

TETRA All in One

Stereo Phono PCB USER GUIDE

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06/11/2009

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 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.

Tetra All-in-One Phono Preamp Overview

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

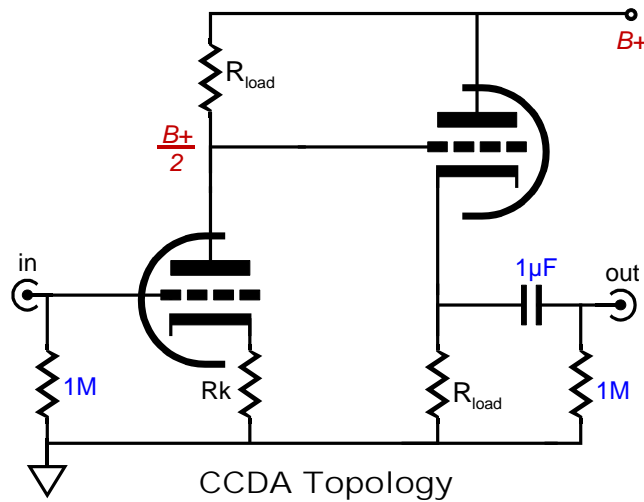
PCB Features

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

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.) In addition, the PCB provides space for four sets of capacitors to decouple each CCDA gain stage from the B+ connection. This arrangement allows a large-valued electrolytic capacitor and small-valued film capacitor to be used in parallel, while a series voltage-dropping resistor completes the RC filter.

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

Introduction to the CCDA Circuit



The **Constant-Current-Draw Amplifier** is a compound circuit that holds a grounded-cathode amplifier directly cascaded into a cathode follower. So what; what's so special about this obvious pairing? Its special status lies in the details.

Each triode sees the same cathode to plate voltage and the same load resistance and same idle current draw. Both grounded-cathode amplifier and the cathode follower are in voltage phase, but in anti-current phase. For example, as the grounded-cathode amplifier sees a positive going input signal, its plate current increases, which increases the voltage developed across the plate resistor, which in turn swings the triode's plate voltage down. This downward voltage swing is then cascaded into the grid of the cathode follower, whose cathode follows its grid's downward swing, which decreases the current through the cathode follower to the same degree that the previous stage's current increased. This results in the constant current draw feature of this topology (a highly desirable feature, as the signal amplification will not alter the amount of current being sourced from the power supply and consequently not perturb the power supply, thus greatly simplifying the design consideration of the power supply).

Gain Calculating the gain from a CCDA amplifier is easy, when the cathode resistor are left un-bypassed, as it roughly equals half the mu of the input triode used. For example, a 12AX7 holds a mu of 100, so the gain will equal 50 (+34dB). The gain from a simple grounded-cathode amplifier, with a bypassed cathode resistor, is a bit more complicated

$$\text{Gain} = \mu R_a / (r_p + R_a)$$

For example, given a 12AX7 loaded by a 150k plate resistor and whose capacitor resistor is bypassed, the gain will roughly equal 70 (+37dB).

The passive equalization network entails a -20dB insertion loss, which must be subtracted from the combined gain from the two CCDA gain stages. For example, two 12AX7-based, +34dB gain stages deliver a final gain of +68dB -20dB, which equals +48dB. Of course, the cathode followers also exact a slight loss of gain, so in the example just given, the final gain would be closer to +44 to 46dB.

B-Plus Power Supply

The high voltage B-plus power supply resides on the Tetra CCDA phono PCB. It contains a full-wave bridge rectifier circuit and reservoir capacitor, which is then followed by two RC-smoothing filters within the phono circuitry. 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 raw B-plus voltage depends on the tubes used. For example, 6DJ8/6922 triodes can be used with a low 100V power supply, while 12AX7s work better with at least a 200V to 300V B-plus voltage. 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 first RC power supply filter.

Resistor R18 and capacitors C15 & C16 define the first RC power supply filter. The larger the R18's value is, the lower the low-pass filter's transition frequency. But the greater this resistor's value the greater the voltage drop across its leads and the greater its dissipation. Resistor heat equals $I^2 \times R$ (and V^2/R); for example, 20mA and 5k will dissipate 2W. Thus, several goals that work against each other: we want the largest voltage-dropping resistor value possible, as it reduces the ripple RC filter's output; and we want the smallest value for R18, as this resistor limits the maximum idle current that can flow through the CCDA stage; and 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. In other words, we cannot have it all. Choices must be made and consequences must be accepted.

An analogy can be made between cars and a tube amplifier. A race car runs high revs and high horsepower and it is obscenely expensive, noisy, unreliable, and glorious to behold. A family's commuter car is cheap, quiet, reliable, and boring. Running high voltage and high current will make for a short tube life and a wonderful sound. Running low voltage and low current will greatly extend tube life and save money on part cost. For example, a typical 250V capacitor is much more volumetrically efficient and cheaper than a 400V capacitor. Thus, running a lower B-plus voltage allows us to increase greatly the total capacitance in the power supply, at a lower cost.

Typical Part Values

() Parentheses denote recommended values

C18 = 33 μ F to 100 μ F* (47 μ F 450V)

C13 = 0.01 μ F to 0.47 μ F \geq 100V

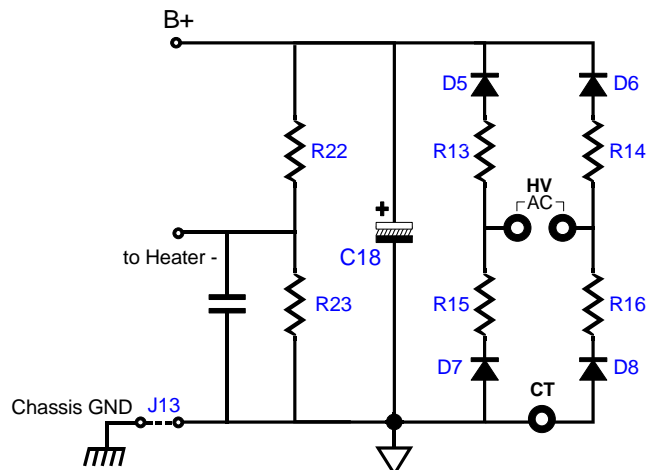
*Voltage rating depends on transformer used; all must exceed the raw B+ voltage.

