ANALOG AUDIO INTERFACING

KEY CONSIDERATIONS FOR MANAGING A PATCHWORK OF AUDIO EQUIPMENT.

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Despite all the talk of digital everything, sound is an analog phenomenon, and much audio equipment remains analog or has analog connections. I believe that analog is still the best choice for many applications because analog audio requires little technical overhead. It's ubiquitous, and it works. Many analog audio conventions evolved from techniques used by the telephone company, and over time some have been standardized by such bodies as the Audio Engineering Society. Let's start by exploring familiar interfacing issues.

A BIT ABOUT DECIBELS

The decibel is a measurement unit with two important characteristics, First, the dB is used to represent the difference between two signals. The dB is not an "absolute" measure of quantity (like a gallon); in audio it usually expresses the difference between a measured level and a reference level. This will become clearer shortly.

Second, the dB scale is logarithmic (dB = 20log (V1/V2)). The dB values do not change linearly with signal values. For example, if 1 volt is the reference, going to 1.12V is a 1dB increase. Going to 10V is 20dB, going to 100V is 40dB. The logarithmic dB scale "compresses" the numeric range needed to express large differences. For our purposes, it's useful to remember certain telltale ratios, such as 6dB being a doubling or halving of voltage.

WHAT YOU NEED TO KNOW ABOUT LEVELS

Analog audio signals fall into three general level categories: microphone, line, and speaker. Line level typically runs between equipment in a system. This developed out of phone company transmission lines which, for reasons we'll skip, were terminated in a 600-ohm load impedance. Since transmission lines are concerned with power transfer, a level called "0 dBm" was defined as 1 milliwatt of power into 600 ohms (which equals .775 volts AC RMS). The common term referring to professional line level as "+4" actually means 4dB above the 0 dBm reference.

While some gear still has a 600-ohm input impedance, or is switchable, most audio systems dropped 600-ohm termination long ago and have high-impedance inputs (see next section). The reference level for high-impedance systems is 0 dBu (also equal to .775V). Therefore, from the equation, +4 dBu is equal to 1.228V. This voltage at an input or output should equate to "0" on a VU or level meter in the equipment (using tone). For measurements, the term dBu is necessary so that the reference is known. Simply stating that a level is "+4dB" begs the question, "relative to what?"

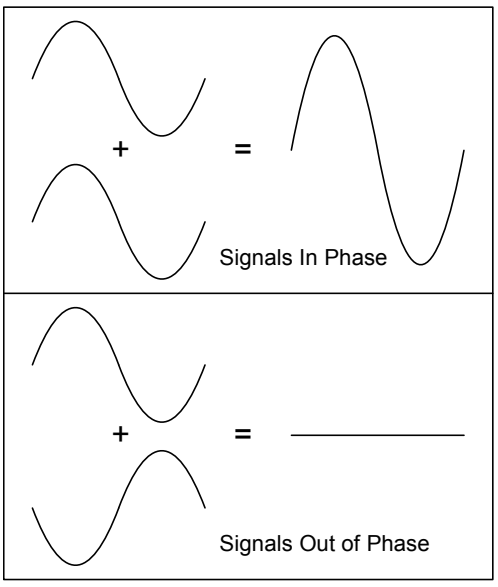

Fig. 1 Signal reinforcement and cancellation

VOLTAGE/DB CONVERSION TABLE

	0	+4	V
dBu (ref to .775)	.775V	1.228V	.245V
dbV (ref to 1V)	1V	n/a	.316V
-10 dbV on dBu meter			-8 dBu (.308V)

All volts are AC RMS (average values slightly lower).
dBu is voltage version (not 600-ohm) of dBm.
For voltage: dB = 20log(V1/V2)

The other common line level, mainly for consumer gear, is often referred to as "-10." This is actually referenced to the dBV standard, where 0 dbV is 1 volt. So -10 is usually 316mV (corresponding to "0" on the equipment meter). You will also find gear that operates somewhere in between -10 and +4 (including Mackie mixers, which equate "0" on their meters to 0 dBu at the output jack, rather than +4). (Table 1)

The terms -10 and +4 refer only to the reference level of signal in the wires between equipment, providing an idea of what levels are present. Most decent pro equipment will handle at least +22 dBu (9.75 volts) at an input before overload. So there's 18dB of headroom at the device input between tone at +4 dBu (0VU) and distortion. Similar specs can be found for -10 equipment.

Incompatible levels is one of the easiest ways to get distortion or noise. Mic level signals (roughly -60 to -30 dBu) require a preamp, in a mixer or other device, to raise them to line level; they are useless otherwise. Speaker level, a voltage high enough to create substantial volume from a loudspeaker, should generally not be connected to anything else! Similarly, plugging line level into a microphone input will usually cause overload distortion (though it should not damage anything—unless phantom power is turned on). Lastly, connecting -10 and +4 equipment together generally requires some type of active or passive "level matching" device.

