Antique Wireless Association – '48 Special Guitar Amplifier PCB

’48 Special: The Circuit

This is one of the simplest possible guitar amps – a pentode gain stage driving a beam power output tube. Fender and Gibson used near identical circuits for the 1948-'52 “Champion” (later the “Champ”) and Gibson’s earliest version of the GA-5 amp. It delivers 3-4 watts, fine for practice or for a church or coffeehouse (though 4 watts can’t keep up with drums or band instruments).

This project was intended to make an instrument amp that is simple to build at low cost, with some options for customization (there’s no perfect amp design, but many have a favorite). There are no hard to get parts, and many will have some of them already – the parts list provided can be followed exactly, or ignored completely (the latter does require a trifle more skill in the art...). So here’s a circuit description by functional blocks (look at the schematic as you follow along):

The gain stage is a 6SJ7, with component values close to what the RCA tube manual recommended for maximum output and lowest distortion. About 180 mV will drive the amp to full output; more than 600 mV will limit in the input stage, so there will be some distortion even with the volume backed down. The gain (it’s about 130X) goes up with the value of the output load resistor R5 (the plate load is R5 plus the 1 meg volume pot and R6, the 1 meg 6V6 grid resistor, all in parallel). Increasing R5 above 330K will not increase gain further and will reduce the maximum output of the stage. Fender and Gibson used “grid leak bias” for the first stage; this could be implemented on this PCB by changing R1 from 1 megohm to 4.7 megs, and replacing R3 with a jumper wire. Grid leak bias is not as predictable, is more susceptible to overload with modern pickups and pedals, but blues harmonica players seem to prefer amps that use it. Lowering the screen resistor R4 to 1 megohm will reduce the plate voltage and headroom, “compressing” at a lower input level, which may be desirable to some, depending on the guitar and playing style. The coupling capacitors C1 and C4 may seem small at .02 uF, but pass frequencies well below the guitar’s low E string at 80Hz. Don’t expect any change if you increase the values. C2 and C3 can be reduced to reduce the low frequency response. R2 is a “grid stopper” which helps reject radio interference.

The output stage is a 6V6 which has a 14 watt dissipation rating. At 300V, with the cathode around 15V, there’s about 285V across the tube. 35 mA x 285V gives 10 watts, a safe operating point for long tube life. If it’s near the maximum 14W, it’s best to reduce it by increasing the cathode resistor – a different tube could be higher. The cathode current can be calculated by measuring the voltage drop across R7, the cathode resistor, and dividing that by the resistor’s value. So if you measure 16V, current is (16 / 470) or .034A. R7 should be changed to a lower value if supply voltage is lower – for instance, about 330 Ohms with a 265V supply. It takes about 30V peak-to-peak (twice the grid bias) to drive the 6V6 from full-on (about 80 mA) to near zero current to obtain full output. The output transformer steps up this

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varying current to a higher value for the low-impedance speaker. Since the cathode bias resistor is in
the current loop with the tube and output transformer, it’s bypassed for signal by C5. Without it, there
would be less gain, less maximum output power, and a “thinner” sound with less bass. A higher value
can be used, though 22 uF is sufficient. There is provision for a “grid stopper” R14, but it will have little
effect – a wire jumper can be used in place of a resistor.

The **power supply** can use one of three different circuits: a voltage doubler for 110-140VAC, a full-wave
bridge for transformers from 220-280VAC, and a full-wave center-tap for transformers from 440VCT to
560VCT. The last one makes less efficient use of the transformer (which has to be 30% larger than the
first two for same performance) but allows the use of many vintage parts. All circuits give about 350V at
the first filter capacitor, dropping to about 310V after R11, and dropping further to power the 6V6
screen grid and 6SJ7 gain stage. The cascade of filter sections reduces power supply ripple to a level
close to tube noise – if this amp hums, it won’t be due to the power supply. R10 is a bleeder that will
discharge the capacitors in case it’s powered up without tubes or powered on, then off before the tubes
draw current. Voltage will drop to less than 50 volts in about 2 ½ minutes after turn-off. For a faster
discharge (or if larger filter capacitors are used), change R10 to 220K, 1W.

