Switching and Grounding in Vintage Audio Systems

How to integrate multiple vintage audio systems with automatic switching, with all sources to all amplifiers, while avoiding ground loops

Introduction: Evolution of a Vintage Audio System

I started my vintage system by restoring an Eico preamp and using two HF-20 power amps as monoblocks. Built a pair of speakers using EV12 triaxial drivers. An Empire turntable completed the basic system (**at left**). Of course, the hobby didn't stop there. Soon there was Sony's first CD player, a Roberts reel-to-reel tape deck and so many other treasures. There were integrated amplifiers, tuners and a seemingly endless array of other things.

This might sound like a familiar story. We end up with far more toys than we can easily play with or accommodate. What to do? Some folks set up multiple stereo systems. There is one in the living room. One in the bedroom. The guest room begins to look like a good prospect. Wouldn't want guests to feel left out, would we?

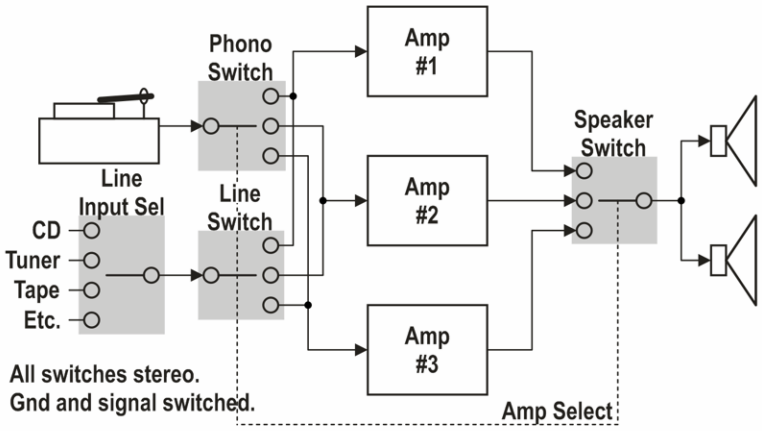
I eventually discovered that it is important to try to integrate the vintage equipment so that multiple sources can be shared among multiple amplifiers and large, singular resources like speakers can be shared. If you are to have much hope of enjoying a large share of the available options, you need to have a convenient way of switching between them. I have been able to implement such a system, which involves four amplifiers, eight line-level sources, a turntable and two speakers. Any source can be enjoyed with any amplifier. Sources and speakers are automatically switched to the amplifier which is turned-on. (They have a priority order if more than one is on.)

In the following pages, I will reference articles describing how you can build a similar system.

Switching a Vintage System

As shown **at right**, there are four distinct switching functions which may need to be addressed in a multiple-source, multiple amplifier (**hereafter "amp"**) vintage system:

- Line input selector
- Line switch
- Speaker switch
- Phono switch



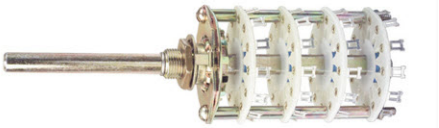
Each of the switch functions has specific requirements. Let's take a look at them:

Line Input Selector

At first, I tried to get away with all of the amps driven in parallel from the line sources. I used a three-way source selector for the tape-like sources. Then there was the CD and tuner. Just had multiple Y-connectors to split the signals which were routed to the amps. This worked okay for the first couple amps. However, my enthusiasm for everything-to-everything waned as I added the third and fourth amps to the system. One had all line sources. Two more had tape and CD and one just had CD. With this arrangement it seemed that I was often running into, "Oh yeah, can't do tape on that one," or something similar. Plus, it was sometimes a chore to remember which input a source went to on a particular amp. I came to the realization that I needed a Line Input Selector box (**below right**) which would handle all of the line sources. This would make it much easier to route them to the amps. When I made a list of all the line source selections that I had or expected in the vintage system, it came to this:

- Front panel connection for iPods and such
- CD
- Reel-to-reel tape deck
- Fisher tuner
- Heathkit Computuner
- Cassette deck
- Minidisc player
- 8-Track player (Hey, this is vintage system!)
- Aux (for future needs)
- Oscillator (I wanted to dedicate a test oscillator to complement the audio scope.)
- Off position (This is handy next to the oscillator, since tones can be annoying.)

As you will see in the grounding discussion, I found that it is important to keep grounds as independent as possible in a complex system like this. To support that, the switch was designed to switch grounds as well as signals, keeping left and right grounds separate. All of this required an 11-position, 4-pole switch, which was fortunately available at Mouser (**shown below**). It wasn't cheap, though.



