# Aikido

Aikido Stereo Phono PCB

# USER GUIDE



06/28/2008

GlassWare
AUDIO DESIGN

## Warning!

This PCB is for use with a high-voltage power supply; thus, a real shock hazard exists. Once the power supply is attached, be cautious at all times. In fact, always assume that capacitors will have retained their charge even after the power supply is disconnected or shut down.

If you are not an experienced electrical practitioner, before applying the B-plus voltage have someone who is experienced review your work. There are too few tube-loving solder slingers left; we cannot afford to lose any more.

## PH-1 Aikido Phono Preamp Overview

Thank you for your purchase of the TCJ Aikido phono preamp PCB. Despite predictions to the contrary, spinning black vinyl by the warm glow of vacuum tubes persists. In spite of the popularly-held belief that both LPs and tubes are dead, long dead—most believe that the vacuum tube died about 50 years ago and that the LP record died 25 years ago at the birth of the CD—both tubes and LPs grow more popular with each coming day. Tubes refuse to fade to black and solid-state audio gear is still embarrassingly being advertised as sounding tube-like; and Marantz once again sells turntables and new records are pressed daily. Adding the Aikido topology to a phono preamp makes perfect sense. The Aikido's low distortion, noise, and output impedance, without the use of negative feedback—all are desirable attributes in a phono preamp.

## PCB Features

**Overview** This FR-4 PCB is extra thick, 0.094 inches (inserting and pulling tubes from their sockets won't bend or break this board), double-sided, with plated-through 2oz copper traces, and the boards are made in the USA. The PH-1 PCB holds two Aikido phono-stage preamplifiers, with each phono preamp holding two Aikido gain stages with a passive RIAA equalization circuit in between. Thus, one board is all that is needed for stereo unbalanced use or two boards for balanced preamplification. The boards are six inches by eleven inches, with ten mounting holes that help to prevent excessive PCB bending, while inserting and pulling tubes from their sockets.

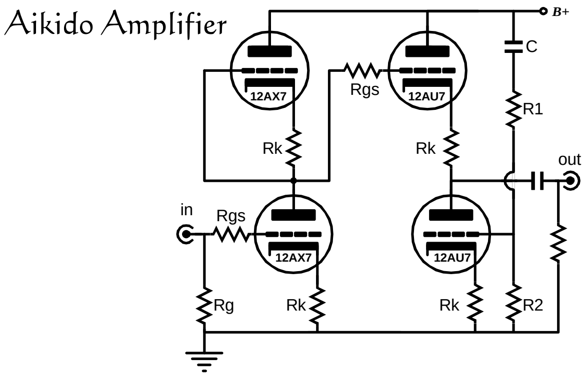
**Multiple Heater Arrangements** The PH-1 PCB allows either 6.3V or 12.6V or 25.2V heater power supplies to be used and 6V tubes, such as the 6N1P, can be used with 12V tubes, such as the 12AU7.

**Power-Supply-Decoupling Capacitors** PH-1 PCB provides space for four sets of capacitors to decouple each Aikido gain stage from the B+ connection. This arrangement allows a large-valued electrolytic capacitor and small-valued film capacitor to be used in parallel, while a series voltage-dropping resistor completes the RC filter.

**Redundant Solder Pads** This board holds two sets of differently-spaced solder pads for each critical resistor, so that radial and axial resistors can easily be used (bulk-foil resistors and carbon-film resistors, for example). In addition, most capacitor locations find many redundant solder pads, so wildly differing-sized coupling capacitors can be placed neatly on the board, without excessively bending their leads.

## Introduction to the Aikido

The Aikido amplifier delivers the sonic goods. It offers low distortion, low output impedance, a great PSRR figure, and feedback-free amplification. The secret to its superb performance—in spite not using global feedback—lies in its internal symmetry, which balances imperfections with imperfections. As a result, the Aikido circuit works at least a magnitude better than the equivalent SRPP or grounded-cathode amplifier.




**Universal Topology** In the schematic above, the triodes are so specified as an example only. Although they would never fit on the printed circuit board (PCBs), 211 and 845 triodes could be used to make an Aikido amplifier. The circuit does not rely on these triodes or any other specific triodes to work correctly. It's the topology, not the tubes that make the Aikido special. (Far too many believe that a different triode equals a different topology; it doesn't. Making this mistake would be like thinking that the essential aspect of being a seeing-eye dog rested in being a Golden Lab.)

**Low Distortion** For example, the Aikido circuit produces far less distortion than comparable circuits by using the triode's own nonlinearity against itself. The triode is not as linear as a resistor, so ideally, it should not see a linear load, but a corresponding, complementary, balancing non-linear load. An analogy is found in someone needing eyeglasses; if the eyes were perfect, then perfectly flat (perfectly linear) lenses would be needed, whereas imperfect eyes need counterbalancing lenses (non-linear lenses) to see clearly. Now, loading a triode with the same triode—under the same cathode-to-plate voltage and idle current and with the same cathode resistor—works well to flatten the transfer curve out of that triode.

**PSRR** The Aikido circuit sidesteps power supply noise by incorporating the noise into its normal operation. The improved PSRR advantage is important, for it greatly unburdens the power-supply. With no tweaking or tube selecting, you should easily be able to get a -30dB PSRR figure (a conventional grounded-cathode amplifier with the same tubes and current draw yields only a -6dB PSRR); and with some tweaking of resistor R1's value, -60dB—or more—is possible. Additionally, unless regulated power supplies are used for the plate and heater, these critical voltages will vary as the power line's voltage falls and climbs your house's and neighbors' house's use, usually throwing the supposedly fixed wall-voltage askew. Nevertheless, the Aikido amplifier will still function flawlessly, as it tracks these voltage changes symmetrically.

**Age Tolerant** Remember, tubes are not yardsticks, being more like car tires—they wear out. Just as a tire's weight and diameter decrease over time, so too the tube's conductance. In other words, a fresh 12AX7 is not the same as that same 12AX7 after 2,000 hours of use. But as long as the two triodes within the 12AX7 age in the same way—which they are inclined to do—the Aikido amplifier will always bias up correctly, splitting the B+ voltage between the triodes.

