GLASSWARE
AUDIO DESIGN

UNBALANCER

USER GUIDE

09/24/2012

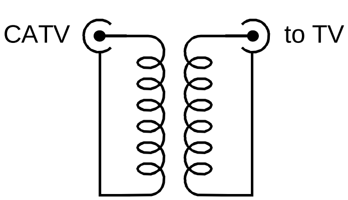
A good test procedure is to detach all the signal inputs and all the output connection from the line-stage amplifier. Then measure the AC voltage between the line-stage amplifier's chassis and the house's ground. If it reads more than a few volts, try reversing the line-stage amplifier's plug as it plugs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

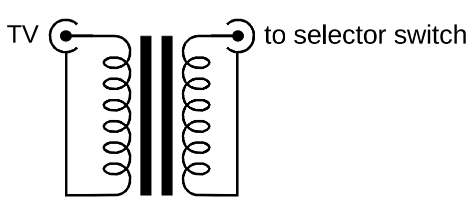
RFI Radio frequency interference can be a hassle to track down and eliminate. First make sure that the source of the problem actually resides in the line-stage amplifier. For example, if only one signal source suffers from RFI noise, make sure that it is normally RFI free. In other words, attach it to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

Ferrite beads can also help; try using beads on the hot lead as it leaves the RCA jack and then again at the selector switch. Increasing the grid-stopper resistors (R3 & R4) values, say to 1k, can also work wonders (use a carbon-composition or bulk-foil resistor or some other non-inductive resistor type).

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

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





Overview

Thank you for your purchase of the Unbalancer 9-pin stereo PCB. This FR-4 PCB is extra thick, 0.094 inches (inserting and pulling tubes from their sockets won't bend or break this board), double-sided, with plated-through heavy 2oz copper traces. In addition, the PCB is lovingly and expensively made in the USA. The boards are 7 by 6 inches, with five mounting holes, which helps to prevent excessive PCB bending while inserting and pulling tubes from their sockets.

Each PCB holds two differential line-stage amplifiers, each followed by a Broskie cathode follower output stages; thus, one board is all that is needed for stereo use. The Unbalancer accepts a balanced input signal and delivers an unbalanced output.

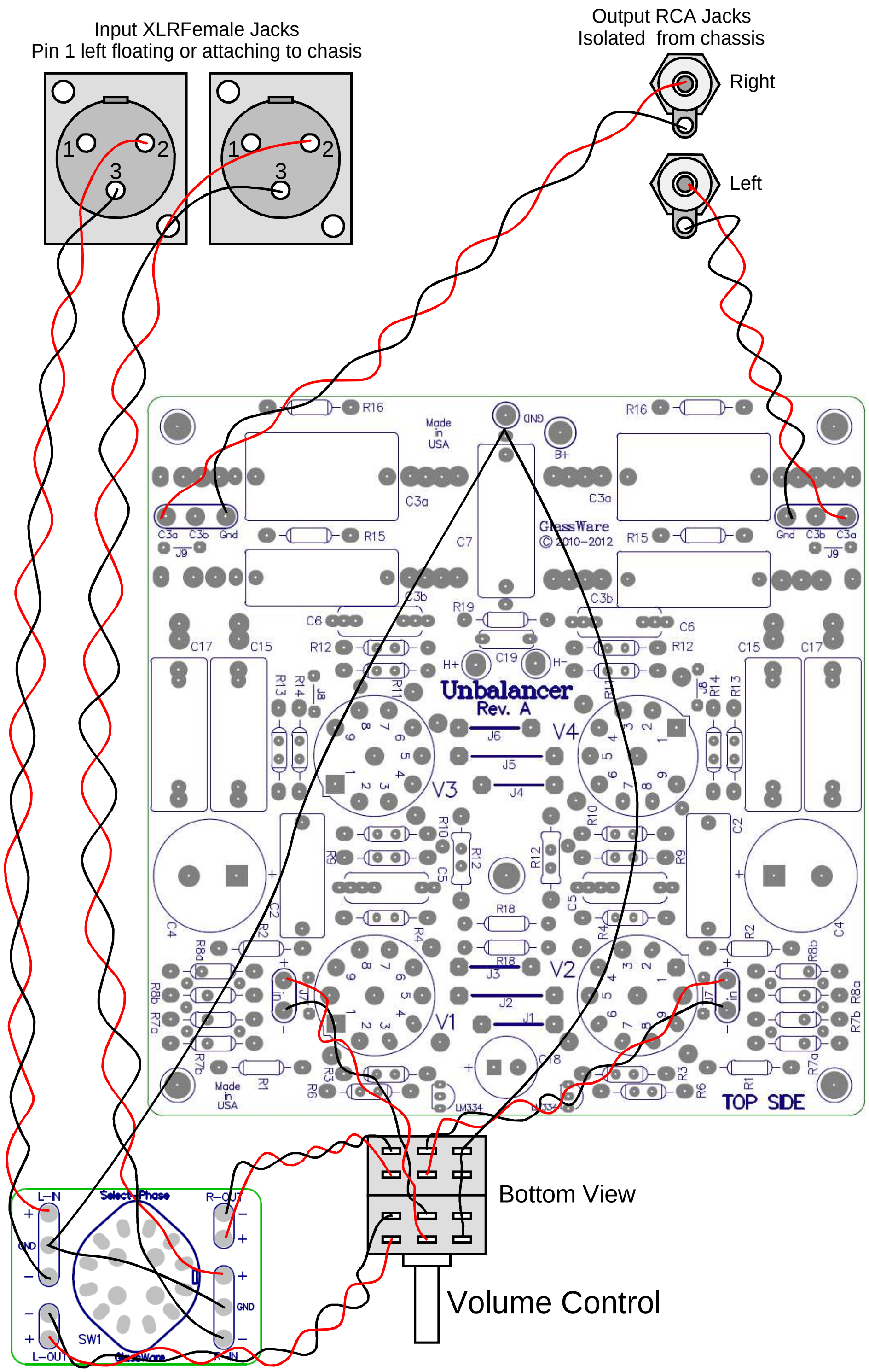
PCB Features

Power-Supply-Decoupling Capacitors The Unbalancer PCB provides cascading RC high voltage power supply filters to decouple both gain stages from the B+ connection and each other. This arrangement uses large-valued electrolytic capacitors and small-valued film capacitor in parallel, while a series voltage-dropping resistor completes the RC filter. In place of the first RC series resistors off-board chokes can be used and resistors R12 can be replaced with off-board chokes as well.

