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Dear Aikido-Ardent Audiophile,

Thank you for your purchase of the TCJ Aikido, 9-pin, Rev A, mono PCB. This new board provides more flexibility than the previous version. The output stage can be configured either as the classic Aikido line amplifier or as an Aikido headphone amplifier (if it is configured with a White cathode-follower-based output stage). The board also sports new ventilation holes around the tubes.

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 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.

Warning!

The PCB is for use with a high-voltage power supply; a real shock hazard exists. Once the power supply is attached, be cautious at all times. 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.

Redundant Solder Pads

The board holds two sets of differently spaced solder pads for each resistor, so that radial and axial resistors can easily be used (bulk-foil resistors and carbon-film resistors, for example). In addition, several 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 wax or wet-slug tantalum... As they used to sing in a candy bar commercial: "Sometimes you feel like a nut; sometimes you don't." Each type of capacitor has its virtues and failings. So use the one that best suits the music; for example, one type of coupling capacitors for old Frank Sinatra recordings and the other for late Beethoven string quartets. Or 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 J5 bridges the two outputs.

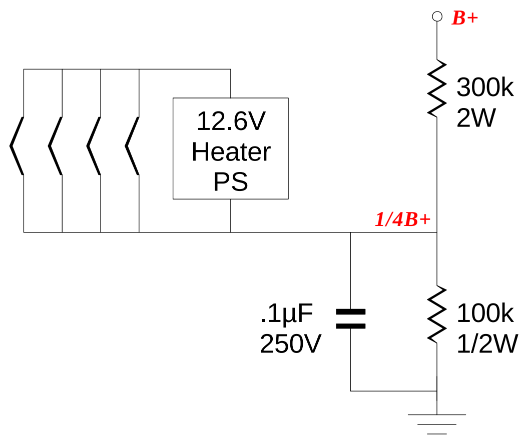
Heater Issues

The boards can be used with either a DC or AC heater power supply; AC-only if the heater shunting capacitor, C5, is left off the board or replaced by a 0.1µF film capacitor. Either 6.3V or 12.6V heater power supplies can be used for the tubes' heaters, so that 6.3V heater tubes (like the 6FQ7 and 6DJ8) or 12.6V tubes (like the 12AU7 or 12BH7) can be used. However, **<u>both tubes V1 & V2 must share the same heater voltage</u>**. For example, 6GC7 for the input tube and a 6H30 for the output tube can be used, although they differ in heater current draw; in contrast, a 12AX7 and a 6FQ7 could *not* be used, as they differ in heater voltage; however, a 12AX7 and a 12FQ7 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, for example a 6922 and a 12BH7 (300mA), but this gets complicated.

The heaters may be wired in series or in parallel: for parallel heaters, use only jumper J2; for series heaters, only jumpers J1 & J3.

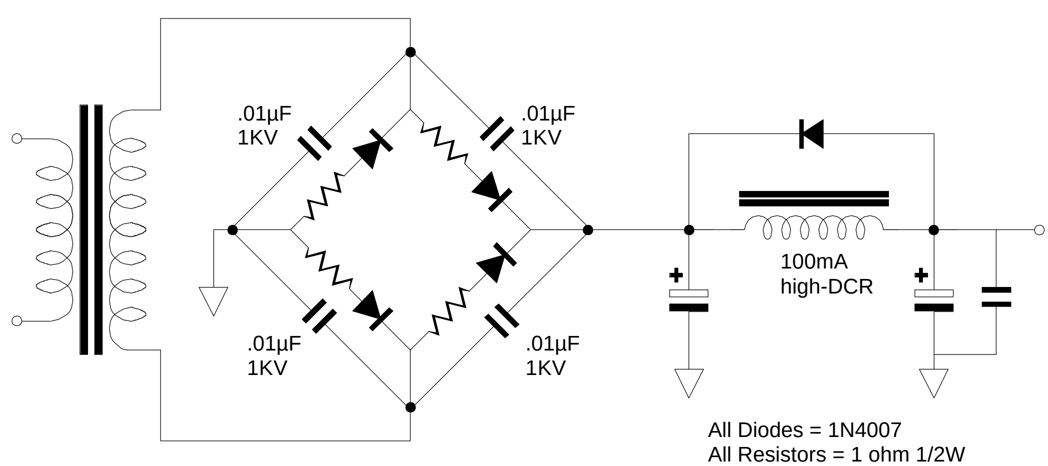
Since in the Aikido topology, both triodes (in the same envelope) stands atop another, they cannot share the same heater-to-cathode voltage relationships. The safest path is to reference the heater power supply to a voltage equal to one-fourth the B-plus voltage; for example, 75V, when using a 300V power 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 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 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, 6GM8s (ECC86) can be used with a low 24V power supply, while 6FQ7s 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 top centermost 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 J4 with a small-valued, high-voltage capacitor (0.01 to 0.1µF, 250V to 600V).

