Exposing Equalizer Mythology

By Dennis A. Bohn

Despite their wide use in just about every aspect of audio production, graphic and parametric equalizers are still widely misunderstood.

John Roberts is one of my heroes. Several years ago, John wrote a regular column in **RE/P** titled "Exposing Audio Mythology." The subtitle was, "Laying to rest . . . or at least exposing the false premises upon which they are based . . . some of the pro-audio industry's more obvious 'Old Wives Tales.' "

Great stuff; you could almost hear the theme music and see the masked rider off in the distance.

Originally, John intended to do a few columns on the most flagrant myths. That was in early 1983. He continued until mid-1986.

Every issue, without fail, John waged war on the mythmakers. John is resting now; myth-exposing is maybe too much for one person. But I'd like to help out by exposing some of the more popular myths about equalizers.

• Myth #1: There exists such a thing as a combining filter.

Many engineers are confused about *what* a combining filter is. So am I. Filter designers have many names for different types of filters—Butterworth, Chebyshev, Bessel, etc.—but combining isn't one of them.

The problem here is with the use of the word "filter." We must distinguish between what is being thought and what is being said. Within the context of using this phrase lies the real intent, i.e., how much ripple exists in the output. (The output being a combination of all of the filter's outputs, or combined output.)

The outputs from filter banks combine (or, in reality, recombine) to form a resultant curve characterized by an overall shape and a ripple content with associated phase shift. How this combining takes place, and the bandwidth of the individual filters, will dictate how much ripple exists. The type of filter used has *nothing* to do with it.

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Combining is done by electronically summing together all of the filter outputs. It is not a filter at all; it is a means of summing the outputs of individual filters. All equalizers combine their filter outputs. It is wrong to say that an equalizer is non-combining. The *only* examples of non-combining multi-band filters are real-time analyzers and active crossovers.

An example of the misuse of the term "combining filter" concerns the comparison between constant-Q and conventional graphic equalizers. (Conventional, as used here, refers to any graphic equalizer that is not constant-Q.) The popular, albeit false, belief is that conventional equalizers use combining filters, while constant-Q designs use non-combining filters. Both designs sum their outputs together. Examples of both designs exist using one or more summers. The difference lies in the smoothness of the combined curves. The fallacy lies in taking the answer out of context.

Setting a conventional equalizer to exhibit the same bandwidth as a constant-Q design produces a combined result *exactly the same* if the number of summers is the same. However, the only condition where this occurs is either full boost or full cut.

Most users do not understand this is the *only* position where the affected bandwidth is ⅓-octave wide (for ⅓-octave designs). At all other boost/cut settings, the bandwidth degrades to over 1-octave wide.

There is no doubt that if two adjacent filters located a ⅓-octave apart degrade to where each is 1-octave wide, then the summed result will be very smooth. There is also no doubt that this is no longer a ⅓-octave equalizer; it now acts as an *octave* equalizer. If that is what is required, then a conventional equalizer is the correct choice; however, if ⅓-octave control is required, then *only* a constant-Q design will do.

• Myth #2: Minimum Phase behavior is an important criterion when buying an equalizer.

Minimum phase is one of the few things you *don't* have to worry about when buying an equalizer. Not that MP isn't important, because it is. It's just that no known examples of commercial equalizers that are *not* minimum phase even exist. Forget all the marketing hype to the contrary.

A precise definition of minimum phase is a detailed mathematical concept involving positive real transfer functions, i.e., transfer functions with all zeros restricted to the left half s-plane. If the last sentence produced a zero in the middle of your brain, don't worry. All you need to know is that minimum-phase behavior is not a problem in *any* equalizer you may consider purchasing.

Here again is an example of sloppy rhetoric; a failure to communicate clearly what is being thought. Somewhere years ago some marketing type needed a buzz word for distinguishing his company's equalizer from everybody else's. Some engineer dropped the term minimum phase and the marketing guy went nuts.

