Aikido

Aikido Mono Octal PCB

Revision C

USER GUIDE

05/28/2008

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.

Additionally, the board's layout is more complex than previous revs due to all the jumpers, so more care must be exercised in following the instructions in this user guide. In other words, this PCB is not so much a plug-and-play endeavor, but a think-plug-and-play undertaking.

Rev. C Overview

Thank you for your purchase of the TCJ Aikido, octal, Rev-C, mono PCB. This new board provides more circuit flexibility than the previous versions. The output stage can now be configured either as the classic Aikido line amplifier or as an Aikido headphone amplifier. In addition, the board also sports new ventilation holes under the tube sockets, two holes around capacitor C1 for using a tie wrap to hold large capacitors in place, pads for a cathode resistor bypass capacitor (C3), and a slightly, but subtly improved part layout.

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. The boards are proudly—and expensively—made in the USA. Each PCB holds one complete Aikido line-stage/headphone amplifier; thus, for stereo, two boards are needed; mono amplification, one board; and five-channel, five boards. The boards are four inches by six inches, with five mounting holes.

Two Output-Stage Topologies The Rev. C board provides substantially more circuit configuration flexibility than the previous versions. The output stage can now be configured either as the classic Aikido line amplifier or as an Aikido headphone amplifier (with a White cathode-follower output stage).

PCB Features

Redundant Solder Pads The 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.

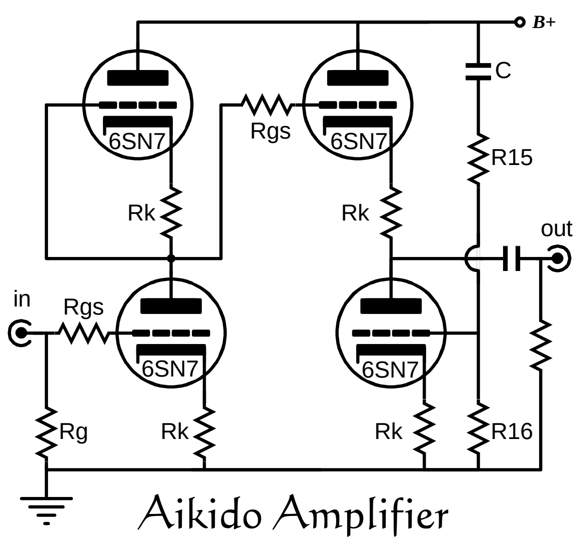
Dual Coupling Capacitors The PCB can hold two coupling capacitors, each finding its own 1M resistor to ground. Why? The idea here is that you can select (via a rotary switch) between coupling capacitors C1 or C2 or both capacitors in parallel. Why again? One coupling capacitor can be Teflon and the other oil or polypropylene or

Each type of capacitor has its virtues and failings. So use the one that best suits the music; for example, one type of coupling capacitor for old Frank Sinatra recordings and the other for late Beethoven string quartets. Alternatively, the same flavor capacitor can fill both spots: one lower-valued capacitor setting a low-frequency cutoff of 80Hz for background or late night listening; the other higher-valued capacitor, 5Hz for full range listening. Or if you have found the perfect type of coupling capacitor, the two capacitors could be hardwired together on the PCB, one smaller one acting as a bypass capacitor for the lager coupling capacitor. On the other hand, each coupling capacitor can feed its own output, for example, one for low-frequency-limited satellites and one for subwoofers. Jumper J1 bridges the two outputs.

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.

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 straight. 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 the amplifier.



In the schematic above, the 6SN7 triodes are so specified for example only. Although they would never fit on the printed circuit board (PCB), 211 and 845 triodes could be used to make an Aikido amplifier. The circuit does not rely on 6SN7 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.)

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); with some tweaking of resistor R15's value, -60dB or more is possible. Additionally, unless regulated power supplies are used for the plate and heater, these critical voltages will vary at the whim of the power company and your house's and neighbors' house's use, usually throwing the once fixed voltage relationships askew. Nevertheless, the Aikido amplifier will still function flawlessly, as it tracks these voltage changes symmetrically.

Remember, tubes are not yardsticks that never change, 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. So the fresh 6SN7 is not the same as that same 6SN7 after 2,000 hours of use. But as long as the two triodes age in the same way— which they are inclined to do, as they do the same amount of work and share the same materials and environment— the Aikido amplifier will always bias up correctly, splitting the B+ voltage between the triodes. Moreover, the Aikido amplifier does not make huge popping swings at start up, as the output does not start at the B+ and then swing down a hundred or so volts when the tube heats up, as it does in a ground-cathode amplifier.

Furthermore, the Aikido amplifier— like other Aikido techniques I have tried— seems to bypass much of the power supply squirrelliness, making the circuit sound as if it were attached to batteries or a well-regulated power supply. (This includes the sonic traces left by imperfect power supply capacitors.)

This circuit eliminates power-supply noise from the output, by injecting the same amount of PS noise at the top and bottom of the two-tube cathode follower circuit. The way it works is that the input stage (the first two triodes) define a voltage divider of 50%, so that 50% of the PS noise is presented to the CF's grid; at the same time the 100k resistors also define a voltage divider of 50%, so the bottom triode's grid also sees 50% of the PS noise. 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).

