

El Cheapo tube amplifier

Introduction

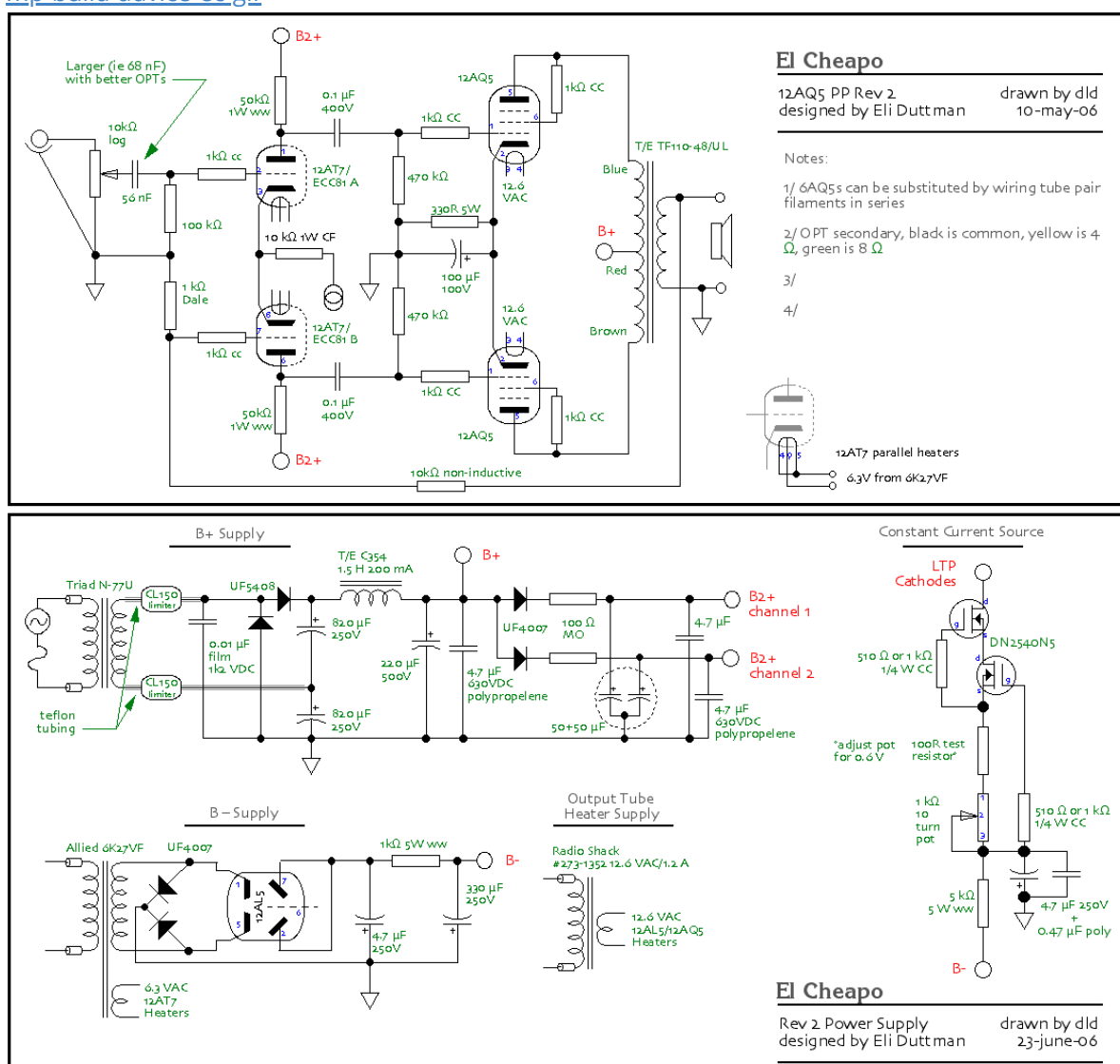
Outcome of a number of forum member on the [Decware audio forums](https://www.diyaudio.com/forums/attachments/tubes-valves/893670d1605483086-stereo-tube-amp-build-advice-ec-gif) designing a cheap beginner tube amp which sounds like a more expensive amp. Currently a lot of information is spread across a lot of threads (e.g. on <https://www.diyaudio.com>), where one of the original designers, Eli Duttman, is still very active. This document hopes to collect quite some scattered knowledge and provide a good starting point in learning about the 'El Cheapo' stereo tube amplifier.

Discussion

In this section we try to shed some light on the schematic, choices of component, both values and type and availability.

Electrical function

<https://www.diyaudio.com/forums/attachments/tubes-valves/893670d1605483086-stereo-tube-amp-build-advice-ec-gif>



Here we discuss the electrical function of component (groups). Let's start at the input and work towards the output, followed by the power supplies and Constant Current Sources (CCS).

