Signal Behavior

A *signal* is information that is sent or received through a medium. A mayday signal from a sinking ship is a call for help – SOS. A traffic signal communicates Stop and Go to drivers and pedestrians.

An *audio signal* is sound information, usually sent through a cable. It's a small amount of voltage (often just milliVolts).

Noise in the Signal

An audio signal, in a perfect world (HA!) would be pure audio, with no undesirable side effects. But in fact, virtually all audio systems have 'built-in' noise. There might be white noise, electronic hum, radio interference, or other problems.

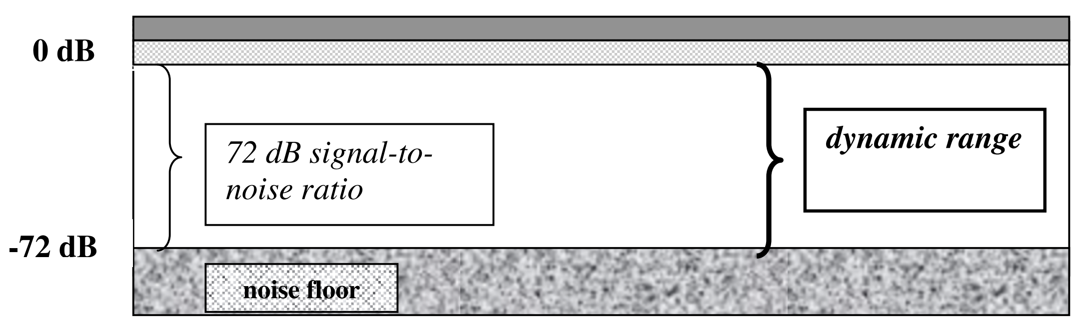
Noise Floor, Nominal Level, Dynamic Range, and Signal-to-Noise Ratio

Virtually every piece of audio equipment produces a little noise, whether it's hiss, hum, or buzz. The noise is usually pretty quiet. You can think of it like the floor in a room, always there, underneath the 'good stuff'! The ***noise floor*** is the noise naturally produced by each device, including hiss and hum, digital noise and radio interference. The noise floor is measured in dB. In the following example, the noise floor is -72dB.

On the other hand, you also want to know about the signal, the 'good stuff'. How loud can you record it without distorting? You call this the ***nominal operating level*** (it's usually 0dB, as in the following example).

If you compare the nominal level to the noise floor, you get what is called the ***signal-to-noise ratio***. It's usually abbreviated "S/N ratio".

Calculating the S/N ratio is easy. You just subtract the noise floor from the nominal level. The S/N ratio in the following example is 72dB (0 minus –72).



Any sound that dips below –72dB in the recording will be buried in noise, and any sound that exceeds 0dB will be distorted. The gap between the noise floor and the point of distortion is called the ***dynamic range***. Notice that it's pretty well the same size as the S/N ratio.

Cassette tape is quite noisy – it has a S/N ratio of about 60dB. CD's have very little noise, and a S/N ratio of 96dB. Good quality mixers may have a S/N ratio over 100dB.

Signal Levels

When you connect different pieces of audio gear together, it's important that the strengths of their inputs and outputs be compatible. If there's a mismatch in signal strength, you might hear mild or serious distortion, or you might hear a lot of extra hiss and buzz and hum.

Here are three common signal levels to know about:

"*Mic level*" – A microphone has a very weak output. You may need to add as much as 50dB of gain to the signal before recording it.

"*Minus 10 dBV*" (-10dB) – Most consumer electronics and many electrical musical instruments operate at –10dB. You'll find –10dB inputs and outputs on things like CD and DVD players, cassette decks, synthesizers, and iPods.

"*Plus 4 dBu*" (+4dB) – Most professional electronics operate at +4dB. You'll find +4dB inputs and outputs on things like mixers and recorders, rack mounted equalizers and compressors, and so on.

The Gain control on mixers and recorders helps you manage different signal levels. If you connect a microphone (weak) to a mixer (strong), you'll need to add lots of gain to the mic signal to make it compatible with the mixer. But if you connect the output of a CD player (strong), you'll only need a little extra gain.

Matching Levels

Always check your gear for MIC/LINE switches, on the outputs and inputs. If they're set incorrectly, you'll have problems.

