 By Thomas M. Perazella

# Maintaining Your Balance, Part 1

Building a better converter box to handle balanced/unbalanced devices.

When studying geography in grammar school, you learned that the Great Divide was the North American mountain range separating the watersheds that drain into the Pacific Ocean from those that drain into the Atlantic. Sometimes it feels as though we have a similar divide in the audio world, with the choice between balanced and unbalanced equipment interconnections.

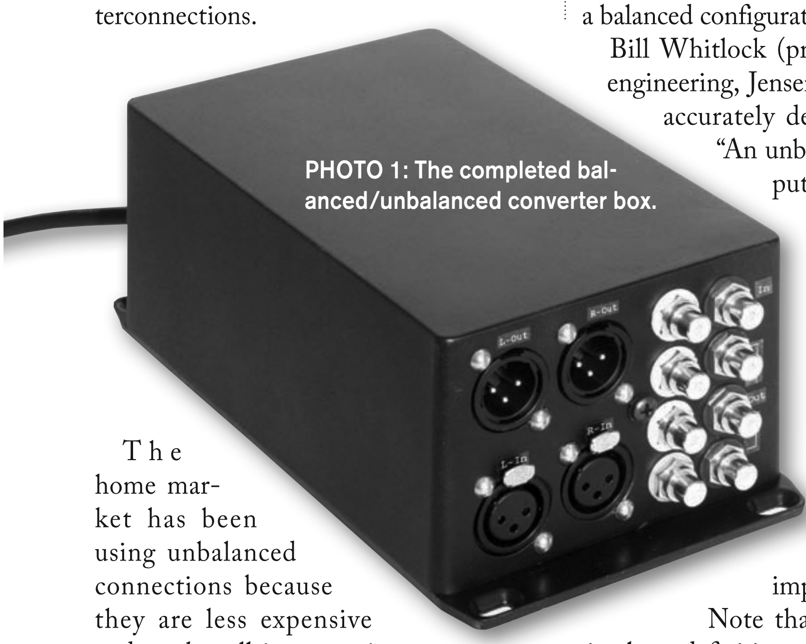

PHOTO 1: The completed balanced/unbalanced converter box.

The home market has been using unbalanced connections because they are less expensive and work well in most situations. You see an increasing number of pro-audio products with balanced connections that are reasonably priced and attractive alternates for home audio use. I use Behringer equalizer and speaker control units along with several amplifiers that all have balanced connections. They need to be integrated with the unbalanced devices that make up the rest of my system. The key is to use the proper method for those connections.

My interest in the balanced/unbalanced scenario was piqued by Gary Galo's excellent article[1] about noise in audio circuits. It was based on information from a seminar that he attended given by Bill Whitlock. This article, a concise description of noise problems and their solutions, mentioned devices from IC-manufacturer THAT Corporation (Milford, Mass.) that were based on Whitlock's work. It also included an analysis of passive devices that can be employed in the quest for lower noise.

## DEFINITIONS

There seems to be confusion regarding what constitutes a balanced circuit. People talk about two signal-carrying conductors instead of one, opposite signal polarities in a balanced configuration, and so on.

Bill Whitlock (president and chief of engineering, Jensen Transformers)[2] has accurately defined "unbalanced": "An unbalanced input or output connects one of its signal conductors to ground and has a non-zero impedance at the other signal conductor."

His correct definition of "balanced" is: "A balanced input or output uses two signal conductors which have equal impedances to ground."

Note that the key difference in these definitions is the impedance between each signal line and ground. The unbalanced circuit does have two signal lines and current does flow in opposite directions in the two lines, but one of them connects to ground. Therefore, the impedances are neither the same nor balanced. The balanced circuit has equal impedances to ground from each line.

Also note that there is no mention of equal voltages, because it is the impedance balance that is critical. Failure to maintain impedance balance on the signal lines is the root cause of common-mode failures with some circuit configurations.

An understanding of this is important because a true balanced circuit has a greater ability to reject common-mode signals, which are of the same polarity and magnitude on both signal lines. These signals represent unwanted noise interference that will degrade signal quality. Reduce those and you will have less noise to interfere with your signal.