D1-4 = 1N4007, UF4007 (HER108)

R13-16 = 10 or 100-ohms 1W

R22 = 300k 1W

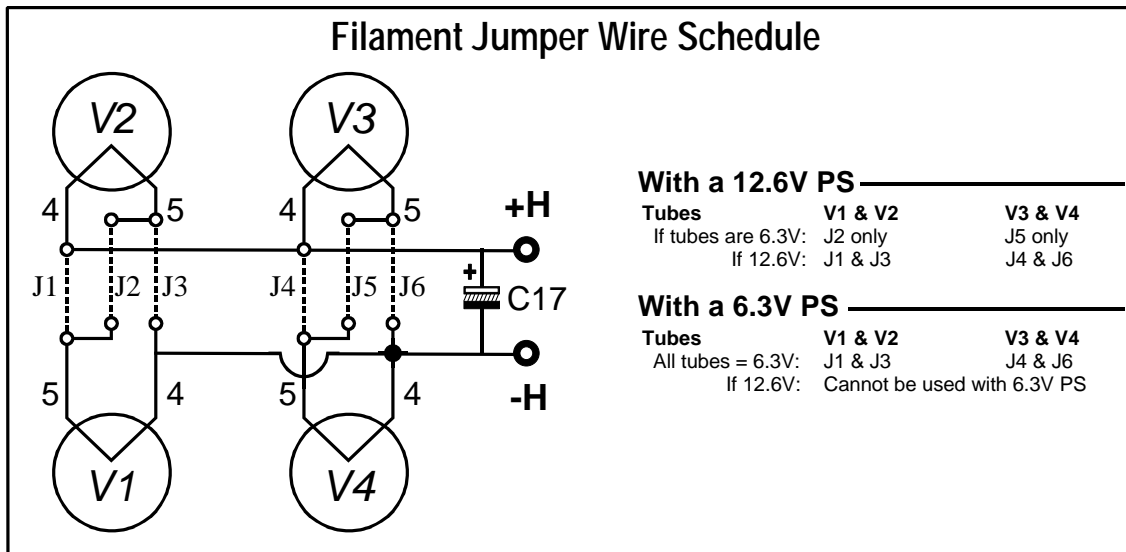
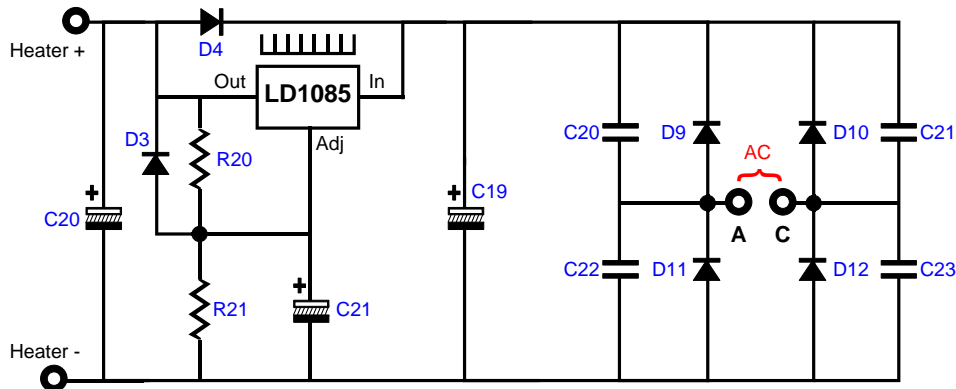
R23 = 50k to 100k 1W



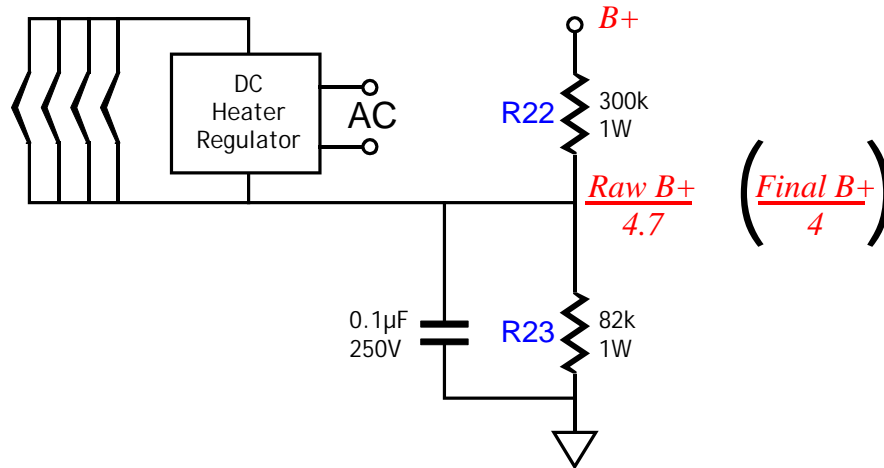
Heater Issues

The Tetra *All in One* phono PCB holds a heater raw power supply and voltage regulator, the LD1085 low-dropout adjustable regulator. The regulator can be set to any output voltage between 5V to 25V, but the assumption is that a 12Vdc output voltage will be used for the heaters, as the rectifier losses will be less and the regulator will enjoy a larger voltage-dropout window, before falling out of regulation. Using a slightly cool 12Vdc instead of 12.6Vdc will increase tube life, without diminishing performance. In addition, with a 12Vdc h power supply, 6.3V heater tubes (like the 6DJ8 and 6N1P) or 12.6V tubes (like the 12AT7 or 12AX7) can be used at the same time. Both voltage types can be used exclusively, or simultaneously; for example a 6N1P for the input tube and a 12BZ7 for the output tube. Thus, if the input tubes (V1 and V2) are 6N1Ps and the second stage tubes (V3 and V4) are 12BZ7s and the heater regulator output voltage is 12Vdc, then use jumpers J2, J4, and J5.

