TETRA Sans PS

Stereo Phono PCB

USER GUIDE

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GlassWare
AUDIO DESIGN
www.glass-ware.com
www.tubecad.com

sales@glass-ware.com

☛ Warning! ☚

This PCB is intended to be used with an external 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 have retained their charge even after the power supply is disconnected or shut down; measure before touching. **If you are not an experienced electrical practitioner, before applying the voltage have someone who is experienced review your work.** There are too few tube-loving DIYers left; we cannot afford to lose any more.

Tetra Sans PS Phono Preamp Overview

Thank you for your purchase of the Tetra Sans PS 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 30 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. The CCDA topology allows an excellent tube phono preamp to be made easily and inexpensively. The CCDA topology's low distortion and output impedance, without the use of negative feedback—all are desirable attributes in a phono preamp.

PCB Features

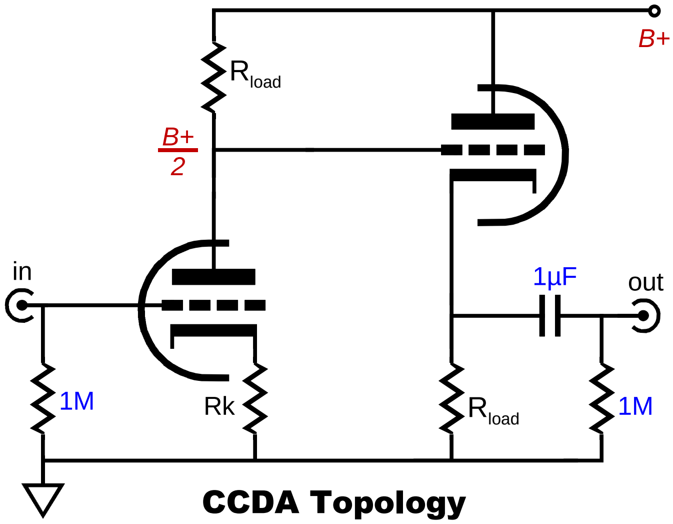
Overview This FR-4 PCB is extra thick, 0.094 inches (inserting and pulling tubes from their sockets won't bend or break this board), double-sided, with plated-through 2oz copper traces, and the boards are made in the USA. The Tetra PCB holds two phono-stage preamplifiers, with each phono preamp holding 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 6 inches by 8.5 inches, with seven mounting holes that prevent excessive PCB bending.

B+ RC Filters On the Tetra Sans PCB, each channel holds two cascading RC filters reside to smooth away ripple from the high-voltage B+ connection. (The PCB requires an external power supply with two DC voltages: one for the B+ and one for the heaters.) A large-valued electrolytic capacitor and small-valued film capacitor are used in parallel, while a series voltage-dropping resistor completes each 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.

Parallel RIAA EQ Resistors & Capacitors The Tetra Sans PS PCB holds pads for parallel RIAA equalization network parts. Getting an accurate inverse RIAA eq curve is essential, which requires exact resistor and capacitor values. Unfortunately, quite often the needed part value simply isn't made. For example, 3.18K or 0.0343µF. But by placing two resistors and two capacitors in parallel, these values can be realized.

Introduction to the CCDA Circuit



CCDA Topology

The **C**onstant-**C**urrent-**D**raw **A**mplifier 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).

CCDA 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

Gain = muRa / (rp + Ra)

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

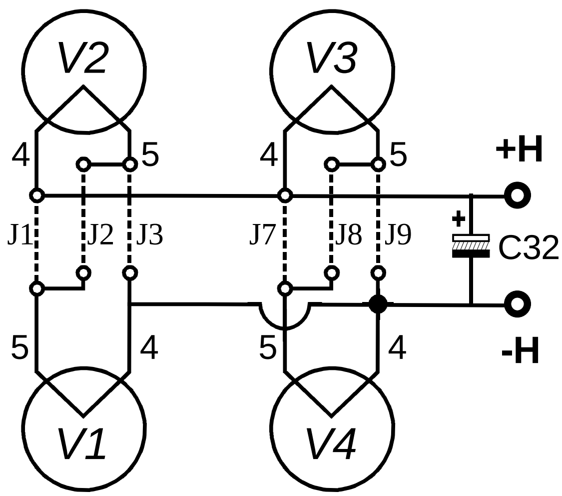
The passive equalization network entails a -20dB insertion loss, which must be subtracted from the combined gain from the two CCDA gain stages. For example, two 12AX7-based, +34dB gain stages deliver a final gain of 34dB - 20dB + 34dB, which equals 48dB. Of course, the cathode followers also exact a 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 Tetra Sans PS phono PCB requires an external power supply. Two RC-smoothing filters, however, do reside upon the PCB. The optimal B+ voltage depends on the tubes used. For example, 6DJ8/6922/7308/ECC88 tubes could be used with an embarrassingly-low 100Vdc B+ voltage, while the 12AX7 work better with a 200V to 300V B+ 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 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 also the greater the voltage drop across the resistor and the greater its dissipation. Resistor heat equals I^2 x R (or 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 amount of ripple at 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 using 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.

Heater Power Supply

The best bet is to use a DC power supply for the heaters, as it greatly minimizes hum problems. In addition, the best heater power supply voltage to use is 12Vdc, even when all the tubes hold 6.3V heaters. Yes, 12V, not 12.6V. Using a slightly cool heater voltage will increase tube life, without diminishing performance (in fact, it often improves it). In addition, with a 12Vdc heater 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. Although the preferred power supply voltage is 12V, perfectly good, indeed fantastically good NIB, NOS tubes with uncommon heater voltages can often be found at swap meets, eBay, and surplus stores (often for only a few dollars each), such as the 7DJ8, whose heater require 7V. Think outside 6.3V/12.6V box.



