Gain Staging and Analog Output Levels

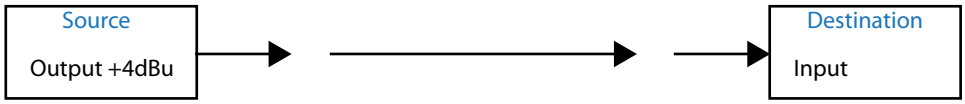
This paper seeks to clarify questions regarding analog input and output levels when using digital transport systems and how these devices can be used effectively for a range of applications.

LOOKING AT LEVEL ACROSS THE SIGNAL FLOW

Some users have connected their system and then asked why there's "signal loss" from analog input to analog output. Coming from a world of largely lossless analog wires, users expect to see a signal move from one place to another without much change in level.

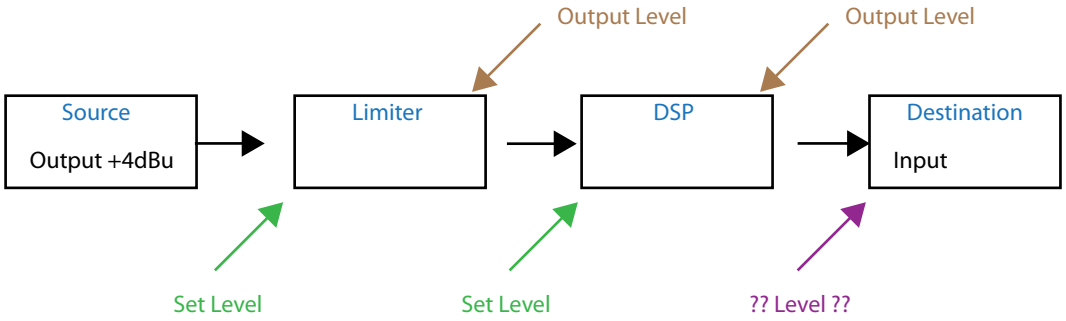
But it's essential to remember that, while both analog cables and digital snakes perform the same basic function of moving audio from one place to another, a digital system—regardless of its manufacturer—is comprised of multiple active electronic circuits (at minimum, one at input and another at output). The devices in a digital snake should be thought of as additional circuits in the signal chain—along with the mixing console, mic preamps, effects processors, DSP, amps, and so on.

In all of these devices, there is no expectation that the input signal and the output signal match, and the industry is full of gear with input and output specs that are different from one another. Unfortunately, input and output level specifications are not standardized.



A typical **analog signal path using copper wire**

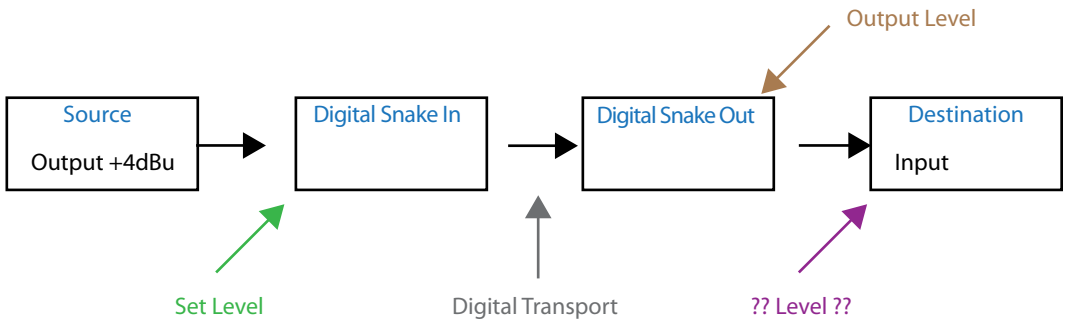
This diagram above shows a typical analog signal path using copper wire. The source device in this example is outputting a +4dBu signal level. That exact level is delivered to the destination device—no processing occurs in the copper wire connecting the two devices.



Two processing stages are added between the source and destination. Note the points where input and output levels need to be set.

In this diagram, the same source (with +4dBu output) and destination devices are used, but two additional processing stages are added in between. At each processing point a new input level must be set. At the Destination, there is no guarantee that the original level, +4dBu, will be available; the actual level presented here is determined by settings on the two previous stages of the signal flow.