Although the preferred power supply voltage is 12V, a 6Vdc (or 6.3Vdc) heater power supply can be configured on the PCB, as long as all the tubes used have 6.3V heaters (or a 5V or 8V or 18V power supply can be used, if all the tubes share the same 5V or 8V or 18V heater voltage). Just use jumpers J1, J3, J4, and J6 only. Note: Perfectly good tubes with uncommon heater voltages can often be found at swap meets, eBay, and surplus stores for a few dollars each. Think outside 6.3V/12.6V box.



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 $\frac{1}{4}$ 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. This means that resistors R17 and R18 values must be experimentally selected. 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 R17 and R18 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 Heater PS 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
D9, 10, 11, 12 =	MUR410G	"	"	"	"
D3, 4 =	1N4007	"	"	"	"
C20, 21, 22, 23, 24 =	1000pF - 50V	"	"	"	"
C13 =	10kµF - 16V	"	"	"	"
C14, C15 =	1kµF - 16V	"	"	"	"
Regulator =	LD1085, LM317, LM350, LT1085				
Vac Input =	7-8Vac @ 3A for 6.3Vdc 12-12.6Vac @ 2A for 12Vdc or 12.6Vdc				

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

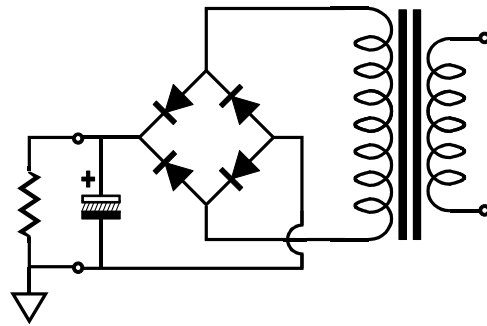
$$V_o = 1.25(1 + R_{21} / R_{20})$$

Thus, using a 125-ohm resistor for R20 and a 2.4k resistor in R21 position, the output will climb to 25.2Vdc. See the values table above.

Power Transformer(s)

The *Tetra All-in-One* phono-stage 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 12AT7s 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 raw DC voltage that a 12.6V heater voltage regulator requires an input voltage equal to remainder of 16V minus 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.

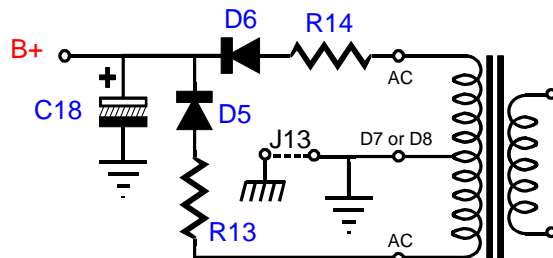


$$I_{out} = I_{ac} / 1.8$$

$$V_{dc} = (V_{ac} \times 1.4) - 2V_{diode}$$

Full-Wave Bridge This is the most popular power supply configuration. The entire primary winding is used and four rectifiers are required. This configuration is seldom used with tube rectifiers, as the rectifier cathodes cannot be heated by just a single heater winding. The two solid-state diode voltage-drops count for little in a high-voltage power supply, but are a big liability in low-voltage power supplies.

A center-tapped primary can be used as well; just leave D7, D8, R15, and R16 off the board, then attach the center-tap to D7 or D8's bottom eyelet, where its label appears.



Center-Tapped Transformer

$$I_{out} = I_{ac} / 1.27$$

$$V_{dc} = V_{ac}^* / 1.43 - V_{diode}$$

*entire primary

Typical Part Values () Parentheses denote recommended values

	12AX7 & 12AT7	6N1P & 12AT7	12AT7 & 12AT7
Gain Rk bypassed =	50dB	41dB	40dB
Gain Rk no Rk bypass =	43dB	34dB	40dB
Raw B+ Voltage =	250V - 400V (335V)	Same	Same
Heater Voltage =	12.6V	12.6V	12.6V
Heater Current =	0.6A	0.9A	0.6A
R1 =	100 - 47K (47k)*	Same	Same
R2 =	1k 1mA	100 - 470 (200 6mA)	200 - 680 (300 5mA)
R3 =	100 - 1k (178)*	Same	Same
R4, 6 =	140K 1W	30K 2W	30k 2W
R5, 12, 15 =	100 - 1k (300)	Same	Same
R7 =	21k/MF or 20k/CF	Same	Same
R8 =	3.16k/MF or 3.2k/CF	Same	Same
R9 =	100 [optional]	Same	Same
R10 =	10k 1/2W to 2W	3.9k 3W	2k
R11, 19 =	1M	Same	Same
R13, 17 =	200 - 680 (300 5mA)	Same	Same
R14, 16 =	30k 1W	Same	Same
R18 =	3k 2W	1k 2W	2k 2W
C1 =	Optional, 50 - 1,000pF	Same	Same
C2, 12 =	Optional, 1kμF 6.3V	Same	Same
C3, 13 =	Optional, 0.1 - 1μF 100V	Same	Same
C4, 16 =	150μF/400V*	Same	Same
C5, 15 =	0.68μF/400V Flim or PIO*	Same	Same
C7 C8 =	0.1μF Flim or PIO*	Same	Same
C9 C10 =	0.0343μF* Film or oil*	Same	Same
C11 =	0.1 - 1μF Film or PIO*	Same	Same
C14 =	0.33 - 4μF (1μF)*	Same	Same

*Voltage rating must equal or exceed B+ voltage. Capacitors C8 & C10 are trim capacitors that in parallel with its partner capacitor brings the combined capacitance to the target value.

