The ground noise issue – an explanation of what's happening and how to maybe fix it..

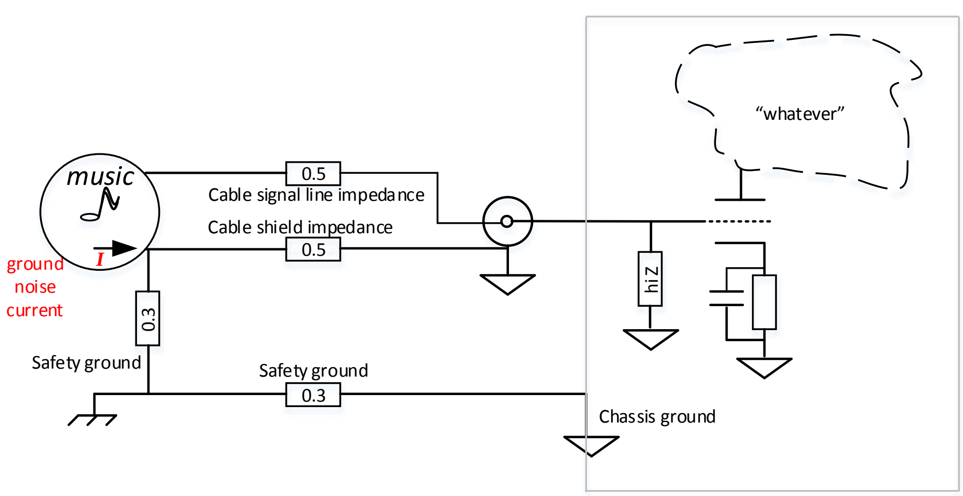
There was recently a post on one of the vendors' forums from a diyer who wanted recommendations for a transformer that he could use to isolate his amplifier from ground noises. The symptoms seemed to be the usual: with nothing connected to the input of his amp, or with its input shorted, there was no hum problem. But after connecting to his system, annoying hum and buzzing noises appear. Connecting or disconnecting other attached system components could make the noise level change or even go away temporarily, but any useful configuration always had the noise.

While using a transformer there could certainly be a fix for this, there are some disadvantages:

- Decent quality transformers are quite expensive
- Using even the best transformers is adding yet another non-ideal component into the signal path
- transformers aren't very small and might not be so easy to install
- Transformers can *inject* hum, too, should their shielding not be up to dealing with AC magnetic fields at the spot and orientation where the devices are being installed

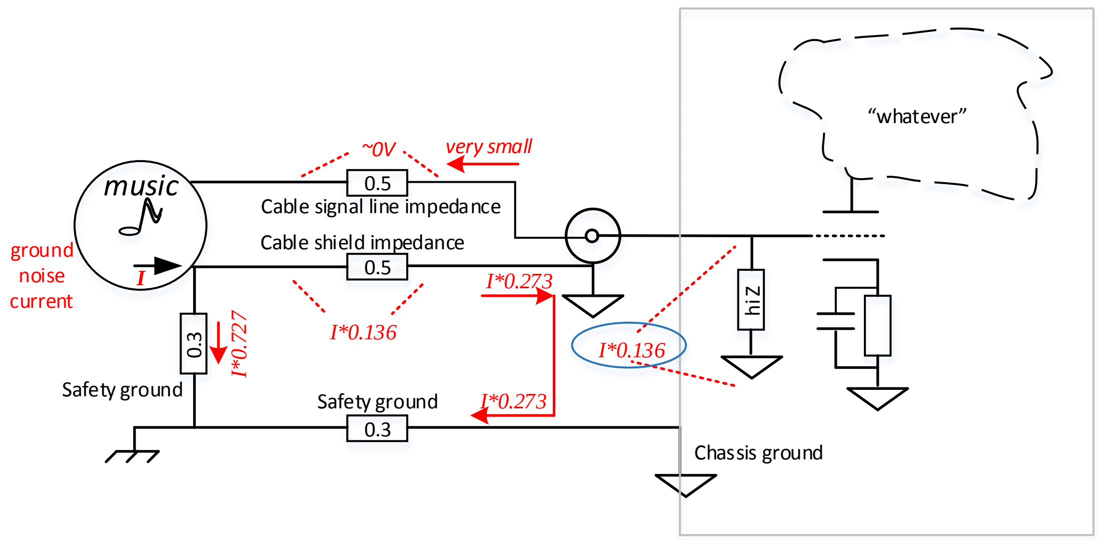
I helpfully suggested that he instead try lifting all the input ground connections from the usual (chassis) ground of his amplifier, connecting those all separately to each other again, and then inserting a low valued resistor in series there back to chassis ground. I recently ran into a similar problem on an amp I made, and this fix made all the difference in my situation. My amp was a single-ended FET input, but the same trick can be applied to many tube or solid state amplifiers as well.

I was trying to picture in my head just why this is so effective, beyond just hand-waving, so I sketched up the situation and applied some numbers (which are often easier for me to grasp). Here is the result, hope this helps some others out there. Apologies if this is already somewhere out there on the net -- I had not run into any actual analyses before. Warning: there's a little math here (but, hey, it's only Current Dividers and Ohm's Law – it doesn't get much easier).



