

*Mods
Modules
&
Miscellaneous*

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Introduction

The remaining section of this catalog is a melting pot of designs and ideas. It includes few Dynaco modifications as well as some modules and kits for preamplifiers, amplifiers, power supplies, etc. Many of the modules are available as customized kits, complete with chassis, and we have used these in our complete kits in the past or will be using them as such in the future.

Throughout this catalog and design manual you will find pockets of information on selecting components, performing upgrades and modifications, or designing circuits from scratch. I think you will be able to pick up bits of useful knowledge from these discussions as well as through a general review of the Welborne Labs designs included herein.

For many of you, this is your first venture into the world of do it yourself audio. So my recommendation is to take a few minutes..days...weeks and think about what you want to achieve before getting started. Decide what kind of a system you want what your preferences are, i.e. tube sound vs. transistor, planer vs. box speaker, analog vs. digital source. Make a budget for your preamp project or system, and stick to it! It makes no sense to spend all your hard earned money or max-out your credit cards on a preamp and not leave any for the rest of your system, if your intent is to build a complete system. You can agonize over your system for ever ... because of the tradeoffs, cost, etc. Therefore up front planning is very important!

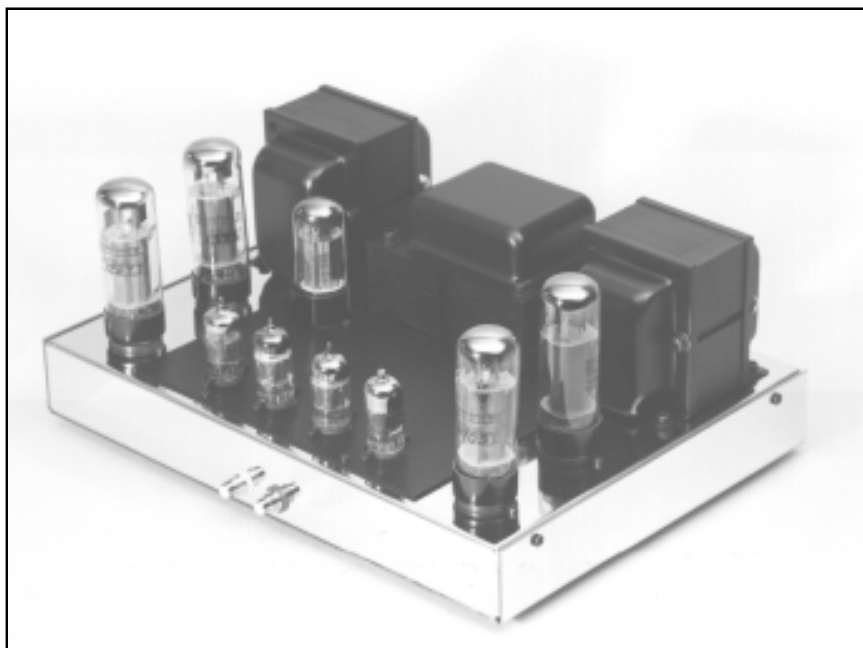
The vast majority of you will have purchased this catalog because you are interested in modifying or upgrading an existing piece of equipment. Why do mods and parts upgrades to equipment? Obviously the reason for mods is sonic improvement. We are taking a good design with old parts or a mediocre design with some good characteristics or components worth salvaging. Therefore mods are performed to bring the sound up to state of the art and turn that old sow's ear into a silk purse! Or in other words, to gain improvements in frequency response, dynamics, resolution, imaging and so on. In addition to sonic improvements, upgrading equipment will improve the reliability (if done right) and help to preserve the unit.

A word of caution concerning preservation vs. radical modifications. Many pieces lend themselves well to radical modifications, however there are several brands of equipment that are valuable and any parts upgrades or modifications should be carried out with caution. Some of these include the Marantz, McIntosh, Futterman, Western Electric, Brooks and others. For one reason or another many of these units command a nice price in original condition and you should consider this before breaking out the chain saw. A unit of this type will always be worth more in original or near mint condition. In my opinion, if you are planning on keeping the piece for many years and it is the focal point of your stereo, go ahead and perform a parts upgrade. Refrain from radical changes that cannot be undone at some future point in time. Don't put a 427 hemi in a '57 Silver Ghost, because no one will want it but you!

Use constraint!!!!!! There is a thing called the "Law of Diminishing Returns". This law holds true for audio equipment. I believe most will agree that a \$15,000 amplifier doesn't sound 5 times better than a \$3,000 amplifier. The same holds true for parts! A \$15.00 Vishay resistor doesn't sound 37.5 times better than a 40 cent Holco resistor. In fact you might be hard pressed to say that in either of the two examples above, that the improvement was even twofold! So we say "use constraint", it doesn't make any sense to put four or five hundred dollars worth of Vishay resistors into your preamp when \$10 worth of Holcos or Roedersteins would work just fine. Because in our opinion, that \$500 would be better spent on something more critical like a good source, or an upgrade to better speakers. A three or four times improvement could more likely be realized with a new set of speakers! Boy is this honesty or what a parts dealer telling you to use constraint!

The same goes with design. Our experience has been that you can overdue it in the design department. Our philosophy is "Simpler is most always Better". For example, many people have advocated a separate voltage regulator for every stage of a tube preamp. Our experience has been that in many cases this actually harms the sound. And in those instances where it didn't corrupt the sound, the improvement, if any, did not warrant the extra hundreds of dollars spent for all that voltage regulation.

One caveat to the above suggestions this is a hobby and as with all hobbies they are a vehicle for people to throw perfectly good money after bad. So if you have deep pockets and you derive great pleasure from putting \$500 worth of Vishay resistors in an old Dynaco preamp, then by all means go for it! We wouldn't want to deny you any pleasure you might derive from spending your money. The suggestion for constraint is intended for those individuals that have a limited amount of funds and are seeking a little guidance on how to get the most bang for the buck.



Another ST-70 Driver Mod?

NO! Not just another ST-70 driver mod. This circuit, designed for us by Alan Kimmel, uses a triode first stage operated in the ideal constant-current mode. This and other features enable this ST-70 to deliver "REAL MUSIC". In fact, in all my years of modification experience, this is the best ST-70 mod I have ever heard! It beats all others hands-down and now this circuit is available to you at a great price.

Why modify the ST-70? The Dynaco ST-70 is probably the most popular tube amp ever built. However, by today's standards its sonic performance is somewhat mediocre. Its bass response is loose and the top-end lacks the detail required to make it a real contender. These deficiencies can be attributed to its less than adequate power supply filter capacitance and its simple but ineffective driver circuit.

There are a lot of ST-70 driver board mods out there but most have taken a classical approach to solving this amplifier's deficiencies. Alan Kimmel's ST-70 modification incorporates an advanced constant-current technique using a 6U8A tube to operate the 5751 triode voltage gain stage in the most linear manner possible. In addition, the output of the 5751 is optimally coupled to the rest of the circuit and this coupling is such that the 5751 sees virtually no capacitance and no loading at all. The amount of negative feedback is modest, and is taken from the 8 ohm output tap which is more effective than taking it from the 16 ohm tap, as most do. This circuitry results in a superior level of detail in both the midrange and top-end. Next, the output tubes' bias supply is regulated resulting in a constant bias point with minimum drift. And finally, over 500uF of capacitance is added to the main power supply circuit resulting in a much tighter bass response and lower distortion throughout the frequency spectrum. High quality parts are used throughout the design which is conveniently mounted on two circuit boards that fit snugly inside the existing chassis.

The result is that this is not just another modification, but a true innovation that brings you closer to the music than you ever thought the ST-70 (and most other amps) could.

ST-70 Design Features

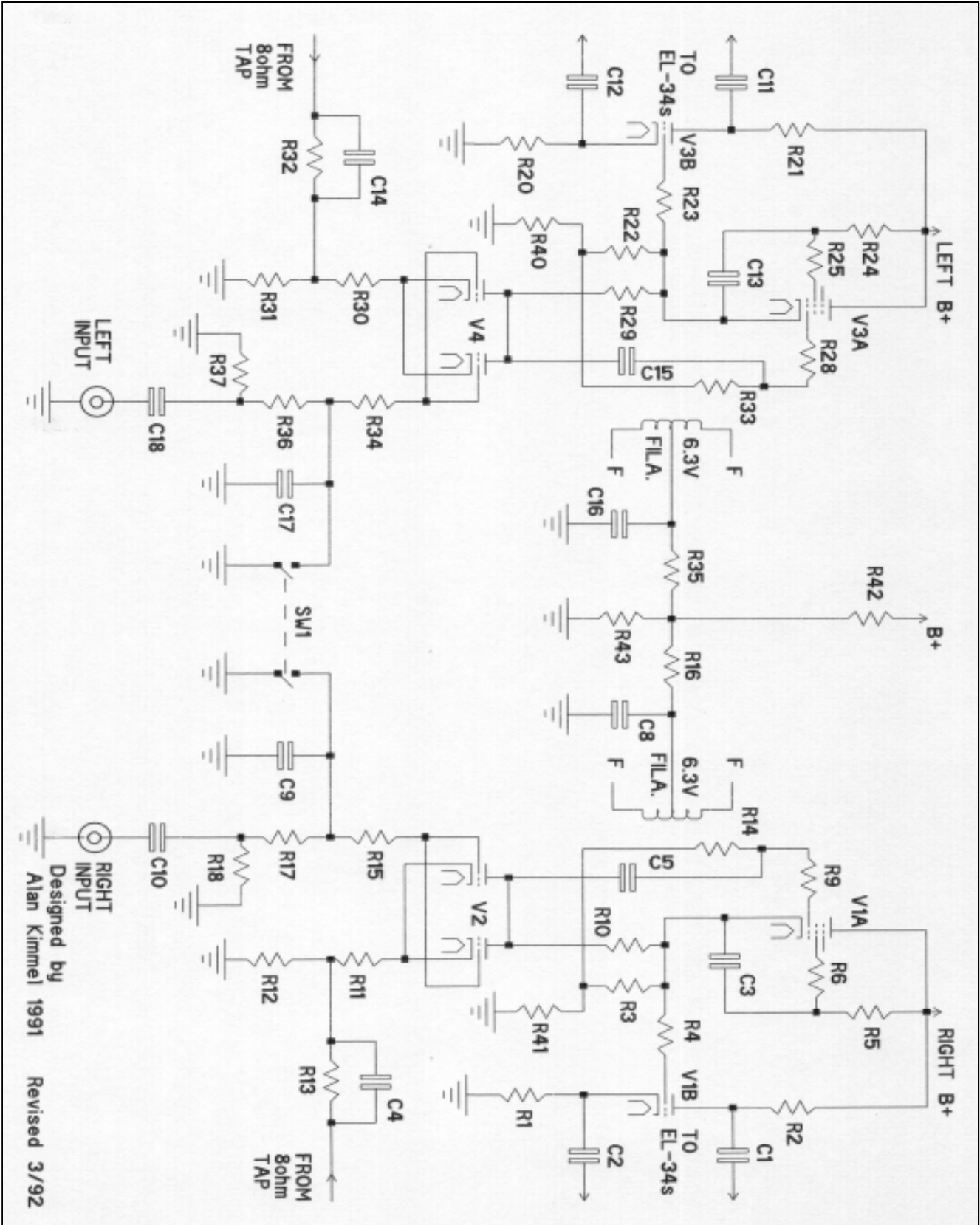
The ST-70 driver mod features: a "main" printed circuit board consisting of the 5751/6U8A peripheral driver circuitry and the additional power supply filter capacitance (>500uF); a second bias-supply printed circuit board which includes the bias rectifier, filter caps, a zener diode regulator circuit and the bias adjustment potentiometers; and finally, a new aluminum mounting plate, with black anodized finish, is supplied which attaches to the top of the ST-70 chassis to support the rectifier and driver circuit tube sockets (with this design, there are no exposed components or circuit traces on top of the chassis). The existing output circuitry is retained.

The existing power supply filter capacitor is removed and no longer used. In place of the original capacitor are five 100uF filter caps plus high quality polypropylene film bypass capacitors. The original filter inductor is retained in our design. These inductors are notorious for failing, leaking and in general making a mess of the interior chassis space, however they can be replaced with resistors if necessary.

A high-pass and low-pass filter network is designed into the front-end of the driver circuit. These filters provide stability and offer much more reliable operation over the life of the amplifier. The high-pass circuit provides a low frequency roll-off at approximately 10Hz.

The original "Mono/Stereo" slide switch is converted to a mute function which allows you to connect and disconnect interconnect cables without turning off the amplifier.

A significant amount of point-to-point wiring still remains within the ST-70 chassis and therefore it is recommended this kit only be attempted by individuals possessing a thorough understanding of tube circuits and having a moderate level of kit building experience.



Dynaco ST-70 Mod Schematic

ST-70 Kit Options

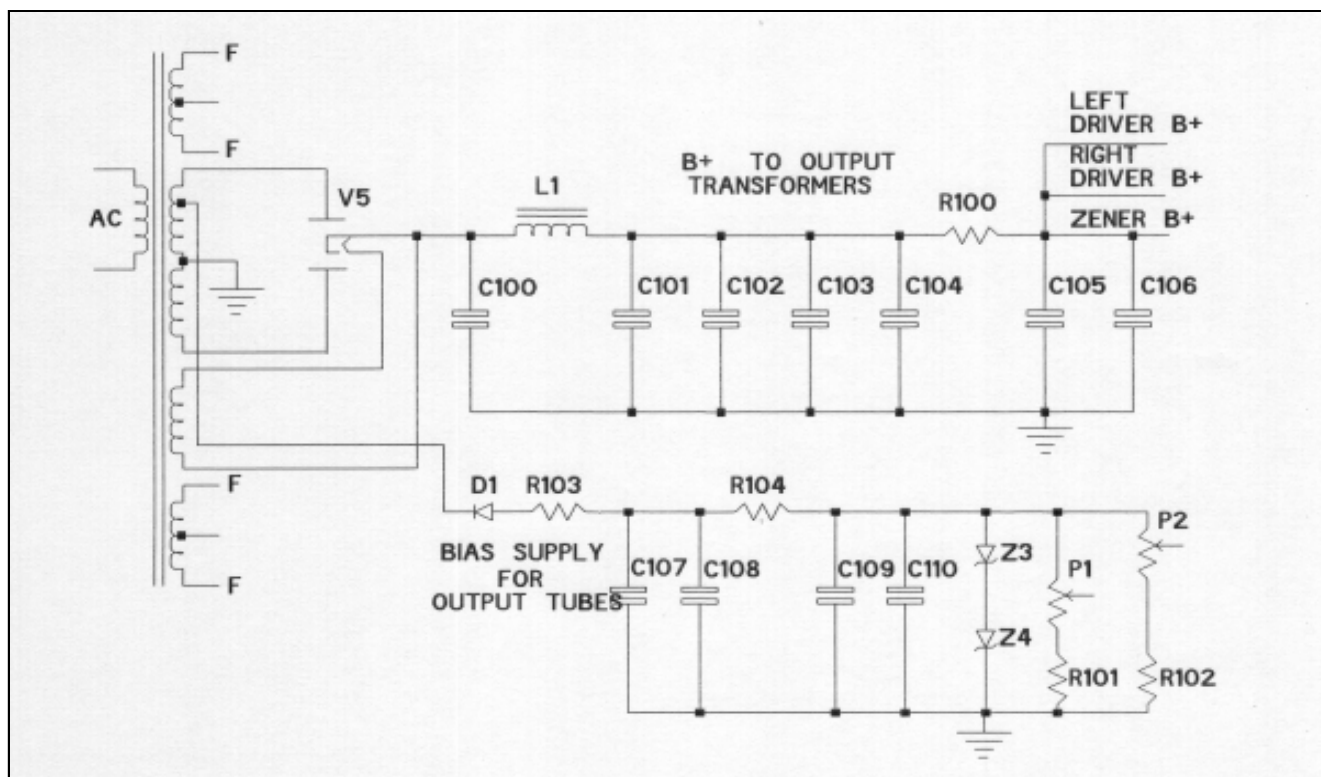
We offer this ST-70 design with several options from which to choose so that you may tailor the design to fulfill your exact needs. It is important to note that the main circuit board will not fit inside the chassis without relocating the existing driver tube sockets (our mounting plate does this). You can purchase just the main circuit board kit and leave the original bias circuitry stock and the printed circuit boards and mounting plate are also sold separately. We offer two upgrade options for vacuum tubes featuring NOS tubes and Tesla or Svetlana EL34s. And finally, the ST-70 kits are available with a Caddock resistor and MultiCap capacitor upgrade option.

Options and Pricing

Catalog Number	Description	Price
ST-70A	Complete Kit Less Tubes (Includes both circuit boards, parts, mounting plate, tube sockets and miscellaneous hardware; see parts list)	\$235.00
ST-70B	Main Driver Board Kit and Mounting Plate (Same as ST-70A, except you must use existing bias circuitry)	\$205.00
ST-70C	Blank Main Driver Printed Circuit Board	\$ 32.00
ST-70D	Blank Bias Supply Printed Circuit Board	\$ 15.00
ST-70E	Custom Mounting Plate (Less tube sockets)	\$ 30.00
ST-70G	NOS/Svetlana Upgrade Set (Includes two Philips 5751's, two Siemens 6U8A's, one Chinese 5AR4, two Matched Pairs of Svetlana EL-34 Output Tubes)	\$110.00
ST-70H	Caddock/MultiCap Upgrade	\$ 91.00

Assembly Manual available for \$15.00.

All ST-70 Catalog Numbers qualify for our discount program.



ST-70 Mod Power Supply Circuit

ST-70 Driver Board Parts List

R1,R2,R20,R21	47 Kohm	2 watt metal oxide resistor
R3,R22	2.21 Kohm	1/2 watt 1% metal film resistor
R4,R6,R9,R15, R23,R25,R28,R34	150 ohm	1/2 watt 1% metal film resistor (Caddock)
R5,R24	300 Kohm	1/2 watt 1% metal film resistor
R7,R8,R26,R27	270 Kohm	1/2 watt 1% metal film resistor (located off circuit board)
R10,R29	15 Kohm	1/2 watt 1% metal film resistor (Caddock)
R13,R32	5.6 Kohm	1/2 watt 1% metal film resistor
R14,R33	2.2 Mohm	1/2 watt 1% metal film resistor
R16,R35	330 Kohm	1/2 watt 1% metal film resistor
R17,R36	10 Kohm	1/2 watt 1% metal film resistor (Caddock)
R18,R37	150 Kohm	1/2 watt 1% metal film resistor
R100	750 ohm	2 watt metal oxide resistor
R11,R30	510 ohm	1/2 watt 1% metal film resistor
R12,R31	100 ohm	1/2 watt 1% metal film resistor
R40,R41	150 Kohm	2 watt metal oxide resistor
R42	360 Kohm	1/2 watt 1% metal film resistor
R43	120 Kohm	1/2 watt 1% metal film resistor

All resistors are 1/2 watt 1% Roederstein metal film unless substituted with (Caddocks)

C1,C2,C11,C12	.47uf/425V	Kimber Kap Polypropylene capacitor (MultiCap)
C3,C13	.47uf/630V	WIMA Polypropylene capacitor
C4,C14	100pf/630V	Siemens Polypropylene capacitor
C5,C15	0.1uf/250V	WIMA Polypropylene capacitor
C8,C16	0.1uf/250V	WIMA Polypropylene capacitor
C9,C17	68pf/630V	Siemens Polypropylene capacitor
C10,C18	0.1uf/630V	Kimber Kap Polypropylene capacitor (MultiCap)
C100	47uf/450V	Panasonic Electrolytic capacitor
C101,C102,C103,C105,C106	100uf/450V	Panasonic Electrolytic capacitor
C104	0.1uf/630V	WIMA Polypropylene capacitor
V1,V3	6U8A	Triode/Pentode tube
V2,V4	5751(12AX7)	Twin Triode tube
PCB1		Driver Board printed circuit board

ST-70 Bias Board Parts List

R101,R102	10 Kohm	1/2 watt 1% metal film resistor
R103	200 ohm	2 watt metal oxide resistor
R104	330 ohm	2 watt metal oxide resistor
C107,C108,C109	100uf/63V	Panasonic Electrolytic capacitor
C110	0.1uf/250V	WIMA Polypropylene capacitor
P1,P2	10 Kohm	Cermet trimpot
Z3,Z4	1N5357B	20 volt 5 watt zener diode
D1	1N5408	1000Volt 3Amp diode
PCB2		Bias Circuit printed circuit board

ST-70 Miscellaneous Parts

PL1	5" x 7" Aluminum mounting plate
TS1,TS2,TS3,TS4	9 Pin chassis-mount tube sockets
TS5	8 Pin chassis-mount tube socket
Miscellaneous	Hardware (screws, nuts, standoffs, solder terminals, etc.)
	Kimber OFC and Teflon-coated Hookup wire

() Indicates parts upgrade

Dynaco MKIII Modification

The Dynaco MKIII was a carefully crafted amplifier designed to match circuits of that era with a new line of "Super Fidelity Output Transformers" designed by David Hafler. The MKIII is therefore a very good candidate for modifications. Whether you are just performing a parts upgrade or are trying a complete mod package like ours described below, your efforts should result in an excellent sounding pair of monoblock amplifiers.

To call our MKIII Mod a "Mod" is a misnomer at best! The Welborne Labs MKIII Mod, designed by Alan Kimmel, is a complete overhaul of the Dynaco MKIII amplifier. The only original hardware that remains untouched, are the transformers and the chassis—everything else goes. In its place is a completely new driver circuit, a compliment of new output tubes and a mosfet-driven voltage regulator. The driver circuit is a slightly modified version of our ST-70 Mu-Stage design and is positioned where the original driver board was mounted on the MKIII chassis. The chosen output tubes are the 6550's. The 6550's provide one of two possible compliments to the Mu-Stage, the other being a push-pull parallel set of EL-34s. There's not enough room on a MKIII chassis for four EL-34s and therefore that option is out. Our MKIII Mod has focused considerable attention on the output stage—by selecting output tubes that operate well with both the driver circuit and the output transformers a unique design is the result with performance that far exceeds that of the original Dynaco MKIII amplifier.

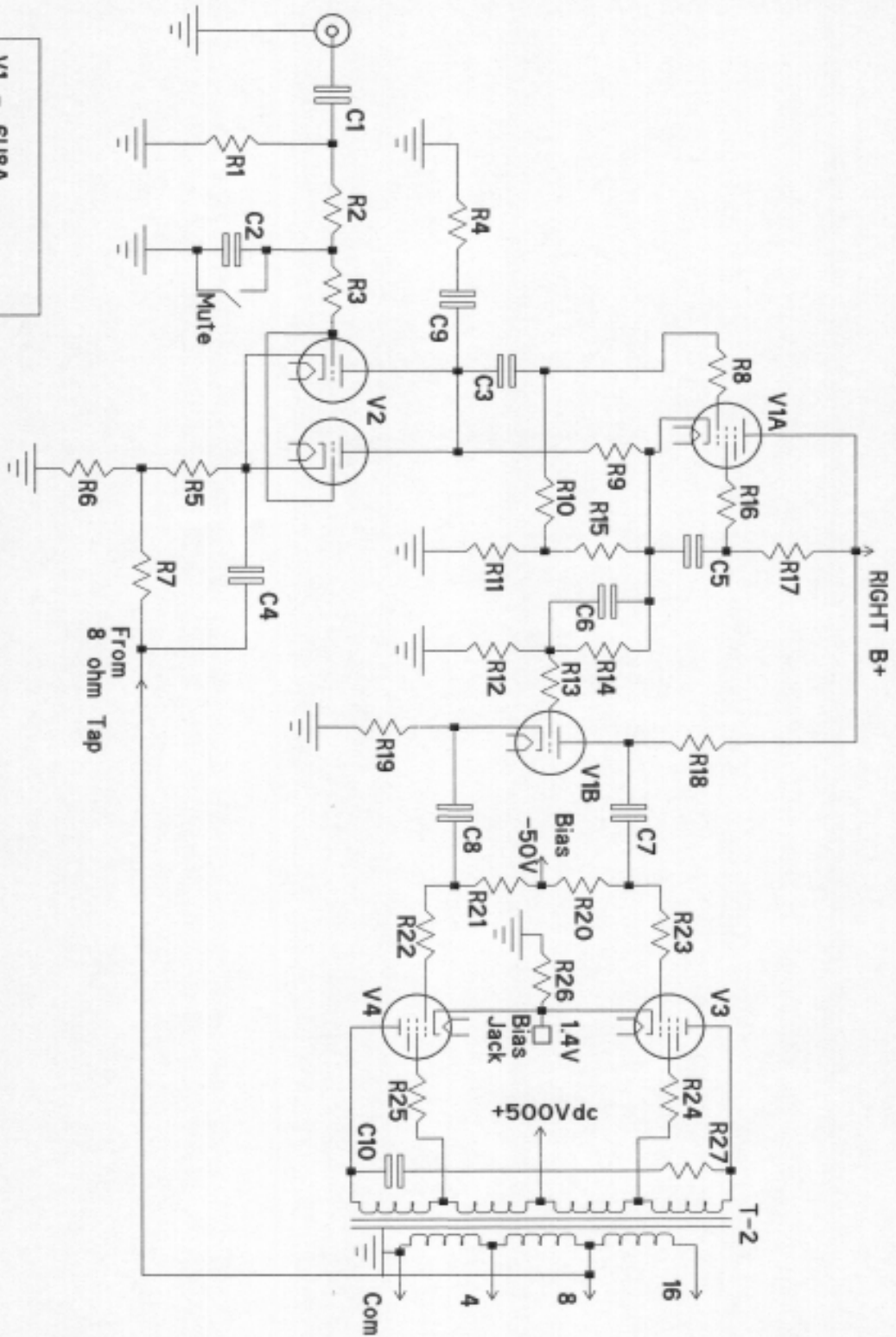
The size of the MKIII chassis does not provide adequate room for the amount of power supply capacitance needed to allow this amp to easily drive a complex load, therefore we have converted the supply to solid-state rectification and designed a voltage regulation stage for the B+. A mosfet is used as the pass element resulting in a very stiff supply. A softstart feature is built into the regulation stage to reduce turn-on surges as a result of adding the diode rectification. The diode rectifier is a bridge circuit that plugs into the existing MKIII tube rectifier socket without any other modifications required. The existing 'can' filter capacitor may be used, if it is still in good condition, or it can be disconnected from the circuit and not used.

Since this is a complete overhaul of the MKIII, our kit supplies all new tube sockets, wiring, terminal strips, resistors capacitors, etc. As was said above, the only items that remain unchanged are the chassis, transformer, filter capacitor, and the input and output jacks. Of course these items are also subject to possible improvements, but we have left them for your scrutiny. The MKIII Mod is a complete package featuring MultiCap and WIMA polypropylene capacitors, Caddock film and Roederstein metal film resistors, and the Svetlana 6550 vacuum tubes. The MKIII Mod includes all components individually packaged and marked along with complete assembly instructions. Please note: the MKIII mod is not recommended for novices or first time kit builders.

CAT NUMBER	DESCRIPTION	PRICE
MKIII-1A	Complete MKIII Stereo Kit with NOS and Svetlana 6550 (per pair)	\$549.00
MKIII-1B	Complete MKIII Stereo Kit Less Tubes (per pair)	\$449.00
MKIII-1C	Driver Circuit—Printed Circuit Board (each)	\$ 20.00
MKIII-1D	Voltage Regulator Circuit—Printed Circuit Board (each)	\$ 15.00
PS-3	Complete Voltage Regulator Circuit (each)	\$ 70.00

Assembly Manual available for \$15.00.