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 a nearly infinite number of ways. For example, a 12AX7 input tube will yield a gain close to 50 (mu/2), which would be suitable for a phono preamp or an SE amplifier's input stage; a 6FQ7 (6CG7) input tube will yield a gain near 10, which would be excellent for a line stage amplifier; the 6DJ8 or 6H30 in the output stage would deliver a low output impedance that could drive capacitance-laden cables or even high-impedance headphones. In other words, the list of possible tubes is a long one: 6AQ8, 6BC8, 6BK7, 6BQ7, 6BS7, 6DJ8, 6FQ7, 6GC7, 6H30, 6KN8, 6N1P, 12AT7, 12AU7, 12AV7, 12AX7, 12BH7, 12DJ8, 12FQ7, 5751, 5963, 5965, 6072, 6922, E80CC, E188CC, ECC88, ECC99... There are only three stipulations: that the two triodes within the envelope be similar, that the tube conform to the 9A or 9AJ base pin-out, and that both input and output tubes share the same heater voltage.

Internal Shields

If the triode's pin 9 attaches to an internal shield, as it does with the 6CG7 and 6DJ8, then capacitors, C6 and C7 can be replaced with a shorting wire, which will ground the shield. However, using the capacitors will also ground the shield (in AC terms) and allow using triodes whose pin 9 attaches to the center tap of its heater, such as the 12AU7. In other words, it best to use these capacitors instead of a shorting wire.

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). When using the same tube for both input and output tubes, 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 tube (V2). This arrangement means that the output tubes will age more quickly than the input tubes, so rotating output for input tubes can extend the life of the tubes.

Assembly

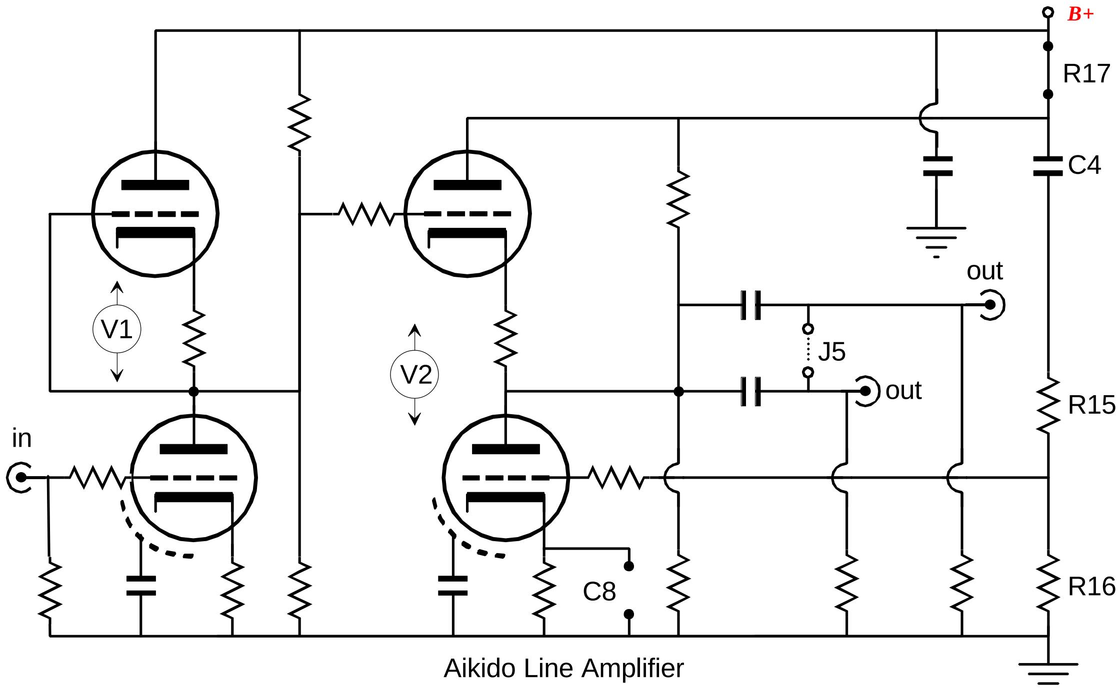
Before soldering, be sure to clean both sides the PCB with 90-99% isopropyl alcohol. Normally, such as when the PCB sits on the floor of its chassis, all the parts sit on the top side of the PCB (the top side is marked). If you wish to have the tubes protrude from holes on the top of the chassis (and 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.

If any of the parts have gold-plated leads, remove the gold flash before soldering the part, as only a few molecules of gold will poison a solder joint, making it brittle; use sandpaper, steel wool, or a solder pot. NASA forbids any gold-contaminated solder joints; you should as well. (Yes, there are many quality parts with gold-flashed leads, but the use of gold is a marketing gimmick, not sound electrical engineering practice.)