Input

The input is first fed to a potentiometer that serves as a volume control. It is 10k as this is a nice middle ground with respect to the input and output impedance. Mouser has the 10 KOhm volume controls. They are \$1.25 Alpha Carbon, stock # 31VJ401. Amps (including "El Cheapo") which employ global NFB loops that encompass the OT "iron" should filter infrasonic noise out, at the unit's input. Suppressing said noise is prophylaxis against core saturation. When the "iron" is of decent quality, a 1 pole RC filter whose F3 is in the 16-18 Hz. range is adequate. The "El Cheapo" schematic shows a no longer recommended guitar amp OT that can't provide full bass extension at full power. F3 for the 0.056 μ F/100k combination shown is 28.4 Hz. For any rational signal topology, better OT "iron" equals better amp.

The other 'input' of the [LTP](#) is fed by the signal from the secondary of the OT to achieve negative feedback to linearize the amplifier and therefore limit distortion. The 10k non-inductive resistor together with the 1k Dale resistor forms a voltage divider, controlling the amount of feedback. More about it can be found in the section about [NFB](#).

Why does it need to be filtered out at the input? The coupling caps also filter it out. Filter in input adds extra low frequency phase shift. Is low frequency phase shift less important (for e.g. stereo imaging)?

Long Tail Pair

The LTP provides the push-pull output stage with two out of phase signals. The long tail is a CCS in this case, making sure the two output signals are of equal amplitude.

Carbon Composition (1k) grid stoppers are used to limit the high frequency content as a result of the high pass filter they form with the Miller Capacitance (~ 92 pF) of the 12AT7. This results in an F3 of 1.7MHz MPOT. Does that make sense?! It seems phase shift is the limiting factor.

A Carbon Composite resistor is advised because it is non-inductive and non-metallic. Grid stoppers are used to suppress parasitic oscillation. Because carbon composition (CC) is non-metallic, it will not act as an antenna for RF. Because CC is non-inductive, adverse resonant interactions with all sorts of capacitances do not occur. The downside to CC resistors is noise and drift. Fortunately, exact value is not critical in a stopper and CC noise is current related. The current present in a control grid circuit is vanishingly small.

Merlin Blencowe: People should stop scaring newbies with this red herring. Resistor inductance is utterly negligible compared with the damping resistance. You do not need bulk carbon stoppers.

DF96: Metal film resistors in the kohm region are substantially resistive up to VHF frequencies. Beyond that they still add loss, and a little inductance may even help. Really high power stuff uses lossy inductors to stop parasitics

DF96: No need for grid stoppers to be purely resistive. There may be some advantage in a little inductance too. You don't have to use CC!

Small grid stoppers prevent RF parasitic oscillation in that stage. Large grid stoppers cause feedback loop instability and treble rolloff, but provide scope for 'tube rolling' to be used as a form of tone control. Hence, typically, hi-fi uses small grid stoppers to keep each stage stable. Guitar amps use large grid stoppers to cope with long wires and poor layout, but not much global feedback.

[High μ , high current valves such as the ECC81 (12AT7) and 12AY7 are well suited as they operate well even at low anode voltages, providing lots of output swing for overdriving the power stage, while the ECC83 (12AX7) performs well when less clean headroom and a touch more preamp distortion is desirable.][LTP_tyube_type]

The plate resistance (R_p) for the 12AT7 is 11 KOhms. It's "normal" to use at LEAST 3X R_p for the load resistor. If we use 47 KOhm load resistors ($> 4X R_p$), the voltage on the 12AT7 plates will be about 189 V. That's not too far off Jim's "ideal" of 200-220 V. It's settled; the 12AT7 plate load resistors will be 47 KOhms.

Something just dawned on me. An INDUCTIVELY wound resistor is the very best choice for the 12AT7 loads. Why? Examination of other PP amp circuitry will show phase compensation networks in the NFB loop. Those networks lower NFB as frequency increases, which is the same as increasing gain as frequency increases. The small amount of inductance in a "regular" wirewound resistor will cause a SLIGHT rise in gain as the frequency increases. Automatic phase compensation is the result. The compensation will not be perfect. Only tweaking with an oscilloscope can achieve "perfection", but every little bit helps.

MPot: Simulation shows no effect of 50uH inductions (upper range of wirewound resistor inductance). 50mH (!) shows a small effect on phase. Effect on gain is more pronounced above 50kHz. Simulation does not show beneficial effect of wirewound resistors.

My choice for the 12AT7 loads is the \$1.86 1% 50 KOhm RS5 by Vishay/Dale, Mouser stock # 71-RS5-50K. It's overkill at 5 W., but you do what you have to do.

TODO how are they biased?

The 10 Kohm CF resistor between the LTP's tail and the CCS drops some volts and also blocks the conduction of heat from the tube (via the wiring) to the CCS. Unwanted heat is the mortal enemy of all things electronic, especially SS. I took no prisoners. BTW, that resistor also slightly increases the net load the LTP tail works into.