The **heaters** (filaments) of the tubes are powered by a 6.3VAC transformer or winding; heater traces are
kept away from the input where the AC voltage could introduce hum. A center-tapped heater winding
can reduce hum since the two sides are 3.15VAC of opposite phase; reduced hum coupling or even
cancellation will result. Two resistors R12 and 13 can provide an artificial center-tap if the winding is not
tapped. Hum coupling can occur inside the tube from heater to cathode; this is best limited by biasing
the heater winding positive – the 6V6 cathode at ~15VDC is a handy source.
'48 Special: The Parts – and Substitutes

Many will have some of the necessary parts on hand; hamfests and salvage can provide some parts at little or no cost. Don’t strip a repairable radio or stereo console for parts, but if it’s in lousy shape, have at it! Some options for substitution are given below:

The **chassis** should be large enough that the heavy parts aren’t all at one edge. Lay out the parts on paper to find an effective arrangement. Measure twice, cut once! The recommended chassis is aluminum; the same size is available in painted steel in gray or black. Steel is harder to drill, file and cut, and of course the painted finish must be protected during construction to avoid scratches.

The ideal **power transformer** would have a heater (filament) winding of 6.3V @ 0.75A or more, plus a high voltage winding of 110-140V rated for 140 mA or more, or 220-280V @ 75 mA or more, or 440-560V center-tapped @ 50 mA or more. Any of these will give the proper B+ voltage of 260 - 320V when connected as shown on the schematic. It’s possible to use a transformer of higher voltage with a (off PCB) resistor or two in series to drop voltage, but this isn’t recommended, since the voltage on the capacitors will be higher (AC voltage x 1.4) until the tubes warm up. The value (and wattage) of such a resistor is not easy to calculate since the AC current waveform has a high peak value. The lowest cost option may be separate transformers for heater and B+. Some other possibilities with both filament and B+ windings:

Hammond 262F6, 261E6, or 270AX
Antek AS-05T120
Allied 6K88VG or 6K49VG

The **output transformer** can be 5K to 8K primary with a secondary to match your speaker (or conversely, you select a speaker that matches the transformer you have). 8K is ideal for a B+ voltage over 300, 5K is ideal if it’s closer to 250V. But it won’t make a big difference. Many radio and TV output transformers were in this range – if it was driven by a 6AQ5, 6V6, 6BQ5, 6CM6 – it’s perfect! Antique Electronics Supply sells (expensive) replacement guitar amp transformers, but also has the inexpensive P-T31 (8K to 8 Ohms).

**Filter capacitors** must be at least 200V for the voltage doubler caps (C7, C8, if used); others should be at least 400V. Value can vary from 47 uF, but not too far – 33 is adequate, 22 is marginal, larger may not fit.

**Resistors** can be carbon comp (measure ’em first!), carbon film or metal film. Modern ones are often small enough that the next larger size (1W for 1/2W, etc.) will fit. The 5W resistor R11 is wirewound. The value of R11 can be adjusted to give the proper B+ voltage – keep it in the range of 220-1200 Ohms (lower and power supply filtering will be decreased; higher and the resistor will dissipate too much power).

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The **coupling capacitors** have a dual footprint for large and small parts. Mylar (polyester) are smallest, any voltage rating 400V or higher will do.

The **6S7J** comes in metal and glass versions, and is the best choice for V1 (though you could use a 12SJ7 and 12V6 with a 12.6V heater transformer). You could try 65H7, but the data sheet says “not recommended for audio” presumably for hum reasons. 6SK7 works well, being fairly linear at the low audio level in this amp. The **6V6** has numerous tubes with the same pin connections, but all of them bias differently. 6F6, 6EZ5, 6EY6 are close but all would require a higher value cathode resistor R7. The oddball 7EY6 will drop in without any changes. A 6L6 could deliver 10W with a lower impedance output transformer and a bigger power transformer – that’s no longer a beginner’s project.
’48 Special - Construction Notes

If you haven’t worked with high voltage or line voltage before, find someone with experience to help. A mistake with 120 VAC or higher voltage DC can be painful, even fatal!

