Mixer Grounding 101

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Introduction

The purpose of this document it to try to explain how grounds,screens, earths and zero volts should be connected in both simple and more complex audio devices. In particular, the scheme used for the EZTubeMixer is explained in detail.

The terms ground and earth are so ambiguous in the context of audio that I try to avoid them unless qualified in some way. The important thing to remember is the **function** that these connections perform. There are three to consider:

1. **Safety earth**. It's purpose is to save your life in the event of a fault. All exposed metalwork that a user can touch must be connected to it. It must be connected to the mains earth input connection as close to the mains input connector as practical.

2. **Signal screen**. It's purpose is to conduct interference currents separately from any signal currents and thus keep interference out of the signal chain. Signal screen usually includes all exposed and non exposed metalwork and cable screens.

3. **Signal 0V**. It's purpose is to act as a reference equipotential for all internal signals. It should carry only internal signal currents. (If for some reason it does carry some interference currents, then this interference will probably appear in the output signals as noise or hum.)

Ideally, these three should only be connected together at a single point in the equipment. Since the Safety Earth **has** to be connected to the exposed metalwork close to the mains input connector, it makes sense to make this the common point. So where the mains enters your equipment, the mains earth should be connected to the chassis using a nice chunky bolt **as close to the mains inlet as possible.** This point is then **the common point**, sometimes called a star point, for the grounding system. All connections made to it should include locking washers.

Since the mains usually enters right near the power supply, then this is where all three usually end up being connected together. Connecting the safety earth to the chassis where the mains enters immediately connects part of the signal screen (the chassis) to the common point. Since the power supply is nearby, then this is the place to connect the **signal 0V** to the **common poin**t. Since we only want to connect these three together **at one point** this means the **signal 0V must not be connected to chassis or screen anywhere else**.

What Can Go Wrong?

Problems occur in the real world because the above three are rarely, if ever, separate. It is almost inevitable that Signal screen and Safety Earth have elements in common. This is normally not a problem because both are carrying **unwanted interference currents** and need to end up at the common point.

Nearly all problems occur when there is overlap between Signal Screen and Signal 0V.

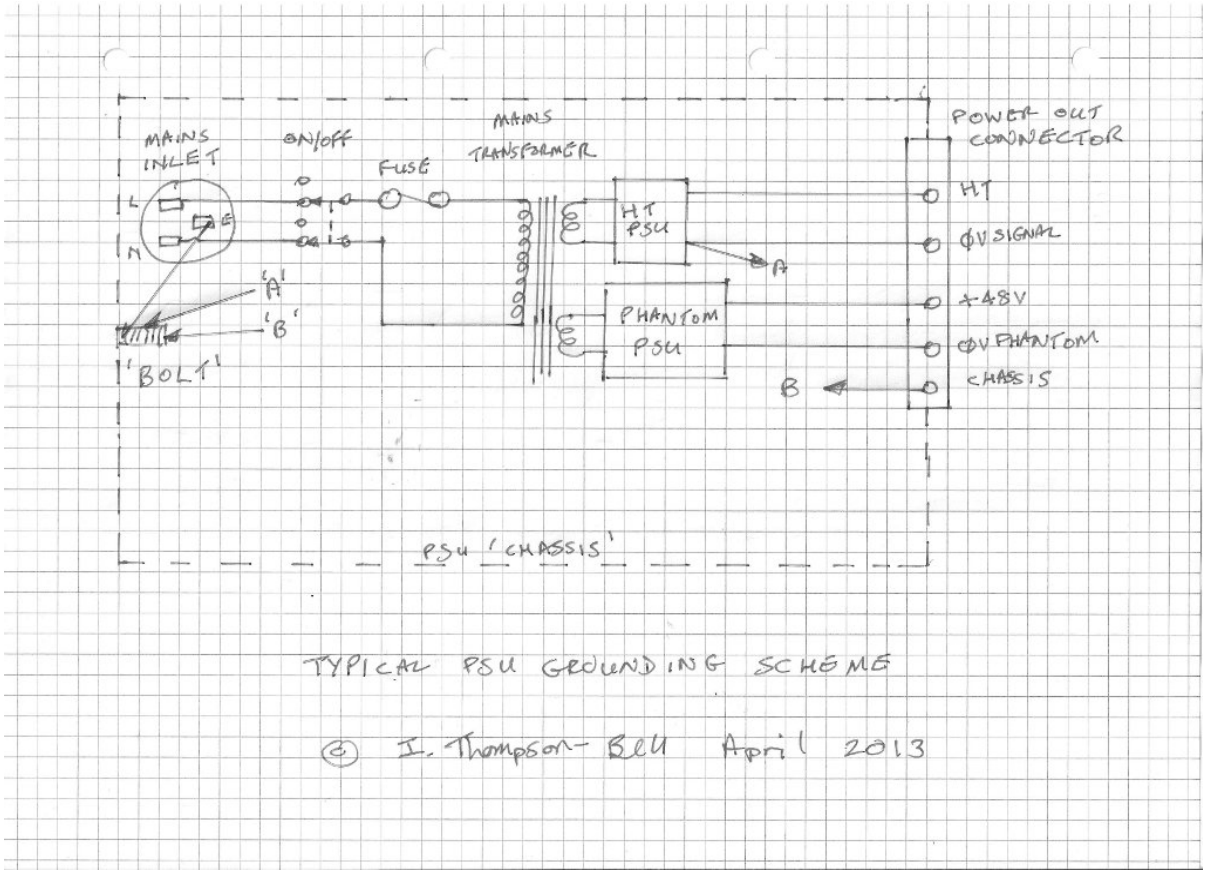
In a fully balanced floating equipment (one with input and output transformers), Signal Screen and Signal 0V can be connected at one point only, because the input and output signals are **not** referenced to Signal 0V. Screens of incoming and outgoing cables simply **connect directly to the local metalwork** so interference currents flow separately from the signal. This is why the AES recommends **connecting pin 1 of XLRs directly to chassis** (and not 0V) **at the connector**. Fully balanced floating systems do not suffer from hum loops because there is no connection of the input and output signal reference between equipment.

