# Exposing Equalizer Mythology

- Combining Filters
- Phase Behavior
- Marketing Buzzwords
- Constant-Q
- Passive and Active Equalizers

**Dennis Bohn**
**Rane Corporation**

**RaneNote 115**


## Introduction

John Roberts is one of my heroes. John wrote a regular column for the now defunct magazine *Recording Engineer/Producer* entitled "Exposing Audio Mythology". "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' "— such was the opening for John's first column. Great stuff, you could almost hear the theme music and see the masked rider off in the distance.

He originally intended to do a few columns on the most flagrant abuses, that was in early 1983. He continued until mid-1986. Every issue, without fail, he waged war on the myth-sayers. John is resting now. Myth exposing is too much for one person. I'm arrogant enough, and angry enough, to help out. So I thought I would expose some of the most popular myths regarding equalizers.

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

Many contractors are very confused over just 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 outputs of filter banks combine (or actually, re-combine) 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 dictates the amount of ripple. The type of filter used has nothing to do with it. 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 individual filter's outputs. All equalizers combine their filter outputs. It is wrong to say an equalizer is non-combining. The only examples of non-combining filters are real time analyzers and crossovers. An example of the misuse of this term concerns 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. 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 have 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 one-third octave wide (for one-third designs). At all other boost/cut settings the bandwidth degrades to over one octave wide. There is no doubt that if two adjacent filters located one-third octave apart degrade to where each is one octave wide, then the summed result will be very smooth. There is also no doubt that this is no longer a one-third 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 one-third octave control is required, then only a constant-Q design will do.

## MYTH #2: Minimum Phase behavior is an important criteria when buying an equalizer.

Minimum phase is one of the few things you *don't* have to worry about when buying an equalizer. It's not that it isn't important, it is. It's just that no known examples of commercial equalizers that are *not* minimum phase even exist. None. 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 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 term, a buzz word if you will, 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, thought he; never mind that it doesn't fit what is trying to be said, it sounds good. Nice and high-tech, so he used it to try to build a smoke screen between comparable products.

What they wanted to say was their product could create boost/cut curves with less phase shift than their competitors, and that this was a good thing. Problem was, 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 characteristics. 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.

Okay, now you know otherwise. Don't be hoodwinked by this 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 equalizer displays symmetrical boost/cut curves (and is minimum phase). The boost curves are mirror images of the cut curves. That means the phase shift of the boost is also a mirror image of the cut. If two things are mirror images of each other, they are complementary. Nothing too profound.

Now, it is not true 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 parametrics on the market. In fact, you have to look long and hard to find examples of equalizers that are *not* complementary phase performers.

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 that 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*. 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. Anything times the reciprocal of itself produces the answer of unity, i.e., $(1/X)(X)=1$. 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 works, and works just as well.

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

Until 1986, I wouldn't have considered this an official myth. At that time, F. Alton Everest published a book, entitled Successful Sound System Operation (TAB Books No. 2606). It is a well done introduction to the business of sound reinforcement, and I recommend it to anyone just starting out. His treatment of constant-Q equalizers (p. 252), however, needs some revising.

Mr. Everest states erroneously and unequivocally that constant-Q equalizers characterized themselves by having asymmetrical boost/cut curves. (This occurred from a misreading of a popular parametric equalizer's data sheet; something easy to do.) 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 and 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*) 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 characterizing 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.

## 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 most unfortunate. This 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 and time are all inextricably mixed by the physics of sound. One does not exist without the others.

An equalizer is a tool. 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 connected. This 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 equalizer type. If an equalizer is not capable of adding the correct phase shift amount, it makes 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 boost/cut amounts make poor room equalizers, and good tone modifiers. They lack the ability to make independent amplitude and phase corrections close together with minimal interference to neighboring bands, restricting their usage 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. Broad smooth curves do not allow you to correct for the existing phase shift. Its 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.