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The Art of Equalization

by *Ethan Winer*

(This article first appeared in the August 1979 issue of *Popular Electronics* magazine.)

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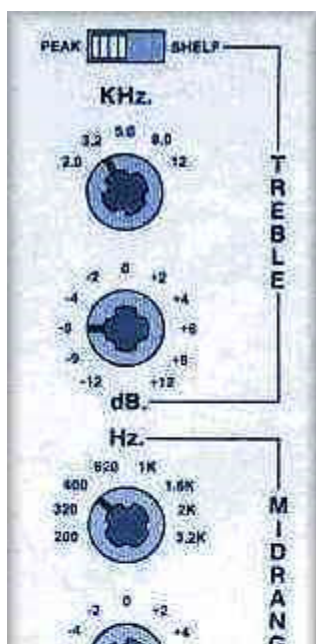
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A growing number of audio enthusiasts are using equalizers to adjust their stereo system's frequency response, whether to compensate for room acoustics or for creative recording purposes. An equalizer is a device that allows you to adjust the frequency response of an audio signal, and even conventional bass and treble controls qualify as equalizers. More often, however, the term implies equipment that is more complex and sophisticated, such as that used by a mixing engineer. Let's take a look at some of the reasons equalization (EQ) is useful and how its implementation has developed into a high art.



Standard bass and treble tone controls are broadband devices that have the greatest effect at the frequency extremes - that is, the highest highs and the lowest lows. While this is fine for touching up the response in your car stereo, it offers little help in correcting narrow-band colorations, which often are quite disturbing. For example, a peak in the response of an audio system in the middle-treble region can produce a shrill or scratchy quality that a normal treble control cannot effectively tame. Turning down the treble enough to eliminate the shrillness kills too much of the highest treble, robbing music of clarity and sparkle. Similarly, using a bass control to correct tubbiness or muddy bass response also falls short of success. Turning the control down to relieve such mid-bass exaggeration would simply remove the deepest frequencies so important to life-like reproduction, while perhaps still allowing some muddiness to persist. There's got to be a better way - and there is.

Enter the Graphic Equalizer. The graphic equalizer has become very popular in recent years. It is called *graphic* because, as the front-panel

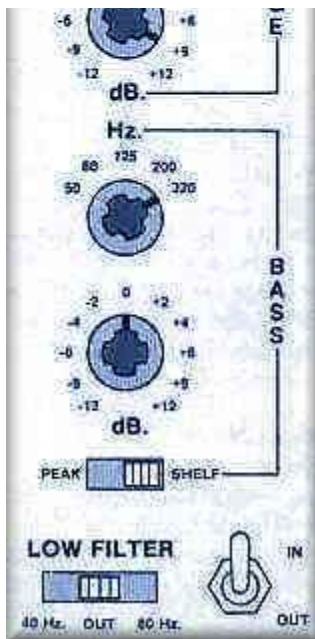


Fig. 1: Layout of a typical console equalizer, with separate controls for low, mid, and high frequencies.

sliders are adjusted, their positions give an approximate display of the resultant frequency response. These devices divide the audible spectrum into five or more frequency bands, and allow adjustments to each band via its own boost/cut control. Instead of broad adjustments of treble, bass, and maybe the midrange (sometimes called *presence*), we now have independent control over the low bass, mid-bass, high bass, low midrange, and so forth. If we attack that shrill mid-treble emphasis with an octave-band graphic equalizer, we should be able, more or less, to correct for only the troublesome peak. We'll have to settle for "more or less" because it is unlikely that any response anomaly will correspond exactly to the frequencies available on even a ten-band device.

Therefore, many professional sound contractors, recording studios, and audio enthusiasts seeking precise results use the even greater resolution afforded by 1/3-octave equalization. The 1/3-octave graphics usually have 27 bands and can, when teamed up with the proper measuring equipment, be used to make just about any high-quality speaker system flat to within a dB. or two over much of the audible range. But there's much more to EQ than simply correcting less than ideal loudspeakers and listening rooms.