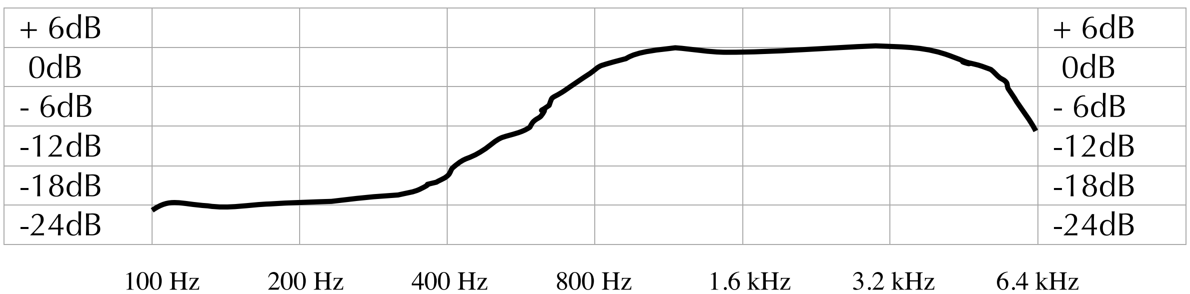
If you connect something with a strong signal (the output of a synthesizer) to something else that is expecting a weak signal (the mic input of a mixer), you'll get distortion.

If you connect something with a weak signal (the output of a microphone) to something else that is expecting a strong signal (the line input of a mixer), you'll get a lot of noise, and not very much signal.

Frequency Response, Resonance & Bandwidth

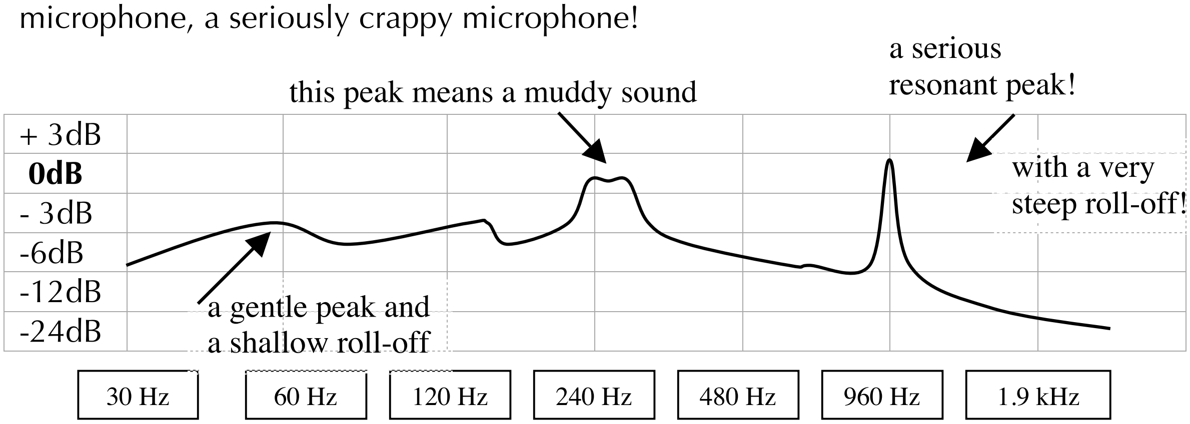
Frequency response is a measure of the audio characteristics of a device, over the range of human hearing (20 to 20,000 Hz). It's a way of describing how sensitive a device is to certain frequencies.

For example, a small speaker, like the speaker in a clock radio, doesn't reproduce bass frequencies very well. It has a weak response in the low frequency range. It's more responsive to mid-range and upper mid-range frequencies. The line graph below shows what its frequency response might look like. See how the sensitivity is measured in dB compared to Hz.



In a recording studio, you usually want the gear, and even the room, to have a ***flat frequency response***; in other words, <u>equally</u> sensitive to all audible frequencies. Modern electronics are well designed in this regard. Loudspeakers and microphones, however, tend to have more uneven responses.

The following graph shows the frequency response curve for an imaginary microphone, a seriously crappy microphone!