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

	12AX7 & 12AX7	6DJ8 & 12AT7	6072 & 6072
B+ Voltage =	250V - 400V (335V)	Same	Same
Heater Voltage =	12.6V	12.6V	12.6V
Heater Current =	0.6A	0.9A	0.6A
R1 =	100 - 47K (47k)*	Same	Same
R2 =	1k 1mA	100 - 470 (200 6mA)	200 - 680 (300 5mA)
R3 =	100 - 1k (178)*	Same	Same
R4, 6 =	140K 1W	20K 2W	30k 2W
R5, 12, 15 =	100 - 1k (300)	Same	Same
R7 =	21k/MF or 20k/CF	Same	Same
R8 =	3.16k/MF or 3.2k/CF	Same	Same
R9 =	100 [optional]	Same	Same
R10 =	10k 1/2W to 2W	3.9k 3W	2k
R11, 19 =	1M	Same	Same
R13, 17 =	200 - 680 (300 5mA)	Same	Same
R14, 16 =	30k 1W	Same	Same
R18 =	3k 2W	1k 2W	2k 2W

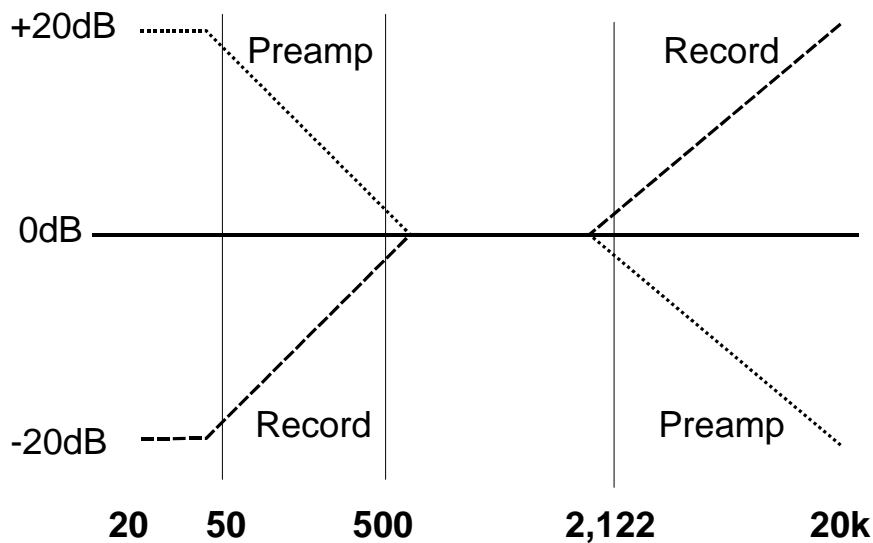
*High-quality resistors essential in this position. All resistors 1/2W or higher where specified

C1 =	Optional, 50 - 1,000pF	Same	Same
C2, 12 =	Optional, 1kμF 6.3V	Same	Same
C3, 13 =	Optional, 0.1 - 1μF 100V	Same	Same
C4, 16 =	150μF/400V*	Same	Same
C5, 15 =	0.68μF/400V Flim or PIO*	Same	Same
C7 C8 =	0.1μF Flim or PIO*	Same	Same
C9 C10 =	0.0343μF* Film or oil*	Same	Same
C11 =	0.1 - 1μF Film or PIO*	Same	Same
C14 =	0.33 - 4μF (1μF)*	Same	Same

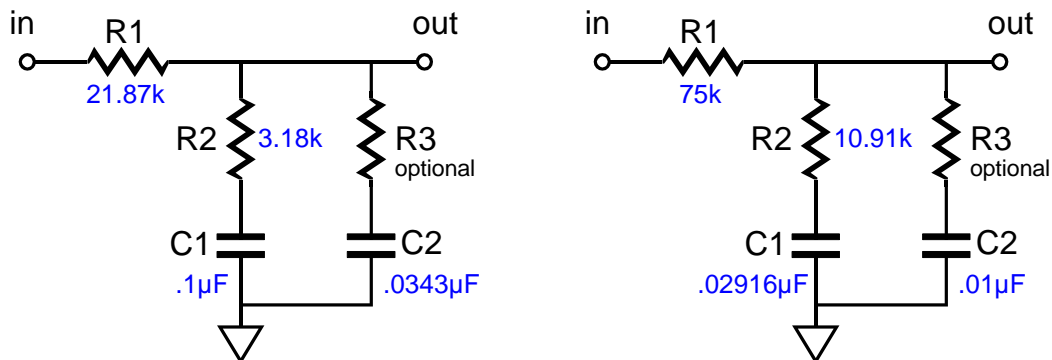
*Voltage rating must equal or exceed B+ voltage. Capacitors C8 & C10 are trim capacitors that in parallel with its partner capacitor brings the combined capacitance to the target value.