EQ IN THE STUDIO

Now, let's look at the professional recording studio with its abundant knobs, lights, and buttons. This is where the multiple original tracks are adjusted in level and equalized before being mixed together to comprise the final two-track product. The key phrase is "before being mixed." Whereas the home listener can alter the program only in its entirety, the recording engineer can - and must - equalize sounds picked up by each microphone separately. The tool of choice for this application is yet another equalizer referred to by many as the *console type*. Virtually all professional mixing consoles use this sort of device, with one available for each mike or line input. Additional equalizers are often devoted to echo and reverb lines to tailor the tone of those devices.

A typical front panel for a console equalizer (Figure 1) shows that we're back to the bass-mid-treble format. But there are no less than five different frequency choices for treble, eight for midrange, and another five for bass. In addition, a three-position low-cut filter is provided, as is an in/out switch for instant comparison of Before and After. Here we have a device that can control fifteen different frequency ranges and also be made small enough to fit in quantity into a single mixing board. (A large console will have some thirty or more of these, so size is an important factor.) Though all fifteen frequencies cannot be adjusted simultaneously as with the graphic, this rarely is needed in a "one-for-each-mike" situation. Besides, you can always patch a graphic EQ into the signal path when you absolutely have to.

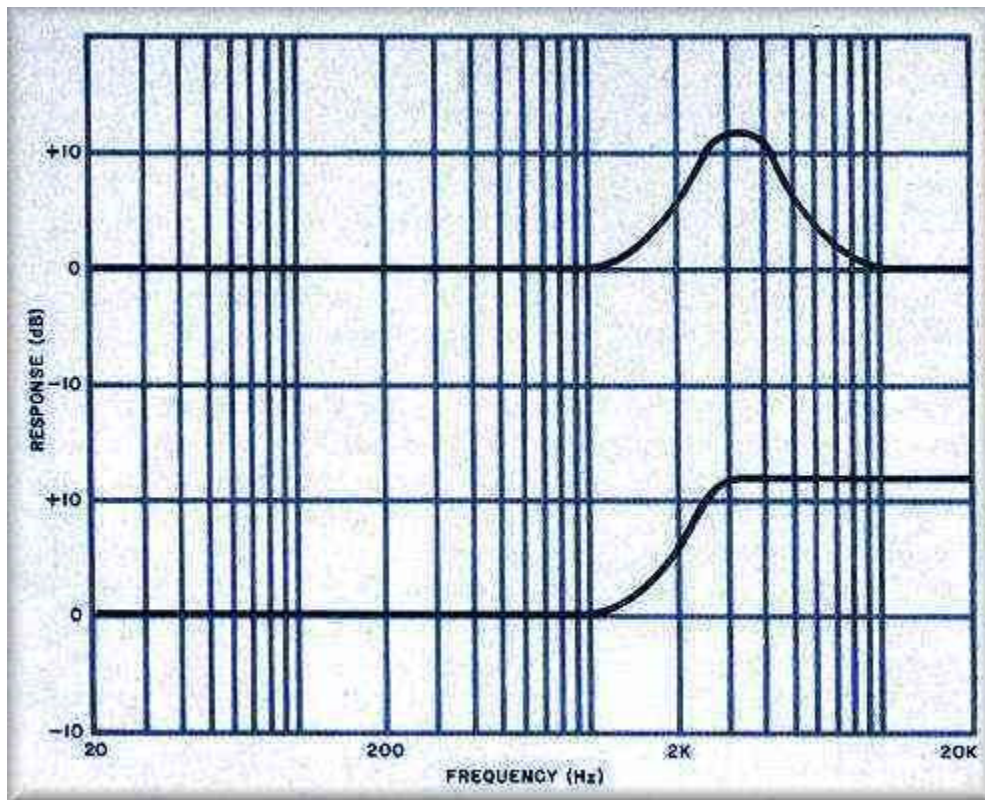


Fig. 2: The top switch in Figure 1 changes the basic shape of the response as shown here to a peak (top) or shelf (bottom).