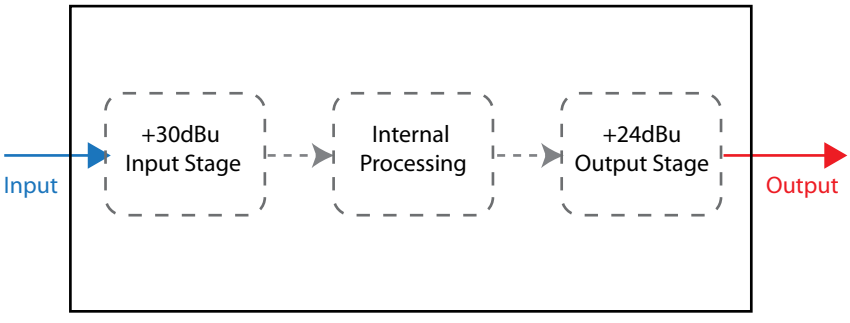
Starting with the previous example, the two processing stages are removed and replaced with a digital snake system (see the diagram that follows). The output from the source (still +4dBu) feeds the digital snake input, where a level needs to be set. The digital system transports the audio as data to the digital snake output device where the data can be returned to an analog state. At the destination device, there is still no guarantee that the original level, +4dBu, will be available, and in fact the levels don't need to be the same; the two active electronic circuits in the digital snake components along with the user's gain setting at the digital snake input determine the level available to this device.



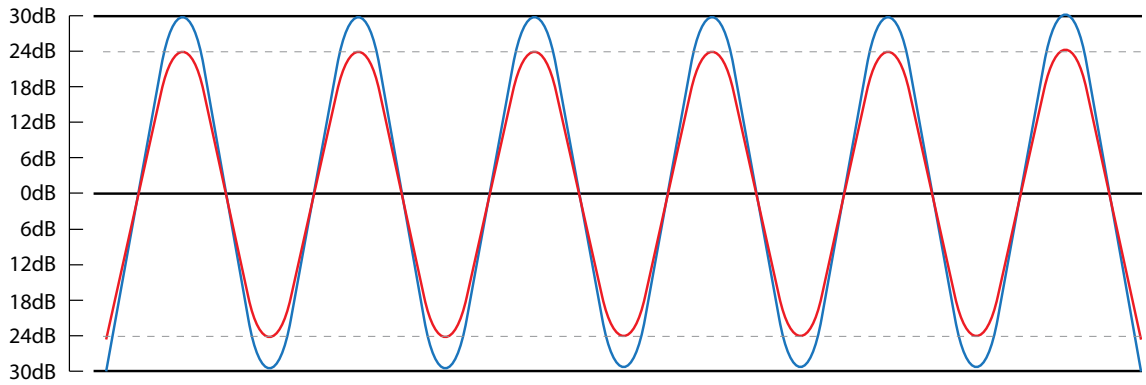
A digital snake replaces the processing devices; note where the I/O levels need to be set.

The reason for this is that, in these devices, input and output circuits are designed for their specific job, not to match one another. For example, consider a mixing console with a level specification of +30dBu maximum on an input channel and a maximum output level specification of +24dBu. These specs indicate that you can send a signal measuring +30dBu into the device but you cannot get that same signal out—you can only get +24dBu from the output. Of course, the console did not "take away" 6dB of audio; rather this illustrates the independence of the input and output circuits—in a single piece of equipment. The same concept applies to a digital snake, except that the input and output circuits are in two separate devices. In both cases—the console with +30dBu in and +24dBu out and the digital snake—there is no inherent barrier to operating the gear with these settings; no loss in fidelity occurs.

Comparing the source signal level to the level available at the variety of outputs available on a typical console will prove that input-to-output levels should not be assumed to be the same. The level of a console's main output compared to a bus, group, aux, or direct output will very likely be different—each circuit is designed for a different purpose.



An audio device designed with a 30dBu maximum input stage and a +24dBu maximum output stage



The blue **line indicates a maximum +30dBu input signal level sent into the audio device described above. The device's resulting +24dBu output, shown in red, is 6dB softer.**

No matter how simple or complex a system is, all devices must be calibrated to even out the variation in levels across the signal flow. Using digital devices to replace analog copper wiring for signal transport involves two active electronic circuits—one for inputs and another for outputs. Each circuit is designed to be connected to other devices in the signal chain; without proper gain staging at every point in the system, input to output sound quality will be compromised.

SELECTING LEVELS THAT WORK

Aviom has designed analog I/O modules to meet the needs of a variety of users and applications. Input stages need to accommodate signals coming from CD and DVD players, as well as the line-level output of mic preamps and processing gear. Aviom input modules are designed to accept a wide range of audio signal levels and have gain range switches to accommodate them. Each gain setting has an effect on the maximum headroom available, and should be selected to maximize signal level while avoiding clipping.