That's it, he thought; never mind that it doesn't fit what is trying to be said . . . it sounds good. Nice and high-tech, so use it to try to build a smoke screen between comparable products.

What they *wanted* to say was that their product could create boost/cut curves with *less* phase shift than their competitors, and that this was a good thing. The problem was that here comes the engineer again to say this simply wasn't true. Any two equalizers producing the same curve do so with *exactly* the same phase shift. Same universe, same physics, same results—much to marketing's chagrin.

So they compromised on claiming their product had *Minimum Phase* charcteristics. Never mind that all the competition also had minimum-phase behavior. The customer wouldn't know that. The promotion implied that the other products didn't. Let the buying public figure out otherwise.

OK, now you know otherwise. Don't be hoodwinked by this year's buzz word.

• Myth #3: Only one brand of equalizer exhibits complementary phase performance.

Speaking of buzz words, here's a beaut: Complementary Phase Shift. Somebody worked overtime on this campaign. I guess what gets me so angry about this issue is the arrogance of the manufacturer. The underlying premise is that the pro-audio public is so gullible they will believe anything, if presented profoundly. Well, they are wrong. All of you are a whole lot smarter than they give you credit for. Street smarts go a long way in solving problems.

Complementary phase shift means nothing more than the fact that an equalizer displays symmetrical boost/cut curves (and is minimum phase). In other words, the boost curves are mirror images of the cut curves, which means that the phase shift of the boost curves are also mirror images of the cut curves. If two things are mirror images of each other, they are complementary. Nothing too profound here.

Now, it is *not* true that all equalizers exhibit symmetrical boost/cut curves. Therefore, not all equalizers have complementary phase shift. At least two of the more popular brands do not. So, if you perceive this to be an important parameter when buying an equalizer, you are correct in asking whether the unit has symmetrical boost/cut curves; I can give you a list of a dozen manufacturers whose equalizers do.

In truth, every example of graphic equalizer I'm familiar with has symmetrical boost/cut curves, as well as most of the parametric equalizers on the market. In fact, you have to look long and hard to find examples of equalizers that are *not* complementary phase performers. As I said, I know of two but there may be more.

The correct question at this point is why do you care if the equalizer has complementary phase shift? Damned if I know. I can tell you why they say it is important, and I can tell you why they are misleading you.

The popular demonstration involves setting up one channel with an arbitrary curve and then adjusting the other channel for the opposite response. Passing a signal through both channels in series produces a flat frequency response. No phase shift. No time delay.

Now this result seems to have overwhelmed them: they describe the results as bizarre, remarkable and baffling. I can find no one else who is the least bit surprised. This is one of the few places where your intuition is correct.

If you take two equalizers set for complementary curves and put them in series you get a response of *unity*. However, you do *not* get an all-pass response, as they claim. There is no amplitude variation, no phase shift, and no time delay.

Basic sophomore electrical engineering tells us why. Something called a transfer function represents each channel. This mathematical equation completely describes the amplitude, phase and time response of a signal passing through that channel. The complementary channel's transfer function is the reciprocal of the first. Putting them in series causes the two transfer functions to multiply.

If two equalizers do not produce the exact transfer function, then they will definitely sound different.

Anything times the reciprocal of itself produces the answer of unity. Nothing too difficult here. One is *not* the transfer function of an all-pass filter; one is the transfer function of a piece of wire.

So what does all this have to do with what kind of equalizer you may want to buy? Not much, really. The implication is that you must have a complementary phase equalizer to correct for a room's frequency anomalies. Not true. Any equalizer that produces the opposite room response will work, and work just as well.

• Myth #4: Constant-Q means non-symmetrical boost/cut curves.

Until recently, I wouldn't have considered this an official myth. Last year Tab Books published a new book by F. Alton Everest, titled *Successful Sound System Operation*. The book comprises a well-written introduction to the business of sound reinforcement, and I recommend it to anyone just starting out. His treatment of constant-Q equalizers, however, needs some revising.

