Bad Vibes!

Shannon Dickson outlines the fundamentals of vibration control in audio systems

A thorough exploration in a magazine article of such a pervasive and complex topic as vibration control in audio systems is next to impossible; vibration and sound are so intimately bonded that it would be very easy to extend this discussion to just about any area of interest in audio. My intention here is simply to lay a foundation for understanding the basic mechanical forces affecting our quest for improved sonic fidelity, and in the process provide the tools for anyone to achieve good, practical vibration control in his or her system.

The plethora of vibration-control products on the market, ranging from the highly effective to some bordering on voodoo, is testament not only to the significant impact "bad vibes" have on our sound systems, but also to the importance of educating ourselves. An informed consumer can make a genuine contribution in the fight against mechanical resonances, while saving time and money over the long term. Knowledge can also help one avoid falling prey to the "tweak-of-the-month" mentality characterized by mistaking tonal manipulation for improved resolution.

Room acoustics, an obvious extension of this issue, will not be covered here. I have, however, examined two products in related reviews elsewhere in this issue: the Vibraplane distributed by Sounds of Silence, and Townshend Audio's Seismic Sink. Both use air as the isolation element in a pneumatic suspension, and represent what I believe to be a superior method for minimizing the impact of external vibrations on sound quality. Before we jump directly to the vibration issue, I'll take a brief look at a few reasons why an in-depth discussion of this issue is timely and worthwhile.

Shakin' all over

Wrestling with vibration has been a cornerstone of our hobby for years. Its obvious impact on transducing components like turntables and speakers evolved into a recognition of the need to address both gross and subtle resonances throughout a stereo system. Many of the techniques and tweaks employed to meet this demand were spawned through trial and error. Some are very effective when properly applied, and are supported by sound, logical theories. Certain other products can work quite well when used appropriately, despite being accompanied by "white papers" or explanations for their effects that are at odds with both common sense and the laws of physics. The audiophile, left adrift on a sea of half-truths dressed in plausible, appealing concepts, can easily stray off course to land in the limbo of compulsive tweaking—boosting a midrange detail here or bass focus there—often while missing the opportunity for more substantial progress.

Such experiences can lead to disillusionment; those so affected may then lump the more effective anti-vibe products or methods (and possibly other high-end pursuits) together with the dubious, and toss the baby out with the bath water. I hope that this article will provide a road map around the hype so that consumers will be more confident in their own decisions when developing strategies best suited for their own systems and budgets.

Something else that has increased interest in vibration is the realization that control of phase distortion—improved time-domain performance—and the need to better understand its relationship to energy storage in the form of electrical or mechanical resonances in components, is necessary to push the edge of the performance envelope

These investigations have led to a growing awareness of the potential impact of "spectral contamination distortion"[1] in helping us better correlate what we can measure with what we hear. Much study remains to be done before accurate relationships can be drawn between specific spectral contamination measurements and subjective experience, but the possibilities are fascinating. I hope to examine this issue in more detail in a future article.

How does all this relate to mechanical vibration? I believe progress in audio design has reached a point that demands serious attention to these and other subtle interactions—along

1 Spectral contamination distortion refers to a distortion process present in any real-world system as it processes a complex signal such as music. It occurs as ultrasonic harmonics due to undamped high-frequency resonances stimulating a broad band of low-level, intermodulation distortion byproducts in the presence of a multitone signal. Originating influences can range from a 50kHz cartridge resonance or the effects of RFI/EMI to a wide range of digital artifacts. This mechanism may be partly responsible for midrange and treble glare and harshness heard in components that otherwise measure well with traditional techniques. Peter W. Mitchell discussed this topic in his "Ground Floor" article in the December 1994 *Stereophile*, pp.102–103. Interested readers will also find an excellent article in "Spectral Contamination Measurement," by Gary Sokolich and the late Deane Jensen, pre-print #2725, the 85th AES convention, 1988

with the more obvious variables—if we are to further reduce the "electronic" signature in reproduced music and move toward a more convincing re-creation of the real thing. This is true whether one is dealing within the electrical, mechanical, or acoustic arenas. From a practical standpoint, the time and frequency domains are alternate frames of reference, and most real progress in sound reproduction is being made by those designers who have a good understanding of the interplay of these realms.

Mechanical resonances may contribute to the spectral signatures of components both directly (in the case of transducing components) and through interaction with other nonlinearities. Vibrations, varying in magnitude from gross (cabinet resonances that can be felt in the fingertips) to tiny, sub-micron levels at subsonic frequencies, can negatively impact music playback through time- and frequency-domain disturbances. On a fundamental level, the issues of phase linearity and mechanical vibration are interrelated; unless properly addressed, each defines a limit to a system's resolution. Since timing and resonance issues are two sides of the same coin, an improvement in one area often effects an improvement in the other, resulting in a net gain in system transient performance.

So as hardware on both sides of the recording/playback chain becomes more refined, mechanisms such as low-level vibration grow increasingly important. Though at first glance it may seem that cheap, flimsy gear would be the primary beneficiary of good vibration control, and while in relative terms this may be so, products that have inherently better resolution due to superior electrical and mechanical design tend to show the greatest absolute profit from effective resonance reduction.

A matter of scale

Perspective can be a difficult thing to convey when describing subtle changes that can lead to significant subjective effects. In our enthusiasm for newly discovered tweaks or ideas that bring favorable alterations to the sounds of our systems, it is all too easy to go overboard in describing their relative effects, in the process blurring the yardstick of merit by which we decide how to allocate our audio dollars. This tendency seems particularly prevalent with certain anti-resonance accessories simply because their effects run the gamut from the barely perceptible to the clearly obvious. They can also vary widely from system to system. In fact, it was the rather dramatic experience of hearing the sonic effects of pneumatically isolating a turntable and—surprisingly—a digital transport with the Vibraplane that led to this report, lest the relative sonic impact of these systems be confused with that afforded by more traditional means of equipment support.

Before floating my source components with the Vibraplane, I was, like many of you, intimately familiar with the array of tonal changes afforded by various tuning devices. But by the time the stylus of my Lyra DaCapo cartridge had reached the inner groove of the first record played on my RPM-2 turntable after a Vibraplane had been installed beneath it, I had experienced a pronounced enhancement in the broadband resolution of my system that was very different in degree and quality from that offered by tonal manipulation alone. These benefits turned out to be both predictable and repeatable with a variety of source components.

I rank an even, natural tonal balance—with the emphasis on *balance*—as one of the most critical factors in true high-end performance. (This is to be distinguished from simply highlighting one area of the spectrum over another just because it sounds "better.")

But I'm *not* anti-tweak. Creative experimentation has often led to real breakthroughs, even when the relationships of cause and effect are not well understood. Tonal alterations that make listening to a given system more enjoyable are perfectly fine in my book as long as the effect is not mistaken for, or promoted as, a de facto increase in fidelity. In my experience, those improvements that prove most fundamental and genuine tend to be consistent throughout the audible spectrum, conferring greater cohesiveness, refinement, and presence to the entire presentation.

Tonal changes, particularly positive ones, are usually expressed with references such as "tight, focused bass," "good midrange detail," "extended and silky highs," etc.—all laudable individual attributes. But the kind of subtle yet significant improvement I'm speaking of breathes new life across the entire range of sonic attributes, enhancing every aspect of the musical experience.

This is what happened to me with the Vibraplane. A certain synergy permeated the individual elements of the usual sonic checklist—and, in a way, superseded them. As a result, I found myself absorbed in one record after another, with barely a thought about sound quality. Clearly, sophisticated pneumatic isolation is a technique that deals with external vibration at a more fundamental level than the usual practices of rigid coupling and elastomer damping, and yet each of these methods plays a critical role in any comprehensive, logical, effective vibe-reduction plan.

