

Aikido

ALL IN One

Aikido Stereo 9-Pin PCB

Rev. A

USER GUIDE

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July 26 2010

GLASSWARE
AUDIO DESIGN

DANGER!

This PCB holds a high-voltage power supply; thus, a real—and possibly—lethal shock hazard exists.

Ideally, a variac should be used to slowly power up the regulator, as it is better to have a mis-oriented electrolytic capacitor or a mis-located resistor blow at low voltages, rather than at high voltages. Remember that the danger increases by the square of the voltage; for example, 200 volts is four times more dangerous than 100 volts and 400 volts is sixteen times more dangerous.

Once the power supply is powered up, be cautious at all times. In fact, even when the power supply is disconnected or shut down, assume that power-supply capacitors will have retained their charge and, thus, can still shock. If you are not an experienced electrical practitioner, before attaching the transformer windings to the board, have someone who is well-experienced in electronics review your work.

There are too few tube-loving solder slingers left; we cannot afford to lose any more.

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👉 Warning! 👈

This PCB contains a high-voltage power supply, thus, a real and lethal shock hazard exists. Once the power transformer is attached, be cautious at all times. In fact, always assume that the high voltage capacitors will have retained their charge even after the power supply has been disconnected or shut down. If you are not an experienced electrical practitioner, before applying the AC 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.

Overview

Thank you for your purchase of the TCJ Aikido *All in One* 9-pin stereo PCB. 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 heavy 2oz copper traces. In addition, the PCB is lovingly and expensively made in the USA. The boards are 6.5 by 6 inches, with five mounting holes, which helps to prevent excessive PCB bending while inserting and pulling tubes from their sockets. Each PCB holds two Aikido line-stage amplifiers; thus, one board is all that is needed for stereo unbalanced use (or one board for one channel of balanced amplification). By including the necessary components for the heater and high voltage B+ power supplies on the PCB, the *All in One* board makes building a standard-setting line stage amplifier a breeze. This assembled board with a chassis, volume control, selector switch, power transformer, and a fistful of RCA jacks is all that is needed.

PCB Features

B+ and Heater Power Supplies On the *All in One* board, two power supplies reside, one for the high-voltage B+ for the tubes and a low-voltage power supply for the heaters. The high-voltage power supply uses an RC filter to smooth away ripple, while the low-voltage power supply uses a voltage regulator to provide a stable and noise-free voltage output. The power supplies require an external power transformer(s) with two secondary windings.

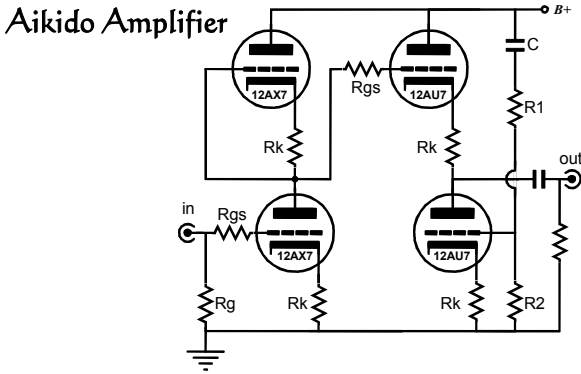
Redundant Solder Pads This board holds two sets of differently-spaced solder pads for each critical resistor, so that radial and axial resistors can easily be used (radial bulk-foil resistors and axial film resistors, for example). In addition, most capacitor locations find many redundant solder pads,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

Two Output-Stage Topologies The Rev. A 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 an Aikido-modified White cathode-follower output stage, which further reduces distortion).

Power-Supply-Decoupling Capacitors The *All in One* PCB provides space for two sets of capacitors to decouple both Aikido gain stages from the B+ connection and each other. 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. In place of the RC series resistor, an off-board choke can be used (one per channel).

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— despite 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 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 with 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 does a 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 triode 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 r_p , 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 followers 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 μ of the input triode used. The gain from a simple grounded-cathode amplifier (with an un-bypassed cathode resistor) is

$$\text{Gain} = \mu R_a / [R_a + (\mu + 1)R_k + r_p]$$

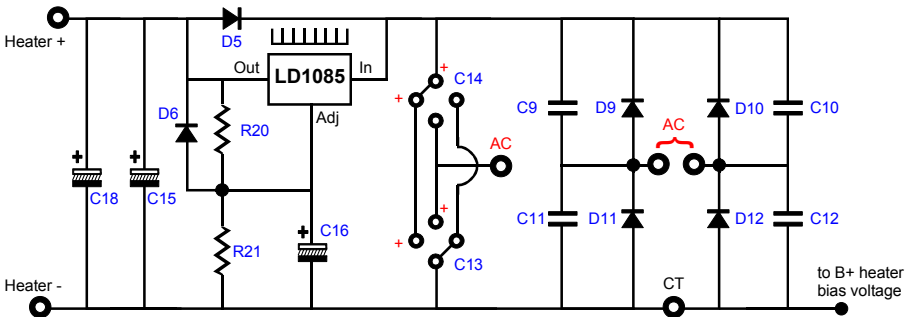
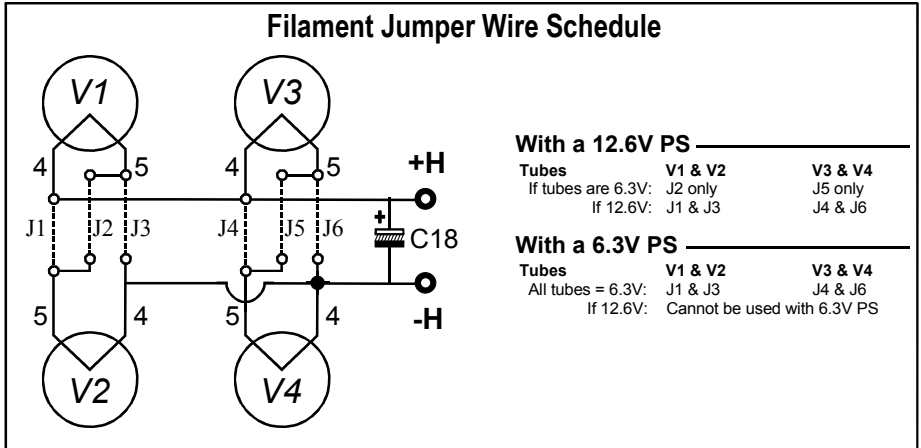
In the Aikido, the resistance presented by the top tube and its cathode resistor is $R' = (\mu + 1)R_k + r_p$. So if you substitute R' for R_a in the above equation and simplify you get