Dual Coupling Capacitors The boards hold two coupling capacitors, each finding its own 1M resistor to ground. Why? The idea here is that you can select (via a rotary switch) between C3a or C3b or both capacitors in parallel. Why again? One coupling capacitor can be Teflon and the other oil or polypropylene or bee's wax or wet-slug tantalum…. As they used to sing in a candy bar commercial: "Sometimes you feel like a nut; sometimes you don't." Each type of capacitor has its virtues and failings. So use the one that best suits the music; for example, one type of coupling capacitors for old Frank Sinatra recordings and the other for Beethoven string quartets. Or the same flavor capacitor can fill both spots: one lower-valued capacitor would set a low-frequency cutoff of 80Hz for background or late night listening; the other higher-valued capacitor, 5Hz for full range listening. Or if you have found the perfect type of coupling capacitor, the two capacitors could be hardwired together on the PCBs via jumpers J9, one smaller one acting as a bypass capacitor for the lager coupling capacitor. On the other hand, each coupling capacitor can feed its own output, for example, one for low-frequency-limited satellites and one for subwoofers.

Redundant Solder Pads The Rev A Unbalancer PCB now holds pads for parallel plate resistor for the input stage, which allows lower-wattage plate resistors to be used. For example, two 1W plate resistors in parallel effectively equal a 2W resistor.

Low-Pass Filter The Unbalancer PCB's holds optional capacitors, C5 & C6, can be used to create a first-order low-pass filter (-6dB per octave), which is useful when the Unbalancer is following a DAC; for most DACs, a -3dB high-frequency cutoff between 80kHz to 160kHz works well. This low-pass filter allows the Unbalancer to scrub away high-frequency noise from other signal sources as well.



The Broskie cathode follower receives a balanced input signal from the differential amplifier and converts it to an unbalanced output. It is a unity-gain buffer (actually a gain of 0.5, so the two phases added together equal 1) that offers a high input impedance, low output impedance, low distortion, and great CMRR. In addition, because the Broskie cathode follower uses a push-pull topology, its use is not limited to line-stages, as the Broskie cathode follower can be used as a headphone buffer-amplifier if the headphone's impedance is high enough (say, 300-ohms). In addition, much like a signal transformer, the Broskie cathode follower offers common-mode signal rejection (CMRR); this means that Broskie cathode follower passes differential input signal, but largely ignores what is common to both input signals. Why is this a feature? Common-mode signals are extraneous to the actual input signal and usually consist of hum, power-supply noise, and RFI.

The Unbalancer PCB holds two power supplies, one for the high-voltage B+ and a low-voltage regulated power supply for the heaters. The high-voltage power supply is unregulated, but uses cascading RC filters to smooth away ripple. Of course, the power supplies require an external power transformer(s) with two secondary windings, one high voltage for the B+ voltage and one low-voltage for the heaters.

Balanced Audio

Balanced audio confuses many—and would confuse many more, if they knew it existed. For those acquainted with balanced audio, what immediately pops into mind are XLR connectors and professional audio equipment. Then soon follows the varied rumors, such as "Although balanced audio is used extensively in making LPs and CDs, balanced audio never sounds good in home systems" and "Balanced systems are the only possible way to get low-noise, high-quality sound and the cheapest, most-humble balanced cable sounds vastly better than the best, most-expensive unbalanced cable." I have heard both of these rumors and many others in between and a few crazy ones, such as "Balanced systems will strip away even-order distortion from a music signal, leaving only odd-order harmonics in place."

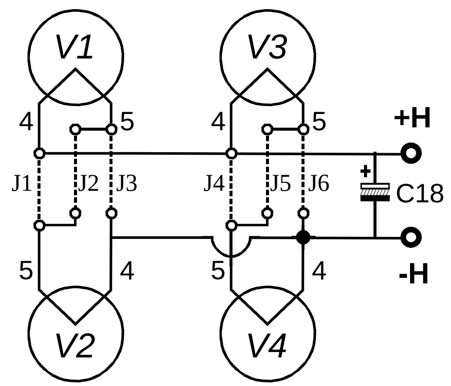
If asked to define a balanced signal, the most popular answer is three wires and two phases. Yes, a balanced signal consists of two* anti-phase and symmetrical signals, thus seemingly implying the necessity of three wires, plus, minus, and ground, but many balanced signal sources only use two wires, such as all telephone systems (excluding optical and radio transmission), microphones, temperature sensors, photo cells, and even phono cartridges. In other words, three wires are not essential. What is essential is that the two signal-carrying conductors be of the same type and that each present an equal impedance relative to the receiving circuit's voltage/signal reference (ground). The key feature here is the two wires presenting equal impedance, not that they be in anti-phase. In other words, getting two phases is something of a freebie in a balanced setup. (The name "balanced" was maybe unfortunate, as would have been "symmetric"; while "stabilized" or "equalized" might have been more fortunate.)

For example, consider a phono cartridge's coil; if one end is grounded, then only one phase is present; no balanced signal. But if the coil is shunted by two equal resistors in series and if junction between the two resistors are attached to ground, cartridge's output signal now offers two phases.

Heater Issues

The Unbalancer PCB requires that a heater power supply be attached. The power supply can be just an AC heater winding or a regulated DC power supply. The best configuration is that a 12Vdc heater power supply will be used for the heaters, so that 6.3V heater tubes (like the 6FQ7 and 6DJ8) or 12.6V tubes (like the 12AU7 or 12AX7) can be used. Both voltage types can be used exclusively, or simultaneously; for example a 6GC7 for the input tube and an ECC99 for the output tube. Although the preferred power supply voltage is 12V, a 6Vdc (or 6.3Vdc) heater power supply can be used with the PCB, as long as all the tubes used have 6.3V heaters (or a 5V or 8V or 18V power supply can be used, if all the tubes share the same 5V or 8V or 18V heater voltage). Just use jumpers J1, J3, J4, and J6 only. Note: Perfectly good tubes with uncommon heater voltages can often be found at swap meets, eBay, and surplus stores for a few dollars each. Think outside 6.3V box.