The input module's job is to take the incoming analog audio signal, digitize it with minimal noise, and then pass this digital signal to another device where the digital signal is converted back to analog audio. Maximizing the signal level at the input stage of a digital system guarantees that the signal passes through the system with maximum fidelity and minimum noise so that it can be returned to an analog state and passed on to the next device in the signal chain. This is where the analog output module comes in.

Aviom analog output modules deliver signals to other devices in an audio system's signal chain, so operating levels are provided that can be connected to mic-level inputs on mixing consoles or line-level inputs on processors, DSP devices, mixers, recording devices, or amps. At this point in the signal flow, the level of the original analog signal measured prior to when it was digitized at the input module is largely inconsequential. What's more important is to calibrate the gain stage between the output module and the next device.

In situations where analog output signals from a digital device (such as the AN-16/o) are connected to devices that have variable input stages (mixing consoles, recording devices, signal processors, etc.), there is no problem: the variable input stage, designed to compensate for the wide range of signal levels that will be connected to it, can be calibrated to match the incoming signal.

SPECIAL CASES

There are some cases where the connected device offers only limited control over the level (such as a powered speaker with only an input attenuator). In these situations, the maximum output level from the digital device should be greater than or equal to the minimum input level of the connected device. If the output from the digital system is too low, a small line amp can be used to boost the level of the analog signal between the two devices.

When using Aviom console cards as part of the signal chain with a digital console (for example a Pro16® Y1 card in a Yamaha® DM2000 connected to an AN-16/o Output Module), the same rules apply. Any time a signal travels through an analog stage to a device with an input level control, proper gain staging practices are mandatory. However, it's important

to realize that once a signal is in the digital domain, it can pass through other digital devices unaltered—assuming no DSP functions (like EQ) are performed on the audio in the process that would alter its level. There is no signal loss incurred by simply passing through a digital mixer. A signal that reads 0dBfs (full scale) on an input channel of a digital console will pass through as a 0dBfs signal to all connected Aviom devices. If the signal appears at a level less than the input, then the path that it is taking through the digital console should be examined to identify the points were the signal level has been changed. When that digital signal exits the Aviom digital system as analog, the next device in the signal path needs to have a level set at its input stage.

UNDERSTANDING INPUT AND OUTPUT SETTINGS ON PRO16 GEAR

To maximize signal-to-noise when setting up Pro16 products it is important to understand how the input and output settings on these products interact. Proper calibration and gain staging with all devices in an audio system is essential. The AN-16/i Input Module has four input gain range settings: -10dBv, 0dBu, +4dBu, and +22dBu. These are designed to accommodate a wide range of input signal sources. Choose the setting that allows maximum input signal level without clipping.

The AN-16/i has a maximum input level of +22dBu. Signal levels above +22dBu will clip the input stage of the device and cause digital distortion. The selected input gain setting on the AN-16/i front panel changes the headroom available for the input signal, but remember that the maximum input level will always be +22dBu regardless of the selection. *See table.*

AN-16/i Gain Setting	Clip Point
-10dBv	+4dBv
0dBu	+14dBu
+4dBu	+18dBu
+22dBu	+22dBu

With the input gain switch set to 0dBu, for example, input signals ranging from -∞ to +14dBu in level can be used. A +14dBu signal level will be transmitted to all line-level output modules as a full-code signal. Signals above +14dBu will clip the input stage of the AN-16/i, and that clipped audio data will be sent downstream to all output modules. There are two options if a signal level above +14dBu needs to be connected to the AN-16/i input: lower the output level of the device feeding the AN-16/i input to eliminate clipping, or choose another input setting. Using the +4dBu setting, for example, provides more headroom, allowing a maximum signal level of +18dBu to be used.

At the output stage, select either a line- or mic-level output based on the type of device that the output module will be connected to. Use that device's input level selector to calibrate the signal. The mic-level output should be used for connecting to mic preamp inputs on mixing consoles.

BOOSTING THE OUTPUT LEVEL

To boost the level of an output module for a particular application, a line amplifier can be added. These devices are designed to add a gain offset to the line-level output signal connected to their input, allowing the user to calibrate a system as desired.

Some commercially available line amplifiers are listed below:
RDL STA-2A Line Amp http://www.rdlnet.com
ATI L200-XLR Dual Line Amplifier http://www.atiaudio.com
Ocean Matrix OMX-LAS2 Dual Channel Audio Line Level Amplifier

REFERENCES

Unity Gain & Impedance Matching http://www.rane.com/note124.html
Setting Sound System Level Controls http://www.rane.com/note135.html
Gain Staging http://www.crownaudio.com/pdf/amps/137467.pdf

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