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A road map

In order to keep things in focus, I will explore the effects of vibration on audio systems by examining how resonances interact with each of the major elements—floor, stands, platforms or shelves, components—and the various means of connecting them. Throughout our discussion I'll be referring to large torsional, or twisting, forces on structures, as well as significant displacements *vs* small movements. However, these are only relative comparisons. On an absolute scale, all of the vibration interactions in a typical audio system are very small (except for some room and speaker-cabinet resonances). Objectively, the degree of sonic changes from effective resonance control is subtle compared to that from switching from one model of speaker to another, yet its subjective impact clearly illustrates the adage that big results can spring from small events—the musical merit can be surprisingly significant.

Take Andy Payor's Rockport Cappella and Sirius II turntables, for example. Each of these 'tables contains a fully developed pneumatic suspension with a vertical and horizontal frequency of *ca* 2Hz or less. Compared with most spring or elastomer suspensions, even those that claim similar resonant frequencies, these pneumatic systems are at least 40dB better in the ultimate isolation of very-low-frequency, *micro*-inch levels of displacement.

However, the bottom line is that truly effective vibration control in audio systems requires a measured, comprehensive approach utilizing rigid, well-damped stands and platforms, careful selection and placement of coupling devices, and isolation of key components—using air-based suspensions wherever possible.

All of our references up to now have concerned typical home audio systems, yet it is my fervent hope that the pro-

ISOLATION AND TUNING SHOULD BE SEEN AS COMPLEMENTARY AND ESSENTIAL PARTNERS IN THE FIGHT AGAINST BAD VIBES.

The Vibraplane, reviewed elsewhere in this issue, is very close to the Rockport suspension in isolation performance, though these cost-no-object turntables have several other key features that contribute to their outstanding sound quality—and high cost. In addition to isolating very-low-frequency vibrations in both planes, the Vibraplane also contains the real-time damping characteristics shared by the Rockport as well as other pneumatic systems like Newport's "BenchTop" or "Noise Block" (the latter is an audiophile version built for Immedia by Newport).[4]

Wrapping it up

The particulars of pneumatic isolation and its sonic contributions are covered in my reviews of the Seismic Sink and Vibraplane. In summing up this evaluation of practical vibration control, it's important to realize that, although the isolation effectiveness of these pneumatic systems surpasses that of traditional suspensions, the complexities of vibration in the audio environment are such that subjective differences are perceptible even between competing pneumatic designs. These differences arise primarily from the relative effectiveness of the various isolated platforms and the coupling methods used to connect equipment to them—particularly how well they damp component-sourced vibrations.

Subjectively, this is the tuning effect we've discussed, and it's perceived as subtle tonal variations, focus, and changes in soundstage perspective. It won't take long, however, before you'll be able to easily distinguish these spectral variations—no matter how pleasing—from the concurrent, across-the-board improvements in system resolution, spatial definition, and greater emotional connection to the music that results from pneumatically isolating your favorite source components.

Though turntables clearly demonstrate the most dramatic improvement from proper isolation with a Vibraplane, digital gear isn't far behind. (This is still the biggest surprise for me.) Even preamps and amplifiers, particularly those containing tubes, show a real enhancement in sound quality with the more affordable Seismic Sink, and there is a definite synergistic effect from floating the entire system. Pneumatic isolation should never be considered just a tweak. When done right, the impact can be more musically significant than changing certain amplifiers or preamps, not to mention many other accessories. This does not mean that gross sonic changes are necessarily greater than that experienced from most component upgrades, but simply that it can be more relevant in conveying the nuances and dynamics that give music so much vitality and presence.

audio world takes notice of the influence vibration has on fidelity. Eliminating the rickety rack systems common in studios around the world, then properly supporting and isolating A/D converters, microphones, preamps, tape drives, and cutting lathes could have a major impact on our treasured source material. Knowing what I now know about the impact of mechanical resonances, I get the willies when I go into a studio, see an A/D converter barely hanging off the edge of a console, and realize that vibration-induced grunge is being encoded into our source material. In some studios you can look through the inspection microscope attached to a cutting lathe *during* the cutting of a lacquer and actually see the light shimmering off the grooves as a truck rumbles past!

While it may seem that I've been a bit hard on tuning products when they're the only means used for dealing with vibration, my intentions were simply to contrast their effects—which are familiar to most audiophiles—with those attainable from a well-rounded program that addresses each element of the equation, including tuning. Isolation and tuning should not be seen as competitive alternatives, but as complementary and essential partners in the fight against bad vibes.

As lengthy as this report has been, I've only outlined this pervasive subject in broad strokes. As you explore the commercially available resonance-control products, you'll discover numerous shades and variations of these principles, some of which work very well. In any event, the purpose of this article will have been served if many of you now feel better equipped to sort through the maze of possibilities, and, above all, have fun in implementing your own vibe-reduction plan. Now take a breather, listen to some tunes, and—when you're ready—take a look at how best to use the Townshend Seismic Sink and the Vibraplane.

Further reading

Interested readers can reference the following:

Fundamentals of Noise and Vibration Analysis for Engineers, M.P. Norton, Cambridge University Press, 1989, reprint 1994 (highly recommended).

Mechanical Vibrations, 4th ed., J.P. Den Hartog, Dover Press.

Shock and Vibration, 3rd ed., Cyril S. Harris, 1988, McGraw-Hill Books.

Newport Corporation's 1995 Catalog, Chapter 16, "Vibration Control," 791 Deere Ave., Irvine, CA 92714, Tel: (800) 222-6440.

Acknowledgment

I'd like to thank Newport Corp. for the kind use of their graphics in our sidebars. I owe a particular debt of gratitude to their Engineering Manager for Vibration Control, Mr. Bowie Houghton, for his invaluable references and insights.

4 Noise-Block Isolation Base, $2300 including air tank and regulator valve. Dimensions: 20" W by 16" D by 2" H. Weight: 22 lbs. Contact Immedia, 2629 Mabel St., Berkeley, CA 90701. Tel: (510) 654-9035.

The Rigid Body Concept

The performance of a table-top or platform is a function of the rigidity of the tructure and the effectiveness of any applied damping. Each solid object will have many resonant frequencies and associated bending modes. The lower the dominant resonant frequency, the higher the modal displacement. Generally, the first several frequencies/modes are the most significant, and largely define the vibration performance of a given platform. By using materials for constructing audio platforms that are very stiff, the dominant resonances can be shifted to a higher frequency where they are associated with less-damaging, lower-displacement modal activity. Appropriate amounts of damping applied to the platform can further reduce the amplitude of any remaining vibrations over a broad frequency range.

The performance of a given platform is plotted on a "compliance," or displacement, curve that shows any deviation from an "ideal rigid body"

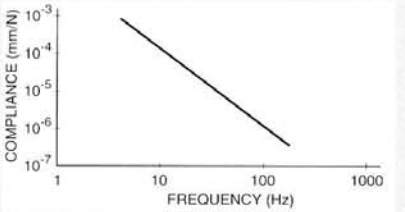

Fig.1 Displacement *vs* frequency of an ideal rigid body (vertical scale: compliance in mm/N.).