Mr. Everest states erroneously and unequivocally that constant-Q equalizers characterized themselves by having asymmetrical boost/cut curves. (Which occurred from a misreading of a popular parametric equalizer's data sheet.) This myth involves a mixing of two separate issues.

Reciprocity of boost/cut curves and constant-Q have *nothing* to do with each other. You can find constant-Q symmetrical and non-symmetrical equalizers, just as you can find non-constant-Q symmetrical and non-symmetrical equalizers. The terms characterize two *different* aspects of an equalizer. Constant-Q refers to the bandwidth behavior for different amounts of boost or cut. If the bandwidth stays constant as a function of boost/cut amounts, then it is constant-Q. If it does not, then it is not a constant-Q design.

If the cut curves are mirror images of the boost curves, then the equalizer has symmetrical (or reciprocal, the terms are interchangeable) response. If the curves are not mirror images of each other, then the equalizer is of the non-symmetrical school.

Two separate issues, both available in any combination from several manufacturers. Your choice.

• Myth #5: Given identical equalizers, one passive and one active, the passive unit will sound different.

The key to whether this is a myth involves the crucial word, "identical." If two equalizers do not produce the *exact* transfer function, then they will definitely sound different. That is not the issue here. At issue is whether there exists some sound quality attributable to active or passive circuits per se. There does not.

A transfer function exists that characterizes every equalizer's output behavior to a given input change. Any two equalizers with the *same* transfer function, when operating within the constraints necessary to behave according to that function, will give the *same* results no matter what physical form makes up the equalizer.

In general, any equalizer response can be implemented by many different types of circuits, both active and passive. The perceived differences between equalizers designed for the same response function must be explained by factors other than whether the equalizer is active or passive.

Some characteristics that can contribute to the misbehavior of the circuit are nonlinearities that occur because the components are being used improperly or stressed beyond their linear operating region. Sometimes the perceived differences are nothing more than one circuit is quieter than another.

Any two equalizers with the same frequency-domain transfer function will behave the same in the time domain. The transfer function determines responses such as overshoot, ringing and phase shift regardless of implementation.

Nothing mysterious exists within the realm of active and passive equalizers. Simple electronic theory explains all differences between these two, if differences exist. If not, they will perform and sound the same to the objective observer. Never assume that because an equalizer is active or passive it is automatically better or worse for your application. Study your needs and consult with knowledgeable people to make the correct equalizer selection.

Additional comments

Following the appearance of this article in ***Sound & Video Contractor*** *in October 1986, Robert Orban, chief engineer of Orban Associates provided the following comment. Also appearing is a reply from Dennis Bohn.*

From: Robert Orban, chief engineer, Orban Associates.

Dear Mr. Bohn,

I believe that it is necessary to define our terms regarding Myth #4. Constant-Q means non-symmetrical boost/cut curves.

As far as I know, I was the first to use the term "constant-Q" back around 1976. I described the boot-cut curve family produced by the Orban 621-series equalizers with this term, for which I had a very specific definition. Specifically:

> *"constant-Q" refers to a family of equalization curves characterized by an unchanging "Q" of the s-plane poles of transmissions, in both boost and cut modes.*

This curve family is most easily produced by adding (boost) or subracting (cut) the output of a two-pole bandpass filter with its input. Such summation affects only the s-plane zeros of transmission of the resulting symmetrical bi-quadratic transfer function.

It is readily shown that if the equalizer is reciprocal and constant "Q" boost curves are produced, then the cut curves which are reciprocal to the boost curves must be generated by changing the "Q" of the poles of the resulting biquad. Therefore, by my original strict definition of "constant-Q," "myth" #4 is in fact true.

Your definition of "Q" appears to be based upon the shape of the resulting quadratic curve, rather than upon pole "Q." However, "Q" cannot be defined as the reciprocal of the fractional bandwidth in the case of a biquad, because (among other reasons) "Q" becomes undefined with equalization of less than 3dB. (In this case, the "3dB" point does not exit.) In fact, I would submit that the term "Q" cannot be meaningfully applied to a biquadratic transfer function in any other way than as the "Q" of the poles.