RIAA Equalization

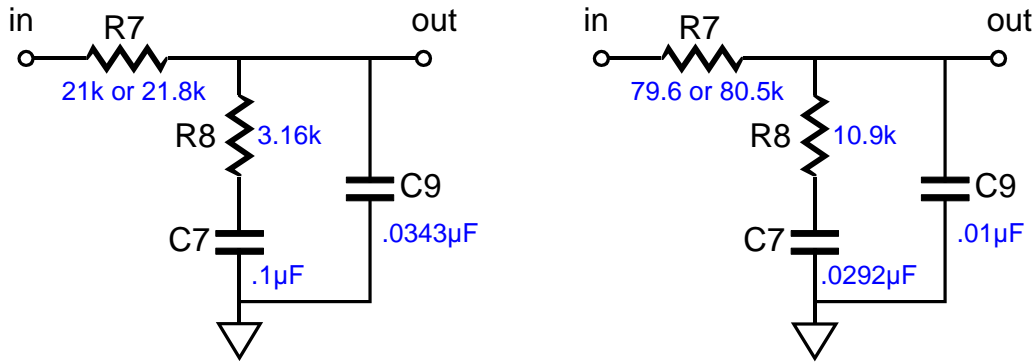
Regardless of the underlying technology used, tube or solid-state, a phono preamp must undo the RIAA (Recording Institute Association of America) equalization curve or the CCIR (Comité Consultatif International des Radiocommunications) or IEC (International Electrotechnical Commission) the European versions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



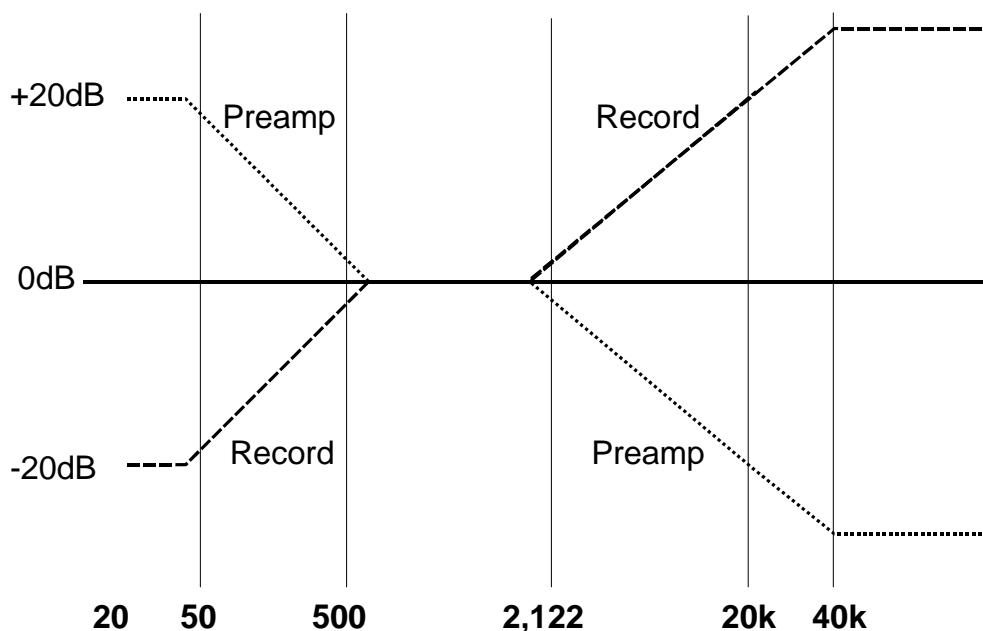
This preamp uses passive equalization, rather than active, feedback-based equalization. The passive equalization network sits in between two CCDA gain stages. Two variations on the same equalization network are shown below. The advantage the lower-resistance version on the left enjoys over the higher-resistance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



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



The Tetra phono stage's passive equalization network holds an optional high frequency correction. Correction? The passive network assumes that the LP's high frequencies continue to climb at 6dB per octave from 2,122Hz to infinity. But do they? Not likely, as the cutting heads and cutting power amplifiers used to make record master have high frequency roll offs that fall closer to 30kHz to 60kHz than to infinity. In other words, the passive equalization will over attenuate the high frequencies beyond the record's intrinsic high frequency corner frequency. Adding the optional resistor, R3 in the schematic on the previous page and R9 on the PCB, will place a countervailing stop to this excessive attenuation. Is it really needed? It depends who you talk to; I have tried it both ways, with the extra and without, and I preferred leaving the resistor out. But feel free to experiment; start with 100 ohms.



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

with C7 (in parallel with C8) as the moving variable					
C in μF		Absolute Values		1% Values	
C7 C8	C9 C10	R7	R8	R7	R8
0.09	0.0309	24300	3533	24.3k	3.57k
0.091	0.0312	24033	3495	24k	3.48k
0.092	0.0316	23772	3457	23.7k	3.48k
0.093	0.0319	23516	3419	23.7k	3.4k
0.094	0.0322	23266	3383	23.2k	3.4k
0.095	0.0326	23021	3347	23.2k	3.32k
0.096	0.0329	22781	3313	22.6k	3.32k
0.097	0.0333	22546	3278	22.6k	3.3k
0.098	0.0336	22316	3245	22.1k	3.24k
0.099	0.0340	22091	3212	22.1k	3.24k
0.1	0.0343	21870	3180	22k	3.16k
0.101	0.0346	21653	3149	21.5k	3.16k
0.102	0.0350	21441	3118	21.5k	3.16k
0.103	0.0353	21233	3087	21k	3.09k
0.104	0.0357	21029	3058	21k	3.09k
0.105	0.0360	20829	3029	21k	3k
0.106	0.0364	20632	3000	20.5k	3k

