

[< Back](#)

John Broskie's Guide to Tube Circuit Analysis & Design

[Next >](#)

25 July 2008

Aikido Phono Preamp PCBs

Here is a short and sweet testimonial from Tom, a long-time TCJer in California's Rancho Cordova, who has finished his Aikido phono stage kit:

Hello John,

The Aikido RIAA is working. There is no audible hum or buzz. There is hiss when it is cranked up. The sound really pops. The voices are separated. More like being there, bigger than the LM4562 Op-Amp creation I have been using is able to do.

In a word, Awesome!

Thanks
Tom



Wristwatch

I like the look of the wristwatch shown above, although it would not prove that useful. Actually the wristwatch that I want most would be a **sundial** on a wristband. What?! No, not an inactive sundial that just sits there and must be aligned carefully with the Earth's rotational axis and true north and geographical latitude. No, the wrist-sundial I want would be a high-tech wonder; for example, the shadow-producing *gnomon/style* would fold away when not in use and the dial face would rotate, in its sunken furrow, so that its marked time matched the shadow. Or the *gnomon* could remain fixed, but a shallow glass dome could fit over wrist-sundial. And if there is no shadow, the wrist sundial would shine its own light source at the *gnomon*, which would require only one white LED.

E-mail from GlassWare Customers

Hi John,

I received the Aikido PCB today - thank you for the first rate shipping speed.

Wanted to let you know that this is simply the best PCB I have had in my hands, bar none. The quality is fabulous, and your documentation is superb. I know you do this because you love audio, but I think your price of \$39 is a bit of a giveaway! I'm sure you could charge double and still have happy customers.

Looking forward to building the Aikido, will send some comments when I'm done!

Thank you, regards, Gary.

Mr Broskie,

I bought an Aikido stereo linestage kit from you some days ago, and I received it just this Monday. I have a few things to say about it.. Firstly, I'm extremely impressed at the quality of what I've been sent. In fact, this is the highest quality kit I've seen anywhere, of anything. I have no idea how you managed to fit all this stuff in under what I paid for it. Second, your shipping was lightning-quick. Just more satisfaction in the bag, there. I wish everyone did business like you.

Sean H.

Aikido

9-Pin & Octal PCBs

High-quality, double-sided, extra thick, 2-oz traces, plated-through holes, dual sets of resistor pads and pads for two coupling capacitors. Stereo and mono, octal and 9-pin printed circuit boards available.

Designed by John Broskie & Made in USA



Aikido PCBs for as little as \$24

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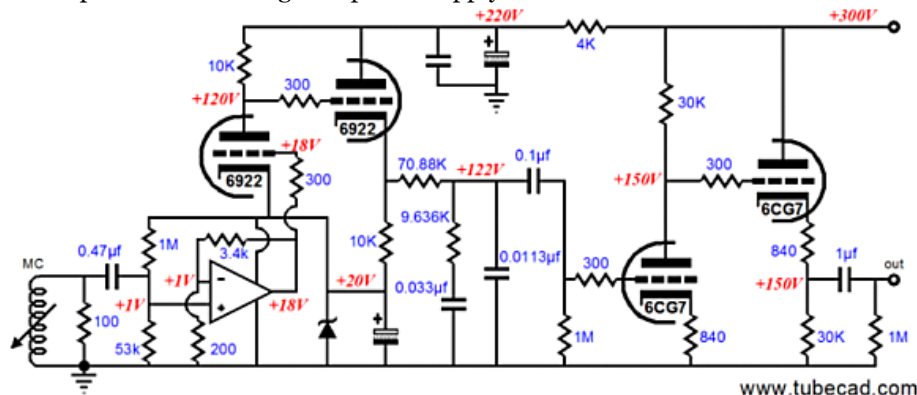


Imagine what a conversation starter it would prove. Imagine how I could make a thousand times more money selling such a wrist sundial (before the China-made replicas put me out of business) than selling PCBs. By the way, before you are tempted to send me an e-mail, I do know that a few have made wristwatches that hold nixie tubes, but a wrist-sundial is much more retro and mindbending. Just imagine all the media interest and free publicity, as the idea seems so crazy—almost as crazy as using tube-based audio gear in this digital age.

MC Pre-Preamplifiers

Moving-coil cartridges often put out so little voltage that +20dB to +30dB of voltage gain must be added before they can be used with a standard +40dB phono preamp. The extra gain can be had either actively or passively. Both approaches are difficult to realize without compromising the tiny and delicate signal's integrity, as quality transformers are supremely difficult to design and all active devices and resistors add noise and distortion to the output signal. Well, what about all those new super-linear, super-quiet OpAmps that are being touted as the easy solution to all audio problems? Aside from the perceived sellout implicit in all hybrid efforts, the OpAmps all require a negative power supply, which many tube-loving folk fear as much as many solid-state-loving folk fear high-voltage power supplies.