$$\text{Gain} = \mu [(\mu + 1)R_k + r_p] / [(\mu + 1)R_k + r_p + (\mu + 1)R_k + r_p] = \mu/2$$

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

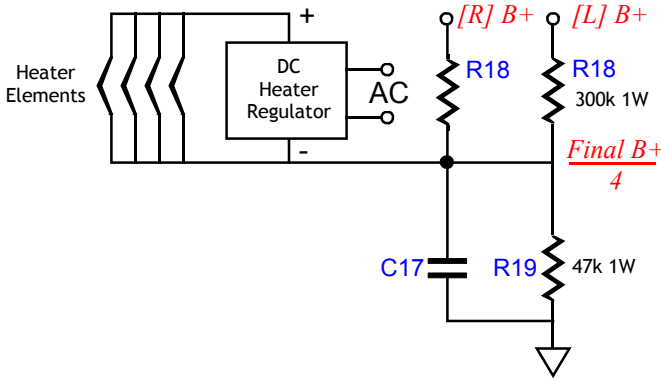
The *All in One* PCB holds the heater raw power supply and voltage regulator. The regulator uses the LD1085 low-dropout adjustable voltage regulator. The regulator can be set to an output voltage between 6V to 25V, but the assumption is that a 12Vdc output voltage will be used for the heaters, so that 6.3V heater tubes (like the 6FQ7 and 6DJ8) or 12.6V tubes (like the 12AU7 or 12AX7) can be used. Both voltage types can be used exclusively, or simultaneously; for example a 6CG7 for the input tube and a 12BH7 for the output tube. Thus, if the input tubes (V1 and V2) are 6CG7s and the output tubes (V3 and V4) are 12BH7s and the heater regulator output voltage is 12Vdc, then use jumpers J2, J4, and J6.



As can be seen, the power supply can accept either full-wave bridge rectifier circuit or a full-wave voltage doubler rectifier configuration. When used as a full-wave bridge rectifier circuit, the two power supply filtering capacitors are placed in parallel by orienting their positive leads to where the heatsink sits; and the secondary attaches to the two encircled AC pads. Configured as a voltage doubler, these capacitors placed in series by being rotated 90 degrees clockwise, so the positive leads point to the center-tap pad at the bottom of the PCB; the secondary attaches to single AC pad in between capacitors C13 and C14 and AC pad that feeds rectifier D9 and D11; and D10, D12, C10, C12 are left off the PCB. If used as a full-wave center-tap circuit, the two power supply filtering capacitors are placed in parallel by orienting their positive leads to where the heatsink sits; and the secondary attaches to the two encircled AC pads and the secondary center-tap attaches to the CT pad.

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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 1/4 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:



The heater's PS reference bias voltage to target is one quarter of the B-plus voltage that the Aikido's tubes use, not the initial raw B-plus voltage at the high voltage rectifiers. 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, leaving resistors R19 and R18s off the board. 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 with certain tubes.

Typical Part Values

Heater Voltage =	6V	6.3V	8V	12V	12.6V
R21 =	470	499	670	1.07k	1.13k
R20 =	124	same	same	same	same
D7 - D10 =	MUR410G	"	"	"	"
D5, D6 =	1N4007	"	"	"	"
C9, 10, 11, 12 =	0.01µF / 50V	"	"	"	"
C13, C14 =	10kµF*	"	"	"	"
C15, C16 =	1kµF*	"	"	"	"
C18 =	1k-3900µF*	"	"	"	"
Regulator =	LD1085, LM317, LM350, LT1085				
Vac Input =	7-8Vac @ 5A for 6.3Vdc 12-12.6Vac @ 2.5A for 8Vdc or 12Vdc or 12.6Vdc				
	*Capacitor voltage must exceed 1.414 x Vac input voltage				