**No Negative Feedback Loop** The Aikido topology does not use any negative feedback, other than the local degenerative feedback because of the unbypassed cathode resistors in the input stage and the active load presented by the bottom triode of the output stage. In fact, the Aikido topology makes use of feedforward noise canceling at the output. Unlike negative feedback that has to wait until something goes wrong before it can work to undo the damage, feedforward feedback anticipates what will go wrong before it does. It is proactive, not reactive, to borrow the terms of pop-psychology.

The Aikido circuit eliminates power-supply noise from its output, by injecting the same amount of PS noise at the inputs of the top and bottom tubes in the two-tube cathode follower circuit. Since both of these signals are equal in amplitude and phase, they cancel each other out, as each triodes sees an identical increase in plate current—imagine two equally strong men in a tug of war contest. So, shouldn't resistors R1 and R2 share the same value, thereby also splitting the power-supply noise at 50%? No. If triode did not present a low plate resistance, then the 50% ratio would apply. Because of the low rp, the correct relationship between resistors R1 and R2 is given by the following formula: **R1 = R2[(mu - 2)/(mu + 2)]**

**Low Output Impedance** The Aikido topology uses a modified cathode follower circuit as the output stage. Cathode follower are famous for providing low distortion and low output impedances, but no voltage gain. This modified cathode follower scrubs away the power-supply noise from its output and provides a complementarily non-linear load for the top triode's cathode. The top triode's capacitor resistor is in series with the output, so its resistance must be added to the cathode follower output impedance. Had the output connection been taken from the top triode's cathode, then the output impedance would be slightly lower, but the symmetry would be broken and the PSRR enhancement would be lost.

**Gain** Calculating the gain from an Aikido amplifier is easy, as it roughly equals half the mu of the input triode used. The gain from a simple grounded-cathode amplifier (with an un-bypassed cathode resistor) is

**Gain = muRa/[Ra + (mu + 1)Rk + rp]**

In the Aikido, the resistance presented by the top tube and its cathode resistor is R' = (mu + 1)Rk + rp. So if you substitute R' for Ra in the above equation and simplify you get

**Gain = mu[(mu + 1)Rk + rp ] / [(mu + 1)Rk + rp + (mu + 1)Rk + rp] = mu/2**

Of course there is a slight loss though the Aikido's modified-cathode-follower output stage, whose gain usually falls between 0.93 to 0.98.

# Heater Issues

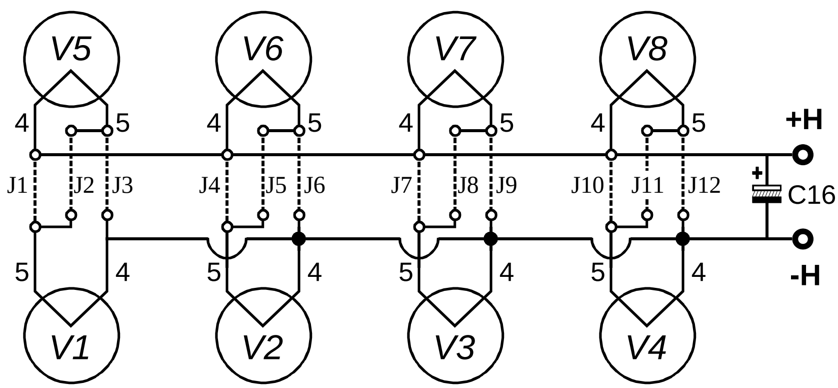
**Heater Power Supply** The board assumes that a well-regulated DC 12V power supply will be used for the heaters; both 6V and 12 tubes can be used with a 12V power supply. A 6V heater power supply, however, can be used with the PCB, as long as all the tubes used hold 6.3V heaters.

Even 5V or 8V or 18V power supplies can be used, if all the tubes share the same 5V or 8V or 18V heater voltage. Just use jumpers J1, J3, J4, J6, J7, J9, J10, and J12 only. Note: Perfectly good tubes with uncommon heater voltages can often be found at swap meets, eBay, and surplus stores for a few dollars each. Thinking outside the 6.3V box can save a lot of money. Do remember that heater bypass capacitor, C16, must be rated greater than the power supply voltage.

A 25.2V (or 24v) heater power supply can be used, if only 12.6V tubes are used; for example, if the input tubes [V2 and V3] are 12AX7s and the output tubes are 12AU7s [V1 and V4]. Just use the jumper J2, J5, J8, and J11 only and C16's voltage rating should be at least 35V.

**AC heater power supply** Although a truly terrible idea, an AC heater power supply (6.3V or 12.6V) can be used, if the heater shunting capacitor C16 is left off the board, or is replaced by 0.01µF ceramic capacitor.

## Filament Jumper Wire Schedule




### With a 12.6V PS

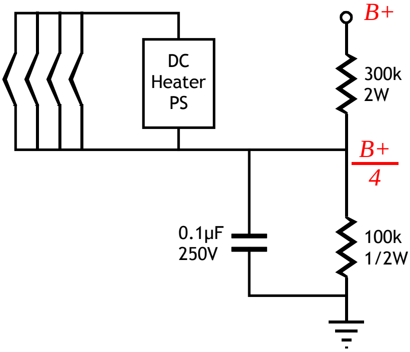
| Tubes | V1 & V5 | V2 & V6 | V3 & V7 | V4 & V8 |
|---|---|---|---|---|
| If tubes are 6.3V: | J2 only | J5 only | J8 only | J11 only |
| If 12.6V: | J1 & J3 | J4 & J6 | J7 & J9 | J10 & J12 |

### With a 6.3V PS

| Tubes | V1 & V5 | V2 & V6 | V3 & V7 | V4 & V8 |
|---|---|---|---|---|
| All tubes = 6.3V: | J1 & J3 | J4 & J6 | J7 & J9 | J10 & J12 |
| If 12.6V: | Cannot be used with 6.3V power supply | | | |

