Application Bulletin AB-17

Isolated I²S Minimizes Distortion

Reaching Isolated Audio Heaven (well, nearly)

We audio geeks are a self-proclaimed strange bunch, and proud of it. We know those poor souls who have never heard a lead violinist shuffle her feet during Sibelius' Violin Concerto, or the slide on Eric Clapton's blues guitar gently rattle the sixth fret in a rare recorded mistake are missing out on one of life's deepest pleasures; Listening, with a capital L. In our world there is no such thing as background music, since music, as defined by an audiophile, is always played to be listened to. There is however one aspect of the audiophile character that troubles most of those I know. The pleasure gained in the listening experience is canceled by the disappointment of the *almost* inaudible imperfections added to the sound by the hi-fi system. That disappointment is always most acute when for example, a new amplifier or CD DAC has been purchased to eliminate specific tonal qualities in the system and the first few tracks played have not lived up to the expected level of sonic perfection touted in the new gear's marketing brochures. The fact that particular disappointment's been true for every upgrade ever purchased never seems to be part of the buying process. But hey, after a few days, the new system's average performance is usually judged closer to perfection than the old one, though still not quite there yet. Another round of domestic negotiations then becomes inevitable for those with the audio bug. "Honey, would you pass me those Hi-Fi magazines again please?"

This application note is about isolation electronics in high fidelity digital sound, and in particular, techniques that can be used to reduce the noise floor of any given system. Let's start with some goals and definitions. If you read the hi-fi trade press you can't help but come away with an impression of ever increasing cost and complexity in pursuing the lofty goal of perfect sound reproduction. *True* sound reproduction is defined as an output sound with nothing added to or subtracted from the original piece, and is as impossible to attain as the state of perpetual motion. It's an unattainable goal. It's also a conundrum since sound that's close to perfectly reproduced from the technical viewpoints of signal to noise ratio and phase symmetry across the spectrum, may not sound as good to the listener as the same piece with a bit of variation in bass tone for example. The human ear and its connected processor are fickle judges of perfection and audio folks have come up with terms to help define classes of distortion. Words like *warmth* and *depth* describe pleasing distortions, while *color, harsh*, and *cold* describe less pleasing variations on the original. The subjectivity brought by the variation in human hearing has spawned a large number of successful hi-fi companies, all with their unique products and a host of followers who perceive the level of distortion they add to the final sound as pleasing.

With that in mind, manufacturers know they will never please every potential customer, but the goal remains the same: elimination of known sources of noise and error in the forward path of the music signal. NVE's unique GMR isolators can help achieve that goal.

Sources of noise versus sources of error in digital Hi-Fi systems

It's important to understand the main difference between error and noise in a digital music signal. Let's look at CD music systems for a moment and examine the major sources of each. Quantization error is the fundamental unit of resolution in any digital representation of an analog signal and is expressed in bits. The higher the number of bits available, the lower the quantization error, and the more accurate the representation of the original analog signal will be. Phase error represents the difference in timing between a recorded sound and the original and is probably the most readily heard source of all system errors. Consider the complex sounds made by an orchestra, or for that matter, any group of musical instruments or voices. Now imagine those sounds on an instantaneous basis and examine what happens when, for example, a group of instruments in the center of the stage begins a loader passage. Both stereo channels should begin the latest notes together, at exactly the same time. If there's a slight difference in timing between the two channels, the listener will perceive movement from one channel to the other, especially during quiet to load or loud to quiet transitions. If phase error is large enough, a detectable echo will appear. If there's jitter associated with the data clock, the phase error will be bipolar, resulting in a horrible "squashing" effect on the dynamic range of the sound produced. Clock jitter of only a few hundred picoseconds has an amazingly loud signature in the end recording.

You may have guessed that error sources and their elimination are responsible for most of the increasing price tag you see in hi-fi components. Noise sources are different. In many cases they come down to user preferences, design choices, room dynamics and interconnect media. When someone asks me to define audio noise from a sonic viewpoint, I usually have them imagine they are lying on a hammock, listening to the sound of the ocean on a fine morning. The grasses are gently rustling in the breeze and the occasional sea bird sings a simple song. At 8.00 a.m. sharp, a neighbor half a mile away switches on a generator that can barely be heard, but because it's not meant to be there, it's the only thing that CAN be heard. So just like you can take a great orchestra and make it sound like your sophomore's school band by having it guided by an incompetent conductor, the most perfect, error free hi-fi system will sound awful if there's audible noise produced somewhere in the output chain.