MPot: I can find no evidence that an CF resistor will block heat better than e.g. metal film. The film is ~200nm thick, 0.2% of a 2mm resistor.

As the B- is much lower, I plan to lower the resistor to (less than) 1k.

Constant Current Source

Jung, W. (2009) High Performance Current Regulators Revisited (letter), AudioXpress, April, pp40-2

<https://www.diyaudio.com/forums/tubes-valves/102335-ixys-ixcp10m45s-ic.html?perpage=25&highlight=&pagenumber=4&perpage=25&highlight=&pagenumber=4> Not much to be found...

6-7mA per LTP. Can be measured by a multimeter across the 100R test resistor. 0.6V translates to 6mA. Adjustable by the 10 turn 1k pot as the gate-source voltage of FETs vary considerably.

We will use smaller TO92 case FETs, but the topology is as shown. Doug used 510 Ohm gate stopper resistors. We'll use 1 KOhm, the same as will go on the grids of the 12AT7s and 6V6's. A 1% 100 Ohm metal film resistor will go in series with the 1 KOhm trim pot to provide a test point. The pot is adusted to yield a drop of 0.6 V across the 100 Ohm resistor. Ohm's Law tells us that the current flowing is 6 mA, exactly what we want. Doug's selection of a 10 turn trim pot. is NICE, but something not quite so slick will work too.

Stopper resistors (grid/gate) stop parasitic oscillation, which is BAD. Stoppers should be Carbon composition, as their non-inductive construction does not form resonant "tanks" with stray capacitance. Carbon, being non-metallic, does not act as an antenna for RF. To ensure the anti-antenna function is maximized, the bodies of stopper resistors need to be as close as possible to

the tube or FET being protected. That means right at tube socket lugs or leaving only enough wire to get a clip on heatsink, like a hemostat, on FET gate leads, while soldering.

MOS semiconductors, like the FETs in the CCS circuitry, are VULNERABLE to destruction by the discharge of static electricity. So, wear a grounded wrist strap while handling MOSFETs. Once the FETs are wired in, they're safe. A grounded wrist strap should be part of everyone's tool box. PC expansion cards can get zapped too.

DN2540N5 are high voltage (400V) depletion mode MOSFETs. The 510R are gate stoppers. F3?

5k resistor and capacitors are used more for B- filtering. TODO why is 5W necessary? $6\text{mA}^2 \times 5\text{k} = 0.18\text{W}$?!

Veroboard seems easy for construction. A single trace is said to be able to conduct 2-3A of current; a lot more than the 6mA required.

Coupling Caps

The 0.1uF 400V coupling caps form a high pass filter together with the 470k grid leak resistors that has an F3 of 3.4Hz. This is far enough below the audible range to pass all audible frequencies without significant attenuation. Good sized interstage coupling capacitors avoid deleterious phase shifts, which can be particularly troublesome in units containing feedback loops. Heaven forbid that most definitely unwanted fulfillment of the Barkhausen Criterion for oscillation occur. We adhere to the 2 octaves away from the passband notion. Some folks follow a slightly more rigorous rule of a decade away.

They are 400V types as they have to block the high DC voltage from the LTP.

Output Stage

The output tubes amplify the signal and drive the load (OT + speakers) in a class AB, push-pull fashion. The 12AQ5 (EL90) was chosen for its low cost. Any member of the 6V6 clan will work using unchanged signal path parts values. Lower heater voltage might result in less heater hum. 6V6 is much easier to buy in Europe, especially as a matched pair.

In any power handling range, push/pull "iron" costs less than the SE stuff.

Triode mode operation is shown in the schematic. If you want the extra power Ultra-Linear mode yields, connect the 1k screen resistors to the UL taps of the OT, instead of the plates.

It is possible to add mode switches. If you do, change mode **ONLY** in the **unpowered state**.

[6A3SUMMER](#) For others who may wish to duplicate your amplifier [red. another amp than this one], I describe what is often a major oversight on push pull amplifier circuits:

Unless you want to find Extremely well matched 6V6 pairs, the Individual Self Bias of Mona's schematic is required. The DC balance is quite good with fairly matched 6V6 pairs, and perfectly balanced for closely matched 6V6 pairs.

Using a common self bias resistor, and single bypass cap, is not a good idea.

Find the \$ and the room for 1 more resistor, and 1 more bypass cap.

That way, the output transformer will be happy with new tubes, and will be happy years later when both tubes have aged.

Make sure to use 1% resistors, or better.

We are talking about a few 100s of microamps un-balanced plate currents; versus several mA of un-balanced plate currents.

We could also use the bias from the Baby Huey. $\sim 0.7V$ over the 16R resistor gives $\sim 44mA$. Change resistor to change current. Current through bottom transistor negligible. Aim for 40mA or less probably. 18R would give 38mA. Or as stated by the Baby Huey designer, Gingertube, himself:

"EL84 Cathode will sit at around +10 to +12 Volts, normal cathode biasing voltage. The voltage will settle at whatever bias is required to maintain the CCS current as idle current through the tube. With the 16 Ohms in the emitter of the bottom transistor in the CCS Bias Blocks you will get 40.6 mA idle.