**Do not use capacitor C16 with an AC heater PS (NOT RECOMMENDED)**

Since one triode stands atop another, the heater-to-cathode voltage experienced differs between triodes. The safest path is to reference the heater power supply to a voltage equal to one fourth the B+ voltage; for example, 75V, when using a 300V power supply. The ¼ B+ voltage ensures that both top and bottom triodes see the same magnitude of heater-to-cathode voltage. The easiest way to set this voltage relationship up is the following circuit:

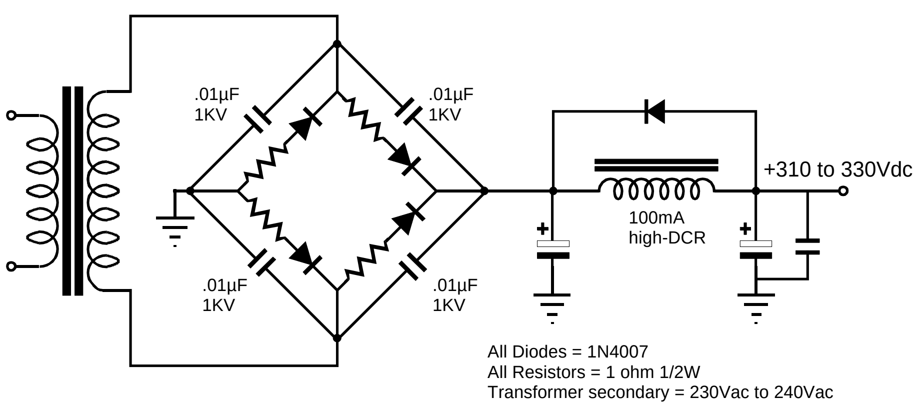



Alternatively, you might experiment with floating the heater power supply, by "grounding" the heater power supply via only a 0.1µF film or ceramic capacitor. The capacitor will charge up through the leakage current between heater and cathodes. Not only is this method cheap, it is often quite effective in reducing hum.

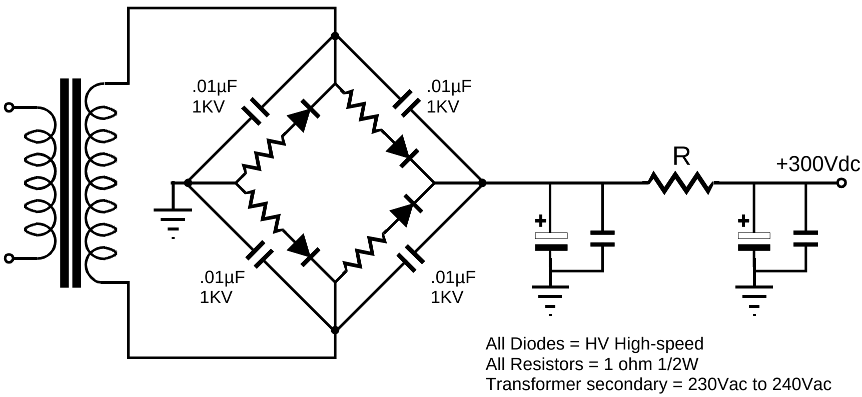
## Power Supply

The power supply is external to the Aikido phono preamp PCB and can be mounted in, or outside, the chassis that houses the PCB. The optimal power supply voltage depends on the tubes used. For example, 6DJ8/6922 tubes can be used with a low 200V power supply, while 12AX7s work better with a 250-300V B-plus voltage. The sky is not the limit here, as the heater-to-cathode voltage sets an upward limit of about 300V.

The genius of the Aikido circuit is found in both its low distortion and great PSRR figure. Nonetheless, a good power supply helps (there is a practical limit to how large a power-supply noise signal can be nulled). I recommend you use at least a solid, choke-filtered, tube-rectified or fast-diode rectified power supply. If you insist on going the cheap route, try the circuit below, as it yields a lot of performance for little money. FRED rectifiers are expensive, but make an excellent upgrade to the lowly 1N4007; and high-voltage, high-speed rectifiers are not that much more expensive.

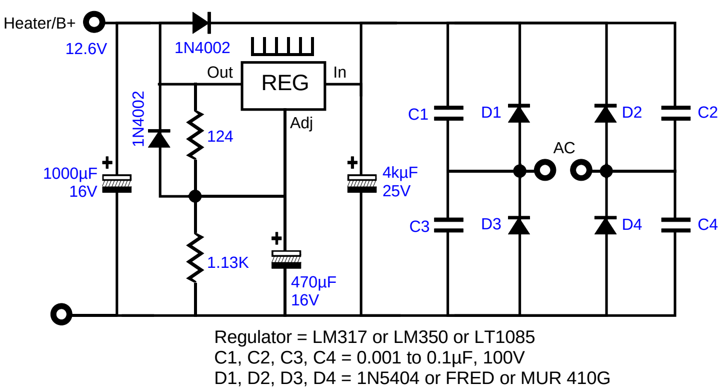


I have found that just about any choke, of any inductance or DCR, is better than not using a choke in a power supply, even if that power supply terminates in a voltage regulator. One inductor and one extra capacitor added to the simple power supply will make a big difference in performance. Because the current draw for the entire phono preamp is relatively slight, the inductor's DCR is not the usual liability. In other words, a high-DCR is quite usable. Try to use a choke with a DCR of 1k -2k ohms. An RC filter also works well. In fact the PH-1 PCB holds two RC filters per channel, so that using the following power supply would effectively make the a total of three RC filters. Resistor R's value should equal the desired voltage drop divided by the total current drawn by the phono stage. For example, 30V / 0.03A = 1,000 ohms. Be sure to grossly over specify this resistor, as it can get quite hot at startup, while the large power supply capacitors charge up.




**Rectifiers** I recommend using tube rectifiers or ultra-fast rectifiers, such as the popular HEXFREDs. (Developed by International Rectifier, in the 1970s, "FRED" stands for Fast Recovery Epitaxial Diode, thus the trade name "HEXFRED." Today, manufacturers include Harris, International Rectifier, IXYS and others.