Filament Jumper Wire Schedule



With a 12.6V PS

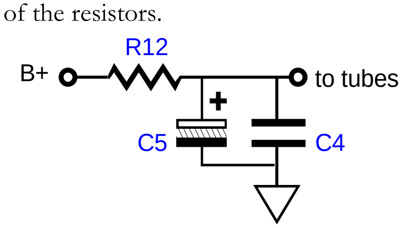
Tubes	V1 & V2	V3 & V4
If tubes are 6.3V:	J2 only	J5 only
If 12.6V:	J1 & J3	J4 & J6

With a 6.3V PS

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

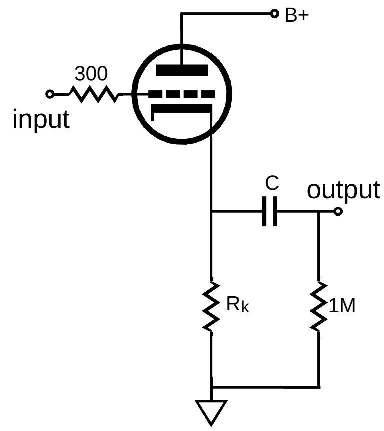
RC Power-Supply Filter

Resistor R12 and capacitors C5 & C4 define the two RC power supply filters used on the Unbalancer PCB. Resistor R12's value can be anything between 0 to 10kohms, depending on tubes used. These resistors will see the current draw that the tubes undergo. The Unbalancer kit supplies eleven pairs of power resistors for R12 use: 100, 200, 300, 470, 680, 1k, 1.6k, 2k, 3k, 3.9k, and 10k. The inside back cover holds a chart that shows the voltage drop across the R12 versus the current flow. Remember each channel gets it own R12 resistor. For example, an Unbalancer line-stage amplifier might run a total of 20mA of idle current per channel, for a total of 40mA for the entire line-stage amplifier. So by looking up the 20mA column, we can see the resulting voltage drops. Thus, a 2k resistor will drop 40V, so a 300Vdc raw DC power supply will deliver 260Vdc to the input and output tubes. An * denotes excessive current or voltage, so that resistor value cannot be used without risking damaging the at least one of the resistors.

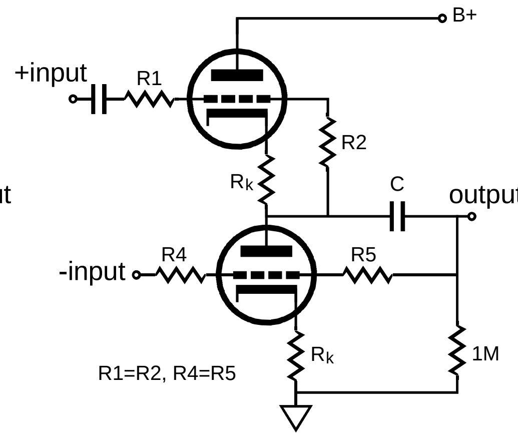


The Broskie Cathode Follower

The Broskie cathode follower (BCF) was created to level the playing field. Designers of solid-state audio gear have held an advantage over their tube-audio competitors in that they can use a simple, inexpensive OpAmp-based circuit to convert a balanced input signal into an unbalanced (single-ended) signal. This solid-state differential circuit requires only one OpAmp and four resistors. Of course, a tube-based OpAmp could also be designed that used the same topology, but this would be quite an undertaking, requiring many tubes and, most probably, a negative power supply rail. The BCF, on the other hand, is a simple affair that uses just two triodes and six resistors and two coupling capacitors.



Cathode Follower



Broskie Cathode Follower

Balanced-to-Unbalanced As a balanced-to-unbalanced converter, the BCF's function is to subtract signal B from signal A; in other words, output = A – B, which makes the BCF a differential amplifier, an amplifier that accepts differences and ignores what is common. Because balanced audio signals consist of two phases, with signal B being equal to –A, the function effectively becomes output = A – (–A), or output = 2A . A signal common to both A and B, let us call it C, is canceled, as the function, C - C =0, obtains. Noise is usually equally shared between two balanced signals and is thus eliminated in the unbalanced, single-ended output signal.

So far, the circuit mimics an audio-signal transformer in function, which was one goal. But the BCF circuit differs from a transformer in that it does not reflect impedances, but rather provides a low output impedance and, unlike a generic cathode follower a symmetrical push-pull current swing, i.e. it can aggressively pull up or down like a White Cathode Follower. In other words, the BCF is like a cathode follower wedded to a plate follower (AKA anode follower)—but not quite, as a typical cathode follower does not hold a pair of resistors wrapped around its input and output. (Resistors R3, R4 were added to better balance the circuit's output swing and output impedance.)

The BCF differs from the classic OpAmp-based differential amplifier and 1:1 isolation transformer in that the BCF's output does not equal 2A, but A. For example, if a balanced pair of input signals that consist of 1kHz at 1Vpk is presented to the BCF, the BCF output will be 1Vpk, not 2Vpk. This can be seen either as a -6dB insertion loss or as preserving unity-gain signal transference, depending on your perspective.

Assembly & Testing

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

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

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

1. Attach only the heater power supply's transformer winding, leaving the high-voltage transformer leads unattached and electrical tape shrouded, with no tubes in their sockets.
2. Use a variac and slowly bring up the AC voltage, while looking for smoke or part discoloration or bulging.
3. Measure the heater regulator's output voltage without and with a load. If the heater regulator fails to regulate, try either lowering the heater voltage a tad, for example 12V instead of 12.6V, as the 0.6V difference might be enough to bring the regulator back into regulation.
4. Next, power down the heater regulator and attach the high-voltage windings and insert the tubes in their sockets.
5. Attach the transformer to a variac and slowly bring up the AC voltage.
6. Measure the voltage across ground and B-plus pads in the center of the PCB; then measure the voltage across capacitors, C2 & C4, at the bottom of R12. If the two channels differ by more than 10Vdc, try switching tubes from one channel to the other. If the imbalance does not follow the tubes, there is a problem, probably a misplaced part.