with C9 (in parallel with C10) as the moving variable					
C in μF		Absolute Values		1% Values	
C7 C8	C9 C10	R7	R8	R7	R8
0.08019	0.0275	28040	3966	28k	3.92k
0.081648	0.0280	27520	3895	27.4k	3.9k
0.083106	0.0285	27030	3826	27k	3.83k
0.084564	0.0290	26550	3760	26.7k	3.74k
0.086022	0.0295	26090	3697	26.1k	3.65k
0.08748	0.0300	25640	3635	25.5k	3.65k
0.088938	0.0305	25210	3576	25.5k	3.6k
0.090396	0.0310	24790	3518	24.9k	3.57k
0.091854	0.0315	24390	3462	24.3k	3.48k
0.093312	0.0320	24000	3408	24k	3.4k
0.09477	0.0325	23620	3355	23.7k	3.32k
0.096228	0.0330	23260	3305	23.2k	3.3k
0.097686	0.0335	22900	3255	23.2k	3.24k
0.099144	0.0340	22560	3207	22.6k	3.24k
0.100602	0.0345	22220	3161	22.1k	3.16k
0.10206	0.0350	21900	3116	22k	3.16k
0.103518	0.0355	21580	3072	21.5k	3.09k

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

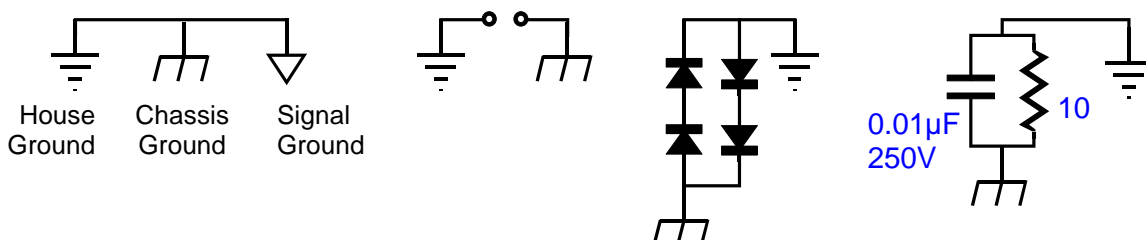
Grounding

The *Tetra All-in-One* phono-stage 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 J13, 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 phono-stage, 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. 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. The Absolute-Star grounding scheme uses a lot of wire and is the most time consuming to layout, 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.

Turntable Ground My advice is not to use jumper J13; instead, attach turntable's grounding jack to the ground pad at the bottom of the PCB where the input tubes are located. Be sure to experiment with the turntable grounding. For example, some turntables "ground" the cartridge's two ground pins to the arm and, by extension, to the turntable ground. In this situation, less hum might be had by only attaching the hot centers of the input jacks to the PCB.

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, while 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.



Tube Selection

By using different tubes, different bias points, different B+ voltages, a nearly infinite number of different CCDA amplifiers can be built. But with a phono preamp, our choices are limited, as high-gain, and low-noise are our key requirements, not high-current or low output impedance. Thus, we can ignore the 6H30 and concentrate on the 6AQ8, 6DJ8, 6N1P, 12AT7, 12AV7 12AX7, 12BZ7, 5751, 6072.... For example, a 12AX7 input tube will yield a gain close to 50 ($\mu/2$) per CCDA stage (with unbypassed cathode resistor), which perfect for a phono preamp; the 6DJ8/6922, 16 (μ of 33), which is a little weak, but if a step-up transformer is used, the 6DJ8's lower noise contribution would certainly override the concern about its low gain. The only hard stipulations are that the two triodes within the envelope be similar and that the tube conforms to the 9A or 9AJ base pin-out.

Cartridge Capacitance Loading

Capacitor C1 is an optional cartridge shunting capacitor. Usually, it is best left off the board, as the phono interconnect is already capacitance laden.

Internal Shields

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

Cathode Resistor Values

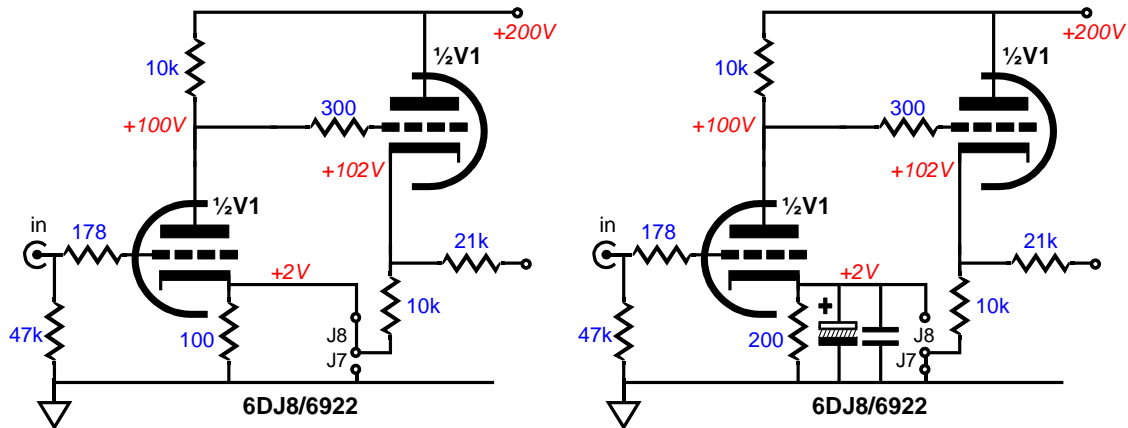
The cathode resistor and plate voltage set the idle current for the triode: the larger the value of the resistor, less current; the higher the plate voltage, more current. In general, high- μ triodes require high-value cathode resistors (1-2K) and low- μ triodes require low-valued cathode resistors (100-1k).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

$$I_q = B+ / (r_p + [\mu + 1]R_k + R_a)$$

So, for example, a 6DJ8 in an CCDA circuit with a B+ voltage of +200V and 200 cathode and 10k plate resistors will draw $200 / (3k + [32 + 1]200 + 10k)$ amperes of current, or roughly 10mA. Because the cathode resistors are unbypassed, they will add noise to the signal, so lower values are preferable. I recommend between 680 to 1.5k for the 12AX7, 5751, 6072 input tubes and between 100 to 330 for the 6DJ8 and 6N1P.