If the output connection were taken from the output cathode follower's cathode rather than the bottom triode's plate, then the balance will be broken. The same holds true if the cathode follower's cathode resistor is removed. Besides, this resistor actually makes for a better sounding cathode follower, as it linearizes the cathode follower at the expense of a higher output impedance.

When driving low-impedance headphones, say 32-ohms, the cathode resistor should be replaced with a jumper wire and the cathode-resistor-bypass capacitor C3 should be used. When used as a line stage amplifier, however, no cathode resistor bypass capacitor should be used, as this capacitor is very much in the signal path and very few do not damage the sound, unless supremely-high-quality capacitors are used.

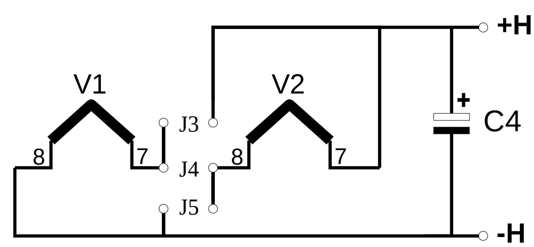
Heater Issues

Either 6.3V or 12.6V heater power supplies can be used for the heaters, so that 6.3V heater tubes (like the 6BX7 and 6SN7) or 12.6V tubes (like the 12SL7 or 12SN7) can be used. However, both tubes, V1 & V2 must share the same heater voltage. For example, a 6SL7 for the input tube and a 6BX7 for the output tube can be used, although they differ vastly in heater current draw; a 12SX7 and a 6SN7 could not be used, as they differ in heater voltage; however, a 12SX7 and a 12SN7 would work, as they share the same heater voltage.

(In theory, a 6.3V and a 12.6V tube could be used in series, if the two tubes' heaters required the same current draw, but this gets complicated; for example a 6SL7 and a 12SN7 draw the same heater current, total of 18.9 volts at 300mA, AC or DC.)

The heaters may be wired in series or in parallel: for parallel heaters, use only jumper J3 and J5; for series, use jumpers J4 only. Important: only place the heaters in series, if both tubes draw the same heater current; for example 6SN7 and 6SN7, not 6SL7 and 6SN7.

Filament Jumper Wire Schedule*



Heaters in series:
Use J4 only.

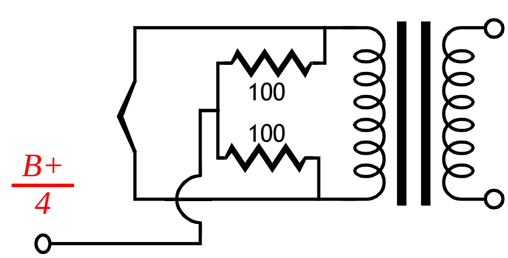
Heaters in parallel:
Use J3 and J5 only.

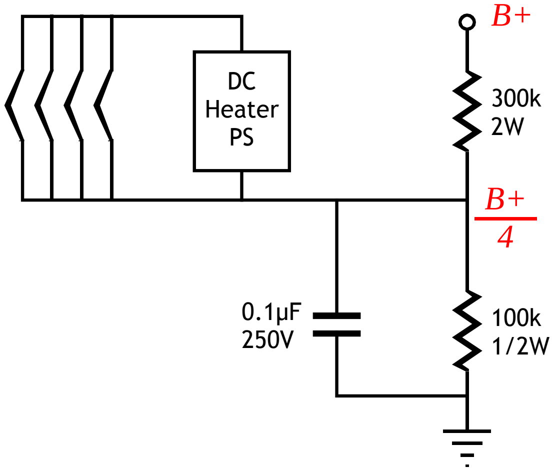
*Both tubes must share the same heater voltage

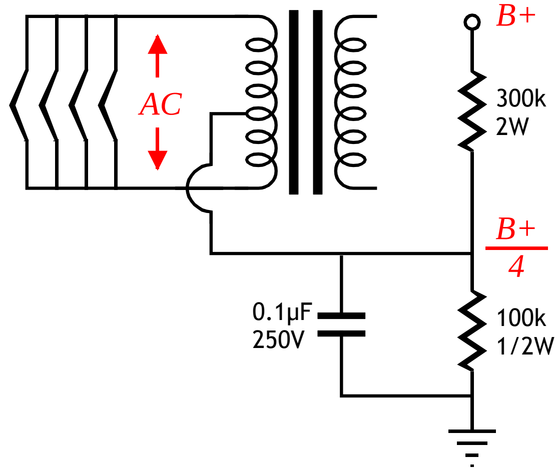
Although DC heater power supply certainly provides the lowest hum level and the clearest bass reproduction, the boards can be used with a DC or an AC heater power supply; if an AC power supply is used, then the heater reservoir capacitor, C4, must be left off the board (or replaced by a 0.1µF film capacitor). (Many 6SN7s hum madly with an AC heater voltage power supply, but are hum-free with DC power supplies.)

