Sound & Noise

Generation, Propagation & Reduction

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Quiet Solution

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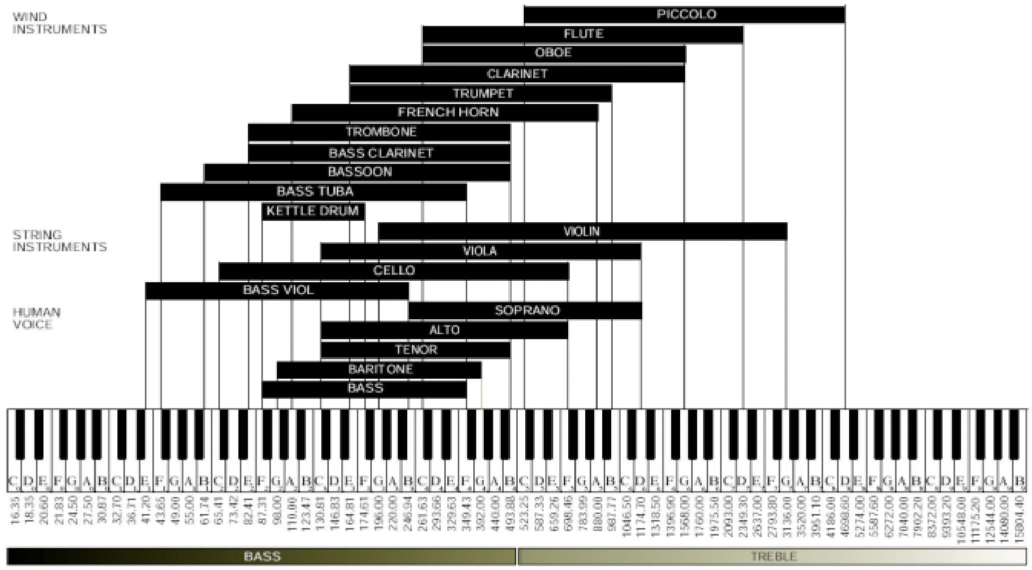
1 What is Noise?

Noise is simply unwanted sound. So first we might want to look at sound and how it is generated. Sound is actually changing air pressure. That is, a generator of sound must move the air back and forth, creating “sound waves” that can be heard (presumably by humans). One way to picture this is thinking of a large concert bass drum. When the mallet strikes the drum head, the head begins to move back and forth, or vibrate. As it does, it “pulls” some air in front of it towards itself, and then as the head moves out it pushes that same air away from it again. In doing so, the drumhead creates small changes in air pressure that move (or propagate) through the air. These ripples in the air move out in all directions (though not always equally), eventually striking our eardrum. The human eardrum is like a very small drum head itself that can be moved by these minor changes in air pressure. As it moves back and forth, we perceive sound.

In the simple example above, we can imagine the bass drum head moving in and out, and we might be able to imagine the waves in the air moving towards us, eventually striking our own ear drum, which moves in harmony with the waves, and our brain “hears” the sound the bass drum made. In real life however, it can get somewhat more complex, even though following the same basic principals.

