All Things Being Equal(ized)

Consoles are great for impressing visitors. "How do you learn to work all those knobs?" is a common question. On most consoles, the majority of the knobs deal with equalization, EQ for short. They must be good for something to warrant all that real estate. Everybody figures they're supposed to EQ, but where to start? and what do the knobs really do? This month we'll explore the terminology and explain how EQ relates to music recording. Those of you looking for the magic numbers won't find them here. But you'll learn the underlying principles of applying equalization and how to make it work for you.

The Phone Company Again

Like many common studio tools, equalization came to us from telephony. We think of a "straight wire" as being the perfect transmission medium, but when it gets very long, its impedance becomes significant, causing it to act as a filter. In order to maintain reasonably uniform frequency response through a phone line, telephone engineers insert networks composed of inductors and capacitors to correct frequency response errors. Those networks were dubbed "equalizers" and the name stuck to anything that intentionally alters frequency response.

Simply, this is what an equalizer does - takes our big bucks ruler flat frequency response and mucks it up, boosting a frequency range here, lowering one there, all in the interest of making what comes out more musical than what goes in, if not subjectively more accurate.

Initially, equalization in the studio was used to correct deficiencies, same as with the telephone system. A loudspeaker or microphone weak in high or low frequency response could be made more "flat" by the use of an equalizer. It's only been in the last quarter century of multitrack recording that we've learned to use EQ as a creative tool, not just a corrective one. But enough history, let's take a look at the how's and what's.

Function Follows Form

Equalizers come in many forms and functions - there are stand-alone equalizers, equalizers built in to consoles, high pass filters built into microphones, single-band, multi-band, graphic, parametric, active, passive, analog, and digital EQ. Bass and treble tone controls on the living room stereo or streetwise boombox are equalizers.

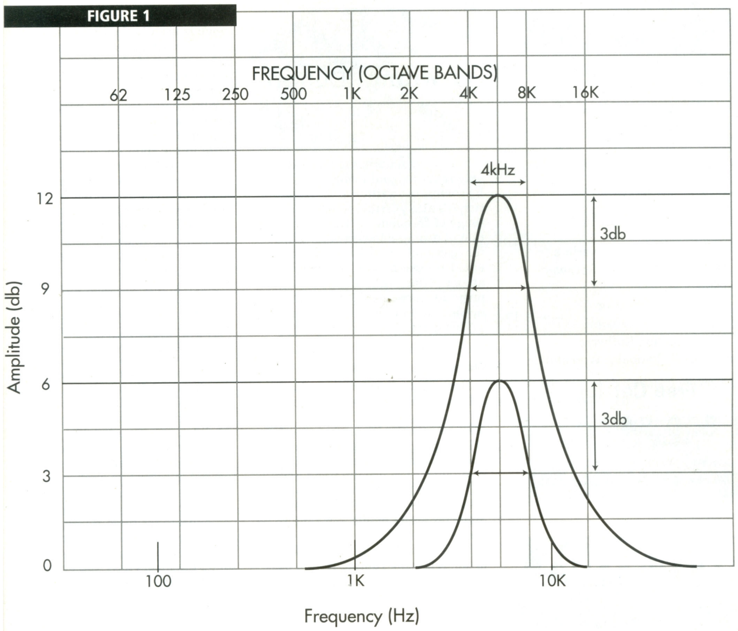
The operation of an equalizer is nearly always described by its frequency response, sometimes in words, sometimes in numbers, but most graphically with (Duh!) a graph of amplitude versus frequency. The plot of an equalizer at work is anything but a straight line. Let's look at the fundamental building blocks that comprise an equalizer in terms of their frequency response curves.

Logs and Octaves

Frequency response is normally plotted with frequency on the horizontal axis, using a logarithmic scale. Each decade (10 Hz, 100 Hz, 1 kHz, 10 kHz, etc.) is represented by a major division of the graph, with the intermediate frequencies scrunched closer together as we get nearer the next major division. This lets us represent a wide range of numbers while maintaining good resolution in areas that relate to how we hear. A frequency response curve based on a horizontal axis with 20,000 equal divisions to represent the audible frequency range would look strange to us. The vertical axis of a frequency response curve is normally plotted on a linear scale of decibels (dB) which are in themselves logarithmic, relating to the way we hear loudness.