If your B+ is higher than say 320V I would advise using 18 Ohms instead which will give you 36.1 mA idle."

Output Transformers

The Dynaco ST35 Z565 OT's are highly regarded. Clones are available, with different quality as can be seen in a link present here:

<http://triodeelectronics.com/z517wadyoutr.html> TODO Not in stock

<https://www.dynakitparts.com/shop/z-565-output-transformer/>

TODO are these the same?

Hammond 1608/20?

Elcor (available in Europe from Don Audio): <https://www.don-audio.com/Edcor-CXPP25-MS-8K>

<https://www.tbtroehrentrafo.com/produktseite/gegentakt%C3%BCbertrager-atr-15-e-f%C3%BCr-el-84o-%C3%A4> 34,00 euro

<https://www.ringkerntrafo.nl/shop/high-end-audio/uitgangstrafo-s/s-series-push-pull-ugt/756/20watt-8kohm-push-pull-uitgangstrafo.html> 78,50 euro (located in Neede)

<https://www.ringkerntrafo.nl/shop/high-end-audio/uitgangstrafo-s/h-series-push-pull-ugt/761/20watt-8kohm-push-pull-uitgangstrafo.html> 134,59 euro (located in Neede)

OT's (and iron in general) is heavy and expensive to ship. That, together with 'customs', makes importing them expensive. Buying local is cost effective.

Negative Feed Back

10k non-inductive. During the development of "El Cheapo" DIY Audio "guru" SY pointed out that the NFB was working into a high impedance non-inverting control grid. An inductive NFB resistor could cause trouble. Both MF and CF resistors are spiral trimmed and that introduces inductance. The low cost answer was employing meter matched (between channels) CC resistors. Use Caddock parts, if your bank balance can tolerate the "hit". MPot MF capacitance is comparable to 1cm of wire. Why bother using CC?

Dale resistor because of noise. Vishay/Dale 1% tolerance RNnn milspec metal film resistors are quiet and non-magnetic. They are excellent where low noise is important and the tight tolerance is (obviously) good.

B+ supply

Parallel caps seems to be [unnecessary](#).

The needs of the 12AT7 splitter/driver rule the roost. A 12AT7 section sounds **good** with 200 to 220 V on the plate and an IB of 3 mA. Therefore, the B+ rail should be about 355 V. We need more than 250V on the secondary for that. Something like 275V would be more appropriate.

The thermistors make a big difference. The power trafo does not clang at turn on and B+ rise is delayed a bit, which reduces the chances of cathode stripping.

You can put the NTC devices on either the primary or secondary. The secondary connection is particularly useful when B+ and heater windings share the primary. The shared primary is not a concern in "El Cheapo". However, a proven track record is. Jim McShane uses a CL120 on each side of the rectifier winding in H/K Cit. 2s, with CONSIDERABLE success. Follow the leader!

Jim: Eli's explanation of where I use the limiters is correct. I DO NOT want to delay heater current or (worse by far) bias circuit. So I use the limiters in the secondary supply between the power tranny and the voltage doubler. It works VERY well!

MPot: These thermistors remove the initial voltage overshoot, which could go up to 550V with nothing or 440V with 5R (cl150) on both side of the secondary. 10R (cl120) keeps it limited to 360V. Choke resistance (65R) was not taken into account...

I like BIG caps. in doubler stacks. They keep the rail voltage up and the ripple fundamental down. The choke is ESSENTIAL to kill the "hash" that comes from PN diode rectification and the considerable amount of ripple overtones the large caps introduce. Follow the "extended" CLC filter with SUFFICIENT energy storage for the task at hand. The ferrite beads on the primary leads keep any SS diode switching noise from escaping and they keep power line crud out of the primary. The beads I called for have large enough holes to allow a 1 turn loop and they are burnished, which prevents cutting of wire insulation.

You will be very hard pressed to find a more economical high performance setup for the B+ PSU than "full wave" doubling a boosted [Triad N-77U](#) with UF5408 diodes.

A \$0.27 ferrite bead [stock # 623-2643250402] is mounted on each primary lead of the trafo.

Why not take the B- also from the B+ PT? Roughly same voltage.

Current draw: 6mA (as sunk by the CCS) and ~79mA according to EL90 datasheet x2 (as this is a stereo system) = ~200mA

Believe it or not, 3 transformers were (sic) the inexpensive route. Triad's N-77U and N-68X are **bargains** for getting 300+ V of B+. Things change over time. Anybody in North America considering an "El Cheapo" build can get a complete set of power "iron" from [Allied Electronics](#).