Filament Jumper Wire Schedule

With a 12.6V PS

Tubes	V1 & V2	V3 & V4
If tubes are 6.3V:	J2 only	J5 only
If 12.6V:	J1 & J3	J4 & J6

With a 6.3V PS

Tubes	V1 & V2	V3 & V4
All tubes = 6.3V:	J1 & J3	J4 & J6
If 12.6V:	Cannot be used with 6.3V PS	

R10 or R18	Imax mA	Vmax	Wattage	F3 150µF	F3 270µF
100	100	10	1	10.61	5.89
200	70	14	1	5.31	2.95
300	57	17	1	3.54	1.96
470	46	21	1	2.26	1.25
680	38	25	1	1.56	0.87
1000	31	31	1	1.06	0.59
1600	43	69	3	0.66	0.37
2000	39	77	3	0.53	0.29
3000	32	95	3	0.35	0.20
3900	28	108	3	0.27	0.15
6800	21	143	3	0.16	0.09
10000	14	170	3	0.11	0.06

Resistor	Voltage Drop Against Current									
100	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
200	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
300	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00
470	0.47	0.94	1.41	1.88	2.35	2.82	3.29	3.76	4.23	4.70
680	0.68	1.36	2.04	2.72	3.40	4.08	4.76	5.44	6.12	6.80
1000	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
1600	1.6	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0
2000	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
3000	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0
3900	3.9	7.8	11.7	15.6	19.5	23.4	27.3	31.2	35.1	39.0
6800	6.8	13.6	20.4	27.2	34.0	40.8	47.6	54.4	61.2	68.0
10000	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
	1	2	3	4	5	6	7	8	9	10

Current in mA

Resistor	Voltage Drop Against Current									
100	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
200	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
300	3.30	3.60	3.90	4.20	4.50	4.80	5.10	5.40	5.70	6.00
470	5.17	5.64	6.11	6.58	7.05	7.52	7.99	8.46	8.93	9.40
680	7.48	8.16	8.84	9.52	10.20	10.88	11.56	12.24	12.92	13.60
1000	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
1600	17.60	19.20	20.80	22.40	24.00	25.60	27.20	28.80	30.40	32.00
2000	22.00	24.00	26.00	28.00	30.00	32.00	34.00	36.00	38.00	40.00
3000	33.00	36.00	39.00	42.00	45.00	48.00	51.00	54.00	57.00	60.00
3900	42.90	46.80	50.70	54.60	58.50	62.40	66.30	70.20	74.10	78.00
6800	74.80	81.60	88.40	95.20	102.00	108.80	115.60	122.40	129.20	136.00
10000	110.00	120.00	130.00	*	*	*	*	*	*	*
	11	12	13	14	15	16	17	18	19	20

Current in mA

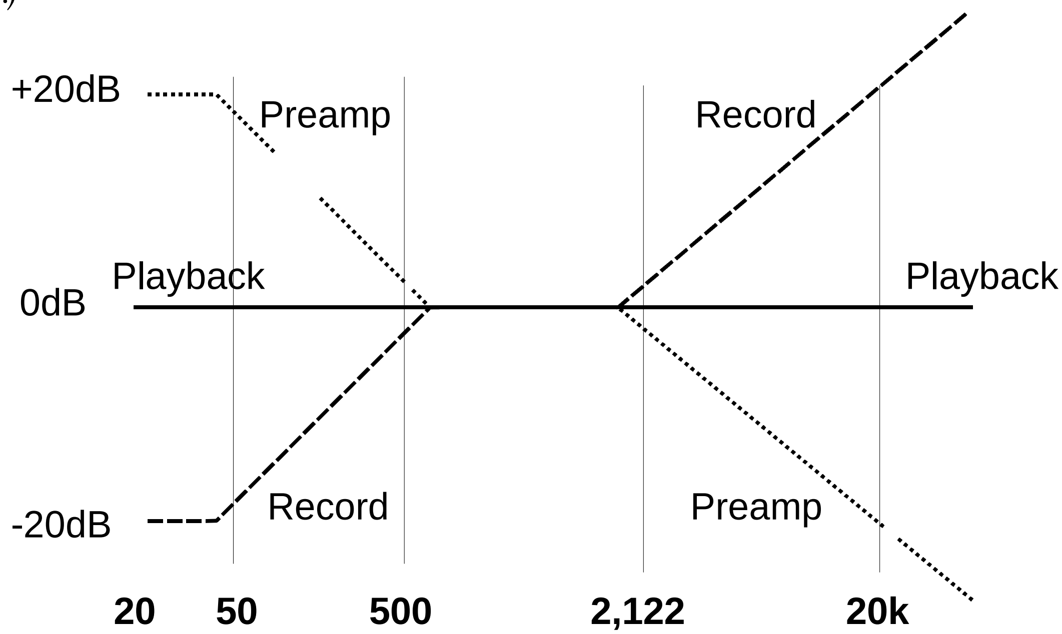
Resistor	Voltage Drop Against Current									
100	2.10	2.20	2.30	2.40	2.50	2.60	2.70	2.80	2.90	3.00
200	4.20	4.40	4.60	4.80	5.00	5.20	5.40	5.60	5.80	6.00
300	6.30	6.60	6.90	7.20	7.50	7.80	8.10	8.40	8.70	9.00
470	9.87	10.34	10.81	11.28	11.75	12.22	12.69	13.16	13.63	14.10
680	14.28	14.96	15.64	16.32	17.00	17.68	18.36	19.04	19.72	20.40
1000	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00
1600	33.60	35.20	36.80	38.40	40.00	41.60	43.20	44.80	46.40	48.00
2000	42.00	44.00	46.00	48.00	50.00	52.00	54.00	56.00	58.00	60.00
3000	63.00	66.00	69.00	72.00	75.00	78.00	81.00	84.00	87.00	90.00
3900	81.90	85.80	89.70	93.60	97.50	101.40	105.30	109.20	*	*
6800	142.80	*	*	*	*	*	*	*	*	*
10000	*	*	*	*	*	*	*	*	*	*
	21	22	23	24	25	26	27	28	29	30

Current in mA

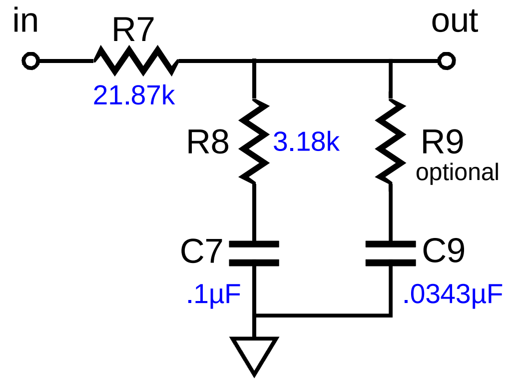
* Exceeds maximum Voltage/Current

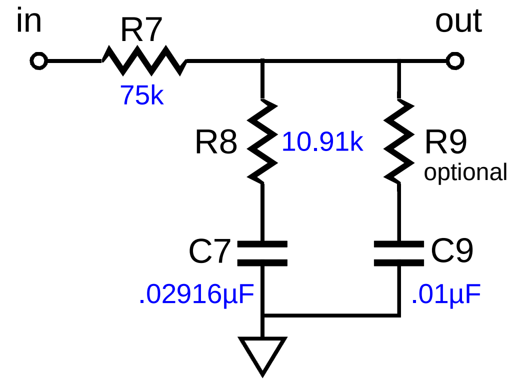
RIAA Equalization

Regardless of the underlying technology used, vacuum 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 grove 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.)