All of the above MKIII Mod Kits are Eligible for Our Discount Programs



V1 - 6U8A
V2 - 5751 or 12AX7
V3, V4 - 6550

One Channel Shown

Designed by
Alan Kimmel 1992

Dynaco MKIII Mod Schematic Diagram

Dynaco MKIII Mod Parts List (for one channel only)

Resistors

R1	150kohm	Roederstein 1/2W 1% metal film
R2	10kohm	Caddock 3/4W 1% film
R3,R8,R13,R16	150ohm	Caddock 3/4W 1% film
R4	221kohm	Roederstein 1/2W 1% metal film
R5	560ohm	Roederstein 1/2W 1% metal film
R6	100ohm	Roederstein 1/2W 1% metal film
R7	3.6kohm	Roederstein 1/2W 1% metal film
R9	15kohm	Caddock 3/4W 1% film
R10,R14	2.2Mohm	Roederstein 1/2W 1% metal film
R11	150kohm	2W metal oxide
R12	3.0Mohm	Roederstein 1/2W 1% metal film
R15,R22,R23	1.0kohm	Caddock 3/4W 1% film
R17	330kohm	Roederstein 1/2W 1% metal film
R18,R19	47kohm	2W metal oxide
R20,R21	150kohm	Roederstein 1/2W 1% metal film
R24,R25	270ohms	2W metal oxide
R26	11.0ohms	2W metal oxide

Capacitors

C1	0.1uf/600V	MultiCap polypropylene capacitor
C2	68pf/630V	Siemens polypropylene capacitor
C3	0.1uf/630V	WIMA polypropylene capacitor
C4	47pf/630V	Siemens polypropylene capacitor
C5	0.47uf/630V	WIMA polypropylene capacitor
C6	0.1uf/600V	MultiCap polypropylene capacitor
C7,C8	0.47uf/600V	MultiCap polypropylene capacitor
C9	47pf/630V	Siemens polypropylene capacitor

Vacuum Tubes

V1	6U8A	Driver tube
V2	5751	Driver tube
V3,V4	6550	Svetlana output tubes (matched pair)

Miscellaneous

PWB	Printed circuit board
TS1,TS2	Driver tube sockets
TS3,TS4	Octal tube sockets
Hookup Wire	Kimber Kable hookup wire
Hardware	Terminal strips, bias jack, mute switch

Power and Bias Supply Parts List (for one channel)

D11,D12,D13,D14		Solid state rectifier (Plug-in replacement for 5AR4)
D10,D11	1N4007	1000V 1A diode
C107,C111	80uf/250V	Panasonic electrolytic capacitor
C108,C109	100uf/100V	Panasonic electrolytic capacitor
C110	.1uf/400V	MIT MultiCap polypropylene capacitor
R109	10kohm	Roederstein 1/2W 1% metal film
R110	20kohm	2W metal oxide
P1	10kohm	Potentiometer
Z6	1N4761A	75V 1W zener diode
Miscellaneous		Terminal strips, hookup wire, octal socket

The Welborne Labs MKIII Mod designs, schematics and printed circuit board layouts are the property of Welborne Labs and Alan Kimmel. They have been included in this catalog for your personal use.

Dynaco MKIII Mod Parts List cont'd

B+ Regulator Board Parts List (for one channel only)

Resistors

R100,R101, R107,R108	220kohm	2W metal oxide
R103	6.0kohm	2W metal oxide
R104	10Mohm	Roederstein 1/2W 1% metal film
R105	332ohm	Roederstein 1/2W 1% metal film

Capacitors

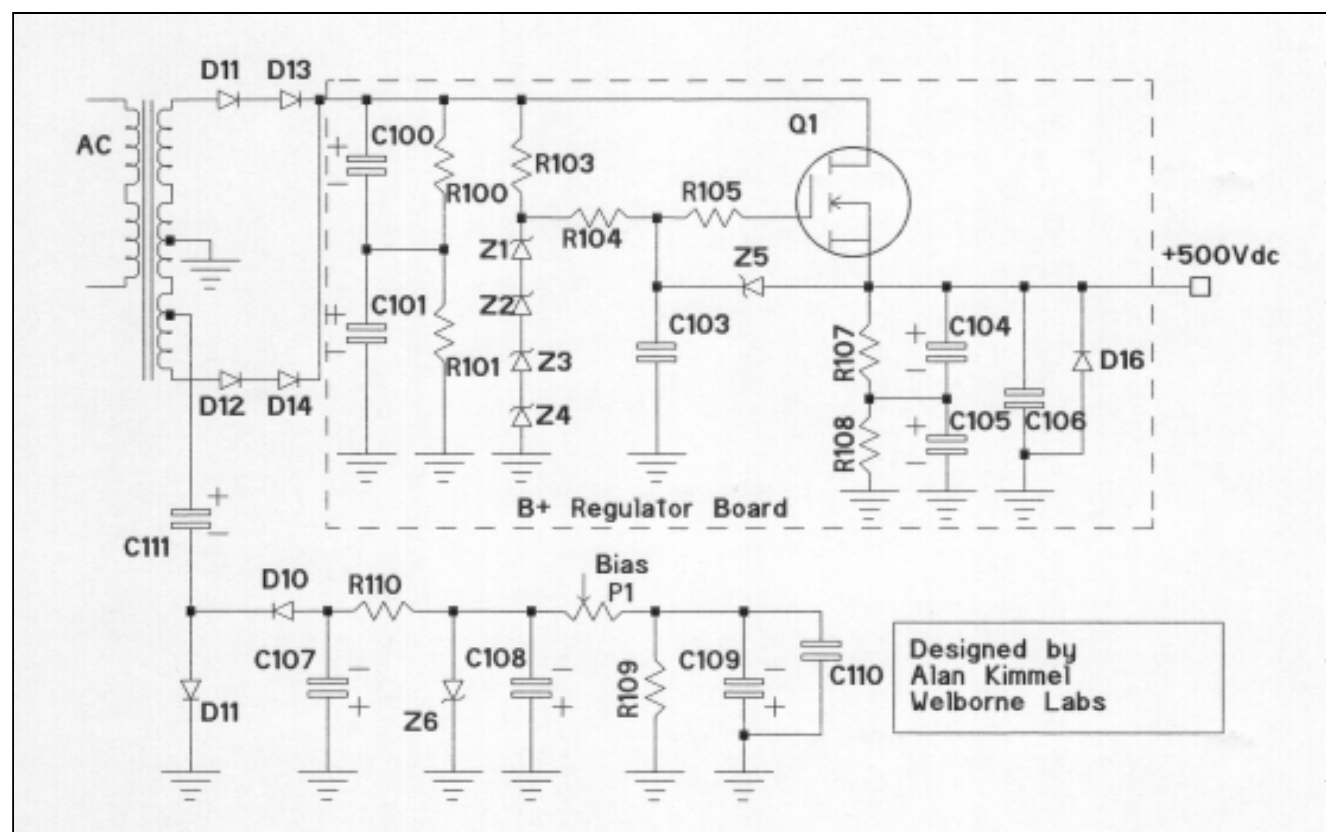
C100,C101	100uf/450V	Panasonic electrolytic capacitor
C103	1.0uf/630V	Solen polypropylene capacitor
C104,C105	68uf/450V	Panasonic electrolytic capacitor
C106	10.0uf/600V	Solen polypropylene capacitor
C107	0.1uf/600V	Solen polypropylene capacitor

Semiconductors

Q1	2SK1511	MOSFET 1000V 5A
Z1,Z2	1N5378B	100V 5W zener diode
Z3, Z4	1N5383B	150V 5W zener diode
Z5	1N4742A	12V 1W zener diode
D16	1N4007	1000V 1A diode

Miscellaneous

PCB	Printed Circuit Board, Heatsink
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Dynaco MKIII Mod B+ Regulator and Bias Circuit

Mini Tube Compendium

Back by popular demand, our Tube Compendium contains tube amplifier schematics derived from some of the old Acrosound designs. We have changed them slightly to make a few minor improvements short of completely overhauling the designs. If you are looking to build an amplifier from scratch, you would not do wrong by starting with one of these designs. Acrosound produced some of the best amplifiers available back in the early 50's and their designs featured the use of some very good transformers and materials. Some of the designs still feature a fixed bias arrangement on the output tubes and could benefit from an adjustable bias circuitry. Increasing the power supply capacitance and bypassing with film capacitors will improve the bass response and lower the distortion (both IM and TIM). Increasing the size of the coupling capacitors will generally improve the bass response. Converting the higher power amps to triode operation will also result in an overall improvement in sound. We have included these circuits to give you some ideas or a starting point. Also included are some available output transformers that should work with the circuits.

10 Watt Triode Amp (page A13)

The 2A3 type of triode has been a favorite of high fidelity constructors for many years especially in Europe and Japan. They are just now beginning to catch on here in the states. Many amplifiers using this tube or its modern equivalent, the 6B4, are still in existence and can be improved substantially with a complete parts replacement and some new iron. This circuit provides 10 watts of super high quality sound with a wide bandwidth and lower distortion than had been available in older type circuits. If you have never heard a true "all-triode" amplifier, you've missed out.

24 Watt Williamson Type Circuit (page A14)

This Ultra-Linear Williamson arrangement provides about 24 watts of low distortion amplification and good transient performance. Many thousands of these amplifiers have been constructed by experimenters, kit assemblers and manufacturers. It is hard to beat this circuit's performance in its power bracket. A good design for bi-amped systems.

50 Watt Push Pull Parallel Ultra-Linear Amplifier (page A15)

This push pull parallel circuit is the "big-brother" of the previous Williamson circuit. It does better than twice the output power for a given distortion and makes an amplifier with less than 1% intermodulation distortion at 60 watts of output, and 40 watts is available at .25% IM. With a new transformer, this amp can produce a frequency response well beyond 40khz.

High Power Ultra-Linear Williamson Amplifiers (pages A16 and A17)

The amplifier on page A18 is very similar to the previous one but has been converted for use with 6550's, EL-34's or KT-88's. Depending on the output tube selected, up to 60 watts or more of clean power can be achieved. On page A19 is a more modern version of a KT-88 amplifier although it still has the fixed bias on the output tubes.

Western Electric 300B Amplifier (A18)

This 300B amplifier schematic is reprinted from the first issue of the Sound Practices audio journal. It is a Western Electric design of an amplifier that was used in movie theaters many years ago.

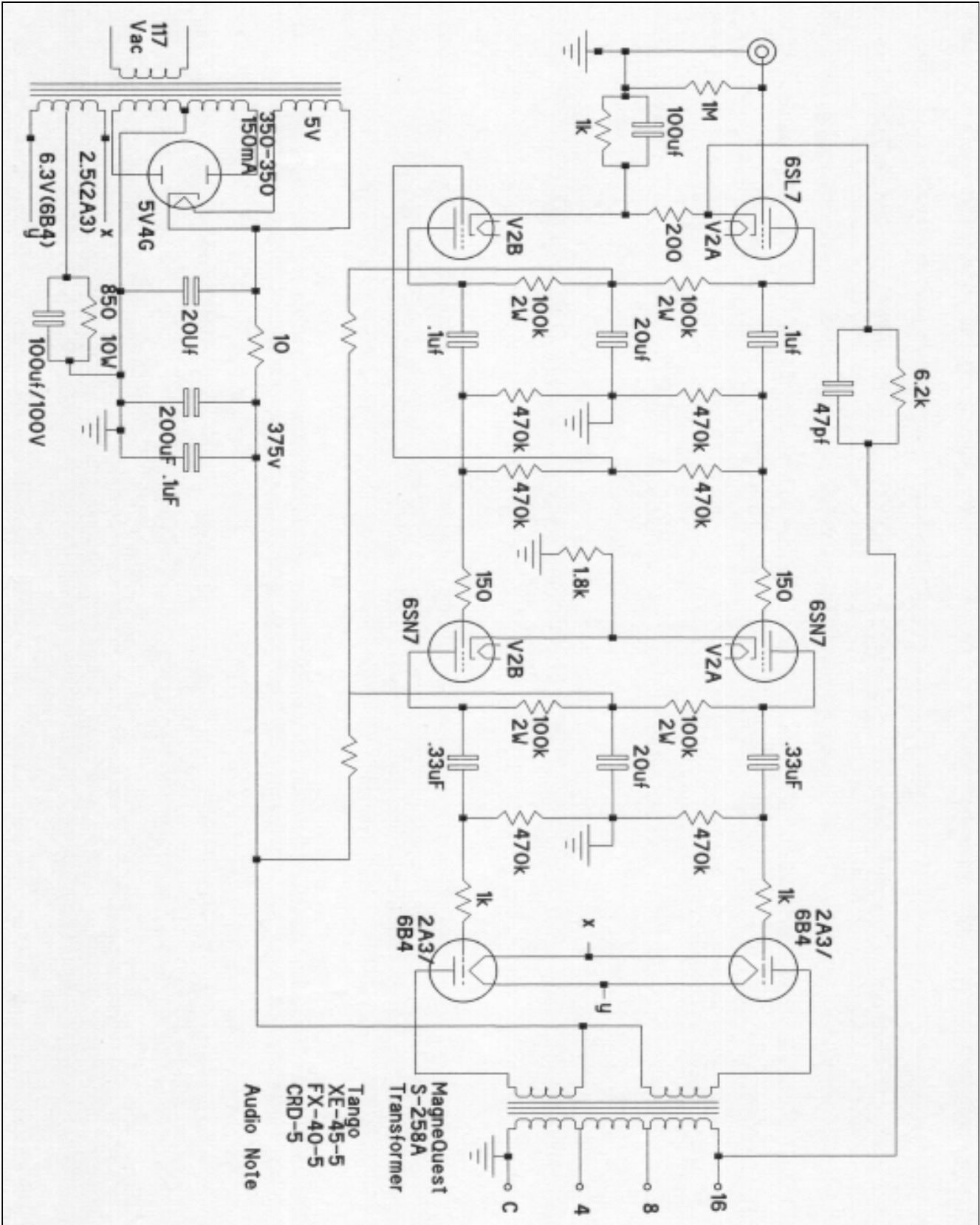
Possible Improvements (page A19 and A20)

On page A19 are a few circuits that can produce improvements in both sound and functionality. Included are two schematics with adjustable bias circuitry schemes for output tubes. Adjustable bias is highly recommended for any amplifier with pentode operation. One general purpose circuit is included for converting pentode output tubes to triode operation. Output power is reduced in the triode mode (generally about 50%), but the sonics can be improved and this scheme works well with high efficiency speakers or if using the amp in a bi or tri-amp configuration.

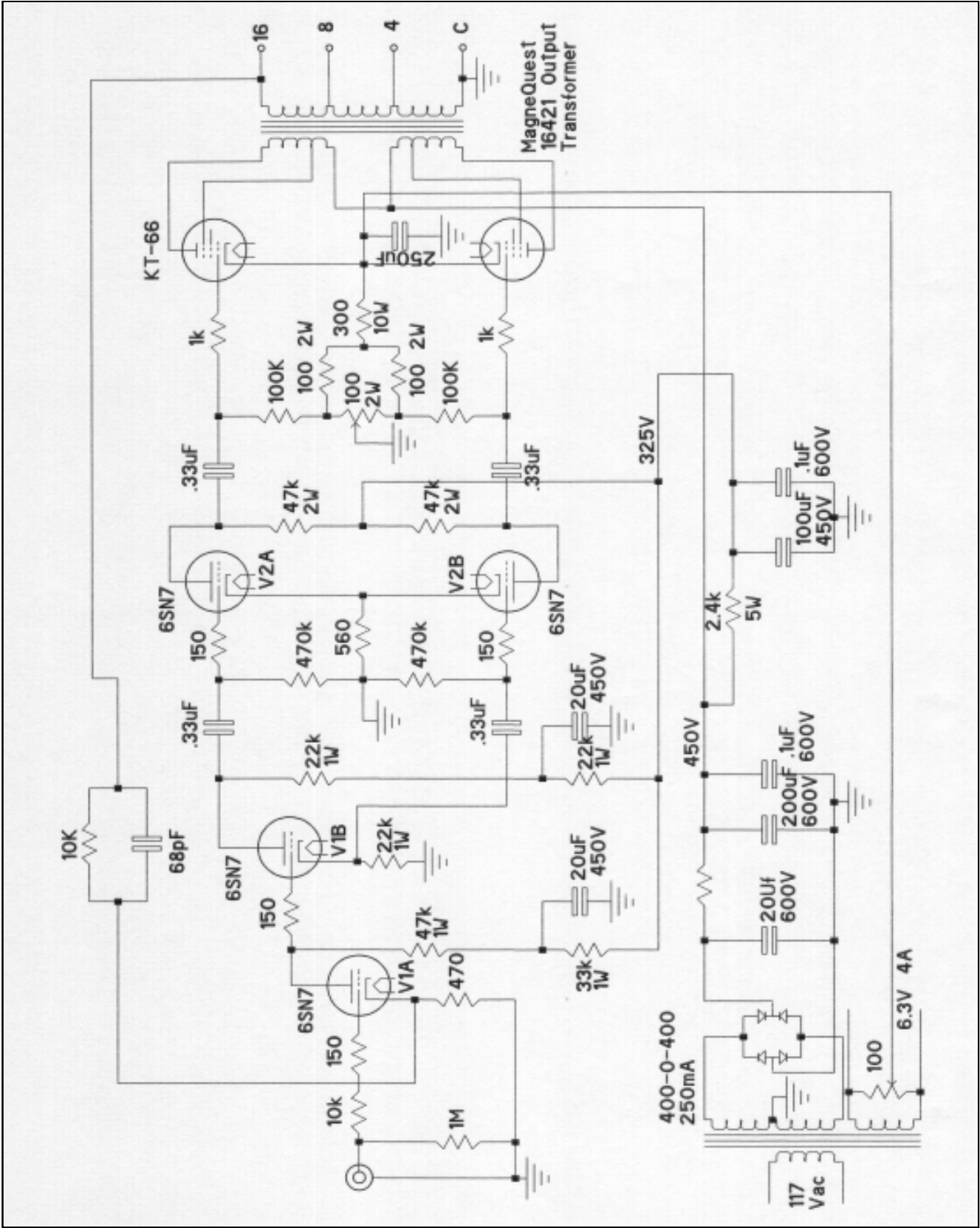
To convert an output stage, first remove the screen grid from its power supply or transformer tap and tape or isolate the wires. Then solder a 100-200 ohm 1 watt resistor between the plate of each tube and its screen grid. For example on an EL-34 you would connect pin 4 through a 100 ohm resistor to pin 3. For push pull operation, you must do both tubes. That's all there is to it. You might want to hook up a toggle switch in the circuit so you can easily switch back and forth from pentode to triode operation.

Page A20 contains formulas for modifying the gain and negative feedback in amplifiers. It shows the relationships between closed-loop and open-loop distortion in an amp or preamp. These notes have been provided courtesy of Alan Kimmel.

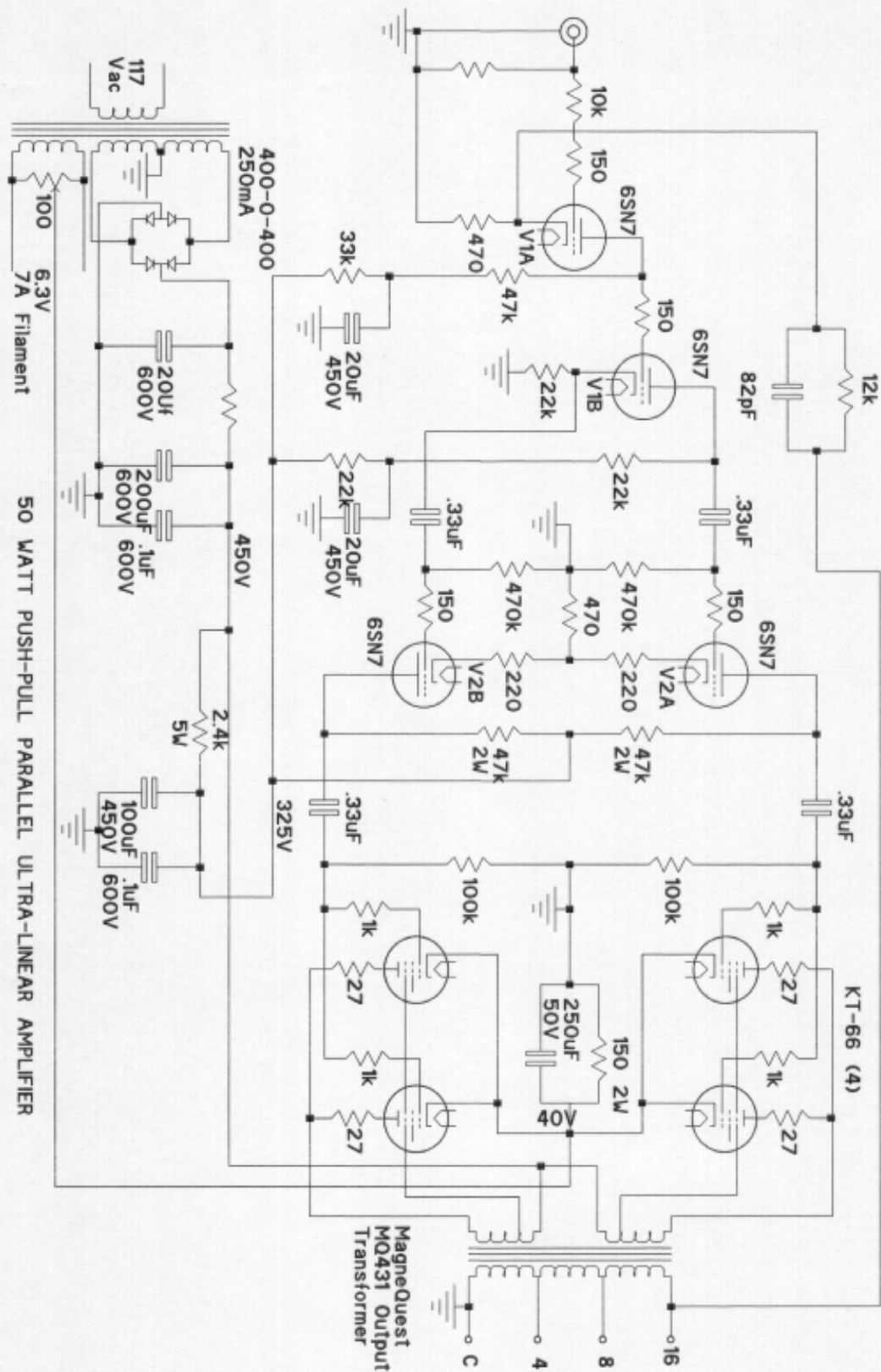
Note: These circuits should not be attempted by the novice. They will require fine tuning (i.e. compensation networks, feedback adjustments, etc.) depending on the output tubes and transformers selected.



