parts list

In addition to the parts in the BOM you might need to the following parts to complete the amp. The Mouser part number is included. The list includes both metal jacks and insulated jacks. Either use the metal jacks with insulating washers or the insulated jacks. To insulate a metal jack you can use two shoulder washers or a shoulder washer with a matching flat washer depending on the thickness of the chassis.

Quantity	Part	Mouser Part #	Notes
1	Fuse, 1A SLO-BLO	5760-13001	
1	Fuse Holder	5767-345321	
1	Lamp Holder	606-5100-822	
1	Lens	606-25P-307G	Plastic lens
1	6.3v lamp	606-CM47	
1	1/4" plug	171-1206	Speaker plug
1	Power connector	161-0707-1	Modular connector for AC line cord
10	8 lug terminal strip	158-1008	
10	5 lug terminal strip	158-1005	
4	knobs	45KN012	Chicken head knobs
2	Insulated 1/4" jack	502-N-112-A	
2	Metal 1/4" jack	502-112	Use with washers below
4	Shoulder washer, .385	534-3069	
2	flat washer	534-3222	
Other parts			
1	12x8x2 chassis		
1	Speaker		
2	9 pin tube socket		
	22 gauge solid wire		
	assorted grommets		For protecting transformer leads
	#4-40 machine screws		For 9 pin sockets
	#6-32 machine screws		For terminal strips, etc.
	#4,#6 lockwashers, nuts		
	solder		
	heat-shrink tubing		