In equipment with **differential inputs and outputs** (often erroneously called balanced) the input and outputs **are** referenced to Signal 0V so although you get the benefits of common mode interference suppression, you are not immune to hum loops.

In equipment with unbalanced inputs or outputs t**he Signal Screen and Signal 0V are one and the same**. We therefore have interference currents flowing in the Signal 0V and the likelihood of noise and hum is increased.

Power Supplies

Whether your power supply is internal or external, the same basic grounding rules apply. The figure below shows a block diagram of the insides of a typical power supply that illustrates how the rules can be applied.



The mains enters at the top left via the mains inlet (usually an IEC connector). The safety earth pin of this connector is connected directly to a bolt on the chassis close to the connector. This bolt then serves as the common point. The mains passes through a switch and fuse to the mains transformer. Separate secondaries provide power to the main (HT) and phantom power supplies ensuring that the signal 0V and phantom 0V are isolated (you will see why this is important later on). A connection is taken from the signal 0V, right where it emerges from the HT supply and is connected to the common point (link 'A').

The power supply output are showing emerging from a connector on the right. If this power supply is **inside** the audio equipment (like a stand alone mic pre), then the chassis of the equipment is already connected to the chassis of the power supply because they are one and the same thing.

If the power supply is external to the audio equipment then there is no obvious way in

which the chassis of the power audio equipment gets connected to the common point. That is the purpose of the output connector pin labelled 'chassis' . Where the power cable from the external power supply enters the audio equipment the 'chassis' pin is connected directly to the chassis right at the connector. The chassis pin at the power supply end is then connected directly to the common point (link 'B'). There is now a single connection between the audio equipment chassis and the power the common point so that interference currents are fed directly to the common point.

If the power supply is some distance from the audio equipment, there is a danger that interference may be picked up by the dc power supply leads. To avoid this it is preferable to screen the this cable. Since the screen is there to prevent interference it should be connected to the chassis pin at both ends of the cable.

Avoiding Hum #1

In simple equipment like a microphone preamp, it is fairly easy to avoid hum and interference due to external ground loops. Input and output transformers can guarantee there is no connecting of the signal 0V to the chassis or safety earth **except at the common point.** You simply connect the pin 1 of all input and output XLRs directly to chassis at the XLR.

If you have a significant cable run from an XLR to or from a transformer you will want to screen it, as much from the point of view of preventing internal interference (crosstalk) as preventing external interference. Wire the screened cable to the XLR in the normal way with its screen connect to pin 1 and connect the other end to the transformer. But what do we do with the screen at the transformer end? The answer is we don't need to do anything with it. It already has a connecting to the chassis to conduct away interference current – it does not need another. So you leave it unconnected.