Resistors R20 and R21 set the voltage regulator's output voltage. The formula is

$$V_0 = 1.25(1 + R_{21} / R_{20})$$

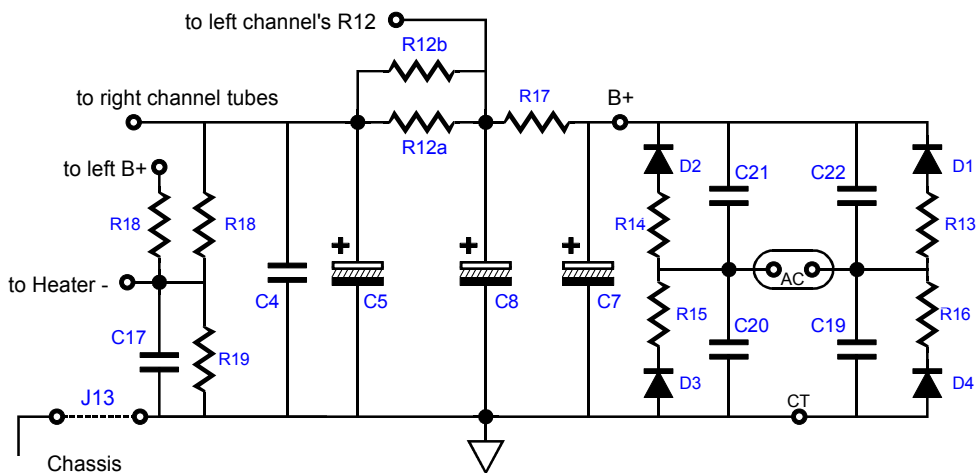
Thus, using a 124-ohm resistor for R20 and a 2.4k resistor in R21 position, the output will climb to 25.2Vdc. See the values table above.

B-plus Power Supply

The high voltage B-plus power supply resides on the Aikido *All in One* PCB. It contains a full-wave bridge rectifier circuit and reservoir capacitor, which is then followed by an RC-smoothing filter. The high voltage power transformer is external to the PCB and can be mounted in, or outside, the chassis that houses the PCB.

The optimal B-plus voltage depends on the tubes used. For example, 6GM8s (ECC86) can be used with a low 24V power supply, while 6DJ8s work better with a 150V to 240V B-plus voltage; 6CG7s, 200V to 300V. The sky is not the limit here, as the power supply capacitors and the heater-to-cathode voltage set an upward limit of about 350V for the power supply voltage after the rectifiers and about 300V at the tubes after the RC filter. Resistors R12a and R12b are in parallel, so that greater dissipation and value selection are possible; for example, treat two 10k/3W resistors as one 5k/6W resistor. Resistor heat equals $I^2 \times R$ (and V^2/R); for example, 20mA and 5k will dissipate 2W. See pages 13 and 14 for more information.

Bear in mind, there is a practical limit to how large a power-supply noise signal can be nulled at the Aikido's output. So there are several goals that work against each other: we want the largest voltage-dropping resistor value possible, as it reduces the ripple appearing at the tubes' power supply connection; we want the lowest raw B-plus voltage possible, as it will allow a larger-valued reservoir capacitor and limit the heater-to-cathode voltage; and we want the highest plate voltage possible for the tubes, as it makes for better sound. We cannot have it all. A typical 250V capacitor is much more volumetrically efficient than a 400V capacitor. Thus, running a lower B-plus voltage allows us to increase greatly the capacitance in the power supply. Running lighter current allows us to maximize resistor R12's (combined) value.



Typical Part Values () Parentheses denote recommended values

C4 = 0.1 μ F to 1 μ F* (0.68 μ F 400V)
 C5 = 47 μ F to 470 μ F* (150 μ F 400V or 270 μ F 200V)
 C7, C8 = 47 μ F to 300 μ F* (47 μ F 450V or 220 μ F 200V)
 C17 = 0.01 μ F to 0.47 μ F \geq 100V
 C19-22 = 1000pF to 0.01 μ F 1kV

D1-4 = HER108, 1N4007, UF4007

R12(a & b) = 100 to 20k
 R13-16 = 10-ohm 1W
 R17 = 100-1K
 R18 = 300k 1W
 R19 = 100k 1W

*Voltage depends on transformer used.
 All must exceed the B+ voltage.

Power Transformer(s)

The Aikido *All in One* PCB requires a power transformer(s) to energize its two power supplies. The heater power supply power transformer must offer at least 1.8 times more current than the heaters will draw. For example, four 12AU7s will draw 0.6A @12.6v, so the heater power transformer must be able to sustain an AC 1.08A current draw. In addition, with sine waves, the AC voltage equals the peak voltage divided by the square root of 2, i.e. 1.414. Thus, a 10Vac sine wave peaks at 14.14V; a 6.3Vac, 8.9V. In other words, a sine wave that peaks at 14.14V will produce the same amount of heat in a resistance as a 10Vdc voltage source would produce in the same resistance; thus, we label the 14.14Vpk sine wave as being 10Vac. Thus, in order to get the 16Vdc a 12.6V heater voltage regulator requires an input voltage equal to sum of 16V and the rectifier loss (about 2V) divided by 1.414, which is roughly 12.6Vac.

The high voltage power transformer must also follow the same rules. Thus, to achieve 300V of raw DC voltage, the transformer primary must deliver $(300V + 2V) / 1.414$, or about 214Vac. And if 50mA is required, the power transformer must be rated for 50mA x 1.8, or about 90mA. Such a transformer VA rating would equal 33VA.

A center-tapped primary can be used; just leave C19, C20, D3, D4, R15, and R16 off the board, then attach the center-tap to CT eyelet.

Configuring the PCB as a Line Amplifier

The Aikido topology makes a perfect line amplifier, as it offers low distortion, low output impedance, and excellent power-supply noise rejection—all without a global feedback loop. For guidance on part values, look at the page 12, which lists different tube design examples.