- Stock # 70218190 = main B+ \$32.59
- Stock # 70218344 = 2 "12" VAC windings for B+ boost and heater power. \$16.73
- Stock # 70009000 = B- feed and 12AT7 heater power. \$16.83
- Stock # 70218145 = B+ filter choke \$8.62

Approx. 75 dollar for a reasonably sophisticated set of power "iron" is (IMO) a pretty good deal. FWIW, [Triode Electronics](#) charges approx. \$100 for a ST-35 power trafo and that chunk of "iron" will not completely satisfy the needs of an "El Cheapo".

And for Europe:

Transformers:

- (~~<https://www.digikey.nl/product-detail/nl/triad-magnetics/N-67A/237-1869-ND/4915283>~~ 37,53 euro, with end bells and more power, 150VA iso 100VA), B+ only
- (~~<https://www.tbtroehrentrafo.com/produktseite/netztrafo-ntr-110>~~ 39,80 euro. B+ 220mA & heater 4A, no end bells, lay down, bells available I think.
- <https://www.tbtroehrentrafo.com/produktseite/netztrafo-ntr-1600> 86,90 euro. B+ 250V 260mA & heater 3.5A & 55V 100mA. Standup with end bells.
- <https://www.tbtroehrentrafo.com/produktseite/netztrafo-ntr-400> 76,30 euro. B+ 250V 400mA & heater 6A & 50V 100mA. Laydown no end bells. End bell: <https://www.tbtroehrentrafo.com/produktseite/endbell>

- afo.com/produktseite/haube-f%C3%BCr-baogr%C3%B6%C3%9Fe-m-102 7,50 euro
- <https://www.ringkertrafo.nl/shop/high-end-audio/voedingstrafo-s/719/4n1885-voedingstrafo-voor-buizenversterkers-103va.html> 89,00 euro 250V 300mA & 2x heater 2.5A & 50V 100mA. Also 275V tap which seems to be what we need.
- <https://www.ringkertrafo.nl/shop/high-end-audio/voedingstrafo-s/322/5n1609-voedingstrafo-voor-buizenversterkers-140va.html> 95,00 euro 230V 400mA, heater 7A & 40V 100mA
- <https://www.ringkertrafo.nl/shop/high-end-audio/voedingstrafo-s/722/6n1917-voedingstrafo-voor-buizenversterkers-196va.html> 105,00 euro 230V 720mA, 2x heater 2A & 50V 100mA.
- <https://www.digikey.nl/product-detail/en/hammond-manufacturing/369AX/HM5076-ND/454574> 62,45 euro, with end bells, 125-0-125 @ 115mA, 6.3V @ 2A TODO what is the B+/- current need? B+ 200mA, B- 15mA

Standup transformers are preferred with laydown transformers and vice versa for lower hum coupling. With toroidal (laydown) output transformer, a standup power transformer is preferred.

4n1885 is unpotted. One could use pvc pipes or just an end cap to cover them.

Chokes:

- <https://www.hammfg.com/part/266C24> 15,09 euro. No end bells. 24V 85mA. circuit change needed
- <https://www.don-audio.com/Hammond-Choke-5H-200mA-DC-193H> 29,96 euro, End bells, 5H (!), 200mA
- Hammond 193J or M?
- <https://www.digikey.nl/product-detail/nl/triad-magnetics/C-24X/237-1777-ND/4915191> 7,61 euro, no end bells, 1H 240mA

The method employed by Hegeman and others was used in "El Cheapo" (schematic provided). The LC reservoir section is critical to high performance. A refinement is inserting a LC "hash" filter made from a high current RF choke and a 1000 pF. mica or high quality ceramic (NP0/C0G) cap. between the doubler stack and the reservoir section.

The currently recommended choke is the Triad C-24X (1 H./240 mA.). The doubler's pair of **LARGE** electrolytics do a good job of crushing the ripple fundamental. However, the highly triangular ripple waveform contains overtones of the fundamental extending well up into the RF region. That trash, along with any SS diode switching noise, is the primary target of the choke. If you want to improve filter action, insert an LC section made from a RF choke and a 1000 pF. mica or NPO ceramic capacitor between the doubler stack and the "standard" style inductor.

As for voltages, the needs of the 12AT7 based small signal circuitry rule the roost. The 12AT7 triode sounds *good* with 200 to 220 V on the plate and an IB of 3 mA. That makes a B+ rail slightly over 350 V. "perfect". By itself, the N-77U does not get there. Use 1 of the 2X "12" V. windings of a Triad VPS24-1800 to boost the B+ rail voltage up and the 2nd "12" V. winding to energize the heaters of the 12AL5 and the "finals".

Builders residing in "240" VAC zones can use the Triad power "iron" mentioned, as both the N-77U and the VPS24-1800 have dual primaries. Unfortunately, the Allied 6K27VF is strictly "120" VAC. Builders outside of North America need to find something else to power the B- rail. The requirements of the B- rail are modest. About 30 V, to power the CCS, and sufficient extra Volts to allow the 12AT7 cathodes to follow the negative swings of the input signal. 40 V should be plenty. Please observe that the schematic drops 90 V of B- in resistors. The 6K27VF was chosen for its cost control virtues.

