NUTS and BOLTS

PART 7

Equalization, Part 1

BY ALEX CASE

The latest installment in our series for the novice is all about tone shaping and how to deal with it.

The Equalizer. You may well wonder: what sounds in a studio need to be made equal? Equal to what? A more descriptive term for equalizer would be spectral modifier, or frequency-specific amplitude adjuster. Then again, sometimes a very simple term will do—even something as mundane as tone controls,like “Bass” and “Treble” or “Low” and “High.”

The audio job of an equalizer is to change the frequency content of an audio signal. If the audio signal is dull, lacking high frequency sparkle, the equalizer is the tool used to fix this—provided that there is some high frequency content in the signal in the first place that the equalizer can bring out. If the sound is painfully bright, harshly assaulting our ears with too much high frequency sizzle, the equalizer again offers the solution, this time by reducing the offending portion of the sound’s high frequency content.

You’ll see that common sense and your ears have at least as much to do with good use of equalizers as the theory behind them. Yet it pays to know that theory; you’ll do better work knowing the theory where common sense would only get you so far.

Engineers use equalizers to adjust the amplitude of a signal within specific and controllable frequency ranges. The master fader on your console adjusts the amplitude of the entire audio signal. Think of an equalizer as a frequency-specific fader; it increases or decreases the amplitude of a signal at certain frequencies only.

Looking high, looking low

The frequency response of a device describes its ability to create output signals that are consistent across the entire audio frequency range. Figure 1 shows a typical example, in this case a device with an output that emphasizes the low frequencies and de-emphasizes the high frequencies. It crosses 0 dB amplitude change (unity gain, neither more or less amplitude) at about 1 kHz.

Musically speaking 1 kHz is a rather high pitch, almost two octaves above middle C. But keep in mind that many instruments playing lower notes will have some harmonic content at this frequency, which we may need to alter.

Imagine routing a couple of sine waves into this device. One is set to a 1 kHz frequency, and the other we’ll move up and down to various frequencies in comparison to our 1 kHz reference. We’ll use meters to assure that both sine waves are kept at the same amplitude (to our ears, higher pitched sine waves sound much louder than equal-amplitude waves at lower frequencies).

When you measure the output of the device that is set up to boost low frequencies and reduce high frequencies (as per Fig. 1), a 100 Hz tone (a bit more than an octave below middle C) will measure louder than a 1 kHz tone input at equal amplitude. And a very high frequency sine wave (say 10 kHz) will measure softer.

If you’ve ever had to listen to sine waves for very long—as in the experiment above or when aligning analog magnetic tape recorders—you’ve learned that they can create

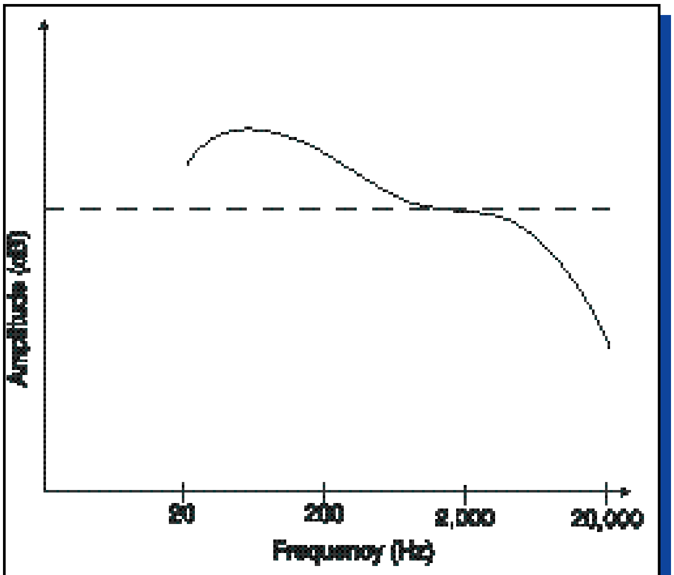

Figure 1: Frequency Response

a rather unpleasant, distinctly non-musical listening experience, becoming more and more annoying the higher their frequencies get. That's because sine waves have no overtones, which makes them useful for testing and calibrating purposes but not usually for making music.