Configuring the PCB as a Line Amplifier

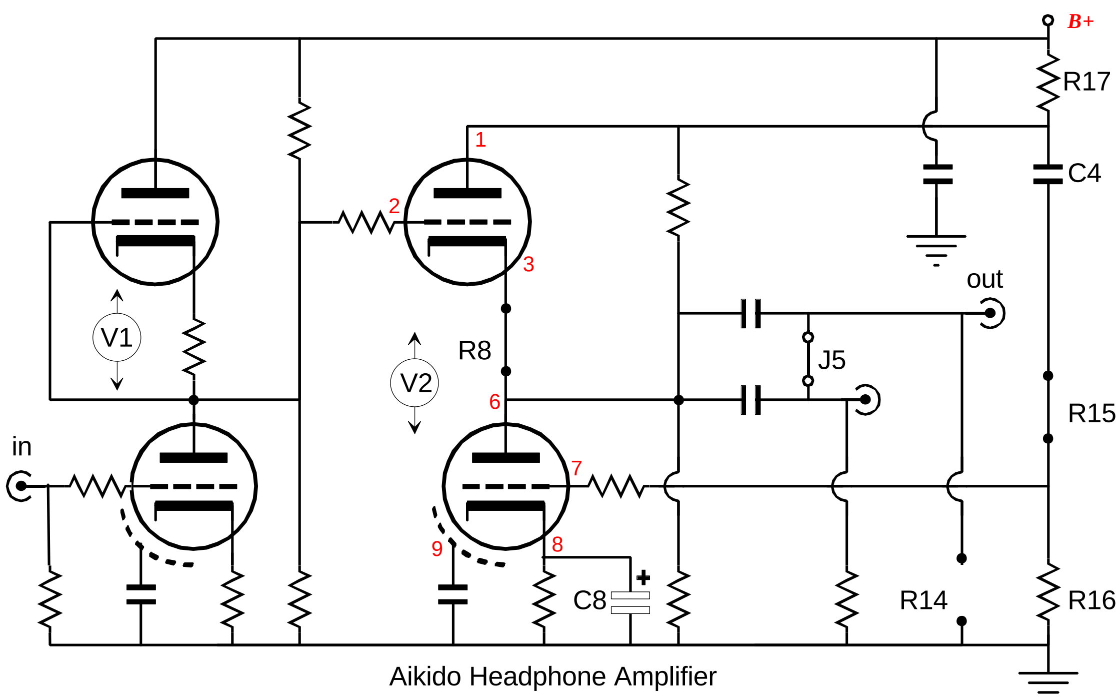
The Aikido topology is perfect for line amplifier use, as it offers low distortion, low output impedance, and excellent power-supply noise rejection—all without a global feedback loop. The key points are not to use capacitor C8 and resistor R17 and be sure to use resistor R15. For guidance on part values, look at the page that lists several line-amplifier design examples. R15's value equals R16[mu -2)/(mu + 2)].



Aikido Line Amplifier

Configuring the PCB as a Headphone Amplifier

The standard Aikido is a thoroughly single-ended affair, nothing pulls while something else pushes; in fact, even the input and output stages work in the *same* current phase. 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 stages can only deliver up to the idle current into a load, whereas class-A push-pull 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; really, a 32-ohm load is brutally low impedance for any tube to drive. Fortunately, the PCB can be configured with an optimal White cathode-follower stage, which will both retain 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 capacitor C8 and replace two resistors R8 & R15 with jumpers. The following headphone-amplifier schematic shows the changes that must be made.



Aikido Headphone Amplifier

High transconductance output tubes are best for driving headphones, for example, the 6DJ8, 6H30, 12BH7, ECC99. A coupling capacitor of at least 30µF is required when driving 300-ohm headphones; 300µF for 32-ohm headphones. Capacitor C8 should be at least 470µF.

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 equals the reciprocal of the transconductance of the triodes used.

How the Optimal White Cathode Follower Works

Push-pull output stages are, at heart, difference amplifiers; which is why a phase splitter is needed. When both output tubes' grids are presented with the exact same signal, the amplifier does not amplify. This works wonderfully to reduce power supply noise in a conventional transformer coupled push-pull amplifier, as the much of the power-supply noise is common to both phases (or at least we hope it is). The problem with totem-pole (inline) push-pull amplifiers is that the noise is not always equally imposed on the two phases of signal. This discrepancy gives rise to noise at the output. So in order to reduce the noise at the output of an optimally-designed White cathode follower, we must ensure equal noise, equal in both amplitude and phase, superimposed on the signal at each grid for bottom and top triodes.