What if we could get away without using a negative power supply rail for the super-audio OpAmp? I have presented the following capacitor-coupled hybrid MC phono preamp before. The 0.47µF coupling capacitor at the OpAmp's input allows the 1V DC bias voltage to be developed, which allows us to get away with not using a negative power supply rail. If a negative power supply rail were added, the input coupling capacitor could be eliminated (and the 20V zener could be replaced by a few forward-biased signal diodes in series); but we then return to the problem of the negative power supply rail.



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If only we could find an inexpensive and readily available electric device that could pass AC signal as well a coupling capacitor and offer a fixed DC offset voltage. If only...well, what about a battery, say a AA 1.5V single cell battery? (Yes, I know that anything that cost less than \$1,000 isn't worth listening to...but maybe

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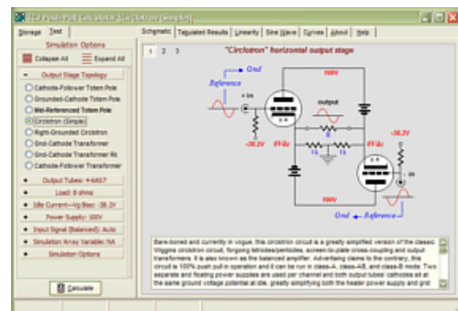
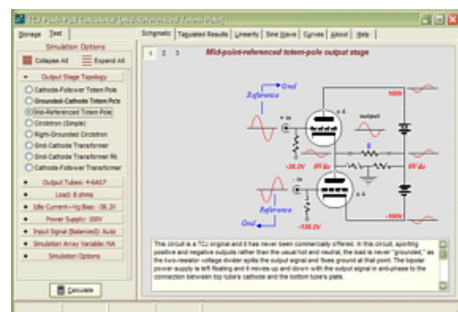
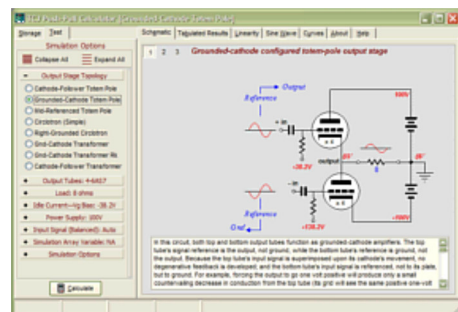
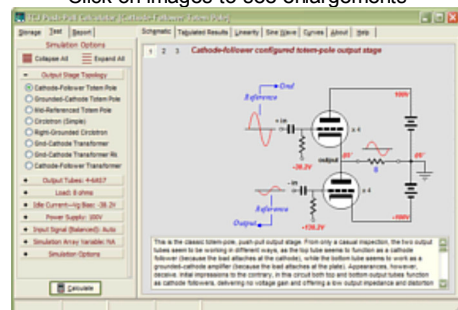
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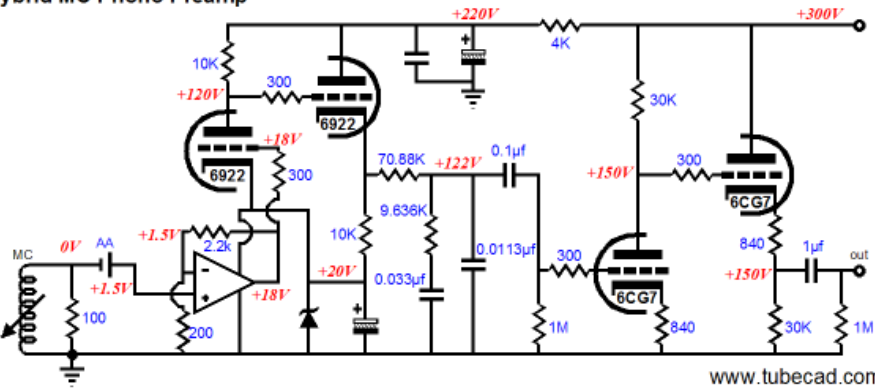
TCJ Push-Pull Calculator
Version 2

Click on images to see enlargements



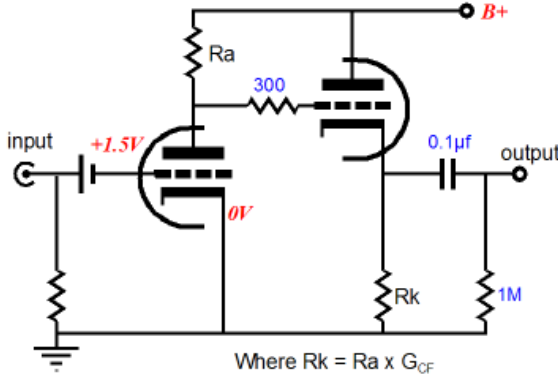
if some compassionate high-end-audio company could wrap the batteries in some fancy, patented, irreplaceable shrink-wrap that would up the price to a few hundred dollars...)