So let's take another look at the meaning of the frequency response plot in Figure 1. Consider an input that is not just a simple sine wave, but is instead an entire mix—a killer mix. The mix is a careful blend of instruments and effects that fills the audio spectrum exactly to your liking, with a gorgeous, present midrange, an airy, detailed high end, and a rich, warm low end.

Sent through the device in Figure 1, that spectral balance is altered. The mix you found oh-so-perfect becomes too heavy in the low frequencies and loses detail up high.

The frequency response plot quantifies exactly the sort of changes in frequency content you can expect when a signal is run through the device. You've probably already absorbed the idea that a "flat" frequency response is often desirable, at least during audio production. We'd like devices like microphone cables and mixing consoles to treat the amplitude of all signals the same way at all frequencies. We hope these sorts of devices don't change the frequency character of the mix "behind our back" unless we choose to make such changes.

And when we want to make such changes away from a flat frequency response we resort to using the equalizer. If you feel your vocal track or your entire mix needs a little more low end and a little less high end, you might run it through an equalizer with a frequency response like that in Figure 1.

> Dialing up just the right eq 'curve' for a given situation will require experience, good ears, a good monitoring environment, and good judgment.

To understand equalization you need only understand this: you are changing the frequency content of a signal by running it through a device whose frequency response is distinctly non-flat—on purpose.

The trick, and we'll discuss this in more detail later, is to alter the frequency response in ways that are tasteful, musical, and appropriate to the sound. It's easy to get it wrong. Dialing up just the right eq 'curve' for a given situation will require experience, good ears, a good monitoring environment, and good judgment.

How many knobs?

If you consider the frequency response like that in Figure 1 to be adjustable from flat to the specific contour shown, you discover that configuring a device that actually controls these sorts of changes isn't obvious. To see how this is done we'll take a tour of the equalizers you are likely to find in a studio (leaving out equalizers that exist in software for now).

We begin with the most flexible type of all: the parametric equalizerNo one got a Nobel Prize for naming this thing. It is a parametric eq because it offers you the most parameters for changing the spectral shaping. That's it. In fact it's got all of three parameters for your knob tweaking pleasure.

Understanding the three parameters here makes understanding all types of equalizers a breeze. All other equalizers will have one or two of these three parameters available for adjusting on the front of the box. When you learn how to use a parametric equalizer, you are learning how to use all types of equalizers.

Perhaps the most obvious parameter needed is the one that selects the frequency you wish to alter. The center frequencyof the spectral region you are altering is dialed up on a knob labeled Frequency. In our search for bass, we might have decided that our signal needs additional low frequency content in the area around 100 Hz. Or is it closer to 80 Hz? These decisions are made at the frequency select control.

Naturally, we then decide how much to alter the frequency we've selected. The addition (or subtraction) of bass happens via adjustment of the second parameter: Cut/Boost.It indicates the amount of decrease or increase in amplitude at the center frequency you dialed in on parameter number one above.

To take the shrill edge off of a horn, select a high frequency (around 8 kHz maybe) and cut a small amount—maybe about 3 dB. To add a lot of bass, boost 9 to 12 decibels at the low frequency that sounds best, somewhere between 40 and 120 Hz perhaps. As you can see, these two parameters alone, frequency select and cut/boost, give you a terrific amount of spectral flexibility.

NUTS and BOLTS

Bandwidth and Q

Consider a boost of 8 dB at 100 Hz. This could be just the trick to make a guitar sound powerful in the lower and fatter notes. You can almost taste the Grammy Award after deciding on this eq move. You can hear the result. But before you know what you really did to alter the frequency response, you need to consider a third parameter. It's a bit more subtle than the first two, and many less expensive equalizers (which we'll cover later) do without it.