In an Aikido headphone amplifier, just what are the existing noise relationships in an optimally designed White cathode follower? For the top triode, the answer is easy enough: its grid sees all the noise present at the previous stage's output, which in an Aikido amplifier is 50%. Similarly, the bottom triode sees half the B-plus noise at its grid as well. This results from specifying that the resistor R17 equal the reciprocal of the triode's transconductance. A pulse of +1V applied to the B-plus voltage will be relayed to the bottom triode's grid. The bottom triode will then fight this positive pulse by increasing its conduction by this +1V against its transconductance, which in this case, let's say is 10 mA-per-volt. Thus, the increase in conduction for both triodes is 10 mA. Now 20 mA (the idle plus the pulse current) through a 100-ohm resistor equals 2 volts. And, as the resistor has just been pulled up one volt, the extra 1 volt developed is displaced by the that pulse. In other words, they cancel, leaving the top triode's plate voltage unchanged. Wait a minute: if the pulse is needed to cancel itself, how can it, once cancelled, work to cancel itself? It can't. The best it can do is tie and leave half of the pulse's magnitude present on the top plate and, in turn, on the bottom grid as well.

Another way of seeing the mechanism at work is to find the effective (not the nominal rp) impedance at the top triode's plate and then figure out the voltage division between resistor R17 and the rest of the circuit. Because the coupling capacitor relays any voltage variation on the top plate to the bottom grid, the effective transconductance for the entire circuit is equal to the bottom triode's transconductance, 10 mA-per-volt. The inverse of the transconductance equals the effective impedance. Thus, the effective impedance of the top plate is 100 ohms. Since this 100 ohms impedance finds itself in series with a 100-ohm resistor, the voltage division is 50%, which matches the 50% voltage division of the Aikido's input stage.

Let me know what you think

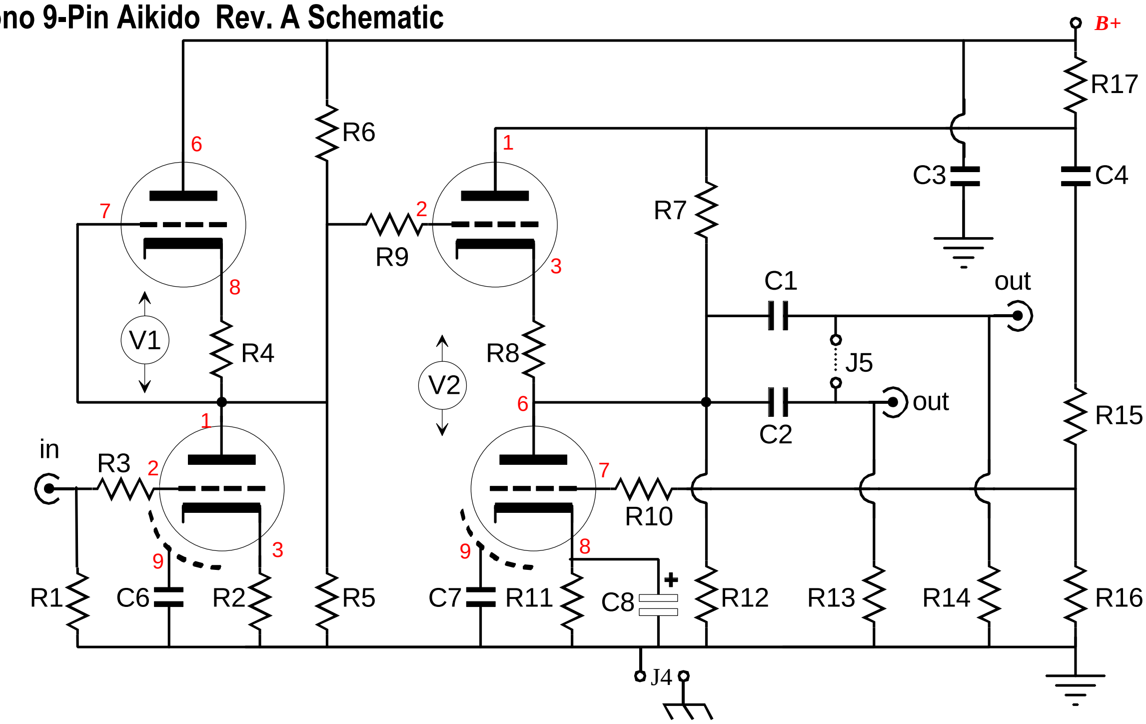
If you would like to see some new audio PCB or kit or recommend a change to an existing product or if you need help figuring out the heater jumper settings or cathode resistor values, drop me a line by e-mail to the address above (begin the subject line with either "Aikido" or "tube").