Mathematically, if the transfer function H(s) of a bi-quadratic function is as follows:

$$H(s) = \frac{as\pm + bs + c}{as\pm + ds + c}$$

Hence, the "Q" of the poles is defined as Q=SQR(ac)/d.

From: Dennis A. Bohn, vice president research and development, Rane Corporation, Mountlake Terrace, WA.

Dear Mr. Orban,

I welcomed your letter and the chance to further clarify our use of the term "constant-Q." Thank you for your thoughtful comments.

I, indeed, acknowledge your first use of the term "constant-Q" in 1976, and welcome it as a succinct delineator for a complex issue. You are also correct in recognizing our using the term in a wider context; however, our definition would include yours, word for word.

In the case of equalizers, the informed customer needs to know whether the resultant curves exhibit constant bandwidth for all slider positions or not. We use the term "constant-Q" equivalently for constant bandwidth. I apologize for not making this clearer. Our feelings are that the end-user doesn't need (or care) to know what happens to the s-plane poles of transmissions. And, yes, there can be no definition of Q if the amplitude response does not change at least 3dB. While true, that is not relevant to the user's understanding of the product's behavior. Loose rhetoric? Perhaps, but clear rhetoric.

As for the mathematical details, I refer you to my recent paper in the Journal of the Audio Engineering Society. I demonstrate that with proper topology, reciprocal curves can be produced without any change to the Q of the bandpass function. Hence, the term "constant-Q" applies to symmetrical curves as well as non-symmetrical curves, if the appropriate circuit configurations are used. The only difference is whether the bandpass function is subtracted from (non-symmetrical), or put into the feedback loop with (symmetrical), the original signal.

Orban's products are examples of constant-Q equalizers that exhibit non-reciprocal curves; Rane's products are examples of constant-equalizers that exhibit reciprocal curves. Applications exist for both types of products.

I hope the foregoing clarifies our use of the term "constant-Q" as meaning constant bandwidth and demonstrates its appropriateness.

• Myth #6: An ideal equalizer would add no phase shift when boosting or cutting.

Phase shift is not a bad word; it is the glue at the heart of what we do, holding everything together. That it has become a maligned term, is unfortunate. Such a belief stands in the way of people really understanding the requirements for room equalization.

The frequency response of most performing rooms looks like a heart attack victim's EKG results. Associated with each change in amplitude is a corresponding change in phase response. Describing them as unbelievably jagged is being conservative. Every time the amplitude changes so does the phase shift. In fact, it can be argued that phase shift is the stuff that causes amplitude changes. Amplitude, phase shift and time delay are all inextricably mixed by the physics of sound; one does not exist without the others.

An equalizer is a tool that allows you to correct for a room's anomalies. It must be capable of reproducing the exact opposite response of the one being corrected, a criterion that requires precise correction at many neighboring points with the associated phase shift to correct for the room's opposing phase shift. It takes phase shift to fix phase shift. Simple as that.

One way people get into trouble when equalizing rooms is using the wrong type of equalizer. If an equalizer is not capable of adding the correct amount of phase shift, it will make equalizing much more difficult than it has to be. The popularity of the many constant-Q designs has come about because of this phenomenon.

Equalizers that produce broad, smooth curves for modest amounts of boost/cut make poor room equalizers, and good tone modifiers; they lack the ability to make amplitude and phase corrections close together. Lacking the ability to make many independent corrections with minimal interference to neighboring bands, restricts their application primarily to giving a shape to an overall response rather than correcting it. Serious correcting requires sharp, constant-Q performance, among many other things.

Only by adding many precise, narrow phase shift and amplitude corrections do you truly start equalizing a system's blurred phase response. You do not do it with gentle, smooth curves that lack the muscle to tame the peakedness of most rooms.

It's just that simple: you must pre-shape the signal in both amplitude and phase. And that requires narrow filters that preserve their bandwidths at all filter positions. R-E/P

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