Since in the Aikido topology, one triode stands atop another (in the same envelope), both triodes can never share the same heater-to-cathode voltage relationships. The safest path is to reference the heater power supply to a voltage to one-fourth the B-plus voltage; for example, 75V, when using a 300V power supply. The ¼ B-plus 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 circuits.

If the AC heater winding does not hold a center-tap, two 100-ohm resistors placed in series across the winding will create a pseudo center-tap that will work just as well as a true center-tap.





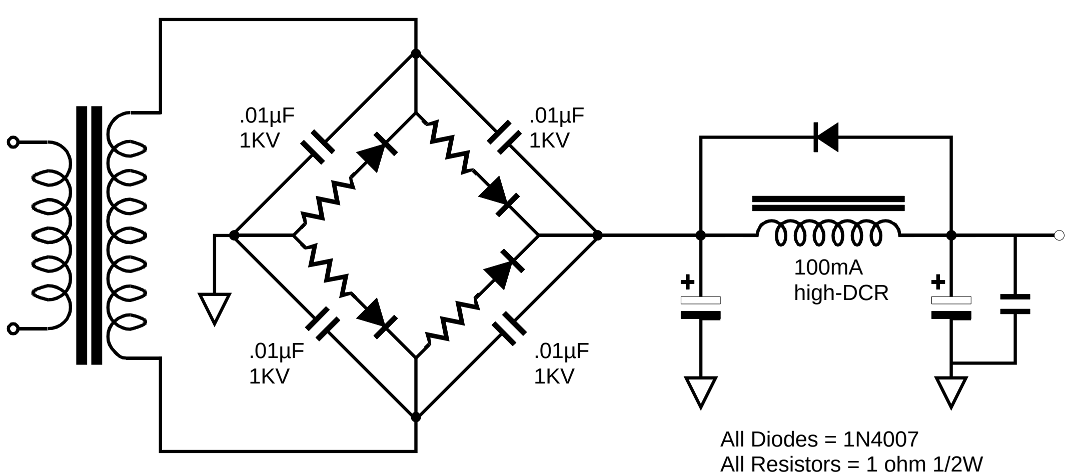


Alternatively, you might experiment with floating the heater power supply, by "grounding" the heater power supply via only a 0.1µF film or ceramic capacitor. The capacitor will charge up through the leakage current between heater and cathodes. Not only is this method cheap, it is often quite effective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

Power Supply

The power supply is external to the Aikido 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, 12SX7s can be used with a low 100V power supply, while 6SN7s 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 400V.

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 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.



Jumper J4 connects the PCB's ground to the chassis through the bottom rightmost mounting hole. If you wish to float the chassis, leave jumper J4 out; if you wish to capacitor couple the chassis to ground, replace jumper J2 with a small-valued, high-voltage capacitor (0.01 to 0.1µF, 250V to 600V). Warning: if rubber O-rings are used with PCB standoffs, then the ground connection to the chassis is not likely to be made.

Tube Selection

Unlike 99.9% of tube circuits, the Aikido amplifier defines a new topology without fixed part choices, not an old topology with specified part choices. In other words, an Aikido amplifier can be built in many different ways. For example, a 6SL7 input tube (V1) will yield a gain close to 35 (mu/2), which would be suitable for a phono preamp; a 6SN7 (5692) or 12SX7 input tube will yield a gain near 10, which would be excellent for a line stage amplifier; the 6AS7 or 6BX7 in the output stage (V2) would deliver a low output impedance that could drive capacitance-laden cables or even high-impedance headphones. The list of possible tubes is not overly long: 2C50, 6BL7, 6BX7, 6H30Pi, 6SL7, 6SN7, 6SU7, 12SL7, 12SN7, 12SX7, 5691, 5692, 6080, ECC32, ECC33. The only stipulations are that the two triodes within the envelope be similar and that the tube conforms to the 8BD base pin-out. Additionally, both input tube must match each other in heater voltage.

If the Aikido amplifier job is to be a front-end for an SE power amplifier, then the best input tube is the 6SL7/6SU7/5691 or 12SL7, as they provide the highest gain. And in this application, the 6SN7/5692 is a good choice for the Aikido's output tube and resistors R5 and R6 should be 10 Meg-ohm.

Cathode Resistor Values

The cathode resistor sets the idle current for the triode: the larger the value of the resistor, the less current. In general, high-mu triodes require high-value cathode resistors (1-2K) and low-mu triodes require low-valued cathode resistors (100-1k). I recommend running the output tubes hotter than the input tubes. For example, 1k cathode resistors for the input tube (V1) and 300-ohm resistors for the output tubes (V2), when using 6SN7s or 12SX7s throughout. Thus, the output tubes will age more quickly than the input tubes, so rotating output for input tubes can extend the useful life of the tubes.

