

How to Wire up an Audio Power Amplifier for Zero Noise Problems

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Andrew C. Russell

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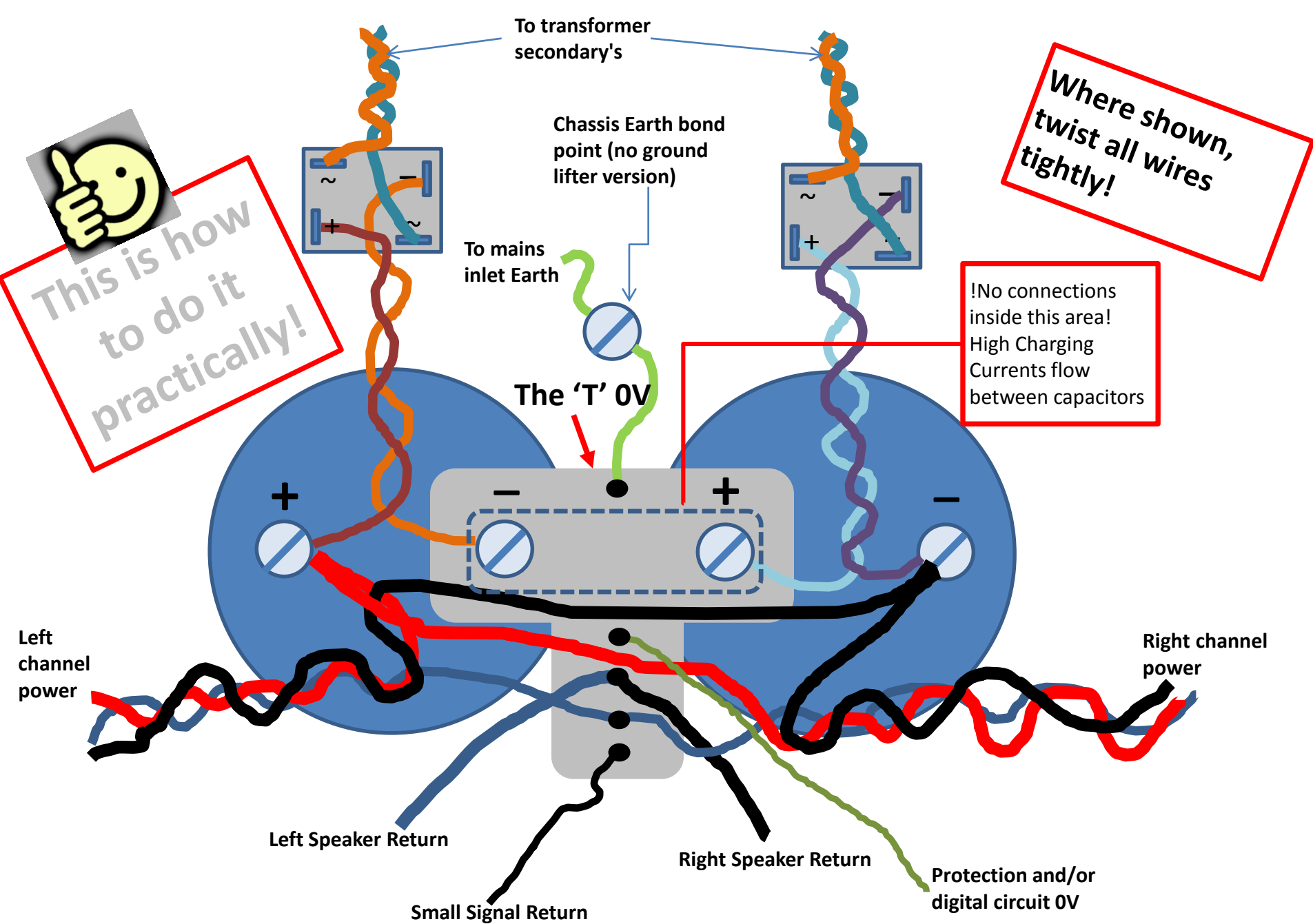
Achieving 'Zero Noise' is Easy if You Follow These Basic Rules