The last controls, the Peak/Shelf switches, change the basic shape of the response curve. This is shown in Figure 2, where in both cases treble frequency has been set to 3.2 KHz. and 12dB. of boost is applied. The upper curve represents the switch in the Peak position while the lower curve shows a Shelf. Notice that, while the treble peak affects mainly the specified frequency, there is still some influence on nearby frequencies, whether boosting or cutting. In the Shelf position, the boost or cut reaches its maximum [or more commonly, is 3 dB. shy of the maximum] at that frequency and remains there for all higher frequencies. The same principle applies to the bass control. The boost or cut reaches maximum at the named frequency but instead continues downward thereafter. The midrange has no shelf capability, but the more expensive recording consoles generally have a second, additional midrange control for added flexibility. Figure 3 shows bass shelf cuts at four different frequencies. Figure 4 illustrates the effect of varying the bandwidth of a midrange dip. *Bandwidth?* Well, now we're talking about the parametric equalizer, the most recent addition to the EQ machine family.

PARAMETRIC POWER

In a sense, the parametric equalizer is the most powerful of the equalizer types, allowing continuous adjustment of all equalization parameters (hence the name). It is structured similarly to the console equalizer, but there are differences worth elaborating. First, and probably most important, all controls of a parametric are continuously adjustable. Potentiometers, rather than discrete, switch-related resistors, are employed as the tuning elements, allowing a choice of virtually any center frequency. Boost and cut controls are also continuous and frequently offer a range of +/-20 dB, more than is characteristic of other equalizer types.