Above is a diagram of the problem, with some not-unrealistic values given for some of the impedances. For simplicity, I'm treating all the impedances as just resistances, though inductance can get into the picture as well (with similar results). I also am drawing the amp as having a tube input for no particular reason. I'll let the ground current noise just be designated "I" and for simplicity here assume it is from power supply leakage somewhere in the music source back to the power lines' safety ground (it could also be from the amp itself, or from induced currents into the loop made by the cables and wires, or from all). I used 0.5 ohms for the series resistance of the input cable to the amp, same value in center conductor and shield. For the safety grounds on the power amp and of the music source, I assigned 0.3 ohms each.

Below, I've calculated noise voltages and currents around the loop.



The two paths for the noise current out of the music source cause the noise current to divide between them, inversely proportional to their resistances. There is 0.3 ohms in the music system safety ground for one path, and 0.3+0.5 ohms in the path made by the cable shield and the safety ground of the power amplifier. The result of that is a noise current through the cable shield of

$$I*0.3/(0.3+0.5+0.3) = I*0.273 \text{ [A]}$$

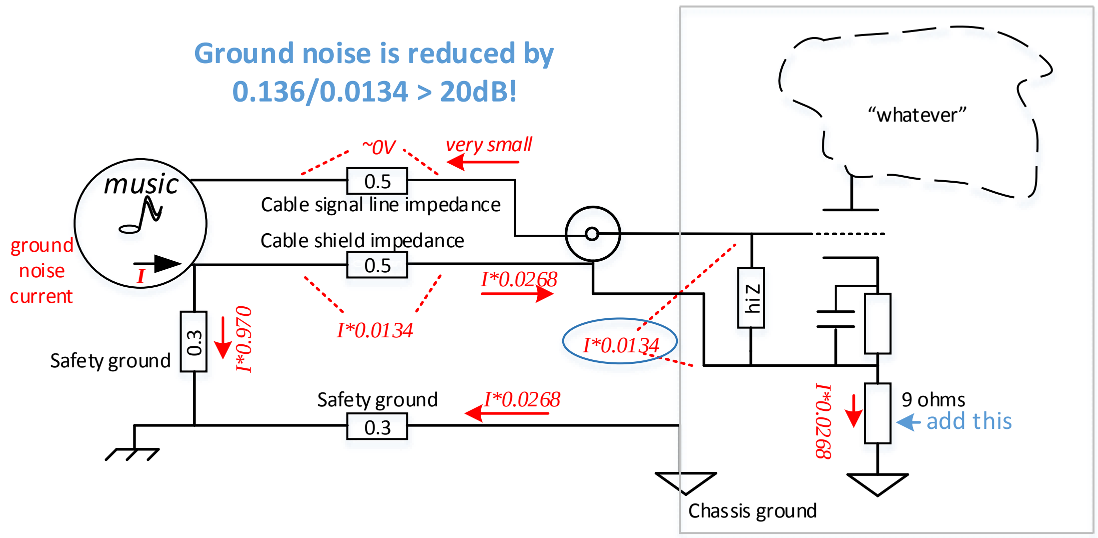
By Ohm's Law, that current results in a noise voltage across the cable shield impedance of

$$I*0.136 \text{ [V]}$$

Since the amp's input impedance is assumed to be very high (compared to all the other impedances), noise current through the cable signal line's impedance will be very low, as will any noise voltage then induced across it. So that causes the noise voltage of about I*0.136 to appear at the amplifier's input, which the amplifier dutifully amplifies and proceeds to bother you with. For a feel of the scale of things here, to get 1mV of noise at the amplifier input (causing about 20mV of noise at the speaker with most amplifiers), the ground noise current needs only to be a little above 7mA.

Reducing the cable shield impedance (magic cables?) would lower the noise voltage, but not as much as you might expect since that would also force more current through it because of the changed current division! Putting a lower resistance safety shield on the amp will INCREASE the induced noise in this example, as more current gets pulled through the cable shield! Lowering the resistance of the safety ground to the music source can help. But both depend on where the noise current is actually getting injected, so are not particularly good strategies.

Now, let's inject a "return lift" resistor of 9 ohms into the amplifier's input circuit (below). The added resistor in the cable shield's current path changes the current division for noise significantly. Now, less than 3% of the noise current travels through the audio cable shield, reducing the noise voltage induced across it by a little over 20dB, which is quite a lot for just the cost of a 9 ohm resistor!



But what does this do to the music signal? Well, the music signal between the amp's input and its effective signal return is unchanged and is also unaffected by the small series resistance in that circuit, that feeds the high impedance input. The bias voltage and idle current of the amp input is also very nearly unchanged. Its effective supply voltage might be reduced by some millivolts because of the stage's DC current flowing through the added resistor, which will depend on what that current is and what the resistor value is. Which is why you wouldn't want to put something like a 1k resistor there, as the voltage drop could start to get significant. The noise current that goes through the added resistor will also cause a very small noise modulation on the effective supply voltage for the stage, some of which might appear at its output depending on the devices used - another reason to not go too large with the resistor value. I've had good results with values between 2.2 ohms and 15 ohms.

You also should consider safety - you now have the added resistor possibly (though unlikely) inhibiting the ability of the safety ground circuit to blow a fuse should the cable shield connection somehow come in contact with the AC line hot lead. So it is probably a good idea to make your added resistor a 5W or 10W rated part so that it would live long enough to blow a fuse should such a (rare) occurance happen.