Interestingly, when plotted on a logarithmic scale, octave intervals come out equally spaced. A book on the mathematics of music theory will tell you why. This is handy because we often describe the working range, or bandwidth, of an equalizer in terms of octaves. Scoot on over to Figure 1 for a moment. Notice the logarithmic divisions labeled at the bottom of the graph, and the same scale along the top divided into intervals of one octave. When looking at spec sheets, you might see EQ curves plotted with either horizontal scale. They're equivalent. The audible spectrum is "centered" around 1 kHz, so we use this as our reference point for octave, doubling the frequency each division above 1 kHz and halving it at each division below. For sanity's sake, decimals are rounded off.

FIGURE 1



Building Blocks and Dangerous Curves

The basic EQ building block is a filter. A high pass filter passes frequencies higher than its design frequency and attenuates frequencies which are lower. For this reason, it's also called a low-cut filter. Similarly, a low pass (high-cut) filter allows frequencies below its design frequency to pass through unaltered while reducing the amplitude of frequencies above its design frequency. (Figure 2a). A resonant filter puts a bell-shaped hump in the frequency response, flattening out on either side of its resonant frequency. (Figure 2b). A filter with a “shelving” characteristic only goes so far down along the attenuation slope and then the curve flattens out. (Figure 2c) This allows us to adjust a range of frequencies equally.

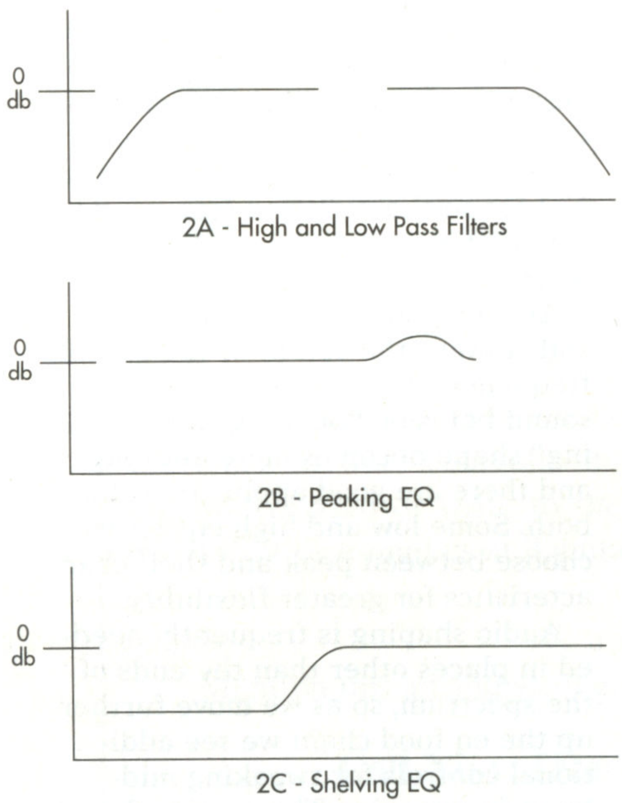


FIGURE 2

Because this is the real world, the frequency response of a filter doesn’t just drop off like the face of a cliff. Its attenuation changes with frequency at a rate determined by the filter’s design. A simple filter has a slope of 6 dB per octave, meaning that a signal one octave above a low pass filter’s design frequency will be attenuated by 6 dB (one-half), a frequency two octaves above will be attenuated by 12 dB, and so on, down to the point where the signal gets lost in the noise.

Filters, by nature, are lossy - they only reduce signal’s amplitude. But by combining a filter with an amplifier, it’s also possible to boost a range of frequencies. With the exception of a simple low- or high-cut filter (generally an in-or-out switch), an equalizer can be adjusted so that, relative to “flat”, the frequency response curve can be pulled either upward or downward. This is starting to look like a pretty useful gadget.

Knobs, Dials, and Switches

The various flavors of equalizers differ in the degree of control they offer in shaping the frequency response. At the low end of the scale is a simple pair of low and high frequency EQ knobs. Their operating frequencies are usually fixed, typically around 120 Hz for the low EQ, around 8 kHz for the high. These frequencies aren’t magic, but tend to be useful in doing basic tailoring - putting more “whump” into a kick drum, removing rumble from a bass or guitar, or adding brightness to a sound. Both bell-shaped (peaking) and shelving characteristics are found this application.

