Gain Staging Like a Pro

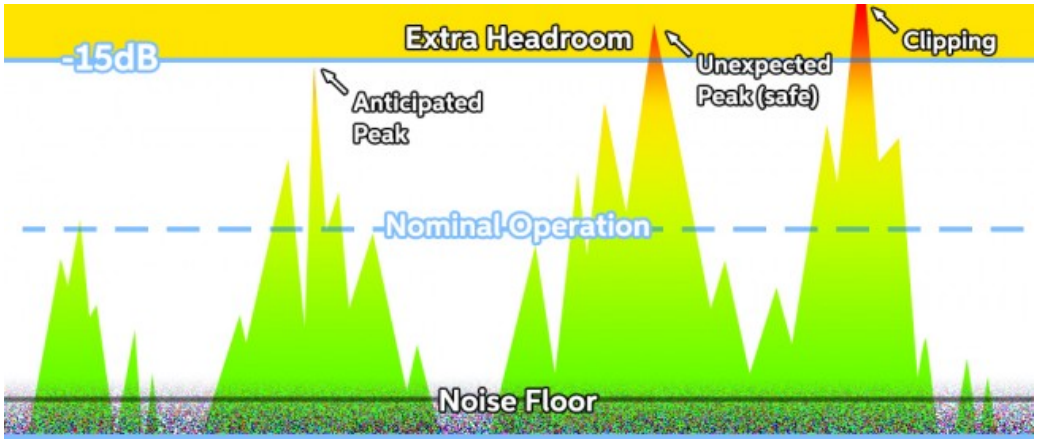
By Sweetwater *on Mar 1, 12:00 AM*

What Is Gain Staging?

Gain staging, or gain structuring, is the act of setting the gain for each amplification stage (gain stage) in a sound system to achieve a target system volume that minimizes noise and distortion. Said another way, proper gain staging allows your sound system to achieve the best signal-to-noise ratio. By attempting to reach the loudest peaks possible (without clipping) at each stage, you can achieve an ideal gain structure, but to do this, you need to consider each part of your system and understand the principles involved.

Part I: Definitions

Before we get into the nuts and bolts of gain staging, it's important to understand a few key concepts. The following simple definitions will help you get started.



Gain Stage

A gain stage is any point in your system where signal passes through an amplifier. The most important gain stage in your live sound system may be your mixer's preamp, but everything from the microphone to the power amplifier driving your PA speakers counts.

Noise

At its simplest, noise is any unwanted sound in your signal, whether it's bleed from other instruments onstage or the low-level hum and hiss inherent to electronic circuitry. Whether you're working with acoustic instruments and analog equipment or running instruments direct to a cutting-edge digital board, every gain stage both introduces noise and has the potential to amplify all noise in the signal path before it. Proper gain staging allows you to minimize noise by amplifying it as little as possible, and you can cut out a lot of noise by eliminating unnecessary gain stages altogether.

Noise Floor

The noise floor is the level in a gain stage where the noise is louder than the signal. The more you amplify your signal across multiple gain stages, the more you amplify the noise and raise the noise floor.

Distortion (Clipping)

Distortion occurs when signal overloads any given gain stage. As peaks exceed the capacity of a gain stage, the tops of the waveforms are clipped off, leading to distortion in the signal. Unexpected peaks are the primary cause of clipping in the preamp, but distortion is also common in intermediary gain stages, such as the EQ or dynamics processing. The only way to avoid distortion is to prevent the signal from overloading gain stages.

Peak/RMS

Peak volume and RMS loudness are two ways to measure the signal strength, and even though metering may not play a large role in how you mix live, it's important that you understand how these

factors affect gain structure. RMS (root mean square) is the average level of signal, which is what your ears perceive; whereas peak volume measures the loudest parts of the signal. For instance, in an acoustic guitar track, your ears tune into the constant sound of the strummed or sustained notes, even though the sound of the pick striking the strings is significantly louder. When setting levels, it's important that you adjust the gain so that the loudest peaks don't clip.

Nominal Operation

The nominal operating range of any gain stage is the average volume (RMS) when peak levels are just below clipping.