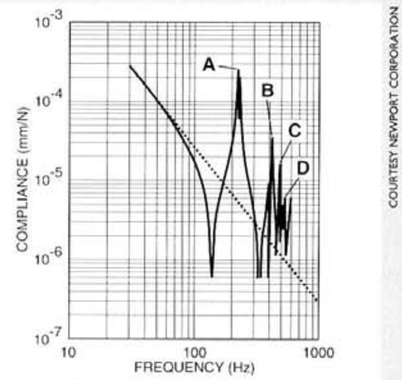

Fig.2 Typical dynamic response of undamped platform to random vibrations. Note deviation from ideal rigid body curve. Letters A–D correspond to vibrational mode shapes shown in fig.3.

—as defined in the main article. "Compliance" is used rather than "displacement" to show the ratio of displacement to a constant applied force. This curve is represented by a perfectly straight line sloping down the Y axis (representing displacement) from the upper left corner toward the lower right side of a log-log plot, at a slope of –2 across the X axis (representing frequency). This plot shows a platform's actual dynamic response to random vibrations compared to that of an ideal rigid body line.

Fig.1 illustrates the ideal rigid line on the compliance curve. Fig.2 shows a typical dynamic response curve for an undamped table-top and plots the maximum amplification of the first four resonant peaks, labeled A through D, in terms of compliance and frequency. Fig.3 illustrates the relationship between the undamped platform's vibration modes or bending shapes, the corresponding resonant peaks, and the specific frequencies plotted on the curve in fig.2. The scale of the mode shapes is exaggerated here to better illustrate the bending forces of vibration. Note that dominant peak A is the lowest in frequency *and* has the highest displacement or amplitude.

Also, displacement decreases inversely proportional to the square of the applied frequency. A real-world platform will follow the ideal rigid body line up to about 80Hz or so, above which structural vibrational modes are excited and begin to deform the platform's shape. By drawing an imaginary plane through the four platform diagrams, points of minimum motion, called "nodes," will be found. Ideally, any coupling devices between a platform and a component or floor should be located at these "quieter points," or nodes. —**Shannon Dickson**

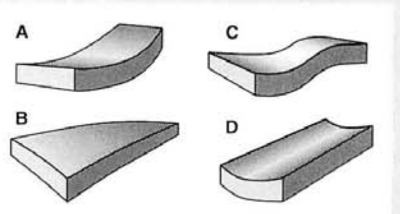

Fig.3 Vibrational modes of platform corresponding to the resonant peaks shown in fig.2.

peak amplitude of displacement that results when the particular natural frequency of a platform is excited into resonance by external vibrations of the same frequency.

Every solid object, particularly irregularly shaped ones, will have numerous modes, yet the lowest natural frequency of a given platform will usually be the most dominant, with the next few adding a significant contribution to its overall "resonant signature." Modal analysis begins with the concept of "degrees of freedom" of a system or object. This refers to the minimum number of directions of motion necessary to define how an object can move in its particular environment. For instance, a single, independent particle has three degrees of freedom, while our ideal rigid body has six: up and down, front to back, left to right, and rotation around each of these three axes. There is a direct relationship between the number of degrees of freedom an object has and the number of natural resonant frequencies and modes it is subject to. Most fixed objects or enclosed acoustic spaces have many hundreds of degrees of freedom and related modes (see sidebar 1, "The Rigid Body Concept").

Because audio components are non-ideal, three-dimensional objects, it doesn't take much imagination to see how complex the twisting, bending, and flexing of modal forces can become when random and variable vibrations stimulate multiple resonant frequencies in such structures. As a result, vibrations in the horizontal *and* vertical planes must be dealt with. (Keep this requirement in mind; it has a major impact on the real-world performance of most vibe-reduction products.)

When you multiply the modal signature of a platform by those simultaneously at work on shelves connected to a rack or stand—which is contributing its own complex resonant pattern to the mix—and include vibrations from the floor that the stand is coupled to, you have a real problem. Toss in a few stereo components whose non-uniform chassis contain vibration-generating transformers that make their resonant frequencies particularly complex, and an incredibly elaborate set of mode interactions will likely occur that will add sonic colorations and can result in a genuine limit to a system's resolution.

In vibration analysis, the minimum resonant frequency of a platform or suspension and the maximum amplitude of that resonance are of paramount importance. This is due to the effect of displacement. In vibration analysis, "compliance" is often used interchangeably with displacement as a measure of the tendency of an object to move in response to vibration. As such, it is directly related to mode shape and defines a structure's dynamic rigidity. Compliance is a ratio of displacement to the amount of applied force, and is also the inverse of stiffness, whether of a solid object like a shelf, or of a spring-like suspension; in the latter case, the stiffer the spring, the lower the compliance, and vice versa.

There are several reasons why the minimum resonant frequency of a rigid structure is so important. For starters, a reduction in frequency leads to an increase in displacement and a corresponding amplification of the resonance, resulting in a "noisier," less stable platform.

Realistically, the lowest natural frequency of any practical platform or table-top is around 80Hz or so, meaning that all vibrations of frequencies lower than this will transmit through the platform with little change in amplitude. Actually, most materials and shapes used for platforms have natural frequencies ranging from around 120Hz up to 400Hz or more—well into the midrange. The lower the resonant frequency of a platform, the less desirable—the associated increase in amplitude will cause more serious ringing that damping can only partially reduce. A very stiff structure will have a higher dominant resonance, and, since an increase in frequency correlates with a reduction in physical displacement, less complex mode shapes will form, even though the total amount of energy remains the same.

This, then, is the most practical solution for a good supporting platform: Employ specific materials and geometry that increase the platform's stiffness:weight ratio so that the improved rigidity raises the resonant frequency, reduces its amplitude, and minimizes the structure's bending mode shapes. In addition, enough damping should be applied to the platform to further lower the displacement of resonances over a broad frequency range without degrading the structure's stiffness. As we've seen, damping is particularly important for supporting platforms used in audio systems, to help dissipate equipment-borne and acoustically coupled resonances.

Platform construction

Very few structural materials deal efficiently with the requirements of both rigidity and damping. Some materials address one aspect while degrading the other. Therefore, better performance is usually obtained by a composite approach to platform or shelf construction. Mass can be a desirable quality in a material used for equipment supports as long as it contributes to dynamic rigidity. But excess mass that does not aid the cause of stiffness may actually be detrimental, as it can cause a reduction in the platform's resonant frequency, requiring extra damping material to attenuate the increased displacement. Since most materials used for damping tend to be compliant, the amount needed to even partially reduce lower-frequency amplitudes can cause an unwanted reduction in the stiffness of the structure. Also, *if* a platform's ratio of mass to stiffness is excessive, mass may contribute to a subtle sagging of the platform, degrading static and dynamic rigidity.

Most materials that are desirably stiff do have a good deal of mass, so successful plinths, platforms, or shelves used for audio combine rigid mass with the right amount of uniform damping, often by constraining one or more layers of viscoelastic material (such as E.A.R. "Isodamp") between two or more much thicker layers of stiff material (such as granite, steel, or 6061-T6 aluminum). Another successful technique sandwiches lighter but damped materials, such as MDF or acrylic, between two skins of steel or granite. Steel has a better stiffness:weight ratio than granite, though both can be used to good effect either singly or combined, as long as their tendency to ring in the lower midrange/upper bass is controlled with damping. High-quality aluminum is approximately one third as stiff as steel but is nonmagnetic, which can be useful with some components. Certain carbon-fiber composites show particular promise as well, as do several new designs offered with well-built stands using multiple layers of various hardwoods alternating with thin damping layers. The ubiquitous shelves made from medium-density fiberboard (MDF) benefit from uniformity and are fairly well damped, but are not particularly stiff.