Line Switch

My system does not have this yet, but I have come to believe that a line switch is very important. It leverages the value of the Line Input Selector, distributing the selected source to all of the amps. It keeps the grounds of the amps separate. Plus, sources no longer have to drive all of the amps and cables at once. For now, my system does drive all four amps in parallel from the line selection. However, I look forward to the day when I can add line switching to the automatic switch functions.

Speaker Switch

Since speakers are large, they need to be shared amongst all of the amps. Thus, a switch is needed. Initially, I used a Radio Shack switch, meant for sharing a single amp among multiple speaker systems. It had a common ground, which for that application was fine. I didn't realize at the time, that turning it around and connecting all of the amps to a common speaker ground was asking for trouble. (More on that later.) The idea of keeping left and right speaker grounds

separate was even further from my mind, because I already had a headphone box which required a single ground. I also had an audio scope (with a single ground) connected to the speakers.

Of course, the speaker switch was manually operated, which I didn't see as a burden at the time.

Phono Switch

Since the turntable is fairly large and singular, it too is a resource which you will probably want to share among the amps. I wanted to be able to listen to each of the amps' phono preamps, compare them and enjoy them, as if each amp were a part of its own separate stereo system. The challenge here is the fact that the low-level phono signals are much more susceptible to hum. Also, capacitance from excess cable length could be a problem. Finally, one grounding requirement which I did know at the time was the fact that left and right phono grounds should be switched separately.

To solve the problem, I constructed the relay-controlled phono switch box shown **at left**. I didn't want to have to deal with another manual, amp selector switch. The relays are driven from AC adapters at each amp. Those are plugged into the switched AC outlets on the amps. Whichever amp is turned-on gets the connections. Priority logic handles conflicts. A manual override allows amp comparisons.

The concept was to use miniature relays, mounting them close to the phono connectors. Wiring between the connectors and relays would be kept very short. Great care was taken to minimize hum in the box, so AC adaptors producing regulated DC were used. Since grounds had to be switched as well as signals, four-pole relays were needed.

With the phono switch on the floor, directly below the turntable, this works reasonably well. I do have to be careful to keep the phono cables away from the power strips and power cords which are nearby, though.

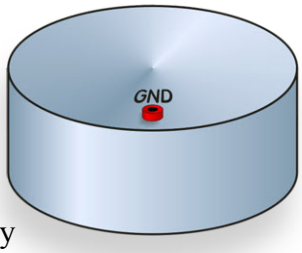
Integrating the Speaker and Phono Switches

Perhaps inevitably, I eventually decided that the manual speaker switch should be replaced by a relay box (**at right**) as well, operating from the control circuitry already in the phono switch. An umbilical cable connects the control signals between the boxes. With this arrangement, the switching is fully automatic. I have only to turn on the amplifier I want to listen to. Inputs and speakers are automatically connected. Is that cool or what? :) It felt like audio paradise.

Running Aground in Paradise

Not all was well in this seemingly utopian setup, though. There were issues with having all of the amp grounds connected together through the line inputs: I began to see problems with ground loops. This manifested itself in two ways: hum and (rarely) low frequency feedback.

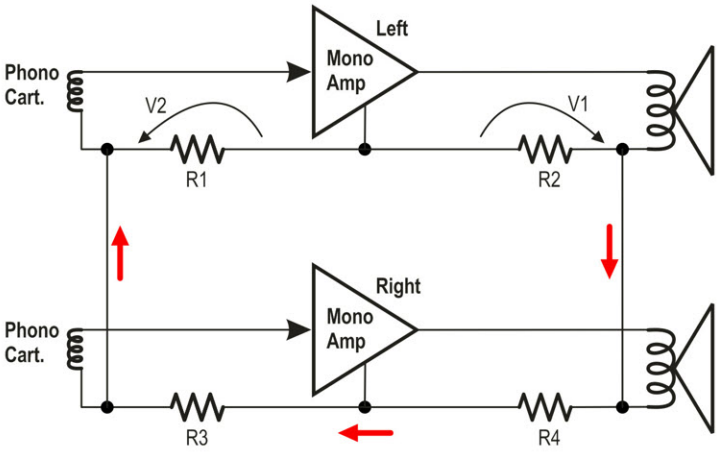
Do We Understand Ground?



I encountered my first introduction to ground confusion when I was a grad student helping a lab full of neophyte electrical engineering students. For years, there had been a cylinder of solid steel sitting in the lab. This cylinder was about 8-inches in diameter and 4-inches thick, so it was pretty impressive. No one knew why it was there but no one volunteered to move it! There was a hole in it. For a joke, someone had poked a banana jack in the hole and labeled it "Ground."