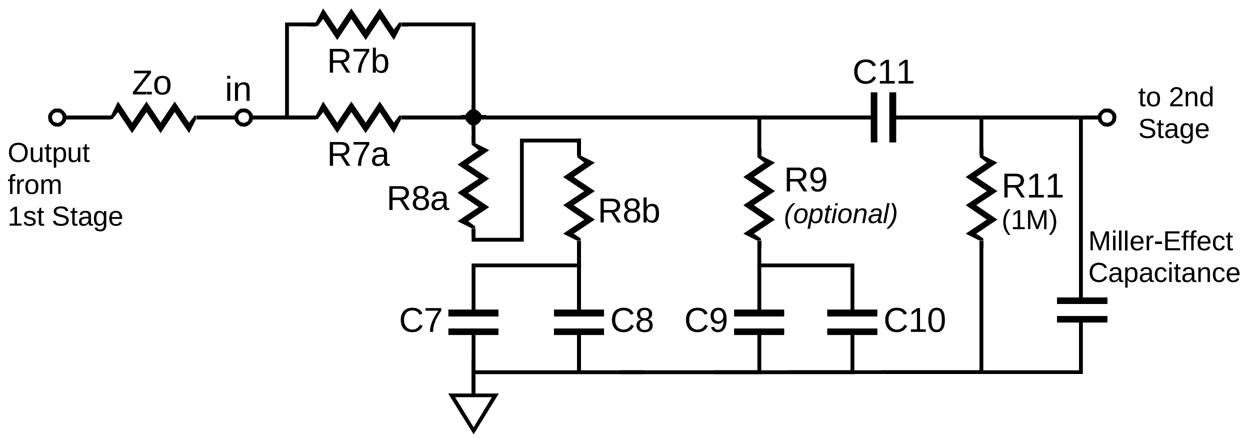


This preamp uses passive, rather than active, feedback-based equalization. The passive equalization network sits in between two CCDA gain stages. Two arrays of part values on the same equalization network are shown below. The advantage the lower-resistance version on the left enjoys over the higher-resistance 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 played by the first CCDA gain stage's output impedance; in addition, the capacitors C7 & C9 will be smaller (and cheaper).

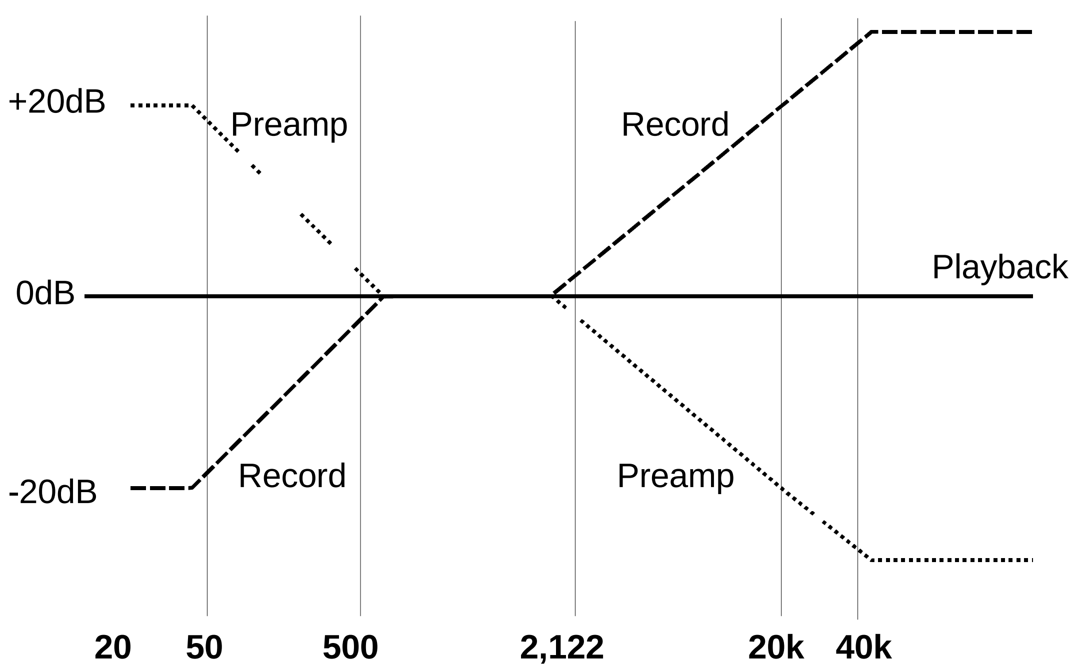




Each CCDA gain stage holds a cathode follower as its output stage, so CCDA's output impedance is fairly low. Nonetheless, this extra resistance must be factored into the equations, as must the 1M grid resistor to ground at the input of second CCDA gain stage. The equalazation network values shown page 5 are idealized; below we see real-world circuit that includes output impedance and a 1M grid resistor, R11. (Resistor R7 is obviously the varied component, but C9 must include the in-parallel Miller-effect capacitance from the second CCDA gain stage.)



Optional High Frequency Correction 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, R9, 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 resistor and without, and I preferred leaving the resistor out. But, by all means, do feel free to experiment; start with 100 ohms, which will impose a frequency transition at 46.4kHz. Frequency = 159155/R/C, where C is in µF.



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.

C in µF		Absolute Values	
C7‖C8	**C9‖C10**	**R7**	**R8**
0.099	0.0340	22091	3212
0.0991	0.0340	22069	3209
0.0992	0.0340	22046	3206
0.0993	0.0341	22024	3202
0.0994	0.0341	22002	3199
0.0995	0.0341	21980	3196
0.0996	0.0342	21958	3193
0.0997	0.0342	21936	3190
0.0998	0.0342	21914	3186
0.0999	0.0343	21892	3183
0.1	0.0343	21870	3180
0.1001	0.0343	21848	3177
0.1002	0.0344	21826	3174
0.1003	0.0344	21805	3170
0.1004	0.0344	21783	3167
0.1005	0.0345	21761	3164
0.1006	0.0345	21740	3161

These two tables include the effect of the 1M grid resistor, R11. The absolute resistor values are just that— absolute— and they assume an output impedance of zero from the output of V1 and V2. In reality, their output impedance ranges from a low of 108 ohms with a 6DJ8/6922 based cathode follower stage to a high of 1.05k with a 12AX7-based cathode follower. The output impedance is roughly equal to the triode's rp divided by its mu. For example, a 6N1P with a 47kohm cathode resistor, will result in an output impedance equal to about 320 ohms, which must be subtracted from the equalization networks R7's value, which in turn is in parallel with R11.