John Broskie

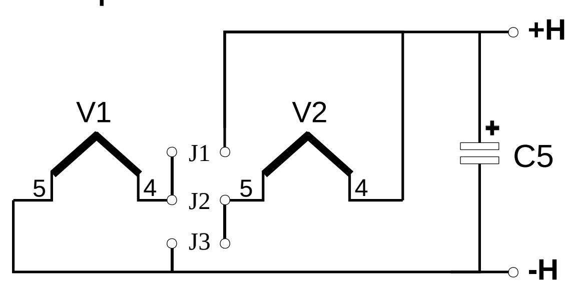
P.S.

Since the Aikido circuit came out in the *Tube CAD Journal*, people have been building it and marveling at its sound. A prediction: just as the 1980s were the cascode decade and the 1990s, the SRPP decade, this decade will be known as the Aikido decade. Spread the word.

Mono 9-Pin Aikido Rev. A Schematic



Filament Jumper Wire Schedule*

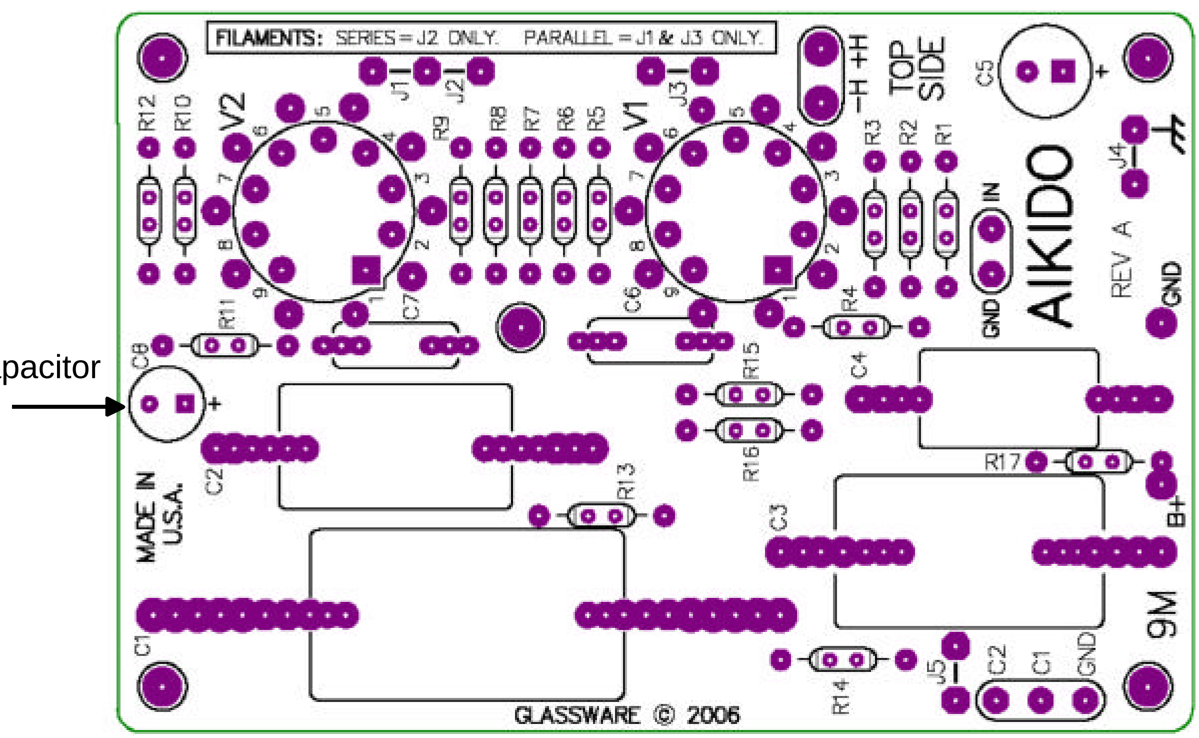


Heaters in series:
Use J2 only.