The only potential problem area is phantom power.

Phantom power is a bit of a kludge and breaks the cardinal rule that you must not use a screen for signal or power. Screens are for carrying interference currents **away** from signals. In phantom power the +ve supply goes via the two 6k8 resistors down the mic cable and into the mic. The internal 0V of the electronics in the phantom powered mic is connected to the **mic cable screen**!!! This has to get back the phantom power supply 0V somehow. Now there are two ways you can do this.

1. Connect phantom PSU 0V to chassis at the power supply just like the regular signal 0V. The problem with this is that all the phantom supply return current from the microphone flows through the chassis along with all the other interference currents the chassis is

picking up and safely shunting to safety earth. So what you have just done is put a noise generator in series with the 0V line of the phantom supply. Fortunately the the PSRR of the phantom mic electronics should ignore most of this and any that gets onto the signal lines should be common mode so very little should get through to the mic pre. But why take the risk?

2. If you wire the phantom 0V direct to the mic input XLR pin 1s you avoid this potential problem because you are not taking the phantom 0V via the chassis any more. This is also the reason why it is a good idea to generate phantom power from a separate transformer winding so its 0V is **isolated** from signal 0V.

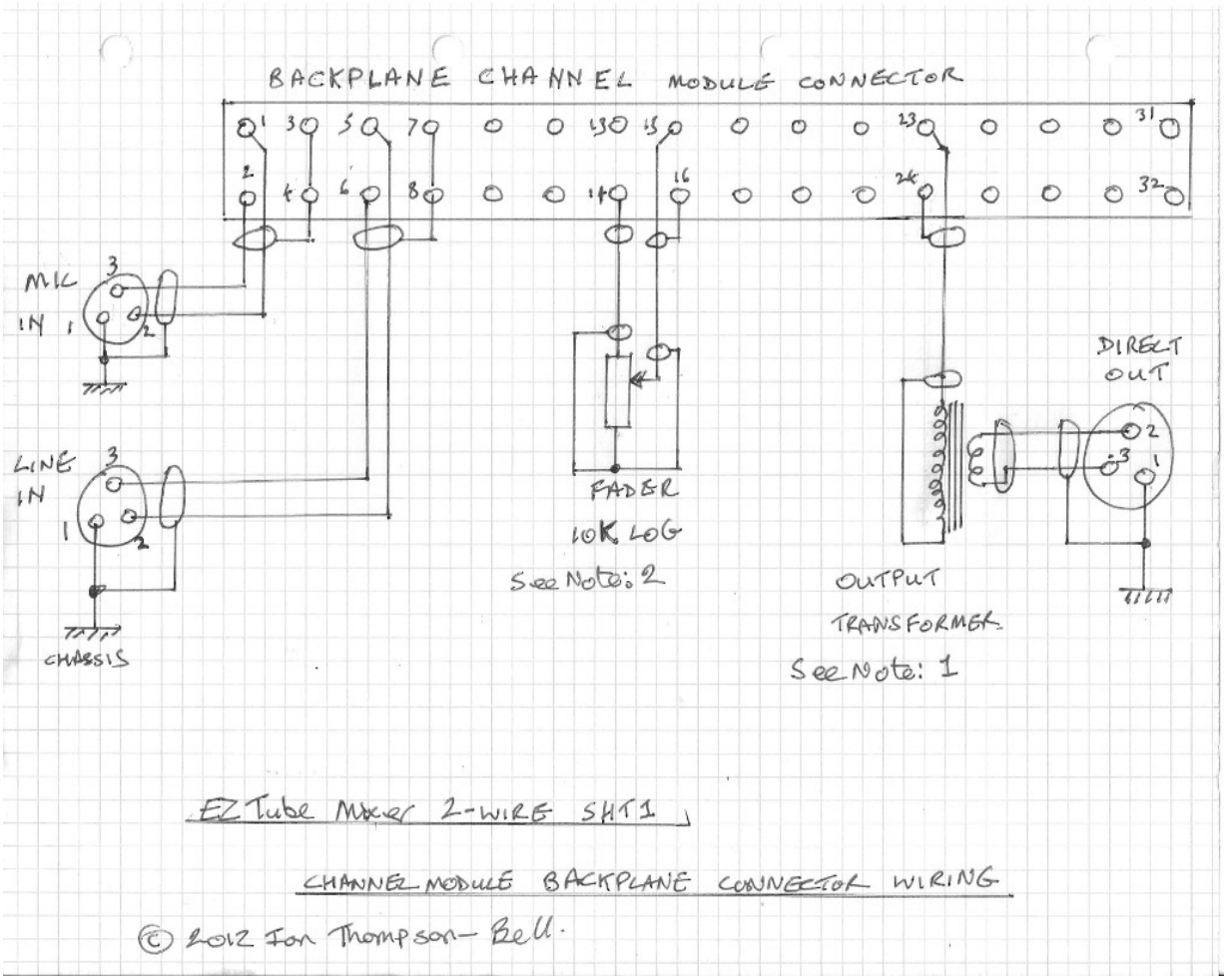
Phantom power is still not ideal because any interference picked up by the mic cable itself also appears in series with the phantom 0V connection but there is nothing you can do about that. In the good old days, condenser mics had their own built in power supplies and there was no need for the phantom compromise. Screens were screens and never carried signal or power.