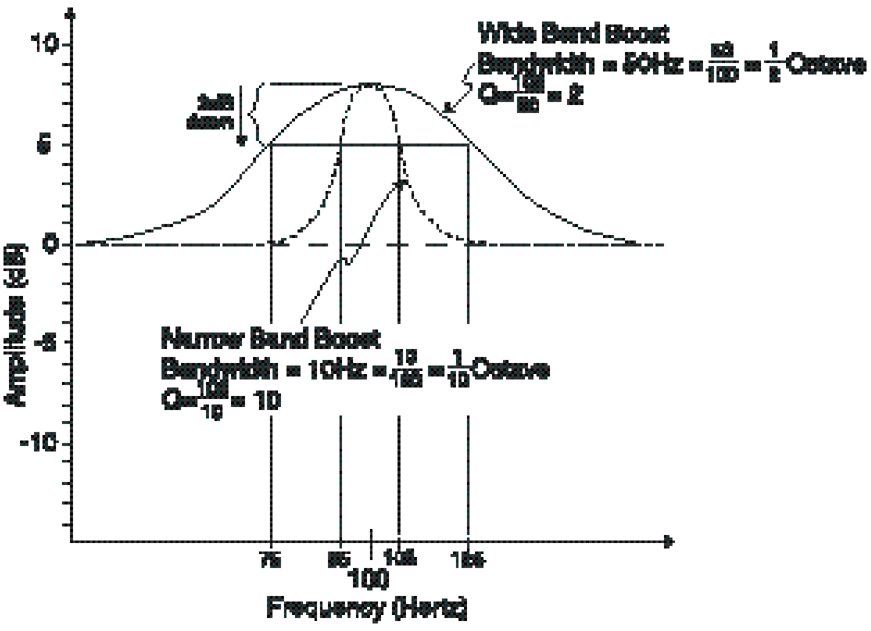

Figure 2: Bandwidth and Q

We know where we boost (at 100 Hz in the above example) and how high we boost (by adding 8 dB)—but we don't just boost the narrow and exclusive frequency of 100 Hz, even though that's the one we dialed up. Instead we affect a range of frequencies both below and above that 100 Hz frequency. Remember—that 100 Hz is called the centerfrequency. Just how wide is the boosted region to either side of that center going to be?

Figure 2 demonstrates two possible results from the same center frequency and boost settings. Check them out and you'll see what we meant by saying that selecting a center frequency to boost affects not just that single frequency but the neighboring frequencies as well.

The degree to which we also boost other frequencies nearby is defined by the third parameter, Q. The Q describes the width of the cut or boost region.

Let’s define first the bandwidth of an equalization change. Bandwidth is closely related to but not the same as Q. Bandwidth is considered to be the frequency region on either side of the center frequency that is within three decibels of the center frequency’s cut or boost.

Starting at the center frequency and working our way out both above it and below it in frequency, we can find the points on the curves in Figure 2 where the signal is three decibels down from the amplitude at the center frequency. The bandwidth of a cut or boost at a specific frequency describes the frequency range bounded by these ‘3 dB down’ points.

In our example of an 8 dB boost at 100 Hz, the bandwidth is based on the frequencies that are boosted by 5 dB (8 – 3 = 5) or more. Figure 2 shows two such possible boosts. The wide boost has ‘3 dB down’ points at 75 Hz and 125 Hz. The bandwidth then is 50 Hz (the spectral distance from 75 Hz to 125 Hz). The narrow boost is 3 dB down at 95 Hz and 105 Hz, giving a smaller bandwidth of just 10 Hz.

Now expressing values in actual Hertz is rarely very useful in the studio. We humans don’t process music that way. When you are writing a horn chart, you don’t decide to add a flute part 440 Hertz above the tenor sax. Instead you describe it musically, saying that the flute should be perhaps one octave above the tenor sax.

> an extra $20 to make an eq sweepable will bump up the price of a 32-channel mixer by over $600.

For music we think in terms of musical ratios or intervals, the most famous of which is the octave. The octave represents nothing more than a mathematical doubling of frequency, whatever the frequency may be—440 Hertz (“tuning” A above middle C) is one octave above 220 Hz, 1000 Hz is one octave above 500 Hz, etc. Because this is how we hear, we stick to this way of describing spectral properties on the equalizer.

Using a ratio, we compare the bandwidth to the center frequency and express them in relative terms—in octaves rather than Hz. For example a 50 Hz bandwidth around a 100 Hz center frequency represents a bandwidth that is half an octave wide; the bandwidth is half the value of the center frequency.