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

To bypass or not to bypass? In our analyses of the circuit's output impedance, the cathode resistors were assumed to be bypassed, but in actual use, the BCF's cathode resistors should be left unbypassed. What happens to the output impedance if the resistors are unbypassed? Normally, an unbypassed cathode resistor will greatly increase the output impedance. In a Grounded Cathode amplifier the effective increase in the value of rp is equal to the (mu + 1) times the value of the cathode resistor. Here the value one cathode resistor is simply added to what the output impedance would be with bypassed cathode resistors. The formula for the output impedance with bypassed cathode resistors is given by:

$$Zo = (rp / [\mu + 1]).$$

And with unbypassed cathode resistors:

$$Zo = (rp / [\mu + 1] + Rk),$$

or roughly

$$Zo = 1 / Gm + Rk.$$

In the case of a 6922 with a Gm of 10mA per volt and a cathode resistor of 200, the Zo will equal 100 ohms with bypassed cathode resistors and 300 ohms with unbypassed cathode resistors. The result is basically the same as a single cathode follower that used the same tube. In many ways, what we have created here is one super triode out of two triodes.

Re-Balancing the Input Impedances The BCF presents mismatch input impedances, with the positive (the top) input being much higher than the negative (the bottom) input. Because the top two-resistor voltage divider terminates into the output, the resistor string's effective impedance is magnified, as the output is in phase with the positive input signal. The top resistor string's effective impedance is increased by 1/(1 – gain); for example, if the BCF output gain is 0.9, then the resistor string's effective impedance will be 1/(1 – 0.9) or 10 times greater than its nominal resistor values would indicate.

Is this important? For most applications, no. Most modern balanced input signal sources offer a relatively low output impedance. But certain old balanced gear and some audio matching transformers do not. In fact, an audio transformer works best when it is loaded by an optimal impedance. For example, say the transformer expects to see 600 ohms across its secondary, we should give 600 ohms then. We can place two 300-ohm resistors at each BCF input and to ground, which will then present 600 ohms to the secondary.

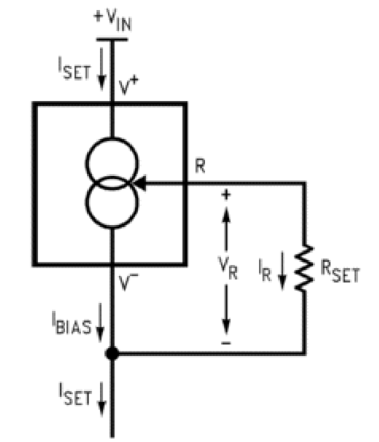
Output Coupling Capacitor This coupling capacitor is primarily responsible for restricting the BCF's low frequency extension. The larger the capacitor, the lower the low-frequency cutoff frequency. The formula is an easy one:

$$Frequency = 159155/C/R,$$

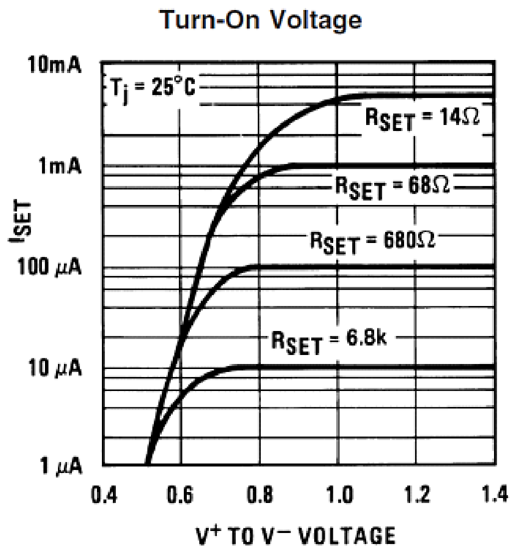
Where C is in µF and frequency is in Hertz and R equals resistors R5 & R7 in parallel with the external load impedance. For example, if R5 = 47k and R7 = 1M and the load = 20k, the resulting resistance will equal 13.8k, which with a 1µF coupling capacitor will give a -3dB frequency of 11.5Hz. If the BCF is used to drive 300-ohm headphones, a job that the BCF is amazingly good at, at least a 30µF coupling capacitor is needed.

LM334

The National Semiconductor LM334 constant-current source is a well established device. It comes in four different packages, but the Unbalancer PCB is configured for the TO-92, three-lead package. The LM334 offers excellent performance and requires only one resistor, Rset, to establish its idle current. The following graph shows the turn-on voltages and bias currents set by various Rset resistor values.

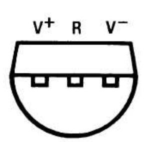


$$I_{SET} = I_R + I_{BIAS} = \frac{V_R}{R_{SET}} + I_{BIAS}$$



Note that 10mA, the optimal value for most Unbalancer setups, does not receive a resistor value, but we can readily see that 6.8 ohms is the correct value. (The LM334 datasheet goes into much more detail, but for tube work, 6.8 ohms is close enough.) Although 10mA is the LM334's maximum current flow, the device sees less than 10V with most tubes, such as the 6CG7 and 12AU7, so the device's dissipation is usually less than 100mW, well below its 400mW limit. Nonetheless, it is a good idea to attach a small heatsink to the IC, as it better ensures an accurate idle current.

TO-92 Plastic Package



Bottom View

LM334 Specifications

V+ to V- Forward Voltage	
LM134/LM234/LM334	40V
V+ to V- Reverse Voltage	20V
R Pin to V- Voltage	5V
Set Current (max)	10mA
Power Dissipation	400mW
ESD Susceptibility	2000V
Operating Temperature Range	
LM334	0°C to +70°C
Soldering Information	
TO-92 Package (10 sec.)	260°C

Configuring the Unbalancer as a Line Amplifier

The Unbalancer circuit makes a perfect line amplifier, as it offers low distortion and a low output impedance. The input and output tubes do not have to be the same type or even share the same heater voltage; and the following design examples are not exhaustive by any means. For example, the 6H30 and ECC99 would make powerful output tubes and the 5693 might make a stellar input tube (followed by a 5695 in the Broskie cathode follower position would make an all-computer-tube unbalancing line-stage amplifier). In general, we want low-mu triodes for the differential amplifier stage and high-gm triodes for the Broskie cathode follower stage. An excellent pairing is the 12AU7 and the ECC99. The input tube's plate resistors hold two parallel resistors per plate (R7a & R7b and R8a & R8b), so two lower-wattage resistors can be used to make a higher-power plate resistor.