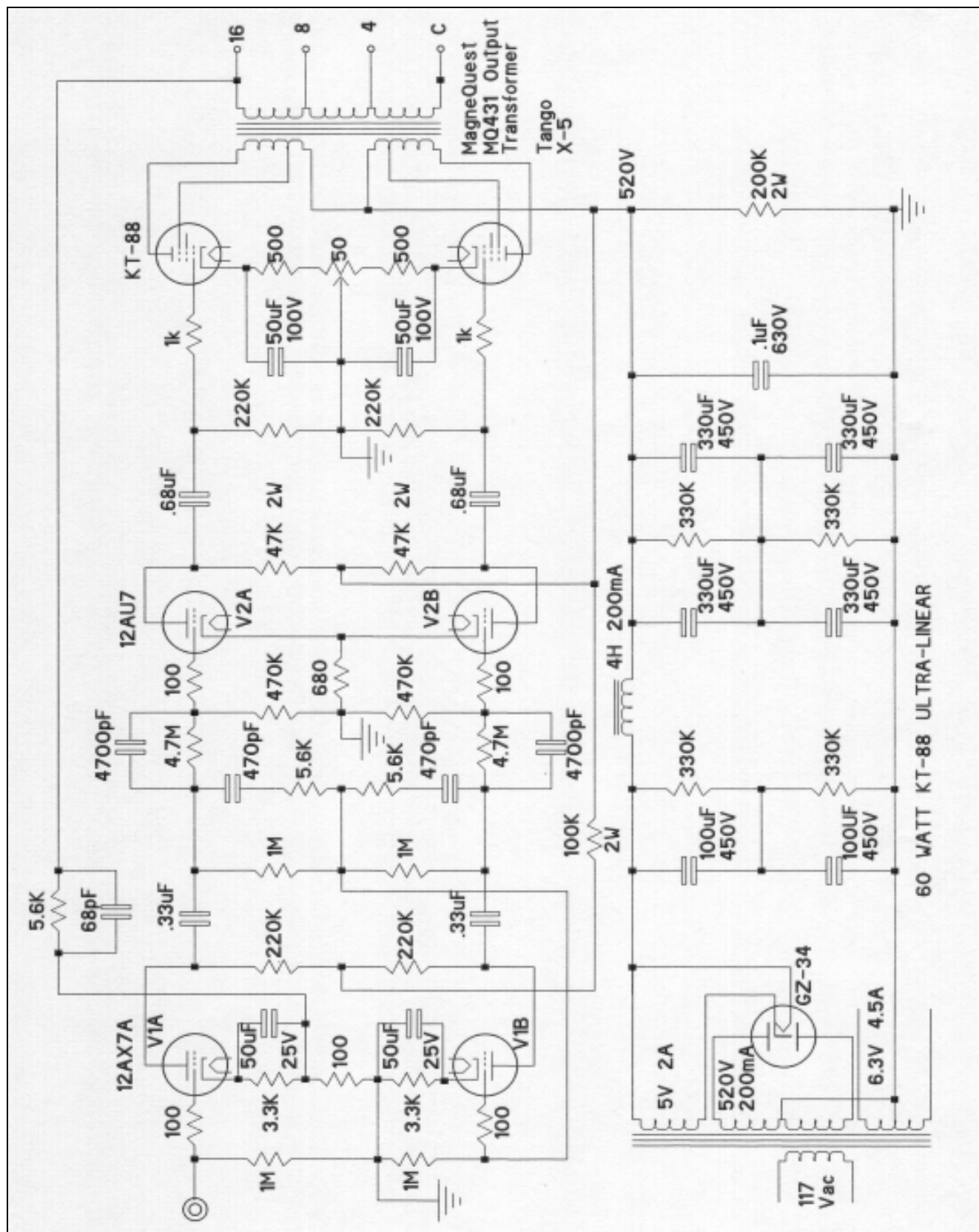
10 Watt Push Pull 2A3 Triode Amp



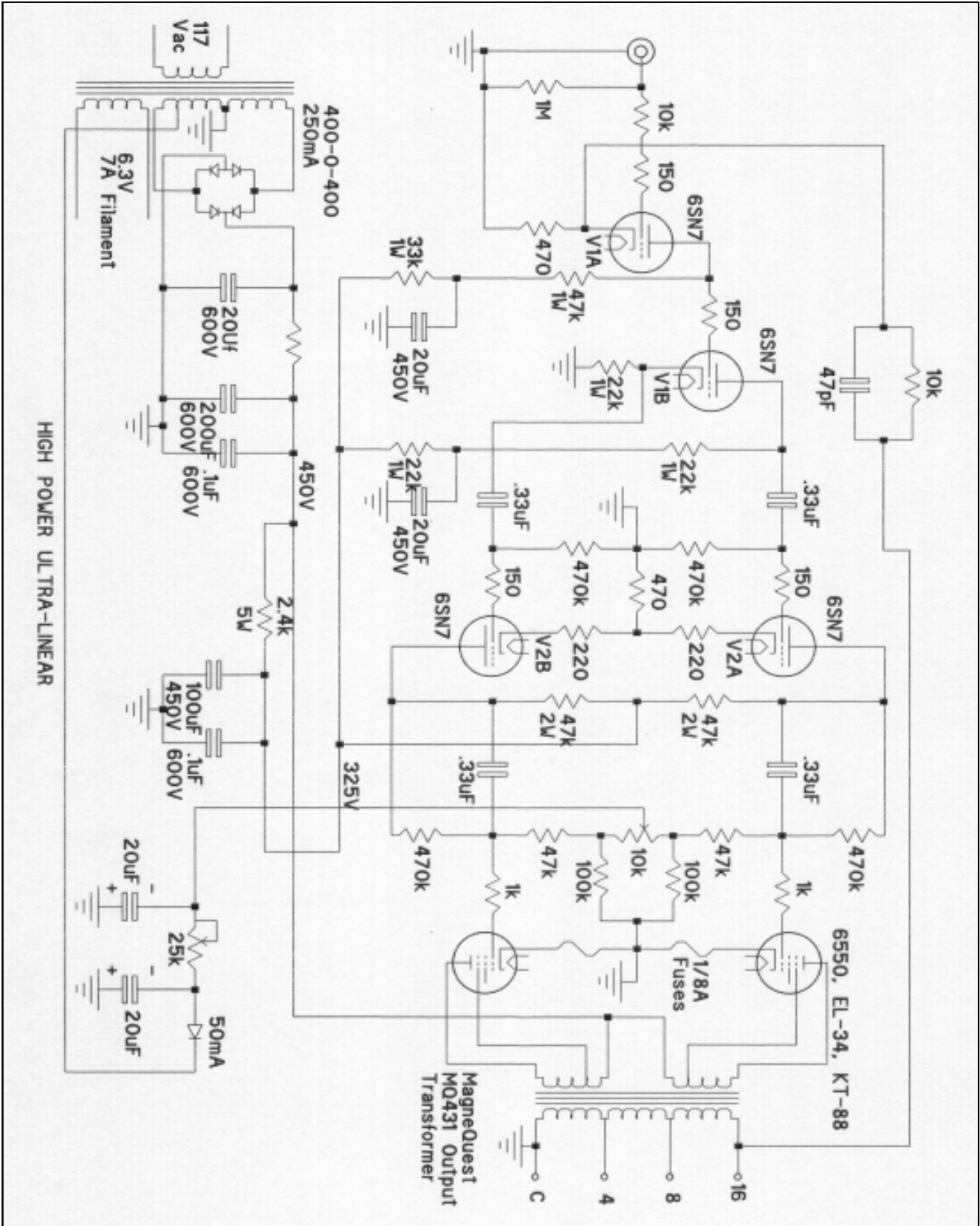
24 Watt Williamson Type Circuit



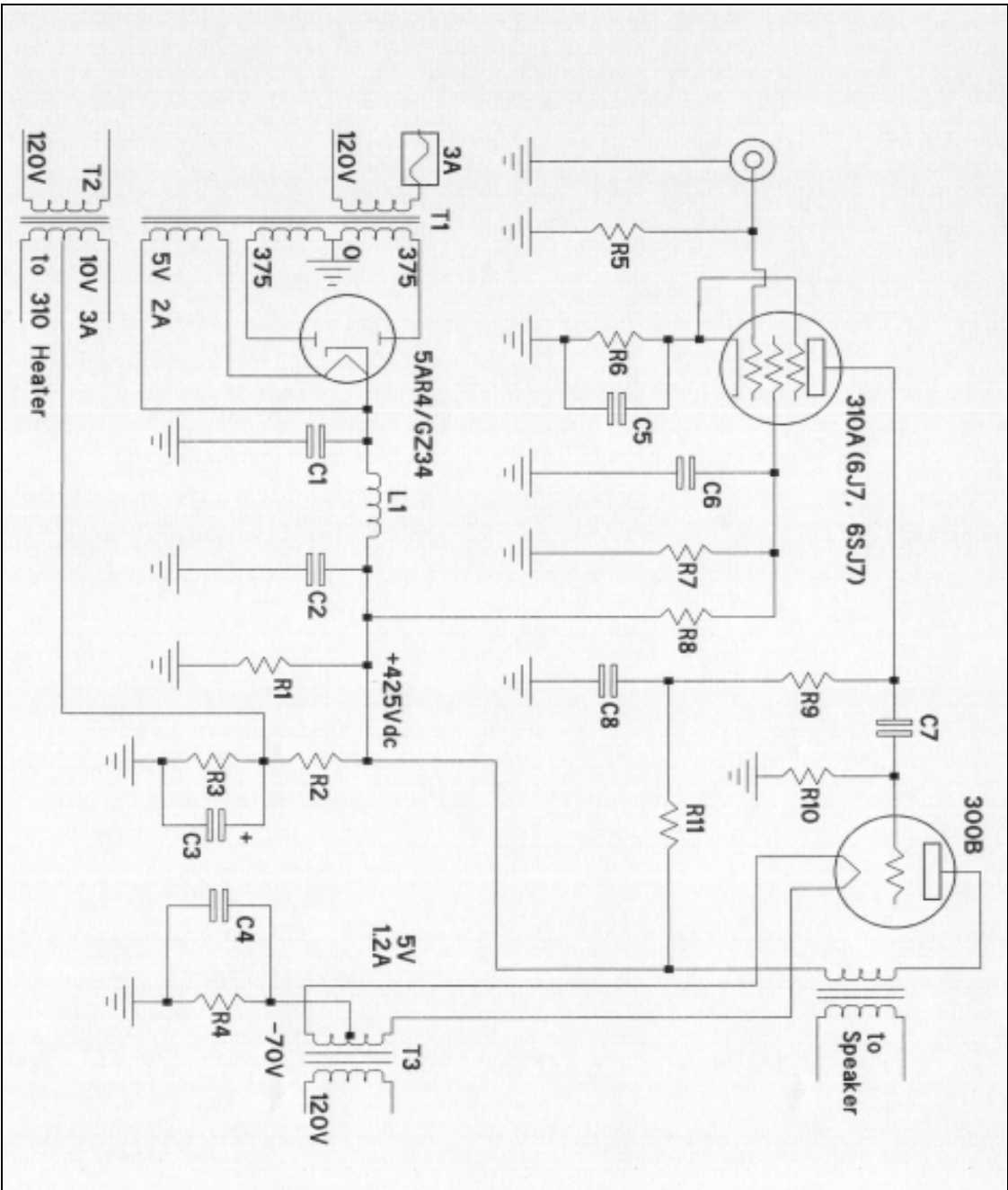
50 Watt Push Pull Parallel Ultra-Linear Amplifier



60 Watt Ultra-Linear Williamson Amplifier



High Power Ultra-Linear Williamson Amplifier

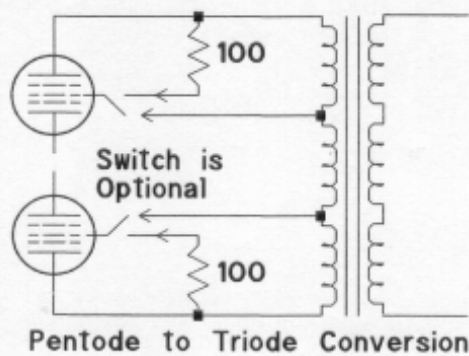
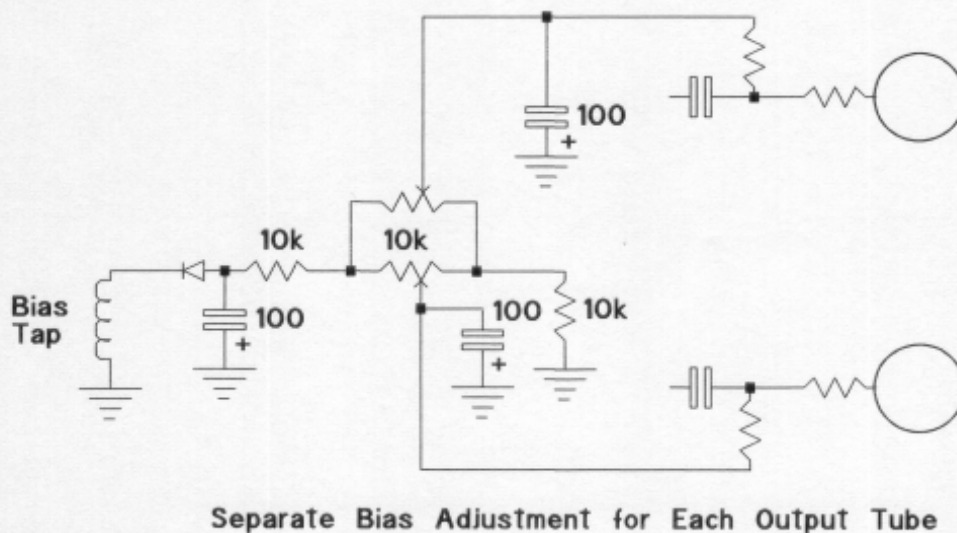
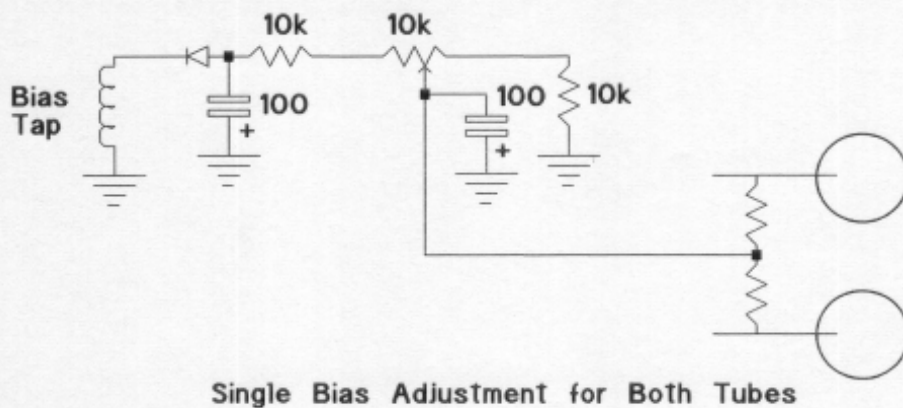


- | | | | |
|-------------------------|---|----------------------------------|----------------------------|
| R1 - 50K 25 W wirewound | R8 - 75K 5W wirewound | C1, C2 - 15uF/1000V oil cap | C6 - film or oil 8uF 200V |
| R2 - 270K 2W | R9 - 91K 2W | (or use 2 x 8uF in parallel). | C7 - .1uF 600V Vitamin Q |
| R3 - 20K 2W | R10 - 390K 2W | 500V electrolytics if you insist | C8 - 15uF 1000V oil cap |
| R4 - 880 ohm 50W Ww | R11 - 27K 10W wirewound | on being conventional | T1 - 375 - 0 - 375V @125mA |
| R5 - 220K 2W | | C3 - 50uF 100V electrolytic | T2 - 10Vdc @ 500mA |
| R6 - 1.2K 2W | | C4, C5 - 16uF 75V oil cap | T3 - 5Vdc @ 1.2A |
| R7 - 30K 5W wirewound | | | L1 - 10H @ 125mA |
| | All 2W resistors Allen Bradley carbon comps | | |

This 300B amplifier schematic is reprinted from the first issue of the Sound Practices audio journal. It is a Western Electric design of an amplifier originally used in movie theaters many years ago.

If you are not a subscriber to Sound Practices...you should be. It is an excellent publication and recommended for the DIY'er. Give them a call.

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Tips for Improved Performance

Gain, Negative Feedback and Distortion Formulas

This page contains miscellaneous formulas for setting or modifying gain and NFB, and for showing the relationship between closed-loop and open-loop distortion of an amp or preamp. Some of these formulas are difficult to find elsewhere. This information is intended primarily for those who have built an amp or preamp and wish to set or modify its NFB. (Modifying the NFB of commercially-made amps or preamps is not recommended.)

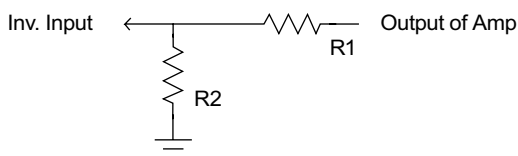
There are limitations to the application of NFB. For example, some amps or preamps are not stable at unity gain or very low gains. This is because such low gains require a very large amount of NFB and some amps or preamps will tolerate only so much NFB. If you want your amp or preamp to have such a low gain you will have to see if it is stable with the amount of NFB required to set that gain. Its stability, or lack thereof, should be checked with a scope. (Instability would manifest itself as oscillation, ringing, etc.)

To set closed-loop gain:

$$R1 = (R2/B) - R2$$

$$B = (1/Av_{CL}) - (1/Av_{OL})$$

To get R1:



Note: If the amp has multiple output taps, connect R1 to the tap you will be using and use that tap for all measurements.

1. Choose a convenient value for R2. If it is a power amplifier, 47 to 100 ohms is recommended.
2. Measure the open-loop gain of the amplifier (Av_{OL}). With a power amplifier load its output with an appropriate dummy load.
3. Decide what closed-loop gain you want (Av_{CL}).
4. Calculate the feedback fraction B.
5. With the first formula you can now calculate R1.

Related Formulas:

$$B = Av_{OL} - Av_{CL} / [(Av_{OL})(Av_{CL})] = R2 / (R1 + R2)$$

$$Av = \text{Antilog} * \frac{Av \text{ in dB}}{20}$$

$$Av_{CL} = Av_{OL} / [1 + (Av_{OL})(B)]$$

$$\text{NFB in dB} = 20 \log [1 + (Av_{OL})(B)]$$

Relationship of closed-loop distortion (DCL) to open-loop distortion (DOL):

$$DCL = DOL / [1 + (Av_{OL})(B)] \text{ and } DOL = DCL [1 + (Av_{OL})(B)]$$

Many tube amps take the NFB from the 16 ohm tap but most speakers are 8 ohm. The best arrangement is to have the NFB and your speaker both connect to the same tap. The following formulas are for changing the NFB of a tube power amp to a different tap. These formulas give the amp the same amount of NFB with the new tap that it had with the original tap. (R1 and R2 are as in the above schematic).

If AMP output is standard 4, 8, & 16 ohm and $R1 \gg R2$:

$$\text{Existing R1} \sqrt{\frac{\text{New Tap}}{\text{Tap for Existing R1}}} = \text{New R1}$$

And if R1 is bypassed by a capacitor C1:

$$\text{Existing C1} \sqrt{\frac{\text{Tap for Existing C1}}{\text{New Tap}}} = \text{New C1}$$

Circuit Modules for Vacuum Tubes Preamps

The following pages describe circuit modules that can be used to build or modify vacuum tube linestages and phonostages.

The Hybrid Linecard

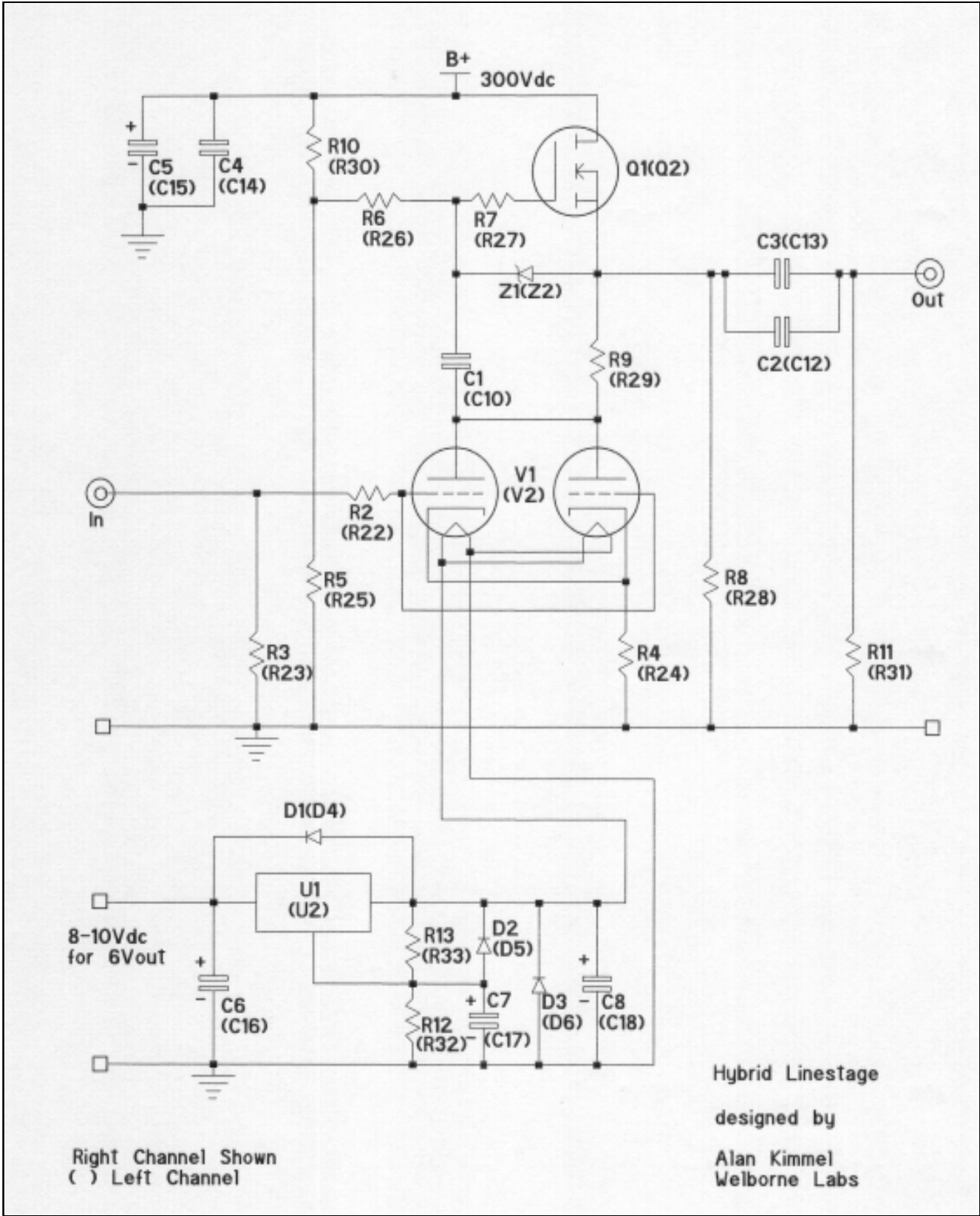
The Hybrid Linestage Card is our original design from 1993. We now offer it as a circuit card module that can be used to build a preamp from scratch using our PS-4 supply, or dropped into an existing chassis as an upgrade. Unlike the Compleat™ Hybrid Linestage kit, the hybrid card is a fixed gain circuit, with the gain determined by the tube chosen. A wide variety of tubes can be used with this design. We have selected the 6FQ7 as our preference of triode tube because of its very linear transfer characteristics, low noise capability, and moderate amplification factor. The 6FQ7 provides a gain of approximately 25dB. The 6DJ8 triode can also be used in the circuit if more gain is required, however it may provide too much gain (~30dB) for many applications. The 12AU7A is another good choice providing a gain of approximately 25dB. All of the tubes mentioned above can drop directly into the circuit, however the 12AU7A requires a couple of jumper wire and resistor changes to operate at a filament voltage of 6 volts and bias the circuit properly.

The Hybrid Linestage Card is two (2) completely separate channels located on a single 4" x 6" circuit board. There is one tube/mosfet combination per channel and both sections of each tube operate in parallel. Each channel has on-board B+ capacitance and its own DC filament voltage regulator circuit. High quality components are used throughout the design including an FR-4 grade circuit board with solder plated 2oz. copper foil, RAM Labs tested and graded vacuum tubes (tube dampers included free with purchase) or the Golden Dragons, WIMA polypropylene capacitors, and Holco metal film resistors. Also available is the option of using the MultiCap polypropylene capacitors and the super high quality, low inductance and low noise Caddock MK132 film resistors.

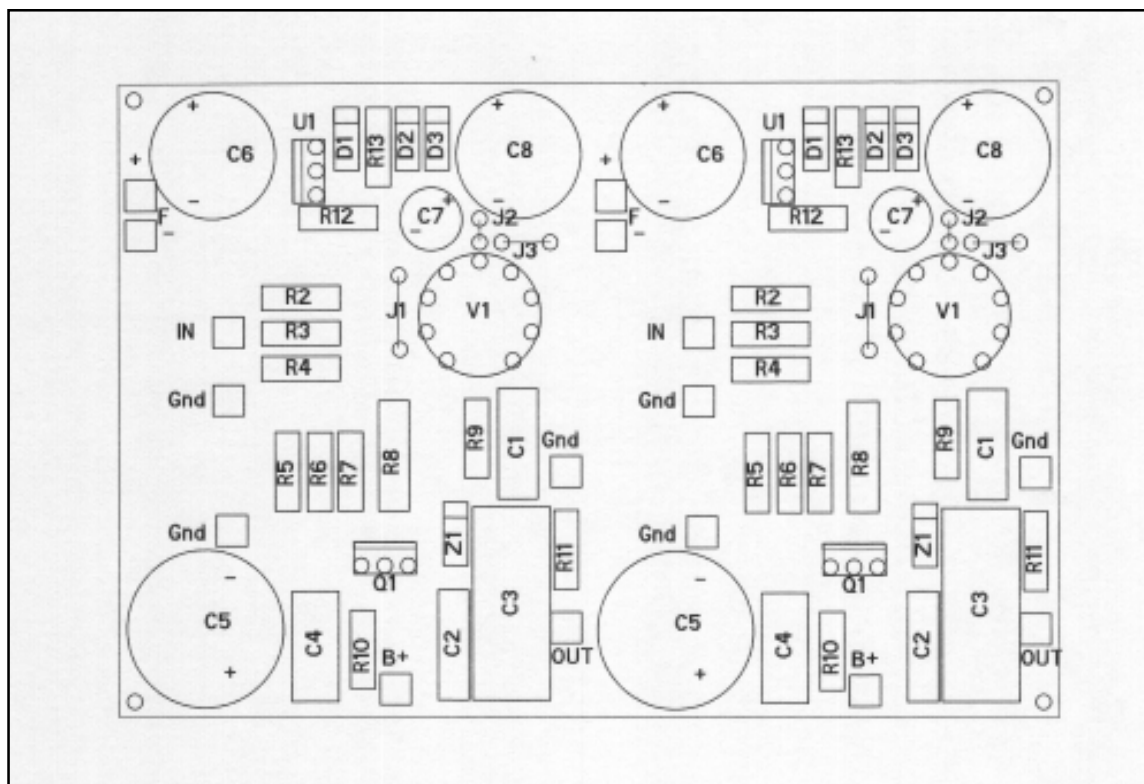
Starting with the Welborne Labs Hybrid Linestage Card, and adding a power supply, associated controls, connectors, and enclosures, you can build a complete linestage preamplifier for well under \$600 having all of the sonic characteristics of preamplifiers costing 5 times as much. The Hybrid Linestage has a very detailed but natural sound, superb bass, and an incredible timbral accuracy throughout the midrange and upper octaves. If you like tube preamps, you'll want to try this one.

Cat Number	Description	Price
HYB-1A	One <u>stereo</u> linestage card less tubes	\$115.00
HYB-1B	One <u>stereo</u> linestage card with Caddock/MultiCap Upgrade, less tubes	\$240.00
HYB-1C	Circuit Board Only (Stereo)	\$ 22.00
6FQ7 EI	EI Yugoslavia 6FQ7 (one pair)	\$ 16.00
12AU7-LN	RAM Labs Low Noise 12AU7 (one pair)	\$ 56.00
12AU7-G	Golden Dragon Low Noise 12AU7 (one pair)	\$ 52.00
6DJ8-LN	RAM Labs 6DJ8 Low Noise (one pair)	\$ 56.00
5814	Phillips/JAN 5814 (one pair)	\$ 12.00
5963	Sylvania 5963 (one pair)	\$ 16.00
6189W	Phillips/JAN 6189W Industrial Grade Version of 12AU7	\$ 12.00

Photo



Hybrid Linestage Card Schematic Diagram

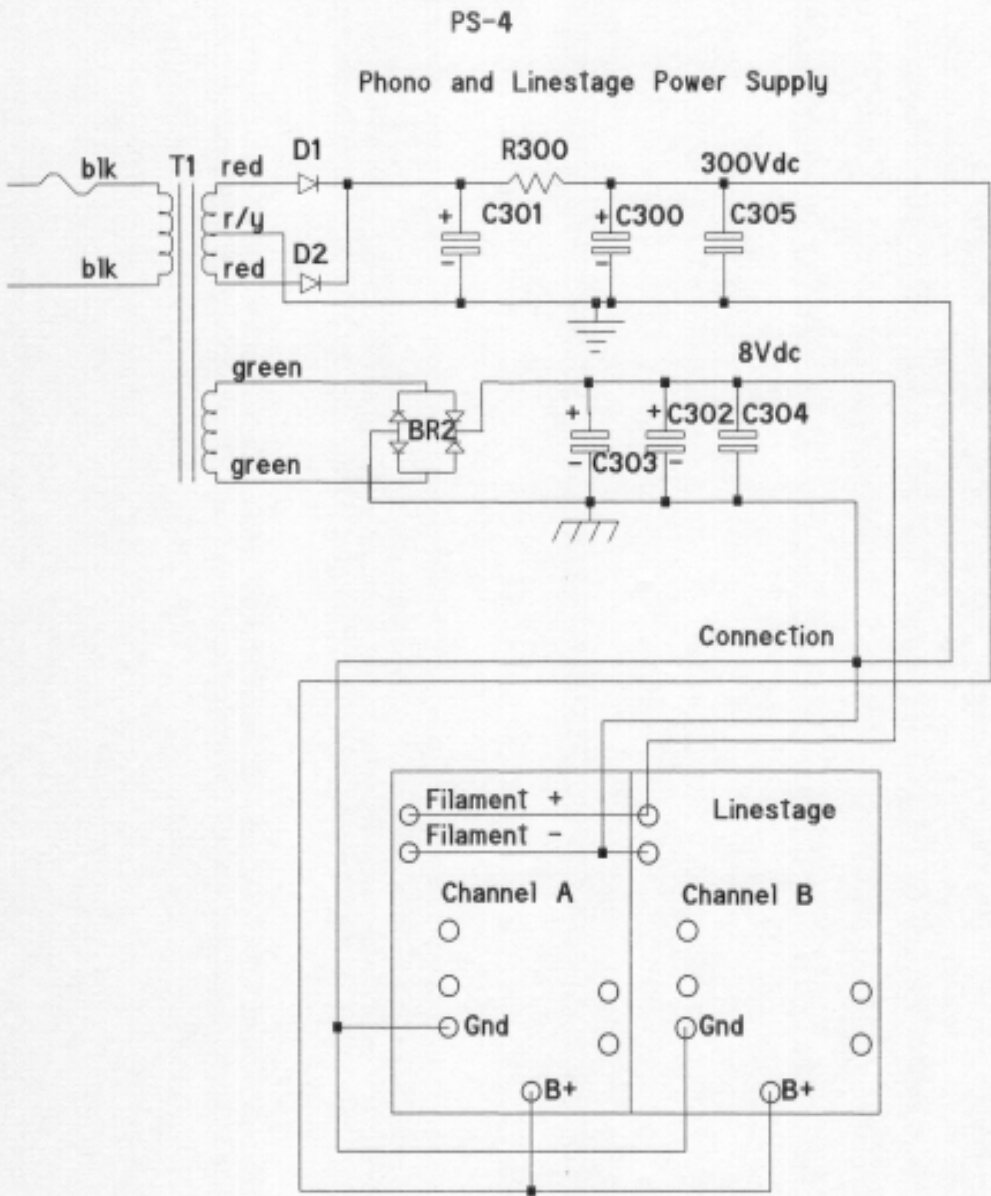


Hybrid Linestage Card Stuffing Diagram (Board Dimensions 4" x 6")