$$R_7 = \frac{R(R_s + R_{11}) - R_sR_{11}}{R_{11} - R}$$

Where R equals R7's absolute value, usually 21,870 ohms. Now if the calculated value for resistor R7 comes out to a non-standard value, such as 20.1k, then two 40.2k resistor can be placed in parallel by placing one in R7a & R7b. (Resistors R8a & R8b are in series.) In much the same way, the equalization capacitors, C7 & C9, can be made by using two capacitor in parallel, which simply add together. For example, if the target capacitance is 0.01µF, then a 0.009µF in parallel with 0.001µF (1nF or 1,000pF). The formula for parallel resistors is the following:

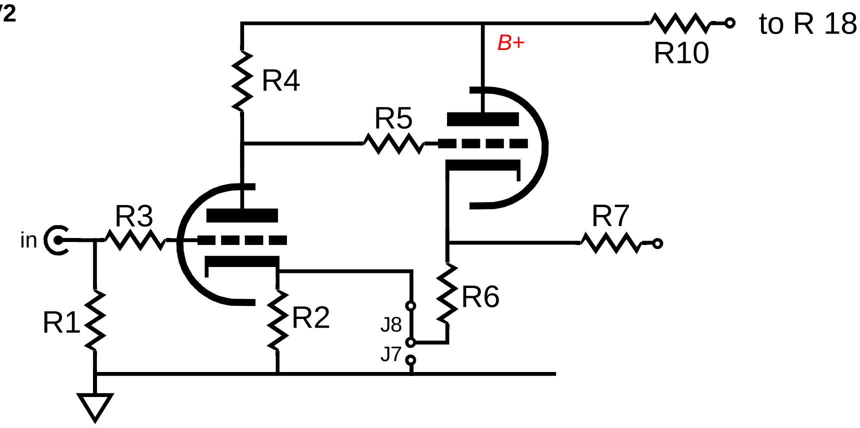
$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

Resistors in series just add together. $R = R_1 + R_2$

1st Stage with Positive Feedback Typical Part Values

() Parentheses denote recommended values

Input Tubes V1 & V2

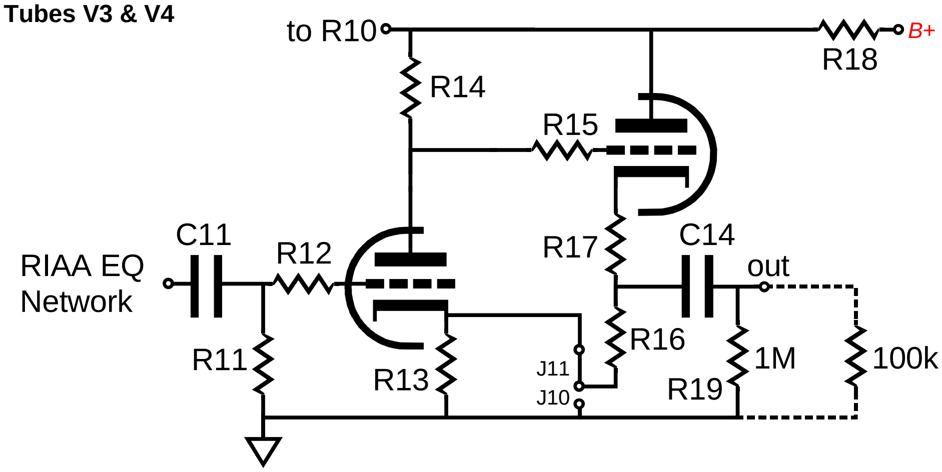


Tube =	12AX7	6N1P	12AT7	12BZ7	6922	5751
Gain =	65	27.6	48	65	25	47
Gain in dB =	36dB	28.8dB	33.6dB	36dB	28dB	33.4dB
Zo =	845	390	254	420	137	1050
Raw B+ Voltage =	250V - 400V (340V)	Same	Same	Same	Same	Same
B+ at Tube =	200V - 300V (250V)	"	"	"	"	"
Heater Voltage =	12.6V	6.3V or 12.6V	12.6V	12.6V	6.3V or 12.6V	12.6V
Heater Current = (2 tubes)	0.3A	1.2A or 0.6A	0.3A	0.6A	0.6A or 0.3A	0.35A
R1 =	100 - 47K (47k)	Same	Same	Same	Same	Same
R2 =	540	390	200	270	240	845
R3 =	100 - 1k (178)	Same	Same	Same	Same	Same
R4, R6 =	150K 1W	47K 1W	47k 1W	75K 1W	20K 2W	150k 1W
R5 =	100 - 1k (300)	Same	Same	Same	Same	Same
R7 =	21.5k	22k	22.1k	22k	22k	21.5k
R10 =	10k 1W to 2W	3.9k 3W	3.9k 3W	6.8k 1W to 2W	3.9k 3W	10k 1W to 2W