Typical Part Values

() Parentheses denote recommended values

(input) V1, V2 =	6CG7/6FQ7	12AU7	12BH7	6DJ8[1]
B+ Voltage =	240V	240V	240V	150V
AC Secondary =	330Vac	330Vac	330Vac	120Vac
DC Heater Voltage =	6.3V or 12.6V	12.6V	12.6V	6.3V or 12.6V
R1,2,15 =	1M	1M	1M	1M
R3,4 =	100 - 1k (300)*	Same	Same	Same
(without CCS) R6 =	287*	370*	499*	87*
(with CCS) R6 =	6.81*	6.81*	6.81*	6.81*
R7, 8 =	24k/1W*	24k/1W*	24k/1W*	15k/1W*
Jumper J7 =	?	None	None	Use

(output) V3, V4 =	6CG7	6H30[1]	12AU7	12BH7	ECC99	6DJ8[1]
R9,10,11,12 =	100k*	100k*	100k*	100k*	100k*	100k*
R13,14 =	300-560*	150-400*	300-845*	240-470*	240-470*	100-200(120)*
Jumper J8 =	?	None	None	None	None	Use

*High-quality resistors essential in this position.

1. Low-Voltage Operation

C15, C17 =	0.1 - 0.68µF*	Same	Same	Same	Same	Same
C2, C7 =	0.22 - 1µF*	"	"	"	"	"
C3a, C3b =	0.1 - 4µF*	"	"	"	"	"
C4 =	150µF* 400V	270µF 200V	150µF* 400V	150µF* 400V	150µF* 400V	270µF 200V
C17 =	1k - 4.7kµF 16V	Same	Same	Same	Same	Same

*Voltage rating must equal or exceed B+ voltage; Film or PIO

Note that the assumption here has been that the differential input stage runs under a total idle current of 10mA, the optimal value for most Unbalancer setups. The second assumption is that plate resistors, R7 & R8, will split the B+ voltage; for example, if the B+ voltage is 300Vdc, the voltage drop across the plate resistors would equal 150Vdc. Because of the two internal coupling capacitors, C15 & C17, this 50% does not have to be observed. If more gain is required, the plate resistors can see more of the B+ voltage; if greater linearity is desired, the triodes can receive the lion's share of B+ voltage. Of course, the 10mA is not set in stone; it is, unfortunately, it is limit that the LM334 can sustain.

The Broskie cathode follower portion of the Unbalancer circuit is much more flexible in possible idle current settings. The formula for setting the BCF idle current is an easy one:

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

Output Impedance What is the output impedance of this circuit, considering the two-resistor networks wrapped about the circuit? Imagine a positive voltage pulse being fed into the output of our circuit. We also assume the cathode resistors are bypassed to make the circuit analyses simpler. Let's say a 1 volt pulse is forced into the output by an ultra- low-output- impedance solid- state amplifier. The BCF's output is now forced 1 volt higher. This 1 volt increase is relayed through the top resistor network (R1 & R2) to the top tube's grid. Since the two resistors are wired in series, not all the voltage can present itself to the grid; in fact, as the two resistors are equal in value, only half of the 1 volt increase reaches the top grid. Effectively, this is equivalent to the grid having been driven ½ volt negative relative to the cathode, as the cathode has moved up 1 volt and the grid has only moved up ½ volt. The top triode will conduct less as a result of the negative voltage on its grid. How much?

The transconductance of the triode times ½ volt is basically the amount of decreased current. In the case of a 6922 with a Gm of 10 mA per volt, the current will decrease by 5 mA. On the bottom triode, the positive pulse is also relayed to its grid via a two-resistor voltage divider. Once again only half of the pulse makes it to the grid. But this time the current increases by the Gm times the ½ volt positive pulse. In the case of a 6922, the current will increase by 5 mA. The sum of the positive increase in current flow by the bottom tube and the negative decrease in current flow by the top tube is what the solid-state power amplifier must be able to source to maintain the pulse in the face of the change in current flowing through the tubes. Assume the at idle our balanced converter draws 10 mA. But in the presence of the 1 volt pulse, the top tube draws 5 mA less, which leaves it with 5 mA of current flow; the bottom tube's current draw increases by 5 mA, which leaves it with 15 mA of current flow. Thus net change in current is the absolute difference in each tube's change in current, as the top tube is now only conducting 5 mA and the bottom tube is conducting 10 mA more current than the top tube this extra current must flow into the amplifier causing the pulse. Consequently, the solid-state power amplifier must be able to source 10 mA of current or the pulse will not be sustainable. Now we can figure out the output impedance: V / I = R. Thus, 1 volt / 0.01 amps = 100 ohms. Had the circuit consisted of one triode configured as a simple cathode follower, the output impedance would have also been 100 ohms. Asides from converting a balanced input signal into an unbalanced output, the BCF offers lower distortion than the conventional cathode follower and it offers a symmetrical pulling up and down, whereas the simple cathode follower can only aggressively pull up.