We've now defined our near-ideal audio support platform. It will be uniform in structure as well as rigid for its size, weight, and shape. If we map out the composite sum of its modal shapes, we will find relatively few areas of significant displacement. As a result, the motion of the platform will be limited to the six basic degrees of freedom defined earlier. It will have a relatively high natural frequency and correspondingly low amplitude of resonance that will be further reduced by use of sufficient damping. This applied damping will also provide a sink for a broad range of component-generated vibrations. Sounds pretty good, doesn't it?

Several available platforms are headed in the right direction. One example, offered as a separate item to audiophiles by D.J. Casser Enterprise's Black Diamond Racing label, is a carbon-fiber composite platform simply called "The Shelf."[2] It's reasonably stiff, has a fairly simple modal signature, and contains a good degree of self-damping.

THE IDEAL AUDIO SUPPORT PLATFORM WILL BE RIGID, UNIFORM IN STRUCTURE, AND HAVE A RELATIVELY HIGH NATURAL FREQUENCY.

The rigid coupling surprise

Unfortunately, once we've built or purchased our dream platform, we then have to connect it to a stand or floor and place a component on top. This is the kicker: When you couple the most ideal practical platform to the floor with cones, spikes, or any other rigid footing, even at the ideal locations with respect to each, the best vibration performance you can achieve is nearly 100% transmission of floor-borne vibrations *through* the platform, without amplifying them or generating any new resonances in floor *or* platform! The same applies to component-generated vibration. At the very best, the combined structures will roughly approximate the "ideal rigid body" we mentioned earlier, moving through space in synchrony relative to each other so that the motion of the floor is matched by the motion of the shelf, with nothing added.

Any technique that does not provide isolation of external vibrations will only vary the amount of resonant stimulation *added* to the components concerned. It cannot reduce *at all*

2 For information about "The Shelf," contact Black Diamond Racing, 301 North Water St., Milwaukee, WI 53202. Tel: (414) 224-5300.

the level of baseline vibrations in the floor or those coupled from the air!

This principle is illustrated by both the "ideal rigid body" line in the compliance curves shown in sidebar 1, and the horizontal unity-gain line (labeled "1.0" in the various transmissibility graphs of sidebar 2). A perfectly rigid structure would not diverge from this unity-gain baseline in either direction, indicating nearly complete transmission of all vibrations between both the floor and the coupled elements.

At first glance, transmitting nearly all of the floor vibrations to a component might seem to be of no benefit at all. On the contrary, this would be a significant accomplishment compared to most real-world coupling schemes, due to an appreciable reduction in random levels of resonance affecting key components, as described above.

Indeed, it is the degree of deviation from this ideal that defines the wide variety of subjective sonic changes experienced by audiophiles using various non-ideal rigid coupling devices, stands, shelves, and components in actual audio systems. Also, when you consider all the ramifications of this jective improvement resulting from effective pneumatic isolation is clearly different in kind, not just in degree, from that afforded by resonance tuning, and can be quite dramatic, particularly when used with source components—or, better yet, the whole system. Confusing the tuning of system resonances with an across-the-board enhancement of resolution can be a trap that leads the unwary down the slippery slope of tonal manipulation.

Making the connection: of modes & nodes

Rigid cones actually create a frequency-selective coupling between any two or more structures, acting somewhat like random low- and high-pass filters. Which frequencies are de-coupled *vs* which are coupled between two specific objects will depend primarily on the modal patterns of the two connected surfaces and the placement of the cones relative to each. In other words, their beneficial effect will generally not be uniform over a broad frequency range, or be equally translatable to a wide variety of components in different environments. If we map out the composite modal

Certain purveyors of cones and spikes claim that these devices have a directional "diode-like effect." It just doesn't work that way.

scenario, it appropriately undermines the claim by certain purveyors of cones and spikes that these devices have a directional "diode-like effect," forcing discrete vibrations to flow like water from a dam: out of a component, through a coupled shelf, and then into the floor, where they are finally dissipated.

This may be an appealing concept, but it just doesn't work that way. Certain ambitious advertising campaigns for these devices make it sound as if all the bad vibes will be sucked out of your audio gear as if by a hose containing a one-way check valve (often made of exotic materials and special shapes), while simultaneously preventing any floor or rack vibrations from coupling to the component via the cones. This idea is misleading at best, even though rigid coupling can play a critical role as an adjunct to an overall vibration-reduction plan incorporating isolation and damping. But before some of you "cone-heads" start writing flame mail, let's talk about what cones actually do.

What began—with the likes of Tiptoes and Sorbothane pucks—as a cottage industry within a cottage industry has evolved into a bewildering array of products, all promising to enhance the resolution of our cherished systems. Most of these devices do result in a noticeable *change* in the sound of one's system, often for the better. However, the prospective buyer must understand that the changes wrought by some of these vibration-control products are primarily a function of *tuning*. In other words, they merely shift the frequency and level of offending resonances around in the system, hopefully achieving a more pleasing balance.

Like many of you, I use cones and spikes for coupling certain components—with good results. However, a basic understanding of how to use cones within the mechanism of rigid coupling will not only help to get the most out of them, but will contrast their tuning benefit with the overall increase in resolution resulting from more elaborate methods of equipment support (for example, exceptional pneumatic isolation systems). As I related earlier, my experience is that the sub-

shapes of a given platform, we will find areas of very large relative motion, and points of minimal movement known as "nodes"—actually, these are points of zero displacement.

Try visualizing a long ruler, on edge, moving like a sinewave. Now imagine a straight line cutting through the center of the sinewave and representing the ruler at rest. Even when the ruler is flexed, certain points will remain at rest along the center line; these are the nodes. The points of maximum excursion represent peaks of the bending modes. Expand this view to a three-dimensional platform and the complexity of vibrational forces becomes clearer (see "The Rigid Body Concept," fig.3).

The pointed tips of a cone will tend to enhance the mechanical interface between the cone and the structure it touches. If, through empirical experimentation, the tips of each of the applied cones were located at minimum nodes on a supporting platform, a reduction in the amount of added system resonance would result. This improved mechanical interface due to the tip's contact with a narrow point on a platform (at least on one end) provides the primary benefit of cones over standard solid equipment feet (which are usually broad on both ends). On the other hand, the broad, flat end of the cone will generally have a poorer mechanical interface with the bottom of a component or platform to which it is coupled—more like that of the stock feet.

In the case of an audio component with its irregular distribution of modal shapes, it's likely that the contact area of the cone's flat end will overlap areas that vary in degree of motion. You'll probably be better off with cones or spikes that are relatively narrow on both ends. Regardless, if either end of the cone is placed at a point of maximum modal displacement on its connecting surface, not only will all of the original floor vibration couple to the platform, but those frequencies that are related to the resonant modes of the platform—and stand, component, etc.—will be amplified. Also, additional resonances will likely be generated and added to the mix, leading to probable changes to the system's tonal

Fundamentals of Isolating Suspensions

In Sidebar 1 I explained, graphically, how the resonant frequencies of a solid structure relate to its modal activity when stimulated by vibrations. It is apparent that, regardless of which method of rigid coupling, damping, or a combination thereof is used to minimize the negative impact of vibration on a platform, stand, or component, the best one can achieve through these means alone is a reduction in amplitude approximating the ideal rigid body line.

To further reduce the impact of vibration, we must isolate any rigid structure from outside sources of resonant excitation. Isolation systems are evaluated through two models: The Simple Harmonic Oscillator, consisting of a rigid mass connected to the floor or supporting element by a linear spring (fig.1), forms a suspension that has no applied damping to dissipate mechanical energy. Every suspension has a natural resonant frequency determined by the supported mass and the spring compliance. It decreases for a heavier mass and/or a more compliant (softer) spring. Theoret-ically, the peak displacement caused by the excitation of a truly undamped harmonic oscillator's resonant frequency is infinite (fig.2).

