

[speaker](#) [diyAudio logo](#) [diyAudio logo](#) [speaker](#)
[home](#) . [forums](#) . [wiki](#)

Aleph-X

[Home](#) | [diyAudioWiki](#) | [RecentChanges](#) | [Preferences](#)

Aleph-X Project

Welcome to the Aleph-X Project home page. Here you will find information about the evolution of the Aleph-X, as well as comprehensive information on the circuitry, and how to construct your own.

This is turning out to be a pretty large body of text, as we continue to add information gathered from the various Aleph-X discussion threads. I hope it's not too overwhelming for newcomers. This page is, fortunately, a dynamic work, so hopefully it will improve over time, becoming more concise with editing, and with more accurate information culled from the collective experience of Aleph-X builders.

Before You Proceed...

A few obligatory words of caution:

1. This project is based upon the intellectual property of Nelson Pass and Pass Laboratories, and is also the copyrighted creation of Grey Rollins, and the other diyAudio forum members who have contributed their individual efforts to the design. **IT IS STRICTLY FORBIDDEN TO USE THIS DESIGN INFORMATION FOR PROFIT OR OTHER COMMERCIAL PURPOSES.** The Aleph-X design, and related information are for use by individual hobbyists ONLY!!!

2. Only the finalized, fully tested versions of this project are recommended for construction by hobbyists who do not have the equipment or knowledge to properly test and verify the stability of an audio power amplifier. It is also entirely possible to build a "known good" version incorrectly, resulting in damage to equipment connected to the circuit, destruction of the circuit itself, or possible injury or death of a person in close proximity to the circuit. Maintainers and members of this website hereby disclaim any and all liability for said damage, injury or death resulting from use or misuse of the Aleph-X Project information. Please ensure that you are sufficiently skilled and knowledgeable to successfully complete this project, and **FOLLOW ALL PERTINENT SAFETY PRECAUTIONS** when working with electronic circuits. If you have questions about the Aleph-X circuit or electrical safety in general, there are plenty of people on the diyAudio forum who will be willing to answer your questions and help you out.

OK, enough with the legalese, and on with the show...

1 - History

The Aleph-X is not, in fact, designed by Nelson Pass himself (though his fingerprints are unmistakably present throughout the design). It is originally the creation of Grey Rollins, inspired by the patents (5,376,899 and 5,710,522) and technology behind the Pass Labs commercial products: the X-series amplifiers, which employ "Super-Symmetry" feedback, and the previous generation of Pass Labs product, the Aleph series amplifiers, legendary for their incredible sound quality. By combining the unique circuitry of the Aleph amplifiers, and the Super-Symmetry circuit topology (aka SUSY, and often referred to as "X" circuitry due to the characteristic X shaped connection present in the schematics), Grey created what is likely the first DIY design to employ the X technology. He aptly named it the Aleph-X, and started a thread in the diyAudio forums [\[here\]](#). Since Grey's initial posting on May 24 2002, there has been tremendous discussion and input from the diyaudio.com members, and the design has grown and evolved into what is now a nearly complete project, ready for the ambitious DIY audio hobbyist. Hopefully by the time this wiki is done, it will be a complete project (or several complete and tested variants), ready for anyone armed with a soldering iron and adventurous spirit.

2 - Which Version?

One of the great things about the Aleph-X project is the tremendous amount of technical discussion and ideas for improvements it has generated on the forum. While this has been a healthy mental exercise for many members, a vast array of circuit variations and component choices has resulted. This has left some of the less experienced hobbyists feeling a little overwhelmed and confused. Hopefully, this wiki page will help cut through the confusion.

So, which version of the circuit is right for you? Fortunately, the large number of possibilities make the Aleph-X suitable for builders ranging from an intermediate hobbyist level right through to the most advanced hobbyists and Engineers. **The key lies in recognizing your own skill level**, and deciding for yourself how much legwork and design decisions you can confidently handle yourself, and how much to leave to others. Keep in mind that the Aleph-X is a fair bit more complex than other Pass designs, such as the Zen series and the Aleph clones, which are already complete, optimized designs ready for construction by anyone who can follow a schematic and read the accompanying tutorials by Nelson. At this point, the Aleph-X circuit is not quite mature enough for such carbon-copying, but hopefully with improved documentation and as more 'standard' versions get built and tested, the design will become suitable for ambitious beginners at some point in the near future.