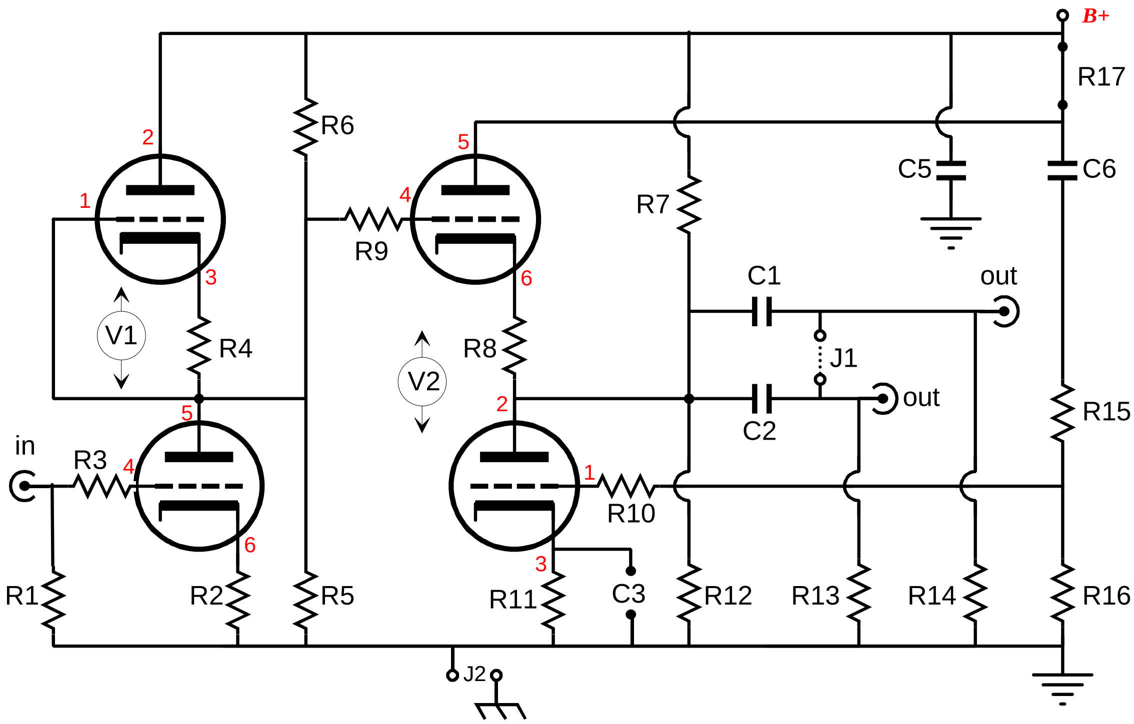
Assembly

Before soldering, be sure to clean both sides the PCB with 90-99% isopropyl alcohol. Normally, such as when the PCB sits on the floor of its chassis, all the parts sit on the top side of the PCB (the top side is marked). If you wish to have the tubes protrude from holes on the top of the chassis (and to place the PCB within 1" of the top panel with the aid of standoffs), then all the other parts—except the tube sockets—can be placed on the PCB's backside; it is a double-sided board after all (be sure to observe the electrolytic capacitors' polarity and glue heavy coupling capacitors to the PCB). 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.

Configuring the PCB as a Line Amplifier

The Aikido topology is perfect for line amplifier use, as it offers low distortion, low output impedance, and excellent power-supply noise rejection—all without a global feedback loop. The key points are not to use neither capacitor C3 nor resistor R17 and be sure to use resistor R15. For guidance on part values, look at the page that lists several line-amplifier design examples. R15's value equals R16 [(mu -2)/(mu + 2)].

Aikido mono octal Rev-C schematic as line amplifier



Typical Part Values

() Parentheses denote recommended values

	[6/12]SN7 & [6/12]SN7	[6/12]SL7 & [6/12]SN7	6SN7 & 6BX7
B+ Voltage =	170V - 300V (300V)	200V - 300V (300V)	200V - 300V (200V)
Heater Voltage =	6.3V/12.6V	6.3V/12.6V	6.3V
R1,5,6,7,12,13 =	1M	Same	Same
R2,4 =	270 - 1k (470)*	470 - 2k (1k)*	270 - 1k (330)*
R3,9,10 =	100 - 1k (300)*	Same	Same
R8, R11 =	240* [Iq = 10mA]	390* [Iq = 17mA]	158* [Iq = 30mA]
R15 =	83.3k	Same	66.1k
R16 =	100k	"	Same
R17 =	0, Jumper	"	"