With a fixed bandwidth of “exactly half an octave,” sweeping the center frequency down from 100 Hz to 50 Hz would be accompanied by a bandwidth that decreases automatically from 50 Hz to 25 Hz. This narrowing of bandwidth as measured in Hertz ensures that the equalization character you hear doesn’t change as you zero in on the desired center frequency.

Bandwidth expressed in octaves is more musically useful to our ears than bandwidth expressed in Hertz. If the bandwidth during the previous move (from center frequency 100 Hz to down to 50 Hz) had remained at a bandwidth of “exactly 50 Hz” it would have sounded like a wider, less precise equalization adjustment at lower frequencies. That's because a bandwidth of 50 Hz around a center frequency of 50 Hz is—you guessed it—a full octave.

That's the idea of bandwidth. And that's almost the end of the math in this article. But there is one more idea to take in here before we're done. Bring on Q.

And Q makes three

While expressing the bandwidth of an equalizer boost or cut in octaves makes good sense, the tradition is to flip the ratio over mathematically (the fancy term for this is to take the reciprocal—impress your clients!). We consider center frequency divided by bandwidth instead of bandwidth divided by center frequency. The spectral 'width' described this way (still in octaves) is the Q parameter.

The wide boost discussed above and shown in Figure 2 is 50 Hz wide at a center frequency of 100 Hz. The Q therefore is 2 (center frequency of 100 Hz divided by the bandwidth of 50 Hz). The narrow boost has a Q of 10 (100 Hz divided by the narrow 10 Hz bandwidth). Studio-speak includes phrases like "low Q" and "high Q" to describe wide (low Q) and narrow (high Q) boosts and cuts.

It then follows that the higher the Q, the more surgical your intervention. If you have a particular note or tone or hum or buzz that you need to pull out, of course you go for the narrowest bandwidth around the offending center frequency, with the steepest cut your equalizer can provide. Such a move is called notching or notch filtering.

> Expressing values in Hertz is rarely useful in the studio. When writing a horn chart, you don't decide to add a flute part 440 Hertz above the tenor sax.

So for a full complement of equalization parameters you have Frequency Select, Cut/Boost, and Q as the three controls needed to achieve any kind of alteration to a frequency response, from broad and subtle enhancements to aggressive and surgical notches. Parametric equalizers give you these three controls for every band of equalization.

Band of equalization? That's right. These three controls often appear in sets. A 4-band parametric eq has 12 controls on it (3 controls x 4 bands = 12 controls in all)! It offers the three parameters four different times so that you can select four different spectral targets and shape each of them with their own amount of boost or cut, and each with a unique bandwidth.

The result, if your ears can follow it all, is the ability to effect a tremendous amount of change on the spectral content of a signal. Figure 3 shows a possible result of 4-band parametric equalization. The terrific amount of sonic shaping power that four bands of parametric equalization offer makes it a popular piece of gear in any studio.

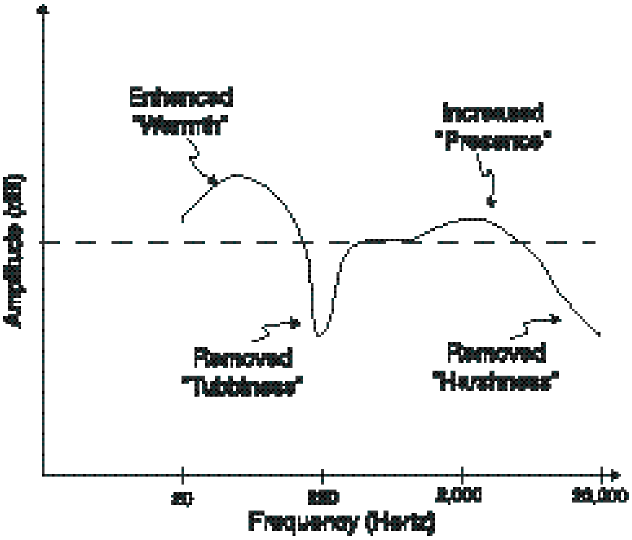

Figure 3: The Creative Power of a Four Band Parametric Equalizer

But other options exist.