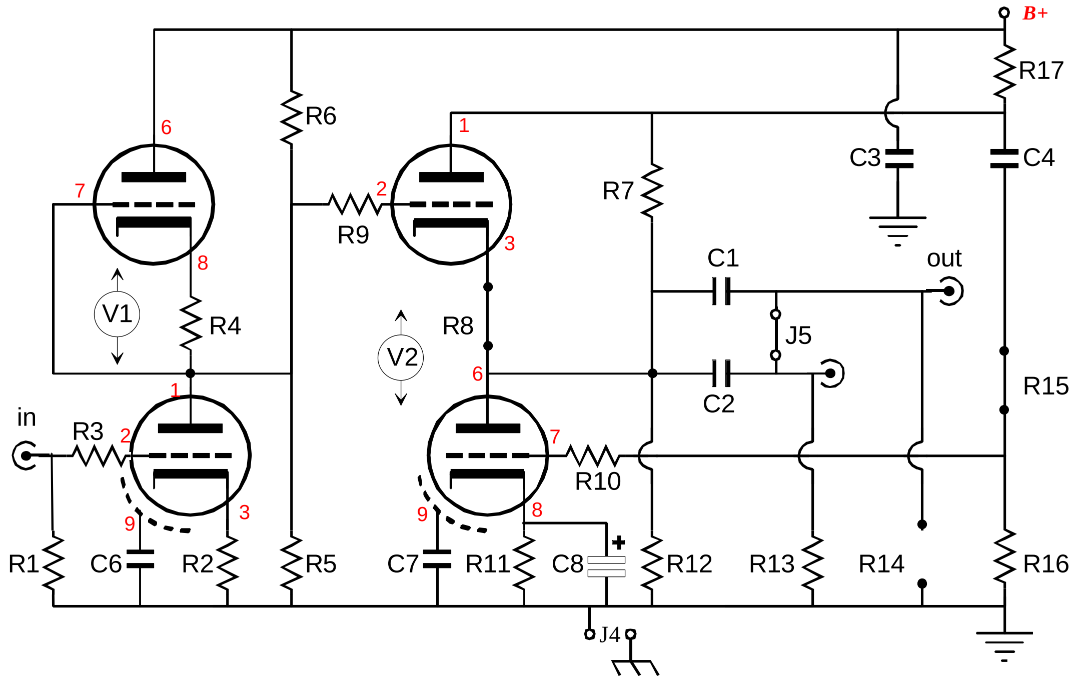
Heaters in parallel:
Use J1 and J3 only.

*Both tubes must share the same heater voltage

Capacitor C8



Aikido mono 9-pin revision-A schematic as headphone amplifier



Typical Part Values

() Parentheses denote recommended values

	6CG7 & 6DJ8 / 6H30	6CG7 & 6CG7	12AU7 & 12BH7 / ECC99
B+ Voltage =	170V - 250V (200V)	200V - 300V (300V)	200V - 300V (250V)
Heater Voltage =	6.3V	6.3V	12.6V
R1,5,6,7,12,13 =	1M	1M	1M
R2,4 =	270 - 1k (470)*	470 - 2k (1k)*	470 - 2k (1k)*
R3,9,10 =	100 - 1k (300)*	100 - 1k (300)*	100 - 1k (300)*
R8,11 =	200 - 330 (200)*	200 - 470 (330)*	200 - 470 (330)*
R15 =	0, Jumper	0, Jumper	0, Jumper
R16 =	300k - 1M (470k)	300k - 1M (470k)	300k - 1M (470k)
R17 =	100*	360*	127*

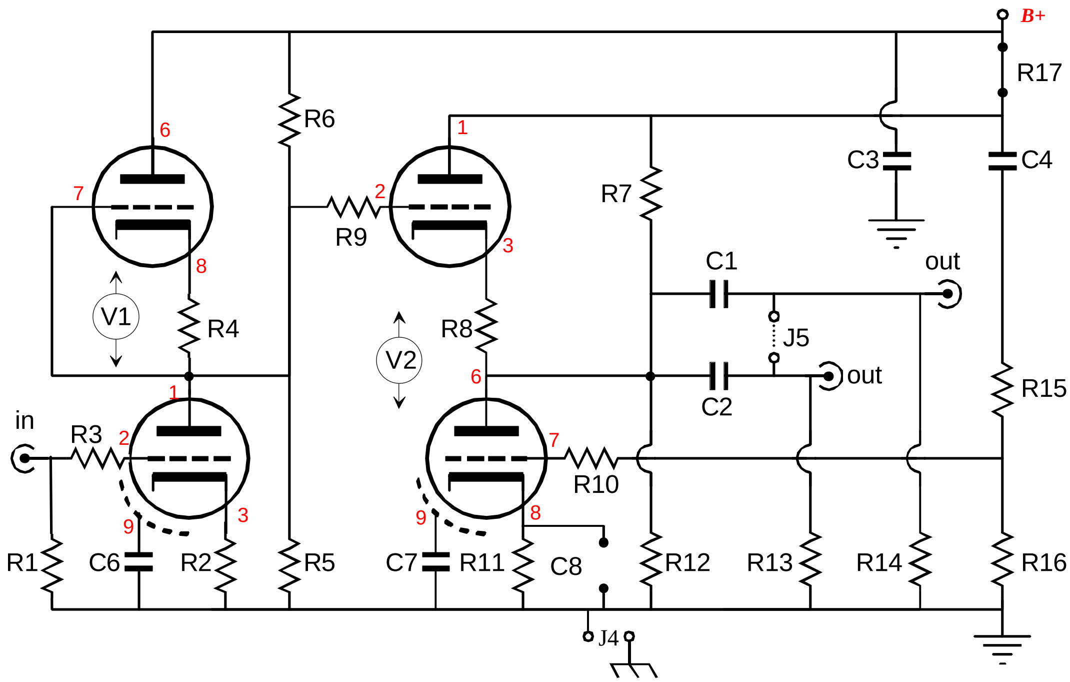
*High-quality resistors essential in this position
All resistors 1/2W or higher