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

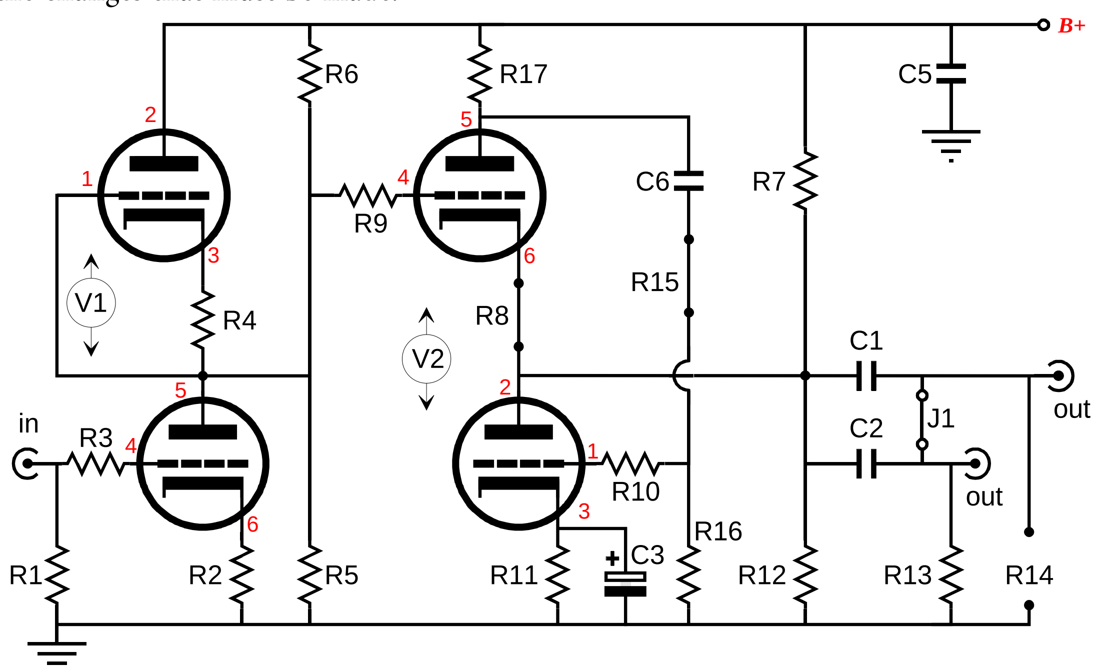
C1 =	0.1 - 10µF* Film or oil	Same	Same
C2 =	0.1 - 10µF* Film or oil	"	"
C5 =	0.1 - 10µF*	"	"
C6 =	0.047µF - 0.22µF* Film or oil	"	"
C4 =	100 - 1kµF, 16V Electrolytic	"	"

*voltage rating must equal or exceed B+ voltage

(input) V1 =	6SN7, 12SN7, 12SX7, 5692, B65, ECC32, ECC33	6SL7, 6SU7, 12SL7, 5691	6SN7, 12SN7, 12SX7, 5692, B65, ECC32, ECC33
(output) V2=	6SN7, 12SN7, 12SX7, 5692, B65, ECC32, ECC33	Same	6BL7, 6BX7

Configuring the PCB as a Headphone Amplifier

The standard Aikido is a thoroughly single-ended affair, nothing pulls while something else pushes. Unfortunately, wonderful as single-ended mode is sonically, it cannot provide the larger voltage and current swings that a push-pull output stage can. Single-ended output stages can only deliver up to the idle current into a load, whereas class-A push-pull output stages can deliver up to twice the idle current (and class-AB output stages can deliver many times the idle current). For a line stage, big voltage and current swings are seldom required; headphones, on the other hand, do demand a lot more power; in truth, a 32-ohm load is brutally low impedance for any tube to drive. Fortunately, the octal mono PCB can be configured with an optimal-White-cathode-follower output stage, which will both retain much of the Aikido's great PSRR and allow twice the idle current to be delivered into low-impedance loads. All that is required is to include resistor R17 and cathode-bypass capacitor C3 and replace resistors R8 & R15 with jumpers. The following headphone-amplifier schematic shows the changes that must be made.



The best output tubes for driving low-impedance headphones are the 6H30Pi, 6BL7, and 6BX7; for high-impedance headphones, the 6SN7/12SN7 works well. What about the 6AS7 or 6080? Unfortunately, this dual power triode is less suited than it first appears. Asides from the 2.5A heater requirement, the triode must be run at a fairly high idle current to move into its more linear range, say 40-60mA. Second, its low mu of only 2 means that it require a huge cathode bias resistor and plate resistor; in other words, it should be used with fixed bias, not cathode bias.

A coupling capacitor of at least 30µF is required when driving 300-ohm headphones; 300µF for 32-ohm headphones, which means electrolytic capacitor, as nothing else will fit on the PCB. If an electrolytic capacitor is used, try to find a photo-flash capacitor or a high-frequency electrolytic. A small-valued coupling capacitor (0.1 to 0.47µF) should be used in capacitor C2 position and should be soldered in place before coupling capacitor C1. Space is tight, which can be increased by using several layers of adhesive foam below capacitor C1.

Typical Part Values

() Parentheses denote recommended values

	[6/12]SN7 & [6/12]SN7	6SN7 & 6BL7	6SN7 & 6BX7
B+ Voltage =	170V - 300V (250V)	300V	200V - 300V (300V)
Heater Voltage =	6.3V/12.6V	6.3V	6.3V
R1,5,6,7,12 =	1M	Same	Same
R2,4 =	270 - 1k (470)*	"	"
R3,9,10 =	100 - 1k (300)*	"	"
R8 =	0, Jumper	"	"
(300-ohm HP) R11 =	100* [Iq = 14mA]	270* [Iq = 21mA]	470* [Iq = 21mA]
(32-ohm HP) R11 =	100* [Iq = 14mA]	270* [Iq = 21mA]	290* [Iq = 32mA]
R13 =	10k	10k	10k
R15 =	0, Jumper	Same	Same
R16 =	300k - 1M (470k)	"	"
(300-ohm HP) R17 =	310*	170*	205*
(32-ohm HP) R17 =	280*	140*	127*