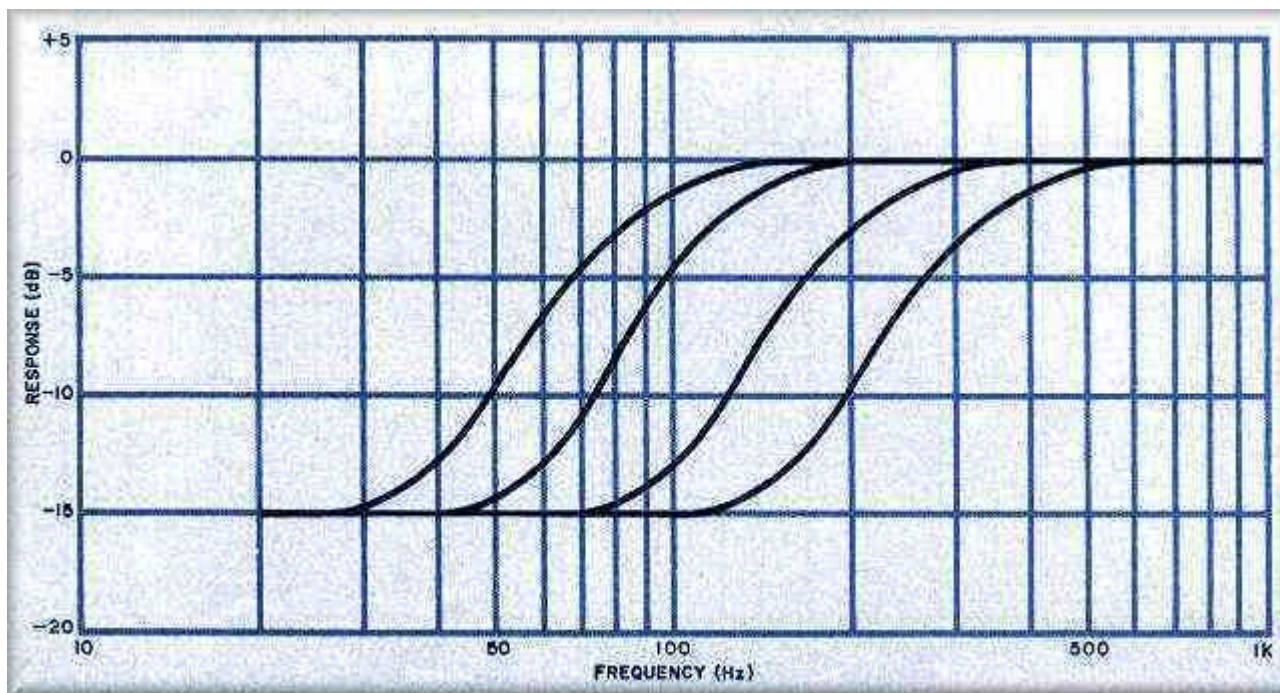


Fig. 3: This shows the response curves for a low frequency shelving cut at four different frequencies.

Another important difference is the inclusion of a bandwidth control. It was explained previously that when boosting or cutting a frequency, the effect spills over to adjacent frequencies. How far away from the indicated center this influence extends is determined by the setting of the bandwidth control. When set to Narrow, only a small range of frequencies are influenced. This is particularly useful for applications such as removing extraneous ringing and false tones from a drum, but without changing the basic sound character. On the other side of the coin, this narrow-band setting can be used to emphasize a single tone and can often effectively "purify" a muddy-sounding tom tom by boosting the fundamental pitch. Of course, this is not a substitute for proper tuning of the drums, but when all else fails... Except when dealing with drums and perhaps some tuned percussion instruments like triangles or cowbells, narrow-bandwidth boosts should usually be avoided because unpleasant resonances or other bad effects may be revealed when the mix is heard on different speakers. In fact, most recording studios have alternate speaker systems available for making instant comparisons.

Broad-bandwidth settings accentuate a larger range of frequencies, which is often more natural sounding than narrow bandwidths. Parametric equalizers are inherently peaking rather than shelving devices, but a wide setting can reasonably approximate a shelf. Do not confuse peaking with boosting, though. Peaking refers only to the shape of the curve, not to whether it is being boosted or attenuated.