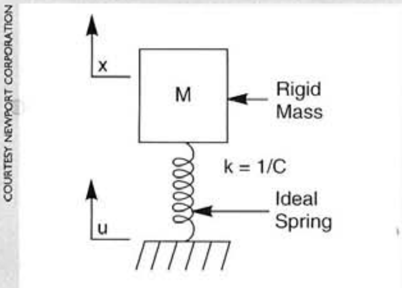

Fig.1 Simple Harmonic Oscillator.

The Damped Harmonic Oscillator is the same, with the addition of a damping mechanism to reduce the amplitude of displacement (fig.3). As damping increases, the amplitude at resonance decreases. However, the "rolloff" rate at higher frequencies also flattens out, meaning that the decline in the transmissibility of vibration occurs more slowly. Since the theoretical Simple Harmonic Oscillator does not exist in the real world, all practical systems are some variation of the damped suspension model (fig.4).

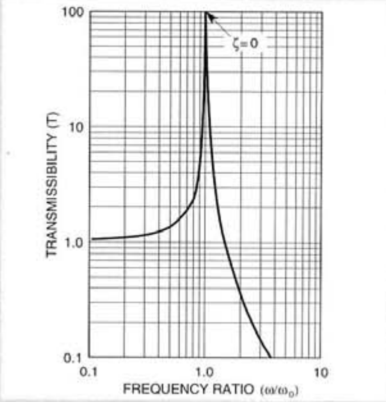

Fig.2 Transmissibility of Simple Harmonic Oscillator. Note that without damping, amplification at the resonant peak would be infinite!

Since isolation only begins at a frequency near 1.4 times the resonant frequency of a suspension—at best—it is important to push this frequency as low as possible, while maintaining stability. A transmissibility curve is a method used for evaluating the performance of an isolation system. Transmissibility is the ratio of the amplitude of vibrations transmitted through an isolator to that of the driving force. The Y axis of the log-log graph defines the amount of vibration transmitted through the suspension. The baseline, represented by the line at unity (1.0), corresponds to transmission of 100% of the vibration inherent in the structure supporting the suspension. (It's also roughly analogous to the ideal rigid body line on a solid structure's displacement curve, as shown in sidebar 1, in that any deviation from the ideal rigid body line occurs above this baseline.) The X axis shows frequency and, combined with the Y axis (transmissibility), defines the system's resonant frequency, the height and breadth of its corresponding zone of amplification, and the amount of attenuation for any frequency beyond the amplification zone. The figures are fairly self-explanatory.

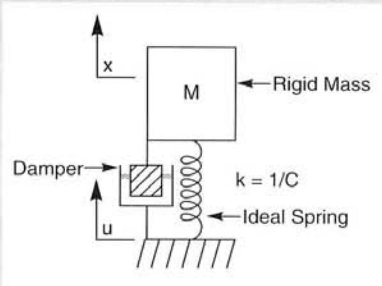

Fig.3 Damped Harmonic Oscillator.

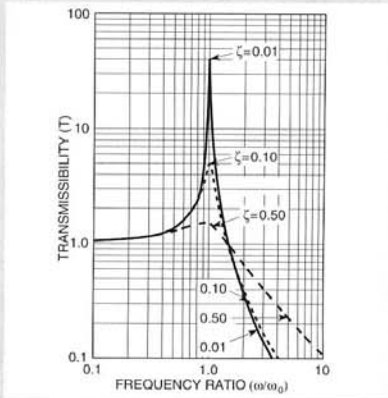

Fig.4 Transmissibility of Damped Harmonic Oscillator. Note that as damping increases, the amplitude at resonance decreases and the rate of vibration attenuation below resonance declines.

Keep in mind that all forms of rigid coupling using cones or damping techniques will either increase or decrease the amplitude of any given resonant frequency band only above the baseline represented by 1! Level 10 on the Y axis equals 1000% amplification of baseline vibrations, and 0.1 equals a 90% reduction in transmission of the same to the isolated components. The curve is asymptotic, so 0.01 equals 99% reduction, 0.001 is equivalent to 99.9% reduction in transmissibility, and so forth. 100% isolation is, of course, never reached.

Fig.5 shows transmissibility curves showing actual measured performance for a typical high-quality pneumatic isolation system in both the horizontal and vertical planes. Note the near-equal performance in both planes, the suspension's very low, well-damped resonant frequency, and its steep 12dB/octave rolloff.

—Shannon Dickson

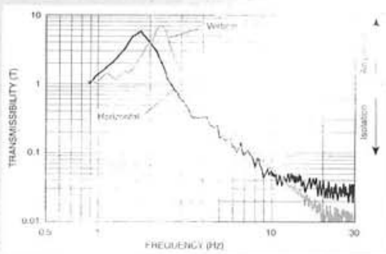

Fig.5 Transmissibility of a high-quality pneumatic suspension in horizontal (dark curve) and vertical planes. The actual vibration isolation at 10Hz is approximately 95% in both planes!

balance, and—well, you get the picture. Cones can be a mixed bag.

The ideal scenario of rigid coupling is predicated on our ability to perfectly align the minimum nodes of a concrete floor with those of our damped, rigid platform. The chances of this happening in reality are about as likely as folding the continent in half and having the Rocky Mountains fit perfectly with the Adirondacks. The much larger concrete floor will have its own varied resonant modes, but since the platform's size is so small compared to that of the floor, the floor is "seen" by the platform, via cones, as a more or less rigid body. Note that, with respect to a suspended wooden floor, the mutual excitation of resonant modes between the stand, platform, and floor can be *much* more complex and unpredictable. On wooden floors, try locating your equipment near structural support beams or other weight-bearing regions. If possible, also use house jacks to shore up the areas of the floor directly under and around your equipment rack and speakers.

you the spacing between the two cones, keeping them the same distance from the two ends of the platform. This corresponds to the minimum node of the first, most prominent bending mode on a typical shelf, and should put you in the ballpark. (I'm having an independent lab test a well-made platform for transmissibility when it's supported by a number of different cones and elastomer pucks. If we gain further insights with respect to cone placement, I'll be happy to share them with you in a future article.)

Stand design

So far, I've primarily dealt with the problems faced by uniform supporting structures such as shelves and floors. The modal shapes of most equipment stands are far more complicated, and add a second challenging element to the vibration equation. Since space limitations generally require the use of shelved stands, knowing what to look for is critical.

Again, the most important quality is rigidity. Though a number of stands on the market are very rigid in the vertical

IDEAL RIGID COUPLING IS PREDICATED ON THE PERFECT ALIGNMENT OF THE MINIMUM MODES OF A CONCRETE FLOOR WITH THOSE OF A DAMPED, RIGID PLATFORM. THE CHANCES OF THIS HAPPENING ARE REMOTE.

For those fortunate enough to have concrete floors, the modal waves are spread out, and the peaks of the waves are far apart compared to those in the platform or stand. From the point of view of the platform, it would be similar to driving over a broad speed bump. You'll notice it as a gentle rolling, but nothing like hitting a sharp, narrow bump. In other words, most vibrations transmitted to the floor, from whatever source, will couple directly through the cones without much amplification of the modal activity from the floor. In any event, there isn't a whole lot we can do about floor vibrations, whatever their origin, by using rigid coupling alone. Therefore, in order to get the best performance from this method, we must direct our attention toward placing the cones at the minimum nodes on the bottom of the platform.