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

(300-ohm HP) C1 =	47µF* Film	Same	Same
(32-ohm HP) C1 =	470µF*	"	"
C2 =	0.47µF* Film or oil	"	"
C5 =	0.1 - 10µF*	"	"
C6 =	0.047µF - 0.22µF* Film or oil	"	"
C4 =	1kµF, 16V Electrolytic	"	"
C3 =	1kµF, 10V Electrolytic	"	"

*voltage rating must equal or exceed B+ voltage

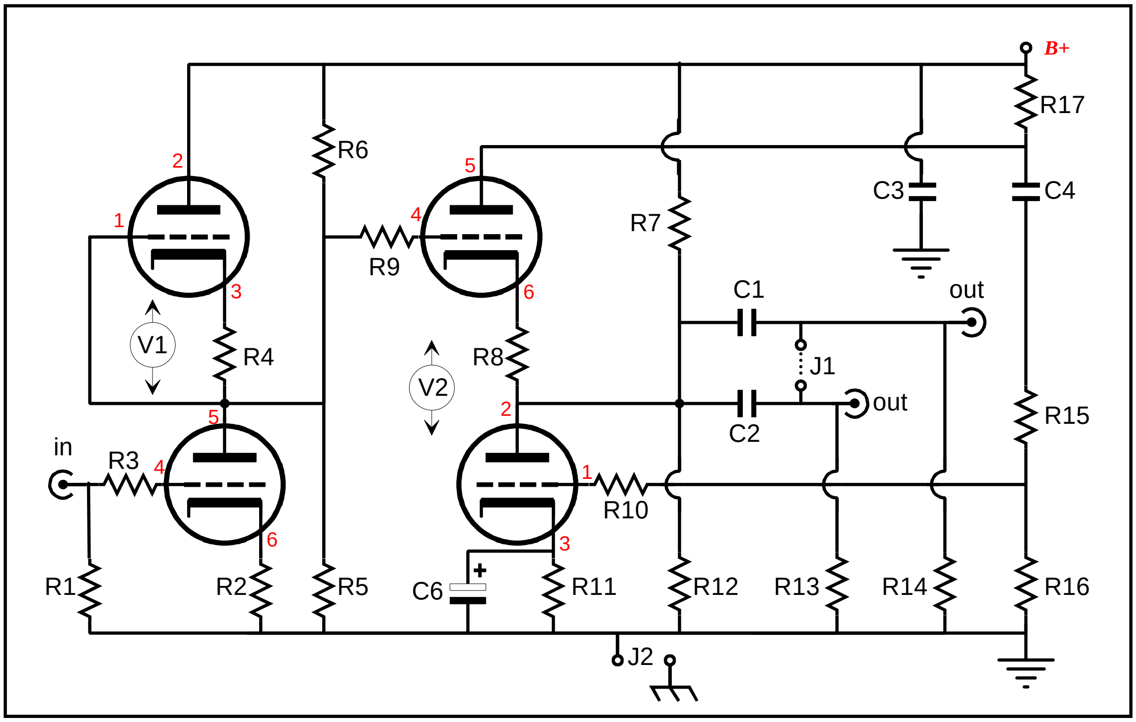
(input) V1 =	6SN7, 12SN7, 12SX7, 5692, B65, ECC32, ECC33	Same	Same
(output) V2=	6SN7, 12SN7, 12SX7, 5692, B65, ECC32, ECC33	6BL7, 6BX7	6BL7, 6BX7

Capacitor C3 should be at least 470µF and its voltage rating must exceed the voltage drop across the cathode resistor. A small high-quality bypass capacitor can be added, although no pads for it appear on the PCBs; just solder its leads across those for resistor R11 and position the capacitor above the resistor, with a small air gap between resistor and capacitor. On the other hand, if only 300-ohm headphones are going to be driven, then the best choice might be to use a 6SN7/12SN7 and retain both cathode resistors, R8 and R11, leaving both resistors unbypassed. The output impedance will be higher, but the distortion will be lower, although the low bass will probably suffer.

In the optimal White cathode follower, the critical resistor is R17. This resistor is used to sense current variations through the top triode and the resulting anti-phase signal is relayed to the bottom triode. In other words, it sets the balance between top and bottom tubes and it establishes the excellent PSRR figure for the entire amplifier. A value that is too high or too low will compromise performance. Finding the correct value for resistor R17 is easy: it roughly equals the reciprocal of the transconductance of the triodes used; In other words, rp/mu. The exact formula is:

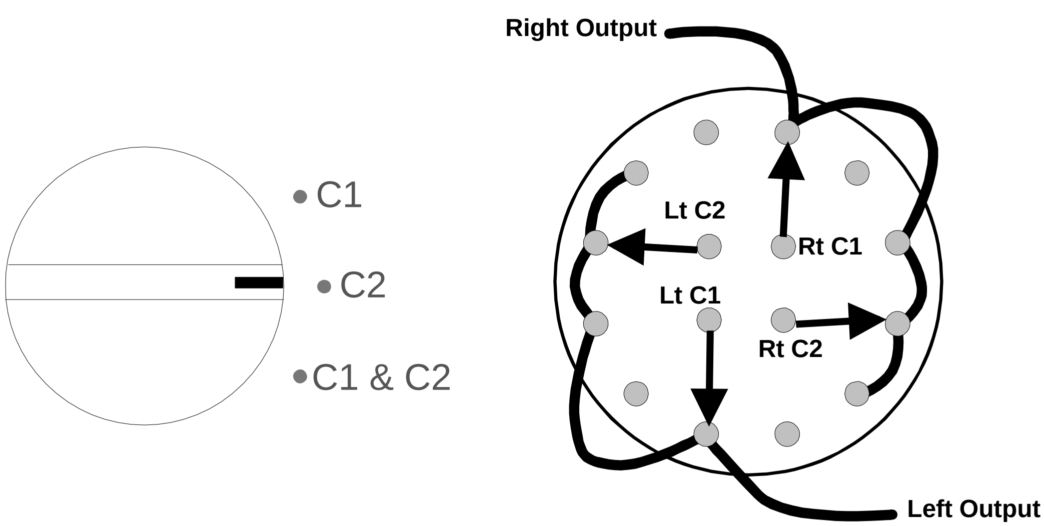
$$R17 = (rp + 2Rload)/mu$$

For example, a 6SN7 as the output tube, with a B+ voltage of 300V and an idle current of 10mA, has an rp of 7500 ohms and a mu of 22, roughly. Thus, with 300-ohm headphones as a load impedance, resistor R17 equals 368 ohms.