Cathode Resistor Bypass Capacitors

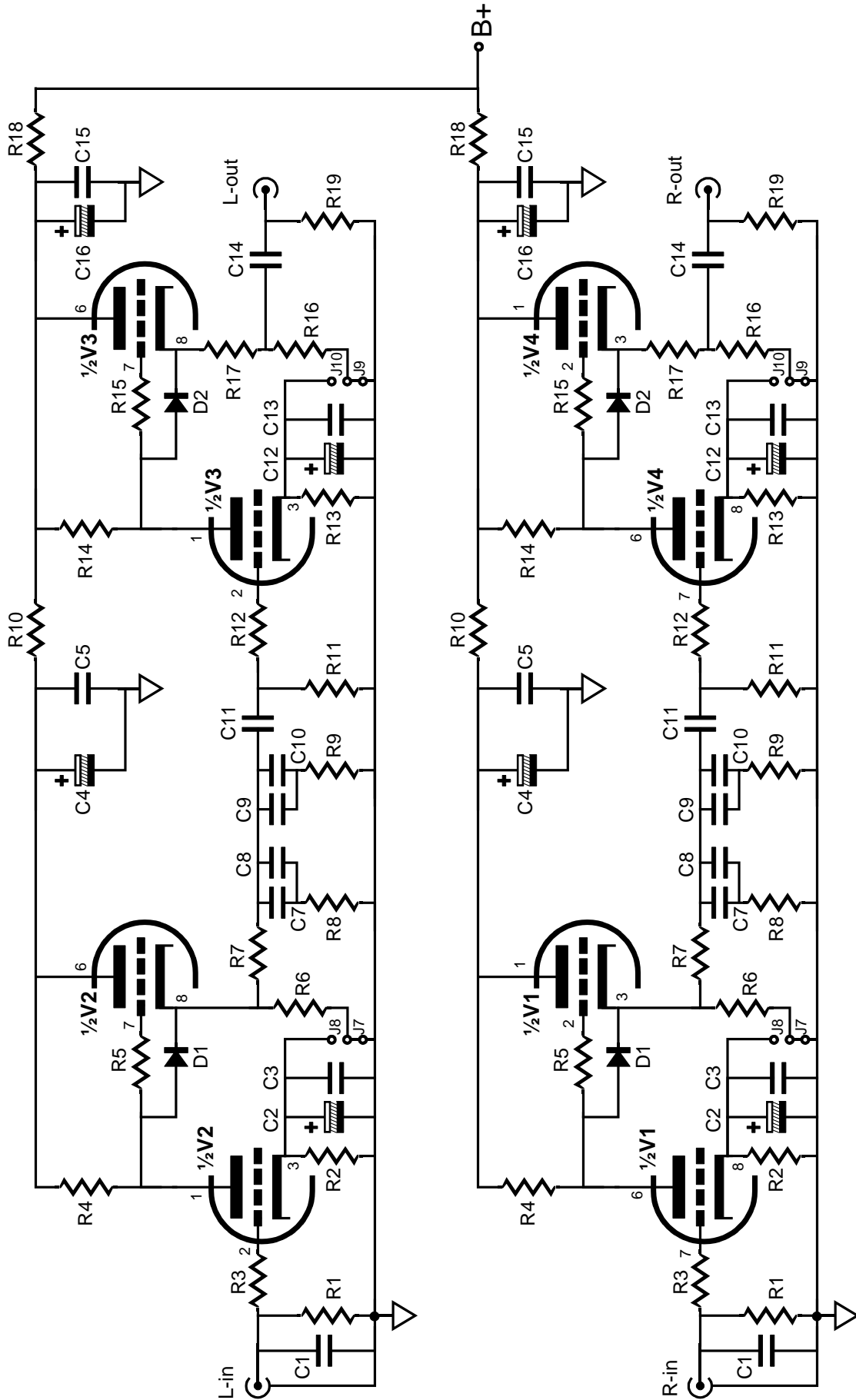
With or without a bypass capacitor, the cathode resistor helps set the idle current through the triode. Without a bypass capacitor, it also provides a form of negative feedback that linearizes the triode's transfer function, reducing distortion, but decreasing gain and worsening the PSRR figure for a grounded-cathode amplifier. Thus, the dilemma we face is choosing between more gain and less noise or more noise and less distortion. Usually, in a phono preamp, the need for gain triumphs. Nonetheless, first try to get away with not using any cathode bypass capacitors, as these capacitors are very much in the signal path and they can easily pollute the sound. If they must be used, use the best obtainable capacitors, such as the Panasonic FC and FM series or the famous Blackgate electrolytic capacitors.



Alternate Cathode Resistor Connection For the advanced practitioner, the Tetra All-in-One phono PCB accepts two ways of bypassing the grounded-cathode amplifier's cathode resistor. The first is to use jumper J7 (and J9 for the second CCDA gain stage) and capacitors C2 & C3. The second approach is to use jumper J8 (and J10 for the second CCDA gain stage) and forgo the bypass capacitors. The first configuration requires halving the cathode resistor's nominal value, as twice the current will flow through the resistor. The resistor is effectively bypassed, however, as anti-phase AC current flows from the cathode follower side of the circuit into the cathode resistor, effectively establishing a DC current flow and constant voltage drop across the resistor. (In reality, a small amount of AC current signal will superimpose a small AC signal across the resistor.) Just as we can wear a belt with suspenders, the bypass capacitors can be added to this configuration. But do first try it without the capacitors.