While many people have noticed positive changes in system tonal balance with various cones, others have at times experienced degradation, particularly if they did not make an effort to find the quietest locations for their cones. As we inferred, the shape of a cone and its composition may contribute somewhat to its sonic effect, particularly if it contains some inherent damping qualities. However, it is their placement relative to modes and nodes on the coupled structures that has the largest impact on overall performance. Regardless, it is clear that this method, which falls in the domain of system tuning, is best used as an element in a more comprehensive vibe-reduction plan incorporating isolation and damping. (The benefits and limitations of compliant Navcom-like pucks are discussed under "Suspension Fundamentals.")

Even though rigid coupling has limitations, it does play a necessary and important role in nearly every stereo system. Therefore, if you've had bad luck with certain cones, try placing them in a variety of locations before you give up or rush out to buy new ones touted as sounding inherently better.

A good place to start your experimentation for that quietest location is 22% in from the two ends of any homogeneous rectangular platform. Simply measure the width of the platform and multiply that figure by 56%; the result will give

plane, most bend like a house of cards in the horizontal plane when bearing a heavy payload; *eg*, a turntable on a granite slab. This happens because stands are usually made of three or four vertical legs connected with horizontal tiebars at the top and/or bottom. If diagonal tiebars or turnbuckles were placed across one side and/or the rear, these stands would be far more stable in both planes of motion. Fortunately, many heavy-duty steel or aluminum stands are filled with sand and lead shot, which increases mass and partially damps the tendency for the metal shelves to ring when stimulated by both floor- and acoustically coupled vibrations. A few stands are made with inherently well-damped materials.

It's as simple as this: Keep your stands as short as possible. The shorter the stand, the more rigid it will be.

Use all of these tips when shopping for a stand, and by all means don't skimp on quality and rigidity for the sake of looks alone. Armed with these guidelines and a willingness to investigate the available options, you're likely to find some creative and unique variations on these techniques that work very well.

Component level control

The first elements in the vibration equation affecting audio systems, and the final constituent in our look at rigid coupling, are, of course, the actual components. Since vibrations are best dealt with closest to their source, equipment designers bear the brunt of responsibility for minimizing internally generated resonances and the damaging effects of external vibrations on their chassis. As we've seen, building an inert component that is immune to outside disturbances is completely impractical; informed designers attempt to minimize the strength of offending internal vibrations while shifting inevitable resonances to a less harmful region through careful layout, strong chassis construction, and local damping.

Those manufacturers who fine-tune the sounds of their electronic devices with minor circuit adjustments or component changes are, in part, adapting the sound to the resonant signature inherent in their components' designs. The

Jeff Rowland Design Group products—as well as the MFA MC Reference, CAT Signature, Accuphase gear, and the new electronics from Balanced Audio Technologies—are just a few of a growing list of examples in which attention to vibration at the design level has paid off in improved low-level detail and subtle refinements in tonal balance.

Since most chassis have anything but uniform resonant signatures, the problems encountered in connecting a platform to the floor are compounded further when spiking a component to the top of the platform mounted on a stand. It's virtually certain that the irregular modal profiles of most components' thin enclosures will not only encourage significant amplification of related external frequencies, but the creation of new resonances as well.

floor and those excited in the speaker's cabinet by the driving force of the woofers will be somewhat reduced, lowering the overall resonance of both structures.

This theory may provide some explanation for the effect of spiking a speaker, but the biggest impact results from simply stabilizing its motion relative to the air in the room. If a speaker is placed on a carpet or uneven floor, it will subtly rock back and forth due to the large excursions from the bass drivers. For example, when a signal comes down the cable, telling the woofer to move 1/16", its movement may be slightly reduced relative to the air due to the cabinet's pivoting action. In this example, spiking will tend to fix the pivot and result in a tighter, better-defined bass response and a cleaner presentation in the midrange. Very heavy speakers make this

THERE ISN'T A WHOLE LOT WE CAN DO ABOUT FLOOR VIBRATIONS BY USING RIGID COUPLING ALONE.

less of an issue, but since we're dealing with a transducing element, even subtle variations can have an audible effect.

These hypotheses are more straightforward when applied to a concrete floor. Spiking a speaker to a suspended wooden floor is fraught with the same difficulties as using a stand, yet the consequences for the whole system can be even worse.

Limited vibration attenuation provided by composite cones that possess a degree of damping may provide some latitude with respect to their placement between components and platforms, falling somewhere between solid cones and compliant pucks in performance. However, for the reasons described above, these devices, and rigid cones as well, can actually exacerbate a resonance problem when misapplied. Also, I've yet to find any devices from either category that produce repeatable, predictable results, regardless of what component or system they are used with. I'm therefore concerned that audiophiles be aware of those few products that do address the issue of vibration control at a more fundamental level.

Sand damping

We've noted the benefit of using sand to fill equipment stands. Another important damping application is in products like the Bright Star sand bases.[3] These boxes, ranging from 2" to 5" deep, are filled with sand on which a plinth is placed to support a component. The ability of sand to conform to the entire surface of the plinth material efficiently constrains and partially damps the platform's vibrational modes. While the volume of sand typically used in these bases will not result in true isolation—particularly for the most damaging low frequencies—it is sufficient to reduce the amplitude of resonances across a broad range of frequencies arising from the modal activity of the floor, stand, and supported component. This damping effect can be surprisingly beneficial.

Speaker coupling

Perhaps nowhere are cones and spikes more widely used and accepted than when coupling speakers to a floor. Their sonic effects in this application are generally more pronounced in scale and more uniformly positive than when coupling linestage components to various shelves and stands. While many of the foregoing principles also apply to spiking speakers, there are important differences. An argument could be made that by placing speakers on cones rather than setting the entire speaker flush with the floor, the contact area between the various modal waves of the

3 Bright Star Audio, 2363 Teller Road #115, Newbury Park, CA 91320. Tel: (805) 375-2629.

Fundamentals of isolating suspensions

Now that some of the benefits and limitations of rigid coupling are better understood, we should maximize its usefulness by employing rigidity where it counts: through supporting structures and the selective application of cones as an integral part of a complete isolation/damping/tuning system. In so doing we can move beyond simply reducing additive resonant effects transmitted by the floor/stand/component interface, through genuinely de-coupling key components from the main sources of vibration while providing an efficient mechanism for attenuating residual disturbances.

Before I explore these issues of suspensions and isolation in more depth, I'd like to address another misconception prevalent in our hobby: that of "over-damping" non-transducing electronic components.

Damping is always present to some degree in any real system. Without it, there would be no way to limit the amplitude of a resonance. The materials employed to provide damping, the ratio of these materials to those elements that need damping, and the method in which they are applied, all determine how effective any scheme is at reducing broad-band vibrations. However, you *cannot* mechanically "over-damp" a structure or component that is not designed to be a transducer. You can over-damp some circuits electrically; you can over-damp the "Q" of a speaker as well. You can also over-damp structures associated with a phono cartridge: a tonearm, plinth, etc. But you cannot over-damp a preamp's chassis or an equipment rack. What you *can* do is "mis-tune" the chassis or structure by shifting resonances around and attenuating them in a frequency-selective manner that results in a dulling of the sound, which is then characterized as over-damped. You can also misapply certain damping materials in the construction of a platform so that its overall rigidity is compromised.

This may all seem like a minor issue of semantics, but it's important to understand the distinction in order to prevent conceptual errors when deciding how best to deal with a particular vibration problem. Complete damping of a non-transducing component would imply the absence of any offending resonances to tune. This type of electronic component should act as an inert conduit for the signal; *any* resonances added to that signal via, say, an amplifier chassis, are, by definition, distortion—no matter how sonically pleasing.