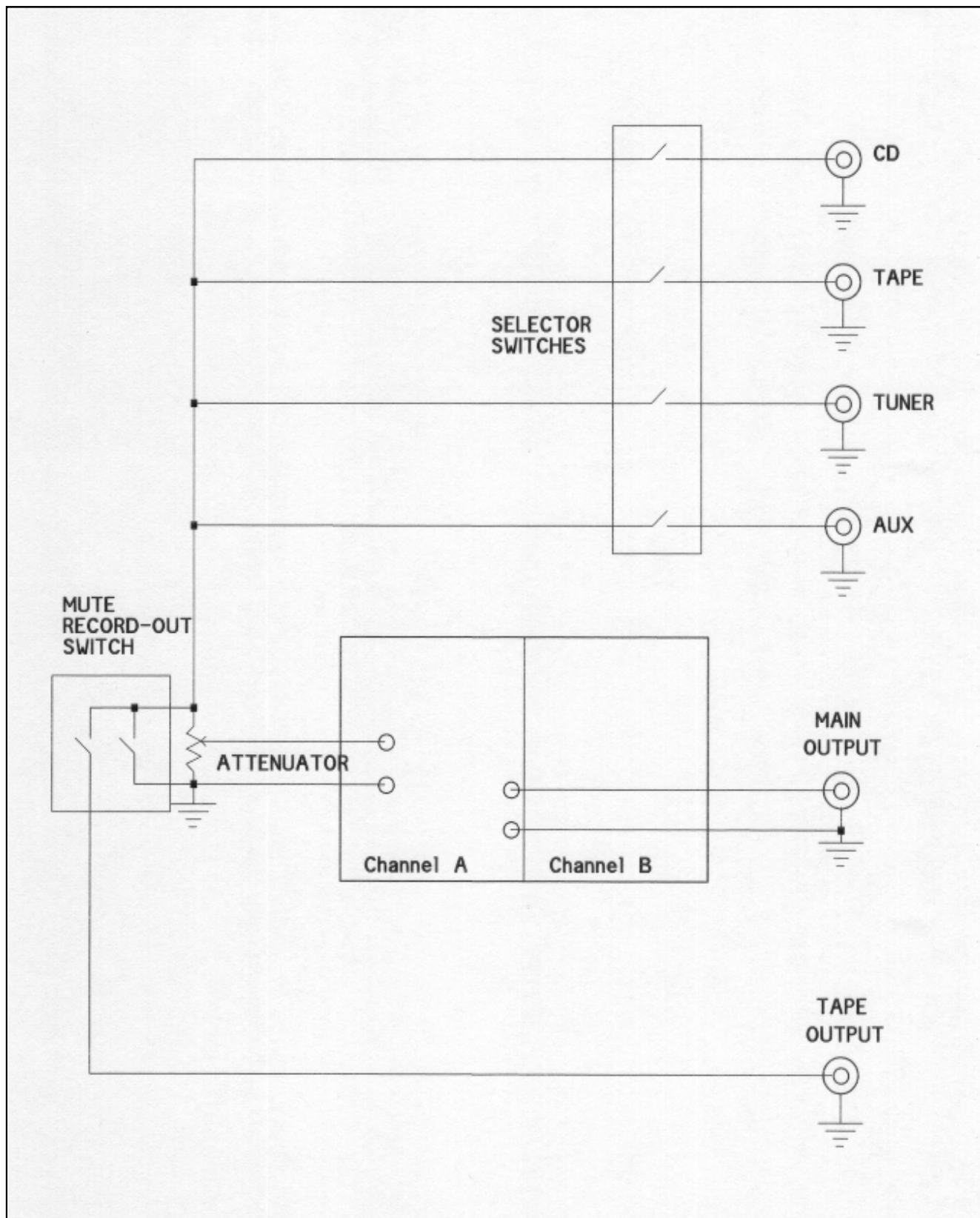
Parts List

R2,R7,R22,R27	100ohm	1/2 watt 1% mf resistor (Caddock)
R3,R23	330kohm	1/2 watt 1% mf resistor (Caddock)
R4,R24	1.00kohm	1/2 watt 1% mf resistor (Caddock)
R5,R25	270kohm	1/2 watt 1% mf resistor (Caddock)
R6,R26	10.0Mohm	1/2 watt 1% mf resistor (Caddock)
R8,R28	33kohm	2 watt 5% metal oxide resistor (Caddock)
R9,R29	6.8kohm	1/2 watt 1% mf resistor (Caddock)
R10,R30	221kohm	1/2 watt 1% mf resistor (Caddock)
R11,R31	1.00Mohm	1/2 watt 1% mf resistor (Caddock)
R13,R33	750ohm	1/2 watt 1% mf resistor (6 volt filament)
R12,R32	2.74kohm	1/2 watt 1% mf resistor (6 volt filament)
C1,C10	.022uf/630V	WIMA polypropylene capacitor (MultiCap)
C2,C12	.01uf/630V	WIMA polypropylene capacitor
C3,C13	1.0uf/250V	WIMA polypropylene capacitor (MultiCap)
C4,C14	.1uf/400V	WIMA polypropylene capacitor (MultiCap)
C5,C15	68uf/450V	Panasonic low impedance electrolytic
C6,C8,C16,C18	2200uf/35V	Panasonic low impedance electrolytic
C7,C17	100uf/63V	Panasonic low impedance electrolytic
D1,D2,D3,D4,D5,D6	1N4002	100V/1A diode
Z1,Z2	1N4742	12V/1W zener diode
Q1,Q2	IRF710 or IRF712	International Rectifier mosfet
U1,U2	LT1085CT	Linear Technology voltage regulator
V1,V2	6FQ7 or 6DJ8 or 12AU7	Medium-mu triodes
()	misc	Tube sockets, heatsinks, FR-4 printed circuit board

THE HYBRID LINESTAGE CARD DESIGN IS THE PROPERTY OF WELBORNE LABS AND ALAN KIMMEL. COMMERCIAL USE IS NOT AUTHORIZED WITHOUT LICENSE AGREEMENT.



Example Power Supply Connections



Example Linestage Layout (one channel shown)

Hybrid Phono Drive 1

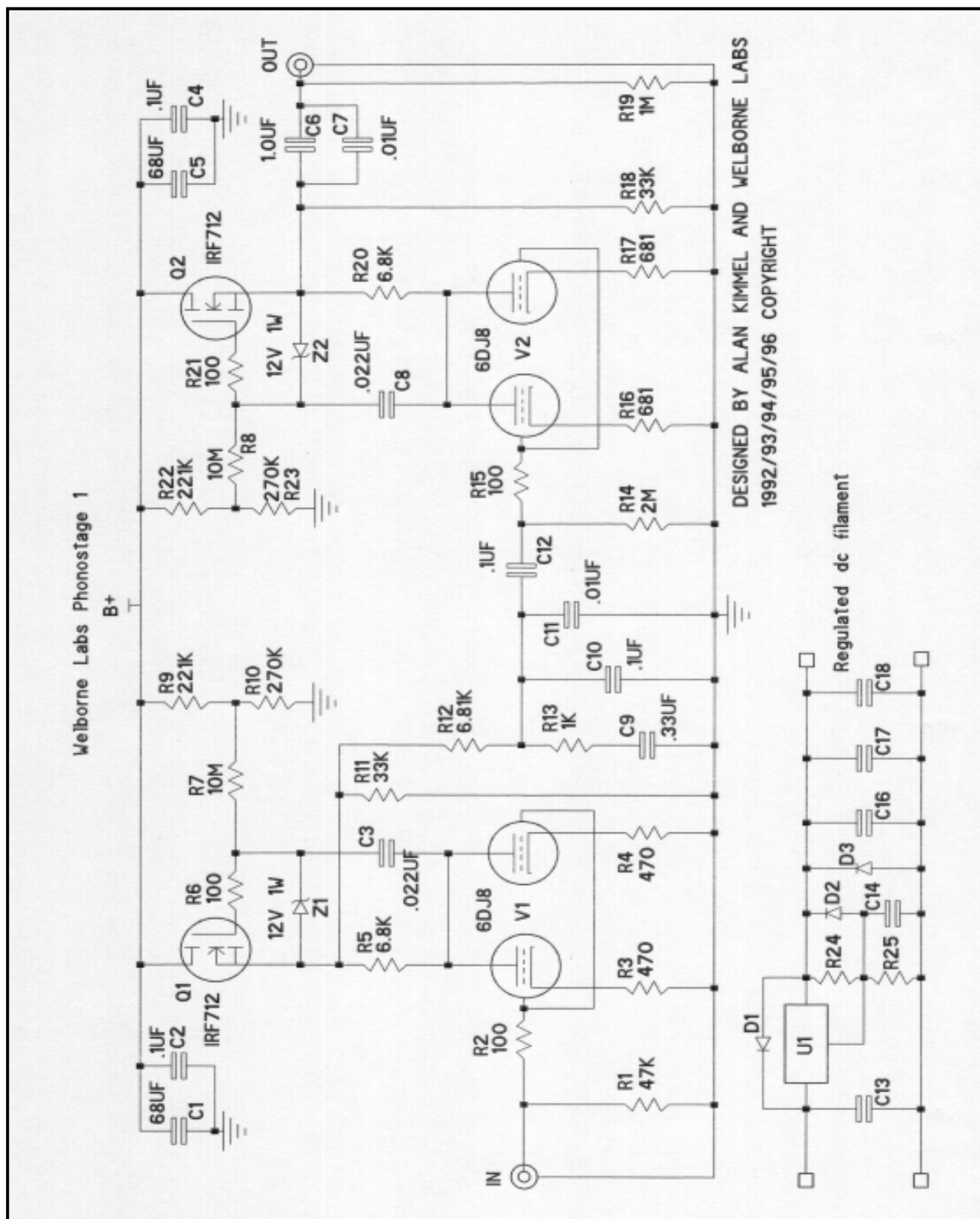
The Hybrid Phono Drive is a high gain, passive RIAA phono preamplifier circuit card kit and is the same card used in our Compleat Hybrid Phonostage Kit. The mu-stage is a very linear circuit and is less sensitive to component quality and type than most other circuits. The Hybrid Phono Drive 1 has received much praise from our customers.

With the Hybrid Phono Drive there is plenty of gain (~36dB) for most medium-to-high output moving coil and moving magnet cartridges and the ultra low output impedance of this circuit (<200 ohms) lets you drive difficult loads. Input impedance is set for 47kohms but can be changed to operate with any cartridge by merely replacing one resistor in the circuit. A double-sided circuit board including a specially designed ground plane helps to reduce the circuit's susceptibility to rf and other unwanted disturbances thereby reducing the overall noise level. Bass response is good and fast and the midrange and top-end is just breathtaking!

The Hybrid Phono Drive is made up of two 4" x 6" circuit boards (one per channel). There are two tube/mosfet combination (6DJ8/IRF710) gain stages per channel and both sections of each tube are operated in parallel. Each channel has on-board B+ capacitance and its own DC filament voltage regulator circuit set for 6Vdc operation. High quality components are used throughout the design including a double-sided FR-4 grade circuit board with solder plated 2oz. copper foil, RAM Labs tested and graded vacuum tubes (tube dampers included free with purchase), WIMA polypropylene capacitors, and Holco metal film resistors. Also available is the option of using the MultiCap polypropylene capacitors or the super high quality, low inductance and low noise Caddock MK132 film resistors. The RIAA network resistors and capacitors are selected for <1% tolerance to insure accurate frequency response and a typical unit measures less than +/- .25dB deviation. Each kit includes circuit boards and all components individually packaged and marked with their appropriate reference designation.

CAT NUMBER	DESCRIPTION	PRICE
PD-1A	Stereo Phono Drive with RAM Labs low noise 6DJ8-LN tubes	\$350.00
PD-1B	Stereo Phono Drive less tubes	246.00
PD-1C	Double-Sided Circuit Boards Only (Stereo)	48.00
PD-1D	Caddock/MultiCap resistor/capacitor upgrade package	280.00

Note: Phono circuits are amplifying signals that are very small (typically less than .005 volts) and these signals are very close the noise "floor" which also gets amplified. Therefore in order to keep your signal-to-noise ratio as high as possible it is very important that every effort be made to minimize circuit noise and extraneous sources of noise. Circuit noise can be minimized by first using very low noise tubes. We highly recommend the RAM Labs low noise tubes because you literally will not find a quieter tube on the market as these tubes are tested, graded and selected especially for phono preamps. Use of low noise metal film resistors is also very important in the circuit. Using either the Roederstein resistors or the Caddock film resistors is a must. The Caddock resistors are very expensive, but if there is one area in the entire audio chain where I would without any guilt recommend the use of these resistors, THIS IS IT. As for extraneous noise, it is highly recommended that power supply transformers not be mounted inside the same enclosure as the phono board. If any ac voltage is brought into the enclosure it should be twisted wire pairs and shielded. For that matter, all audio signal wiring should be shielded and kept as close to the chassis as possible. Don't make antennas out of your signal wires!! Good grounding techniques should be incorporated and in most cases, the chassis should be connected to signal and power ground (not earth ground) at a single point inside the enclosure.



Phono Drive 1 Schematic Diagram

Parts List for One Channel Only

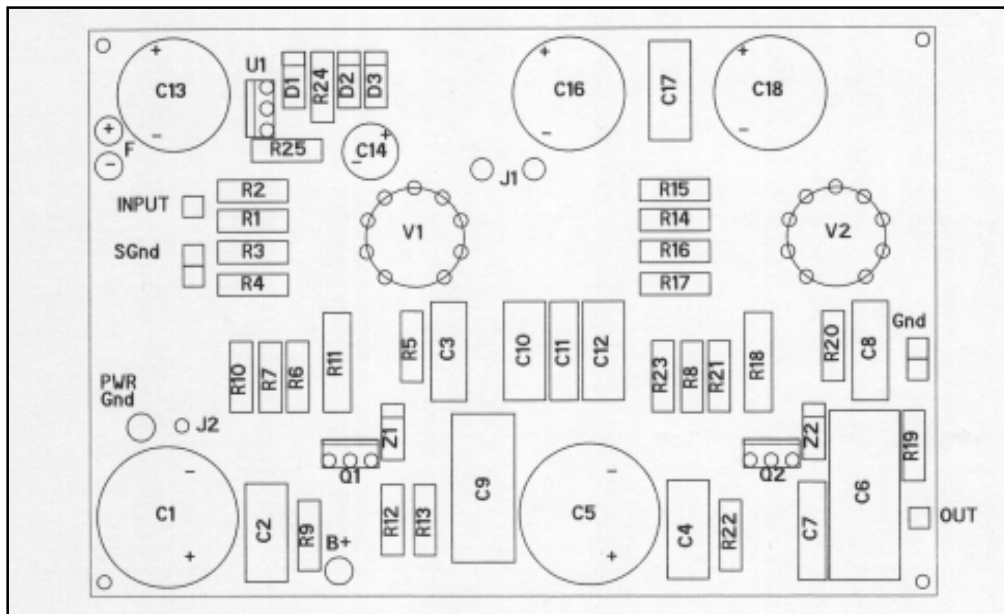
Phono Circuit

R1	47kohm	1/2 watt 1% mf resistor (Caddock)
R2,R6,R15,R21	100ohm	1/2 watt 1% mf resistor (Caddock)
R3,R4	470ohm	1/2 watt 1% mf resistor (Caddock)
R5,R20	6.81kohm	2 watt 1% mf resistor (Caddock)
R7,R8	10.0Mohm	1/2 watt 1% mf resistor (Caddock)
R9,R10	221kohm	1/2 watt 1% mf resistor (Caddock)
R22, R23	270kohm	1/2 watt 1% mf resistor (Caddock)
R11,R18	33kohm	2 watt 1% metal oxide resistor (Caddock)
R12	6.81kohm	1/2 watt 1% mf resistor (Caddock)
R13	1.0kohm	1/2 watt 1% mf resistor (Caddock)
R14	10.0Mohm	1/2 watt 1% mf resistor (Caddock)
R16,R17	681ohm	1/2 watt 1% mf resistor (Caddock)
R19	1.0Mohm	1/2 watt 1% mf resistor (Caddock)
C1,C5	68uf/450V	Panasonic low impedance electrolytic
C2,C4,C12	.1uf/400V	WIMA polypropylene capacitor (MultiCap)
C3,C8	.022uf/630V	WIMA polypropylene capacitor (MultiCap)
C6	1.0uf/250V	WIMA polypropylene capacitor (MultiCap)
C7	.01uf/630V	WIMA polypropylene capacitor (MultiCap)
C9	.33uf/400V	WIMA polypropylene capacitor (1%) (MultiCap)
C10	.1uf/400V	WIMA polypropylene capacitor (1%) (MultiCap)
C11	.01uf/630V	WIMA polypropylene capacitor (1%) (MultiCap)
Z1,Z2	1N4742	12V/1W zener diode
Q1,Q2	IRF710 or IRF712	International Rectifier mosfets
V1,V2	6DJ8	Triodes
misc		Tube sockets, heatsinks, FR-4 pcb, tube dampers

Filament regulator

R24	750ohm	1/2 watt 1% mf resistor (6 volt filament)
R25	2.74kohm	1/2 watt 1% mf resistor (6 volt filament)
C13,C16,C18	2200uf/35V	Panasonic low impedance electrolytic
C14	100uf/63V	Panasonic low impedance electrolytic
C17	.1uf/160V	WIMA polypropylene capacitor
D1,D2,D3	1N4002	100V/1A diode
U1	LT1085CT	Linear Technology voltage regulator
J1,J2,J3		jumper wire and feedthru

() Indicates parts upgrade



Phono Drive 1 Stuffing Diagram (Board Dimensions 4" x 6")

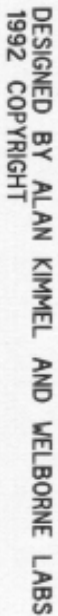
Hybrid Phono Drive 2

The Hybrid Phono Drive 2 is a high gain, passive RIAA phono preamplifier circuit card kit and is the same card used in our Compleat Hybrid Phonostage Kit. The mu-stage is a very linear circuit and is less sensitive to component quality and type than most other circuits. The Hybrid Phono Drive 2 has received much praise from our customers.

With the Hybrid Phono Drive-2 there is plenty of gain (~50dB) for most medium output moving coil cartridges and the ultra low output impedance of this circuit (<200 ohms) lets you drive difficult loads. Input impedance is set for 47kohms but can be changed to operate with any cartridge by merely replacing one resistor in the circuit. A double-sided circuit board including a specially designed ground plane helps to reduce the circuit's susceptibility to rf and other unwanted disturbances thereby reducing the overall noise level. Bass response is good and fast and the midrange and top-end is just breathtaking!

The Hybrid Phono Drive-2 is made up of two 4" x 6" circuit boards (one per channel). There are two tube/mosfet combination gain stages per channel and both sections of each tube are operated in parallel. Each channel has on-board B+ capacitance and its own DC filament voltage regulator circuit set for 6Vdc operation. High quality components are used throughout the design including a double-sided FR-4 grade circuit board with solder plated 2oz. copper foil, RAM Labs tested and graded vacuum tubes (tube dampers included free with purchase), MultiCap and WIMA polypropylene capacitors, and Holco metal film resistors. Also available is the option of using the low inductance and low noise Caddock MK132 film resistors. The RIAA network resistors and capacitors are selected for <1% tolerance to insure accurate frequency response and a typical unit measures less than +/- .25dB deviation. Each kit includes circuit boards and all components individually packaged and marked with their appropriate reference designation.

CAT NUMBER	DESCRIPTION	PRICE
PD-2A	Stereo Phono Drive w/RAM Labs low noise 6DJ8-LN/12AX7-SLN tubes	\$420.00
PD-2B	Stereo Phono Drive less tubes	270.00
PD-2C	Double-Sided Circuit Boards Only (Stereo)	48.00
PD-2D	Caddock resistor upgrade package	190.00



Hybrid Phono Drive 2 Schematic Diagram

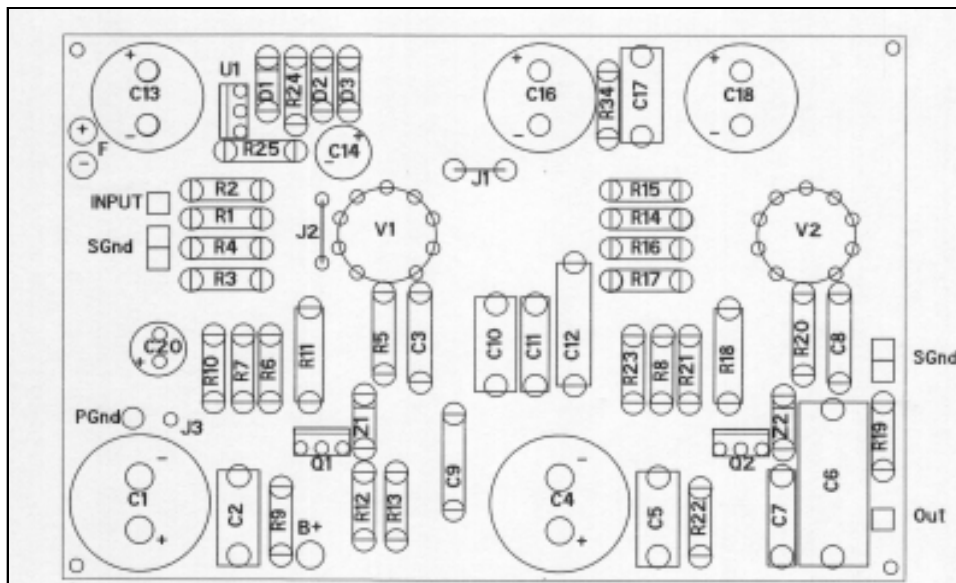
Parts List for One Channel Only

Phono Circuit

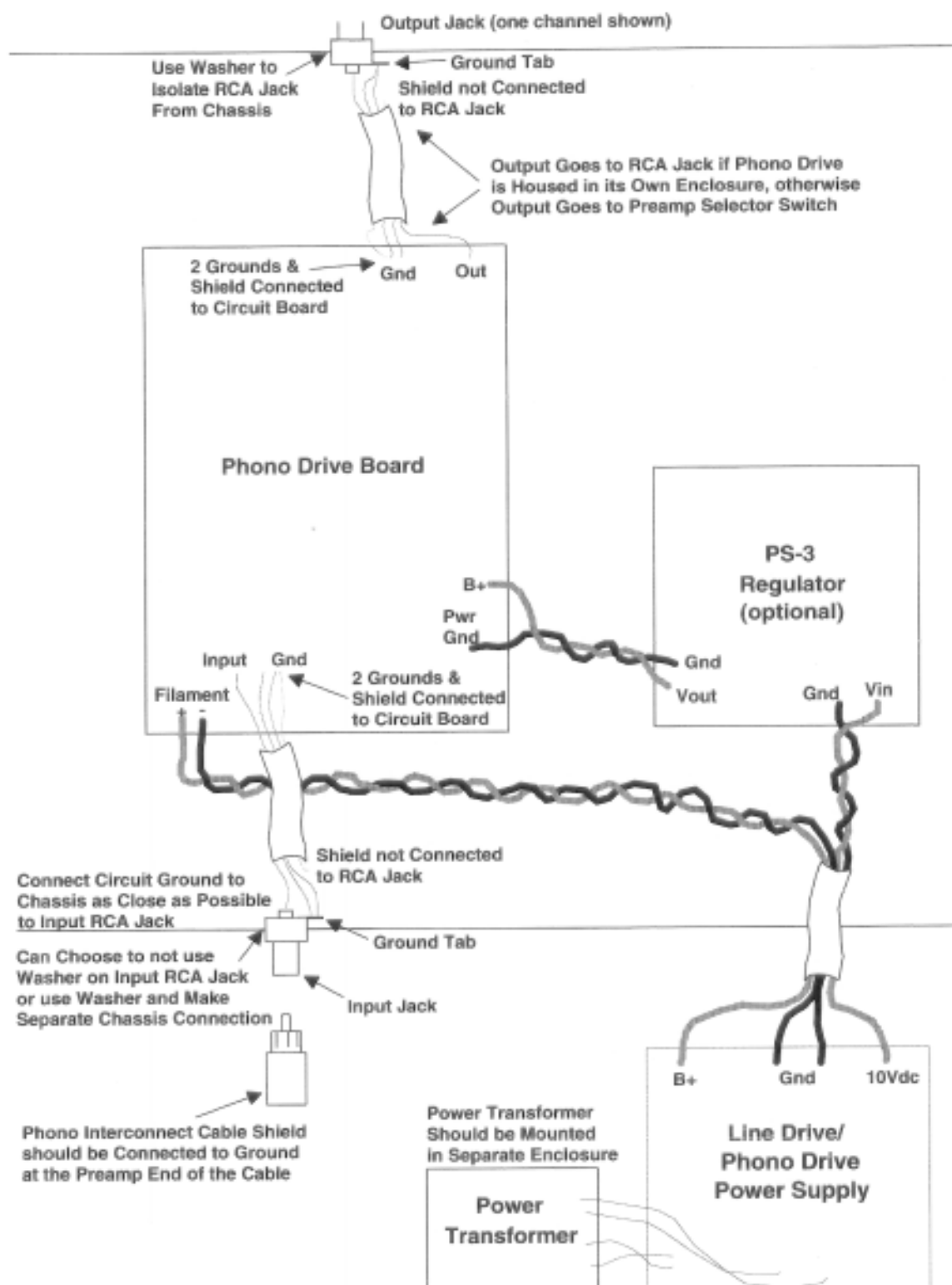
R1	47kohm	1/2 watt 1% mf resistor (Caddock)
R2,R6,R15,R21	100ohm	1/2 watt 1% mf resistor (Caddock)
R3,R4	909ohm	1/2 watt 1% mf resistor (Caddock)
R5	15.0kohm	2 watt 1% mf resistor (Caddock)
R7,R8	10.0Mohm	1/2 watt 1% mf resistor (Caddock)
R9,R22	221kohm	1/2 watt 1% mf resistor (Caddock)
R11,R18	33kohm	2 watt 1% metal oxide resistor (Caddock)
R12	68.0kohm	1/2 watt 1% mf resistor (Caddock)
R13	10.0kohm	1/2 watt 1% mf resistor (Caddock)
R14	2.2Mohm	1/2 watt 1% mf resistor (Caddock)
R16,R17	681ohm	1/2 watt 1% mf resistor (Caddock)
R19	1.0Mohm	1/2 watt 1% mf resistor (Caddock)
R20	6.81kohm	2 watt 1% mf resistor (Caddock)
R10,R23	274kohm	1/2 watt 1% mf resistor (Caddock)
C1,C4	68uf/450V	Panasonic low impedance electrolytic
C2,C5	.1uf/400V	WIMA polypropylene capacitor
C3,C8	.022uf/600V	MultiCap polypropylene capacitor
C6	1.0uf/250V	WIMA polypropylene capacitor
C7	.01uf/600V	MultiCap polypropylene capacitor
C9	.033uf/600V	MultiCap polypropylene capacitor (1%)
C10	.01uf/600V	MultiCap polypropylene capacitor (1%)
C11	.001uf/600V	MultiCap polypropylene capacitor (1%)
C12	.1uf/400V	MultiCap polypropylene capacitor
C20	10uf/200V	Low Impedance electrolytic
Z1,Z2	1N4742	12V/1W zener diode
Q1,Q2	IRF712	International Rectifier mosfets
V1,V2	12AX7/6DJ8	Triodes
misc		Tube sockets, heatsinks, FR-4 pcb, tube dampers

Filament regulator

R24	750ohm	1/2 watt 1% mf resistor (6 volt filament)
R25	2.74kohm	1/2 watt 1% mf resistor (6 volt filament)
R34	499ohm	1/2 watt 1% mf resistor
C13,C16,C18	2200uf/35V	Panasonic low impedance electrolytic
C14	100uf/63V	Panasonic low impedance electrolytic
C17	.1uf/160V	WIMA polypropylene capacitor
D1,D2,D3	1N4002	100V/1A diode
U1	LT1085CT	Linear Technology voltage regulator
J1,J2,J3		jumper wire and feedthru



Phono Drive 2 Stuffing Diagram (Board Dimensions 4" x 6")



Phono Drive Interconnect and Wiring Diagram

Power Supplies

We offer a nice selection of power supply modules to be used primarily for preamplifiers, crossovers, CD players and other low power equipment. They are intended to be used in new designs as well as upgrades to existing power supplies. From left to right pictured below: PS1 low voltage regulator module, PS4 high voltage/filament supply, PS5A dual-mono low voltage supply, PS3 high voltage regulator module, PS8 vacuum tube power supply.