WHAT YOU NEED TO KNOW ABOUT IMPEDANCE

In the 600-ohm-terminating days, the output impedance of the source had to match the input impedance of the receiving device. If the input impedance was higher than 600-ohms, the signal level would rise. If it was lower the signal would fall. (This is still the case in video systems, where each connection must have one, and only one, 75-ohm termination to get the correct level.) Today the general rule is that the input impedance of a device should be at least 10 times the output (source) impedance of the preceding device, and most equipment is designed this way. Consequently, you can connect outputs to inputs without worrying about unexpected level changes. You can even connect one output to several inputs (splitting or "bridging" the circuit) without affecting level because several high input impedances in parallel do not "load down" the preceding output circuit.

This 10:1 rule does not work in a few situations. One is with power amplifiers and speakers, where the impedances need to be correctly matched for optimum power transfer (please follow the manufacturer's directions). Sometimes impedance can affect the sound of microphones because of electrical influences on the delicate mic signal, so fancy studio preamps may have switches to select different input impedances.

Unfortunately, impedance is often discussed incorrectly. The previously mentioned level matcher for converting between -10 and +4 is sometimes called an "impedance matching" device which, in most cases, is wrong (or unimportant). In practice, impedance is a minor issue in modern audio systems with well-designed equipment; it is rarely the actual cause of problems.

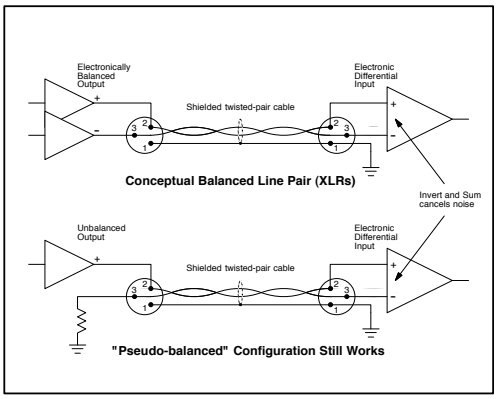

Fig. 2 Balanced Line Operation

ON BEING BALANCED OR UNBALANCED

The phone company also developed the concept of "balanced" lines. In this scheme, the principle of

SIMPLE CHART OF AUDIO CONNECTORS AND SIGNAL LEVELS

CONNECTOR TYPE	DESCRIPTION	TYPICAL USES	OPERATING LEVELS	TYPICALLY FOUND
XLR (aka Canon) *Note: Usually signal flow follows direction of pins.* *Note: In most audio applications Pin 1 is ground/shield. Generally do not connect Pin 1 to shell!*	3 pins plus shell	Balanced Audio	Mic level	· Mics, mixers, preamps
			Line Level (+4)	· Pro audio gear · Interfaces · Pro video gear
TRS Phone Plug (aka 1/4" Stereo Plug)	Tip/Ring/Sleeve	Balanced Audio	Line Level (+4)	· Mixers · Pro audio gear
		Headphone	Line / speaker Level	· Headphones
TS Phone Plug (aka 1/4" Mono Plug)	Tip/Sleeve	Unbalanced Audio	Line Level (+4 / -10)	· Semi-pro audio gear
		Musical Instruments	Varies	· Musical instruments
		Speakers	Speaker Level	· PA speakers
Mini Plug (aka mini phone, 1/8" Plug)	Tip/Ring/Sleeve (or T/S)	Bal or Unbal Audio	Line Level (-10)	· Computer audio · Audio players · Misc. device ins/outs
		Headphone / earpiece	Line / speaker Level	· Audio players, earbuds
RCA (aka Phono)	Center Pin w/ metal surround	Unbalanced Audio	Line Level (-10)	· Semi-pro audio gear · Computer interfaces · Consumer gear
TRS Patch Plug (aka 1/4" or Longframe telephone patch) *Note: Although similar, Patch plugs and jacks do not mate well with Phone plugs and jacks.*	Tip/Ring/Sleeve	Balanced Audio	Line Level (+4)	· Pro (broadcast) patchbays
Bantam Patch Plug (aka Tiny Telephone or TT)	Tip/Ring/Sleeve	Balanced Audio	Line Level (+4)	· Pro (broadcast) patchbays
Terminal Block (aka terminal strip, screw terminals, screw contacts, Phoenix block...) *NOTE: Some connectors above, particularly XLR, mini plug and terminal blocks, may be used for non-audio applications (such as control or power).*	Screws or screw-down slots	Any	Any	· Distribution amps · Converters · Device ins/outs · Misc.

signal inversion is used to reduce electromagnetic interference noise (RFI) in wiring. Referring to Fig. 1, when the two sine waves are added in-phase the peaks and troughs combine, doubling the level. When they are 180-degrees out of phase the peaks and troughs cancel, so no signal.