Sometimes the operating frequencies of high and low EQ controls can be selected by a switch to increase its flexibility. Choosing whether the EQ is centered around 100 Hz or 250 Hz can be handy to bring a particular bass instrument out in a mix, while a choice between, say, 6 kHz or 12 kHz on the high end lets you add articulation to a vocal or shimmer to a cymbal. As high and low EQ frequencies shift toward the center of the audible frequency range, the difference in sound between “peaking” and “shelving” shape becomes more audible, and there are good applications for both. Some low and high EQ’s let you choose between peak and shelf characteristics for greater flexibility.

Audio shaping is frequently needed in places other than the ends of the spectrum, so as we move further up the EQ food chain, we see additional controls for tweaking mid-band frequencies. The fancier the EQ, the more control you have. A single control centered in the 2 - 4 kHz range is usually the first one you’ll find. Sometimes two mid-band controls are provided, and you might find switches to select the mid-band EQ frequency.

While basic, fixed frequency EQ is useful for overall trimming, when using EQ as a sound shaping tool, it seems that the fixed frequencies are never quite in the right place. The “sweepable”, or “semi-parametric” equalizer gives us another level of flexibility. Here, rather than a fixed (or switchable) frequency, another control lets us tune the equalizer’s center frequency over a fairly wide range to put the action precisely where it’s needed. The hip term for this is “dialing-in the EQ”.

A specialized type of fixed frequency EQ is the graphic equalizer. It consists of a large number of peaking filters with center frequencies spaced one or one-third octave apart, covering the full audio range of about ten octaves. Typically the boost or cut in each band is adjusted with a vertical slider, giving a graph-like representation the frequency response. Graphic equalizers aren’t favored in recording applications, but are the choice in PA applications for overall system tuning to compensate for room acoustics or to eliminate feedback by cutting gain at the howling frequency. Skilled live sound engineers have the uncanny ability to hear a squeak and immediately grab the right graphic EQ slider, even in the dark.

Parameters

One type of equalizer is known as a Parametric. Frequency, slope, and bandwidth are all parameters which describe the curve of an equalizer, and a parametric equalizer lets you control all of them. We’ve been talking about these parameters in general terms, but let’s take a close look at them.

Bandwidth is defined as the number of kilohertz between the points along the curve where the amplitude drops by 3dB off the peak. Figure 2 shows the frequency response of an equalizer at 6 kHz, for both 12 dB and 6 dB of boost. Both curves are 3 dB down at 4 kHz and also at 8 kHz. Since those two frequencies are an octave apart, we say that this equalizer has a one octave bandwidth, and it’s independent of the amount of boost.

Sometimes “Q” is used to specify an equalizer’s bandwidth. It’s a much hipper sounding term than octaves, though the term is actually more useful to a designer than a musician. Q is defined as the center frequency divided by the bandwidth. It’s just a number, with no units. For our example equalizer, we have:

$$Q = \frac{6\text{ kHz (center frequency)}}{8\text{ kHz (high 3 dB point)} - 4\text{ kHz (low 3 dB point)}} = 1.5$$

The bandwidth control on a parametric equalizer is frequently marked in Q, typically ranging from 2 to 10 or more, but it’s rarely marked in octaves of bandwidth. More often than not, it’ll be marked graphically, with a gentle bell on one end of the control’s rotation representing a wide bandwidth (low Q) and a narrow hairpin at the other end representing a high Q.

Notice that Q is independent of the amount of boost or cut, boosting (or cutting) large amounts affects frequencies surrounding the center frequency to a greater extent. This is apparent by comparing the 6 dB and 12 dB curves in Figure 2.   Higher values of Q mean narrow bandwidth (steep slope) while lower values of Q give a wider bandwidth with a gentler slope. If you want 12 dB of boost at 6 kHz but don’t want more than, say, 3 dB boost at 4 kHz, you must increase the Q of the equalizer.