Typical Part Values () Parentheses denote recommended values

	6CG7 & 6DJ8	6CG7 & 6CG7	12AU7 & 12AU7	6DJ8 & 6DJ8 <small>Low-Voltage Operation</small>
B+ Voltage =	200V	300V	250V	150V
AC Secondary =	150 - 170Vac	230 - 250Vac	200 - 250Vac	115 - 120Vac
Heater Voltage =	6.3V or 12.6V	6.3V or 12.6V	12.6V	6.3V or 12.6V
Heater Current =	2A or 1A	2.5A or 1.25A	0.75A	1.5A or 0.75A
R1,11 =	1M	1M	1M	1M
R2,5,8 =	100 - 1k (300)*	Same	Same	Same
R3,4 =	270 - 1k (300)*	470 - 2k (870)*	470 - 2k (680)*	300 - 680 (470)*
R6,7 =	200 - 330 (200)*	270 - 680 (470)*	180 - 470 (200)*	100 - 300 (180)*
R9 =	100k	Same	Same	Same
R10 =	87.5k	83.2k	80k	87.5k
R22 =	Jumper	Same	Same	Same
*High-quality resistors essential in this position. All resistors 1/2W or higher				
C1, C2 =	0.01-0.33µF (optional)	Same	Same	Same
C3 =	0.1 - 4µF* Film or PIO	"	"	"
C4 =	0.01 - 1µF* Film or PIO	"	"	"
C5 =	150µF* 400V	"	"	270µF 200V
C6 =	0.1 - 1µF* Film or PIO	"	"	Same
C7, C8 =	47µF 450V	"	"	220µF 200V
C23 =	None	"	"	Same
*Voltage rating must equal or exceed B+ voltage				
(input) V1, V2 =	6CG7, 6FQ7	6CG7, 6FQ7, 12FQ7	12AU7, 5814, 5963, 6189, ECC82	6922, 7308, E88CC
(output) V3, V4 =	6DJ8, 6922, 7308, E88CC	6CG7, 6FQ7, 12FQ7	12AU7, 5814, ECC82	6922, 7308, E88CC

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 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. In other words, the list of possible tubes is a long one: 6AQ8, 6BC8, 6BK7, 6BQ7, 6BS8, 6DJ8, 6FQ7, 6GC7, 6H30, 6KN8, 6N1P, 12AT7, 12AU7, 12AV7, 12AX7, 12BH7, 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. Sadly, the 12B4 and 5687 cannot be used with this PCB.

Internal Shields

If the triode's pin 9 attaches to an internal shield, as it does with the 6CG7 and 6DJ8, then capacitors C1 and C2 can be replaced with a jumper, which will ground the shield. However, using the capacitors rather than jumpers will also ground the shield (in AC terms) and allow swapping in triodes whose pin-9 attaches to the center tap of its heater, such as the 12AU7.

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- μ triodes require high-value cathode resistors (1-2K) and low- μ triodes require low-valued cathode resistors (100-1k). The formula for setting the I_q is an easy one:

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

So, for example, a 6CG7 in an Aikido circuit with a B+ voltage of +300V and 1k cathode resistors will draw $300/2(8k + [2 + 1]1k)$ amperes of current, or 2.6mA. I recommend 680 to 1.1k for the 12AX7, 5751, 6072 tubes and 100 to 330 for the 6DJ8 and 6N1P tubes. Other tubes, such as the 6CG7, 12AT7, 12AU7, 12BH7 work well with 470-ohm cathode resistors. Because the cathode resistors see so little voltage differential, $1/2W$ resistors can readily be used. Be sure to see the tube chart on the last page for many illustrations.

Coupling-Capacitor Values

The bigger in value the coupling capacitor, the lower the -3dB high-pass corner frequency will be. The formula is as follows:

$$\text{Frequency} = 159155/C/R$$

where C is in μF . For example, with a $1\mu\text{F}$ coupling capacitor and a power amplifier with an input impedance of 47k, the corner frequency would be 3.5Hz. The higher the load impedance, the lower the corner frequency. The coupling capacitor voltage rating must at least equal the B+ voltage, for safety's sake. Although pads weren't provided for bypass capacitors for the coupling capacitors, a small bypass capacitor can be solder on the bottom of the PCB, using two of the redundant solder pads.

Assembly & Testing

Assembly Cleanliness is essential. Before soldering, be sure to clean both sides the PCB with 90% to 99% isopropyl alcohol. Do not use dull-looking solder; solder should shine. If it doesn't, first clean away the outer oxidation with some steel wool or a copper scouring pad. If the resistor leads look in the least gray, clean away the oxidation with either steel wool or a wire snip's sharp edges. Admittedly, with new resistors and a fresh PCB, such metal dulling is rare; but if the parts have sat in your closet for a year or two, then expect a good amount of oxidation to have developed.

First, solder all the small diodes in place, and then solder the resistors, rectifiers, capacitors, and heatsinks. Be consistent in orienting the resistors; keep all the tolerance bands on the resistor's body at the right side as you face the resistor straight on. This will pay dividends later, if you need to locate a soldered a resistor in the wrong location. Because the board is double sided, with traces and pads on each side, it is easier to solder the resistors from their top side. It is often easier to attach the LD1085 (heater regulator) to its heatsink first (using the heatsink hardware kit) and then to solder both the heatsink and regulator to the PCB at once. As the PCB is so overbuilt, it is extremely difficult to remove an incorrectly placed part. Be sure to confirm all the electrolytic capacitor orientations, as a reversed polarized capacitor can easily vent (or even explode) when presented with high-voltage. Confirm twice, solder once.