A great introduction to the subject of noise, grounding, and safety in audio connections is the *Journal of the Audio Engineering Society* v43n6 (June 1995), which includes papers and reports by Neil Muncy, Bill Whitlock, Charles Atkinson, Philip Giddings, Stephen Macatee, John Windt, Cal Perkins, and Kenneth Fause that are a gold mine of important information. There are also citations to additional references. Copies of the individual papers in PDF form are available from the AES website: www.AES.org/journal/search.cfm. You can search for any articles by the volume and number, title, or author.

Probably the least effective method to connect balanced and unbalanced devices is to make adapter cables. This is generally not a good solution, but there are adapter cable designs that take into account the type of connectors and the direction of the connection (balanced-to-unbalanced or unbalanced-to-balanced). One of the best explanations of interconnects, with a table of different connections, is in a paper from Rane™ Corporation[3]. I have built cables using their tables and have obtained effective results in situations where noise is not a major factor.

## SOLVING THE NOISE PROBLEM

With noise, reality sets in when two problems are introduced: improper connections of an XLR's pin-1 to ground [AES14, SMPTE RP134, EBU R50-1988, and IEC 268 part 12 all standardized that an XLR connector's pin-1 is ground, pin-2 is the positive signal connection, and pin-3 is the negative signal connection—**David J. Weinberg**], and differences in the impedances of the two signal lines in a balanced circuit. This article does not address the pin-1 problem, which is covered in several articles in the previously-mentioned AES issue.

To reduce susceptibility to noise, high-quality transformers can retain common-mode rejection even with relatively high levels of impedance mismatch, due to their high common-mode input impedances. In addition, they can provide a high degree of voltage isolation where offsets exist between devices. Unfortunately, they are not inexpensive, and less-expensive versions often have severe performance limitations. As a result, many attempts have been made to develop active circuits that can be used as balance inputs and outputs.

At first blush, some of these active devices seem to offer ideal solutions. The Analog Devices AMP03 precision unity-gain differential amplifier has a common-mode rejection ratio (CMRR) of 100dB at 0Hz (= DC), and a respectable 70dB at 20kHz. The amp has internal resistors balanced to within 0.002% to make this performance possible and free the equipment manufacturer from having to select precisely matched external resistors.

However, any output impedance differences from the driving equipment can destroy the performance improvement achieved by this precise on-board resistor matching. It does not take much of an imbalance to produce a large drop in CMRR[4]. A balanced system acts like a Wheatstone bridge, with the driver output impedances and receiver input impedances forming the legs of the bridge. If any of the impedances become out of balance, rejection drops. For example, for an input impedance of 5kΩ, a 1Ω imbalance in the output of the driving circuit can cause a 60dB drop in CMRR.

The severity of the problem is minimized if the impedances of the bridge's output and input sections are very different. The impedances in each line of the driving side, and of the receiving side, must still be closely matched for the rejection to be maximized. Low output impedances are common in driver stages, but high common-mode input impedances in receiving stages are not, generally due to noise concerns. Transformers are an exception, routinely having common-mode input impedances in the tens of megohms.

The products from THAT Corporation include newly developed input line receivers based on Whitlock's work. Balanced-output drivers were also mentioned. There are two device families:

- The "InGenius"™ family of line receivers uses a bootstrapping technique developed by Whitlock to feed common-mode signals back to the input to increase the common-mode input impedance while maintaining lower DC impedances[5]. These devices can provide many of the benefits of transformers without the cost penalty or extreme low-frequency losses.
- The "OutSmarts"™ family of line drivers uses a dual-feedback-loop design described by Gary K. Hebert[6] that prevents excessive ground currents when clipping into single-ended loads. In cross-coupled output stages, that can lead to difficulties in the power supply and additional distortion[7].

## PROJECT IDEA

These devices seemed to be the perfect solution for a project I was formulating for copying many of my LPs to CDs. Part of the setup included the use of an equalizer to correct recordings that were either not tonally balanced to my taste, or used equalization curves other than RIAA. You can find a reference to EQ curves of old records at www.