A Q of 10 or more with a large amount of cut is useful for notching out a narrow band of frequencies like AC hum or air handler noise. A Q of 1.5 with a small amount of boost is a good for a gentle correction of spectral balance. While some equalizers boast of “Constant Q”, not many of them actually work that way. Equalizers generally sound more musical when the Q varies with the amount of boost or cut so that “out of band” frequencies are affected in proportion to the bandwidth, so this design characteristic has been adopted by many manufacturers.

I Say, Old Chap

One can’t write about equalization without mentioning the famous “British EQ”. About a dozen years or so ago, console manufacturers (particularly the British ones) began to advertise that their products had the famous British EQ sound. What they’re really saying is that they’ve come up with a combination of interacting parameters that does flattering things to music when applied judiciously. Nobody has ever been able to accurately quantify that combination, though so try as I might, I can’t tell you what “British EQ” is other than a marketing term. But it’s hard to argue with success.

A Little EQ Philosophy

A common question today is “What’s the correct EQ for _____ [your favorite instrument]?”. I preach that the right starting point is with no EQ. Don’t try to fix something until you know it’s broken. How do you know it’s broken? When you can’t get a good mix just by balancing levels and panning, then, and only then is the time to start twiddling the EQ knobs.

A common piece of advice when EQing is to first try cutting rather than boosting. If the basic tracks are well recorded, most mix problems are the result of two or more sounds trying to occupy the same portion of the spectrum. That frequency range just gets too loud and you’re tempted to boost something else to balance it. Better to clean it up rather than pile more junk on top.

It’s very helpful to know the range of instruments in your mix (charts can be found in just about any recording reference book), but it’s also important to know how the overtone structure affects the timbre of an instrument. By cutting the fundamental frequency range of a lead instrument by a few dB, but leaving its most important overtones relatively unchanged, it will still sound like that instrument in the mix and you’ve made room for something that was fighting for its spectrum space. It’s a fairly common technique to use a high pass filter to clear away most of a guitar below 80 Hz or so to leave room for the bass and kick drum.

While I really hate to generalize about this tender subject, most rhythm instruments, when close miked, tend to have an unnatural build-up in the 200 - 250 Hz range if you’re not careful in your tracking. One approach that works for me more than I care to admit is to start out a mix with a couple of dB scooped out of this range on everything but the bass and kick, then add some back in judiciously to recover the missing warmth. It might work for you, too.

In addition to making a mix work, EQ is sometimes used to modify the tone of an instrument or voice. Sometimes it’s to add one of those obtuse characteristics like “warmth” (around 250 Hz) or “air” (around 10 kHz), but at other times, it’s to create a new sound. When going for the throat, as it were, using an equalizer with a bandwidth of less than an octave will allow you to operate on specific overtones, pulling them up or dropping them back to change the instrument’s characteristic timbre.

Sometimes, corrective surgery is called for when an instrument booms at a certain note. Tuning in on that note and attenuating it with a narrow band parametric equalizer maintains much more of the instrument’s characteristic than simply limiting or compressing the track to even it out. This sort of work requires careful listening to determine just what the problem really is, but now that ear muff season is about over, you should get your ears back in shape. Use ‘em.

Practice Safe EQ

Traditional hardware EQ is pretty much limited to knobs and dials that you can grab and tweak. With the increased popularity of digitally controlled equalizers and software equalization on workstations, while you don’t have tactile feedback of knobs, you often get more control than you ever dreamed using, coupled with a meaningful screen display of frequency response. More control means more opportunity to really mess it up, so careful listening is more important than ever.

In the May and June 1977 issues when we discussed phase in this series, I wrote that frequency response and phase shift go hand in hand. It’s possible to build an equalizer digitally with phase response that’s flat over the audio frequency range regardless of how you twist its frequency response. Since part of what we’ve become accustomed to hearing when we adjust a physical equalizer is changes in phase as well as spectral balance, virtual EQ tends to sound different and takes a little getting used to, but most people don’t take very long to appreciate losing this excess baggage.

Successful equalization is all about understanding what you’re hearing. A skill that will make you a better engineer is the ability to recognize weakness or overemphasis of certain frequency ranges so you’ll know where EQ is required. Sharpen your listening skills by running well mixed music through an equalizer and learn what happens when you boost or cut different frequency ranges. And keep your ears clean.