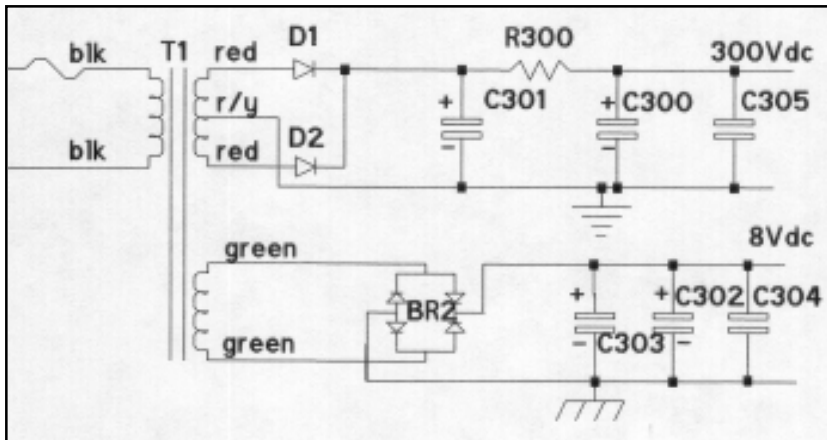
PS4 Power Supply with Ultra Fast Rectifiers

The Hybrid Phono Drive and Hybrid Linestage Power Supply is an unregulated supply consisting of a laminated transformer with end bells, or now available with a toroid transformer, and a circuit board providing rectified B+ and filament voltages of 300Vdc and 8Vdc respectively. The 8 volt filament is regulated down to 6 volts onboard the phono and linestage boards. The circuit board consists of filament bridge rectifier, ultra fast B+ rectifier diodes, dropping resistor (optional), filter capacitance for both voltage rails and the transformer primary circuit is fused. The dropping resistor can be jumpered when using this supply with our PS-3 voltage regulator stage. Without the dropping resistor, the PS-4 puts out about 350Vdc.

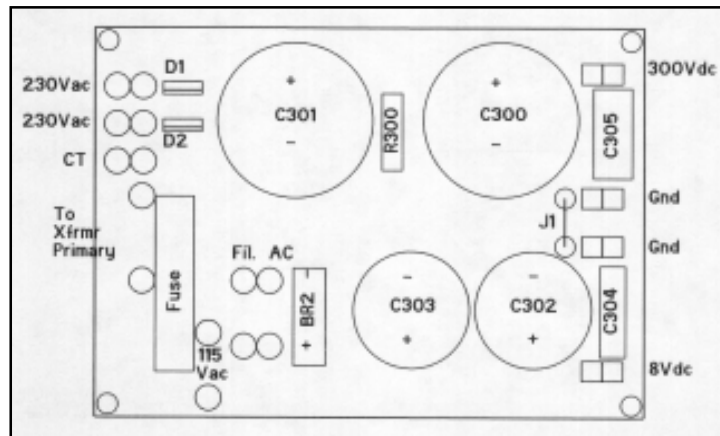
Parts List

R300	Select	Select or use jumper wires
C300, C301	220uF/400V	Panasonic low impedance electrolytics
C302, C303	3300uF/35V	Panasonic low impedance electrolytics
C304	0.1uF/160V	WIMA polypropylene capacitor
C305	0.1uF/400V	WIMA polypropylene capacitor
D1,D2	8A/600V	Ultrafast Rectifier Diodes
BR2	4A/200V	Bridge Rectifier
T1		Laminated Transformer
Misc		Circuit Board, fuse, fuseclips, 18ga. Teflon hookup wire

PS-4A	Complete Power Supply with Tran4 Transformer	\$ 99.00
PS-4B	Complete Power Supply with A1200 Toroid Transformer	\$148.00
PS-4C	Power Supply Less Transformer	\$ 61.00
PS-4D	Power Supply Circuit Board Only	\$ 15.00
TRAN1	Power Transformer 230V-0-230V @60mA, 6.3V @3.0A	\$ 42.00
A1200	Toroid Power Transformer 2 x 230V-0-230V @60mA, 2 x 6.3V @2.5A	\$ 85.00



PS4 Schematic Diagram



PS4 Stuffing Diagram (Board Dimensions 3" x 4.25")

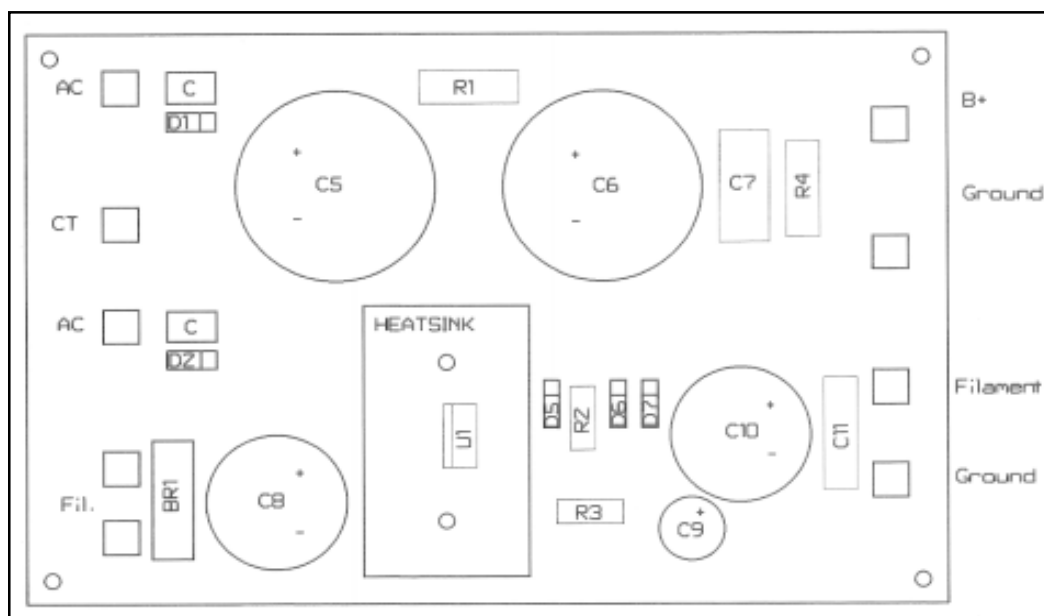
PS-8 Power Supply

The PS-8 is a combination unregulated B+ and regulated filament supply for vacuum tube preamps. It includes a laminated transformer with end bells, or now available with a toroid transformer, and a circuit board providing rectified B+ and filament voltages of 280 to 350Vdc and 6 to 12Vdc respectively. The dropping resistor can be jumpered for higher voltages when using a voltage regulation stage. Without the dropping resistor, the PS-8 maximum output is approximately 350Vdc. The B+ rectifier section can be configured for either a standard full-wave or a bridge full-wave. See schematics on next page.

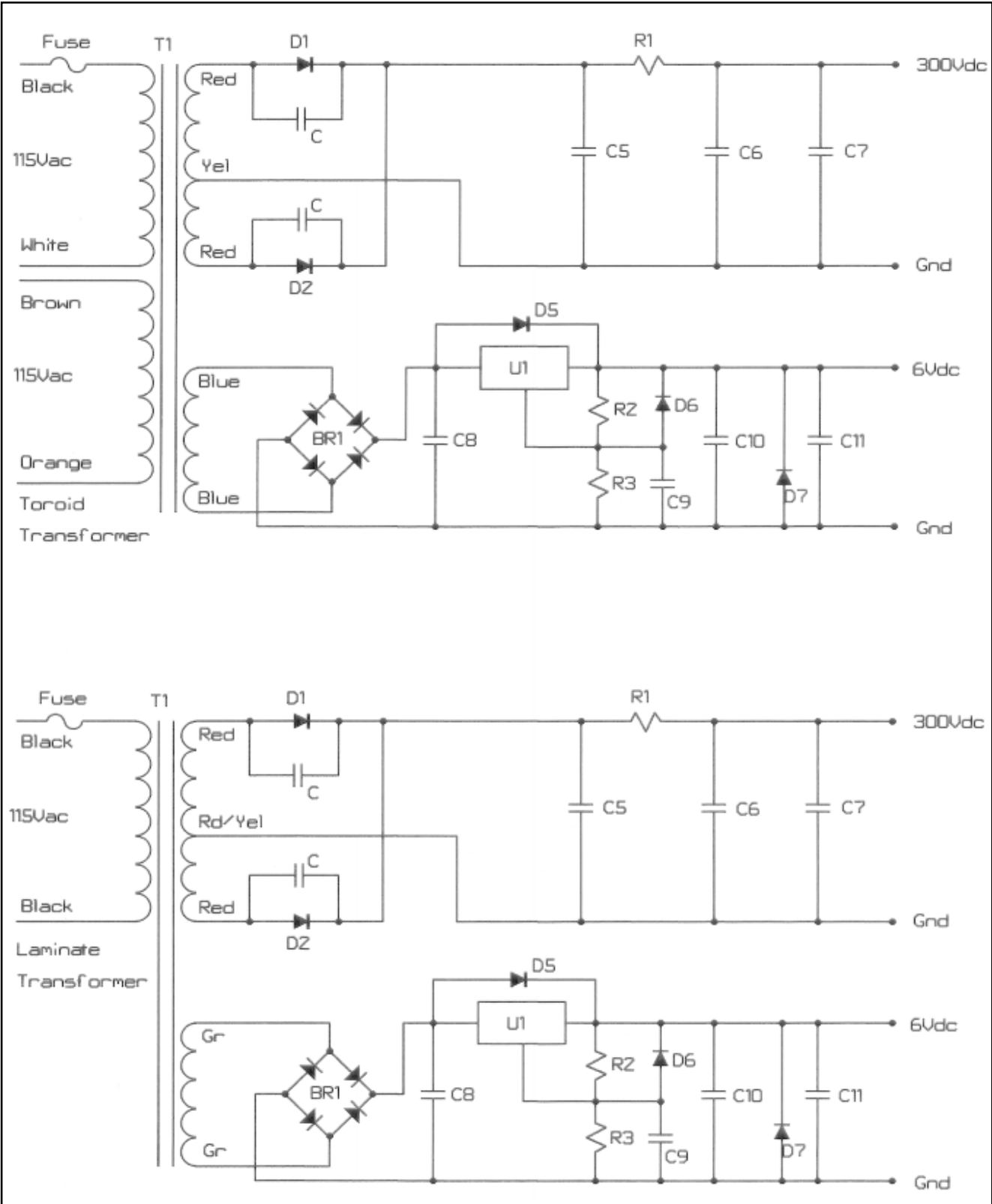
Parts List

D1,D2	1A/600V	Fast Rectifier Diodes
C	.01uf/600V	Option bypass cap (not included with kit)
R1	Select	Dropping resistor select or use jumper wires
C5, C6	220uF/400V	Panasonic low impedance electrolytics
C7	0.1uF/400V	WIMA polypropylene capacitor
R4	470k/2watt	Metal oxide discharge resistor
BR1	4A/50V	Bridge Rectifier
C8, C10	2200uF/35V	Elna low impedance electrolytics
C11	0.1uf/160V	WIMA polypropylene capacitor
D5,D6,D7	1N4002	Diode
R2	750/1.21k	6volts/12volts (please specify filament voltage)
R3	2.74k/10k	6volts/12volts (please specify filament voltage)
C9	100uf/35V	Elna low impedance electrolytics
U1	LT1085CT	Voltage Regulator
T1		PowerTransformer
Misc		Circuit Board, Heatsink, Standoffs, 18ga. Teflon hookup wire

PS-8A	Complete Power Supply with Tran1 Transformer	\$115.00
PS-8B	Complete Power Supply with A1000 Toroid Power Transformer	\$158.00
PS-8C	Power Supply Less Transformer	74.00
PS-8D	Power Supply Circuit Board Only	15.00



PS8 Power Supply Stuffing Guide (Board Dimensions 3.5" x 5.5")



PS-8 Power Supply Schematic Diagrams

New Improved PS-3 Voltage Regulator

Our new PS-3 regulator board is versatile in that it can be used for both vacuum tube power amps and preamplifiers. The PS-3 regulator board is a low cost solid state voltage regulator circuit that provides very good load and line regulation resulting in a ripple output that is extremely low. In fact, it converts 2 volts of ripple voltage on a stock Dynaco MKIII amplifier into 0.2 volts of ripple!! The PS-3 regulator is constructed on a 3 x 5 board. The height of the board, mounted, is approximately 1.5 inches and can therefore fit in many existing chassis.

As with all regulators, it is limited by the power dissipation in the series pass transistor. However, this circuit is very versatile and can be used within a range of 100 volts to 550 volts as long as the input-to-output voltage is carefully balanced with the current requirements (see equation on next page for calculating the mosfet power dissipation). The desired output voltage of the regulator is achieved by properly selecting the total voltage of the zener diode stack. The pass transistor, Q1 can be thought of as a simple source-follower dc amplifier. It increases the load resistance seen by the zener diodes by a factor of beta. In this circuit arrangement the diode stack is required to supply only the gate current for Q1. The net result is that the load regulation and ripple characteristics, of the zener diodes, are improved by a factor of beta. In the case of the PS-3, the beta is very high due to the use of the mosfet. Additionally, C103 reduces the ripple even more and also provides a slow start capability for the PS-3.

The PS-3 is offered as a kit or you may purchase the circuit board separately. If you purchase the complete kit, please specify your input and output voltage requirements and I will calculate and select the appropriate resistor and zener diode values. If you are purchasing just the circuit board, I have included the design equations on the next page for calculating your own values. We use the PS-3 in our Dynaco MKIII mod and it can also be used with our Hybrid Linestage or either of the Phono Drives we sell.

PS-3A	Includes all parts and 3" x 5" circuit board for one channel of regulation	\$75.00
PS-3B	Circuit Board Only	\$15.00

Please be sure to specify your input voltage supplied to the regulator and your desired regulated output voltage

Design Notes

Several calculations are required for the design of the PS-3 circuit. These are the resistance and power dissipation of R103, and the power dissipation of Q1. Additionally, the voltage values of the zener diodes must be selected and summed to obtain the approximate regulated output voltage. R103 is designed to supply the zener current to the zener diode string. The resistance value is calculated as follows:

$$\text{Resistance}_{R103} = (V_{B+(min)} - V_Z) / 1.1 I_Z$$

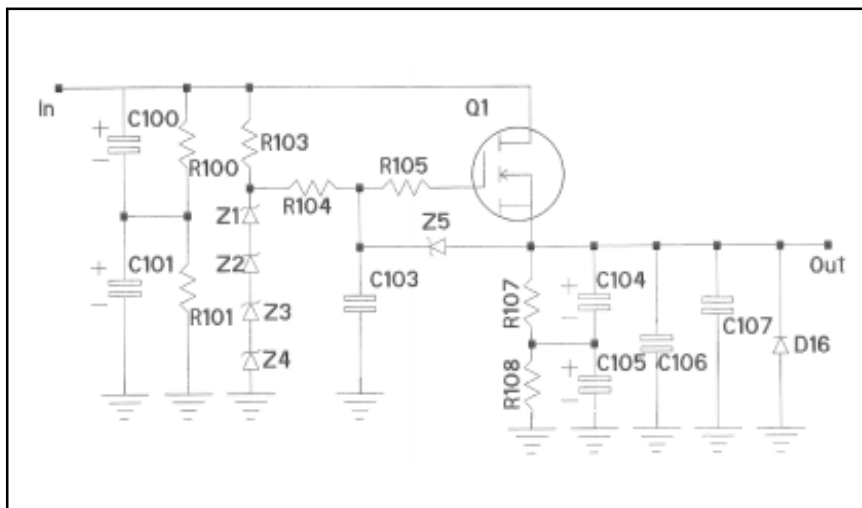
I_Z is the approximate current required for the zener diodes to regulate. This value is approximately 8 to 12 mA for the 5 watt zener diodes in the 50 to 150 volt range. The power dissipation in the resistor can be calculated as follows:

$$P_{R103} = (V_{B+(max)} - V_Z)^2 / \text{Resistance}_{R103}$$

The power dissipated in the pass transistor can be calculated with the following equation:

$$P_{Q1} = I_{L(max)} \times V_{DS}, \text{ where } V_{DS} \text{ is the input-to-output voltage differential}$$

The power dissipation in the mosfet should be kept to approximately 15 watts or less for reliable operation. The regulated output voltage is obtained by selecting four zener diodes with voltage ratings that sum to the desired output voltage. The final voltage will be the sum of the zener diode string.



PS-3 Voltage Regulator Schematic Diagram

PS-3 Regulator Board Parts List

Resistors

R100,R101, R107,R108	220kohm	2W metal oxide
R103	8.2kohm	2W metal oxide
R104	10Mohm	Roederstein 1/2W 1% metal film
R105	332ohm	Roederstein 1/2W 1% metal film

Capacitors

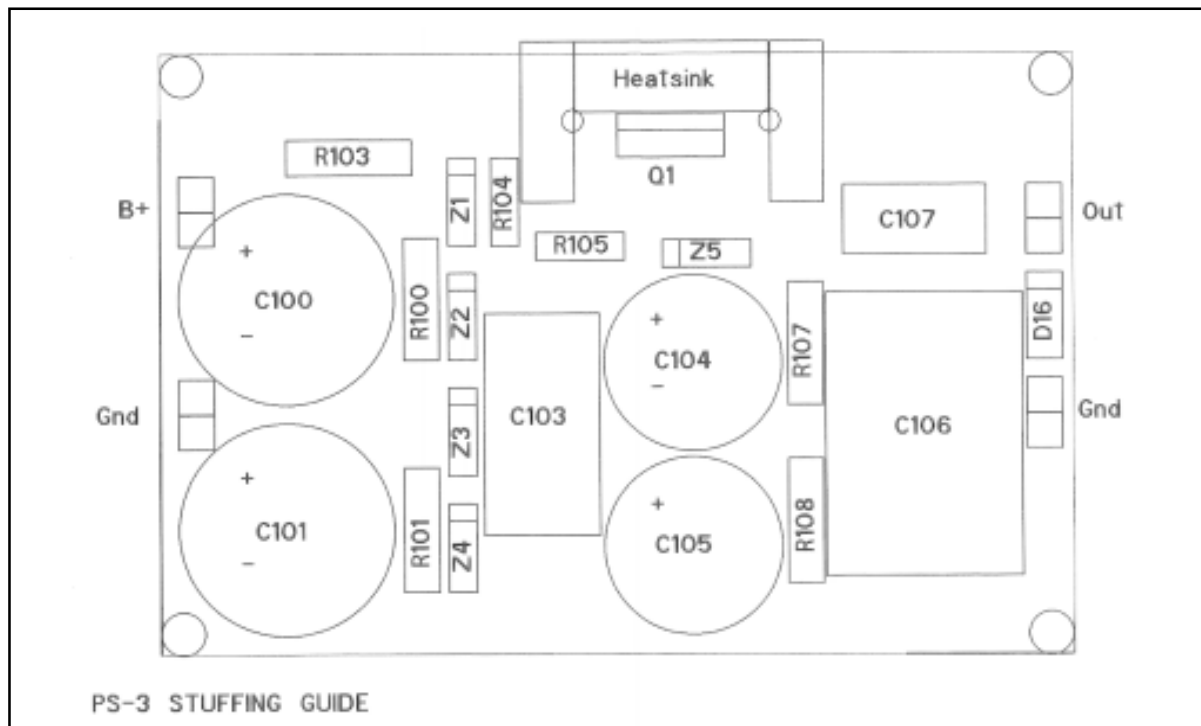
C100,C101	100uf/450V	Panasonic electrolytic capacitor
C103	1.0uf/630V	Solen polypropylene capacitor
C104,C105	68uf/450V	Panasonic electrolytic capacitor
C106	10.0uf/630V	Solen polypropylene film capacitor
C107	.1uf/630V	Solen polypropylene film capacitor

Semiconductors

Q1	2SK1511	MOSFET 1000V 5A
Z1,Z2	1N5378B	100V 5W zener diode
Z3, Z4	1N5383B	150V 5W zener diode
Z5	1N4742A	12V 1W zener diode
D16	1N4007	1000V 1A diode

Miscellaneous

PCB	Printed Circuit Board, Heatsink, Standoffs
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PS-3 Voltage Regulator Stuffing Diagram (Board Dimensions 3.5" x 5")

PS-1 Regulated Power Supply

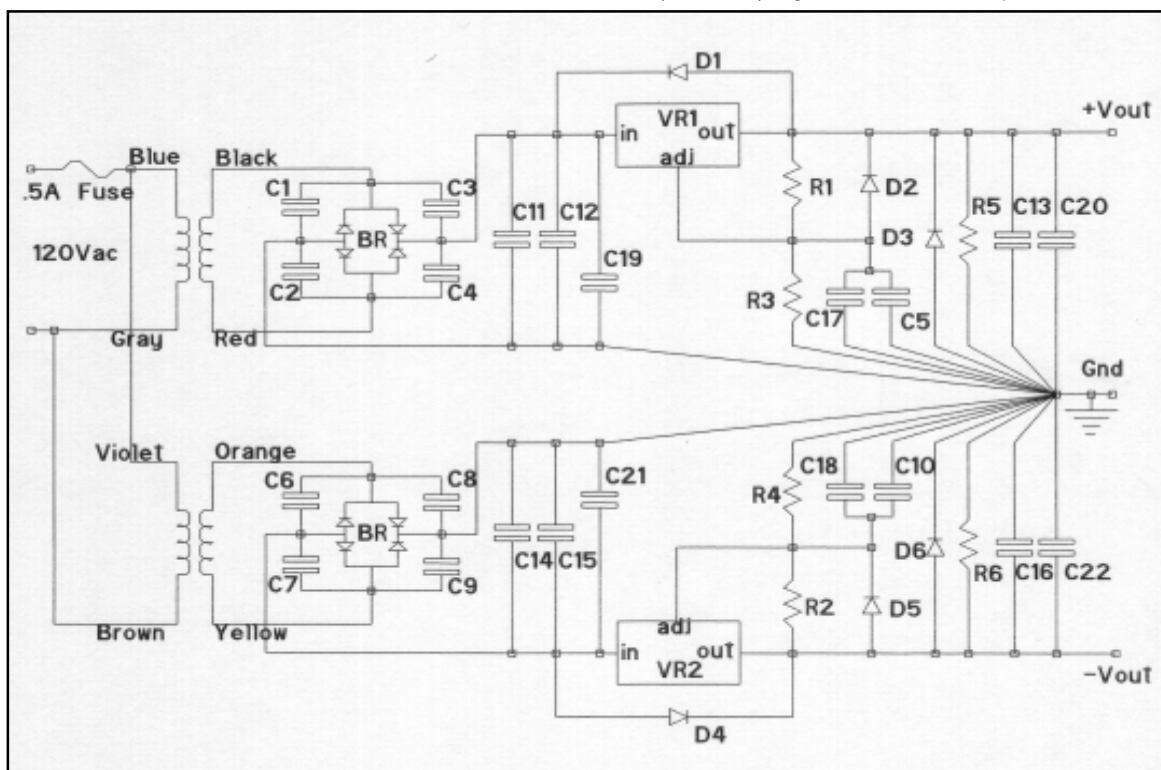
The PS-1 is a high quality low voltage regulated power supply. It is recommended for use with solid state preamplifiers, active crossovers, filters, CD players, and other circuits with low-to-medium current requirements. It is the same supply used in our IOC2 kit. The PS-1's voltage can be fixed from +/- 2 volts to +/- 24 volts by the selection of a few resistors, and its output is capable of supplying up to one ampere of current. The regulators are rated at 3 amps, so if your current requirements are higher than 1 amp, a larger transformer can be substituted without altering the present circuit configuration. The supplied toroid transformer can be used with both 120Vac/60Hz or 240Vac/60Hz operation. The figure below depicts the schematic diagram of the PS-1 circuit. This power supply is similar to the one designed by Walt Jung and Gary Galo and published in TAA and uses the Linear Technologies LT1085CT/LT1033CT voltage regulators. These regulators are low dropout, high efficiency devices highly recommended for audio applications. The main differences between the TAA design and the PS-1 are: The PS-1 uses a smaller VA rated transformer and a lower value output filter capacitance (the 4A transformer was really overkill); More bypass capacitors are used throughout the PS-1 circuit to prevent transients and other supply-related noise from reaching the audio circuitry; we have added the ultra-fast rectifier diodes, and most importantly the PS-1 is less expensive. Several options are available below:

PS-1	(Includes all parts, circuit board, toroidal transformer)	\$150.00
PS-1A	(Includes all parts, circuit board, Less transformer)	\$100.00
PS-1B	(Circuit board only)	\$ 18.00

*** Please specify desired output voltage. Typical outputs available are +/-5V, +/-12V, +/-15V, +/-18V, +/-24V*** and we can provide others, but please specify as this will reduce delays in processing your order.