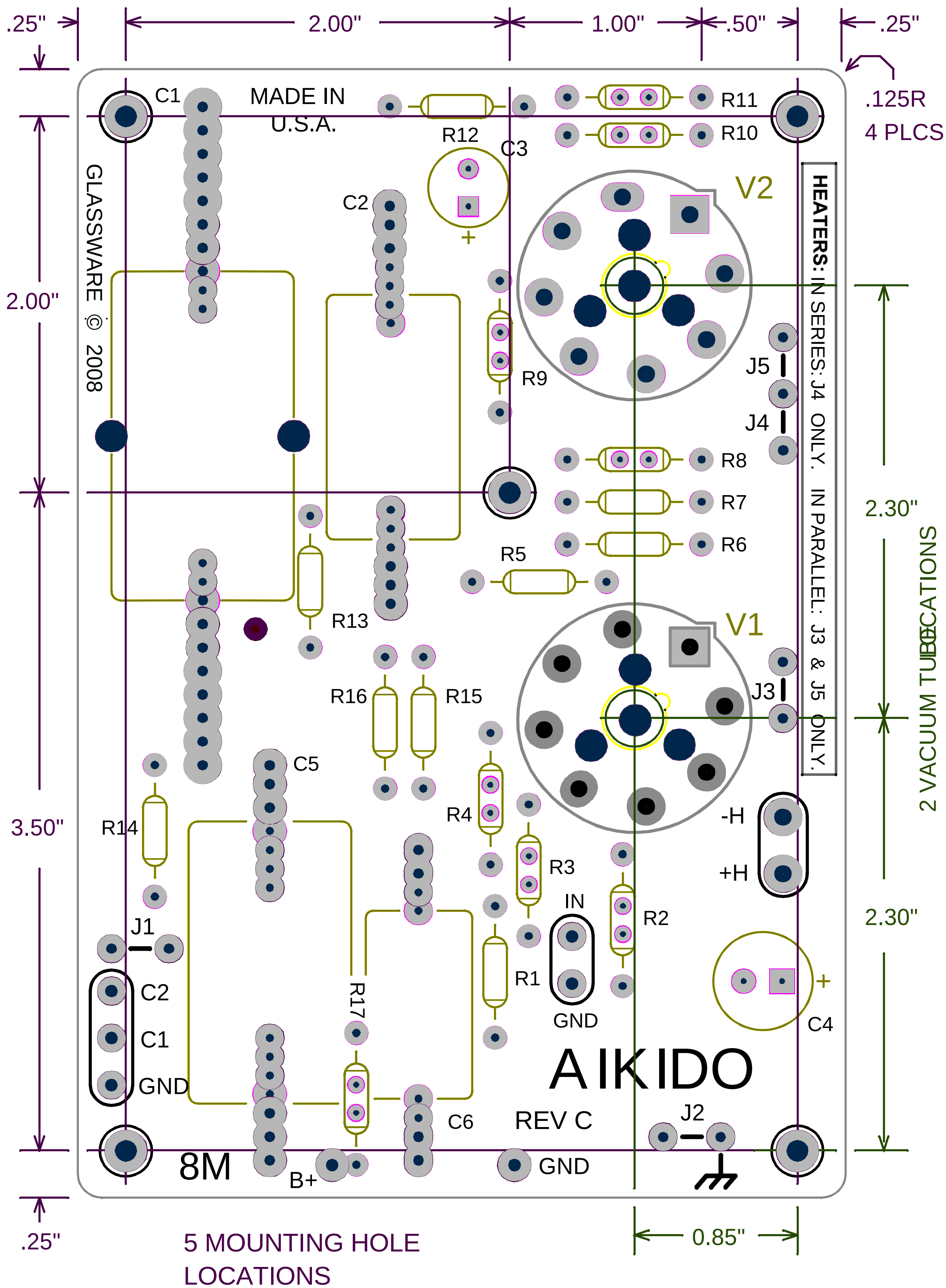
Octal Mono Aikido Schematic Revision B

How do I wire up a rotary switch for switching between the two coupling capacitors? We need a four-pole, three-position switch and some hookup wire. All four coupling capacitors attach to the input contacts and the two channels of output can receive either coupling capacitors C1's or C2's or both capacitors' outputs. The drawing below shows the knob on the faceplate and the rotary switch from behind. (The switch is shown on the "C1 + C2" position.)



Switch Front

Switch Rear



Top Side PCB Mechanical Layout

Tube	mu	Rp Ohms	Rk Ohms	Ik (mA)	B+ Volts	R15 Ohms	R16 Ohms	Input Gain	Input Gain dBs	Output Gain	Output in dBs	Zo Ohms
6AS7	2.23	234	55	100.0	100	5437	100k	1.1	0.9	0.60	-4.47	95
6AS7	2.0	310	205	75.0	150	0	100k	1.0	0.0	0.61	-4.28	220
6AS7	1.87	441	530	50.0	200	0	100k	0.9	-0.6	0.61	-4.24	456
6BL7	14.80	3140	196	10.0	150	76190	100k	7.4	17.3	0.91	-0.83	343
6BL7	15.40	2470	94	20.0	200	77011	100k	7.7	17.7	0.91	-0.86	219
6BL7	15.40	2540	165	20.0	250	77011	100k	7.7	17.7	0.91	-0.79	283
6BL7	15.90	2200	114	30.0	300	77654	100k	7.9	18.0	0.91	-0.79	219
6BX7	8.96	1760	267	10.0	100	63504	100k	4.5	13.0	0.87	-1.24	370
6BX7	9.44	1420	182	20.0	150	65035	100k	4.7	13.5	0.87	-1.21	273
6BX7	9.80	1270	158	30.0	200	66102	100k	4.9	13.8	0.87	-1.16	239
6BX7	10.10	1170	147	40.0	250	66942	100k	5.0	14.0	0.88	-1.13	220
6BX7	9.52	1730	542	20.0	300	65278	100k	4.7	13.5	0.89	-1.04	565
6SL7	70.00	43000	1000	1.3	300	94444	100k	31.4	29.9	0.98	-0.17	1174
6SN7	20.50	10200	583	3.0	150	82222	100k	10.0	20.0	0.93	-0.59	827
6SN7	21.10	8960	397	5.0	200	82684	100k	10.4	20.3	0.93	-0.59	657
6SN7	21.00	9250	626	5.0	250	82609	100k	10.3	20.2	0.94	-0.56	820
6SN7	21.90	7530	243	10.0	300	83264	100k	10.8	20.7	0.93	-0.60	489
6SN7	21.10	9000	680	5.8	300	82684	100k	10.3	20.3	0.94	-0.54	846
6SN7	21.40	8360	470	7.2	300	82906	100k	10.5	20.4	0.94	-0.56	685
6SN7	20.80	9840	1000	4.5	300	82456	100k	10.1	20.1	0.94	-0.53	1063
12SL7	See **6SL7**											
12SN7	See **6SN7**											
12SX7*	21.20	8750	218	5.0	80	82759	100k	10.5	20.4	0.93	-0.64	519
5691	See **6SL7**											
5692	See **6SN7**											
6080	See **6AS7**											
6082	See **6AS7**											
B65	See **6SN7**											
ECC32	See **6SN7**											
ECC33	35.00	9700				89189	100k	17.3	24.8	0.95	-0.48	248

*12SX7 can also use 6SN7's data.

The table above lists many triodes suitable for the octal-based Aikido amplifier PCB. The table lists the same tube under different B+ voltages and with different cathode resistor values. Two gains are listed: the first is the gain the tube realizes in the input position in the Aikido; the second is the gain of the same tube in the output stage. To calculate the final gain multiply the two voltage gains together (or add the gain in dBs together). For example, given an Aikido line amplifier with a B+ voltage of 300V, and a 6SN7 input tube with cathode resistors of 680, and a 6BX7 output tube with cathode resistors of 542 ohms, the final voltage gain equals 10.3 from the 6SN7 against the 0.89 gain of the 6BX7, with a product of 9.17. or, working with dBs instead, 20.3dB plus -.1.04dB, for a total of 19.26dB. (Aren't decibels great?)

If you have additional data, send it in and I'll add to the list.

Let me know what you think

If you would like to see some new audio PCB or kit or recommend a change to an existing product or if you need help figuring out the heater jumper settings or cathode resistor values, drop me a line by e-mail to the address above (begin the subject line with either "Aikido" or "tube"). Send email to editor@ tubecad.com.