One day, I walked into the lab where the students were busily doing their lab experiments, and noticed that they had strung-up a series of interconnected banana leads, from each of the students' experiments. My eye quickly traced the connections back to –yes– the steel cylinder. Somehow, one of the students had gotten the idea that his experiment needed to be connected to "ground" and they had all followed suit like lemmings. Har! I don't know what they were thinking but it sure was good for a laugh. Little did I know that I had a lot to learn about grounding too.

Example: The Problem of Combining Mono Amps for Stereo



Think that a discussion of grounds couldn't possibly be interesting? Well, what if I told you that the simple act of using a pair of mono amps for stereo, could lead to feedback which threatens your speakers? That is exactly what happened to me and got me thinking about grounding and switching issues.

There wasn't any apparent reason to tie the grounds together at the amps. Each was connected to the speakers and to the input sources. Everything seemed to be working fine until I turned up the volume on the phono input (with no record playing). Suddenly, there was a humongously loud, very low frequency feedback which caused havoc with the ported speakers.

The diagram **above** shows what was happening. The resistors represent resistance in the ground wires of the phono and speaker leads. I had two Heathkit EA-3 mono integrated amps which were being used together as a stereo amp. The speaker grounds were tied together at the headphone switch box. Unfortunately, the wiring under the turntable was also tying together the grounds of the left and right phono cartridge signals.

Let's look at the system from the point of view of the left amp: The large output current develops a voltage (V1) across the resistance (R2) in the ground side of the speaker wire. The voltage is coupled through R4 and R3 but is shunted by R1. That leaves a portion of V1 which appears as V2. That voltage is added to the left phono signal and goes back into the input of the left amp. Now, let's try some numbers to get a feel for the results. Suppose the resistors are all 0.1-ohms and the speakers are 8-ohms.

V1 will be about 40dB below the output level of the amp. It drops another 10dB by the time it gets to V2. Virtually all of V2 appears at the input of the left amp. The result is 50dB attenuation in the feedback around the left amp. Typical gain of a phono preamp is roughly 40dB at 1kHz. With RIAA equalization, you can get about 60dB gain at low frequency–10db *more* than the attenuation in the feedback path. So we already have more than enough gain to cause runaway low frequency oscillation and we haven't even factored-in the gain of the power amp section!

The solution to the problem? Break the connection between the phono cartridge grounds and tie the grounds of the two amps together with a thick wire. Notice that we cannot break the tie between line source grounds, so those still have a similar issue. Of course, there is much less gain at line inputs. That helps a bunch. Tying the amp grounds interdicts the path of the feedback, by connecting it to the ground of the Left Amp between R3 and R4. Mind you, it is working against a pretty low source impedance–just 0.2-ohms in our example. To get even 20dB attenuation, we have to get the resistance of the ground tie down to 0.02-ohms.

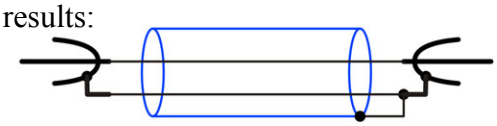
However, I don't want to focus too heavily on this particular example of ground problems. It just serves to illustrate that grounding can be more interesting than it might seem at first.

Amps Which Float the Speaker Grounds

By the way, since I have mentioned that my present system combines the speaker grounds, I should point out that not all amps allow that. Since I cannot call the non-signal side of the speaker "ground" in those cases, I will call it "return." Amps like the Eico ST-70 and Heathkit AA-21 prohibit the left and right speaker returns from being connected to each other or to ground. That causes problems for switching, connecting headphones, connecting other auxiliary components and for lab testing. My article on mods for the ST-70 includes a fix for that. An upcoming article on the AA-21 has a fix for that case as well.

Grounding Strategy for a Vintage System

To deal with the ground and hum problems of the complicated vintage system, I have tried a number of techniques over the years. Here are some of the results:



Attempts Which Did Not Help

- Grounding the chassis of most components to a central ground bar, using #12 wire. This didn't seem to help, overall. In a couple cases, it made things worse.
- Using a pseudo-balanced cabling method (**shown above**). This was supposed to reduce inductive hum injection. It didn't seem to make much difference. The decreased size of the ground wire seemed to hurt in one case.