Take away the Q

Some equalizers fix the bandwidth internally, providing access only to the Frequency Select and Cut/Boost parameters. Because of the downgrade from three parameters to two this type of eq is sometimes called a semi-parametric (or demi-parametric or even quasi-parametric) equalizer

These devices suffer from having an even less imaginative name than parametric equalizers. It's probably best to call them sweepable eq to emphasize that you can adjust the frequency that you are cutting or boosting. When you see such a term in a product's specs it's implied that you cannot adjust the bandwidth. Believe me, if the bandwidth were adjustable the brochure would brag that the device is fully parametric!

This configuration in which only two parameters (Frequency and Cut/Boost) are adjustable is common; it is easy for the recordist to use, easier for the manufacturer to design than a fully parametric, and still very useful in music production.

Take away the frequency

Down one more step, sometimes we only have control over the amount of cut or boost and can adjust neither the frequency nor the Q of the equalization shape. Generally called program eq, this is the sort of equalizer found on most home stereo equipment (those "Treble" and "Bass" knobs, remember?).

You also see this type of eq on many consoles, vintage and new. It appears most often in a 2- or 3-band form: three knobs labeled High, Mid, and Low that are fixed in frequency and Q and offer you only the choice of how much cutting or boosting you're going to apply.

In the case of consoles, remember that there may be the same equalizer repeated over and over on every channel of the console. If it costs an extra 20 bucks to make the equalizer sweepable, that translates into a bump in price of more than $600 on a 32-channel mixer. If it costs 50 bucks to make them fully parametric, and it's a 64-channel console...well, you do the math.

The good news is that even well designed program equalization can sound absolutely gorgeous. And often the preset center frequencies are close enough to the ideal spectral location to get the job done on many tracks. Sometimes you don't even miss the frequency select parameter.

Take away the knobs

A variation on the equalizer described so far is the graphic equalizer. Like program eq, this device has fixed Q and center frequencies, offering the engineer only the cut/boost decision.

On a graphic eq, the various frequency bands are presented not as knobs but as sliders—like faders on a console. The result of such a hardware design is that the faders provide a decent visual description of the frequency response modification that is being applied—hence the name 'graphic.' (To be exact, the actual eq curve outline looks more like a series of sharp bumps above and below a straight line than than the smooth continuous curve one might expect.)

Handy also is the fact that the faders can be made quite compact. It is not unusual to have dual 31-band graphic equalizers that fit into one or two rack spaces.

Graphic eq is an extremely intuitive and comfortable way to work. Being able to see an outline of what you hear will make it easier and quicker to set up the sound you are looking for. Turning knobs on a 4-band parametric equalizer is more of an acquired taste than moving sliders.

There are times in the course of a project when one must reshape the harmonic content with great care using a parametric eq. In other instances there is no time for such careful tweaking and a graphic eq is the perfect, efficient solution. Plan to master both.

Some knobs are switches

Early in my audio career while attending the AES show in New York City, I admired a rather impressive British eq. It was a super high quality equalizer intended for mastering houses. That didn't stop me from thinking it could be useful for tracking a vocal, radically reshaping a guitar tone, and other silliness.

I accidentally let slip my disappointment that despite a 5-figure price tag, the frequency select knobs 'clicked.' Frequency select wasn't continuously sweepable from, say 125 Hz to 250 Hz; the knob clicked from 125 Hz to 250 Hz. If you wanted your equalization contour to be centered on exactly a frequency between clicks you were out of luck.

How could this be? I was politely informed that for this particular device, selecting a different frequency by clicking a knob on the faceplate selected different electronic components inside the device. The equalizer was physically using different parts for different frequency selections! It wasn't just adjusting some variable piece of the circuit, it was physically changing the circuit. That made frequency selection surgically precise and absolutely repeatable, a must for mastering applications.

I was instantly humbled, and learned a lesson. In choosing which type of equalizer to use, you have to trade off sound quality versus price and processing flexibility versus ease of use.