C1 =	47µF* Film for 300-ohm HP	Same	Same
	470µF* for 32-ohm HP	Not recommended	470µF* for 32-ohm HP
C2 =	0.47µF* Film or oil	Same	Same
C3 =	1 - 10µF*	"	"
C4 =	0.047µF - 0.22µF* Film or oil	"	"
C5 =	10 - 1kµF, 10V Electrolytic	"	10 - 1kµF, 16V Electrolytic
C6 =	0.1µF 160V(optional)	"	None
C7 =	0.1µF 160V(optional)	"	None
C8 =	47µF-1kµF, 10V Electrolytic	"	Same

*voltage rating must equal or exceed B+ voltage

(input) V1 =	6CG7, 6FQ7	6CG7, 6FQ7	12AU7, 5814, 5963, 6189, ECC82
(output) V2=	6DJ8, 6H30, 6922, 7308, ECC88	6CG7, 6FQ7	12BH7, ECC99

Aikido mono 9-pin revision-A schematic as line amplifier



Typical Part Values

() Parentheses denote recommended values

	6CG7 & 6DJ8	6CG7 & 6CG7	12AU7 & 12AU7	12AU7 & 12BH7
B+ Voltage =	170V - 250V (200V)	200V - 300V (300V)	200V - 300V (250V)	200V - 300V (300V)
Heater Voltage =	6.3V	6.3V	12.6V	12.6V
R1,5,6,7,12,13 =	1M	1M	1M	1M
R2,4 =	270 - 1k (470)*	470 - 2k (870)*	470 - 2k (680)*	470 - 2k (1k)*
R3,9,10 =	100 - 1k (300)*	Same	Same	Same
R8,11 =	200 - 330 (200)*	270 - 680 (270)*	180 - 470 (200)*	200 - 470 (523)*
R15 =	87.5k	83.2k	80k	79.3k
R16 =	100k	Same	Same	Same
R17 =	0, Jumper	"	"	"

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

C1 =	0.1 - 4µF* Film	Same	Same	Same
C2 =	0.1 - 4µF* Oil	"	"	"
C3 =	1 - 10µF* Film or Oil	"	"	"
C4 =	.1µF* Film or Oil	"	"	"
C5 =	47µF - 1kµF, 10V	"	47µF - 1kµF, 16V	47µF - 1kµF, 16V
C6 =	0.1µF 160V (optional)	"	None	None
C7 =	0.1µF 160V (optional)	"	"	"
C8 =	None	"	"	"

*Voltage rating must equal or exceed B+ voltage

(input) V1 =	6CG7, 6FQ7	6CG7, 6FQ7	12AU7, 5814, 5963, 6189, ECC82	12AU7, 5814, 5963, 6189, ECC82
(output) V2=	6DJ8, 6H30, 6922, 7308, ECC88	6CG7, 6FQ7	12AU7, 5814, 5963 6189, ECC82	12BH7, ECC99