At the most basic level, Grey's original version can be built with a minimum of component choices and calculations. This version has been built and tested by numerous builders, and is known to work as-is. Detailed explanations and notes are available to help with the choices which do need to be made, but be aware that careful reading and some understanding of the circuit is still required. Going up a notch, minor modifications are not terribly difficult to make -- the 'basic' configuration can be tailored to personal taste, within limits. This will require more detailed research and good planning, as well as a more complete understanding of how the circuit operates. This is where the spreadsheets and how-to recipes come in handy, as well as the various notes and comments about part substitution and so on. Tweaked versions of the basic circuit are good for about 50W max, optimized for loads in the range of 4 to 8 ohms.

Beyond the basic and 'tweaked-basic' level are the 'high-powered' versions, which use multiple parallel output devices and higher power supply voltages to give more output power. Like the different Aleph models, which each give different power outputs, the high-powered versions require different device choices and circuit values. At this time, unless you copy a verified working circuit, you're venturing into experimental territory.

This will require a lot more effort in terms of research, design choices and planning, probably some circuit simulation or detailed calculations, and a good deal of knowledge about how the circuit's behaviour will change as you add more output devices and crank up the supply voltage.

Over time, more versions of the circuit will be built and verified, and there should be a larger number of 'standard' versions which beginners and intermediates can simply copy without modification.

3 - The Circuit

[\[Figure 1\]](#) shows Grey's original schematic. As much as possible, newer schematics attempt to use the same component designations to avoid confusion when discussing the many variants now in existence. The hifizen/grataku PCB schematic and bill of materials (complete with notes on important components) can be downloaded [\[here\]](#). The hybrid of Aleph and supersymmetry topologies result in a balanced single-ended class A power amplifier, where a single differential pair feeds a balanced pair of Aleph-style output stages. Thus, it is a two gain stage design, where Q5 and Q7 form the first gain stage (diff. pair), while Q2 and Q11 form the second gain stage on each side. Q1 and Q10 are the primary power transistors for the dynamic current sources with controlling elements Q3 and Q8.

The input impedance is set with R18, R19, R28, and R29 at about 47k. D2-D5 provide input protection (overvoltage, ESD), while R21 can be used to help break ground loops. The front end diff pair Q5/Q7 is fed by a constant current source consisting of D1, R17, R20, Q6, R24, R26, V2. The voltages developed across R23 and R25 drive the primary output power transistors Q2 and Q11. Grey has included overcurrent protection using Q4 and Q9. These transistors are inactive (off) during normal operation, and the max current setpoint is determined by the R6, R10, R13, and R41, R39, R35 networks.

R2, R3, R5 and R40, R42, R43 are current sensing elements for the dynamic current sources (they must all be the same value). Looking at the left side, Q3 senses quiescent current (I_q) through Q1 as a voltage across R5. This voltage arrives at the base of Q3 via R8. R12 forms a voltage divider with R8, influencing Q3 when AC current flows to the load (speaker) via R2/R3 (C1 decouples R12 from DC voltages present on R2/R3). Thus, as Q2 draws more current during a signal peak, V_{ce} at Q3 increases. This in turn draws more current through R15, lowering V_{gs} at Q1, and Q1 will carry less current. Similarly, when Q2 is carrying less current, Q1 will carry more. The ratio of current variance in Q1 will be set by R8 and R12. At a 50% ratio, Q1 will theoretically carry no current when Q2 sinks $2 \times I_q$, and Q1 will source $2 \times I_q$ when Q2 sinks zero current. In practice, the ratio is set slightly lower. **<more discussion needed here about the dynamic current source ratio>** C3 is a bootstrap capacitor to keep the current source operating properly as the whole sub-circuit rides up and down on the output voltage. R11 and V1 provide some biasing current to Q3, and allow some adjustment of the output stage bias / I_q . Once set (and the amp is nicely broken in), both V1 and V3 can be replaced with fixed resistors, if you desire. A good reference for more info about the Aleph current source can be found [\[here\]](#).

R1, R4, R44 and R45 help control absolute DC offset at the outputs by sinking current to ground when the outputs sit either above or below 0V potential. The fairly low value of around 30 ohms means these resistors must be rated to dissipate substantial power when the amplifier is delivering maximum power to the speaker.

Successful Aleph-X builders appreciate that such a simple and elegant circuit requires careful construction, component selection and matching in order to deal with factors normally solved with added complexity in standard amplifier designs. While early prototypes of this circuit showed great promise, some difficulty was encountered with managing the common-mode (absolute) and differential DC offsets of the circuit.