**Heater Regulator** A low-voltage, linear-regulated power supply is easy to build, as shown below. Care must be taken not to exceed the regulator's maximum output current and ensure adequate heat-sinking.



## Tube Selection

By using different tubes, different bias points, different B+ voltages, a nearly infinite number of different Aikido amplifiers can be built. But with a phono preamp, our choices are limited, as high-gain, and low-noise are our key requirements, not high-current or low output impedance. The input tubes (V1, V5, V3, V7) provide all the gain in this preamp. Thus, we can ignore the 6H30 and concentrate on the 6AQ8, 6DJ8, 6N1P, 12AT7, 12AV7 12AX7, 12BZ7, 5751, 6072.... For example, a 12AX7 input tube will yield a gain close to 50 (mu/2) per Aikido stage, which perfect for a phono preamp; the 6DJ8/6922, 16 (mu of 33), which is a little weak, but if a step-up transformer is used, the 6DJ8's lower noise contribution would certainly override the concern about its low gain.

The output tubes (V2, V6, V4, V8) isolate the input tubes and deliver a low output impedance, yet they are not required to deliver high current into high-capacitance cables or headphones. Thus, a larger list of possible tubes is available: 6AQ8, 6BC8, 6BK7, 6BQ7, 6BS8, 6DJ8, 6FQ7, 6GC7, 6H30, 6KN8, 6N1P, 12AT7, 12AU7, 12AV7, 12AY7, 12AX7, 12BH7, 12BZ7, 12DJ8, 12FQ7, 5751, 5963, 5965, 6072, 6922, E188CC, ECC88, ECC99... The only stipulations are that the two triodes within the envelope be similar and that the tube conforms to the 9A or 9AJ base pin-out. A tube lineup of 12AX7 12AT7 passive equalization 12AX7 12AT7 or 12AX7 12AU7 passive equalization 12AX7 12AU7 works well and yields a final gain of over +45dB.

## Cartridge Capacitance Loading

Capacitor C1 is an optional cartridge shunting capacitor. Usually, it is best left off the board, as the phono interconnect is already capacitance laden. If more is needed, however, use the two pads nearest the "C1" marking. If an RC Zorbel network is needed to tame a step-up transformer, use the two pads nearest the "C2" making and use resistor R26.

## Internal Shields

If the triode's pin number 9 attaches to an internal shield, as it does with the 6DJ8 and 6N1P, then capacitors, C2, C5, C10, C13 can be replaced with a jumper wire, which will directly ground the shield. However, using the capacitors will also ground the shield (in AC terms.

## Cathode Resistor Values

The cathode resistor and plate voltage set the idle current for the triode: the larger the value of the resistor, less current; the higher the plate voltage, more current. In general, high-mu triodes require high-value cathode resistors (1-2K) and low-mu triodes require low-valued cathode resistors (100-1k). the formula is an easy one:

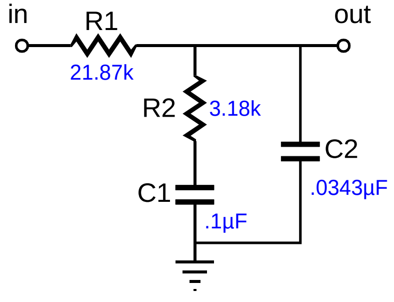
$$Iq = B+/2(rp + [mu + 1]Rk)$$

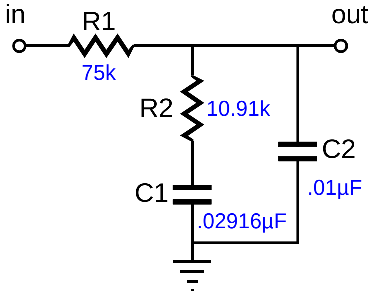
So, for example, a 12AX7 in an Aikido circuit with a B+ voltage of +300V and 1k cathode resistors will draw 300/2(60k + [100 + 1]1k) amperes of current, or 0.93mA. because the cathode resistors are unbypassed, they will add noise to the signal, so lower values are preferable. I recommend between 680 to 1k for the 12AX7, 5751, 6072 input tubes and between 100 to 330 for the 6DJ8 and 6N1P. Output tubes, such as the 6CG7, 12AT7, 12AU7, 12BH7 work well with 470-ohm cathode resistors.

## RIAA Equalization

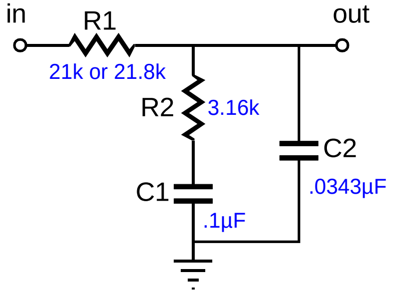
Regardless of the underling technology used, tube or solid-state, a phono preamp must undo the RIAA (Recording Institute Association of America) equalization curve or the CCIR (Comité Consultatif International des Radiocommunications) or IEC (International Electrotechnical Commission) the European versions of the RIAA) curve used in making the record. Why was this curve imposed on the records? Using it improved the signal-to-noise ratio of the record by boosting the highs going to the cutting head, while greatly extending the play-back time by cutting the lows. The end result was a fairly even grove cut, regardless of the frequency. The inverse of the RIAA curve returns the signal to flat by cutting the highs and boosting the bass. (Bare in mind that most records made before 1950 may not have followed the RIAA curve, but some other proprietary-to-the-record-label curve.)

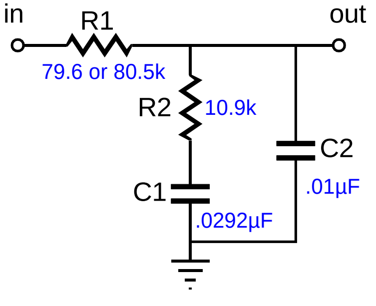
This preamp uses passive equalization, rather than active, feedback-based equalization. The passive equalization network sits in between two Aikido gain stages. Two variations on the same equalization network are shown below. The advantage the lower-resistance version enjoys over the higher-resistance version on the right is that the lower resistor values will add less noise to the signal. The advantage the higher-resistance version holds over the version on the left is that the high resistor values will diminish the role the first Aikido gain stage's output impedance; in addition, the equalization capacitors will be smaller (and cheaper).




