Gain Structure 101 (adapted from a minidsp datasheet)

Some basics

Any hardware component of a sound or hifi system has some fundamental properties, like gain, noise, and maximum signal levels. When multiple components are combined into a system, mismatches in these factors can sometimes lead to unsatisfactory performance, such as excessive noise or signal overload (clipping and other distortion) in one or more components.

Noise

Noise is present in all electronic systems. You cannot get away from it, but it must be minimized to an acceptable level. In sound or hifi components, the noise level is typically specified as a signal-to-noise ratio (SNR), or how far down the noise is relative to 1 V RMS (typically for line-level components) or full power output (for power amplifiers).

Maximum signal levels

A component has a maximum signal level that it can accept on its input, or generate on its output. In a typical analog line-level component, the output signal is the one to worry about, and is usually determined by the power supply voltage. DSP-based components, however, have very specific maximum input and output levels. In the miniDSP 2x4 kit, for example, the maximum input level can be set by a jumper to either 0.9 V RMS or 2.0 V RMS, and the maximum output level is always 0.9 V RMS.

Gain

The *gain* of a component is the ratio of its output signal level to its input signal level. A preamp with 12 dB of gain, for example, would generate an output signal four times higher than the input signal (with the volume control turned all the way up). A buffer is a special type of component that has 0 dB or unity gain - the output signal is the same as the input signal. A DSP component typically has 0 dB of gain, although some units may vary from this or have switchable input or output levels.

With loudspeakers, we can consider the sensitivity of the speaker (or the drive units, in the case of an active speaker) to be analogous to gain. That is, a speaker with high sensitivity will need less power to produce a desired acoustic output level, which will mean lower signal levels in the electronics components earlier in the chain.

Gain structure

The concept of gain structure is that, at each connection between components in the system, the signal level is as high as it can be (to minimize noise), but no higher than the maximum level that either component allows (so there is no distortion due to overload).
In the diagram below, the dynamic range of a music signal is indicated by a colored rectangle. (Review: dynamic range is the range of levels, in dB, from the quietest parts to the "loudest" parts.) For example, this might represent the output level of a microphone preamp that is connected to the input of a mixer, or to the input of and audio interface. In this example, we are adjusting the output level control of the microphone preamp.

The signal example in red is set too high, and will cause distortion in the mixer or interface. The signal in yellow is too low and the lower signals in the music are below the noise floor. The signal in green is "just right" and represents the ideal music signal level at that connection point. In an optimized system, each interconnection point would be "green" when the volume control is set to the maximum volume that you ever listen to.