Some notes on the original circuit:

- Cold bias starts at about 3.6A total for the amp.
- The bias increases over about the first twenty or thirty minutes (this will depend in part on thermal conditions) to approximately 4.5A, which is in close accordance with what you'd calculate from the schematic. $.5V/.22\text{ ohms} = 2.27A$ per side or 4.54A draw for the entire amp.
- Output increases as the amp warms up, but it will swing on the order of 17.5Vrms across 8 ohms. This works out to a little over 38Wrms.
- The efficiency, in terms of current in/current out approaches 50%.
- Gross clipping, meaning overdriving the amp until the output resembles a square wave, only increased the AC on the rail by something like 5 or 10mV.

4 - Practical Considerations

4.1 - Matching Components

The most important components to select and match are:

1. A well matched pair of IRF9610 mosfets for Q5 and Q7. These should be mounted back-to-back (electrically insulated!), or at least on the same heatsink for good thermal coupling. Differences in transistor temperature or characteristics will lead to differential DC offset at the speaker terminals. These transistors really **MUST** be matched!
2. Q2 and Q11 should be matched as closely as possible. Again, differences will lead to DC across your speaker terminals.
3. Q1 and Q10 can be matched if desired. This is not super-critical, but perhaps worth doing.
4. R23 and R25 should be matched, but can conceivably be tweaked to compensate for small differences between the Q5/Q7 or Q2/Q11 pairs. Tweaking to compensate for bad transistor matching is a last resort. 1% tolerance resistors should be OK, but 5% resistors will definitely need matching.
5. R6 and R41 should be matched, especially if their tolerance is worse than 1%. This can be done using a current source (eg. bench supply) and measuring the voltage across the resistor - much more accurate than trying to use a multimeter's resistance mode. A precise 1A current source will allow a direct reading of the actual resistance, at easily 0.001 ohm accuracy!

For builders of high-power Aleph-X versions utilizing parallel devices on each side, it will be important to

match transistors substituted for Q1 and Q10 in the dynamic current source, since only the first one on each side is connected to the current source control circuit Q3/Q8. See below on how to adjust the dynamic current sources for precise 50% current gain.

Here is Nelson Pass' tutorial on MOSFET matching: <http://www.passdiy.com/pdf/mos.pdf>

4.2 - Power Transistors

The usual choices for output device are the stock IRFP044 and the IRFP240. Nelson has recommended higher voltages for the IRFP240 devices in order to lower their distortion figures. See the notes on the passdiy website in the Zen v4 section. Lower V rated FETs like the '044 will maintain their linearity better with the low rail voltage of the stock Aleph-X. This puts us in a compromise between choosing higher rails or higher bias current in order to lower distortion. Tentative recommendation is to use IRFP044s for rail voltages under 20V (eg. 14V rails at 2A bias per device), or IRFP240 for high-power versions of the Aleph-X (eg. 25V rails, and 1A bias per device). The '044 parts can be biased much harder so keep this in mind when deciding on the output FETs. HifiZen?'s prototype Aleph-X was built with IRFP044, 12.5V rails, and 2.5A bias per device (to handle 4ohm loads).

Power dissipation of the output transistors should be kept to around 25 - 30W per device for best reliability.

4.3 - Calculating Circuit Values

4.3.1 - Source Resistors

R5, R6, R40 and R41 are often called source resistors, because they are in series with the source of each MOSFET. These resistors are very important to the function of the amplifier, acting as current sensing elements for the dynamic current sources and for the current limiting / protection circuits. In high-powered versions, the source resistors also help ensure good current sharing between parallel devices.

Grey(?) says:

"To calculate the Source resistors, divide the total bias current in half to get the amount for each side. Since I'm assuming one pair of devices per side (four total for the channel), we'll end up biasing the pair at 1.9375A (3.875A/2 sides). We'll set the voltage at .5V across the Source resistors (don't forget that you can adjust this a bit with the pots). From here, it's a simple Ohm's Law calculation: $.5V/1.9375A = .258 \text{ ohms}$." Choosing higher source resistor values will reduce the bias accordingly.

4.4 - Heatsinking

Back-to-back IRF9610s (eg. the input diff pair) must be electrically isolated! Use a silpad or if you don't mind the mess, try mica with thermal grease, and use either insulating shoulder washers or nylon screws.

Heatsinks should run no hotter than 60 degrees Celcius. 50 degrees or less is preferred for good reliability and longer component life.