Signal-to-Noise Ratio

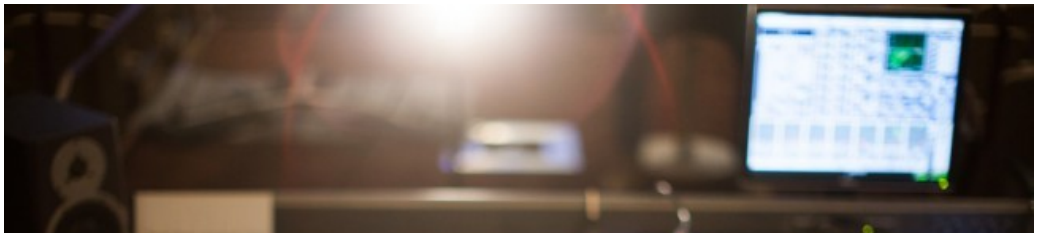
The signal-to-noise ratio (S/N) is the proportional amount of dB between the nominal operation level and the noise floor. The higher the S/N, the lower and less noticeable the noise is.

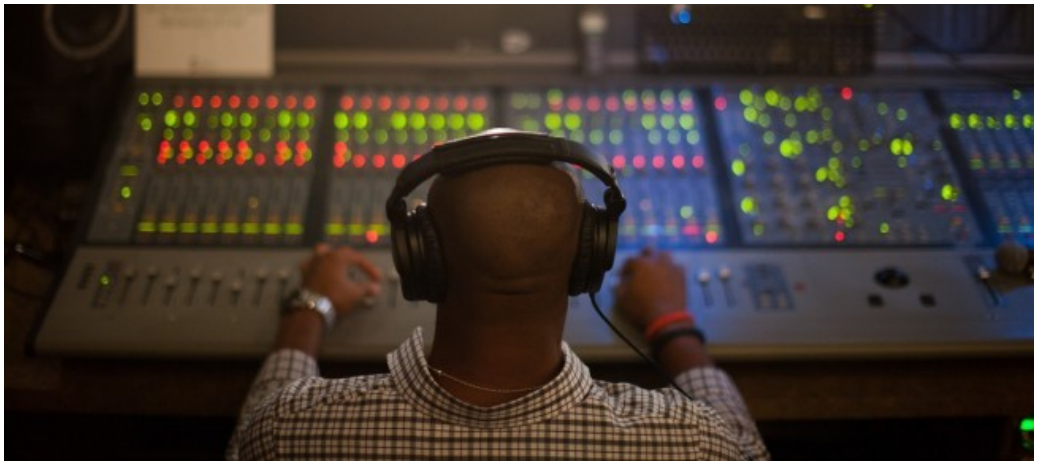
Headroom

Headroom is the difference between the nominal operating level and clipping. While less headroom means greater overall signal loudness, more headroom means sudden peaks are less likely to cause distortion. Proper gain staging provides the perfect balance between loudness and headroom.

Unity Gain

Often indicated by a U, unity gain is when a gain stage in a piece of equipment (e.g., a channel fader on a mixer or an output volume knob on a compressor) neither boosts nor cuts the incoming signal. In other words, by achieving unity gain, you affect the signal as little as possible.