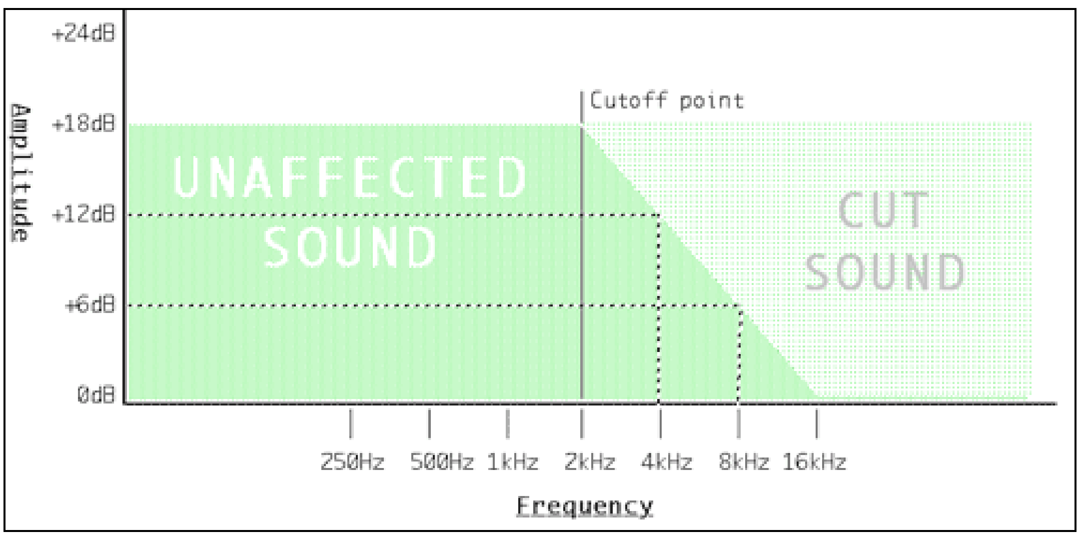
In this graph, the frequency response is fairly flat until about 240Hz, where there's a jump of about 3dB. The response drops again at about 300Hz. Then the response falls off gradually until 960Hz, where there is a steep spike, about 9dB up. This is a ***resonant peak***. Above the 960Hz, the response drops sharply and eventually reaches down towards silence. The sound of this microphone would be very dark with a strong emphasis in the lower mids.

Filters

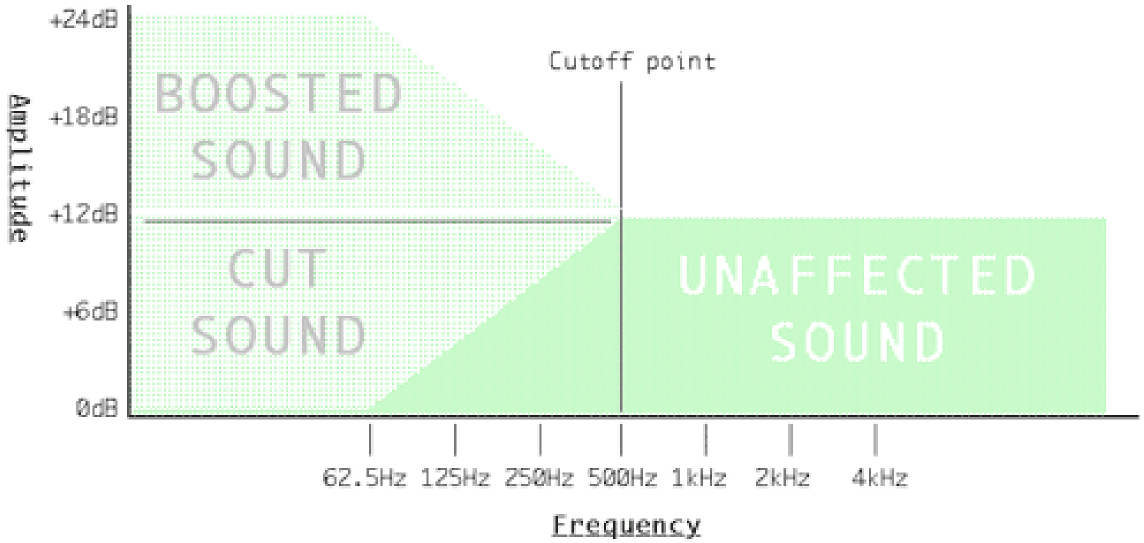
An easy way to start understanding frequency response is to look at filters. Synthesizers and Eqs have filters that remove *low* frequencies (a high pass filter), or *high* frequencies (a low pass filter), or *both* (a band pass filter).