Low-Pass Filter

The Unbalancer's two optional capacitors, C5 & C6, can be used to create a first-order low-pass filter (-6dB per octave). Parts C5 and R9 set the low-pass filter on the positive input signal, while Parts C6 and R12 do the same for the negative input signal. The formula:

Frequency = 159155/C5/R9 or 159155/C6/R12

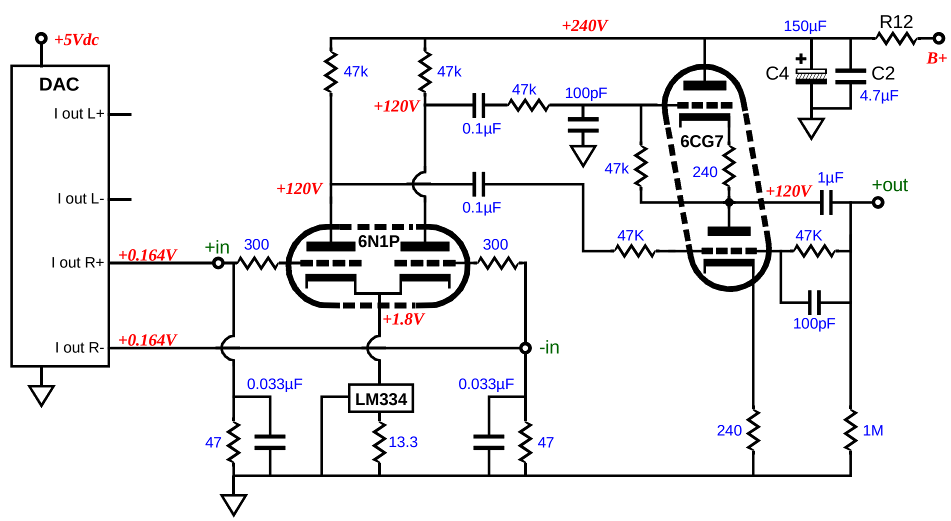
where C5 and C6 are in µF. For most DACs, a -3dB frequency between 80kHz to 160kHz works well. To keep the resistor noise to a minimum, use 20k resistors for R9, R10, R11, R12. With 10k resistors, 100pF for capacitors C5 and C6 will impose a cutoff frequency of about 80kHz. Since resistor R12 is effectively in parallel with resistor R15, the output coupling capacitor, C3, should be at least 1µF in value, with 3µF providing deeper bass with less phase shift.

Double-Sided Board Because the board is double sided, with traces and plated-through pads on each side, it is often easier to solder the resistors from the top side. In addition, it is often easier to attach the LD1085 (heater regulator) to its heatsink first (using heatsink hardware kit) and then to solder both heatsink and device to the PCB at once. You may solder the tube sockets on the top of the PCB and solder all the remaining parts on the bottom, which allows attaching the PCB to the chassis's top panel, with the tubes protruding through holes, which can easily be done with the Unbalancer PCB, as the solid-state regulator and LM334 can be soldered on the bottom without having to twist their leads to conform to the inverted pad positions, as the heater regulator gets a redundant set of solder pads on the PCB's bottom side. Just be sure to attach the regulator the other side of the heatsink.

Capacitors Because the PCB is so overbuilt, it is extremely difficult to remove an incorrectly placed part. Thus, be sure to confirm all the electrolytic capacitor orientations, as a reversed polarized capacitor can easily vent (or even explode) when presented with high-voltage. Confirm twice, solder once. In addition, large coupling and bypass capacitors should be adhered to the.

Standoffs Tubes are microphonic by nature, being mechanical structures. Thus, it pays to prevent vibrations from reaching the tubes. One easy technique is to use small rubber O-rings below and above the PCB where the screws enter the PCB's mounting holes. The screws should be just tightened enough to keep the PCB from ringing or rattling when tapped.

DACs & Unbalancer If the DAC used offers a balanced output, then the Unbalancer can readily receive its voltage signal. If the Unbalancer used directly with a voltage-output DAC's balanced outputs, the signal's DC offset is not a problem and no coupling capacitors are needed, as the constant-current source (or cathode resistor) will simply absorb the offset. If a current-output DAC is used, then low-resistance load resistors will be required. The DAC's varying current output into these resistors creates a small voltage signal that must be amplified greatly, so a high-mu input tube should be used, such as the 6N1P or 12AT7, 12AX7, 6072, 5965.



Since the cartridge's coil is not hardwired to a reference/ground, we can decide where the reference point will be attached. (Even if phono cartridges had always come with center-tapped coils, we could choose to ignore the center-tap and treat the coil as a free, non-referenced signal source.) Sure, this makes sense with a phono cartridge's coil, as it is just a length of coiled wire, but what about an actual active electronic audio signal source? Surely here the signal reference is hardwired defined and not free-floating. Sometimes it is, but sometimes it's not. Imagine an unambiguously unbalanced signal source, such as an old portable mono cassette tape player housed in a big metal box and its two output signal wires exiting the box. (Since the tape player uses batteries, no connection needs to be made to the house wall voltage.)

Do we now have a balanced or unbalanced signal source? The answer can be that it is balanced, as long as we do not "ground" the tape player's own internal ground directly to the house ground or to our line-stage amplifier's ground. This signal source can be—and maybe must be—voltage referenced in some fashion to our line-stage amplifier. If we wish to treat this signal source as a balanced signal, then we can attach the two-equal-valued-resistor voltage dividers across the two leads, thereby referencing the tape player's output at the midpoint of its output signal and thereby creating two signal phases (and effectively halving the signal amplitude). In other words, the tape player's internal ground becomes a signal output, just as much as its conventional signal output. As far as our line-stage amplifier is concerned, both signal phases are equal in amplitude and output impedance and, thus, are interchangeable. This allows easy phase reversals and eliminates the need for a phase splitter.

How can that be? Since one of the two wires leaving the box attaches directly to the tape player's ground, the output impedance of this wire must be zero. Ground, unfortunately, is something of a metaphysical notion, not an actual physical entity. In an airplane or a satellite or a ship or the iPod in your pocket, where is ground? (Many designers worship Ground, seeing in it the one and only reference point. They ascribe magical powers to Ground, claiming that Ground can never become noisy or RF polluted, and that Ground, like a black hole gobbling solar systems, can sink infinite current and voltage. When the reference point is moved to some different part of a circuit, these designers grow nervous, their knees weaken and they perspire.)

The tape player's ground exists only within the tape player, nowhere else. Give an electrical engineer the black box with two wires protruding, but do not tell him what is inside. He measures all that he can measure but he never discovers a ground. If the tape player is turned off, he would conclude that the box held a single resistor; if the tape player is turned on but not playing a cassette, he would deduce that the box held a complex RC network that used noisy resistors; and if audio signal left the box via the two wires, he could only speculate on its actual source. Maybe the box concealed a radio or MP3 player or a phonograph or…But he could never make a distinction between the two wires, never differentiate one wire as being the hot and the other as the ground. How could he? The phase of the signal would not help, as the tape player's circuitry might invert the phase and who knows what the phase relationship was on the tape itself. One wire cannot be measured in isolation, so one wire cannot exhibit zero ohms of impedance, thus betraying its designated "ground" status. As far as the VOM can tell, both wires present the same impedance, much a single resistor would. (Imagine if some fool told you that each resistor held a ground lead and an output lead, that the ground lead offered zero resistance and output lead presented all of the resistor's resistance.)