Suspension basics

The concept of a successful suspension is simple. Once we've done everything practical to reduce the amount of added resonant energy generated in our stand and platform, the next step is to reduce the propagation of baseline external vibrations into our components through isolating as much of the remaining energy as possible with an effective suspension.

A suspension's resonant frequency is determined solely by the ratio of the coupled mass (composed of the supporting platform and component) to the stiffness of the spring support. As in our platform discussion, the natural frequency of a suspension is amplified at resonance. For frequencies well below the suspension's natural resonance, transmission is close to 100%. Then isolation begins for all frequencies greater than 1.4 times the resonant frequency. For undamped or sophisticated pneumatic and NSM (negative stiffness mechanism) designs, the reduction in amplitude continues to decrease at a nice, steep rate of nearly 12dB/octave.

Obviously, the issue of vibration in solid objects and the issue of isolation have resonance as a common problem. However, as we pointed out at the beginning of our discussion, there are important differences between these two aspects of vibration control in both theory and practice. Unlike the platform example, in which we pushed the resonant frequency as high as possible to reduce displacement from modal activity, a suspension will only *begin* to offer effective isolation at frequencies significantly above its natural resonance. Since a really effective suspension will need to isolate *all* structure-borne vibrations that can have an audible impact, we must push its natural frequency as low as possible so that the resulting zone of amplification is as far away as possible from the audio band—the main source of disturbance.

Two basic models are used by engineers to define an isolating suspension. First is the example of a "simple harmonic oscillator" which is formed by a rigid mass suspended by an ideal linear spring, yet has no method for dissipating the mechanical energy of its movement. There are some basic characteristics of this model that are important to remember: Any vibrations that are at or near the resonant frequency of the suspension will be significantly amplified. If the suspension truly lacked any damping, the displacement at the resonance peak would be infinite (you won't find many of these at your local hi-fi hut). The frequency at which the height of the resonant peak has fallen back to unity is equal to the natural frequency multiplied by the square root of two. Another way of looking at this relationship is to multiply the resonant frequency of any suspension by 1.4; the result will approximate the frequency at which isolation actually begins.

Transmissibility is the ratio of vibrational amplitude that is transmitted through the suspension to the total vibration input. The transmissibility of vibration is constant for all frequencies well *below* the resonant point. In other words, essentially all of the low-frequency energy transmitted to the system will pass right on through without modification—as if the suspension wasn't even there.

The amount of vibration transmitted to the isolated elements will continue to attenuate for all frequencies above the zone of amplification—*ie*, after the resonance has subsided to the baseline level of unity. This is, in effect, like a low-pass filter at 12dB/octave, or 40dB per decade. Therefore, the lower you can establish the suspension's resonant frequency, the greater the degree of isolation for all frequencies above that point. Remember, too, that the suspension's resonant frequency is different from the inherent natural frequency of either the isolated platform or the component.

Unfortunately, the large displacement accompanying super-low frequencies—particularly those well below 10Hz—in an undamped suspension can make it very unstable and can lead to severe operational problems. The practical solution for the stability problem employed in most real-world suspensions is some variation of the second model called, appropriately, a "*damped* simple harmonic oscillator." This system differs from the first example by adding a damping mechanism to the spring that reduces the amplitude and shape of the resonance. In contrast to the first model, the damped isolation system not only curtails the maximum displacement of the suspension, making it more stable—a desirable trait—but can also, unfortunately, reduce the rate of attenuation for all frequencies above that point, in effect flattening the low-pass rolloff characteristics from a 12dB/octave slope to as shallow as 6dB/octave for some heavily damped suspensions (see Sidebar 2, fig.2).

Actually, the zone of amplification for a damped suspension is broadened on both sides of the resonance, though the low-pass region is of greater importance. For any given point above resonance—say, 20Hz for a system with a 10Hz resonant frequency—the damped system will usually provide *less* isolation than the undamped suspension! Also, some materials used to damp the action of a typical isolator can add stiffness to a spring which, in turn, would raise its resonant frequency. All things considered, we have a classic Catch-22 that defines the fundamental limitation of the steel-spring and elastomer-based suspensions commonly used in audio.

Fortunately, this dilemma can be solved with good pneumatic isolation systems. Traditional isolators tend to have "reactive" damping characteristics, while the more sophisticated, dual-chambered pneumatic designs combine real-time damping along with other unique qualities. These factors allow good air-based systems to achieve the fast rolloff of a simple harmonic oscillator above resonance, *and* the low amplitude at peak resonance of a damped harmonic oscillator—resulting in a clearly superior suspension all the way around.

> **Keep your stands as short as possible. The shorter the stand, the more rigid it will be.**

Elastomer supports

A rudimentary version of the traditional damped suspension is formed when elastomer materials such as Navcom or

Sorbothane are used to support a heavy preamp or amplifier, either directly or with an intervening platform. These elastomer pucks can be quite effective at isolating moderate amplitudes of vibration ranging from the upper bass and above, and will generally have a fairly predictable performance throughout this range of frequencies when used with a wide range of gear. Also, a broad band of vibrations generated within the component is partially damped by these compliant materials. Unfortunately, their damping and isolation ability is not only ineffective at very low-level vibrations of any frequency, but is essentially transparent to *all* amplitudes of very low frequencies, acting basically like rigid coupling rather than an isolator in response to vibrations lower than the natural resonance of the suspension.

For many systems using rubberlike pucks, the resonant frequency ranges from approximately 10Hz to 20Hz or higher depending on the actual compliant material, how it is shaped, and the load it bears. So even though the peak displacement at resonance will be reduced, vibrations below resonance will either pass right on through or be amplified. In practice, many such suspensions have relatively high resonant points, so this amplification will often extend into the lower audio band. For example, a system formed by typical rubber pads or pucks supporting a moderately heavy steel plate will have a vertical resonance of around 15Hz or so. Its related resonant displacement is fairly well controlled, yet the zone of amplification actually extends from approximately 3Hz up to around 25Hz—above which isolation finally begins. This scenario can contribute to the subjective impression of a "mushy," "soft," or "boomy" bass response, even as the suspension reduces the amount of transmitted vibrations from the midbass on up, and partially damps the component-generated vibrations.

Unfortunately, this limitation of certain elastomer supports is often misconstrued as "over-damping," even when describing its effect with amps and preamps, and has led to the unfortunate condemnation, by some, of any sort of damping at all. Actually, this negative subjective effect, reported when elastomer supports are used in some systems, stems from the amplification of the suspension's relatively high resonant frequency intruding into the lower audio band (the opposite of damping).

Paradoxically, systems that emphasize the bass can sometimes sound rolled-off in the treble as well, although this is usually a psychoacoustic effect rather than a genuine rolloff. In any event, this example highlights the danger in drawing cause-and-effect conclusions about subjective experiences in audio without trying to tie them back to real physical principles. The positive sonic effects of elastomers are almost entirely due to their damping and isolating qualities; when properly applied, elastomers can result in a significant reduction of vibrations from the upper bass on up.

Incidentally, several equipment supports or footers now on the market combine a degree of rigidity with a measured amount of damping, without being overly compliant. These devices seem particularly well suited for connecting components to a platform already isolated by a suspension. (See my Townshend/Vibraplane review elsewhere in this issue for some examples.)

The phono challenge: the pneumatic edge

Far more elaborate and effective examples of damped suspensions can be found in certain high-end turntable designs employing very compliant, viscous-damped springs, generally with lower, less intrusive resonant frequencies. However, the tonearm mass and cartridge compliance of most LP players results in a natural resonance with a frequency between 10Hz and 15Hz. Therefore, with a typical turntable, we need to achieve excellent isolation by just 10Hz! Unfortunately, the vertical resonant frequency of many turntable suspensions overlaps this region of tonearm resonance. To complicate matters, the suspension's horizontal frequency will tend to be even higher than the vertical. In such a system, amplification of the suspension's natural resonance directly exacerbates that of the tonearm/cartridge, resulting in the addition of sonic colorations.