PART II: How to Achieve Perfect Gain Staging

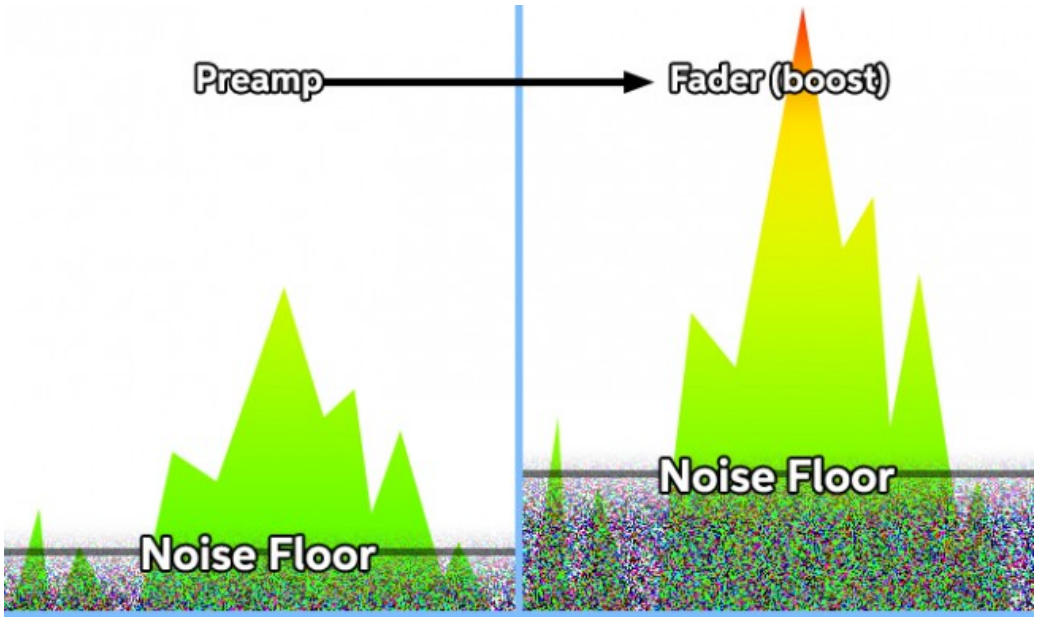
Start with the Best Possible Sound

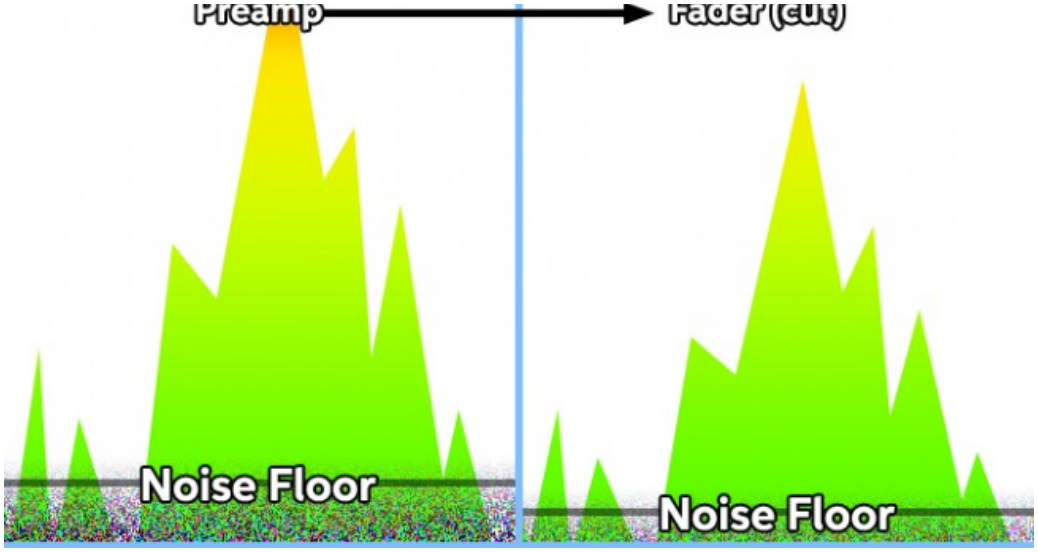
There are many ways to ensure you're starting off with the best possible sound, but here are a few quick tips. For microphones, getting each mic as close to the source as possible is key, because you'll get a stronger signal and pick up less noise. Avoid using pads if possible (see more about pads below), but don't overload your mics. Guitar amplifiers feature a pair of gain stages that are notoriously mismanaged. Unless the guitarist needs to crank the output to get the right kind of distortion, try to encourage lower stage volume. This will allow you to run cleaner signal through the PA, and it will cut down on spill into microphones across the stage.

Turn Up the Pres and Mix with the Faders

One of the biggest mistakes even seasoned live sound engineers make is setting up a mix from the preamps and then mixing again from the faders (and from the aux sends). While it's often the result of working with extremely little setup time, this practice is inefficient and invariably leads to poor gain structuring. A far better method is to start dialing in each channel by setting the channel fader to unity gain and then bringing up the mic pre until the input is at an ideal nominal operating level.