Hybrid MC Phono Preamp



Note how the battery presents a +1.5Vdc bias voltage to the OpAmp; had a pure-tube circuit been used instead, as it is in the circuit below, the battery's orientation must be reversed.

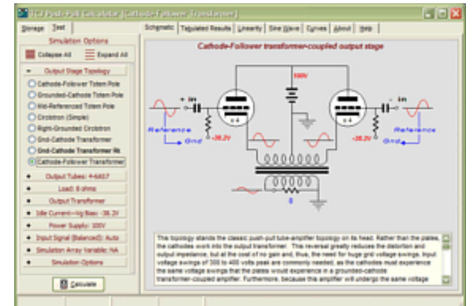
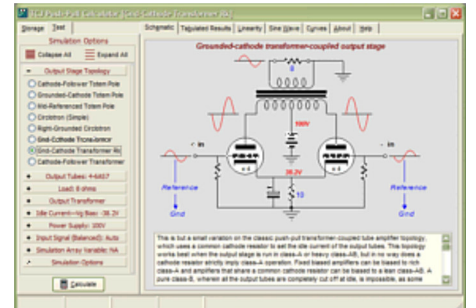
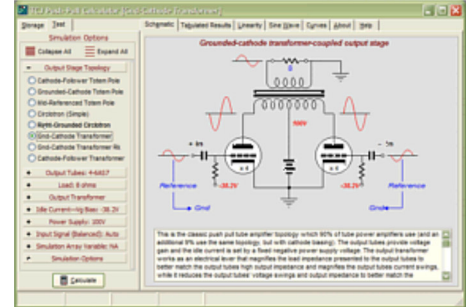
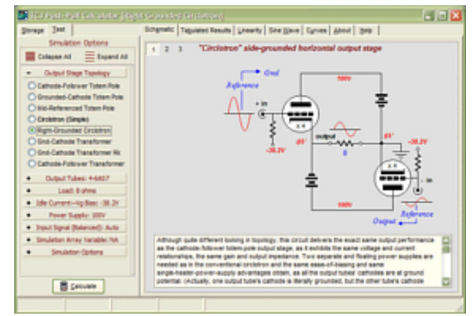
Constant Current-Draw Pre-Preamp Amplifier



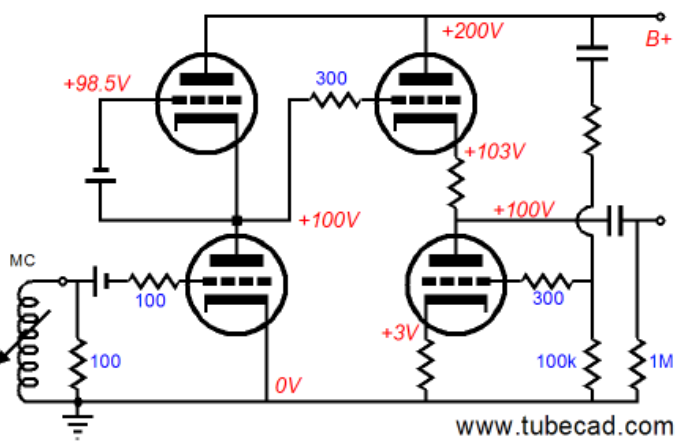
Of course, the battery can be bypassed by a small-valued high-quality capacitor. But the interesting feature of using a battery as a coupling capacitor is that the battery will last as long as its shelf life, as it sees no significant current draw, as the input resistance of both the triode and the OpAmp is supremely high.

Aikido Phono Pre-Preamp

Since the Aikido is known for its low noise and low distortion, it would seem a natural for a pre-preamp—and it is, as long as one is willing to accept the higher noise that all tubes must intrinsically add, because of their low transconductance and high plate resistances. Even the unbypassed cathode resistors will add noise to the circuit. The following circuit uses two batteries to create an Aikido phono pre-preamp that forgoes cathode resistors in the first stage.