Testing Before testing, visually inspect the PCB for breaks in symmetry between left and right sides. Wear safety eye goggles, which is not as pantywaist a counsel as it sounds, as a venting power-supply capacitor will spray hot caustic chemicals. Make a habit of using only one hand, with the other hand behind your back, while attaching probes or handling high-voltage gear, as a current flow across your chest can result in death. In addition, wear rubber-soled shoes and work in dry environment. Remember, safety first, second, and last.

1. Attach only the heater power supply's transformer winding, leaving the high-voltage transformer leads unattached and electrical tape shrouded, with no tubes in their sockets.
2. Use a variac and slowly bring up the AC voltage, while looking for smoke or part discoloration or bulging.
3. Measure the heater regulator's output voltage without and with a load. If the heater regulator fails to regulate, try either lowering the heater voltage a tad, for example 12V instead of 12.6V, as the 0.6V difference might be enough to bring the regulator back into regulation.
4. Next, power down the heater regulator and attach the high-voltage windings and insert the tubes in their sockets.
5. Attach the transformer to a variac and slowly bring up the AC voltage.
6. Measure the voltage across ground and B-plus pads in the center of the PCB; then measure the voltage across capacitors, C4 & C5. If the two channels differ by more than 10Vdc, try switching tubes from one channel to the other. If the imbalance does not follow the tubes, there is a problem, probably a misplaced part.

Only after you are sure that both heater and B-plus power supplies are working well, should you attach the line-stage amplifier to a power amplifier.

Grounding

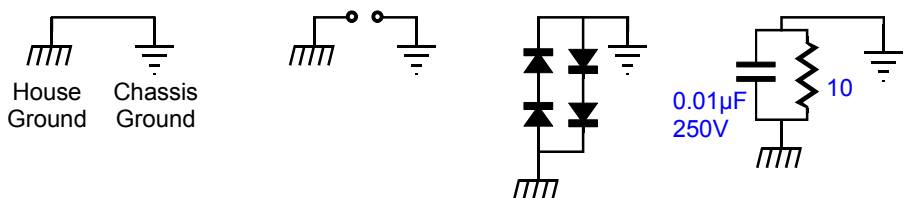
The *All in One* PCB holds a star ground at its center. Ideally, this will be the only central ground in the line-stage amplifier. Ground loops, however, are extremely easy to introduce. For example, if the RCA jacks are not isolated from the chassis, then the twisted pair of wires that connect the PCB to the jacks will each define a ground loop (as will jumper J7, which bridges the PCB's ground to the chassis). The solution is either to isolate the jacks or use only a single hot wire from jack to PCB (the wire can be shielded, as long as the shield only attaches at one end). Thus, the best plan is to plan. Before assembling the line-stage amplifier, stop and decide how the grounding is going to be laid out, then solder.

Three different schools of thought hold for grounding a piece of audio gear. The Old-School approach is to treat the chassis as the ground; period. Every ground connection is made at the closest screw and nut. This method is the easiest to follow and it produces the worst sonic results. Steel and aluminum are poor conductors.

The Semi-Star ground method uses several ground "stars" that are often called spurs, which then terminate in a single star ground point, often a screw on the chassis. This system can work beautifully, if carefully executed. Unfortunately, often too much is included in each spur connection. For example, all the input and output RCA jacks share ground connection to a long run of bare wire, which more closely resembles a snake than a spur ground. In other words, the spurs should not be defined just physical proximity, but signal transference. Great care must be exercised not to double ground any spur point. For example, the volume control potentiometer can create a ground loop problem, if both of its ground tabs are soldered together at the potentiometer and twisted pairs, of hot and cold wires, arrive at and leave the potentiometer, as the two cold wires attaching to the PCB will define a ground loop.

The Absolute-Star grounding scheme uses a lot of wire and is the most time consuming to lay out, but it does yield the best sonic rewards. Here each input signal source and each output lead gets its own ground wire that attaches, ultimately, at one star ground point; each RCA jack is isolated from the chassis. The *All in One* PCB was designed to work with this approach, although it can be used with any approach.

House Ground The third prong on the wall outlet attaches to the house's ground, usually the cold water pipe. The line-stage amplifier can also attach to this ground connection, which is certainly the safest approach, as it provides a discharge path should the B+ short to the chassis. Unfortunately, this setup often produces a hum problem. Some simply float the ground, others use several solid-state rectifiers in parallel to attach the chassis ground to the house ground (**NOT NEUTRAL**) via the third prong, and others still use a 10-ohm resistor shunted by a small capacitor, say 0.001 μ F to 0.1 μ F/250V.



A good test procedure is to detach all the signal inputs and all the output connection from the line-stage amplifier. Then measure the AC voltage between the line-stage amplifier's chassis and the house's ground. If it reads more than a few volts, try reversing the line-stage amplifier's plug as it plugs into the wall socket. Use which ever orientation that results in the lowest AC voltage reading. Then measure the chassis ground to the first signal source's ground (while the signal source is turned on). Once again flip the signal source's plug until the lowest AC voltage setting is found. Then do the rest with the rest of the system. The results can prove far more satisfying than what would be yielded by buying thousand-dollar cables.

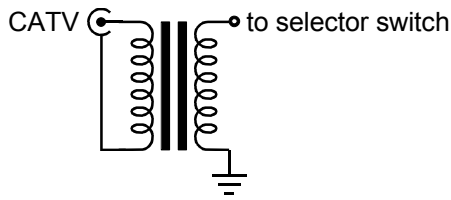
RFI Radio frequency interference can be a hassle to track down and eliminate. First make sure that the source of the problem actually resides in the line-stage amplifier. For example, if only one signal source suffers from RFI noise, make sure that it is normally RFI free. In other words, attach it to another line-stage amplifier and see if the RFI persists. If it does pass this test, then try soldering small capacitors, say 100pF, from this signal source's RCA jacks to the chassis, as close as possible to the jacks: if it fails, fix the source.