2nd Stage with Positive Feedback Typical Part Values

() Parentheses denote recommended values

Output Tubes V3 & V4

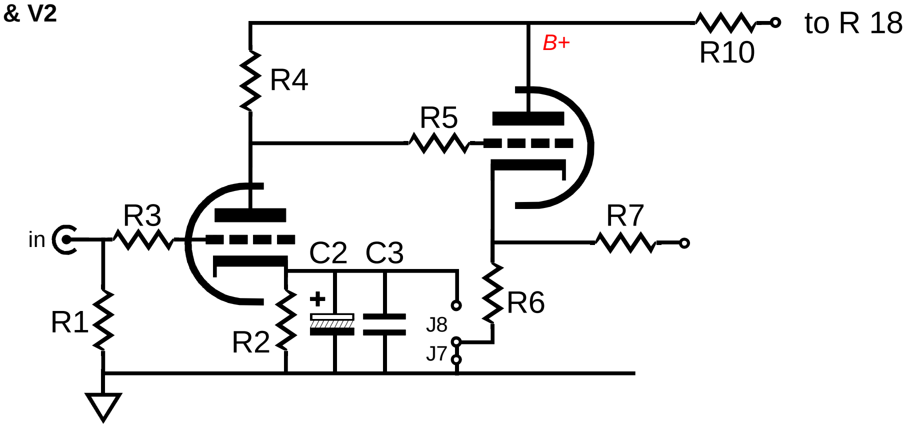


Tube =	12AX7	6N1P	12AT7	12BZ7	6922	12AU7
Gain =	64	27	47.8	64	27	12
Gain in dB =	36.1dB	28.6dB	33.6dB	36.1dB	28.6dB	21.6dB
Zo =	1500	830	700	530	440	680
Raw B+ Voltage =	250V - 400V (340V)	Same	Same	Same	Same	Same
B+ at Tube =	200V - 300V (280V)	"	"	"	(250V)	(280V)
Iq (1 tube total) =	2mA	6mA	6mA	4mA	12.5mA	14mA
Heater Voltage =	12.6V	6.3V or 12.6V	12.6V	12.6V	6.3V or 12.6V	12.6V
Heater Current = (2 tubes)	0.3A	1.2A or 0.6A	0.3A	0.6A	0.6A or 0.3A	0.3A
R11 =	100 - 47K (47k)	Same	Same	Same	Same	Same
R13 =	560	390	200	270	240	240
R12 =	100 - 1k (178)	Same	Same	Same	Same	Same
R14, R16 =	150K 1W	47K 1W	47k 1W	75K 1W	20K 2W	20k 1W
R17 =	100	Same	Same	Same	Same	Same
R15 =	100 - 1k (300)	Same	Same	Same	Same	Same
R18 =	10k 1W to 2W	3.9k 3W	2k	6.8k 1W to 2W	3.9k 3W	3.9k 2W

1st Stage with C2 & C3 Typical Part Values

() Parentheses denote recommended values

Input Tubes V1 & V2

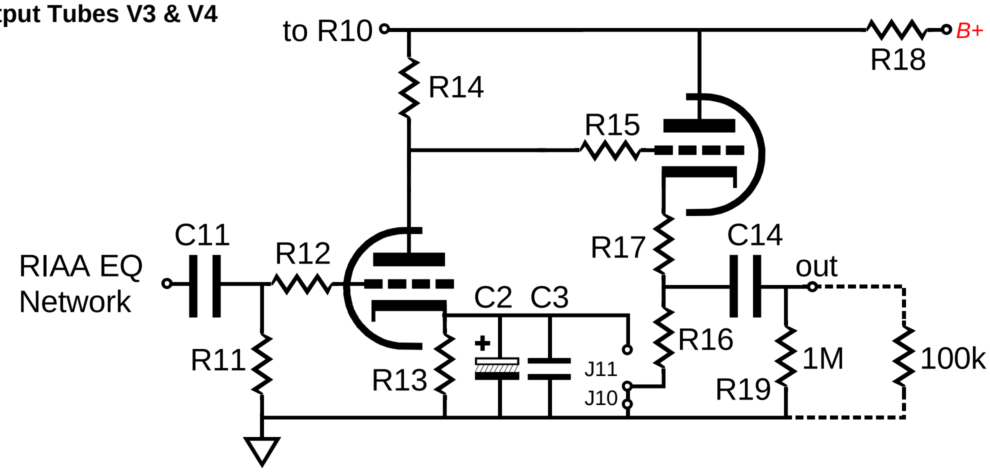


Tube =	12AX7	6N1P	12AT7	12BZ7	6922	5751
Gain =	65	28.7	48	65	25	48
Gain in dB =	36.2dB	29dB	33.6dB	36.2dB	28dB	33.6dB
Zo =	845	320	200	422	106	830
Raw B+ Voltage =	250V - 400V (340V)	Same	Same	Same	Same	Same
B+ at Tube =	200V - 300V (250V)	"	"	"	"	"
Heater Voltage =	12.6V	6.3V or 12.6V	12.6V	12.6V	6.3V or 12.6V	12.6V
Heater Current = (2 tubes)	0.3A	1.2A or 0.6A	0.3A	0.6A	0.6A or 0.3A	0.35A
R1 =	100 - 47K (47k)	Same	Same	Same	Same	Same
R2 =	1.2k	750	430	560	470	1.5k
R3 =	100 - 1k (178)	Same	Same	Same	Same	Same
R4, R6 =	150K 1W	47K 1W	47k 1W	75K 1W	20K 2W	150k 1W
R5 =	100 - 1k (300)	Same	Same	Same	Same	Same
R7 =	22.1k	22k	22.1k	22k	22.1k	21.5k
R10 =	10k 1W to 2W	3.9k 3W	2k	6.8k 1W to 2W	3.9k 3W	10k 1W to 2W

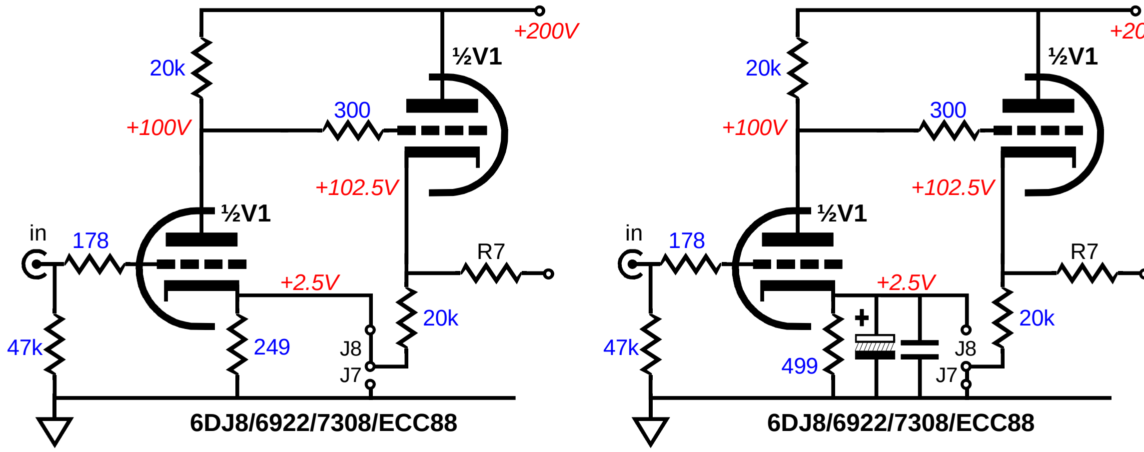
2nd Stage with C12 & C13 Typical Part Values