A balanced audio connection sends identical audio signals, with one out of phase, on a pair of twisted wires to the next device. That device has a differential input, which means that it will electrically invert one of the two signals and then add them together. So our two audio signals are maintained because they will combine positively. But any noise that impinged on the wires along the way is in-phase on both (known as common-mode), and when one side gets inverted they cancel! By inverting and summing, the differential input produces only the difference between the two signals.

Properly done, balanced audio on twisted-pairs rejects noise so well that the cable does not even require a shield (though they usually have one). In fact, since it's the differential input that is cancelling the noise, the twisted-pair does not have to carry the same signal out of phase—it could have signal on one wire and ground on the other. The differential sum will still preserve the signal and cancel the noise. This is the configuration of many outputs on less-expensive mixers (a block diagram usually shows a TRS phone jack with the Ring terminal connected to ground, hopefully through a resistor). These still provide some advantages of balanced lines as long as the next device input is differential. (Fig. 2)

Unbalanced connections, such as the RCA (phono) connector, have one signal wire and a ground—usually configured as a shield around the signal. These are mostly okay for short distances but they can cause noise problems. Not only do unbalanced lines not reject electromagnetic interference, but noise can enter equipment on the shield because it is actually part of the audio circuit. Generally, the same level matcher that converts between -10 and +4 levels also converts between unbalanced and balanced lines—another reason to use them!

CONNECTORS MAKE IT ALL HAPPEN

There are many connector types in use and sometimes the same connector is used for very different signals.

- A common example is the 3-pin XLR (sometimes called Cannon) connector, which is used for microphones and for balanced line-level equipment. Just because the connectors match does not mean they should be plugged together. (Table 2)
- The "phone" plug is another easily misused connector. The three conductor (tip-ring-sleeve, TRS) version is found everywhere on pro equipment for balanced line-level connections. The two-conductor (TS) version is only good for unbalanced signals, and traditionally used for electric musical instruments.
- The TRS phone plug is also used for headphones (or the "mini" version for earbuds). In this case the connector is carrying two unbalanced signals,

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left and right, with a common ground. The same is true for audio outputs from computers and music players. Feeding those into an audio system requires, at minimum, an adapter which breaks out the left and right channels. If they must feed a balanced/+4 device, you'll want that level matcher.

• Note that the two signals used in a balanced connection are often referred to as + /- (with + being the in-phase signal), or high/low or hot/cold. For an XLR the + is usually on pin 2, the - on pin 3, though there are exceptions. For TRS, the + is tip, the - is ring. For headphones, left is usually tip, right is ring.

• Bottom line is that some configurations may function, but not optimally, if the wrong connector and/or wrong signal is used.

KEY GUIDELINES TO KEEP IN MIND

• Use specs and diagrams to determine what signal and connector types are present on equipment. The connector does not define the signal.

• Pay attention to compatible levels between equipment and to level changes in a signal path. Lots of conversions back and forth between +4 and -10 (or mic and line level) can add noise.

• Use balanced connections whenever possible, keep unbalanced connections short. For long runs (say over 10 ft.) consider adding converters—especially when going between different rooms or equipment on different power circuits.

• Connecting balanced/+4 equipment to unbalanced/-10 usually requires a level matcher (which also handles the balancing conversion). There are ways around this, but you must understand how the circuits work!

• Transformers are not used much any more for input or output balancing, but they behave differently than electronically balanced circuits and require special considerations.

• Generally you can split a line-level output signal to two inputs, but do not passively combine two outputs together. This is a poor way to "mix" signals because it can cause distortion in the output circuits. Depending on the circuit design it may work, but is not advisable.

• Know how "legacy" equipment actually operates. For example, a turntable for playing vinyl records has RCA plug outputs, but the signal is too low for a line-level input. And it cannot feed a mic input because records require special equalization to sound correct. This situation requires a phono preamp.

• "Phantom" power is a DC voltage which rides along with the audio signal to power condenser microphones. Plugging anything other than a mic into a jack with phantom power can cause damage. Keep it turned OFF unless it's needed! Professional intercom systems also send DC voltage and audio on XLR connectors. This is known as a "wet" intercom line and must be treated carefully.

"Just because the connectors match does not mean they should be plugged together."

info

AUDIO LEVELS AND READINGS
http://www.dk-technologies.com/index.php

JENSEN TRANSFORMERS
http://www.jensen-transformers.com/apps_wp.html

SHURE REFERENCE MATERIALS
http://www.shure.com/americas/support/downloads/publications

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