Ferrite beads can also help; try using beads on the hot lead as it leaves the RCA jack and then again at the selector switch. Increasing the grid-stopper resistor's (R2) value, say to 1k, can also work wonders (use a carbon-composition or bulk-foil resistor or some other non-inductive resistor type).

Terminating Resistors Here's a cheap trick to try: at each input RCA jack, place a 100k to 1M resistor, bridging input hot and jack ground. Why? The resistor provides a path for the AC signal present at the jack, so given a choice between radiating into the chassis or going through the relatively low-impedance resistor, the AC signal chooses the latter path, reducing crosstalk.

Chassis Ground Jumper J7 connects the PCB's ground to the chassis through the top leftmost mounting hole. If you wish to float the chassis or capacitor couple the chassis to ground, then either leave jumper J7 out or replace it with a small-valued capacitor (0.01 to 0.1μF). Warning: if rubber O-rings are used with PCB standoffs, then the ground connection to the chassis is not likely to be made; tubes, use metal washer in place of top O-ring.

CATV Ground Attaching a line-stage amplifier to TV or VCR can cause huge hum problems, as the "ground" used by the connection CATV connection may introduce hum. Isolation transformers work supremely well in this application. In fact, an isolation transformer can be used on all the input signals only (one transformer per channel is required, if it is located after, rather than before the selector switch.) Look on the Web for more complicated solutions to the CATV hum problem.



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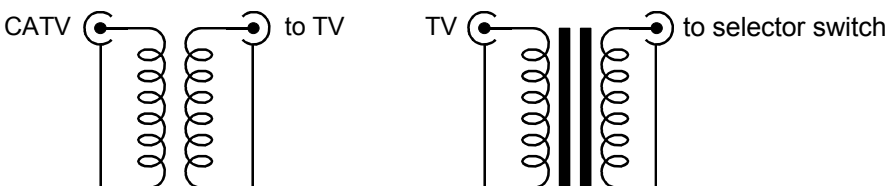
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RC Power-Supply Filter

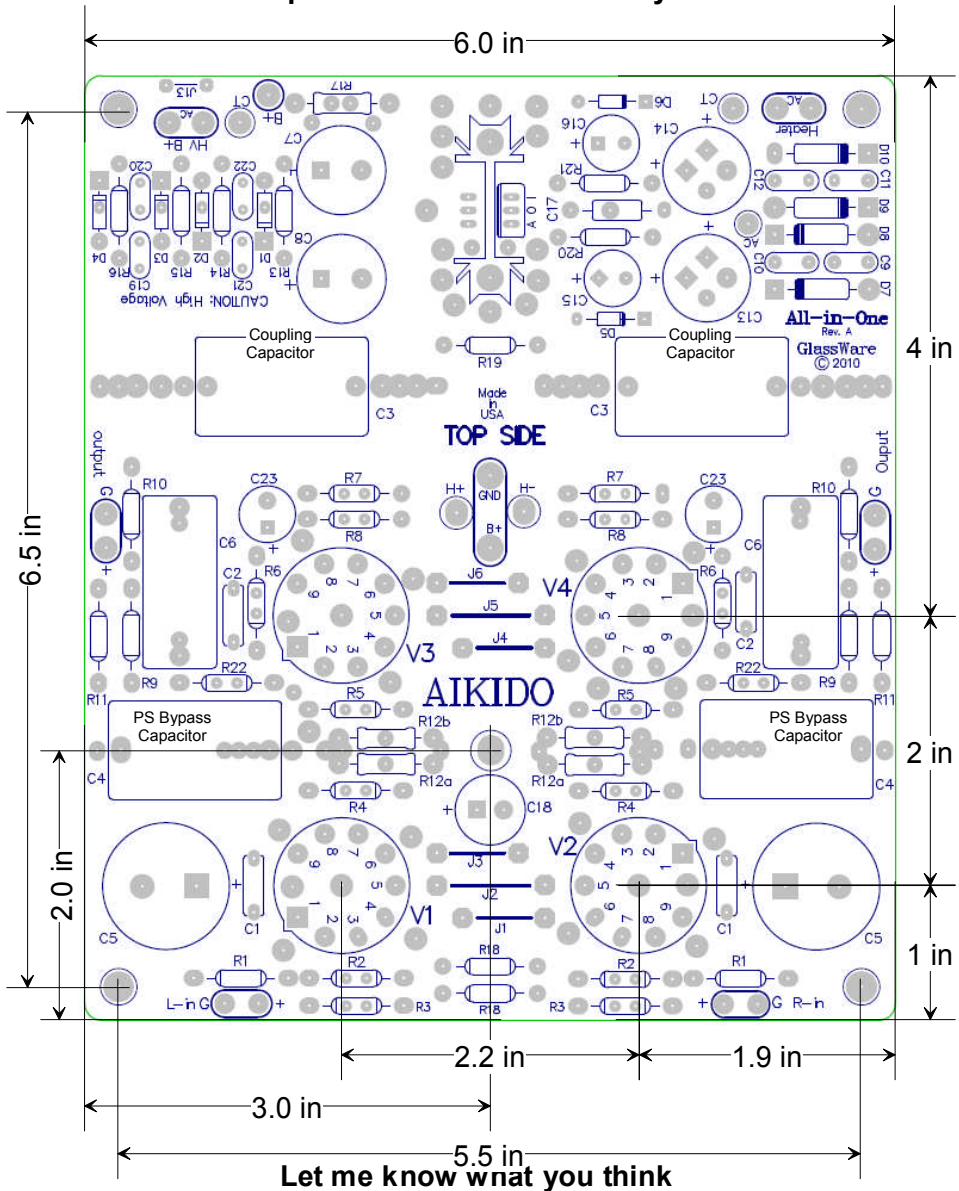
Resistors R12a and R12b are in parallel. The *All in One* kit supplies five 3W resistors for R12 use: 1.6k, 2k, 3k, 3.9k, and 10k. Each resistor can be used in isolation or in parallel with one other resistor. Fifteen possible combinations are possible; the resulting parallel resistance is shown in the chart at the top of page 13. The charts that follow show the voltage drop across the R12 versus the current flow. Remember each channel gets its own pair of R12 resistors. For example, an *All in One* line-stage amplifier might run each tube with 5mA of idle current, for a total of 10mA per channel. So by looking up the 10mA column, we can see the resulting voltage drops. Thus, one 3k resistor will drop 30V, so a 280Vdc raw DC power supply will deliver 250Vdc to the tubes. An * denotes excessive current or voltage, so that combination cannot be used without risking damaging the at least one of the resistors.