() Parentheses denote recommended values

Output Tubes V3 & V4



Tube =	12AX7	6N1P	12AT7	12BZ7	6922	12AU7
Gain =	65	27	48	65	25	12.3
Gain in dB =	36.2dB	28.6dB	33.6dB	36.2dB	28dB	21.8dB
Zo =	730	420	310	415	205	450
Raw B+ Voltage =	250V - 400V (340V)	Same	Same	Same	Same	Same
B+ at Tube =	200V - 300V (280V)	"	"	"	(250V)	(280V)
Iq (1 tube total) =	2mA	6mA	6mA	4mA	12.5mA	14mA
Heater Voltage =	12.6V	6.3V or 12.6V	12.6V	12.6V	6.3V or 12.6V	12.6V
Heater Current = (2 tubes)	0.3A	1.2A or 0.6A	0.3A	0.6A	0.6A or 0.3A	0.3A
R11 =	100 - 47K (47k)	Same	Same	Same	Same	Same
R13 =	1100	750	430	590	470	470
R12 =	100 - 1k (178)	Same	Same	Same	Same	Same
R14, R16 =	150K 1W	47K 1W	47k 1W	75K 1W	20K 2W	20k 2W
R15 =	100 - 1k (300)	Same	Same	Same	Same	Same
R17 =	100	Same	Same	Same	Same	Same
R18 =	10k 1W to 2W	3.9k 3W	2k	6.8k 1W to 2W	3.9k 3W	3.9k 2W



Alternate Cathode Resistor Connection The Tetra Sans PS phono PCB accepts two ways of configuring the CCDA topology. The first is to use jumper J7 (and J10 for the second CCDA gain stage) and capacitors C2 & C3; this is the conventional way of bypassing a grounded-cathode amplifier's cathode resistor. The second approach is to use jumper J8 (and J10 for the second CCDA gain stage) and forgo the bypass capacitors; this configuration makes use of a little positive feedback, which requires halving the cathode resistor's nominal value, as twice the current will flow through the resistor. The cathode 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, as I am sure that you will love the results.

RFI Radio interference can be a headache for the vinyl lover. One solution is the use a large shunting capacitor across the input resistor, R1; this remedy, however, seldom works. Instead, try placing a small ferrite beads over the wires leaving both the input RCA jacks and at 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, computers, cordless telephones, and cheap switching power supplies can create RFI noise in high-gain audio circuits; 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, as just getting noise-free telephone reception can be difficult.

Input Step-Up Transformer With only two gain stages, the Tetra Sans PS phono stage has a hard time coming up with sufficient gain for a low-output moving coil cartridge. Even if a third gain stage were added, the tube noise would be severe. Thus, many use step-up transformers with an MC cartridge, as the transformer can provide up to +30dB of gain with little added 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.

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 un-bypassed cathode resistor; 70 with a bypassed cathode resistor or in the positive-feedback configuration), which perfect for a phono preamp; the 6DJ8/6922, 16 (mu 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 same tube need not be used throughout. For example, a 6DJ8/69222 input tube and 12AT7 second-stage tube make a good-sounding match, as sonic fingerprints complement. On the other hand, using the same tube type allows you to choose the quietest tubes for the first stage. Do not ignore the 12BZ7, which is like a 12AX7 with half the rp.

Cartridge Loading Capacitor C1 is an optional cartridge shunting capacitor. Usually, this capacitor may not be needed, as the phono interconnect is already quite capacitance laden. Be sure to look up the cartridge's maker's recommendations on optimal load resistance. In general, 47k for MM cartridges; 30k, Grado variable flux cartridges; and 100 to 1k, MC cartridges.

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-mu triodes require high-value cathode resistors (1-2K) and low-mu triodes require low-valued cathode resistors (100-1k). The formula is an easy one: **Iq = B+/(rp + [mu + 1]Rk + Ra)**
So, for example, a 6DJ8 in an CCDA circuit with a B+ voltage of +200V and 200-ohm cathode and 10k plate resistors will draw 200/(3k + [32 + 1]200 + 10k) amperes of current, or roughly 10mA. If the cathode resistors are unbypassed, they will add noise to the signal, so lower values are preferable. 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, such as the CCDA positive-feedback configuration, 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, the Nichicon audio capacitors, the Elma silk series, or the famous Blackgate electrolytic capacitors.

Heater Voltage Reference 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 ¼ B+ voltage ensures that both top and bottom triodes see the same magnitude of heater-to-cathode voltage.

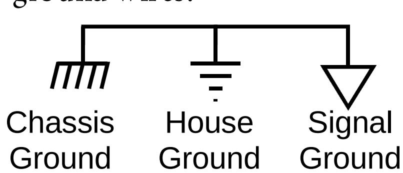
Grounding

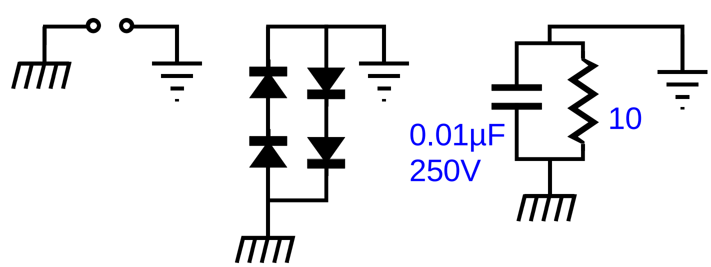
The Tetra Sans PS phono-stage PCB holds a star ground at its center. Ideally, this will be the only central ground in the phono preamplifier. Ground loops, however, are extremely easy to introduce. For example, if the RCA jacks are not isolated from the chassis, then the twisted pair of wires that connect the PCB to the jacks will each define a ground loop. 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.