The Aikido gain stage uses a modified cathode follower as the output stage, so the output impedance is fairly low. Nonetheless, this extra resistance must be factored into the equations, as must the 1M grid resistor to ground at the input of second Aikido gain stage. The network values shown above are idealized; below are real-world values that include output impedance and a 1M grid resistor. (Resistor R1 is obviously the varied component, but C2 must include the Miller-effect capacitance from the second Aikido gain stage.)



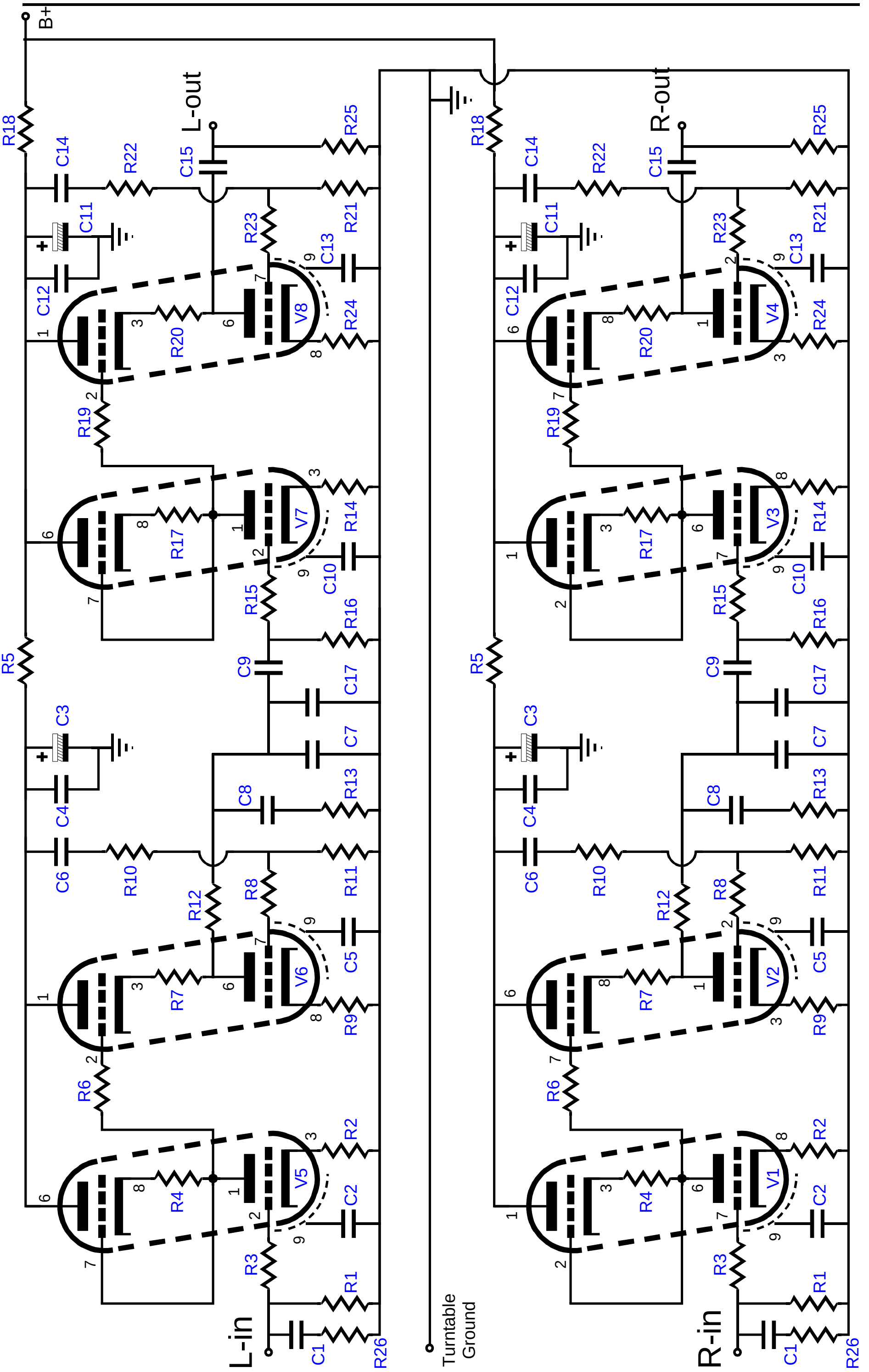
The following two tables lists some of the possible RIAA equalization network values based on C1 and C2 as the moving variables. On the PH-1 PCB, capacitor C1 is marked C8 and capacitor C2 is made up from two capacitor in parallel, C7 and C17.

| with C1 as the moving variable | | | | | |
|---|---|---|---|---|---|
| C in µF | | Absolute Values | | 1% Values | |
| C1 | C2 | R1 | R2 | R1 | R2 |
| 0.09 | 0.0309 | 24300 | 3533 | 24.3k | 3.57k |
| 0.091 | 0.0312 | 24033 | 3495 | 24k | 3.48k |
| 0.092 | 0.0316 | 23772 | 3457 | 23.7k | 3.48k |
| 0.093 | 0.0319 | 23516 | 3419 | 23.7k | 3.4k |
| 0.094 | 0.0322 | 23266 | 3383 | 23.2k | 3.4k |
| 0.095 | 0.0326 | 23021 | 3347 | 23.2k | 3.32k |
| 0.096 | 0.0329 | 22781 | 3313 | 22.6k | 3.32k |
| 0.097 | 0.0333 | 22546 | 3278 | 22.6k | 3.3k |
| 0.098 | 0.0336 | 22316 | 3245 | 22.1k | 3.24k |
| 0.099 | 0.0340 | 22091 | 3212 | 22.1k | 3.24k |
| 0.1 | 0.0343 | 21870 | 3180 | 22k | 3.16k |
| 0.101 | 0.0346 | 21653 | 3149 | 21.5k | 3.16k |
| 0.102 | 0.0350 | 21441 | 3118 | 21.5k | 3.16k |
| 0.103 | 0.0353 | 21233 | 3087 | 21k | 3.09k |
| 0.104 | 0.0357 | 21029 | 3058 | 21k | 3.09k |
| 0.105 | 0.0360 | 20829 | 3029 | 21k | 3k |
| 0.106 | 0.0364 | 20632 | 3000 | 20.5k | 3k |