So, mic input XLRs are **the one and only place** where you need to connecting both a screen **and** 0V together but **ONLY** on mic input XLRs. You should connect pin one of the mic input XLR directly to the chassis at the XLR and also connect the phantom power 0V to pin 1 of the mic input XLR.

If you have a cable run from the mic input XLR to the transformer you can wire it exactly as described earlier with the screen unconnected at the transformer end.. Again, the only exception is the phantom powered mic input. You probably have a PCB somewhere with the phantom power switch on it along with a series resistor and a decoupling capacitor. One end of this capacitor needs to be connected to phantom power 0V and we have already connected that to the mic input XLR pin 1. So in this case we **do** use the screen at the transformer end and connect it to the phantom power decoupling capacitor.

Avoinding Hum #2 - EZTubeMixer Grounding Scheme

In more complicated systems like mixers, the same principles apply for external inputs and outputs. Use transformer balanced inputs and outputs and connect pin 1 of all incoming and outgoing XLRs directly to the chassis at the XLR. Cable runs from XLRs to transformers follow the same rules as before. The EZTubeMixer is a useful example as it illustrates all the techniques described above. The schematic below shows the wiring to/from a channel module:



On the left you can see the mic and line inputs. Both have pin1 of their XLRs connected directly to the chassis. Both have twin screened cables from the XLRs to the backplane connector. For the mic input, this is because the mic pre that plugs into the backplane connector includes a phantom on/off switch with a smoothing capacitor. The screen supplies 0V phantom to this capacitor. The line input screen is connected to provide signal screening. On the mic pre, a screened cable is wired from the line input connector pins to the line input transformer but the screen is left unconnected at the transformer end.

On the right hand side you can see a direct output. Again the XLR pin 1 is connected directly to chassis. A screened lead connects to the output transformer but the screen is

left unconnected at the transformer end.

In the centre you can see the internal wiring of an unbalanced fader. As this is unbalanced you have to take care not to create ground loops. Unbalanced connections break the rule that signal 0V and screens should always be kept separate. In a mixer it is important that no signal leaks through when the fader is fully down (or anticlockwise if using a rotary pot). To achieve this you really need the anticlockwise or fader down terminal of the pot the be referenced to the receiving amplifier. In the EZTubeMixer example this is achieved by connecting the screen of the cable from the down terminal of the pot to pin 16 of the mic pre which is internally connected to the 0V of the gain make up amplifier. The screened cable carrying the signal to the top of the pot/fader is **not** connected to 0V at the mic pre connector. No earth loop is created as the screen is connected at only one point.

The general rule for unbalanced connections inside a mixer is connect the screen of the cable at one end only and preferably at the receiving amplifier end. A sort of exception to this rule is wiring to transformers from output amplifiers as shown on the schematic above. The amplifier output and its 0V are connected via a screened cable to the transformer. The screen is connected at the amplifier and transformer ends, but the rule is obeyed because the screen is connected to 0V only at one end.

Lastly, as usual, the exception is phantom power. In a mic pre with only one mic XLR is is easy to connect phantom 0V to the mic XLR pin 1 . But how do you do it if there are 6 or 16 or more mic inputs. In my mixers I put all the mic input XLRs on one panel if I can. I connect pin 1 of each direct to the chassis at the XLR. I also run a fat copper bus bar wire strapping all the pin 1s together. From one end of this bus bar I run a wire to the 0V of the phantom supply PCB.