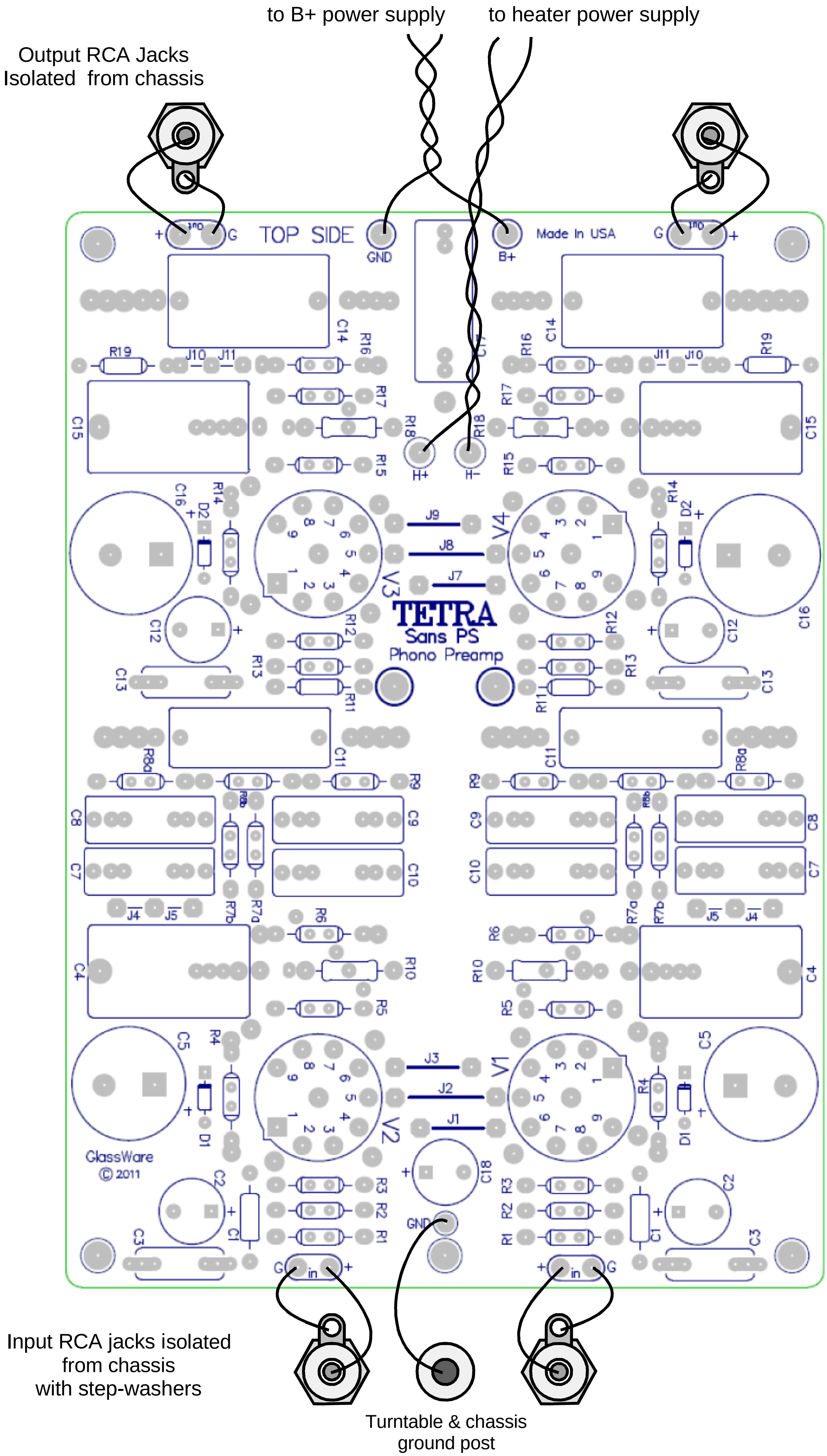
Three different schools of thought hold for grounding a piece of audio gear. The Old-School approach is to treat the chassis as the ground; period. Every ground connection is made at the closest screw and nut. This method is the easiest to follow and it produces the worst sonic results. Steel and aluminum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

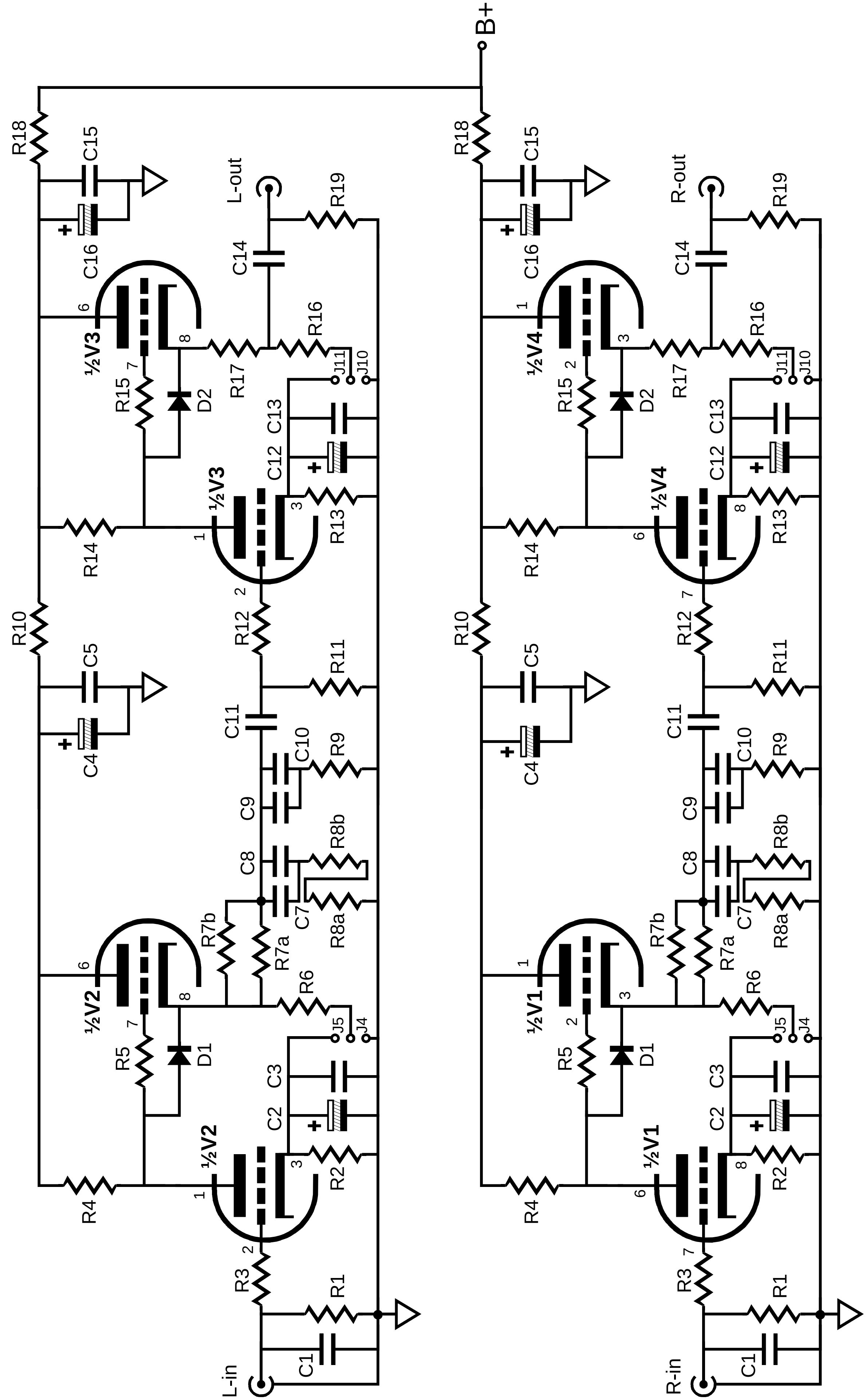
Turntable Ground My advice is to attach turntable's grounding jack to the ground pad at the bottom of the PCB where the input tubes are located. But be sure to experiment with the turntable grounding. For example, some turntables "ground" the cartridge's two ground pins to the arm and, by extension, 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 Tetra Sans PS requires an external power supply. This power supply might attach its ground to the house's ground— or it might not. Ideally, all equipment holding dangerous voltages should have its chassis attached to the house ground, as safeguards us from dangerous failures wherein the B+ shorts with the chassis. Unfortunately, because of the way houses are actually wired up to use the least amount of wire (daisy-chained rather than star wired), the house ground often is contaminated with noise signal. Thus, having all of our audio equipment directly attached to the house ground can add noise. The usual solution is to let the biggest, nastiest power supply (usually the power amplifier) attach its power supply and chassis to the house ground through the power cord's third prong and let all the other audio equipment indirectly attach to the house ground through the audio interconnect's ground wires.






