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Noise, SNR, and the Importance of Input Referred Noise

Input referred noise is a noise specification found on some audio equipment and preamplifiers. While it is an extremely useful specification when comparing noise performance between different preamplifiers, it is not as widely used as it should be.

In this article, we will discuss the benefits of input referred noise and why it should be the only specification used when comparing noise between audio preamps.

1. What is Noise

Noise is a common term used for a verity unwanted sounds from audio equipment. Noise in audio electronics is often characterized as unwanted buzz, hiss, and shhhhhh sounds created by the audio component and heard through the speakers.

Other unwanted background noises in an audio system, including ground loop hum and digital noise from Wi-Fi routers, are examples of interference and are not part of specifying the self-noise of an audio component.

The most common noise types developed in audio equipment are the following:

- White Noise - the typical high frequency shhhhhh with your ear next to a tweeter.
- 50/60 cycle Noise – noise caused by the AC frequency of a wall power outlet, often heard because the unit is powered from the wall. Sounds like a low frequency hum.
- Rectified power supply noise – harmonics of the AC wall outlet due to rectifiers in the power supply. Rectifiers have a doubling effect of the AC wall frequency and will case 100/120Hz and higher frequency harmonics. Sounds like a buzz.

2. Measuring Noise

Noise of audio equipment is measured using high quality audio analyzers. Typically, the output of the Device Under Test (DUT) is connected to the audio analyzer with the input of the DUT shorted. By shorting the input, there is no additional cabling causing noise and the likelihood of interference is low. This is extremely important for high gain systems like phono preamps.

The noise measured by the analyzer is the output noise of the device. For audio devices, this is typically in the microvolt (uV) range.

2.1 A-Weighting

Noise not only has an amplitude but some associated bandwidth (frequency response). For example, pure white noise, with the shhhhh sound, has a flat amplitude across an infinite bandwidth. Since no frequency is louder than any other, we do not hear a pitch associated with this noise and instead, the shhhhh type sound. Noise measurements by audio analyzers are typically A-weighted in accordance with IEC standards. A-weighting is a frequency response curve applied to a noise source in accordance to the human ear's sensitivity to frequency across the audible bandwidth.

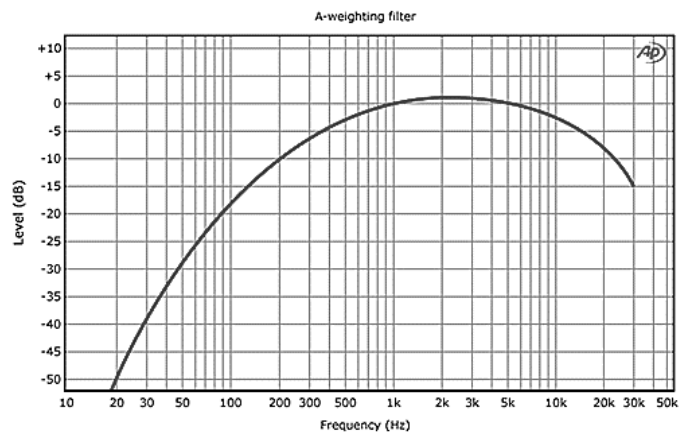

Figure 1: A-Weighting Frequency Response

Figure 1 shows the A-Weight curve which is applied to the output noise of audio equipment. The A-Weighting filter attenuates the analyzer measurement by approximately 50dB at 20Hz and rises gradually 0dB at 1KHz. 20Hz is an extremely low frequency where our ears have difficulty hearing. 1KHz is right in the middle of the audible band which is where our hearing is the most sensitive.

3. Input Referred Noise

For audio preamplifiers, input referred noise is the best way to specify the measured noise.

Input referred noise is simply the measured output noise (measured by an audio analyzer) divided by the gain of the preamplifier.

This is called input referred noise because if we assumed this noise source was an input signal to a noiseless amplifier, the output noise would be the input referred noise multiplied by the gain of the amplifier.

Input referred noise can be A-weighted just like standard output noise measurements.

$$Input\_Referred\_Noise = \frac{Output\_Noise}{Gain}$$

Equation 1: Input Referred Noise

3.1 Importance of Input Referred Noise

What makes input referred noise so useful is that give us a meaningful noise measurement regardless of the gain of the device.

For example, it is not unreasonable to assume that a preamp with 20dB of gain will have higher output noise than a preamp with 10dB of gain. The preamp with 20dB of gain is much more sensitive to white noise sources or 50/60 cycle hum from the power supply internal to the device because it will scale these noises more due to the higher gain. However, this does not necessary make the preamplifier bad.

Instead, by taking the input referred noise of these two preamps, we get a noise measurement per unit gain for each preamp. Since this input referred noise measurement removes the effects of different preamp gain, we can now effectively compare the noise performance of these preamplifiers and determine which is better.

For a given audio input signal level, a preamplifier with lower input referred noise will provide lower noise in a system. This is not necessarily true of output noise.

What makes this so?

If the input referred noise of to 20dB gain preamp is lower than a 10dB gain preamp and the input audio signal amplitude to these preamps is identical, the output amplitude of the 20dB preamp will be much larger because the gain is higher. Therefore, even if the output noise of the 20dB preamp is larger, so too is the output signal!

Therefore, an audio preamplifier with higher gain and lower input referred noise is usually best not only because the noise is lower, but we will get a larger output signal which will give more fixability to drive power amplifiers and other components.

Also note that a preamp with higher gain does not necessarily mean it will have lower input referred noise. In fact, it is often more difficult to get lower input referred noise on a higher gain system.

3.2 What about SNR

So why not use SNR (Signal to Noise Ratio)? Well we can, but it is better to specify input referred noise, especially for preamps.

Since the output of an audio preamp can be connected to a variety of components (other preamps or power amplifiers), we don't know the output level from the preamp required to get full output power to the speakers.

Therefore, it is unfair and misleading to specify SNR of a preamp. One power amplifier may require 0.5VRMS to hit full output power while another may require 2VRMS. Since SNR is a ratio between output voltage and output noise, what output voltage do we use for the measurement, 0.5V or 2V?

Depending on what we choose, we will get a 12dB difference in SNR!

$$SNR = \frac{V_{out}Max}{Output\_Noise}$$

Equation 2: SNR

$$SNR(dB) = 20 \times LOG_{10}\left(\frac{V_{out}Max}{Output\_Noise}\right)$$

Equation 3: SNR in dB

Equation 2 above show the calculation of SNR and its dependence on output voltage. SNR is usually specified in dB by taking the 20 times the base 10 Logarithm of the SNR voltage ratio (Equation 3).

From the example above, if the manufacturer used the 2VRMS output reference for SNR and the customer only required 0.5VRMS, the actual in-system SNR would be 12dB lower!

Even worse, manufactures can choose any output voltage they want, so SNR cannot be easily compared between products.

To make meaningful noise comparisons regardless of the component driven by the preamp, input referred noise should be used. Input referred noise removes any effects of gain and SNR on the noise measurement of the preamplifier and different products can be directly compared.

4. Power Amplifiers

For power amplifiers, SNR is much more valid to use as a specification. Why?

A power amplifier is the end electrical component of most audio systems, and therefore the output level (and output power) the amplifier can produce into a speaker is known. Unlike a preamplifier, which can be used in systems requiring vastly different output voltages from the preamplifier, a power amplifier's output voltage is fixed to is maximum rated output power.

As before, input referred noise is still a valid measurement, but offers less insight for power amplifier noise performance. In this case, it removes any influence of the actual output power the amplifier is capable of. And in a power amplifier, power is what we are interested in most.