Tube Selection

A Unbalancer line-stage amplifier can be built in a nearly infinite number of ways. For example, a 12AU7 input tube will yield a gain of +13dB (+16dB with LM334 constant-current source), which would be excellent for a line stage amplifier; the 6DJ8 or 6H30 or ECC99 as the output tube would deliver a low output impedance that could drive capacitance-laden cables. In other words, the list of useable tubes is a long one: 6AQ8, 6BC8, 6BK7, 6BQ7, 6BS8, 6DJ8, 6FQ7, 6GC7, 6H30, 6KN8, 6N1P, 12AU7, 12AX7, 12BH7, 12DJ8, 12FQ7, 5963, 5965, 6922, E188CC, ECC88, ECC99… In general, a low-mu tube works best as the input tube and a high-transconductance tube works best as an output tube. The only stipulations are that the two triodes within the envelope be similar and that the tube conforms to the 9A or 9AJ base pin-out. Sadly, the 12B4 and 5687 cannot be used with this PCB.

Internal Shields

If the triode's pin 9 attaches to an internal shield, as it does with the 6AQ8 and 6DJ8 and some but not all 6CG7 tubes, then jumpers J7 and J8 can be used, which will ground the shield. However, using small-valued disc capacitors rather than jumpers will also ground the shield (in AC terms) and allow swapping in triodes whose pin-9 attaches to the center tap of its heater, such as the 12AU7.

Cathode Resistor Values

If the LM334 constant-current source is not used, then common cathode resistor R3's value should be gleaned from inspection of the tube's plate curves, although the following formula is a good starting point. The BCF cathode resistors, R13 & R14, and B+ voltage set the idle current for the Aikido cathode follower output stage: the larger the value of the resistor, less current; the higher the plate voltage, more current. In general, high-mu triodes require high-value cathode resistors (1-2K) and low-mu triodes require low-valued cathode resistors (100-1k). The formula for setting the Iq for the BCF output stage is an easy one:

Iq = B+/2(rp + [mu + 1]Rk)

So, for example, a 6CG7 in the BCF, with a B+ voltage of +300V and 1k cathode resistors, will draw 300/2(8k + [2 + 1]1k) amperes of current, or 2.6mA. I recommend 100 to 330 for the 6DJ8 and 6N1P tubes. Other tubes, such as the 6CG7, 12AT7, 12AU7, 12BH7 work well with 470-ohm cathode resistors. Because the BCF's cathode resistors see so little voltage differential, 1/2W resistors can readily be used here.

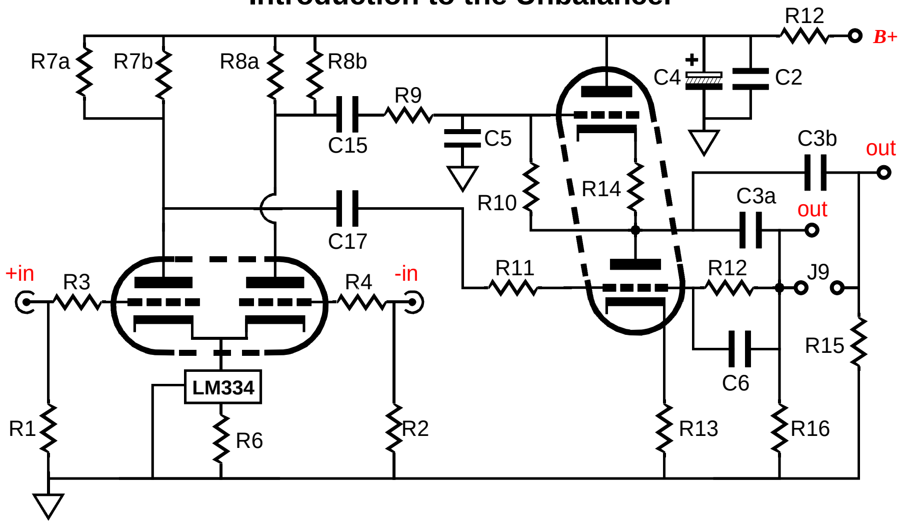
Coupling-Capacitor Values

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

Frequency = 159155/C/R

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

Introduction to the Unbalancer



Unbalancer Topology The Unbalancer circuit accepts a balanced input signal and delivers an unbalanced, single-ended output. Besides performing the conversion, the Unbalancer circuit provides voltage gain and exhibits a fine CMRR (Common Mode Rejection Ratio), which means that it largely ignores common-mode signals. Balanced signals offer some real advantages, such as lower noise and easy phase reversal and no need for a phase splitter, in a push-pull power amplifier.

The Unbalancer circuit deconstructs into a differential amplifier whose output feeds a Broskie cathode follower. The differential amplifier works by presenting each grid with a signal equal in amplitude, but inverted in phase relative to the other grid. This arrangement results in one triode drawing greater current and the other less current. To the degree that the two triodes are matched, the net effect will be a an unvarying constant current flow through the total circuit. If the current does not vary through the cathode resistor, nor will the voltage across it, which means that the cathode voltage will not vary as well. Thus whatever anti-phase, balanced voltage is presented to both triodes' grids won't be mitigated by degeneration at the cathode of each triode, which means more gain—the same amount as a grounded-cathode amplifier would yield with the same triode and plate load resistor and with no cathode resistor (or with a bypassed cathode resistor). On the other hand, a common-mode signal presented to both grids will result in a slight change in the current flowing through the cathode resistor, which will cause the cathode voltage to follow the grid voltages, thus greatly reducing the gain at the output. Hence, the name "Differential Amplifier." This circuit amplifies the differences in grid signals and largely ignores what is common to both grids. The effectiveness of a Differential Amplifier at rejecting common signals to both inputs is denoted by CMRR.