R	Voltage Drop Against Current															
889	9	11	12	14	16	18	20	21	23	25	27	28	30	32	34	36
1043	10	13	15	17	19	21	23	25	27	29	31	33	35	38	40	42
1135	11	14	16	18	20	23	25	27	29	32	34	36	39	41	43	45
1200	12	14	17	19	22	24	26	29	31	34	36	38	41	43	46	48
1295	13	16	18	21	23	26	28	31	34	36	39	41	44	47	49	52
1322	13	16	19	21	24	26	29	32	34	37	40	42	45	48	50	53
1379	14	17	19	22	25	28	30	33	36	39	41	44	47	50	52	55
1545	15	19	22	25	28	31	34	37	40	43	46	49	53	56	59	62
1600	16	19	22	26	29	32	35	38	42	45	48	51	54	58	61	64
1667	17	20	23	27	30	33	37	40	43	47	50	53	57	60	63	67
1696	17	20	24	27	31	34	37	41	44	47	51	54	58	61	64	68
2000	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	x
2082	21	25	29	33	37	42	46	50	54	58	62	67	71	75	79	83
2308	23	28	32	37	42	46	51	55	60	65	69	74	78	83	88	92
2479	25	30	35	40	45	50	55	59	64	69	74	79	84	89	94	99
2806	28	34	39	45	51	56	62	67	73	79	84	90	95	101	107	x
3000	30	36	42	48	54	60	66	72	78	84	90	x	x	x	x	x
3900	39	47	55	62	70	78	86	94	101	x	x	x	x	x	x	x
4048	40	49	57	65	73	81	89	97	105	113	121	130	138	x	x	x
6800	68	82	95	109	122	136	x	x	x	x	x	x	x	x	x	x
10000	100	120	140	x	x	x	x	x	x	x	x	x	x	x	x	x
mA	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40

x denotes that either the voltage or the current exceeds the resistor(s) limit

R	R12a	R12b	I _{max} mA	V _{max}	Wattage	F3 150µF	F3 270µF
889	1600	2000	78	69	5.4	1.19	0.66
1043	1600	3000	66	69	4.6	1.02	0.56
1135	1600	3900	61	69	4.2	0.94	0.52
1200	2000	3000	64	77	4.9	0.88	0.49
1295	1600	6800	53	69	3.7	0.82	0.46
1322	2000	3900	58	77	4.5	0.80	0.45
1379	1600	10000	50	69	3.5	0.77	0.43
1545	2000	6800	50	77	3.8	0.69	0.38
1600	1600	none	43	69	3.0	0.66	0.37
1667	2000	10000	46	77	3.6	0.64	0.35
1696	3000	3900	56	95	5.3	0.63	0.35
2000	2000	none	39	77	3.0	0.53	0.29
2082	3000	6800	46	95	4.3	0.51	0.28
2308	3000	10000	41	95	3.9	0.46	0.26
2479	3900	6800	44	108	4.7	0.43	0.24
2806	3900	10000	38	108	4.2	0.38	0.21
3000	3000	none	32	95	3.0	0.35	0.20
3900	3900	none	28	108	3.0	0.27	0.15
4048	6800	10000	35	143	5.1	0.26	0.15
6800	6800	none	21	143	3.0	0.16	0.09
10000	10000	none	14	170	3.0	0.11	0.06

Top Side PCB Mechanical Layout



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 on the back cover (begin the subject line with either "Aikido" or "tube" or the spam filters are sure to eat your message).