RFI Radio interference can be a headache for the vinyl lover. One solution is the use large shunting capacitors across the input resistor, R1; this remedy seldom works, alas. Instead, try placing a small ferrite beads over the wires leaving both the input RCA jacks and the PCB; add small ceramic capacitors (say, 100pF) from the input RCA jacks ground (and maybe hot) to the shared grounding jack and chassis ground point. Sometimes the only solution is to move the turntable and phono stage to another part of the room or to a different room. Light dimmers and cheap switching power supplies can create noise in a high-gain audio circuit; to help locate such noise culprits use a hand-held AM radio tuned off any station as a RFI stethoscope; you might be surprised by where RFI is originating in your house. If you live next to a radio or TV station, life can be miserable for the audiophile; just getting noise-free telephone reception can be difficult. Look into getting RFI notch filters tuned to the radio station's broadcast frequency.

Input Step-Up Transformer With only two gain stages, the Tetra phono stage has a hard time coming up with sufficient gain for a low-output moving coil cartridge. Even if a third gain were added, the tube noise would be severe. Thus, many use a step-up transformer with an MC cartridge, as the transformer can provide up to +30dB of gain and little additional noise. Be sure to check with the transformer maker for extra information on how to squeeze the most performance from the transformer. For example, many step-up transformers benefit from a Zobel network loading its secondary.



Assembly & Testing

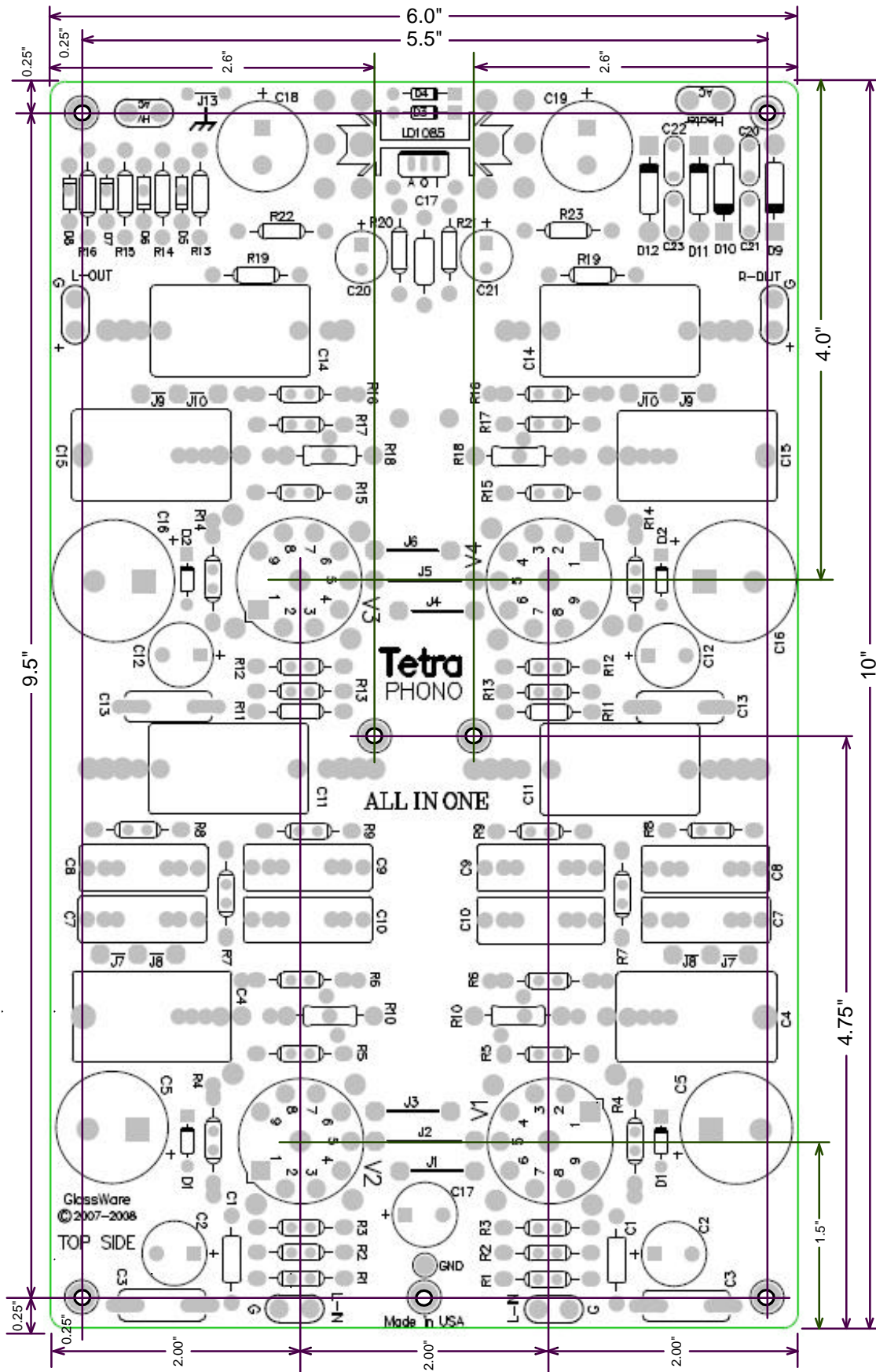
Assembly Cleanliness is essential. Before soldering, be sure to clean both sides the PCB with 90% to 99% isopropyl alcohol. Do not use dull-looking solder; solder should shine. If it doesn't, first clean away the outer oxidation with some steel wool or a copper scouring pad. If the resistor leads look in the least gray, clean away the oxidation with either steel wool or a wire sniper'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.



Top Side PCB Mechanical Layout

OVERALL PC BOARD DIMENSIONS: 6.0" x 10.0"

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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