Second, the fuse size - I think about 3A normal blow should offer protection without frequent failures on peaks.

RC filter after channel splitting and diodes has an F3 of only 31Hz. Is it more for diode hash than 50Hz filtering? Increase to 500R?

Add bleeder resistor.

An LC filter has a steeper drop than an RC filter. It does however oscillate. This frequency should be below 10Hz, giving the capacitor value $C = 1 / (L * (2 * \pi * f))$, which amounts to at least 170uF for a 1.5H choke.

B- supply

TODO: how is this used? What is the B- voltage? -125V, but not critical, other values are ok; adjust 10k tail accordingly.

Transformer: Allied 6K27VF <https://www.alliedelec.com/product/hammond-manufacturing/6k27vf/70009000/>

See B+ for some all-in-one transformers.

Again, the hybrid rectified B- supply was chosen for cost containment reasons. However, the "soft" start protects against having the 12AT7 grids go positive, with respect to the cathodes, which is an undesirable event.

The situation with the B- rail is different. What's needed is enough volts to operate a CCS plus what's required to provide compliance with the I/P signal. 40 V. are *plenty*. The 6K27VF B- trafo was selected for reasons of cost. After hybrid bridge rectification, over 100 V. are present at the CRC filter's I/P. Remember, the CCS is set for 6 mA. Notice the voltage drops in the 5 Kohm resistor and (particularly) the 10 Kohm carbon film thermal isolation resistor. If a different transformer with a "shorter" rectifier winding voltage was employed, the thermal isolation part's value gets adjusted. Reduction to as little as 100 Ω could be correct.

Add bleeder resistor.

Tube rectifier has two advantages:

- ss diode hash is stopped from entering the circuit. Heavily debated.
- slow start allows 12at7 to heat up and start conducting. Otherwise the cathode would be pulled negative with respect to the grid. Could probably also be solved using a diode between the grid and cathode as advised by ValveWizard for [DC coupled cathode followers](#)

Heater supply

The only place DC heater power makes any sense is for the 12AT7's and that's overkill. The tail CCS does more than provide a high AC impedance. PSRR is pushed way up. This is a power amp, not a phono preamp. Good layout, careful grounding, and proper lead dress are all that's needed to obtain a low residual hum level.

12AT7, 0.3A at 6.3V heater current x2 = 0.6A

6AQ5, 0.45A at 6.3V heater current x4 = 1.8A

Total (without tube diode): 1.8A

See B+ transformers for some all-in-one solutions.

Chassis

First tried A4-like format with chassis from Hammond. Was too small. Switched to Hammond 1444-32 (431.8 x 254 x 77.5 mm)

Grounding

Think in terms of a "star", AKA single point, ground. A way to construct a SPG is to use a long machine screw. Put soldered ring terminals at the ends of grounded leads. A lock washer and nut at the sheet metal secures the screw. Then place the ring terminals on the screw. A flat washer, 2nd lock washer, and 2nd nut complete the stack. Tighten WELL. Oh yeah, clean all the mechanically joined metal surfaces FULLY with DeOxit before assembly.

Heat

BC547 : I don't think they have any significant current through them nor voltage across them.

MJE340: $40\text{mA} \times 25\text{V} = 1\text{ Watt}$, rated for 20W.

DN2540: $6\text{mA} \times 59\text{V} = 0.35\text{W}$ (worst case, max estimate), rated for 15W.

Bill Of Material

<http://www.mcshanedesign.net/elcheapo.htm>

UF5408: <https://www.tube-town.net/ttstore/diode-uf5408.html>

grommets

grounding lug(s)

fuse holder chassis

thin(ner) wire

NTC on primary of PT: <https://www.tube-town.net/ttstore/thermistors-cl60-sl12-5-a-10-ohm.html>

ptfe tubing to protect one from long exposed (HT) leads

stand-offs

banana jack 2x: <https://www.don-audio.com/Gold-plated-High-End-Banana-plug-Set-jack-with-terminal-binding-and-safety-casing>

rca jack 1x: <https://www.don-audio.com/RCA-Cinch-Panel-connector-Set-Goldplated-black-white>
<https://www.jukebox-revival.eu/index.php/aansluitklem-met-plastic-afscherming.html>

iec power jack 1x: <https://www.don-audio.com/IEC-iec-power-jack-chassis-mount-with-10a-fuse-holder-switch-DFS-Clip>

chassis: <https://www.tube-town.net/ttstore/chassis-al-1444-32.html>

bottom plate:

tube socket nonal 2x: belton micaalex

tube socket octal 4x: belton micaalex

fuses TBD 3A Slow blow. Jim "Second, the fuse size - I think about 3A normal blow should offer protection without frequent failures on peaks. 2A might get by, but only if slow blow, which is more money. Feel free to suggest a different value, I di some real quick and dirty figuring is all."