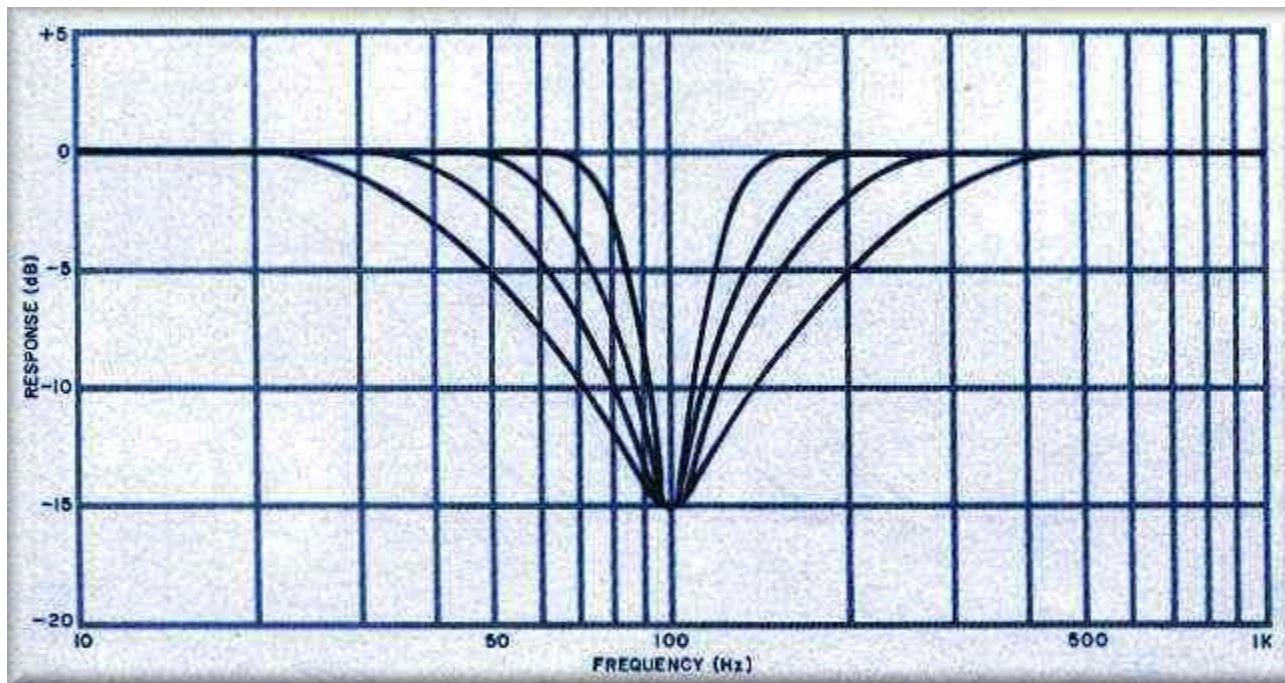


Fig. 4. Response curves showing the effect of varying the bandwidth of a midrange dip.

All this newfound versatility, however, is not without some potential drawbacks. Probably the most obvious is the lack of precise repeatability. Since the operating controls are continuously variable, it may be difficult to recreate settings exactly to perhaps undo something you later don't like. Another factor is noise. Parametric equalizer designs generally use more op amps per frequency band than do graphic and console types. This means that cumulative noise can be more of a problem, especially when large amounts of boost are used. Distortion can build up in a similar fashion, though the latest high-slew rate, low-noise FET input op amps are bringing both of these factors under better control. Still, most commercially available units have a switch to bypass each band or section when it's not needed.

While studios have not unanimously traded in all their old equalizers for parametrics, many have added at least one or two. And some of the newer mixing boards are showing up with equalizers having a sweepable midrange band or a two-position switch for sharp or broad peak shape selection. So a few of the conveniences are added without having to go to a full parametric design. Now that we've looked at the different types of devices and know how they operate, how can we use EQ to best advantage? When and how would a professional recording engineer use it? Well, first we should note that equalization can be used in two basic ways; as a tool and for personal taste.

EQ AS A TOOL

If you reflect on the task of a recording engineer, the idea that he or she is going to run into problems should not seem surprising. The difficulties encountered may lie in the areas of instrumental balances, equipment overload, signal-to-noise ratio, and frequency response, to name a few possibilities. When the problem can be traced to frequency response - and quite a few can - the equalizer becomes an extremely valuable tool.

For example, one problem that occurs regularly is caused by *proximity effect*, a bass boost that occurs when a directional microphone is placed close to the sound source. Here, the low-cut filter

would be your best bet. First, it will attenuate the excessive low-frequency signal before it enters the rest of the EQ circuitry, minimizing the chance of overload; second, it will leave the bass control free for other uses if needed. (If the mike offers a switchable low-cut filter, use that to keep the unwanted frequencies from getting into the preamp in the first place, for even more overload protection.)

Another proper occasion to use the low-cut filter is when recording vocals close-up. Not only to reduce the proximity effect just mentioned, but also to minimize popping Ps, which contain a lot of low-frequency energy. Moreover, rumble and low-frequency mud can enter your recordings from extraneous vibrations such as walking on non-concrete floors, air conditioners, and the like.

Treble is often accentuated to increase clarity or to enhance the presence of a vocal or string part that might otherwise be lost in the mix. Horns, cymbals, acoustic guitars and many other instruments can also be greatly enhanced in this way, but the engineer must know where the formants (the most important characteristic frequencies for the various instruments) lie. Boosting high treble on an instrument with little output in that region will do nothing but add hiss. In fact, when dealing with such an instrument, it is often possible to make a substantial improvement in the signal-to-noise ratio by carefully reducing the unnecessary high-frequency bandwidth with a treble control on each channel for frequencies beyond the range of interest. This is most effective when done during mixdown, as tape hiss will also be reduced. For this same reason, when treble boost is employed it is usually best applied before the tape recorder.