Tube	B+	Ik(mA)	mu	rp	Rk	R10	R9	Input Gain	Input Gain dBs	Output Gain	Output in dBs	Zo Line Amp.
6AQ8	300V	10.0	57.0	9700	100	93.2k	100k	28.1	29.0	0.97	-0.24	248
6BK7	300V	10.0	43.0	4600	200	91.1k	100k	21.2	26.5	0.97	-0.27	279
6BQ7	300V	10.0	38.0	5900	191	90.0k	100k	18.7	25.5	0.96	-0.32	311
6BS8	300V	10.0	36.0	5000	220	89.5k	100k	17.8	25.0	0.96	-0.33	321
6CG7	150V	3.0	20.5	10200	583	82.2k	100k	10.0	20.0	0.93	-0.59	827
6CG7	200V	5.0	21.1	8960	397	82.7k	100k	10.4	20.3	0.93	-0.59	657
6CG7	250V	5.0	21.0	9250	626	82.6k	100k	10.3	20.2	0.94	-0.56	820
6CG7	300V	4.5	20.8	9840	1000	82.5k	100k	10.1	20.1	0.94	-0.53	1063
6CG7	300V	7.3	21.4	8370	470	82.9k	100k	10.5	20.4	0.94	-0.56	686
6CG7	300V	10.0	21.9	7530	243	83.3k	100k	10.8	20.7	0.93	-0.60	489
6CG7	350V	10.0	21.8	7680	352	83.2k	100k	10.7	20.6	0.94	-0.57	576
6DJ8	100V	5.0	30.2	3670	182	87.6k	100k	15.0	23.5	0.96	-0.39	273
6DJ8	150V	10.0	30.7	2870	124	87.8k	100k	15.2	23.7	0.96	-0.39	199
6DJ8	200V	10.0	30.0	2960	205	87.5k	100k	14.9	23.4	0.96	-0.37	274
6DJ8	250V	10.0	29.6	3060	291	87.3k	100k	14.6	23.3	0.96	-0.36	350
6DJ8	250V	5.0	28.6	3980	673	86.9k	100k	14.0	22.9	0.96	-0.35	667
6DJ8	300V	5.0	28.3	4080	845	86.8k	100k	13.8	22.8	0.96	-0.34	787
6DJ8	300V	8.0	28.9	3400	481	87.1k	100k	14.2	23.0	0.96	-0.35	511
6FQ7	See 6CG7 and 6SN7											
6GM8	24V	2.0	14.0	3400	187	75.0k	100k	7.0	16.8	0.90	-0.90	357
6H30	100V	20.0	15.4	1140	69	77.0k	100k	7.7	17.7	0.91	-0.80	127
6H30	150V	30.0	15.9	1040	74	77.7k	100k	7.9	18.0	0.92	-0.75	124
6H30	200V	20.0	15.4	1310	221	77.0k	100k	7.7	17.7	0.92	-0.68	267
6H30	250V	20.0	15.4	1380	294	77.0k	100k	7.7	17.7	0.93	-0.66	330
6H30	300V	15.0	15.0	1670	530	76.5k	100k	7.4	17.4	0.93	-0.65	528
6N1P	200V	3.0	39.8	12200	328	90.4k	100k	19.4	25.8	0.96	-0.32	539
6N1P	250V	5.0	36.0	9480	221	89.5k	100k	17.7	25.0	0.96	-0.36	422
6N1P	300V	5.0	35.0	956	642	89.2k	100k	17.1	24.7	0.97	-0.25	569
6N27P	24V	2.0	14.0	3400	187	75.0k	100k	7.0	16.8	0.90	-0.90	357
9AQ8	See 6AQ8											
12A7	200V	3.7	60.0	15000	270	93.5k	100k	29.1	29.3	0.98	-0.21	457
12AU7	100V	2.5	17.0	9560	427	78.9k	100k	8.4	18.4	0.92	-0.75	757
12AU7	150V	3.0	16.6	9570	741	78.5k	100k	8.1	18.2	0.92	-0.71	959
12AU7	200V	4.0	16.7	9130	768	78.6k	100k	8.2	18.2	0.92	-0.69	959
12AU7	250V	8.0	17.9	7440	336	79.9k	100k	8.8	18.9	0.92	-0.71	601
12AU7	300V	10.0	18.1	7120	328	80.1k	100k	8.9	19.0	0.92	-0.70	581
12AV7	200V	9.0	37.0	6100	120	89.7k	100k	18.3	25.3	0.96	-0.36	258
12AV7	300V	18.0	41.0	4800	56	90.7k	100k	20.4	26.2	0.96	-0.35	160
12AZ7	See 12A77											
12AX7	200V	0.5	100.0	80000	2000	96.1k	100k	39.0	31.8	0.99	-0.11	1719
12AX7	300V	1.0	100.0	62500	1100	96.1k	100k	42.6	32.6	0.99	-0.12	1238
12BH7	100V	4.0	16.1	5480	340	77.9k	100k	8.0	18.0	0.92	-0.76	549
12BH7	150V	4.0	15.7	6090	706	77.4k	100k	7.7	17.7	0.92	-0.71	826
12BH7	200V	5.0	15.9	6140	787	77.7k	100k	7.8	17.8	0.92	-0.68	877
12BH7	250V	10.0	17.4	4870	383	79.4k	100k	8.6	18.7	0.93	-0.67	541
12BH7	300V	15.0	18.4	4300	267	80.4k	100k	9.1	19.2	0.93	-0.65	422
12BZ7	300V		100.0	31800		96.1k	100k	48.5	33.7	0.98	-0.17	292
12DJ8	See 6DJ8											
12FQ7	See 6SN7											
5751	200V	0.8	70.0	58000	1250	94.4k	100k	30.5	29.7	0.98	-0.17	1407
5963	250V	10.0	21.0	6600	200	82.6k	100k	10.4	20.3	0.93	-0.63	433
5965	300V	8.2	47.0	7250	220	91.8k	100k	23.1	27.3	0.97	-0.26	337
6072	300V	2.0	44.0	25000	1250	91.3k	100k	20.3	26.2	0.97	-0.25	1272
ECC81	See 12A77											
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 *All in One* 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 cathode follower position. 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-plus voltage of 300V (at the tubes' plate not the at the rectifiers), 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?)