- Mains wires to the fuse, switch and to the transformer primary are tightly twisted* together
- Transformer wires from each secondary to its associated bridge rectifier are tightly twisted together
- Wires from each bridge rectifier to their associated filter capacitor(s) are tightly twisted together
- The V+, V- and 0V to each of the amplifier boards are twisted tightly together. *These wires come directly off the filter capacitors* – note carefully how this is drawn in the diagram
- Keep the speaker output wire from the amplifier board to the output terminal as short as practical
- Keep the speaker return wire from the speaker socket back to the 'T' as short as possible. Ideally, you should twist the speaker + and – cables together, but this is usually difficult in practice due to layout limitations.
- There is only ONE and only ONE chassis bond point in the amplifier – multiple bond points run the risk of creating earth loops. Make sure it's a high quality connection – use serrated washers and lock nuts and ensure they are tight. Use a meter to check that all parts of the metal chassis connect to this bond point.
- The input or output sockets may NOT make any direct connection to the metal chassis
- Keep high current wires away from small signal wires
- Use a 'decoupling resistor (that's the 15 Ohms devices you see in the previous slide) to prevent significant ground currents flowing between the source device and receiving amplifier. The signal ground connects to the amplifier on-board ground through this resistor.

* Twin wires also work, though not as well as twisting

How to Order the 'T' – its Important for Low Noise

- Note carefully the order to the 'T' section – from right to left on the diagram
 1. filter capacitor junction
 2. Take off point to earth bond connection
 3. Any protection circuits or digital signal boards
 4. Speaker returns – these are high current
 5. Decoupling and small signal Amplifier module/PCB 0V
 6. Any small signal analog board – e.g. preamplifier stage(s)
- The total length of the 'I' in the 'T' need not be longer than 3~4 centimeters
- Keep the top bar the T as short as possible – to do this, mount the filter caps right next to each other
- See the next page for how to do these things practically.



General Rules

- Keep input wiring away from output wiring
- Keep mains wiring away from all other wiring
- Keep the secondary connections to the rectifiers and capacitors as short as possible, and away from other wiring.
- Use good quality screened cable for the input socket to amplifier board connection. Cheap cable simply bundles the 'screen' with the core and offers less than adequate protection against noise (see next page for comments on RFI). Good quality screen cable has a tight woven screen. If you do not have screened cable, tightly twist the signal and ground wire – this can be very effective as well. Keep the input wiring well away from any high current wiring
- Twisting the feed and return wires between transformer, rectifiers, smoothing caps and amplifier modules minimizes the radiating area, and thus noise emissions.
- You will note a 15 Ohm resistor in the amplifier module between the signal ground and the amplifier module 0V.
 - This resistor ensures that equipment plugged into the amplifier input does not cause earth loop currents to flow in the screen cable between the equipment chassis. With this arrangement, the earth currents (fault and normal leakage) are forced to flow in the earth (i.e. ground) wires. This technique is very effective in reducing hum caused by earth loops.
- ALL equipment should have a solid chassis connection to earth/ground through the mains earth wire. This is critical for electrical safety and is also a legal requirement.
 - However, double insulated consumer equipment that only use 2 pin mains connection is typically found in North America and some Asian countries. The techniques described above work on this type of equipment as well – i.e. you can still achieve 'zero noise'

RFI

- Wire 1nF ceramic capacitor from the input socket 0V to the chassis as close to the input socket as possible. This shunts RFI to ground as it enters the chassis and prevents internal radiation, reducing susceptibility to pickup.
- In some designs, you *may* get better immunity by fitting a 10nF capacitor C_{comp} across the AC terminals of the ground lifer bridge rectifier. This shunts any RF on the chassis coming in through the input cables to earth.
- You can test your amplifier immunity once fully assembled with all the panels screwed in by placing your mobile phone on top of your amplifier and then getting a friend to call you. You should hear no buzzing or extraneous noises over your speakers.
- Always ensure you have a band limiting filter on the input of your amplifier. 1k and 220pf is a good compromise. If you are worried about thermal noise, 220 Ohms and 1nF is also ok. But, whatever you do, make sure you have the filter
- Good quality interconnects (tightly woven screen, gold plated plugs and sockets) also help prevent RFI problems