4.5 - Connecting an Input

It is recommended to AC-couple the inputs to the Aleph-X, due to the likelihood that the amplifier outputs will have some absolute DC offset, and thus will draw DC current from any source which is DC coupled. For the hifizen/grataku PCB, input coupling capacitors should be P2P wired off-PCB. Balanced sources connect straight to the +/- inputs via coupling capacitors, as expected, while an unbalanced source should connect via a coupling cap to the (+) input, and the (-) input should be connected to ground via another coupling cap. For amplifiers with both balanced XLR jacks and unbalanced RCA jacks, you may wish to add a switch to short the jack side of the (-) input coupling capacitor to ground (this would be the XLR (-) signal pin) when the unbalanced input is used.

Regarding The 'XLR' input connector on hifizen/grataku PCB: The pinout notes in the rev1.0 schematic are for the PCB input connector only, NOT an actual XLR-type jack mounted on the chassis. Don't confuse this with XLR pin numbering. The input connector pinout is labelled more descriptively on the PCB silkscreen, although the 'SHD' marking is misleading... see next paragraph.

I should also draw some attention to the difference between the Shield/GND line as applied to balanced interconnect vs. the GND connection as used in unbalanced interconnects.

In the case of balanced interconnect, the signal is carried by the + and - lines, and these lines are all that is required to convey the desired signal. The GND or shield connection serves to screen the + and - lines from interference. Thus, the term 'shield' is more appropriate to describe it's function. The XLR ground/shield pin should be terminated to the chassis right at the XLR connector, so that RF noise picked up on the cable does not enter into the chassis.

In contrast, unbalanced interconnect relies on the shield as a reference voltage for the signal carried on the primary signal conductor.

4.6 - Power Supply

While a C-only power supply filter works fine, a pi-filter is generally agreed as the best PSU for the Aleph-X. Since the Aleph-X always draws a constant current from the supply, series impedances in the PSU will not cause rail voltage droop when the amp is delivering peak power. I encourage everyone to simulate their PSU design first, and evaluate the various options (see notes below). Note that sims won't tell you everything you need to know, but they are a useful tool. Try the PSU Designer II software from [\[Duncan's Amp Pages\]](#).

The prototype (hifiZen rev0.9) Aleph-X PCB was built and tested using a C-only supply (68,000uF per rail) with a single Schottky rectifier bridge (4x MBR3045WT), feeding a total of 5A at +/-12.5V to a single channel. The supply rails had 430mV measured ripple, and there was almost no audible hum at the speaker. However, a CRC filter can reduce the ripple to around 15mV. At this level, the Aleph-X is completely silent. CRCRC seems to be a very popular configuration in the discussion threads, although my own simulations show only a minor improvement compared to CRC. Note that CRC will have lower series losses than CRCRC or CLCLC, thus gives higher rail voltage for a given transformer and rectifier (read: more output power!). The same advantage goes to Schottky vs. standard or fast/soft rectifier types, and also to a single rectifier bridge vs. dual bridge rectifiers. At these voltages and currents, losses in the rectifier and filter will be a significant

percentage of the supply voltage, so depending on your implementation and the parts you have available, you should keep this in mind.

Parallel NTC thermistors have been tested in place of series R elements. However, current hogging is apparently an issue if they are not kept in thermal contact with each other. Thermistors have the advantage of reducing the sudden turn-on load to the transformer and rectifiers, especially in supplies with very large capacitances.

L vs. R... Some general notes: Large enough L values are difficult to achieve at typical Aleph-X power currents. Large and expensive coils are needed, and they have high series resistance. Due to the high R and low L values of such inductors, my simulations show little difference in performance between realistic CLC and CRC filters. Magnetic fields from inductors may also be a concern, especially for air-core inductors, so give due consideration to mounting and shielding. Many iron core coils used for speaker crossovers will not be suitable for power supply use, as they will saturate and lose their inductance due to the DC currents.

Update: I did find a Hammond 156B choke which seems to have reasonable specs - 1.5mH at 5A, and only 0.07 ohms DCR. With 68mF -> 156B choke -> 120mF -> 5A load, this gives roughly 5mV ripple. Voltage loss is less but turn-on surge currents are higher than with a CRC filter using the same caps and 0.25 ohm power resistor.