to B+ power supply
to heater power supply
Output RCA Jacks
Isolated from chassis
TOP SIDE
GND
B+
Made In USA
H+
H-
TETRA
Sans PS
Phono Preamp
GlassWare
© 2011
Input RCA jacks isolated
from chassis
with step-washers
Turntable & chassis
ground post


B+
R18
C15
C16
L-out
R19
C14
R16
R17
J11
J10
C13
C12
R13
R14
R15
D2
½V3
R10
C5
C4
R12
R11
C11
C10
R9
C9
C8
R8b
C7
R8a
R7b
R7a
R6
½V2
J5
J4
R5
D1
C3
C2
R2
R4
R3
R1
C1
L-in
R-out
½V4
½V1
R-in

Assembly & Testing

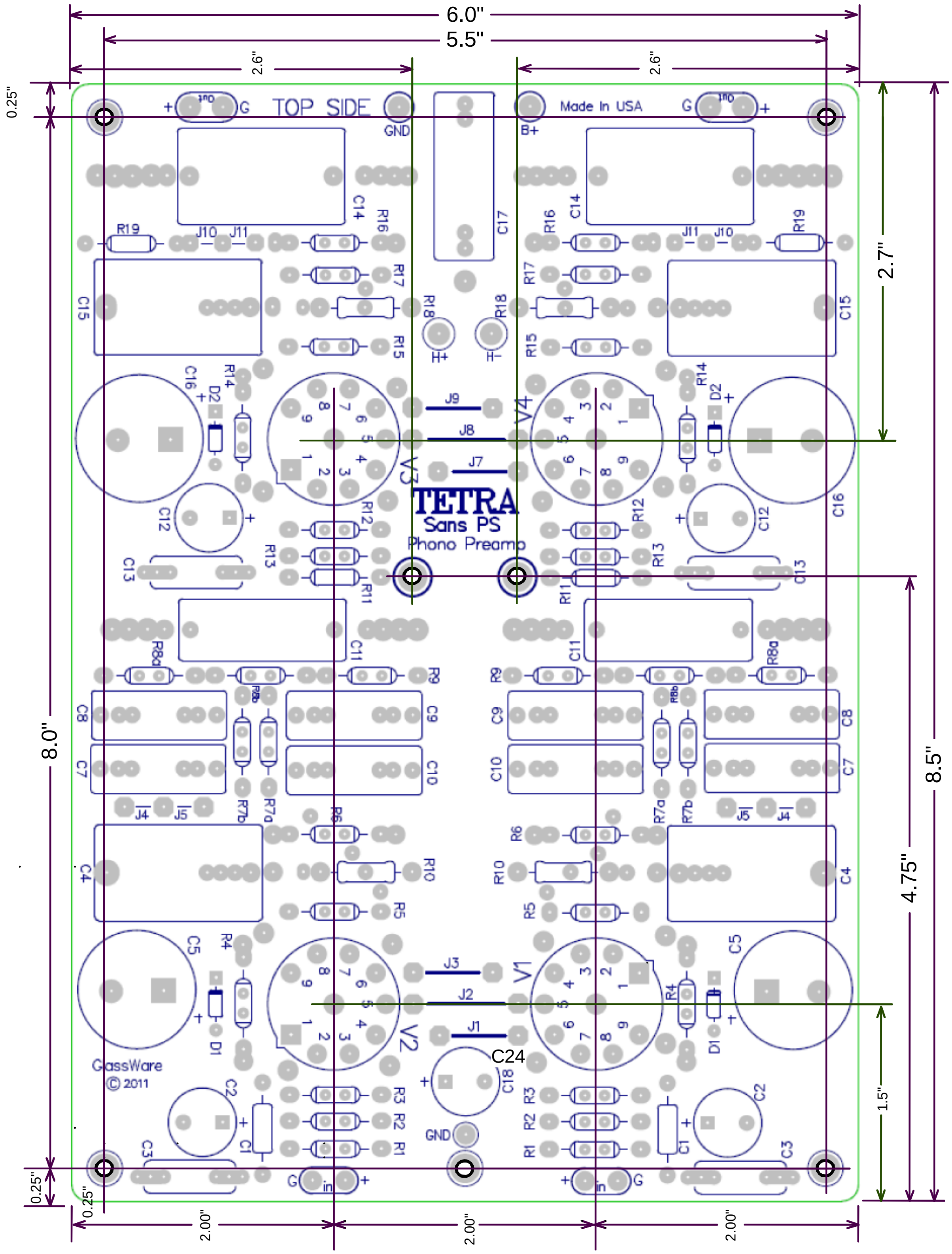
Assembly Cleanliness is essential. Before soldering, be sure to clean both sides the PCB with 90% to 99% isopropyl alcohol. Do not use dull-looking solder; solder should shine. If it doesn't, first clean away the outer oxidation with steel wool or a copper scouring pad. If the resistor leads look in 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 smallest parts in place (the diodes), and then solder the resistors, and capacitors. 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. 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, leaving the high-voltage power supply leads unattached and electrical tape shrouded, with no tubes in their sockets.
2. Use a variac and slowly bring up the heater voltage, while looking for smoke or part discoloration or bulging.
3. Measure the heater power supply's voltage without and with a load. If the heater power supply fails to maintain its output voltage, 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 power supply and attach the high-voltage power supply and insert the tubes in their sockets.
5. Attach the transformer to a variac and slowly bring up the B+ 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 Tetra Sans PS phono-stage preamplifier to the rest of your system.



Top Side PCB Mechanical Layout

OVERALL PC BOARD DIMENSIONS: 6.0" x 10.0"