If You Get it Right, Here Are the Results You Should Expect

- With no inputs plugged into your amplifier, you should see no more than about 200uV pk-pk noise on the output – for a ~100W amplifier, that translates to better than -105 dB noise. If you do a really good job, you can expect half this level, or about 100uV or about -110 dB
- With a preamp plugged in and powered up with volume set to minimum, assuming it is correctly wired up, the noise should not exceed 500uV pk-pk – that's still about -100 dB
- With the preamp plugged in, but powered OFF, the noise level should be -105 dB.

Happy Listening!

Zero Noise Audio Amplifier FAQ's

- I read that you need a balanced input for good noise rejection performance
 - You can achieve ~-110 dB with good wiring on single ended input amplifiers. Balanced inputs are necessary in professional applications where electrical noise levels are usually much higher. For domestic applications, single ended is ample for most applications
- Is it true that balanced inputs sound better than single ended inputs?
 - We are talking about how to wire an amplifier up for lowest possible noise here. I cannot comment on the sound.
- Why do you show a 'screen' on your transformer and what does it do?
 - A capacitance exists between the primary and secondary of a transformer. In a toroid, it is much higher than in a E core or R core. This capacitance couples mains noise from the primary side onto the secondary. The screen is located between the primary and secondary and connects the inter-winding capacitance to GND, effectively shunting the mains noise to ground as well. This technique can deliver 20~30 dB noise reduction if executed correctly and save on the cost of the mains filter.
- What kind of mains power socket (i.e. mains inlet receptacle) do you recommend for the power inlet.
 - For DIY, always use a switched, fused IEC 3PIN socket. Here is a link to a suitable one from mouser: [mains entry socket](#) These types of sockets are safe, incorporate the very important fuse and a switch. Note, if you shop around, you can get good quality inlets for about \$7.
- What is a 'belly band' and what does it do?
 - A belly band is a thin metal overwrap that goes around the outside of a transformer (E core or toroid). It is very effective in reducing the radiated field from the transformer, and thus in reducing noise. If your transformer is wound with a screen and a belly band, it is possible to get very good noise performance. I recommend that you always specify both if you have a transformer custom wound
- Why do you have separate rectifiers on each of the secondaries going to capacitors. What's going on with that part of the circuit? Aren't you wasting a rectifier like this?
 - By rectifying and smoothing and only then combining the secondaries you almost guarantee that the capacitor charging currents – which in a big amplifier can be as high as 50~100A – are kept out of the small signal ground returns through common impedance coupling. However, do also note that you must 'T' off as shown in page 2 to get the full benefit of this approach. If you simply connect all the wires to the top of the 'T' you will probably introduce noise. As a further step, you can phase the secondaries so that their fields partially cancel, reducing noise
- How can I phase the secondaries?
 - Wrap 5 turns of insulated wire around your transformer. Connect the two ends to a pair of headphones. Listen to the sound. Then swap the connections around between the secondary and its associated bridge rectifier on one of the secondaries. If the noise is louder, return the secondary connections to how they were previously, otherwise leave them as is. Its that simple.
- What does the 'decoupling' resistor do?
 - It prevents high ground loop currents flowing through the interconnects, and forces them instead to flow through the chassis earth connections via the mains inlet receptacle. This approach can reduce amplifier hum substantially.



180 W RMS per channel [‘e-Amplifier’](#) featuring VFA topology, 10ppm 20 kHz distortion and peak output currents of $\sim 40\text{A}$, 3 Hz to 200 kHz bandwidth, and better than -100dB noise and hum ref 2.8V peak output into 8 Ohms that uses the wiring techniques described in this document.