fuse holders:

tubes

humdinger (2x): <https://www.tube-town.net/ttstore/rheostat-alpha-100-ohm-5-watt.html>

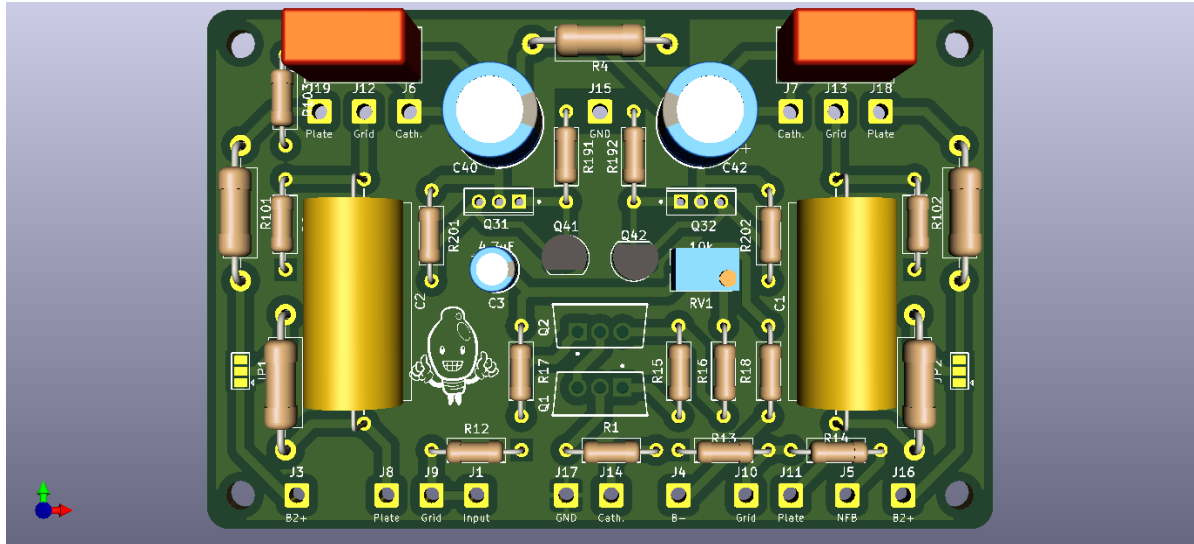
Import of excel sheet (WIP)

Name	** **	Value	Quantity	Tube town	Ringkerntrafo	musikding	Aisler		Subtotaal
C1, C2	solen fast	0,1uF 630V	4	€ 1,95					€ 7,80
C1, C2 (Baby Huey)	solen fast	0,22uF 630V	4	€ 2,16					€ 8,64
C3	radial	4,7uF 100V	2	€ 0,04					€ 0,08
C4	radial	470uF 63V	4	€ 0,51					€ 2,04
C5, C6, C13	F&T	100uF 500V	3	€ 6,29					€ 18,87
C7, C8	F&T	47uF 500V	2	€ 4,36					€ 8,72
C9	radial	100uF 100V	1	€ 0,62					€ 0,62
C10	radial	220uF 100V	1	€ 0,97					€ 0,97
C11, C12		10nF 500V	2						€ 0,00
F1		TODO	1						€ 0,00
F2		TODO	1						€ 0,00
F3		TODO	1						€ 0,00
L17 (193H)	Hammond	5H 200mA	1	€ 32,59					€ 32,59
Q1, Q2		DN2540N5	4				€ 0,00		€ 0,00
Q3		MJE340	4				€ 0,00		€ 0,00
Q4		BC547B	4				€ 0,00		€ 0,00
R1, R4, R5, R13	Metal Film	1K 0.6W	8			€ 0,14			€ 1,12
R10, R11	Metal Film	1K 2W	4			€ 0,14			€ 0,56
R6, R7	Metal Oxide	1K 5W	4			€ 0,15			€ 0,60
R15, R17	Metal Film	1K 0.6W	4	€ 0,15					€ 0,60
R2, R3	Metal Film	50K 2W	2			€ 0,14			€ 0,28
R8, R9	Metal Film	470K 1W	2				€ 0,00		€ 0,00
R12	Metal Film	100K 0.6W	2			€ 0,14			€ 0,28
R16	Metal Film	100 0.6W	2	€ 0,08					€ 0,16
R14	Metal Film	10K 0.6W	2			€ 0,14			€ 0,28
R18	Metal Film	5K 0.6W	2			€ 0,14			€ 0,28
R19	Metal Film	18Ω 0,6W	4				€ 0,00		€ 0,00
R20	Metal Film	5,6K 0.6W	4	€ 0,15					€ 0,60
R21, R22, R23	Metal Oxide	1K 5W	3			€ 0,15			€ 0,45
R24, R29	Metal Oxide	470K 5W	2			€ 0,15			€ 0,30
R27, R28	Metal Film	1,5K 0.6W	2			€ 0,14			€ 0,28
V1, V2	Matched quad	6V6	4		€ 9,95				€ 39,80
V3, V4		12AT7	2		€ 9,90				€ 19,80
VR1	Multi turn	10k	2				€ 0,00		€ 0,00
D1, D2, D3, D4, D7, D8, D9, D10		UF5408	8	€ 0,45					€ 3,60
D5, D6		1N4007?	2	€ 0,04					€ 0,08
Power Transformer	4N1885		1		€ 89,00				€ 89,00