Noise Generators and Attenuators

Have you ever turned up the volume on your system to its maximum position with no input signal? If you do, you'll hear low frequency hum, high-frequency hissing and, most peculiarly, the occasional click. Most of the noise you hear comes from the mains supply itself. Domestic line voltage and current fluctuations are notorious sources of clicks and power supply hissing, and are of course the source of that low frequency hum. Making sure there are no analog signal lines (especially amplifier inputs and speaker wires) running parallel with the power cable will reduce the problem substantially, but if that still won't do, there's a better way.

Isolating Digital Isolators to Reduce Noise

NVE manufactures the lowest distortion digital isolators in the world today. Precision edge placement with 50 ps of jitter allows the designer to transfer signal data from CD transport to audio DAC without noise induced phase error. In doing so, it also eliminates substantial levels of hum in the analog side of the system. Here's how it works. Figure 1 shows a typical CD transport interfaced with I^2S to an audio DAC. In conventional systems, logic ground return currents are mixed with analog ground returns, resulting in modulation of the analog signal, or reference ground. Even when star grounds are employed to route ground currents, the dynamic nature of the digital return current finds returns to analog through parasitic coupling. The ground reference voltage presented to the amplifier is, of coarse, also modulated, so the end signal heard from the speakers is distorted. The isolated system in Figure 2 illustrates a way to ensure analog and digital ground currents never mix, resulting in a speaker output that's closer to the original. The cost of adding three channels of GMR isolation to the system is about $3.00. Good quality CD players will already have separate digital and analog power supplies. The digital isolator ensures there's no digital switching current modulating analog reference ground and adds a tangible improvement in audio quality with, for once, a low price tag.

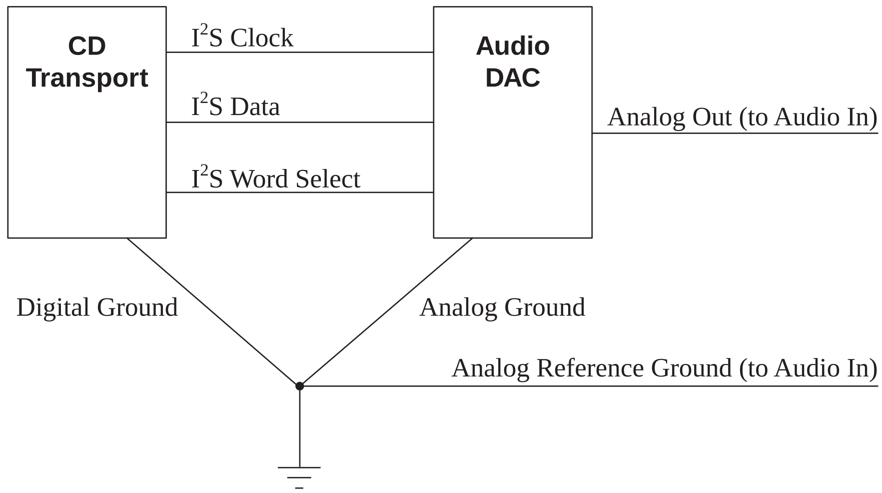

Fig. 1. Typical CD Transport with DAC.

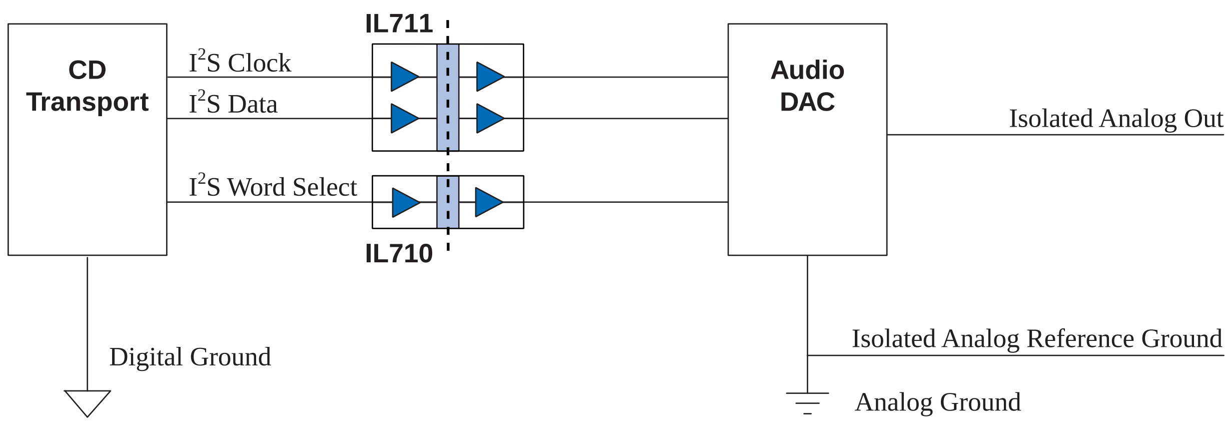

Fig. 2. Isolated CD Transport with DAC.