AUDIO UPDATE

How loud is real?

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DURING THE WILD AND CAREFREE DAYS of my youth, I once participated in a small psychoacoustic experiment. The object was to determine if there was a specific or minimum playback level necessary to achieve a reasonable simulation of "live" sound. After listening to a variety of selections from the best recordings of the day, the participants agreed that there did, indeed, seem to be a specific volume level (that varied somewhat with the recording) at which the music suddenly sounded more "natural." Below that point there was nothing specifically wrong with the sound—it just wasn't *right*. After spending about an hour or so sampling different discs, we found that we generally agreed—within several decibels or so—on the volume setting that sounded best. I don't mean to suggest that the sound was perfect at any level, only that there was a specific volume level at which, for obscure reasons, the reproduced music seemed more realistic.

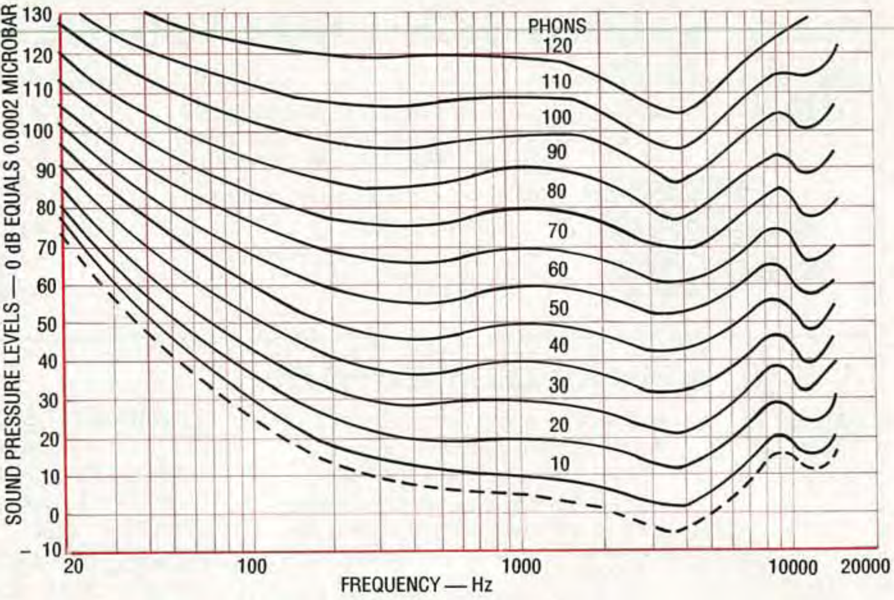

FIG. 1

Calibrating loudness

In the past several decades, I've learned something about the way that the human ear/brain responds to sound levels. Psychoacousticians make a clear and necessary distinction between *loudness* and *sound intensity*. Loudness is the ear/brain's *subjective* auditory reaction to *objective* sound-pressure-level stimuli. It's necessary to distinguish between the subjective and the objective simply because our perception of loudness lacks a one-to-one correspondence with the objective world.

There are good evolutionary reasons why that is so. In respect to volume, for example, the noise created by a jet plane at take-off is about ten-thousand-billion times as powerful as the quietest sound that we can hear. If, on a linear scale, a quiet whisper was assigned one intensity unit, a jet engine would have an intensity of ten-trillion units!

The ability to compress that enormous dynamic range into something that can be handled and evaluated by the human ear/brain was originally investigated by a 19th-century physicist and philosopher, Gustave Theodor Fechner. In 1860, he published a ground-breaking work, *Elements of Pyschophysics*, that attempted to establish a specific relationship between the outer objective world and the inner subjective one in *all* areas of sensation. Fechner's law states, for example, that each time the intensity of a sound is doubled, one step is added to the sensation of loudness. In Fechner's view, sensation increased as the logarithm of the stimulus.