Sources of the Problem

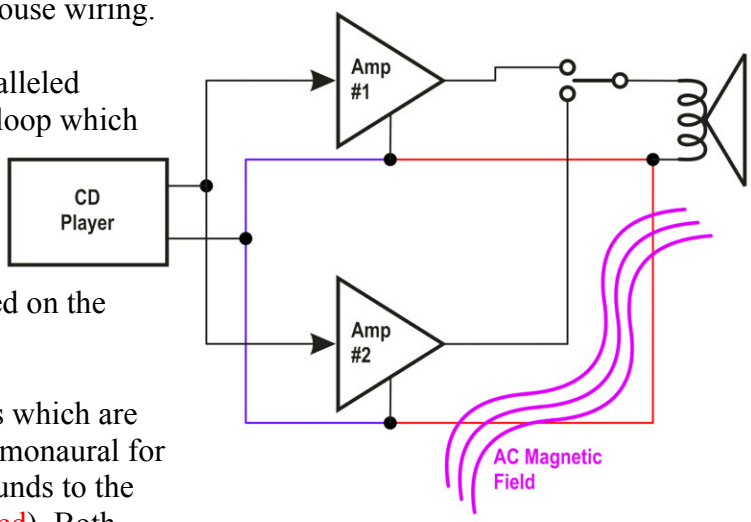
Most grounding problems are due to ground loops, which are simply paralleled ground connections. In other words, ground loops exist whenever there is more than one metallic path from one ground point to another one. That can happen when grounds among multiple components become co-mingled. The two main problems that ground loops cause are:

- Hum induction in the loop formed by the parallel path
- Voltages dropped across a sensitive ground path due to currents intended for the other path. These are typically either speaker currents or currents in AC house wiring.

The ways in which grounds can become co-mingled are not always obvious at first. Here are some examples I have run into:

- CD player drives multiple amplifiers in parallel. The speakers shared a common ground, so some speaker current runs through the CD signal grounds.
- Phono wiring had a common ground between left and right, under the turntable.
- Headphone/speaker switch merged the L/R speaker grounds, since the headphones have only a single, common ground.
- Heathkit audio scope was connected to the speakers. Its common L/R ground bridged the L/R speaker grounds. Since the scope also had multipath signals (with ground) from a receiver coming to it, a troublesome ground loop arose.
- Tape deck is switched to drive separate amplifiers but it also has its input connected to the tape output of one of the amps. The speakers have a common ground, so some speaker current can run in the tape deck signal grounds.
- More than one component whose chassis is connected to AC power ground. The result is hum from ground currents in the house wiring.

Perhaps the worst effect of having paralleled ground paths is that they form a large loop which can pick up magnetic flux from power transformers and AC power lines. That generates a hum voltage across the length of the ground of the audio cable. The hum will be impressed on the audio.



The example **<u>at right</u>** shows two amps which are switched to drive one speaker (shown monaural for clarity). Instead of switching their grounds to the speaker, they are common (shown in red). Both amps are driven from a single CD player, whose ground is shown in blue. A loop is formed by the red and blue grounds. Magnetic flux shown in magenta, induces an AC voltage in the loop, which appears across the CD player grounds, causing hum. The fix is to use a double-pole switch and to switch *both* of the speaker wires. That way, the grounds of the amps are not connected at the speaker.

The importance of such loops was brought home to me when I made a special audio cable and hum actually got worse. The handmade cable had two separate shielded cables (left and right), bonded with cable ties every foot or two. Problem was that this did not keep the cable shields tightly together. Lines of flux from power transformers were getting between and inducing a hum voltage between the left and right grounds. Even the relatively short wire in the amp between the connector grounds was unable to eliminate the hum. Changing from a handmade stereo cable to a commercial one brought the shields tightly together, eliminating the problem.

Grounding Solution

The solution to these problems in a complex system is easy to state but not so easy to implement: Continuously, disconnect all grounds which don't need to be connected. Stated another way: Implement a switching system which connects only those grounds which are needed. Pretty much, this just means that the switching system must switch grounds as well as signal lines. Left and Right grounds must be switched separately. A switching system like the one pictured on page-1 meets these requirements.

The next article in this series presents a Line Input Selector which does part of the job. It takes care of isolating the grounds of the unused source equipment, from the rest of the system.

Coming later will be an article presenting an amplifier switch which switches phono, line sources and speakers among multiple amps, while keeping unnecessary ground connections isolated.

What all this boils down to is simply this: We need a switching system which connects only the components which we are actually using. Electrically, that returns us to the basic single-source, single-amp and pair of speakers which we all know, can work very well.

Another Grounding Solution

My friend David Gillespie suggests another solution for resolving ground loops: inserting (say) 10-ohm resistors in the grounds of signal (not speaker) cables. That expedient is indeed a good trick. It would probably solve most ground loop problems to most people's satisfaction. I guess personally, I have shied away from that because of the worry that it is potentially a compromise. (Ironically, Dave and I usually take reversed roles in the absolute-versus-expedient debate.) Nevertheless, it is quite practical, and probably effective. I would like to thank Dave for reviewing this article and offering that and other helpful suggestions.