EQ can also help to correct for poor room acoustics. Recording live, even the most accurate mike may not capture that terrific sound you hear when you stand right next to the instrument. Close-miking may help, but in many cases this is impractical since many instruments do not radiate sound from a single point source. Consider a grand piano, string bass, xylophone, or gong. All of these project sound from a large surface area, leaving no ideal single mike position that is close to all parts of the source. Such large instruments require a more distant microphone placement if a well-balanced pickup is to be had. Unfortunately, as the distance between source and mike increases, the acoustics of the room begin to affect the sound. This isn't always bad - a good room often adds a warmth and character unobtainable in any other manner. But when a close-up sound with lots of presence is desired, equalization in the form of treble boost or midrange cut can often do the trick.

SEASONING TO TASTE

While no one yet has been able to define what sounds good and what doesn't, recording engineers have developed various techniques for emphasizing what they consider to be the more pleasant qualities of musical sounds. In fact, most engineers pride themselves on getting their own sound. This is an area of taste, so naturally there are no hard, fast rules to apply. Some good starting points can be established, though, as follows. Generally speaking, you would boost treble for clarity or presence (the midrange can affect this too), and bass for fullness or punch. Sometimes it seems that no matter how much top or bottom you add, something is still not right. Often the real culprit is one or more unpleasant resonances caused, as mentioned earlier, by either microphone characteristics or placement, or even by bad qualities within the instrument itself, especially if it is out of adjustment or of low quality. Eliminating these midrange resonances will often improve the sound and minimize a need to boost highs and/or lows.

To find these magic EQ settings, start by turning off all but the principal microphone that is picking up the instrument you're working with. If it's the snare drum, for example, shut off the tom and kick mikes. They'll interact later anyway, but the less you need to concern yourself with now, the better. Next, try boosting some different midrange frequencies, adding at least 10 or 15 dB, to make the

changes obvious. Where you start naturally depends on the instrument. Since physical resonances of instruments usually fall between, say, 100 Hz. and 1 or 2 KHz., these frequencies are likely starting points. After determining which one sounds the *worst*, return to the flat setting momentarily to allow your ears to readjust, and then cut the chosen frequency in small steps until the optimum improvement is reached. The same general plan can work for boosting, although then you'd be looking for frequencies that make the sound better when boosted instead of worse.

When adding treble or bass, be sure the controls are doing what you expect them to. If you don't obtain an appreciable improvement, move on to a different frequency. Remember, a lot of boost at the extreme low end can route excessive infrasonic energy to the loudspeakers, which could damage them. Similarly, too much ultrasonic content can damage tweeters and overload the tape deck. Even with VU meter indicators in the black, safety is not guaranteed: the limited frequency response of most meters sometimes prevents them from giving a true picture. Also, VU meters tend to miss sharp transients from drums and other percussion instruments; the pointer simply cannot move fast enough. Pre-emphasis (a form of treble boost) within the tape deck can also aggravate the situation, so be particularly careful at the slower tape speeds.

SIDEBAR: SPECIFIC INSTRUMENTS AND THEIR CHARACTERISTIC FREQUENCIES

The chart below lists some common instruments with frequencies at which boost or cut can be effectively applied to cure various problems or obtain certain effects. Indicated frequencies are necessarily approximate, as no two instruments sound exactly alike. The Comments column gives cautions or observations based on experience. They should be taken as guidelines rather than prescriptions, because every situation is different and every recordist has his own sonic goals. A few general hints may contribute to the effective use of equalization.

(1) Your memory is shorter than you think; return to a flat setting now and then to remind yourself where you began.

(2) Make side-by-side comparisons against commercial releases of similar types of music; this will help you in judging overall blend.

(3) You can tailor the sound of an instrument only so far without losing its identity; every instrument can't be full, deep, bright, sparkly, etc. all at once. Leave some room for contrast.

(4) Take a break once in a while. Critical listening tends to numb one's senses after a while, especially if you listen at high volume levels. Sounds may appear very different to you the next morning.