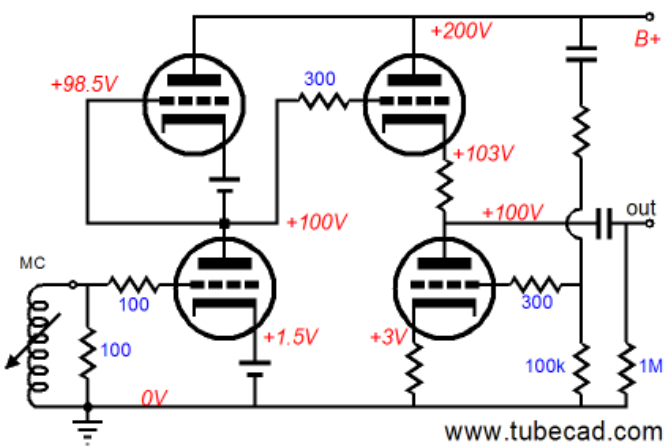
Aikido Phono Pre-Preamp



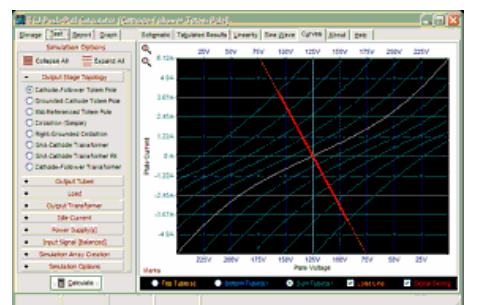
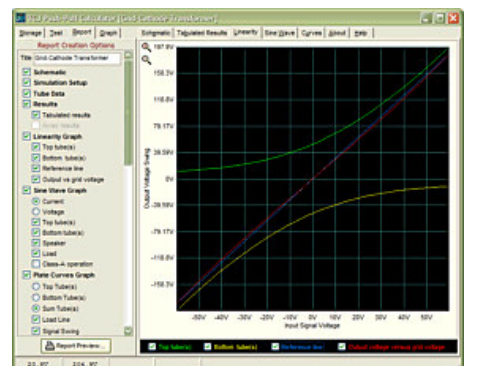
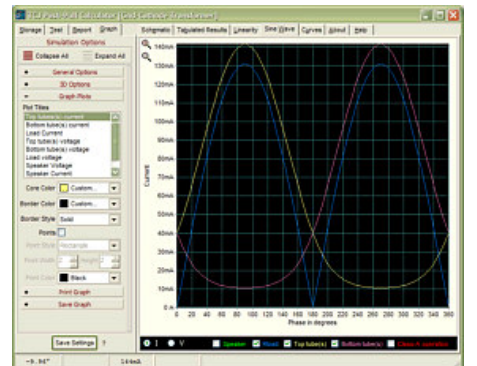
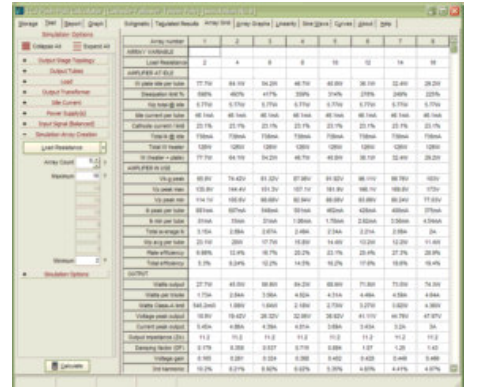
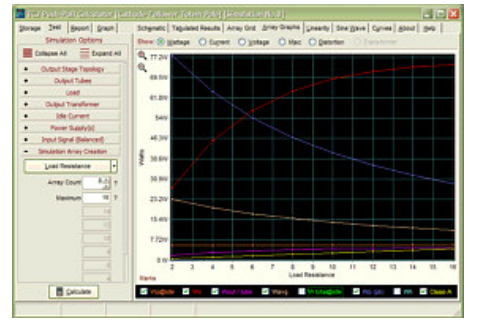
Yes, no cathode resistors are used for the input triodes; instead, the two batteries provide the required negative grid bias voltage for top and bottom triodes.

Some are no doubt thinking that the two batteries could be used place of cathode resistors, which is true, as shown below. The batteries, however, are now very much in the current paths within the amplifier stage and they face a charging current, which may damage an alkaline battery, although it would charge a NiH battery.