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
6AQ8	57	9700	100	10.0	300	93220	100k	28.1	29.0	0.97	-0.24	248
6BK7	43	4600	200	10.0	300	91111	100k	21.2	26.5	0.97	-0.27	279
6BQ7	38.00	5900	191	10.0	300	90000	100k	18.7	25.5	0.96	-0.32	311
6BS8	36.00	5000	220	10.0	300	89474	100k	17.8	25.0	0.96	-0.33	321
6CG7	20.50	10200	583	3.0	150	82222	100k	10.0	20.0	0.93	-0.59	827
6CG7	21.10	8960	397	5.0	200	82684	100k	10.4	20.3	0.93	-0.59	657
6CG7	21.00	9250	626	5.0	250	82609	100k	10.3	20.2	0.94	-0.56	820
6CG7	20.80	9840	1000	4.5	300	82456	100k	10.1	20.1	0.94	-0.53	1063
6CG7	21.40	8370	470	7.3	300	82906	100k	10.5	20.4	0.94	-0.56	686
6CG7	21.90	7530	243	10.0	300	83264	100k	10.8	20.7	0.93	-0.60	489
6CG7	21.80	7680	352	10.0	350	83193	100k	10.7	20.6	0.94	-0.57	576
6DJ8	30.20	3670	182	5.0	100	87578	100k	15.0	23.5	0.96	-0.39	273
6DJ8	30.70	2870	124	10.0	150	87768	100k	15.2	23.7	0.96	-0.39	199
6DJ8	30.00	2960	205	10.0	200	87500	100k	14.9	23.4	0.96	-0.37	274
6DJ8	29.60	3060	291	10.0	250	87342	100k	14.6	23.3	0.96	-0.36	350
6DJ8	28.60	3980	673	5.0	250	86928	100k	14.0	22.9	0.96	-0.35	667
6DJ8	28.30	4080	845	5.0	300	86799	100k	13.8	22.8	0.96	-0.34	787
6DJ8	28.90	3400	481	8.0	300	87055	100k	14.2	23.0	0.96	-0.35	511
6FQ7	See **6CG7**											
6GM8	14.00	3400	187	2.0	24	75000	100k	7.0	16.8	0.90	-0.90	357
6H30	15.40	1140	69	20.0	100	77011	100k	7.7	17.7	0.91	-0.80	127
6H30	15.9	1040	74	30.0	150	76471	100k	7.9	18.0	0.92	-0.75	124
6H30	15.40	1310	221	20.0	200	90431	100k	7.7	17.7	0.92	-0.68	267
6H30	15.40	1380	294	20.0	250	89474	100k	7.7	17.7	0.93	-0.66	330
6H30	15.00	1670	530	15.0	300	89189	100k	7.4	17.4	0.93	-0.65	528
6N1P	39.8	12200	328	3.0	200	89189	100k	19.4	25.8	0.96	-0.32	539
6N1P	36.00	9480	221	5.0	250	75000	100k	17.7	25.0	0.96	-0.36	422
6N1P	35.00	956	642	5.0	300	89189	100k	17.1	24.7	0.97	-0.25	569
6N27P	14.00	3400	187	2.0	24	75000	100k	7.0	16.8	0.90	-0.90	357
9AQ8	See **6AQ8**											
12AT7	60.00	15000	270	3.7	200	93548	100k	29.1	29.3	0.98	-0.21	457
12AU7	17.00	9560	427	2.5	100	78947	100k	8.4	18.4	0.92	-0.75	757
12AU7	16.60	9570	741	3.0	150	78495	100k	8.1	18.2	0.92	-0.71	959
12AU7	16.70	9130	768	4.0	200	78610	100k	8.2	18.2	0.92	-0.69	959
12AU7	17.90	7440	336	8.0	250	79899	100k	8.8	18.9	0.92	-0.71	601
12AU7	18.10	7120	328	10.0	300	80100	100k	8.9	19.0	0.92	-0.70	581
12AV7	37.00	6100	120	9.0	200	89744	100k	18.3	25.3	0.96	-0.36	258

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
12AV7	41.00	4800	56	18.0	300	90698	100k	20.4	26.2	0.96	-0.35	160
12AZ7	See **12AT7**											
12AX7	100.00	80000	2000	0.5	200	96078	100k	39.0	31.8	0.99	-0.11	1719
12AX7	100.00	62500	1100	1.0	300	96078	100k	42.6	32.6	0.99	-0.12	1238
12BH7	16.10	5480	340	4.0	100	77901	100k	8.0	18.0	0.92	-0.76	549
12BH7	15.70	6090	706	4.0	150	77401	100k	7.7	17.7	0.92	-0.71	826
12BH7	15.90	6140	787	5.0	200	77654	100k	7.8	17.8	0.92	-0.68	877
12BH7	17.40	4870	383	10.0	250	79381	100k	8.6	18.7	0.93	-0.67	541
12BH7	18.40	4300	267	15.0	300	80392	100k	9.1	19.2	0.93	-0.65	422
12BZ7	100.00	31800	2200	2	300	96078	100k	48.5	33.7	0.98	-0.17	292
12DJ8	See **6DJ8**											
12FQ7	See **6CG7**											
5751	70.00	58000	1250	0.8	200	94444	100k	30.5	29.7	0.98	-0.17	1407
5963	21.00	6600	200	10.0	250	82609	100k	10.4	20.3	0.93	-0.63	433
5965	47.00	7250	220	8.2	300	91837	100k	23.1	27.3	0.97	-0.26	337
6072	44.00	25000	1250	2.0	300	91304	100k	20.3	26.2	0.97	-0.25	1272
ECC81	See **12AT7**											
ECC82	See **12AU7**											
ECC83	See **12AX7**											
ECC85	See **6AQ8**											
ECC86	See **6GM8**											
ECC88	See **6DJ8**											

The table above lists many triodes suitable for the 9-pin-based Aikido line 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 6CG7 input tube with cathode resistors of 1k, and a 6DJ8 output tube with cathode resistors of 481 ohms, the final voltage gain equals 10.1 from the 6CG7 against the 0.96 gain of the 6DJ8, with a product of 9.7. or, working with dB instead, 20.1dB plus -.35dB, for a total of 19.75dB. (Aren’t decibels great?)

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