(5) Don't be afraid to experiment. If you can't find just what you want with equalization, try moving the mike a little; if that doesn't work, move the instrument. But, most of all, keep trying.

Common Frequencies For Equalization

Instrument	Cutting	Boosting	Comments
<i>Human voice</i>	Scratchy at 2 KHz. Nasal at 1 KHz. Popping Ps below 80 Hz.	Hot at 8 KHz. Clarity above 3 KHz. Body at 200-400 Hz.	Aim for a thinner sound when blending many voices, especially if the backing track is full.

<i>Piano</i>	Tinny at 1-2 KHz. Boomy at 300 Hz.	Presence at 5 KHz. Bottom at 100 Hz.	Don't add too much bottom when mixing with a full rhythm section.
<i>Electric Guitar</i>	Muddy below 80 Hz.	Clarity at 3 KHz. Bottom at 125 Hz.	
<i>Acoustic Guitar</i>	Tinny at 2-3 KHz. Boomy at 200 Hz.	Sparkle above 5 KHz. Full at 125 Hz.	
<i>Electric Bass</i>	Thin at 1 KHz. Boomy at 125 Hz.	Growl at 600 Hz. Bottom below 80 Hz.	Sound varies greatly depending on the type of bass and brand of strings used.
<i>String Bass</i>	Hollow at 600 Hz. Boomy at 200 Hz.	Slap at 2-5 KHz. Bottom below 125 Hz.	
<i>Snare Drum</i>	Annoying at 1 KHz.	Crisp above 2 KHz. Full at 150-200 Hz. Deep at 80 Hz.	Also try adjusting the tightness of the snare wires.
<i>Kick Drum</i>	Floppy at 600 Hz. Boomy below 80 Hz.	Slap at 2-5 KHz. Bottom at 60-125 Hz.	For most pop music, remove the front head, then put a heavy blanket inside resting against the front head.
<i>Toms</i>	Boomy at 300 Hz.	Slap at 2-5 KHz. Bottom at 80- 200 Hz.	Tuning and adjusting the head tension makes a huge difference too!
<i>Cymbals, bells, tambourines, etc.</i>	Annoying at 1 KHz.	Sparkle above 5 KHz.	[Analog only:] Record these instruments at conservative levels, especially at slower tape speeds.
<i>Horns and Strings</i>	Scratchy at 3 KHz. Honky at 1 KHz. Muddy below 120 Hz.	Hot at 8-12 KHz. Clarity above 2 KHz. Strings are lush at 400-600 Hz.	

Added October 7, 2001: A lot of people are concerned about the negative effects of phase shift, and worry that equalizers may be ruining their audio. I addressed this point in an audio forum on musicplayer.com, which is reprinted [here](#).

Added April 9, 2006 - Here's an exchange from a web forum, and my reply relates to this article:

> How do you get those mixes that just seem to sound better and better the louder it gets? <

This is a great question, and more people should think about that when mixing. That's a standard test for me when mixing - if I turn it up really loud does it still sound okay? I've noticed the past few years especially that good mixes tend to have this attribute. However, the first mix I ever heard like that was the debut album by the band Yes all those years ago. They even wrote right on the LP jacket that you have to turn it up really loud to get the full effect.

One factor is the bass level. I don't mean the bass instrument, but the amount of content at very low frequencies. Say, 100 Hz and below. You simply have to make the bass and kick a bit on the thin side to be able to turn the track's volume way up without sounding tubby or distorting. Then when it's really loud the fullness kicks in. You also have to decide if the bass or the kick will provide most of the oomph for the track's bottom end. There's no hard and fast rule, but often in a good mix the kick is clicky while the bass is full, or the bass is on the thin side and the kick is full with more thump and less click.

Another factor is the harshness range around 2 to 4 KHz. A good mix will be very controlled in this

range, again letting you turn up the volume without sounding too piercing. I listen to a lot of movie and concert DVDs, and the ones that sound best to me are never harsh in that range.

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