| with C2 as the moving variable | | | | | |
|---|---|---|---|---|---|
| C in µF | | Absolute Values | | 1% Values | |
| C1 | C2 | R1 | R2 | R1 | R2 |
| 0.08019 | 0.0275 | 28040 | 3966 | 28k | 3.92k |
| 0.081648 | 0.0280 | 27520 | 3895 | 27.4k | 3.9k |
| 0.083106 | 0.0285 | 27030 | 3826 | 27k | 3.83k |
| 0.084564 | 0.0290 | 26550 | 3760 | 26.7k | 3.74k |
| 0.086022 | 0.0295 | 26090 | 3697 | 26.1k | 3.65k |
| 0.08748 | 0.0300 | 25640 | 3635 | 25.5k | 3.65k |
| 0.088938 | 0.0305 | 25210 | 3576 | 25.5k | 3.6k |
| 0.090396 | 0.0310 | 24790 | 3518 | 24.9k | 3.57k |
| 0.091854 | 0.0315 | 24390 | 3462 | 24.3k | 3.48k |
| 0.093312 | 0.0320 | 24000 | 3408 | 24k | 3.4k |
| 0.09477 | 0.0325 | 23620 | 3355 | 23.7k | 3.32k |
| 0.096228 | 0.0330 | 23260 | 3305 | 23.2k | 3.3k |
| 0.097686 | 0.0335 | 22900 | 3255 | 23.2k | 3.24k |
| 0.099144 | 0.0340 | 22560 | 3207 | 22.6k | 3.24k |
| 0.100602 | 0.0345 | 22220 | 3161 | 22.1k | 3.16k |
| 0.10206 | 0.0350 | 21900 | 3116 | 22k | 3.16k |
| 0.103518 | 0.0355 | 21580 | 3072 | 21.5k | 3.09k |

These two tables include the effect of the 1M grid resistor, R16. the absolute resistor values are just that absolute and they assume a an output impedance of zero from the output of V2 and V6. In reality, the output impedance ranges from a low of 200 ohms with a 6DJ8/6922 based cathode follower stage to a high of 2.8k with a 12AX7-based cathode follower. The output impedance is roughly equal to the triode's rp divided by its mu plus the cathode resistor's value. For example, a 6N1P with a 200-ohm cathode resistor, will result in an output impedance equal to about 430 ohms, which must be subtracted from the equalization networks R1's value (resistor R12 on the PCB). The table below lists many common triodes.