In choosing which type of eq to use, you have to trade off sound quality vs. price and processing flexibility vs. ease of use.

This company has such high standards for sound quality that they took away a little bit of user flexibility to get a better and more repeatable sound. Conversely, if you find an equalizer that is fully parametric and sweepable across four bands yet costs $39.99, you would be wise to wonder how it is that they made the eq so infinitely adjustable and how much sound quality was sacrificed in the name of this flexibility.

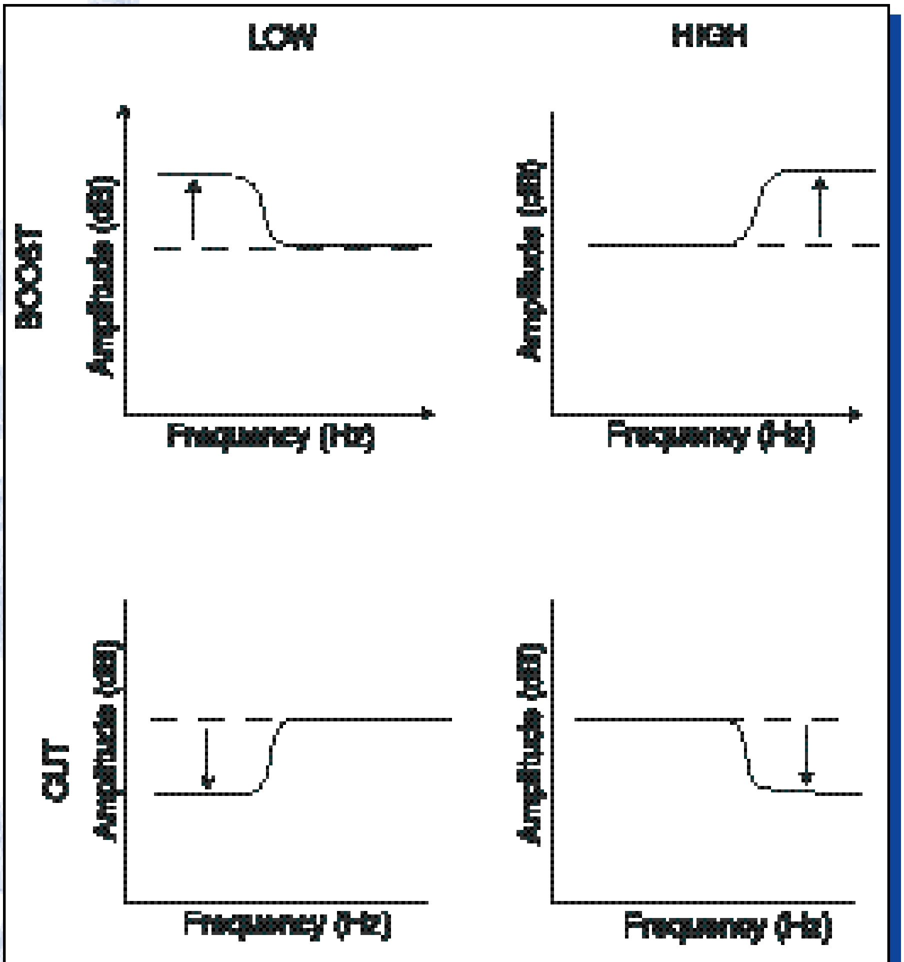

Figure 4: Shelving Equalization

Don't value an equalizer based on the number of controls it has. A simple program eq that allows you only to adjust the amount of cut or boost might contain extremely high quality components inside.

Knobs, switches, filters

So far the most complicated equalizer we can build, the one with the most fancy knobs on the faceplate, is a parametric equalizer. If we allow four bands of eq we are up to 12 knobs. Naturally, it would look cooler if we added some switches. Here's how.

We've talked about equalization changes that offer a region of emphasis when we boost or de-emphasis when we cut. This shape is called a peak/dip because of the visual change it makes in the frequency response. Roughly shaped like a bell curve, it offers a bump up or down in the frequency response.

Two other alternatives exist. The shelving equalizer offers the peak/dip response on one side of the selected center frequency and a flat cut or boost region on the other. Figure 4 demonstrates.