PS-1 Parts List

C1-C10	0.01uf/63V	WIMA Polypropylene capacitors
C11-C16	2200uf/35V	Elna Electrolytic capacitors
C17, C18	100uf/35V	Elna Electrolytic capacitors
C19-C22	0.1uf/160V	WIMA Polypropylene capacitor
R1,R2,R3,R4	Select	1% Metal film resistor (Roederstein)
R5,R6	1.0 Kohm	1% Metal film resistor (Roederstein)
BR1-BR8	3A/200V	HEXFRED Ultra-Fast rectifier diodes
VR1	LT1085CT	Adjustable positive voltage regulator (Linear Technologies)
VR2	LT1033CT	Adjustable negative voltage regulator (Linear Technologies)
D1-D6	1A/100V	Diode
T1	22+22V/1.5A	Toroidal Transformer
Miscellaneous		heatsinks, one circuit board, 3' each (rd, wh, blk) 18ga teflon coated hookup wire, standoffs



PS-1 Power Supply Schematic Diagram

PS-1 Assembly Instructions

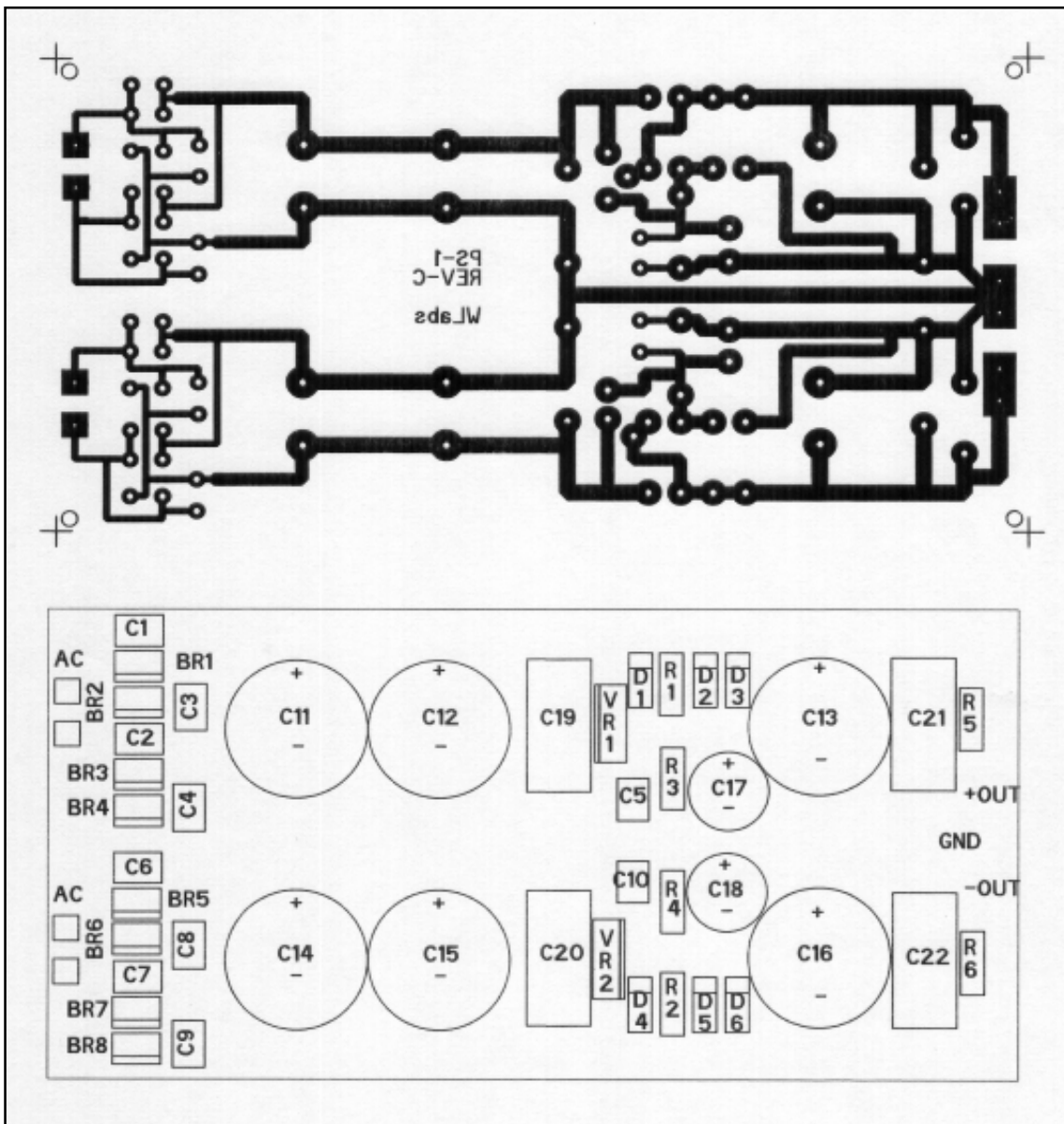
The PS-1 is a small, relatively simple circuit that can be assembled in approximately one hour. Please follow the stuffing guide, Figure 3, and note polarities of the bridge rectifiers, electrolytic capacitors, diodes and voltage regulators.

The following equation can be used to calculate the resistor values required for a specific output:

$$V_{out} = 1.25 (1 + R_3/R_1) + R_3 (50E-6)$$

The table below lists resistor values for several common voltages. If you order our kit, be sure to specify which voltage you will be using, and we will send you the correct values.

Resistance		Voltage	Resistance		Voltage
R1/R2 = 1.00 Kohm	R3/R4 = 2.74 Kohm	+/- 5 Volts	R1/R2 = 0.95 Kohm	R3/R4 = 12.1 Kohm	+/- 18 Volts
R1/R2 = 1.21 Kohm	R3/R4 = 10.0 Kohm	+/- 12 Volts	R1/R2 = 1.91 Kohm	R3/R4 = 33.2 Kohm	+/- 24 Volts
R1/R2 = 1.00 Kohm	R3/R4 = 10.5 Kohm	+/- 15 Volts			



PS-1 Power Supply Stuffing Diagram (Board Dimensions 3" x 6")

PS-5 & PS-5A Power Supply Kits

The PS-5 and PS-5A kits are high quality unregulated power supplies intended for use with the Borbely Class-A Line Amp and the Borbely-Gaertner Active Crossover Kits. These kits have regulation already onboard and therefore require only a raw dc supply. The PS-5 is a single supply consisting of an encapsulated pc-mount toroid power transformer with dual primaries and secondaries, full-wave bridge rectification, and 6600uf of filter capacitance followed by a .1uf MIT polypropylene film & foil capacitor. The PS-5A is a dual-mono supply. The PS-5/PS-5A provides +/- 28 volts of unregulated dc at approximately 750mA.

PS-5	Single +/- 28Vdc Supply	\$110.00
PS-5A	Dual Mono +/- 28Vdc Supplies	\$225.00

PS-5 Part List

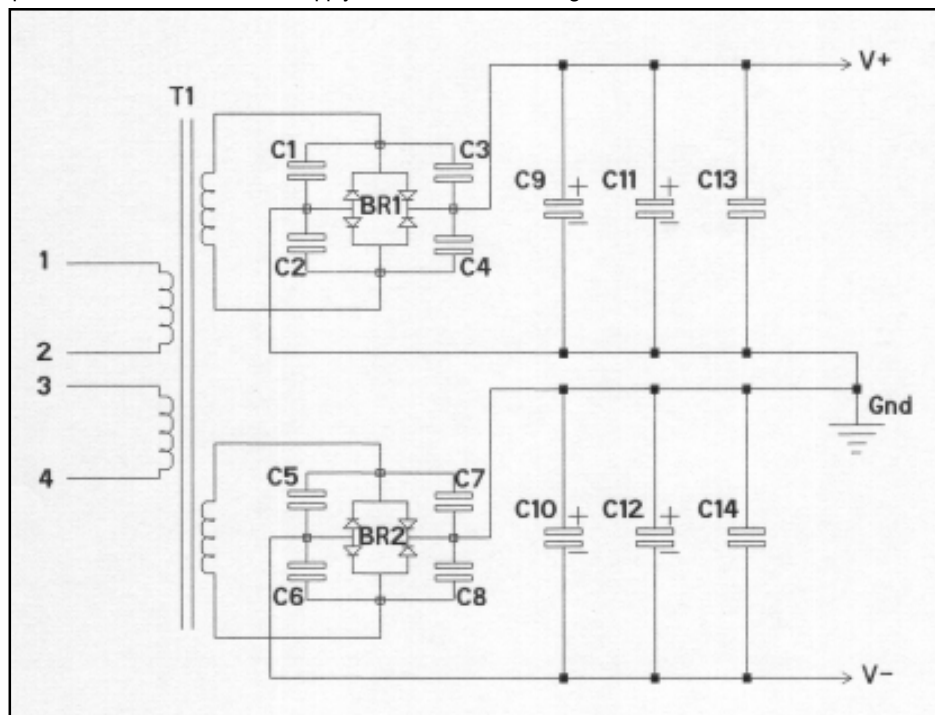
C1 thru C8	.01uf/63V	WIMA Polypropylene Capacitor
C9 thru C12	3300uf/35V	Panasonic Electrolytic Capacitor
C13,C14	.1uf/600V	MIT Polypropylene Film & Foil Capacitor
BR1,BR2	2A/200V	Bridge Rectifier
T1		Encapsulated PC-Mount Toroid Transformer
J1 thru J3		Jumper Wires
Misc		Circuit Board, 18ga. Teflon/Copper Hookup Wire

PS-5A Part List

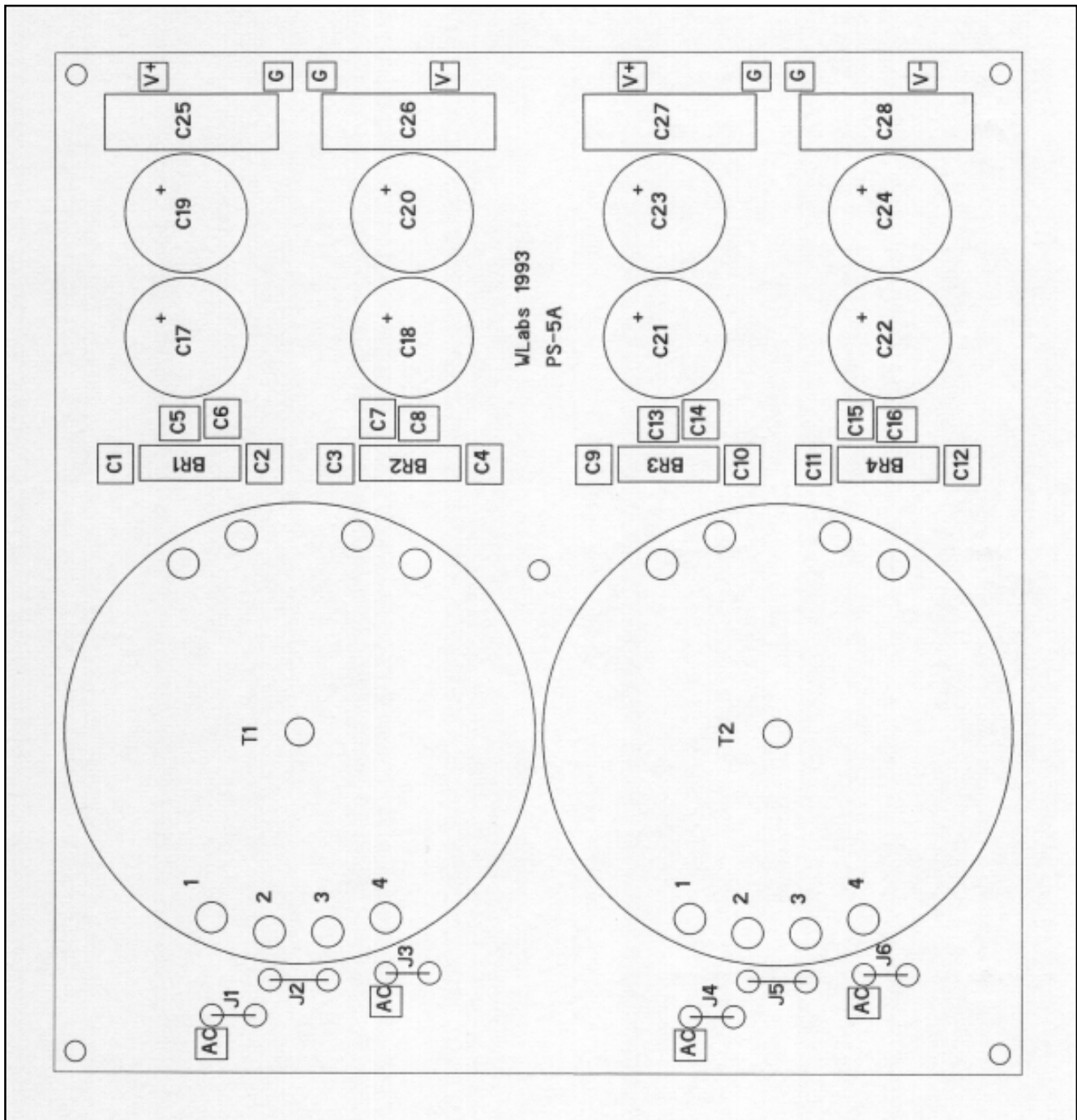
C1 thru C16	.01uf/63V	WIMA Polypropylene Capacitor
C17 thru C24	3300uf/35V	Panasonic Electrolytic Capacitor
C25 thru C28	.1uf/600V	MIT Polypropylene Film & Foil Capacitor
BR1 thru BR4	2A/200V	Bridge Rectifier
T1,T2		Encapsulated PC-Mount Toroid Transformer
J1 thru J6		Jumper Wires
Misc		Circuit Board, 18ga. Teflon/Copper Hookup Wire

Note:

Only jumpers J2 and J5 are used for 230Vac primary operation. For 115Vac primary operation use only jumpers J1, J3, J4, and J6. Only one set of AC inputs is used on the dual mono supply. The other set is tied together via the circuit board traces.



PS-5 Power Supply Schematic Diagram

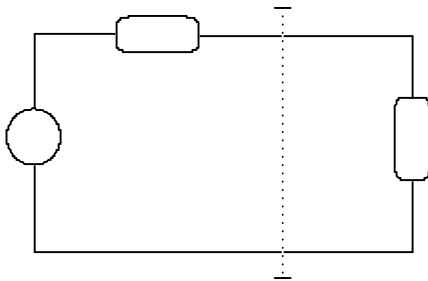


PS-5A Dual Mono Power Supply Stuffing Diagram (Board Dimensions 7" x 7")

The following is a brief discussion on power supplies in general. There are two main areas to consider in power supply design or power supply improvements for audio equipment and they are power supply impedance and noise.

Low Impedance: The ideal power supply would provide an infinite capacity to supply volt/amp (VA) to our load (amplifier/speaker) under any conditions. In order to do this, the ideal supply has to have what I refer to as zero source impedance. In the real world, a power supply has some amount of source impedance and is therefore unable to provide all the current in the world. In fact, the closest we come to an infinite supply would be a power generator on the Hoover dam! And in actuality, the closest we really come to an infinite supply is the output impedance of the closest utility transformer to our home.

What happens when we don't have a perfect supply? A good example is the voltage divider circuit shown below. Consider R_{source} to be our source (power supply) impedance and R_{load} to be our load impedance. Under steady state conditions, the equation for V_2 (the voltage across the load) is given below. Using the values in the figure, we see that under steady state conditions the voltage across the load would be 8 volts. In the ideal power supply, the value of R_{source} would be as close to zero as possible which when plugged into the equation would provide 10 volts across the load R_{load} , which is what we want....we got a 10V supply so we want 10V across the load!...always..forever...



equation:

$$V_2 = \frac{R_{load}}{R_{load} + R_{source}} \times 10V$$

example:

$$V_2 = \frac{8}{8 + 2} \times 10V = 8V$$

ideal condition:

$$V_2 = \frac{8}{8 + 0} \times 10V = 10V$$

Why do we need a low source impedance in a power supply for audio? For several reasons...A low impedance supply contributes to dynamics, perceived bass extension, and reduces distortion. I will elaborate: What happens in a real world system is the load resistance (or impedance) varies with frequency. Or in other words, as music is playing at varying frequencies most speaker's impedance will also vary and this impedance can swing from 2 ohms to 10 ohms for a typical 8 ohm speaker. Well let's see what happens in our voltage divider circuit if the load impedance dips instantaneously to 6 ohms. Plug 6 ohms into the equation for R_{load} and solve for V_2 and we now get 7.5V across the load. How does this effect the music signal you might ask. When the voltage sags because the load impedance dips, it can cause the amplifier to clip earlier than it normally would causing distortion. Also during transients such as kickdrums, orchestra crescendos, etc. the full dynamic impact of these musical events will be lessened if the signal runs up against the voltage rail before it peaks. So in other words crescendos are limited, kick drums don't have that tight punchiness. Another problem incurred is that under typical musical situations the frequent demands are made on the supply and it becomes modulated. i.e. it is not stable because it is constantly varying, this can cause problems as the output stage of a power amp will be causing the supply to modulate and the lower current driver stages will be affected by the voltage rail that is bouncing around. A good experiment to make is to take an old tube amplifier that has not been modified. These amplifiers typically had very wimpy power supplies (i.e. not enough filter capacitance). Put a voltmeter across the voltage rail and put on your favorite disco record (one with a driving bass drum which shouldn't be hard to find since they all have a driving bass drum) and watch the power supply voltage as the music plays. In many cases the voltage will vary by as much as 20 to 50 volts!

But hold on....the real culprit is not the load impedance, or the disco music, it is the source impedance of the power supply!!! Change the value of R_{source} to 0.1 ohms and go back and solve for V_2 using both an 8 ohm load and a six ohm load. Then plug in a 4 ohm load and see what you get for V_2 . Wow, look at the difference...with 8 ohms you get 9.87V, with 6 ohms you get 9.84 V and with 4 ohms you get 9.76 volts. Very little difference with varying loads. If you are really into it, go back and solve for V_2 again using a value of .01 ohms for R_{source} . To cut to the chase, you get almost the same answer 9.98 volts with each load. And 9.98V is about as close to 10V as you can get. So the key to a good stiff power supply is to get the source impedance as low as possible! If the source impedance is low, who cares what the load looks like.

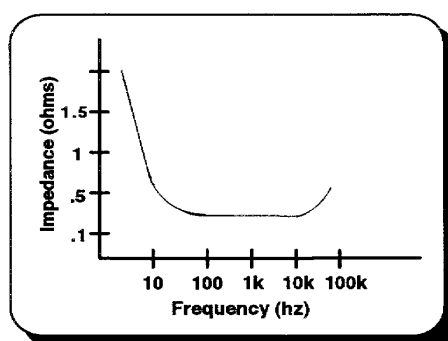
What contributes to the source impedance of a power supply? Many things contribute to the impedance, including: the impedance of the filter caps used, resistance of power supply wiring, resistance of the power transformer windings, and so on. To make matters more complicated, all of these are affected by frequency which I will talk about shortly.

So now that we know what power supply impedance is and what its effects are, how do we go about improving upon it? Simple, we do things to lower the impedance. The easiest method is to increase the power supply capacitance. Capacitors have an internal equivalent series resistance (ESR) which is a component of power supply impedance and contributes to our R_{source} . Typically larger values of capacitance correspond to lower values of ESR. So you can use larger capacitors or use several smaller capacitors in parallel. Placing capacitors in parallel adds capacitance, so for instance if you hookup four 100uf capacitors in parallel you get 400uf total capacitance. But what's really important from a power supply impedance vantage is the ESR decreases because resistance in parallel decreases. For example, let's say the original power supply for a piece of equipment only had one 100uf capacitor. A typical value of ESR for a 100uf capacitor is .5 ohms. So the output impedance of the power supply would be approximately .5 ohms neglecting other items in the supply. Adding three 100uf capacitors to the circuit would be like paralleling four .5 ohm resistors which results in a total resistance of .125 ohms. So just by adding capacitance we have reduced the impedance of the supply by more than an order of magnitude. If you don't have room in your equipment to add extra capacitance replace the capacitor currently used with one than has really good impedance curves. Not all capacitors are created equal! Typically the larger a capacitor is physically per capacitance/voltage rating, the lower its ESR. In the past many people have built huge capacitor banks of paralleled capacitors in order to improve power supply performance. This is OK to a point. A good rule of thumb for choosing the appropriate amount of capacitance for tube amplifiers is to multiply the power output of the amplifier by 20 to 40 times and this is a good range of capacitance to use in micro farads. For example for a 30 watt tube amplifier, multiplying 30 by 40 gives 1200, so use 1200uf of capacitance in the supply. For a 60 watt amplifier, multiply 60 by 30 and get 1800, so use 1800uf. 20 to 40 is a good range, doing more than 40 is overkill (remember the law of diminishing returns). For solid state power amplifiers a good rule of thumb is to multiply the power output by 200 to 400. So for a 150 watt amplifier multiply 150 by 300 and get 45,000 so use 45,000uf per rail (positive and negative).

If you don't have room for a 500V 1800uf capacitor inside your McIntosh MC-60, you might consider a form of cheating called voltage regulation. Voltage regulation is an "active" method of reducing the impedance of a supply by using circuits made up of semiconductor or vacuum tube devices. The active devices, when configured properly, make use of their internal parameters to actually divide the existing circuit impedance by some factor. Our PS3 is an example of a circuit sometimes called a capacitance multiplier circuit. The capacitor on the base of the transistor is effectively multiplied by the hfe of the transistor. So if the transistor has an hfe of 200, then the 100uf capacitor actually looks like a 20,000uf capacitor. But once again it is not really the capacitance that matters but the impedance of the capacitor. Or in other words, instead of calling it a capacitor multiplier circuit, you could call this circuit an impedance divider, because it really divides the impedance of the capacitor by the hfe of the transistor. Are you still with me? So take our 100uf capacitor we used before that had an ESR of .5 ohms. Divide .5 by 200 and you get .0025 ohms!! .0025 ohms is getting pretty darn close to zero. Plug .0025 ohms into our voltage divider circuit for R_{source} and what do we get now.....9.997 volts for an 8 ohm load.....9.994 for a 4 ohm load. That's about as close to 10 volts as you will ever get! You can see that one can control the output impedance of this regulator stage just by varying the capacitor value or by selecting a transistor with a different hfe. Many designs use Darlington transistors which have hfe's in the 1000 range. Divide .5 ohms by 1000 and see what you get! (.0005 ohms). The capacitor multiplier circuit is good for tube amplifiers because of their low current requirements (only a small heatsink is typically required), this circuit topology is also used extensively in tube preamps. A variation of this circuit is our new PS-3 in which we use a mosfet for the transistor.

This circuit does not work as well for solid state power amps because the transistor would need to be able to handle large amounts of current and would therefore require a heatsink the size of the one used for the amp's output transistors. Typically what one sees in solid state power amplifiers these days is a regulated driver stage (low current and easy to do) and a large high-current (10 to 20 amp capacity) power transformer with large filter caps for the output stage. Regulating the output stage is feasible for amps up to about 100 watts, above this it is usually more practical (and easier to implement) to find a big honkin power transformer.

Boy this is easy you say! We can make a power supply with an output impedance of .001 ohms with just a few parts. Well there is a slight twist. As I mentioned above, frequency figures into all of this stuff. A landmark article that addresses this issue as well as regulators, impedance, etc. was published in The Audio Amateur issue x/8x. If we look at just resistance, everything would be cool, but impedance has this frequency thing going on, i.e. the resistance changes with frequency. Or in other words, the impedance of a capacitor or regulator circuit might be great at some frequencies but not so good at others. The figure below shows a typical impedance curve for a capacitor.



As you can see from the curve, the impedance is high at low frequencies and gradually decreases as frequency increases until a certain frequency is reached at which point the impedance starts rising again. No free lunch once again! Typically we would like the impedance to be relatively flat, and low, throughout the audio frequency spectrum. What causes this unflat curve? At the low end of the spectrum, the capacitive element of the capacitors impedance causes the impedance to be high. As we get into the mid frequencies the capacitor looks almost purely resistive in nature (this good), but when we get to the higher frequencies the inductive element of the capacitor (capacitor leads, material, etc.) kicks in and begins to increase the impedance. Very interesting...indeed.

So how can we flatten out this curve? Well on the low frequencies we reduce the impedance by increasing the capacitance and on the high frequencies we reduce the impedance by reducing the inductance. Increasing capacitance is easy to a point (physical size constraints). One technique for reducing the inductance at high frequencies is to parallel (bypass) the power supply electrolytic capacitors with a large film cap. Film caps typically have much lower inductance than an electrolytic, so placing them in parallel will reduce the overall inductance of the circuit. The inductance of a capacitor is more of a mechanical and materials type issue, so capacitor selection is important...i.e. choose "high frequency" electrolytics whenever possible and always keep lead lengths as short as possible between the supply and audio circuit.

Noise: Noise is another important factor in power supplies and this one is much easier to address. The use of "Star" single-point grounds will in most cases eliminate hum. Additionally, the use of high speed diodes will lower the overall noise of the supply by reducing the noise generated from the diodes turning on and off.

Below and on the following pages is a selection guide to help choose appropriate power transformers, rectifiers and filter circuits for power supplies. These equations will provide approximate results. The output voltages and currents will vary depending upon the transformer's secondary impedance, the voltage loss of the diodes and rectifier tubes, the amount of filter capacitance used and the dc resistance of the filter chokes. Equations are provided for resistive loads, capacitive loads and choke loading of the rectifier circuit.

Capacitor loaded rectifier circuits are good for applications where the dc voltage level is not critical and variations in this voltage due to loading are acceptable. Also good if voltage regulation is to be used downstream. For capacitive input loading, be sure to observe the manufacturer's maximum amount of load capacitance for the rectifier tube.

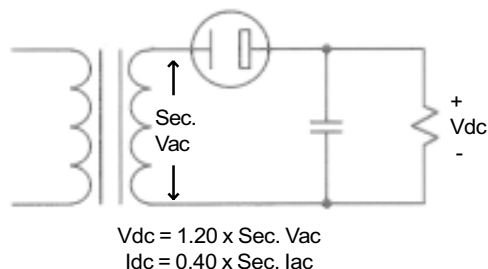
For better performance a choke input filter circuit is required. Choke loaded rectifier circuits will provide better regulation and improved ripple. The dc output voltage will be slightly less but more current is available from a choke loaded supply.

An even better filter topology is called the "pi filter" (see page 48).

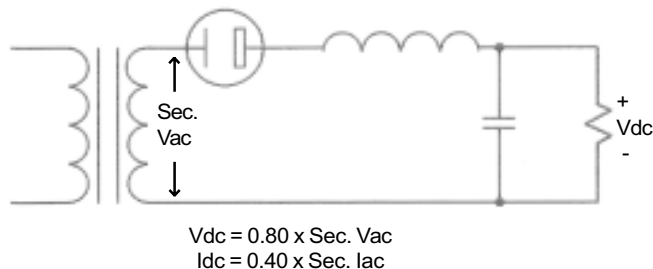
Selection Guide for Choosing Power Transformers, Tube Rectifiers and Filter Circuits

All ac voltages and currents are in R.M.S.

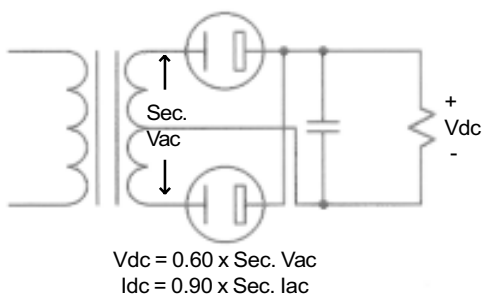
Half Wave w/Capacitor Input Load



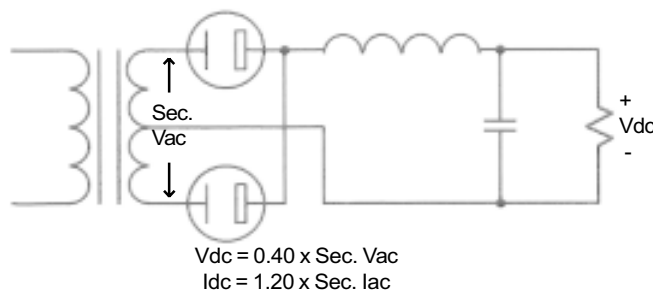
Half Wave w/Choke Input Load



Full Wave w/Capacitor Input Load

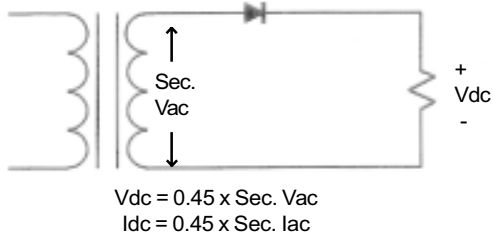


Full Wave w/Choke Input Load

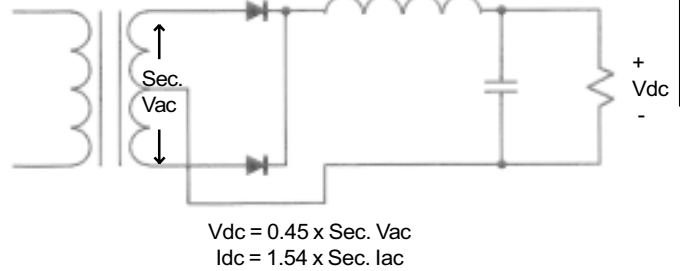


Selection Guide for Choosing Power Transformers, Semiconductor Rectifiers and Filter Circuits All ac voltages and currents are in R.M.S.