The frequency at which the filter begins to work is called the ***cutoff frequency***. In a low pass filter (LPF) the frequencies higher than the cutoff are gradually filtered out. A high pass filter (HPF) is the opposite – frequencies below the cutoff are affected.

The change in volume compared to the frequency is called ***slope*** (or *roll-off* or *response)*. Slope is measured in dB/octave. If the filter has a slope of 6dB/octave, the amplitude of the sound is decreased 6dB by the filter, one octave below or above the cutoff frequency.



In this LPF, the cutoff frequency is 2kHz, and the slope is 6dB/octave. Below 2kHz, the filter exhibits a flat response, no change to the sound. But above the cutoff, the sound is filtered out at a rate of 6dB for every octave up that you go. So at 4kHz, the filter is removing about 6dB of the amplitude. At 8kHz, the filter is removing 6dB more. The higher the frequency, the more of it is lost.



In this HPF, the cutoff frequency is 500Hz, but the slope is only about 4dB/octave. Above 500Hz, the filter exhibits a flat response, no change to the sound. But below the cutoff, the sound is filtered out at a rate of 4dB for every octave down that you go. So at 250Hz, the filter is removing about 4dB of the amplitude. At 125Hz, the filter is removing 4dB more. The lower the frequency, the more of it is lost.

Filter slopes usually come in multiples of six: 6dB/oct, 12dB/oct, 18dB/oct, 24dB/oct. A slope of 6dB is actually pretty 'shallow'. It doesn't take away a whole lot of the frequencies above or below the cutoff. 12dB is a little steeper, a little more intense; 18dB and 24dB are even steeper, their effects more pronounced.

Modulation

A well-known example of modulation is the tremolo of an electric guitar, or the vibrato in a singer's voice. ***Chorusing, flanging, phase shifting, tremolo,*** and ***vibrato*** are all popular forms of modulation. Some of these modulation types involve putting a copy of the signal out of *tune* with itself. Some involve putting a copy of the signal out of *phase* with itself.

Tremolo – modulation of amplitude
Vibrato – modulation of frequency
Chorus, Flange, Ensemble – modulation of harmonic content
Phase Shifting – modulation of phase

Distortion

Distortion is an unwanted (usually) change in the sound caused by limitations in reproduction. It can sound noisy, grungy, weak, fuzzy, or just unclear. It is usually a sign that something is wrong in the signal flow.

Once the audio signal has been distorted (for example, overdriving the input on a mic preamp with a loud shout!), the distortion is almost impossible to remove. Great care must be taken to keep signals as clean as possible.

Sound can be distorted in different ways. Here are a few:

* ***Harmonic Distortion*** When the signal levels are too hot for the system to handle, the result is added harmonics and noise. This distortion is also called *peaking* or *clipping* or *overloading*. The well-known metal guitar sound uses this kind of distortion. Fuzz pedals produce harmonic distortion.
* ***Frequency Distortion*** When the system is unable to handle all the frequencies in the original signal, you have an uneven frequency response. Cassette tape would cause frequency distortion by reducing high end.
* ***Transient Distortion*** When the system cannot respond quickly enough to transients (sudden changes in amplitude, like a fingersnap or the pedal impact on a kick drum), the sound may lose snappiness. Cheap circuitry is one cause of transient distortion.
* ***Phase Distortion*** When the system is unable to keep all parts of the signal in phase, you'll lose certain frequencies, and hear an emphasis on others. Equalizers can cause phase distortion if they delay certain frequencies. Cheap cables and wiring can also cause phase distortion.

Other Signal Problems

Dropout

Dropout is a brief dip in volume, a momentary loss of signal. Dropout can happen in analog AND digital media.

Rumble

Rumble is a lot of low frequencies caused by something physical, such as air conditioning or a subway tunnel. Microphones and mixers often have bass rolloff filters to keep rumble out of a recording.

Crosstalk

In mixers and analog tape systems, adjacent channels of sound may spill over into each other. This is crosstalk, also called 'leakage' or 'bleeding'.

Wow and Flutter

In analog tape systems and turntables, you may have a fluctuation in the playback speed that causes a noticeable wobble in the pitch. If the wobble is slow, it's called Wow. If the wobble is fast, it's called Flutter.