A broad equalization desire might be to brighten up the sound in general. A high frequency shelving eq bumped up 6 dB at 8 kHz will raise the output at 8 kHz and above. It isn't limited to a center frequency and its associated bandwidth. The resulting alteration in the frequency response is flat (like a shelf) beyond the selected frequency.

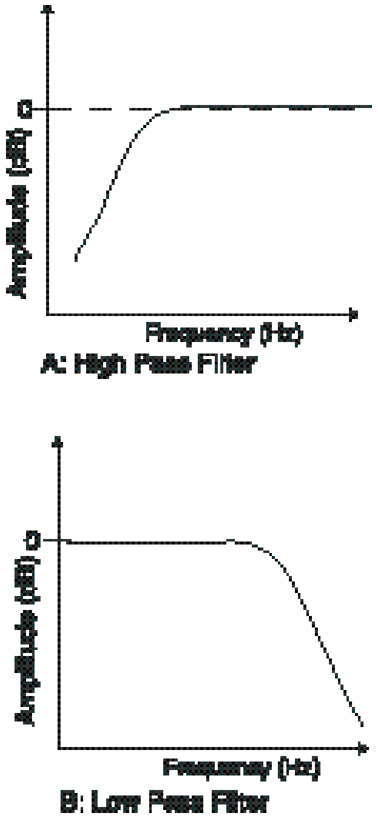

Figure 5: Filters

As Figure 4 shows, the concept of a shelving eq applies to low frequencies as well as high, and cuts as well as boosts. In all cases there is a flat region beyond (above or below) the selected center frequency that is boosted or attenuated. A helpful image comes by way of beer: the shelving eq shape provides a good flat region to set a beer on without risk of spilling. There is nowhere within the eq move to set a beer when using a peak/dip eq contour.

An important final option exists for reshaping the frequency response of a signal: the filter Engineers speak generally about filtering a signal whenever they change its frequency response in any way. Under this loose definition, all of the equalizers we've discussed so far are made up of audio filters. But to be more precise, a stand-alone filter must have one of the two shapes shown in Figure 5.

A highpass filter (Figure 5A) allows high frequencies through but attenuates lows. A lowpass filter (Figure 5B) does the opposite, allowing low frequencies to pass through the device without a change in amplitude, but attenuating high frequencies.

Because the sonic result can be rather similar to shelving equalizers cutting out extreme high or low frequencies, there is some confusion between them. Filters distinguish themselves from shelving equalizers in two key ways.

First, filters are cut-only devices; they never boost at any frequency (except in the case of resonant filters on synthesizers, which we won't go into now). Shelf eq can cut or boost.

Second, and this is important, filters offer an ever-increasing amount of attenuation beyond the selected frequency. They do not flatten out like the shelf; there is nowhere to set the beer. They just keep cutting, and cutting, all the way down to silence.

> If you find a 4-band parametric eq that costs $39.99, you'd be wise to wonder what was sacrificed in the name of all that flexibility.

If there is some unwanted low frequency air conditioner rumble on a track that you never, ever want to hear, a filter can essentially remove it entirely. A shelf equalizer will have a limit to the amount of attenuation it can achieve, perhaps only 12 or 16 dB down. The weakness of using a shelving equalizer in this case is easily revealed on every quiet passage whenever that track is being played, as you'll still heae the air conditioner rumbling on faintly in the background.

Now the faceplate of our equalizer is pretty complicated. The 4-band parametric (12 knobs) gets a low pass and high pass filter at each end, as well as switches that toggle each band between a peak/dip or shelf shape.

But such an equalizer contains a rich amount of capability with which you can freely alter the spectral content of any signal in your studio. These knobs and switches enable you to bend and shape the frequency response of the equalizer into almost any contour imaginable. Your strong creative drive to push the limits of a sound must be balanced by your musical and technical knowledge of your sound and equipment. Listen closely, and have fun.

Alex Case encourages you to insert the words "cup of water" wherever the word "beer" appears above. Request Nuts & Bolts topics via case@recordingmag.com. Thanks.

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