While few live sound mixing consoles provide detailed channel metering, most include an indicator (usually an LED labeled Peak, Clip, or OL) to signal when an incoming peak crosses a threshold just below clipping. One highly successful method of achieving ideal input gain is to turn up the mic pre until that indicator light flashes at the loudest peaks, and then back down the gain by about -15dB. This will ensure a strong signal, while providing a buffer of extra headroom to prevent clipping if you boost the EQ a little or get hit with unexpected transients. From there, you can use the faders to cut unnecessary volume, reducing noise as you mix rather than boosting it.





Applying Pads and Filters

There are two additional input functions found on most live sound mixing consoles that can have a major impact on gain staging: pads and filters. The pad switch introduces an attenuator before the preamp (often fixed at -20dB), allowing you to connect signals that would otherwise overload the input. However, this gain reduction comes from the top of the dynamic range, so it doesn't affect the noise floor, thereby decreasing the signal-to-noise ratio, so you don't want to use the pad unless it's absolutely necessary (the same goes for the pads on your microphones).

Conversely, the switchable highpass filter cuts out low-frequency information that you probably don't want to hear anyway. To put it into perspective, this is the frequency range where stage rumble, handling noise, and wind are present. By judiciously filtering out the low frequencies from channels that don't need extended bass (e.g., virtually everything except kick drums and bass), you can cut a ton of noise out of your system.

Managing EQ Settings

After the preamp, signal either passes to the insert (more on that later) or the equalizer section. First off, if you don't intend to use the EQ, and your EQ has a bypass, then you may as well bypass it and remove an unnecessary gain stage from your signal path. If you do use the EQ, then it's prudent to think of each frequency band as its own gain stage. If you leave the gain at 0dB, then it's at unity and shouldn't affect overall headroom or noise floor. You can cut the EQ without worrying about overloading the gain structure, and, as with any gain stage, cutting will also decrease noise in the selected frequency band. Therefore, it's better to cut out unwanted frequencies than to boost a desired range. If you do need to boost with your channel EQ, then be careful not to boost too much or you'll introduce distortion. This is where giving yourself that extra 15dB of headroom can save your sound quality.

Outboard Gear

If you use outboard compressors, effects units, or other processing equipment, then bear in mind that each piece of gear adds an extra gain stage to your signal path. For compressors, be conservative with makeup gain and try to only boost the signal back up to the same peak volume as it originally had. While compression is a great way to bring up the average loudness of your audio, remember that the more you compress a sound, the more you raise the noise floor with makeup gain. Effects present another challenge for proper gain staging. Reverb can quickly build up a significant volume increase, and many modulation effects sweep a peak boost that can overload your channel if you aren't careful. If you plan to use in-line effects, be sure to give yourself a few dB of extra headroom.

The Mix

You'd think that if you're combining several strong signals together, then you'd quickly overload your mix bus, but the math makes this process a bit more complicated and a lot more forgiving than you may think. For one thing, you're not likely to want to keep all of your levels at unity gain, so as long as you keep the hottest signal in the mix (often the kick drum or other percussion) at unity and mix the rest of

your tracks by cutting levels, you should end up with a solid mix that peaks right around 0dB on the master bus. If you are combining several signals together that all need to remain at a near identical level, as sometimes happens with multiple speakers or small ensembles, then you may need to bring each channel down a few dB to achieve the same results.

The Power Amp

Assuming you have access to your sound system's power amplifiers, you'll want to be mindful of this critical final gain stage. To begin with, set your power amplifier low, at or around 50%. Get the best mix you can peaking at 0dB on the master bus, and then bring up the volume on the power amp until you reach your desired volume.

Unfortunately, many PA systems include power amps that are locked away in machine rooms or otherwise rendered inaccessible to prevent imprudent engineers from blowing the system. Most often, if this is the case, then the power amps are turned up far higher than they need to be, which brings up the noise floor just like cranking the channel or master faders would. This makes it all the more important to be judicious about managing noise and properly structuring your gain stages throughout the rest of the sound system.

Final Recap

Why worry about gain staging? You need to master this because it's one of the most important jobs a live sound engineer has. The good news is that you can do wonders for your sound by understanding the process and following these tips. What's more, the better you familiarize yourself with your gear and the various gain stages in your system, the easier it is to achieve great results.

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