| Tube | mu | rp | Rk | Ik(mA) | B+ | R10 | R11 | Gain | dB | Zo |
|---|---|---|---|---|---|---|---|---|---|---|
| **6AQ8** | 57 | 9700 | 100 | 10.0 | 300 | 93220 | 100k | 0.97 | -0.24 | 248 |
| **6BK7** | 43 | 4600 | 200 | 10.0 | 300 | 91111 | 100k | 0.97 | -0.27 | 279 |
| **6BQ7** | 38.00 | 5900 | 191 | 10.0 | 300 | 90000 | 100k | 0.96 | -0.32 | 311 |
| **6BS8** | 36.00 | 5000 | 220 | 10.0 | 300 | 89474 | 100k | 0.96 | -0.33 | 321 |
| **6CG7** | 20.50 | 10200 | 583 | 3.0 | 150 | 82222 | 100k | 0.93 | -0.59 | 827 |
| **6CG7** | 21.10 | 8960 | 397 | 5.0 | 200 | 82684 | 100k | 0.93 | -0.59 | 657 |
| **6CG7** | 21.00 | 9250 | 626 | 5.0 | 250 | 82609 | 100k | 0.94 | -0.56 | 820 |
| **6CG7** | 20.80 | 9840 | 1000 | 4.5 | 300 | 82456 | 100k | 0.94 | -0.53 | 1063 |
| **6CG7** | 21.40 | 8370 | 470 | 7.3 | 300 | 82906 | 100k | 0.94 | -0.56 | 686 |
| **6CG7** | 21.90 | 7530 | 243 | 10.0 | 300 | 83264 | 100k | 0.93 | -0.60 | 489 |
| **6CG7** | 21.80 | 7680 | 352 | 10.0 | 350 | 83193 | 100k | 0.94 | -0.57 | 576 |
| **6DJ8** | 30.20 | 3670 | 182 | 5.0 | 100 | 87578 | 100k | 0.96 | -0.39 | 273 |
| **6DJ8** | 30.70 | 2870 | 124 | 10.0 | 150 | 87768 | 100k | 0.96 | -0.39 | 199 |
| **6DJ8** | 30.00 | 2960 | 205 | 10.0 | 200 | 87500 | 100k | 0.96 | -0.37 | 274 |
| **6DJ8** | 29.60 | 3060 | 291 | 10.0 | 250 | 87342 | 100k | 0.96 | -0.36 | 350 |
| **6DJ8** | 28.60 | 3980 | 673 | 5.0 | 250 | 86928 | 100k | 0.96 | -0.35 | 667 |
| **6DJ8** | 28.30 | 4080 | 845 | 5.0 | 300 | 86799 | 100k | 0.96 | -0.34 | 787 |
| **6DJ8** | 28.90 | 3400 | 481 | 8.0 | 300 | 87055 | 100k | 0.96 | -0.35 | 511 |
| **6FQ7** | **See 6CG7** | | | | | | | | | |
| **6N1P** | 39.8 | 12200 | 328 | 3.0 | 200 | 89189 | 100k | 0.96 | -0.32 | 539 |
| **6N1P** | 36.00 | 9480 | 221 | 5.0 | 250 | 93548 | 100k | 0.96 | -0.36 | 422 |
| **6N1P** | 35.00 | 956 | 642 | 5.0 | 300 | 89189 | 100k | 0.97 | -0.25 | 569 |
| **12AT7** | 60.00 | 15000 | 270 | 3.7 | 200 | 93548 | 100k | 0.98 | -0.21 | 457 |
| **12AT7** | 60.00 | 15000 | 470 | 3.5 | 300 | 93548 | 100k | 0.98 | -0.19 | 610 |
| **12AU7** | 17.00 | 9560 | 427 | 2.5 | 100 | 78947 | 100k | 0.92 | -0.75 | 757 |
| **12AU7** | 16.60 | 9570 | 741 | 3.0 | 150 | 78495 | 100k | 0.92 | -0.71 | 959 |
| **12AU7** | 16.70 | 9130 | 768 | 4.0 | 200 | 78610 | 100k | 0.92 | -0.69 | 959 |
| **12AU7** | 17.90 | 7440 | 336 | 8.0 | 250 | 79899 | 100k | 0.92 | -0.71 | 601 |
| **12AU7** | 18.10 | 7120 | 328 | 10.0 | 300 | 80100 | 100k | 0.92 | -0.70 | 581 |
| **12AV7** | 37.00 | 6100 | 120 | 9.0 | 200 | 89744 | 100k | 0.96 | -0.36 | 258 |
| **12AV7** | 41.00 | 4800 | 56 | 18.0 | 300 | 90698 | | 0.96 | -0.35 | 160 |
| **12AZ7** | **See 12AT7** | | | | | | | | | |
| **12AX7** | 100.00 | 80000 | 2000 | 0.5 | 200 | 96078 | 100k | 0.99 | -0.11 | 1719 |
| **12AX7** | 100.00 | 62500 | 1100 | 1.0 | 300 | 96078 | 100k | 0.99 | -0.12 | 1238 |
| **12BH7** | 16.10 | 5480 | 340 | 4.0 | 100 | 77901 | 100k | 0.92 | -0.76 | 549 |
| **12BH7** | 15.70 | 6090 | 706 | 4.0 | 150 | 77401 | 100k | 0.92 | -0.71 | 826 |
| **12BH7** | 15.90 | 6140 | 787 | 5.0 | 200 | 77654 | 100k | 0.92 | -0.68 | 877 |
| **12BH7** | 17.40 | 4870 | 383 | 10.0 | 250 | 79381 | 100k | 0.93 | -0.67 | 541 |
| **12BH7** | 18.40 | 4300 | 267 | 15.0 | 300 | 80392 | 100k | 0.93 | -0.65 | 422 |
| **12BZ7** | 100.00 | 31800 | | | 300 | 96078 | 100k | 0.98 | -0.17 | 292 |
| **5751** | 70.00 | 58000 | 1250 | 0.8 | 200 | 94444 | 100k | 0.98 | -0.17 | 1407 |
| **5963** | 21.00 | 6600 | 200 | 10.0 | 250 | 82609 | 100k | 0.93 | -0.63 | 433 |
| **5965** | 47.00 | 7250 | 220 | 8.2 | 300 | 91837 | 100k | 0.97 | -0.26 | 337 |
| **6072** | 44.00 | 25000 | 1250 | 2.0 | 300 | 91304 | 100k | 0.97 | -0.25 | 1272 |


B+
L-out
R-out
L-in
R-in
Turntable Ground
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
R20
R21
R22
R23
R24
R25
R26
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C17
V1
V2
V3
V4
V5
V6
V7
V8

## Typical Part Values

() Parentheses denote recommended values

| | 12AX7-12AT7-12AX7-12AT7 | 6N1P-6N1P-12AX7-12AU7 |
|---|---|---|
| B+ Voltage = | 250V - 400V (335V) | 200V - 400V (335V) |
| Heater Voltage = | 12.6V | 12.6V |
| R1 = | 47k* | 47k* |
| R2, 4 = | 470 - 2k (1k 1mA) | 100 - 470 (200 6mA) |
| R3 = | 100 - 1k (178)* | 100 - 300 (178)* |
| R5 = | 2K 1W | 2K 1W |
| R6, 8, 15, 19, 23 = | 100 - 1k (300) | 100 - 1k (300) |
| R7, 9 = | 300 - 1k (470 3.5mA) | 300 - 1k (200 6mA) |
| R10 = | 93.1k | 83.2k |
| R11 = | 100k | 100k |
| R12 = | 21k/MF or 20k/CF | 21k/MF or 20k/CF |
| R13 = | 3.16k/MF or 3.2k/CF | 3.16k/MF or 3.2k/CF |
| R14, 17 = | 470 - 2k (1k 1mA) | 470 - 2k (1k 1mA) |
| R16, 25 = | 1M | 1M |
| R18 = | 3.9k 3W | 2k 3W |
| R20, 24 = | 470 - 2k (1k 1mA) | 470 -1k (1k 5mA) |
| R21 = | 100k | 100k |
| R22 = | 93.1k | 78k |

*High-quality resistors essential in this position. All resistors 1/2W or higher where specified

| | | |
|---|---|---|
| C1 = | Optional, 50 -1,000pF | Optional, 50 -1,000pF |
| C2, 5, 10, 13 = | Optional, 0.01µF 250V | Optional, 0.01µF 250V |
| C3, 11 = | 150µF, 400V Electrolytic | 150µF, 400V Electrolytic |
| C4, 6, 12, 14 = | 0.1 - 1µF (0.33µF)* | 0.1 - 1µF (0.33µF)* |
| C7 = | 0.033µF Flim or PIO* | 0.033µF Flim or PIO* |
| C8 = | 0.1µF Flim or PIO* | 0.1µF Flim or PIO* |
| C9 = | 0.047µF - 1µF* Film or oil* | 0.047µF - 1µF* Film or oil* |
| C15 = | 0.22 - 4.7µF Film or PIO* | 0.22 - 4.7µF Film or PIO* |
| C17 = | 0.001µF (trim)* | 0.001µF (trim)* |

*Voltage rating must equal or exceed B+ voltage. C17 is a trim capacitor that in parallel with C7 brings the combined capacitance up to 0.34µF.