Among the notable exceptions to this quandary are the unusual and reportedly successful suspensions found in the SME 30 (around 4Hz), the Versa Dynamics 'tables (2.5Hz in both planes), the Kuzma Reference (at 2.2Hz), and a number of other high-end designs. Better turntables employ suspensions that damp both the suspension and tonearm to minimize the amplitude of these resonances, particularly with regard to vibrations in the audible bandwidth, and often achieve good results. However, even these well-designed spring-based suspensions have a tough job handling the isolation requirements of a turntable. These additional factors partially explain why:

Earlier, I alluded to the need for vibration attenuation in both the vertical and horizontal planes. Almost every spring- or elastomer-based design has significantly better vertical than horizontal isolation. As a result, "flanking paths" can be created, allowing horizontal resonances to impair the overall isolation effectiveness of a suspension. Without nearly equal isolation in *both* planes, serious compromise is inevitable for any turntable system. The flanking mechanism can also be exacerbated by the reactive damping inherent in most spring and elastomer systems.

Modern low-output cartridges, the vagaries of the stylus/groove interface, and ever-more-refined amplifying electronics place tremendous burdens on not only the suspension, but every aspect of turntable design. These systems can amplify a signal over 30,000 times to portray the subtlest hall ambience or textural nuance—those tiny details that give recorded music so much life, vitality, and spatial resolution. Since a turntable's arm/cartridge system requires maximum isolation to be achieved in both planes by 10Hz, we need a suspension with a bidirectional natural frequency well below 5Hz, when possible.

Though some of these reactive spring-based systems have resonant frequencies that low, I feel that they simply are not as efficient as a good pneumatic system, and the stability of some is questionable. When properly implemented, air-based isolators attenuate much lower amplitudes of very-low-frequency vibrations than even the best spring designs (with the exception of the new NSM system offered by Newport, which is a little too expensive for home audio in its present configuration).

USING ELASTOMER PUCKS CAN RESULT IN A SIGNIFICANT REDUCTION OF VIBRATIONS FROM THE UPPER BASS ON UP.

Take Andy Payor's Rockport Cappella and Sirius II turntables, for example. Each of these 'tables contains a fully developed pneumatic suspension with a vertical and horizontal frequency of *ca* 2Hz or less. Compared with most spring or elastomer suspensions, even those that claim similar resonant frequencies, these pneumatic systems are at least 40dB better in the ultimate isolation of very-low-frequency, *micro*-inch levels of displacement.

However, the bottom line is that truly effective vibration control in audio systems requires a measured, comprehensive approach utilizing rigid, well-damped stands and platforms, careful selection and placement of coupling devices, and isolation of key components—using air-based suspensions wherever possible.

All of our references up to now have concerned typical home audio systems, yet it is my fervent hope that the pro-

ISOLATION AND TUNING SHOULD BE SEEN AS COMPLEMENTARY AND ESSENTIAL PARTNERS IN THE FIGHT AGAINST BAD VIBES.

audio world takes notice of the influence vibration has on fidelity. Eliminating the rickety rack systems common in studios around the world, then properly supporting and isolating A/D converters, microphones, preamps, tape drives, and cutting lathes could have a major impact on our treasured source material. Knowing what I now know about the impact of mechanical resonances, I get the willies when I go into a studio, see an A/D converter barely hanging off the edge of a console, and realize that vibration-induced grunge is being encoded into our source material. In some studios you can look through the inspection microscope attached to a cutting lathe *during* the cutting of a lacquer and actually see the light shimmering off the grooves as a truck rumbles past!

The Vibraplane, reviewed elsewhere in this issue, is very close to the Rockport suspension in isolation performance, though these cost-no-object turntables have several other key features that contribute to their outstanding sound quality—and high cost. In addition to isolating very-low-frequency vibrations in both planes, the Vibraplane also contains the real-time damping characteristics shared by the Rockport as well as other pneumatic systems like Newport's "BenchTop" or "Noise Block" (the latter is an audiophile version built for Immedia by Newport).[4]

Wrapping it up

The particulars of pneumatic isolation and its sonic contributions are covered in my reviews of the Seismic Sink and Vibraplane. In summing up this evaluation of practical vibration control, it's important to realize that, although the isolation effectiveness of these pneumatic systems surpasses that of traditional suspensions, the complexities of vibration in the audio environment are such that subjective differences are perceptible even between competing pneumatic designs. These differences arise primarily from the relative effectiveness of the various isolated platforms and the coupling methods used to connect equipment to them—particularly how well they damp component-sourced vibrations.

Subjectively, this is the tuning effect we've discussed, and it's perceived as subtle tonal variations, focus, and changes in soundstage perspective. It won't take long, however, before you'll be able to easily distinguish these spectral variations—no matter how pleasing—from the concurrent, across-the-board improvements in system resolution, spatial definition, and greater emotional connection to the music that results from pneumatically isolating your favorite source components.

Though turntables clearly demonstrate the most dramatic improvement from proper isolation with a Vibraplane, digital gear isn't far behind. (This is still the biggest surprise for me.) Even preamps and amplifiers, particularly those containing tubes, show a real enhancement in sound quality with the more affordable Seismic Sink, and there is a definite synergistic effect from floating the entire system. Pneumatic isolation should never be considered just a tweak. When done right, the impact can be more musically significant than changing certain amplifiers or preamps, not to mention many other accessories. This does not mean that gross sonic changes are necessarily greater than that experienced from most component upgrades, but simply that it can be more relevant in conveying the nuances and dynamics that give music so much vitality and presence.

While it may seem that I've been a bit hard on tuning products when they're the only means used for dealing with vibration, my intentions were simply to contrast their effects—which are familiar to most audiophiles—with those attainable from a well-rounded program that addresses each element of the equation, including tuning. Isolation and tuning should not be seen as competitive alternatives, but as complementary and essential partners in the fight against bad vibes.

As lengthy as this report has been, I've only outlined this pervasive subject in broad strokes. As you explore the commercially available resonance-control products, you'll discover numerous shades and variations of these principles, some of which work very well. In any event, the purpose of this article will have been served if many of you now feel better equipped to sort through the maze of possibilities, and, above all, have fun in implementing your own vibe-reduction plan. Now take a breather, listen to some tunes, and—when you're ready—take a look at how best to use the Townshend Seismic Sink and the Vibraplane.

Further reading

Interested readers can reference the following:

Fundamentals of Noise and Vibration Analysis for Engineers, M.P. Norton, Cambridge University Press, 1989, reprint 1994 (highly recommended).

Mechanical Vibrations, 4th ed., J.P. Den Hartog, Dover Press.

Shock and Vibration, 3rd ed., Cyril S. Harris, 1988, McGraw-Hill Books.

Newport Corporation's 1995 Catalog, Chapter 16, "Vibration Control," 791 Deere Ave., Irvine, CA 92714, Tel: (800) 222-6440.

Acknowledgment

I'd like to thank Newport Corp. for the kind use of their graphics in our sidebars. I owe a particular debt of gratitude to their Engineering Manager for Vibration Control, Mr. Bowie Houghton, for his invaluable references and insights. S

4 Noise-Block Isolation Base, $2300 including air tank and regulator valve. Dimensions: 20" W by 16" D by 2" H. Weight: 22 lbs. Contact Immedia, 2629 Mabel St., Berkeley, CA 90701. Tel: (510) 654-9035.