Layout

PCB

The actual audio components (at least cost wise) of an amp are only a small part. Most of an amp is power supply, transformers (and tubes). I tried to make a PCB using KiCad and I managed to make a PCB that supports both the El Cheapo and the Baby Huey (ancient version: v1.1). To switch between El Cheapo and Baby Huey one needs to switch some components and switch the solder jumpers. Also, the Baby Huey is for EL84's. Not a really easy switch...



Dummy Load

Analog discovery 2 in a box with dummy loads

<https://www.tube-town.net/ttstore/high-power-resistor-8r2-8-ohm-150-watt.html> (2x)

Speakers

If you already have speakers, you should design your amp around them.

You want speakers with a reasonably flat impedance curve, as tube amps do not exhibit the gargantuan damping factors seen in SS amps.

Testing

Try different capacitors across the NFB resistor using a 2kHz square wave.

Various posts

<https://www.diyaudio.com/forums/tubes-valves/169914-el-cheapo-builders-thread.html>

The currently recommended choke is the Triad C-24X (1 H./240 mA.). The doubler's pair of LARGE 'lytics do a good job of crushing the ripple fundamental. However, the highly triangular ripple waveform contains overtones of the fundamental extending well up into the RF region. That trash, along with any SS diode switching noise, is the primary target of the choke. If you want to improve filter action, insert a LC section made from a RF choke and a 1000 pF. mica or NPO ceramic cap. between the doubler stack and the "standard" style inductor.

As for voltages, the needs of the 12AT7 based small signal circuitry rule the roost. The 'T7 triode sounds good with 200 to 220 V. on the plate and an IB of 3 mA. That makes a B+ rail slightly over 350 V. "perfect". By itself, the N-77U does not get there. Use 1 of the 2X "12" V. windings of a Triad VPS24-1800 to boost the B+ rail voltage up and the 2nd "12" V. winding to energize the heaters of the 12AL5 and the "finals".

Builders residing in "240" VAC zones can use the Triad power "iron" mentioned, as both the N-77U and the VPS24-1800 have dual primaries. Unfortunately, the Allied 6K27VF is strictly "120" VAC. Builders outside of North America need to find something else to power the B- rail. The requirements of the B- rail are modest. About 30 V., to power the CCS, and sufficient extra Volts to allow the 'T7 cathodes to follow the negative swings of the I/P signal. 40 V. should be plenty. Please observe that the schematic drops 90 V. of B- in resistors. The 6K27VF was chosen for its cost control virtues.

I recommend that potential builders read the Audiophile Talk thread that documents the project's history. Yes it's very lengthy, but (IMO) worth your while. [Thread lijkt niet meer te bestaan.]

<https://www.audioasylum.com/forums/tubediy/messages/20/207934.html>

Let's see how many points I can cover before running out of steam.

I don't want to overheat the vintage power trafo. Yet the value of the caps. in the B+ doubler stack Bogen used are WAY too small. So, some sort of compromise between heating and capacitance is necessary. A pair of 150 μ F. parts in the stack seems about right. As ripple and regulation will not be nearly as good as that which comes from 820 μ F. parts in the doubler stack, both the filter choke and the reservoir cap. should be substantial. An inductor rated for 150 mA. and no smaller than 5 H. is (IMO) in order. Take no prisoners and install a "hash" filter LC section made from a high current RF choke and a 1000 pF. mica or NPO ceramic cap. between the doubler stack and the main filter choke.

Thankfully, prices have come down for high PIV Schottky diodes. Use noise free Cree part # C3D02060F in the B+ doubler.

Bogen did not "cheap out" on the O/P trafos. Notice the presence of a tertiary winding dedicated exclusively to NFB duty. There is no reason I can think of to mess with the values Bogen selected in setting the NFB ratio and phase compensation. Use meter matched carbon comp. parts in the 62 KOhm position and Vishay/Dale RN65 metal film parts in the 1.2 KOhm position. Use CDE silvered mica parts in the 12 pF. phase comp. position. Don't forget that in any "El Cheapo" NFB is applied to the non inverting triode's grid.

For triode wired "finals", tie g2 to the plate with a 470 Ω resistor. That should provide plenty of protection against excessive screen grid power dissipation.

Pentode mode finals will require a regulated g2 B+ supply.

TODO:

- heater elevation
- grounding