In the Unbalancer circuit, the differential input stage sees a constant-current source at its coupled cathodes, which allows the circuit to even better ignore common-mode signals and automatically sets the desired cathode-bias voltage for input triodes. The LM334 only requires one resistor to set its idle current. (The constant-current source can be left off the PCB, that the differential amplifier uses simply a single common cathode resistor.)

Grounding

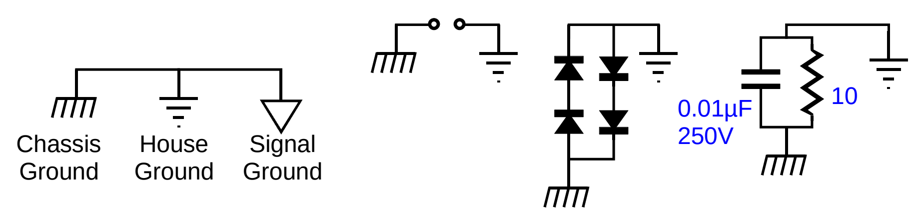
The Unbalancer PCB holds a star ground at its center. Ideally, this will be the only central ground in the line-stage amplifier. Ground loops, however, are extremely easy to introduce. For example, if the RCA jacks are not isolated from the chassis, then the twisted pair of wires that connect the PCB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

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

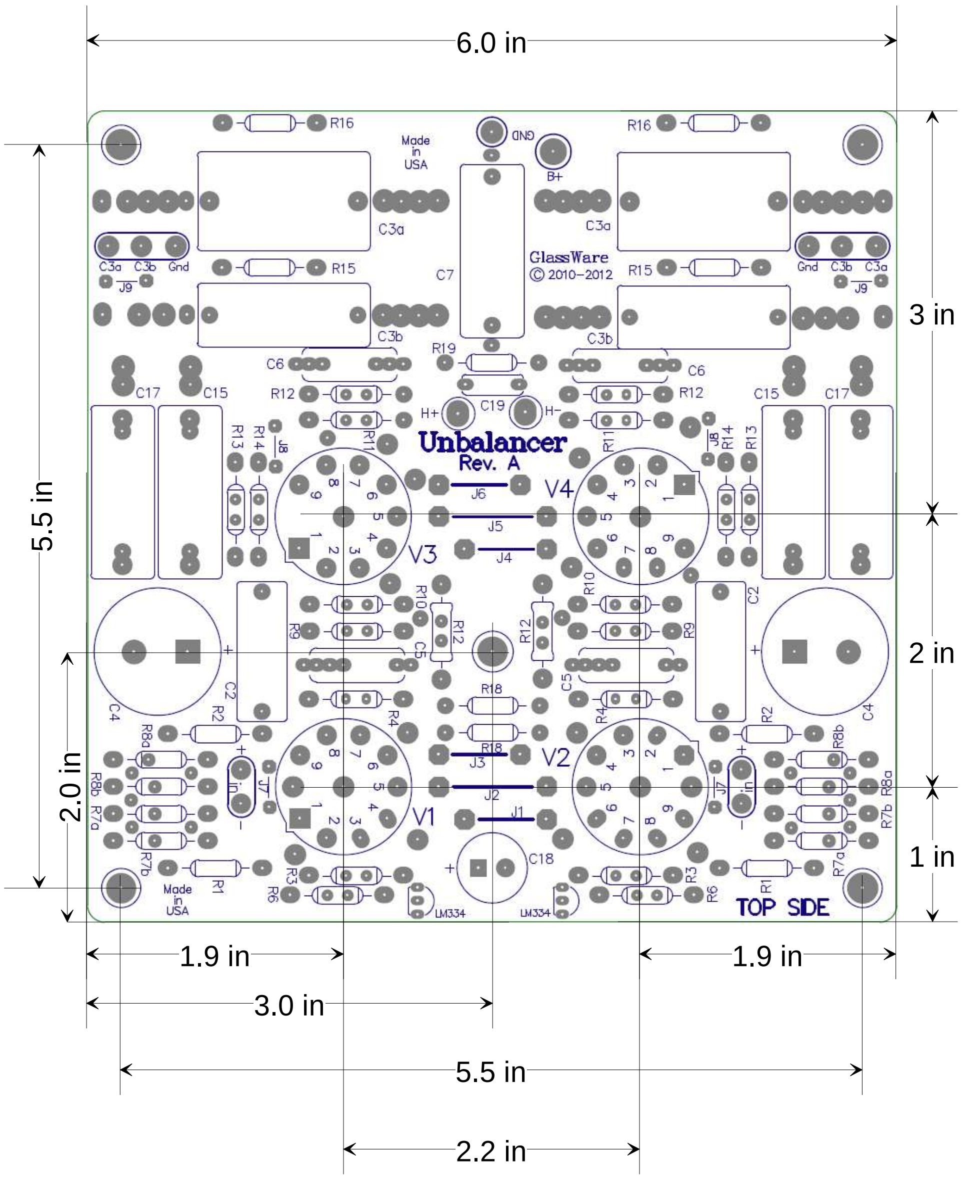
The Semi-Star ground method uses several ground "stars" that are often called spurs, which then terminate in a single star ground point, often a screw on the chassis. This system can work beautifully, if carefully executed. Unfortunately, often too much is included in each spur connection. For example,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

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

House Ground The third prong on the wall outlet attaches to the house's ground, usually the cold water pipe. The line-stage amplifier can also attach to this ground connection, which is certainly the safest approach, as it provides a discharge path should the B+ short to the chassis. Unfortunately, this setup often produces a hum problem. Some simply float the ground (not safe), others use several solid-state rectifiers in parallel to attach the chassis ground to the house ground (**<u>NOT NEUTRAL</u>**) via the third prong, and others still use a 10-ohm resistor shunted by a small capacitor, say 0.001µF to 0.1µF/250V. One last technique might prove the best solution: couple the power supply ground to the house ground via a choke. A low-DCR choke will provide a ready DC discharge path and if its inductance is high enough, it will isolate the audio ground from the AC noise present on the house ground.



Top Side PCB Mechanical Layout



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

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

Current in mA

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

Current in mA

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

Current in mA

* Exceeds maximum Voltage/Current