The decibel, which measures sound energy in logarithmic units, would seem to fit nicely into Fechner's law. But it soon became apparent to anyone who listened carefully, that a noise level of, say, 50 dB, was *not* half as loud as 100 dB. (Fifty dB is the background noise in a library reading room; the perceived loudness of 100 dB—equivalent to a jet plane heard about 1,000 feet overhead—is about 30 times greater than 50 dB.) After much research effort, starting in the 1930's at the Psycho-acoustic Laboratory at Harvard University, Fechner's logarithmic approach to auditory perception was ultimately replaced by a true scale of loudness: the *sone*. The sone scale has a rather straightforward rule: Each intensity increase of 10 decibels doubles the sensation of loudness. Today, it's generally accepted that sound levels have to be raised by 10 dB before they sound twice as loud.

Loudness contours

The names Fletcher and Munson are commonly invoked when amplifier-loudness controls are discussed. In 1933, they were among the first researchers to demonstrate the very non-linear relationships among the objective sound-pressure level of a sound, its frequency, and its subjective loudness. Aside from the fact that the research had conceptual and practical flaws, it also—at least in the audio-equipment area—was misunderstood and misapplied. Let's see where things went wrong.

In the original experiment, listeners in an anechoic chamber were asked to match test tones of different frequencies and intensities with calibrated, 1,000-Hz test tones produced at a variety of specific levels. The general results are familiar to most of us; it was found that the ear looses sensitivity to low frequencies as the sound level is reduced. Later work, by Robinson and Dadson in the mid-1950's, used superior instrumentation and produced a somewhat modified set of loudness contours (Fig. 1). Their results were subsequently adopted by the International Standards Organization and are now known officially as the *ISO equal-loudness contour curves*. Despite the international acceptance of the R-D curves, keep in mind that the techniques used to derive them (pure tones in an anechoic chamber) do not correspond exactly to music listened to in a living room.

Achieving reality

Anyone who has been following my columns with any regularity should, by now, be convinced that realistic reproduction of music is no easy task. The basic problem is the need to present to the listener's ears a *three-dimensional* acoustic simulation of the live musical event. It has become obvious that the problem can't be solved by conventional, two-channel stereo, and digital "dimension synthesizers" are now becoming commonplace. Although adding the extra channels is a necessary step, it's not a sufficient one; the original playback level at the listener's ears still has to be accurately reproduced.

Why should that be so? Although the question may seem dauntingly complex and laden with philosophical booby-traps, some simple—if incomplete—answers are available. Setting aside the question of the absolute accuracy of the loudness curves discussed earlier, we do know that the ear's frequency response changes in accord with the level of the impinging signal. For example, suppose that you were to make a good recording of a live dance band playing at an average level of 70 dB. If you were to subsequently play back the recording at a 50-dB level, the bass frequencies would automatically suffer a 13-dB loss relative to the mid frequencies, as per Fig. 1. Obviously, not only would the bass line be attenuated, but the entire sound of the orchestra would be thinned out.

Other problems

The ear has other loudness-dependent peculiarities. As a transducer, it is both asymmetrical and non-linear and, therefore, regularly creates (and hears) frequencies that are not in the original material. Known as *aural harmonics* and *combination tones*, they correspond to harmonic- and intermodulation-distortion products in non-biological audio equipment. Since the amounts of those acoustic artifacts generated by the ear depend on signal level, any level differences between the recording and playback are going to cause different reactions *in* the listener's ears.

To complicate matters further, low-frequency sounds appear to

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decrease in pitch when intensity is raised, while highs subjectively increase in pitch. Psychoacousticians know enough about that effect to chart it on what they call the *mel* scale.

Those, and other, reasons help explain why music sounds correct only when played at the level (the *original* level, that is) that properly relates to the ear's peculiar internal processing. I doubt that it's possible to design a loudness control that really works. So for the present at least, we will just have to do the best that we possibly can, loudness-wise—neighbors and spouses permitting. **R-E**