One member has used an LC (choke input) filter with a 2.2mH coil and 140mF of capacitance per channel and reports achieving around 18mV of ripple. Choke input filters can be useful for providing the proper rail voltage from a transformer with a secondary voltage which would otherwise be too high. Choke input filters also reduce stresses on the rectifiers and transformer.

Again, try to simulate your PSU first, and study the design tradeoffs for yourself. To get you started, there's a CLC simlution file for PSUD in [\[this post\]](#).

Rectifiers for the Aleph-X are operating at high current, and will dissipate lots of heat. Make sure they are mounted on an appropriate heatsink. Schottky power diodes are recommended for their low forward voltage drop and superb switching characteristics. Schottky's do not need any parallel snubber capacitors (caps will only degrade their switching performance). Schottkys will run cooler and give higher output voltage than standard or fast/soft diodes, however all types will work fine as long as they are rated for high enough max current and are provided sufficient heatsinking. Diodes should be selected to handle at least 2 or 3 times the expected peak currents. 75A peak repetitive forward surge current rating would not be out of line. In this case, higher ratings will not hurt.

Some kind of soft-start circuit / inrush current limiting is recommended. Mr. Pass uses an NTC thermistor in series with the transformer primary (see the Aleph service manuals on www.passdiy.com for schematics). CL-60 part number comes to mind.

4.7 - Bring-up and Adjustment

A variac transformer is very useful when first powering up your newly constructed circuit, but beware that you may experience odd behaviour if the rail voltage is not high enough to bias all of the transistors into normal operation. You may want to install everything except Q1, Q2, Q10 and Q11, then power it up to see that the diff pair and it's current source work properly, and that there are no surprises with the rest of the circuitry. This could save you some expensive matched power transistors. If you do this, be sure to omit C7 and C8 too (you shouldn't need them anyway). Don't forget to discharge the power supply capacitors with a power resistor after turning off the amp each time. Sometimes, a significant residual voltage will remain on

the capacitors after you power off the amp!

4.7.1 - Adjusting the Variable Constant Current Source

Put a 1.5k pot in place of R12/R34.

Connect an 8-ohm 'dummy' load, or even a real speaker to the output.

Feed the amplifier input with a 60Hz sinewave (or perhaps 1kHz if you're using an oscilloscope - 60Hz is suitable for most multimeters).

Measure the AC voltage across the paralleled R2/R3 output resistors, and across R5 (a big advantage is two voltmeters).

Trim R12 until the voltage over R5 is equal to the voltage over R2/R3.

Now your Current source is set to 50%.

Repeat the same procedure for the R34-side.

Measure the value of the 1.5K trimpots and replace them with fixed resistors.

And now the maths:

The adjustment above is correct only if R2/R3/R5 are the same value. The theory behind this is quite simple. The AC current across the source resistor R5 should be half the AC current going through R2/R3. Suppose you measure 0.05V across R5 and 0.05V volt across R2/R3:

$$0.05V / (0.22 / 2) = 0.45A$$

$$0.05V / 0.22 = 0.227A$$

$$(1 - (0.227 / 0.45)) * 100 = 50\%$$

Another example with different resistors and four current source transistors:

Suppose you have 4x 0.22 ohm as paralleled output resistors, and 4x 0.47 ohm as current source resistors.

$$0.05V / (0.22 / 4) = 0.91A$$

$$0.05V / (0.47 / 4) = 0.425A$$

$$(1 - (0.425 / 0.91)) * 100 = 53.3\%$$

You can now adjust R12 for optimal 50%.

You could also have taken 8 parallel 0.22 ohm resistors

Then only the voltage across the resistors has to be equal.

(Credits for the nice math goes to Edwin Dorre)

With a higher value for R12 the current source will deliver a higher percentage of the work. A lower resistance value will lower the percentage. If you want a switchable variable/constant current source, install a switch to break the R12 circuit.

5 - Variations and Improvements

5.1 - Absolute DC Offset Correction

5.2 - Differential Pair Current Source

5.3 - More Power!

There's a handy Excel sheet to calculate different power ratios of the AlephX[?].

There have been a few versions around; each new version has additions on top of the previous one.

Original credits go to wuffwaff for making it.

Most recent version, "AXE-1" can be found here: <http://www.diyaudio.com/forums/showthread.php?s=&threadid=27170>

Regarding use of the 'EXT' connections on hifizen/grataku PCB rev1.0:

The EXT pads are used to connect wires for multiple parallel power transistors off-PCB, in order to build a higher power version. Incidentally, the main EXT holes are sized for 12 gauge solid wire. Power, ground and output holes are sized for 4-40 hardware, while the 4 mounting holes are sized for 6-32 thread.