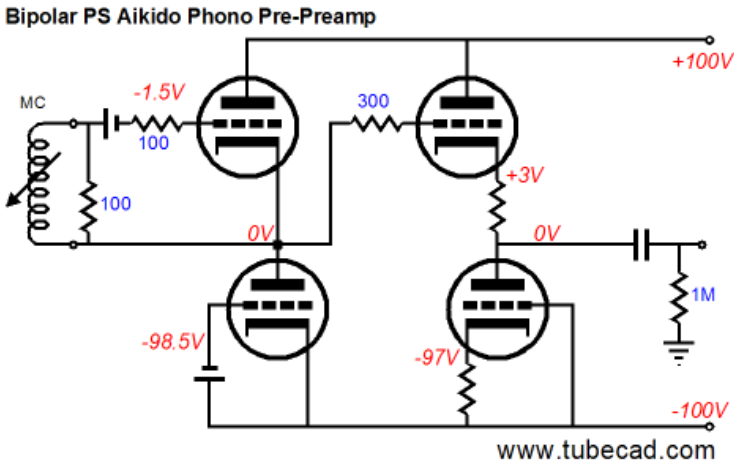
Aikido Phono Pre-Preamp (version 2)



Now that we have done our mental stretching exercises, we can move on to the truly interesting Aikido phono pre-preamp. The circuit below uses a bipolar power supply and the top-leftmost triode is the input tube. The bottom-leftmost triode is but an active load for the top triode, which functions as a grounded-cathode amplifier. What? That has to be backwards, doesn't it?



TCJ PPC Version 2 Improvements



Rebuilt simulation engine
Create reports as PDFs*
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Help system added
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Redesigned array creation
Transformer primary & secondary
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Save user-defined transformer
definitions
Enhanced result display
Added array result grid

*User definable

The top triode is configured in an inverted topology, wherein the input signal phase is preserved and the gain, output impedance, and distortion are identical to a conventional grounded-cathode amplifier. How can that be? Note that there are no ground connection at the amplifier's input; instead, the cartridge's coil spans the top triode's cathode and grid. Remember that this coil floats relative to ground in most turntables (apparently a few British turntables ground one cartridge lead within the tone arm).

Also note that the two-resistor AC voltage divider that is used in the conventional Aikido gain stage to inject power-supply noise in to the output stage's bottom triode is missing; instead, the output stage's bottom triode has its grid attached directly to the negative power supply rail. What is going on here is that both sets of triodes in series define two equal-resistor voltage dividers, which means that as long as the positive and negative power supply rails share the same amount of ripple, differing only in phase, the midpoint for these voltage divider is at a noise null.

TCJ Push-Pull Calculator has but a single purpose: to evaluate tube-based output stages by simulating eight topologies' (five OTL and three transformer-coupled) actual performance with a specified tube, power supply and bias voltage, and load impedance. The accuracy of the simulation depends on the accuracy of the tube models used and the tube math model is the same True Curves™ model used in GlassWare's SE Amp CAD and Live Curves programs, which is far more accurate than the usual SPICE tube model.

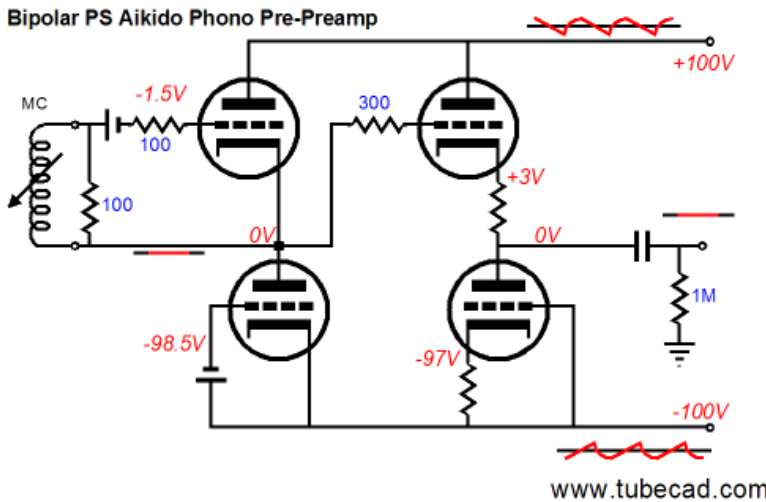
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Ok, what about the output coupling capacitor? Why use it, when the output is already at 0 volts? If all the tube, resistors, and batteries are perfectly matched, then the output coupling capacitor could be eliminated. With real parts, however, expect a big DC voltage offset, say 5V to 10V.

Ok, what happened to the usual Aikido safety resistors? They were left out in an effort to realize the least noise at the output. In a line stage amplifier, the noise contribution is swamped out by the tube noise, but in a phono preamp, we cannot accept any extra noise sources.

//JRB

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