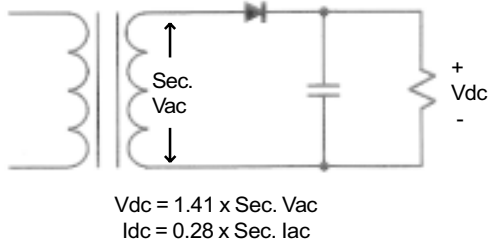
Half Wave w/Resistive Load



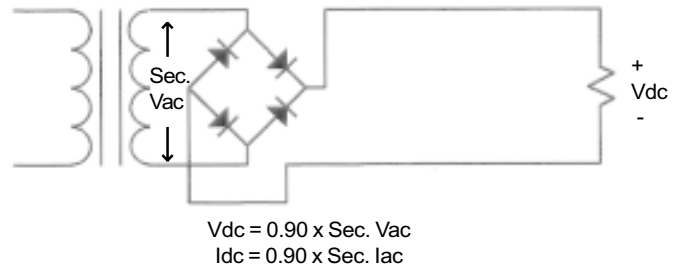
Full Wave w/Choke Input Load



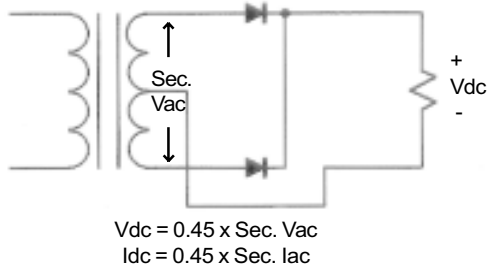
Half Wave w/Capacitor Input Load



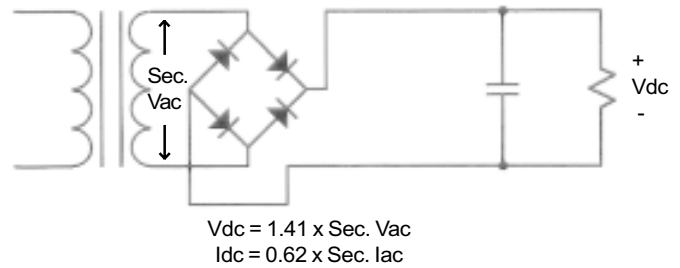
Full Wave Bridge w/Resistive Load



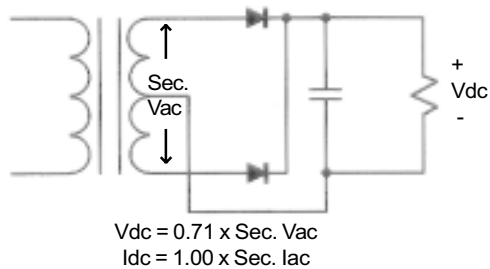
Full Wave w/Resistive Load



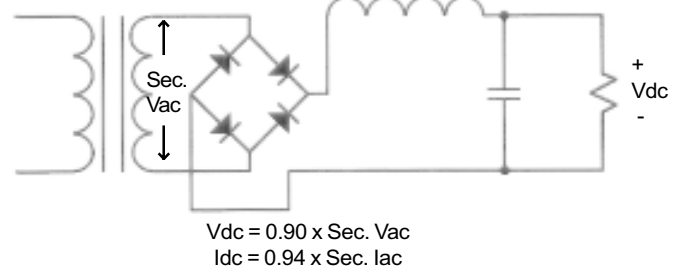
Full Wave Bridge w/Capacitor Input Load



Full Wave w/Capacitor Input Load



Full Wave Bridge w/Choke Input Load



Power Supplies

The "pi filter" reduces the variation of the dc voltage due to loading thereby improving the regulation and ripple level of the power supply output. It is important to minimize the ripple because excessive ripple can be heard as hum and noise in a preamp or amplifier circuit. Below is an equation for calculating the amount of ripple reduction in a pi filter for a full wave rectifier circuit.

$$A = 20 \log \frac{X_c}{X_c + X_L}$$

where A is attenuation in dB
 X_c is capacitor C1's impedance
 X_L is inductor L1's impedance

Example:

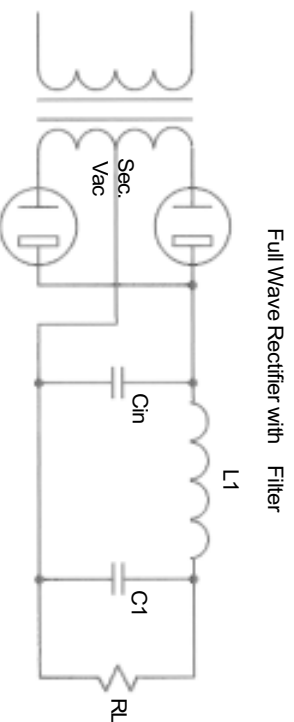
$$\begin{aligned} C_{in} &= 10\mu f \\ C_2 &= 40\mu f \\ L_1 &= 10H \end{aligned}$$

$$\begin{aligned} X_L &= 2 \pi f L \\ &= 2 (120hz)(10H) \\ &= 7540 \end{aligned}$$

$$\begin{aligned} X_C &= \frac{1}{2 \pi f C} \\ &= \frac{1}{2 (120hz)(40\mu f)} \\ &= 33 \end{aligned}$$

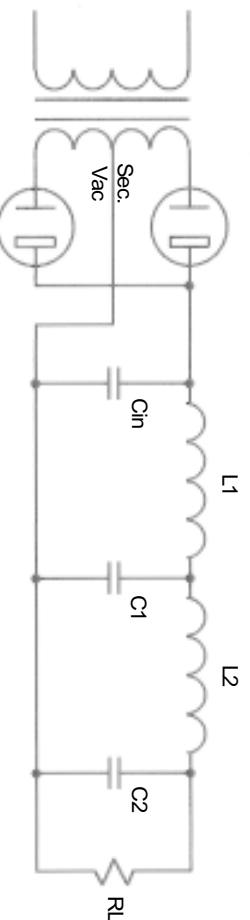
$$\begin{aligned} \text{Therefore: } A &= 20 \log \frac{X_c}{X_c + X_L} \\ &= 20 \log \frac{33}{33 + 7540} \end{aligned}$$

$$A = 20 \log .00434 = -47dB$$



-47dB is a very good level of attenuation. Increasing capacitor C1 to a value of 100uf or 200uf could improve the level of attenuation by as much as -60dB. For even better attenuation, add another pi filter to the circuit to approximately double the level of ripple attenuation.

The pi filter circuit is a unique arrangement in that one can vary the dc output voltage simply by changing the value of the input capacitor Cin. If you look closely at the Vdc output voltages for each of the filter variations on the previous pages you will notice that a choke loaded filter network results in a voltage loss of approximately 30% over a capacitor loaded filter network. By adding an input capacitor Cin to a choke loaded rectifier circuit the output voltage can be adjusted by as much as .80 to 1.2 times the transformer's secondary ac voltage by properly selecting the value of Cin. Depending upon the rectifier tube, the value of 10uf used in our example above will provide close to the full dc output voltage. However reducing Cin to say 1uf could drop the voltage to approximately 90% of the secondary ac voltage. This is a nice design feature as it provides a mechanism for fine tuning circuit voltages without using voltage dropping resistors.



Full Wave Rectifier with Double Filter

Preamps

Preamps

and More

Preamps

More preamplifier modules to have fun with!

The IOC Passive Linestage

The IOC1 is a one input, one output passive control unit. The passive linestage concept allows input/output control without the distortions and non-linear products associated with active amplifier designs. This concept, along with the IOC's component quality, offers the listener a more natural sound capable of greater resolution than most active preamplifiers.

The basic IOC1 is available with Vampire RCA jacks, Kimber hookup wire, plus a Noble potentiometer for the level control. The deluxe IOC1 includes Cardas RCA jacks, Cardas shielded hookup wire, and a Goldpoint series-stepped attenuator for the level control using Holco 1% metal film resistors. The all aluminum chassis measures 2.0"h x 6"w x 6"d, is black textured with an anodized front control panel. All holes are punched and drilled for the chassis.

Basic IOC1 Parts List

Noble Volume Control Please specify potentiometer value 10k, 50k or 100k.
 2 Pair of Vampire M1F RCA Jacks
 Aluminum Knob for Volume Control
 Hookup Wire Plus a Grounding Terminal (Kimber OFC is standard, other hookup wire is optional)
 Silkscreened enclosure

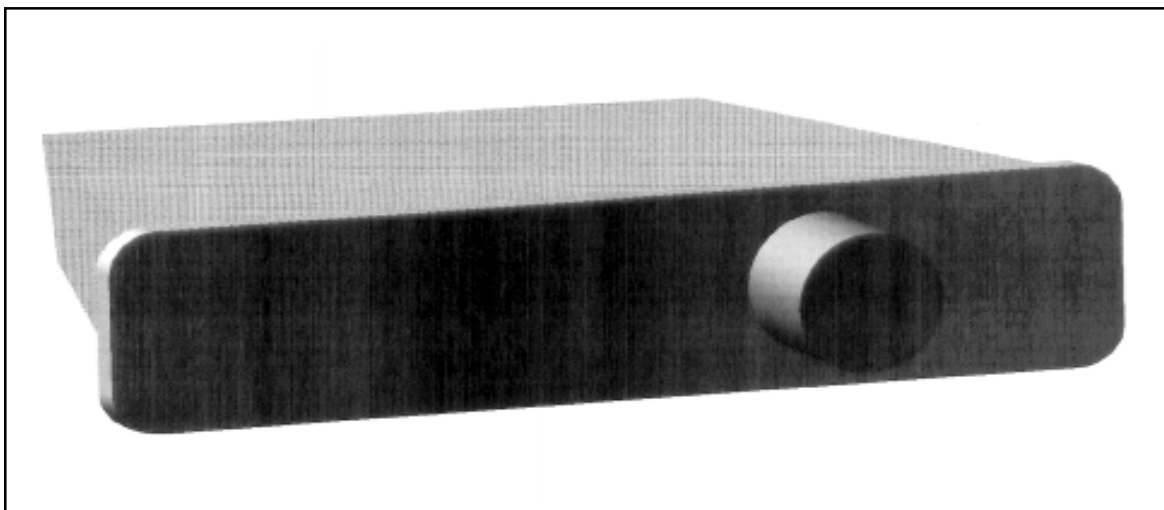
IOC1A-ND	Basic IOC1 as described above...with Noble level control	\$169.00 Kit	\$209.00 Assembled
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Deluxe IOC1 Parts List

Goldpoint Series-Stepped Attenuator Please specify potentiometer value 10k, 50k or 100k.
 2 Pair of Cardas GRFA RCA Jacks
 Aluminum Knob for Volume Control
 Hookup Wire Plus a Grounding Terminal (Cardas sheilded is standard, other hookup wire is optional)
 Silkscreened enclosure

IOC1B-ND	Deluxe IOC1 as described above...with Goldpoint level control	\$299.00 Kit	\$339.00 Assembled
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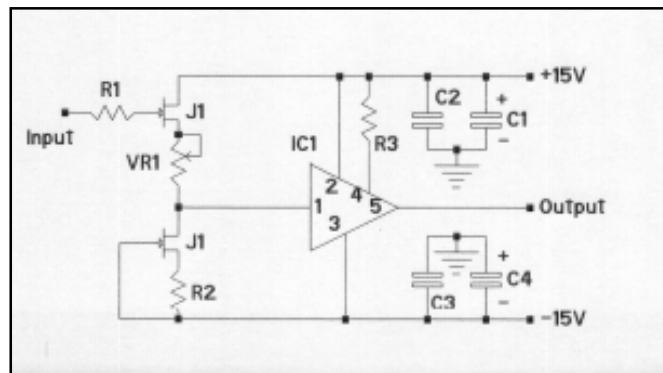
A passive linestage incorporates no active electronic components for amplification such as transistors, opamps, or vacuum tubes. This circuit relies on the gain supplied by the source (CD, tuner, tape, etc.) as being adequately high enough as to not require further amplification. The majority of sources available today provide enough output voltage to drive most amplifiers well into clipping, therefore the sole purpose of the IOC1 is to attenuate, or control, the source's signal. Typically with passive linestages the best sonics are achieved with a low value attenuator such as 10Kohms. This value may not be practical with some vacuum tube equipment and may need to be increased to 50K or slightly more. Passive linestages have highish output impedance's and therefore should not be used to drive, interconnects with high capacitance ratings, or for long runs of interconnect cable between the linestage and amplifier(s). Doing so may result in rolled-off high frequencies. Our Passive Linestages make great entry level kits for those individuals who have never built electronic equipment before, but would like to try.



Unity Gain Buffer Card

This is the Unity Gain circuit using the Linear Technologies LT1010CT buffer that was published in both The Audio Amateur 2/90 and Electronic Design 3/89. The LT1010CT buffer is used in a non-feedback configuration and is biased into Class A operation by selecting the appropriate bias resistor. We have slightly modified the design by using a dual monolithic JFET device (2SK389BL) on the input thereby eliminating the need to match the JFETS. We use this circuit in our IOC2 Compleat Buffered Linestage and through our listening tests feel that it provides a better bass response than the Precision Monolithics BUF-03 buffer used in Corey Greenberg's (Stereophile) control unit. When used in conjunction with our PS-1 regulated supply, this unit provides superb sound quality and can easily drive long lengths of interconnect cable. According to The Audio Amateur article this buffer has an open loop THD of approximately 0.02%. This circuit can be used anywhere there is a requirement for unity gain or impedance matching and is very useful in tape loops, CD outputs, preamps, etc.

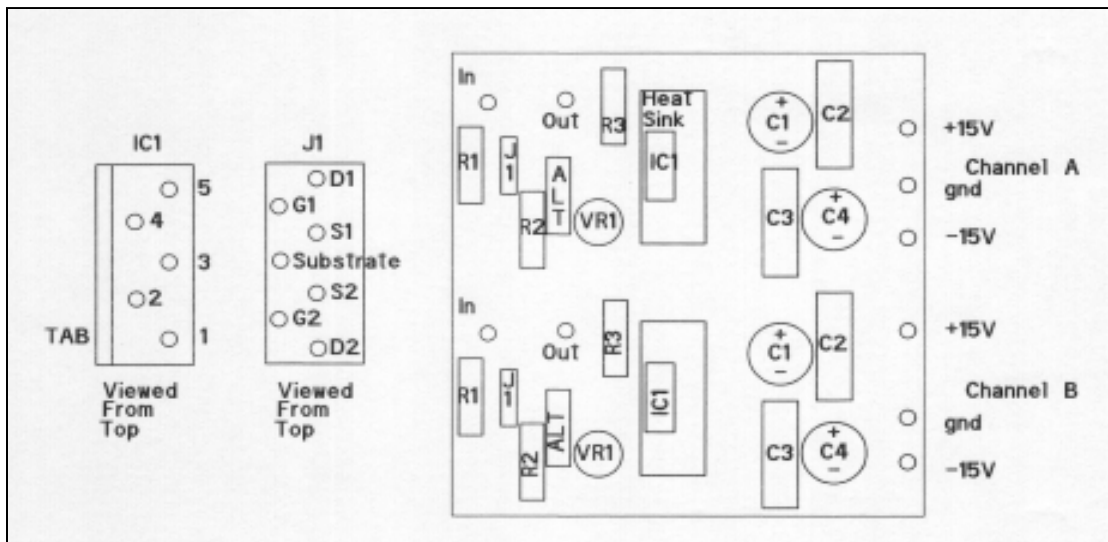
BUF-1	Includes all items in parts list below for one stereo buffer circuit	\$ 60.00
BUF-1A	BUF-1 with Caddock Resistor/MultiCap Capacitor Upgrade	\$ 96.00
BUF-1B	Circuit Board Only (Stereo)	\$ 12.00
LT1010CT	Linear Technologies Buffer	\$ 7.00
2SK389	Dual Monolithic JFETS	\$ 5.00

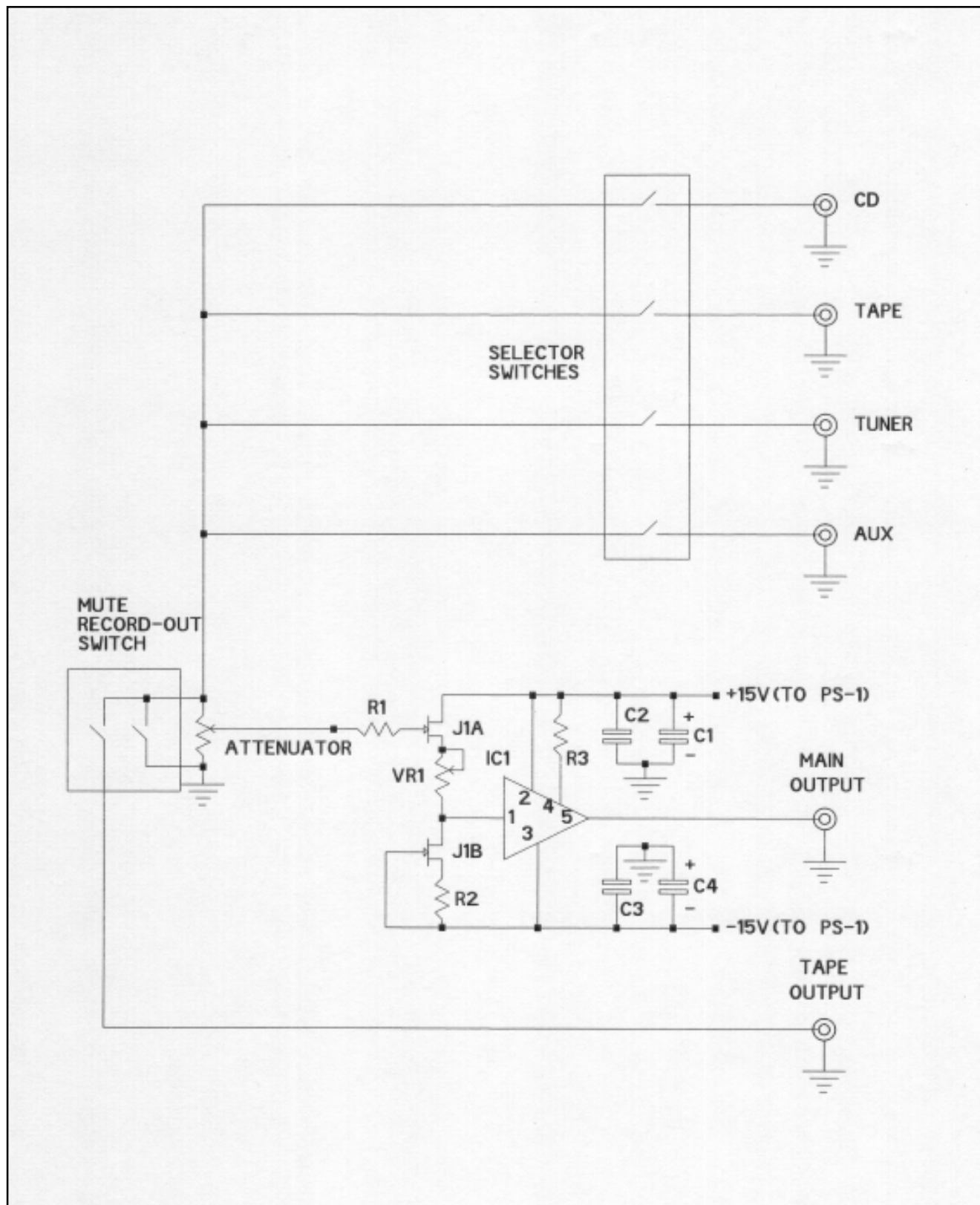


Buffer Parts List

R1A,R1B,R2A,R2B	1.00kohm 1/2 watt 1% Roederstein metal film resistors (Caddock)
R3A,R3B	45 ohm 1/2 watt 1% Roederstein metal film resistor (Caddock)
VR1A,VR1B	5kohm Cermet trim pot (can be replaced w/fixed metal film resistor, ~1.2kohm)
C1A,C1B,C4A,C4B	100uf 63V Panasonic Electrolytic capacitors
C2A,C2B,C3A,C3B	0.1uf 160V WIMA Polypropylene capacitors (MultiCap)
J1A,J1B	2SK389 Dual monolithic JFETS
IC1A,IC1B	LT1010CT Unity Gain Buffer (Linear Technologies)
MISC	One 3" x 3" Printed Circuit Board, two Heatsinks and Hardware

Channel A partslist is identical to channel B, kit and circuit board are stereo. () Indicates parts included in the Caddock/MultiCap upgrade option.





Buffered Linestage Layout (one channel shown)

Dual Class-A Line Amp

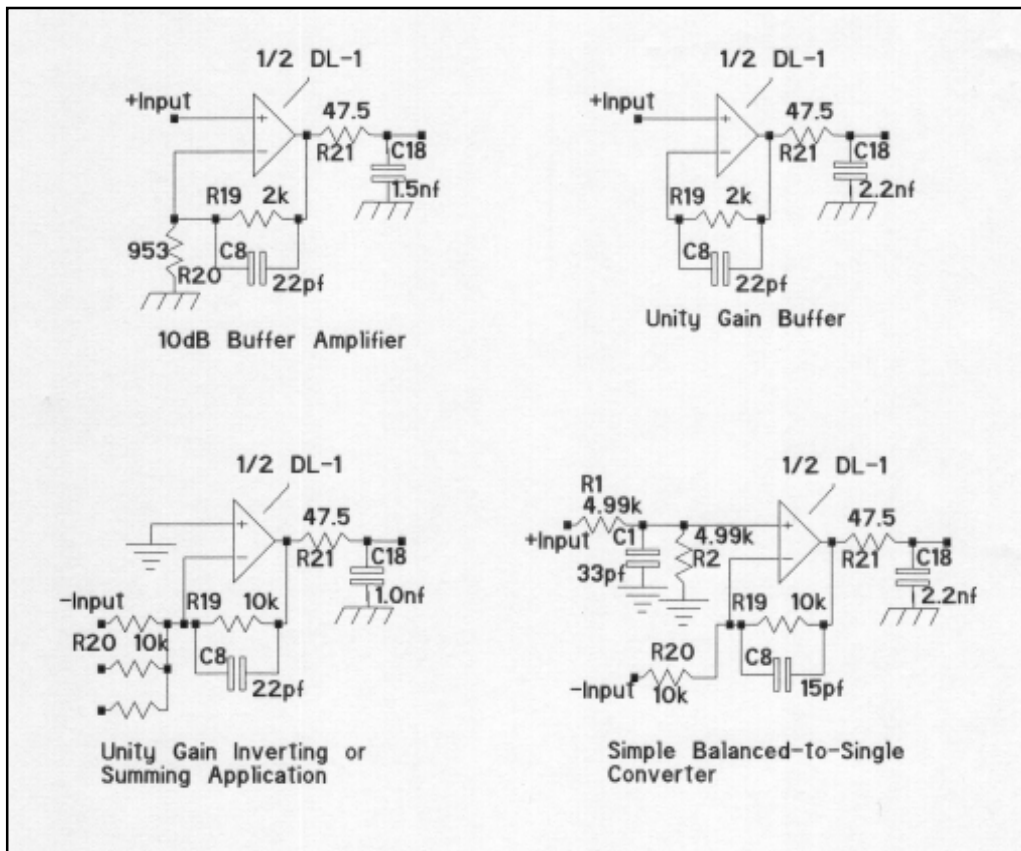
The Dual Class-A line amp, designed by Erno Borbely, is a very high quality preamplifier module that can be operated as a single-ended unit or in a balanced or semi-balanced configuration. This is the circuit we use in our IOC3 Compleat Class-A Linestage and we are offering it here to be used in your own custom applications. For the most part, the Lineamp is a very high quality, discrete class-A operational amplifier. The amplifier has very good open-loop linearity at high frequencies, is extremely stable, and has a total harmonic distortion figure that's so low, it's not even measurable on most equipment. Other specs include an input noise of approximately .65 μ V, output impedance of 75 ohms at 20khz and a slew rate of around 100V/ μ sec.

The Dual Class-A line amp is two separate amplifier stages on one circuit card and there are separate voltage regulators for each amplifier stage. You can use the two halves as single-ended line amplifiers, one for each channel, each with its own regulation. Or you can use the two halves for one channel in a balanced amplifier, in which case you have the choice of using a single regulator for both amps or separate ones for each. We recommend that you use our PS-5 or PS-5A unregulated supplies with the Dual Class-A line amp. The Dual Class-A line amp is a very versatile amplifier and can be used for many applications as demonstrated in the schematics of the following figures.

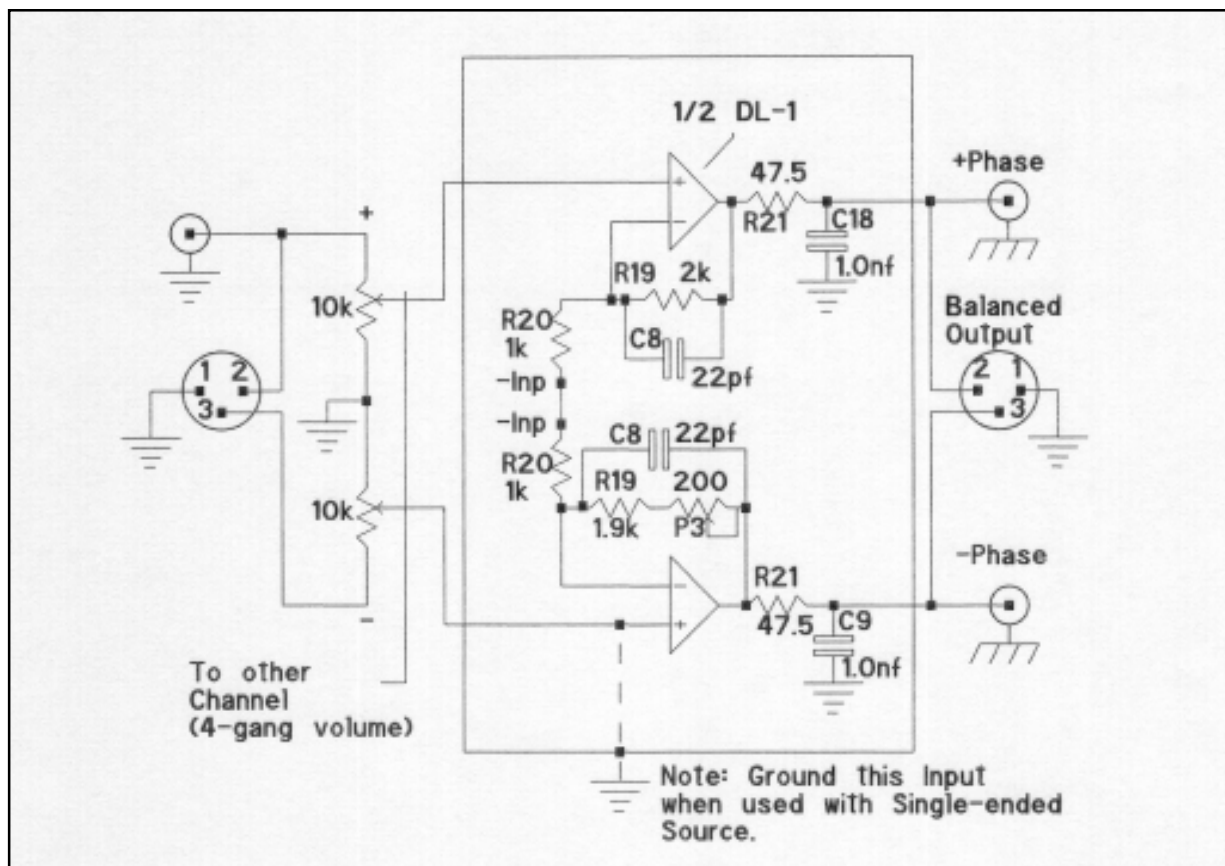
The Dual Class-A line amp is sold as a dual amplifier for normal stereo operation. Two boards are needed for balanced operation, see below. Each kit includes all components necessary for proper operation and all components are individually packaged in plastic bags and marked with their reference designators.