To build a higher powered version, basically what you need to do is hit up passlabs.com for one of the original Aleph amplifier schematics and study how the output transistors and dynamic current sources are connected. Compare that with the basic Aleph-X schematic... the Aleph output stage is just duplicated on each side of the amp, so it's easy to see from the Aleph service manual on how to hook up more parallel devices.

Here's a brief run-down: Use the main EXT connections to extend the +V & -V power rails and main signal return out from the PCB (these are the six outermost, and most prominent EXT connections on the board). EXT points are provided if you want to have off-board power resistor arrays (R2/R3/R42/R43 and/or R1/R4/R44/R45), but these are not strictly necessary. Be careful to figure out the proper power resistor values so that your dynamic current source operates properly. R7, R36, R9, and R38 need to be duplicated for each power transistor, as close as physically possible to the gate pin, and so there are EXT points to run wires out to those resistors. Don't forget that each output transistor also needs it's own R5/R6/R40/R41 source resistor as well. Last, you'll have to add connections for the current sensing resistors... R8, R10, R37 and R39 only need to connect to the first transistor on each side, and thus don't need to be duplicated; There are no EXT connections provided for these, as it is easy to run a thinner wire directly from an unused pad on the PCB, and these resistors can be mounted on or off-board. Although I haven't read it, the High-Powered Aleph-X thread probably has some more details about this. I hope that will be a sufficient starting point for you.

5.4 - Less Power!

A lower power version can be built by simply reducing the output stage bias current. IRFP044s should give better performance than IRFP240s at low rail voltages. However, it is not recommended to reduce the rail voltage below about 10V(?not tested?), since distortions will increase and at some point, circuit biasing headroom will be lost and the amplifier will cease to function properly.

6 - Fully Tested Versions

7 - More unsorted info from The Big Thread

Stuff from Netlist (requires some more editing):

UNCONFIRMED (ignore for now) >> 0.001 μ F RF compensation caps can be added between Collector and Base of Q3, Q8

UNCONFIRMED (ignore for now) >> or 0.01 μ F caps between Collector and Emitter of the same transistors.

Mills wirewounds (non-inductive M series) are good source resistors.

Absolute DC can be stabilized with two resistors from outputs to common sources of input diff-pair (R46/R47).

Quote from Nelson:

"Any absolute DC offset results in opposing bias to the diff pair.

This technique also presumes a DC impedance to ground associated with the input so that the feedback is not unity gain at DC. The lower the resistance, the more effective the control over absolute DC, but then you start depending more on the common-mode output cancellation to get better input common mode rejection. I feel it is probably better to go to higher resistance and use output resistance to ground to additionally stabilize the absolute DC."

Power supply:

A big power supply is required, 200VA transformer is a minimum, capacitance as high as you can afford, say at least 50.000 μ F but the parts you choose will depend on how much power you can dissipate safely on your heatsinks and how low the impedance on your speakers will dip. If you know your speaker load will never dip below 4 ohms and their phase angle is not too steep, you won't need to bias each FETs more than 1A. This will give you lots more flexibility in choosing your voltage rails. The capacitance required is a function of the ripple generated and the ripple generated is a function of the amps drawn so the higher you bias your FETs, the more capacitance you will need. Placing capacitors in parallel to achieve the necessary capacitance is a good idea since it will reduce the parasitic impedance that is in every capacitor.

Diff-pair current source:

Original values were (for 392 ohm loads):

R24 475 ohms

R26 332 ohms

V2 200 ohms

A somewhat tighter combination:

R24 332 ohms

R26 562 ohms

V2 200 ohms

The second set of values gives you finer control, but over a narrower range.

The exact values that you choose for those three resistors aren't important, but it is essential that they give you a control range centered on 221 ohms, plus or minus a fairly small percentage. The first group is 221 ohms \pm roughly 12%. The second group is roughly \pm 5%.

Assuming that you're still using a 200 ohm pot for V2, 390 for R24 and 300 for R26 will give you a range between 169 and 219 ohms.

[Click here now to edit this WikiPage](#) | [View document history](#)

Document last modified Sun, 04 Apr 2004 17:08:07

Search:

[home](#) . [about](#) . [sitemap](#) . [feature requests](#) . [register](#) . [customize](#) . [contact](#)

Copyright ©1999-2004 diyAudio.com.