## Assembly

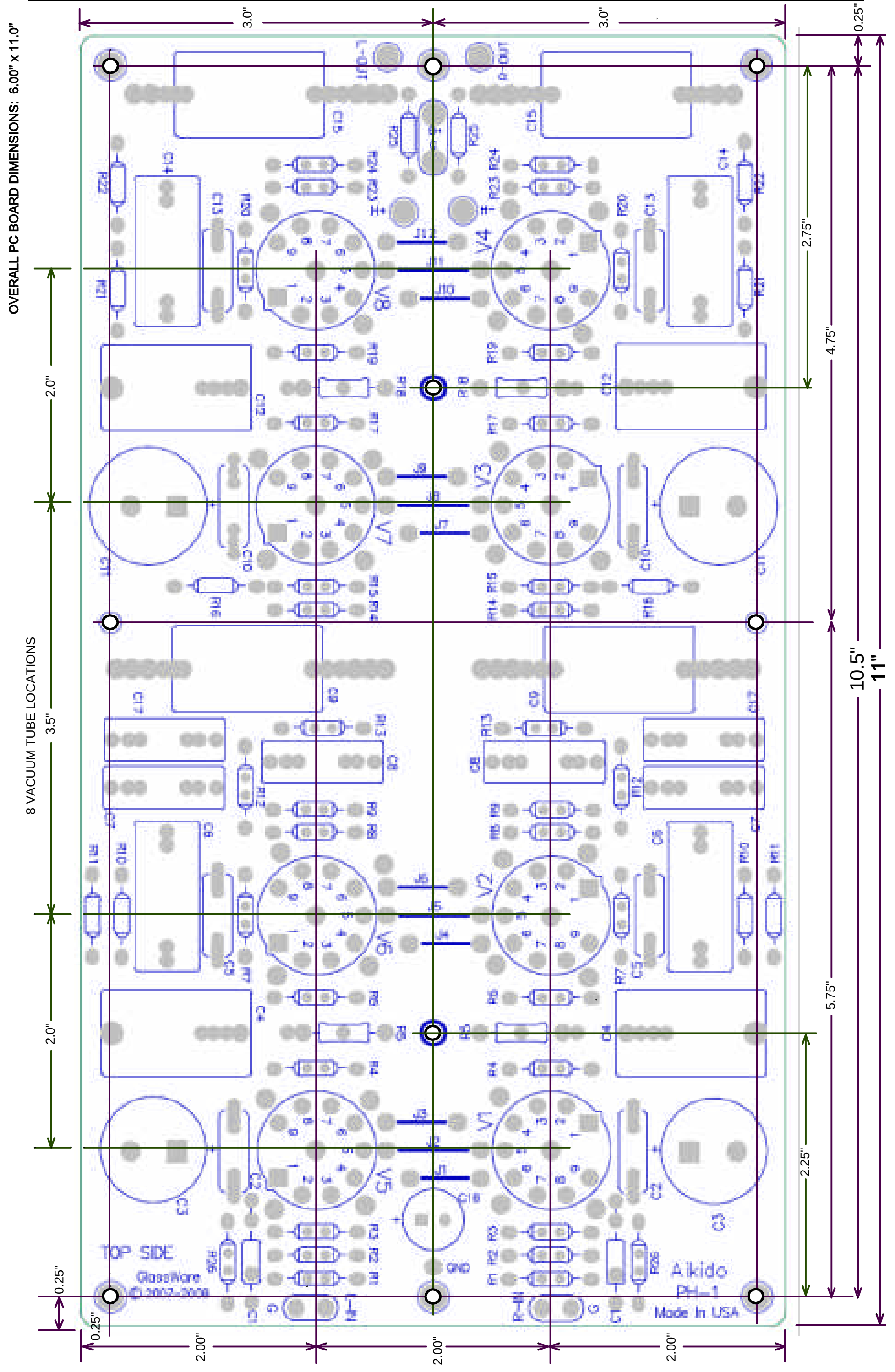
Before soldering, be sure to clean both sides of the PCB with 90% isopropyl alcohol, wiping away all fingerprints. First, solder the shortest parts (usually the resistors) in place, then the next tallest parts, and then the next tallest... Make sure that both the solder and the part leads are shiny and not dull gray. Steel wool can restore luster and sheen by rubbing off oxidation.

As the PCB is doubled sided, parts can be soldered in place from either side. In fact, many of the parts can be positioned on the bottom side of the PCB; the exception being the tubes, as they must always be positioned on the top of the board.

**Important:** **Be sure to observe the electrolytic capacitors' polarity and glue or double-sided tape heavy coupling and bypass capacitors to the PCB.**

**Grounding** Unlike all the other GlassWare PCBs, there is no grounding jumper that connects the PCB's ground to the chassis through a mounting hole. Unfortunately, grounding is an art. My preference is to ground the chassis at the turntable's grounding jack. The PCB holds a grounding solder pad in between the two inputs; use this pad to connect to the grounding jack and chassis.

**RFI** Radio interference can be a headache for the vinyl lover. One solution is the use large shunting capacitors across the input resistor, R1; this remedy seldom works. Instead, place small ferrite beads over the wires leaving the input RCA jacks and the PCB; add small ceramic capacitors (say, 200pF) from the input RCA jacks ground (and maybe hot) to the shared grounding jack and chassis ground point.


OVERALL PC BOARD DIMENSIONS: 6.00" x 11.0"
8 VACUUM TUBE LOCATIONS
3.0"
3.0"
0.25"
2.75"
4.75"
10.5"
11"
5.75"
2.25"
2.0"
3.5"
2.0"
0.25"
0.25"
2.00"
2.00"
2.00"
TOP SIDE
Aikido
PH-1
Made In USA

GlassWare

AUDIO DESIGN

**www.glass-ware.com**
**www.tubecad.com**

sales@glass-ware.com