DL-1	One dual class-A line amp: includes all parts and circuit board for one stereo amplifier.	\$190.00
DL-2	One dual class-A line amp: includes all parts and circuit board less on-board regulators.	\$165.00
DL-3	Circuit board only	\$ 18.00

*Note: For your reference, the Dual Class-A line amp carries the Borbely Audio designation of EB-1190/123. The EB-1190/123 design is the property of Erno Borbely. Commercial use of the design is not authorized without license agreement with Erno Borbely.



Dual Class-A Line Amp Applications



Dual Class-A Line Amp Configured for Balanced Operation

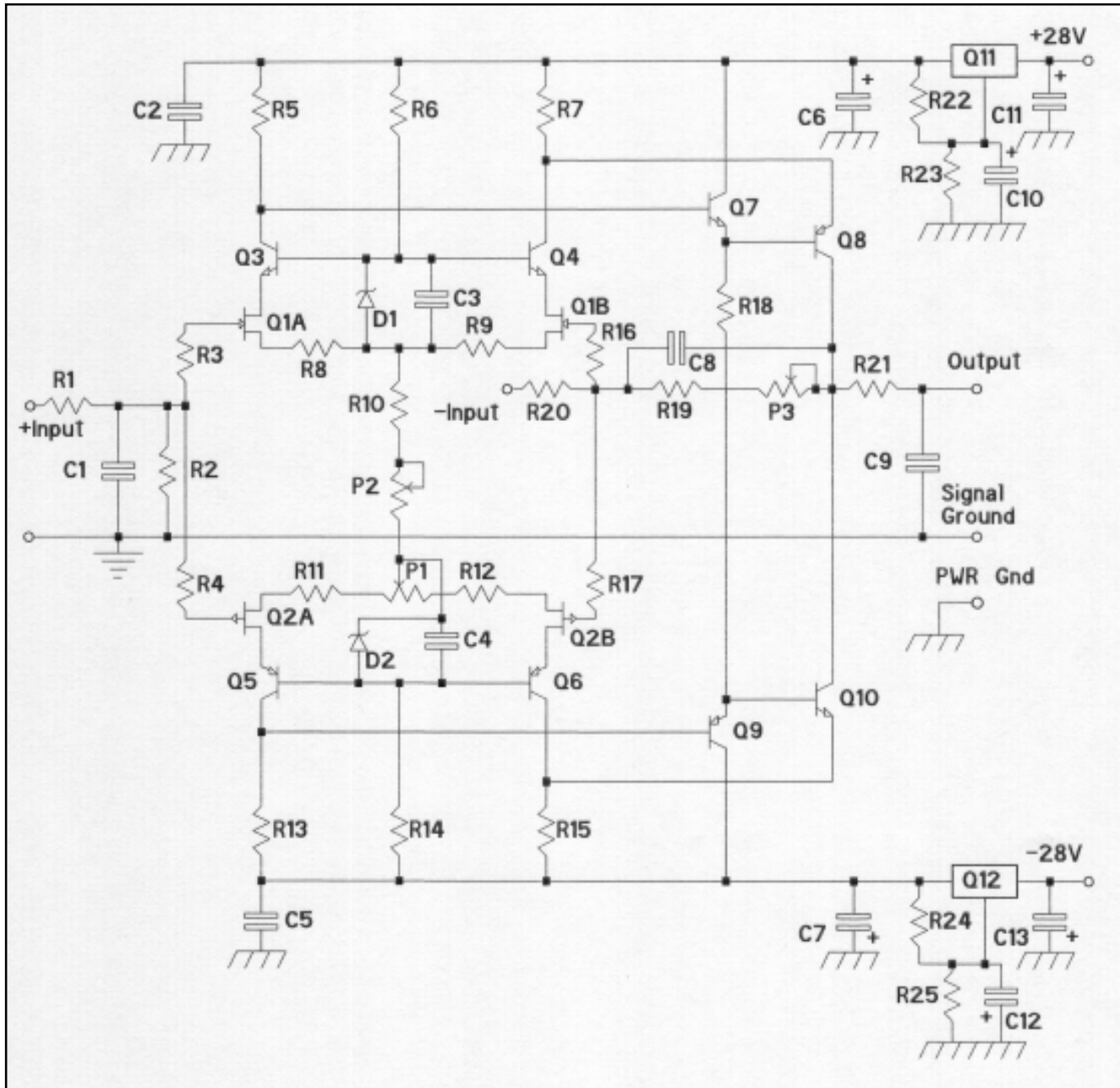
Dual Class-A Line Amp Parts List (parts for one amplifier only)

R1, R3, R4, R7, R8, R9, R15, R16, R17	100 ohms	1/2 watt Holco metal film resistors
R2	1.0Mohms	
R5, R13	1.5kohms	
R6, R14	22.1kohms	
R10	10ohms	
R11, R12	75ohms	
R18	10kohms	
R19	2kohms	(1.91k, when P3 is used)
R20	953ohms	(for 10dB gain)
	1k or 2k	(for Converter/Balanced operation)
R21	45ohms	
R22, R24	121ohms	
R23, R25	2.21kohms	
P1	50ohms	Multi-turn Cermet
P2	200ohms	Multi-turn Cermet
C1	100pf/630V	WIMA polypropylene
C2, C5	0.1uf/160V	WIMA polypropylene
C3, C4	0.1uf/100V	WIMA polypropylene
C6, C7, C10, C12	47uf/63V	Panasonic low impedance Electrolytic
C8	22pf/630V	Siemens Polypropylene
C9	1500pf/630V	WIMA polypropylene
C11, C13	10uf/63V	Panasonic low impedance Electrolytic

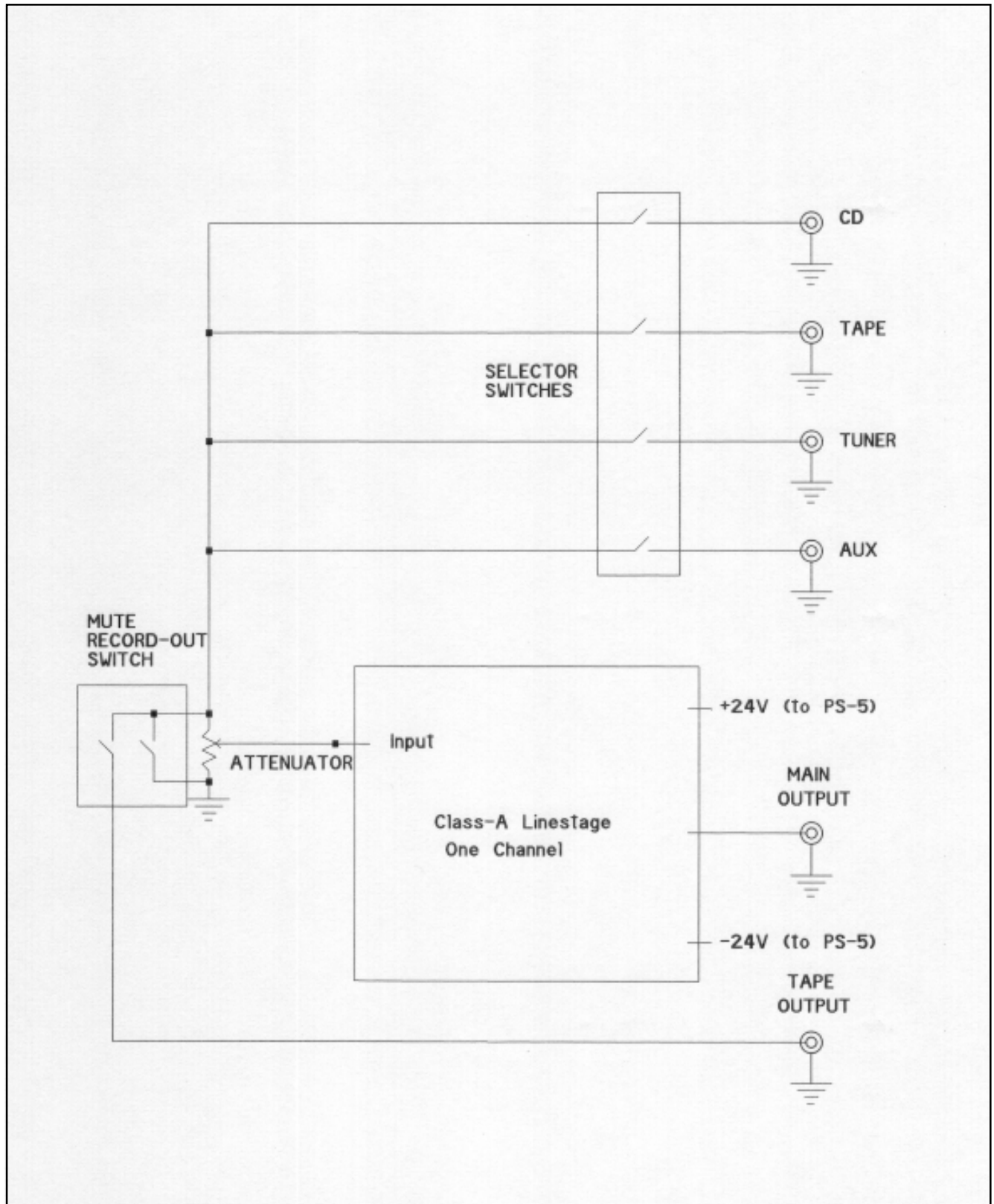
Parts List continued on next page

Dual Class-A Line Amp Parts List cont'd

Q1A, Q1B	2SK389BL/V/GR	(Q1 and Q2 must have the same I_{BSS} group.
Q2A, Q2B	2SJ109BL/V/GR	(Q1 and Q2 must have the same I_{BSS} group.
Q3, Q4	2SC3381GR/BL	(or 2x2SC1775)
Q5, Q6	2SA1349GR/BL	(or 2x2SA872)
Q7	MPSA06	
Q8	2SA1306	(TO-220, BCE-pinout)
Q9	MPSA56	
Q10	2SC3298	(TO-220, BCE-pinout)
Q11	LT1085CT	Linear Technology positive voltage regulator
Q12	LT1033CT	Linear Technology negative voltage regulator
D1, D2	LM336Z-2.5	Voltage Reference
Miscellaneous		Heatsink for Q8 and Q10, Circuit Board



Class-A Line Amp Schematic Diagram



Class-A Linestage Layout (one channel shown)

Fun Projects

The following are a group of projects which we have built, tested and listened to. They are all great sounding units and well worth the effort. We have included a parts list for each one with small budgets in mind. Of course you can always upgrade the parts quality for a high performance product. Not a lot of detail included here so feel free to call if you have questions.

A Headphone Amp

A Single Tube Parafeed Amplifier or Headphone Amp

A 2A3 Push Pull Amp

Laurel 52B

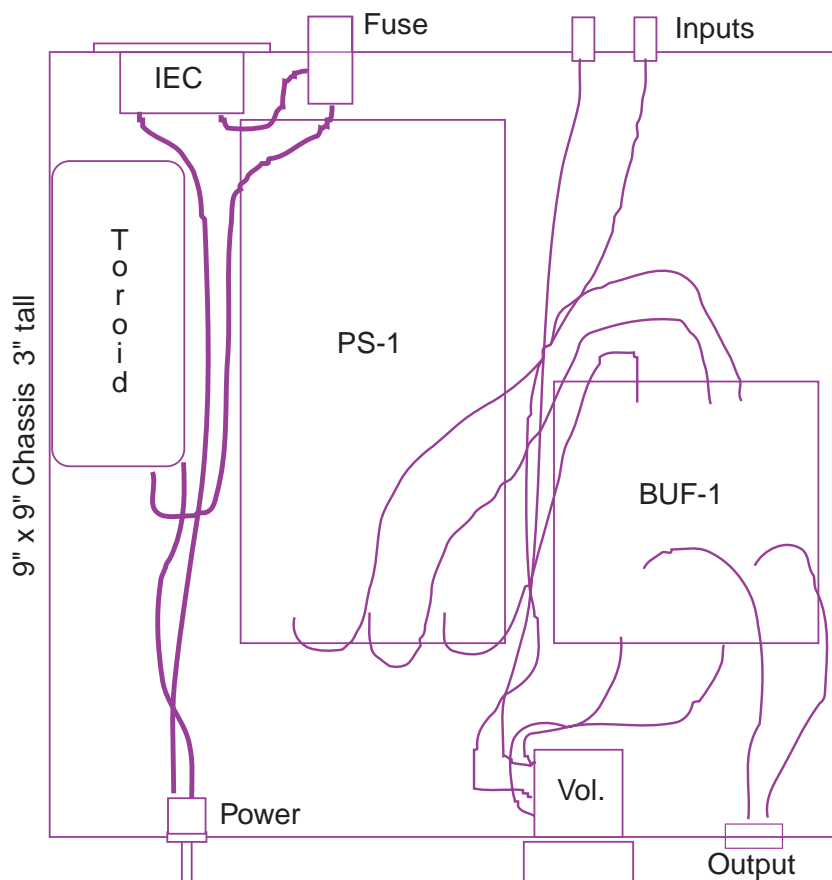
The Headphone Amp (actually it's a headphone buffer)

The Headphone Amp consists of our BUF-1 unity gain buffer card, and the super high quality PS-1 regulated power supply (no wall warts with this baby) dropped into one of our PFT chassis. Add a volume control, rca input jacks and a headphone jack and you're listening to your favorite tunes within minutes. OK, it takes about one evening to assemble. We'll even punch the holes in the chassis for you. This amp has no gain but lots of current drive and should handle most headphones without any problem. We've tried it out with a pair of Grado headphones driven directly by a CD player or tuner and it sounds great! And it's dead quiet too! No hiss, no buzz, no hum, just music.

Parts List

50K Noble Stereo Volume Control	\$ 24.00
Aluminum Knob for Volume Control	\$ 8.50
1 Pair of Vampire M1F RCA Jacks	\$ 11.95
Stereo Phono Jack	\$ 3.50
1 On-Off Power Switch/Fuse Holder and Fuse	\$ 5.75
1 BUF-1 Unity-Gain Buffer Circuit Kit	\$ 60.00
1 PS-1 Regulated Power Supply Kit (Includes torroid transformer)	\$125.00
Kimber Kable Hookup Wire	\$ 3.00
Grounding Terminal	\$ 1.00
Power Cord w/IEC Connector	\$ 14.00
3" x 9" x 9" Enclosure (includes Rub-on Labels, Rubber Feet, Hardware, etc.)	\$ 76.00

Subtotal	\$332.70
10% Discount	- \$ 33.27
Total	\$299.43



A Single Tube Parafeed Amp

This design is intended to be a driver stage for my new SE 25 watt VV52BX (or possibly Vacuum Transistor) power amp. While waiting for Electra Print to wind the high current output transformers I decided to prototype the driver circuit and take measurements. Then, I remembered I just happened to have a pair of Magnequest's TFA-2004 parafeed pinstripe output transformers laying around as well as a pair of his EX0-03 plate load chokes so I said, "what the hell...I'll make a single tube flea-powered parafeed out'a the thing and see what this circuit actually sounds like."

The driver tube is a 6EM7/6EA7 which is a glass octal dual triode originally designed for use as a combined vertical-deflection amplifier and oscillator in television receivers. Unit No. 1 is spec'd with a μ of 64 at 1.5 watts and Unit No. 2 with a μ of 5.4 at 10 watts. With these spec's the tube looked like a good candidate for both voltage swing and current drive. The second section of the tube has a plate resistance of 750 ohms which is perfect because I plan to use an interstage transformer between the driver stage and VV52BX output tube so the low plate resistance will help out in the bandwidth department.

As designed, this parafeed amp produces 3 watts of output power with frequency response measurements that are down 3dB at 2Hz and 42kHz. Plenty of power for my Medallion II speakers. I used Motorola ultrafast rectifiers in the power supply because this same supply will eventually be required to power the VV52BX tube which is capable of current peaks approaching 8 amps. I didn't want a tube rectifier squelching this power capability. I also rectified the filaments for the 6EM7. With ac filaments I measured 1.5mV of hum on the outputs which is unacceptable for me, so I went the dc circuit. With dc filaments the measured output hum is less than 0.4mV. Now the only noise heard through my Lowther PM2As is tube hiss.

Sonically, this circuit is awesome. In fact, it gave my Moondog 2A3 amps a run for their money. It really added more life to vocals and the midrange might actually be a little sweeter than the 2A3s. The Moondoggy amps held up better under heavy demands though with the bass being more solid and better defined. All in all this turned out to be a great little amplifier and with a little massaging it should easily blossom into a nice sounding driver stage too.

While not proto-typed at the time I'm writing this (waiting for the Electra Print OPTs) the plan is to replace the TFA-2004s with an interstage transformer. Nothing in concrete yet on the interstage transformers but I will be auditioning units from Magnequest, Electra Print and Lundahl. The interstage transformer will directly drive the KR Enterprise VV52BX tube which will be driving the Electra Print VT2KB output transformer. The VV52BX will be operating at approximately 150-170mA with a plate potential of 400V which should provide a power output in the neighborhood of 20 to 25 watts. If I'm able to lay my hands on a pair of the Vacuum Transistors the above current would need to be doubled and I would have to step up to Electra Print's big bruiser E48B output transformer. But I'll cross that bridge if and when I get to it.

While messing around with this circuit, I tried direct coupling the two halves of the 6EM7 but lost too much voltage swing to get any kind of output power from the parafeed amp. A direct coupled design might provide enough swing to drive the 52BX so I will most likely revisit this configuration, however I fear I will need all the voltage swing I can get in order to obtain 25 watts. If necessary, I can live with one capacitor in the signal path...they sometimes make a nice tone control if you know what I mean. I'll also be able to backoff on the current through the No. 2 half of the 6EM7 from 40mA to 30mA or maybe even 20mA since once again I will be driving a tube instead of a speaker.

This little parafeed amp might make a killer headphone amplifier too...hmmm.

A Single Tube Parafeed Amp Parts List

Resistors

100K x 2	1/2W	Allen Bradley Carbon Comp	\$ 1.50
1.0K x 2	1/2W	Allen Bradley Carbon Comp	\$ 1.50
330K x 2	1/2W	Allen Bradley Carbon Comp	\$ 1.50
100K x 2	2W	Allen Bradley Carbon Comp	\$ 3.50
220K x 2	2W	Allen Bradley Carbon Comp	\$ 3.50
1.0K x 2	12W	Mills Wirewound	\$ 10.00
33K x 2	12W	Mills Wirewound	\$ 10.00
2.0K x 2	12W	Mills Wirewound	\$ 10.00

Capacitors

100uf x 2	35V	Elna Cerafine	\$ 1.20
100uf x 2	100V	Elna Cerafine	\$ 4.00
10uf x 2	400V	Solen	\$ 9.30
10uf x 2	600V	Solen	\$ 10.50
10uf x 2	400V	Solen	\$ 9.30
0.1uf x 2	450V	Jensen	\$ 24.00
100uf x 100uf x 2	500V	Elna Cerafine	\$ 56.00

Diodes x 2	6A/1200V	Ultrafast Diodes	\$ 8.00
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Sockets x 2		Octal Tube Sockets	\$ 4.50
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6EM7 x 2		Triode Tube	\$ 16.00
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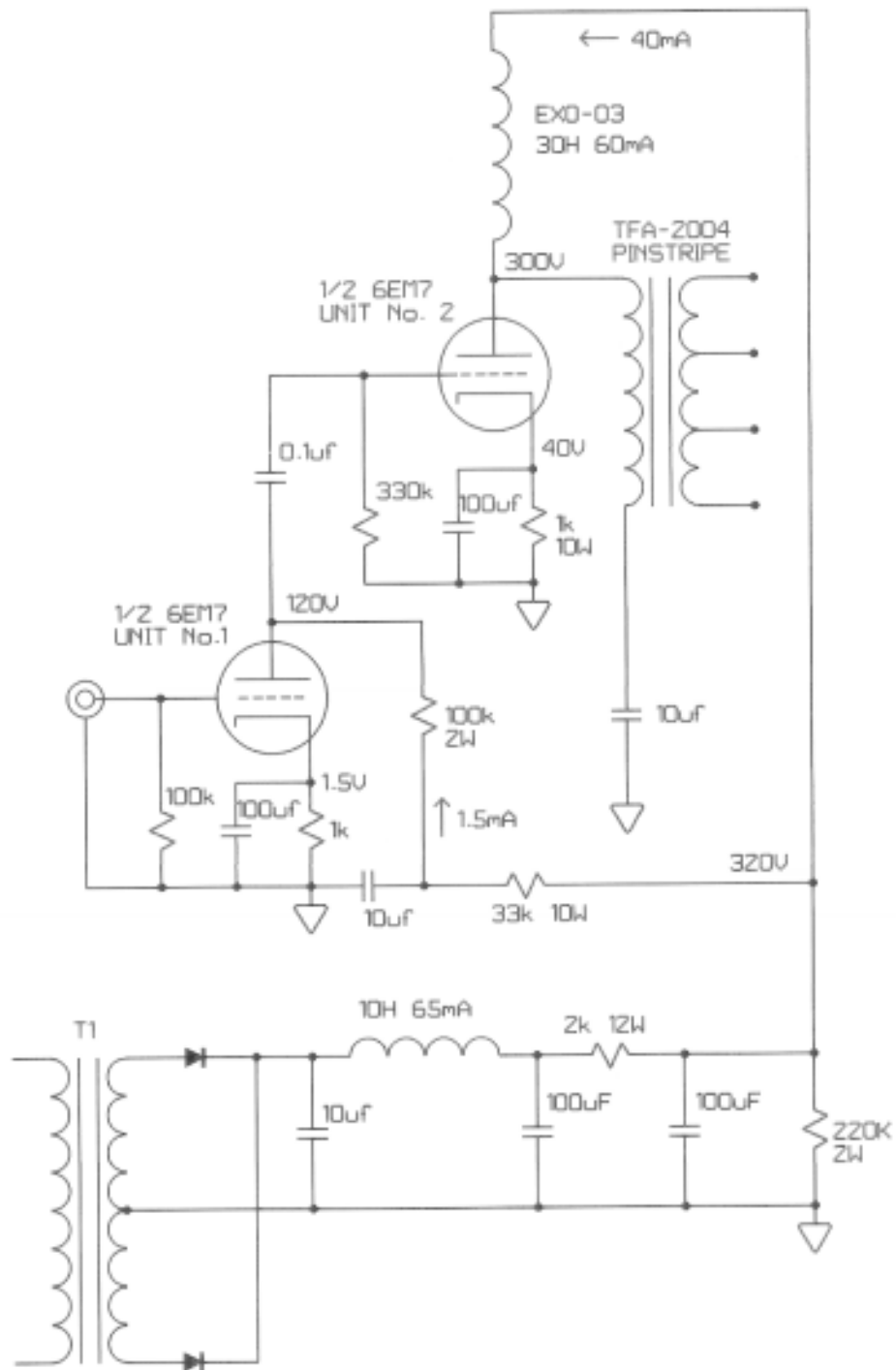
Misc x 2		Power Switch, IEC, Power Cord Hookup Wire, Fuse Holder, Fuse	\$ 28.00
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RCA x 2		Vampire RCA Jacks	\$ 12.00
Posts x 4		Vampire Binding Posts	\$ 30.00

T1 x 2		Hammond 278BX	\$160.00
10H x 2		Hammond Choke 157J	\$ 24.00
EXO-03 x 2		Magnequest Choke	\$130.00
TFA-2004 x 2		Magnequest Output Transformer	<u>\$198.00</u>

Subtotal	\$766.30
10% Discount	- \$ 76.63
Total	<u>\$689.67</u>

\$689.67...not bad for a pair of 3 watt monoblocks. Of course this price doesn't include the chassis. Be creative and you can probably pull something together for under \$800.00. Or make it into a stereo amp and save a few bucks.



A 2A3 Push Pull Amplifier

It has been a few years since I first built this amplifier. It makes for a very sweet sounding piece of equipment. The somewhat front-to-end symmetrical design along with the use of no feedback provides for a very quick and detailed response. The 2A3s add that nice triode sound that sucks you into the music and the push pull outputs add a touch more control on the bottom end than you would normally get from an SE amp.

Resistors

1M x 2	1/2W	Allen Bradley Carbon Comp	\$ 1.50
1.0K x 6	1/2W	Allen Bradley Carbon Comp	\$ 4.50
200 x 2	1/2W	Allen Bradley Carbon Comp	\$ 1.50
470K x 12	1/2W	Allen Bradley Carbon Comp	\$ 9.00
150 x 4	1/2W	Allen Bradley Carbon Comp	\$ 3.00
1.8K x 2	1/2W	Allen Bradley Carbon Comp	\$ 1.50
100K x 8	2W	Allen Bradley Carbon Comp	\$ 14.00
22K x 4	2W	Allen Bradley Carbon Comp	\$ 7.00
1.8K x 4	12W	2 in Parallel Mills Wirewound	\$ 20.00

Capacitors

100uf x 2	35V	Elna Cerafine	\$ 1.20
100uf x 2	100V	Elna Cerafine	\$ 2.40
20uf x 4	400V	Solen	\$ 29.00
22uf x 4	630V	Solen	\$ 17.70
0.1uf x 6	450V	Jensen	\$ 72.00
0.33uf x 2	450V	Jensen	\$ 56.00
100uf x 100uf x 2	500V	Elna Cerafine	\$ 56.00

Sockets x 6	Octal Tube Sockets	\$ 13.50
Sockets x 4	4 Pin Tube Sockets	\$ 20.00

6SL7 x 2	Triode Tube	\$ 20.00
6SN7 x 2	Triode Tube	\$ 20.00
2A3 x 4	Triode Tube	\$ 68.00
5V4G x 2	Triode Tube	\$ 20.00

Misc x 2	Power Switch, IEC, Power Cord Hookup Wire, Fuse Holder, Fuse	\$ 28.00
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RCA x 2	Vampire RCA Jacks	\$ 12.00
Posts x 4	Vampire Binding Posts	\$ 30.00

T1 x 2	Hammond 273BX Power Transformer	\$132.00
166Q2 x 2	Hammond 2.5Vct @6 Amp filament	\$ 44.00
CH x 2	Hammond Choke 193D	\$ 80.00
1650K x 2	Hammond PP Output Transformer	<u>\$210.00</u>

Subtotal	\$973.80
10% Discount	- \$146.07
Total	<u>\$827.73</u>

This price doesn't include the chassis. You can probably pull something together for under \$1000.00. Or make it into a stereo amp and save a few bucks.

2A3 pushpull