If you’ve ever assembled a printed circuit board, that part shouldn’t be difficult. Mount small parts first, then larger ones. 1 watt and larger resistors should be spaced about 1/4” above the PCB for best heat dissipation. The design has the tube sockets on the opposite side from the other parts, and the four tube socket holes can mount the PCB, though corner holes are provided too. Mount the tube sockets to the PCB using screws and threaded spacers before soldering, and the sockets will align with the chassis holes when you get to that stage.

Lay out all components on the chassis (or a sheet of paper the same size) before you drill a hole. Plan locations that keep wire lengths down (or you may have to splice wires to a transformer). The PCB drill template can be printed at actual size and used to punch hole locations in the chassis. Drill all of them with a small bit and check dimensions – if one is off, it can be “moved” with a small round file, then drilled larger as necessary. Holes larger than ¼” can be made with a step drill – get one with a 1 1/4” or larger maximum diameter to handle the socket holes.

The listed IEC connector will fit a 1 1/8” round hole or (1 1/16” with minor filing). Other IEC connectors are more work – drill corner holes and open the rectangle with a jigsaw or nibbler, then file to finish.

Transformers can be mounted inside the chassis if it’s deep enough. If they’re mounted on top, use rubber grommets to protect the wires passing through the chassis.

Remember, tube amplifiers don’t like open circuits – a shorting jack with a load resistor can protect against component damage if the speaker gets unplugged accidentally. A 39 or 47 Ohm 1W resistor is enough; a lower value can be used but should be a higher power rating.

If the fuse blows, check for miswiring or a reversed diode or capacitor. If you have problems after power-up, checking voltages at the tube socket pins may lead to the problem area – below, approximate DC voltages on tube socket pins (clip negative meter lead to ground):

<table>
<thead>
<tr>
<th>Pin</th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>17 (tied to the 6V6 cathode)</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>296</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>293</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>17 (tied to the 6V6 cathode)</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>17</td>
</tr>
</tbody>
</table>
’48 Special: Options and Mods

**Second input:** Many vintage amps had dual input jacks. It’s essential to isolate them with series resistors. Without them, the controls on guitars will interact, and a low impedance source like a keyboard will kill the guitar entirely. Resistors of 50K to 75K are typical. If one of the jacks is a shorting type, the gain on the other one will dropped by half if it’s the only one in use (both are full gain with both in use). Amps with this connection usually labeled the “shorting” jack “HIGH”, the other “LOW”. Using 33K and 68K would make the “Low” input 1/3 of the gain of “High” (about 10 dB less).

![Resistor Diagram]

**Second output:** This can be tricky – plugging in two speakers will present a lower load impedance, resulting in less power and more distortion. A lower load (right down to a short circuit) won’t damage a tube amp. One or both jacks should be a shorting jack connecting a load resistor to prevent a completely unloaded condition – driving a tube amp into clipping with no load risks an arc-over in the output transformer or near it due to the high voltage generated.

![Speaker Diagram]

**Tone control:** This amp doesn’t have enough gain to insert the typical “tone stack” with bass and treble controls. But a 1 to 2 meg pot can be connected across the volume control as shown to cut or boost treble (no boost at full volume). Log (audio) taper will be best.

![Tone Control Diagram]
Pilot light: A 6.3V pilot light can be used by running the filament transformer wires to the pilot light terminals, then wires to the filament terminals on the PCB. A 120V neon pilot light can be used in parallel with the AC transformer primaries. There are switches with a neon pilot light built-in, but most require a rectangular cutout that is difficult to make. There are lighted rocker and pushbutton switches that fit a round hole (most lighted toggle switches are low voltage, but can work if both bulb terminals are separate from the switch).

Component changes: Installing parts on a circuit board is not hard, but replacing parts takes practice, and each replacement is one more chance of PCB damage. If you’d like to try different resistor values, the safest way is to start with the highest value, and “tack solder” another part across it in parallel. When you decide what value is best, calculate the equivalent parallel value and replace with the nearest standard value (or go back to the original one without touching the PCB solder joint).