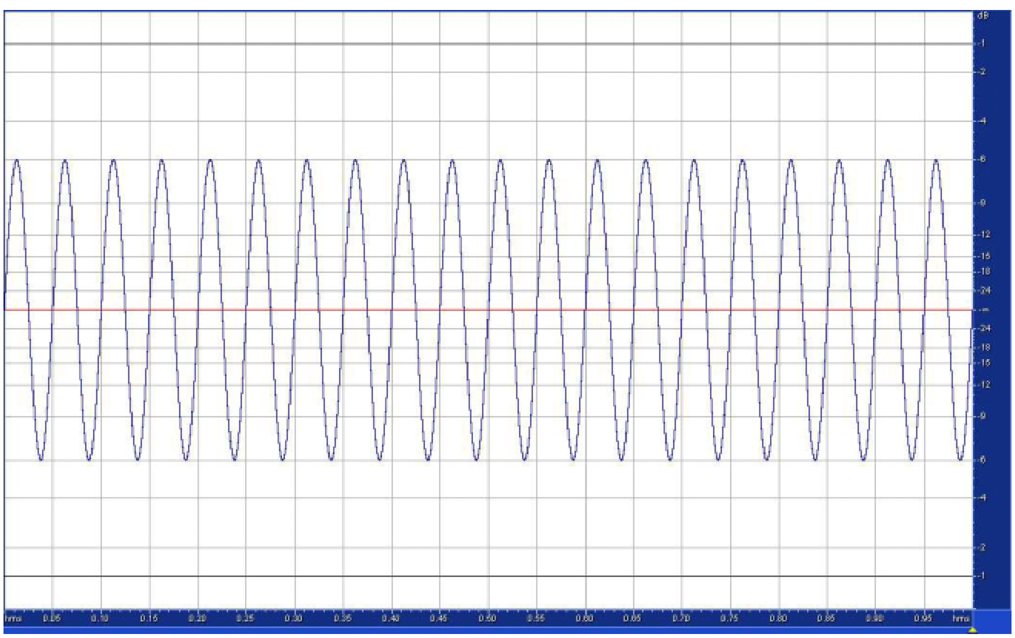
The bass drum has a very low pitched sound. A flute may have a high-pitched sound. We perceive both differently, and that helps us recognize a bass drum from a flute. Humans generally hear sounds that vibrate the air as slow as 20 times per second (or 20 Hertz, or 20Hz). This is often referred to as pitch, frequency, cycles per second or Hertz. When we are young, we can often hear sounds as high as 20,000Hz (or 20 kilohertz or 20 kHz). So humans are considered to have hearing that spans from 20Hz to 20kHz. When we get older, we tend to lose our high-frequency hearing, and it is not unusual for a 60 year old to have hearing that spans 20Hz to 10kHz. While it would seem at first that they have lost “half” of their hearing, in reality, there are not too many sounds above 10kHz, so they may not perceive much difference. We might note that while humans may not hear much below 20Hz, our bodies can feel the pressure changes (or vibration) if they are large enough. For instance, we can easily feel earthquakes, which may have a frequency of 1Hz or less.

Different instruments and voices generate sounds at different frequencies. This frequency diagram demonstrates the range of frequencies of a piano and various instruments.

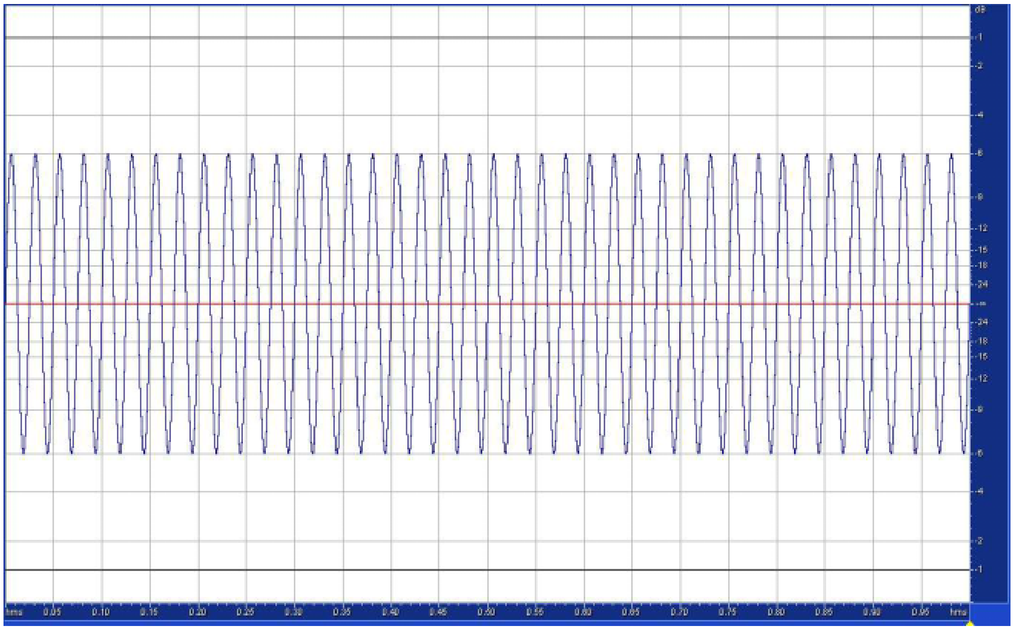


Now that we understand how sound is generated as well as a basic understanding of frequency, we need to understand loudness (or volume) of sounds. Where pitch is how fast the air pressure changes, loudness is determined by how much the air pressure changes. This can be illustrated as such:

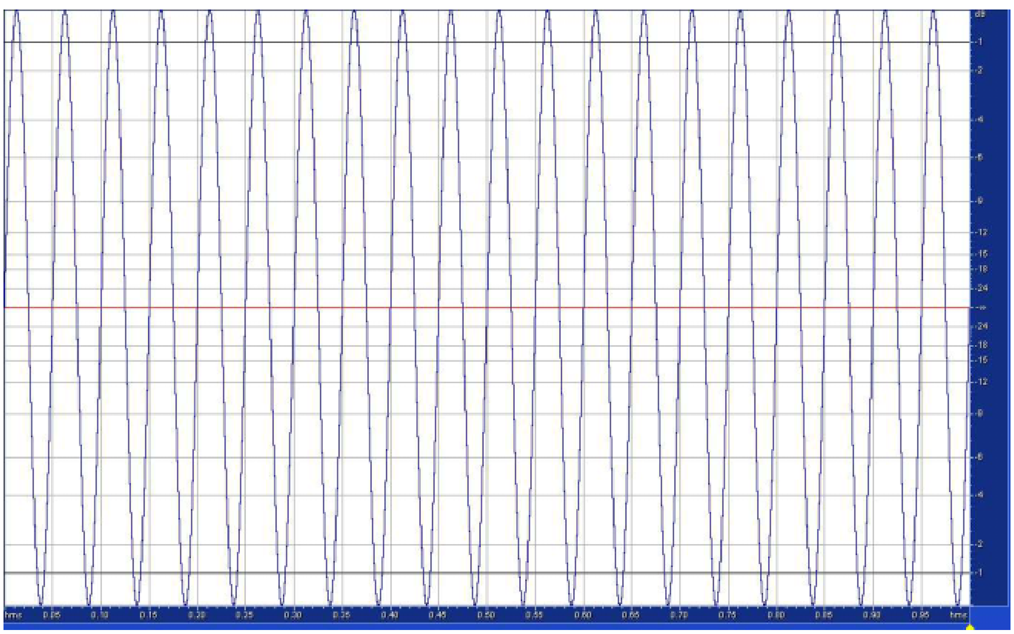
Here is a 20Hz sound shown for one second of time. Notice that during the one second of time we can count 20 complete cycles. The waveform shown is a simple sinusoidal wave, or sine wave for short.



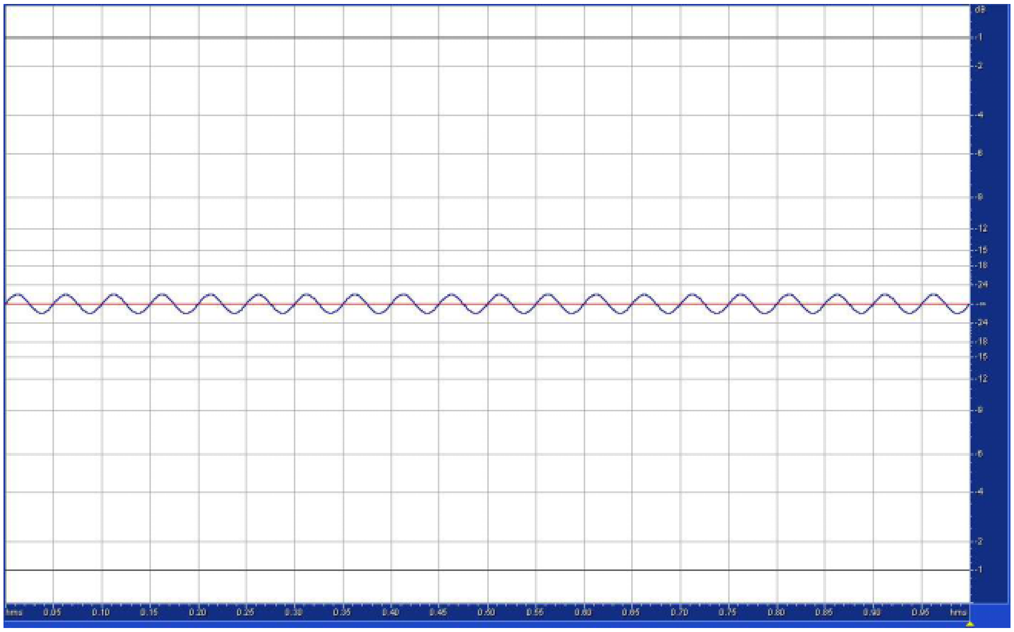
Here we show a 40Hz sine wave. Note that the pitch would be twice as high as the 20Hz pitch. In music, this is also called an octave (as in this pitch is an octave higher than the last one).



Here is the same 20Hz sine wave we saw earlier, but this is now much louder. Note that the highest points are higher and the lowest points are lower…thus creating larger swings in air pressure and a higher perceived volume, even though the frequency is exactly the same.

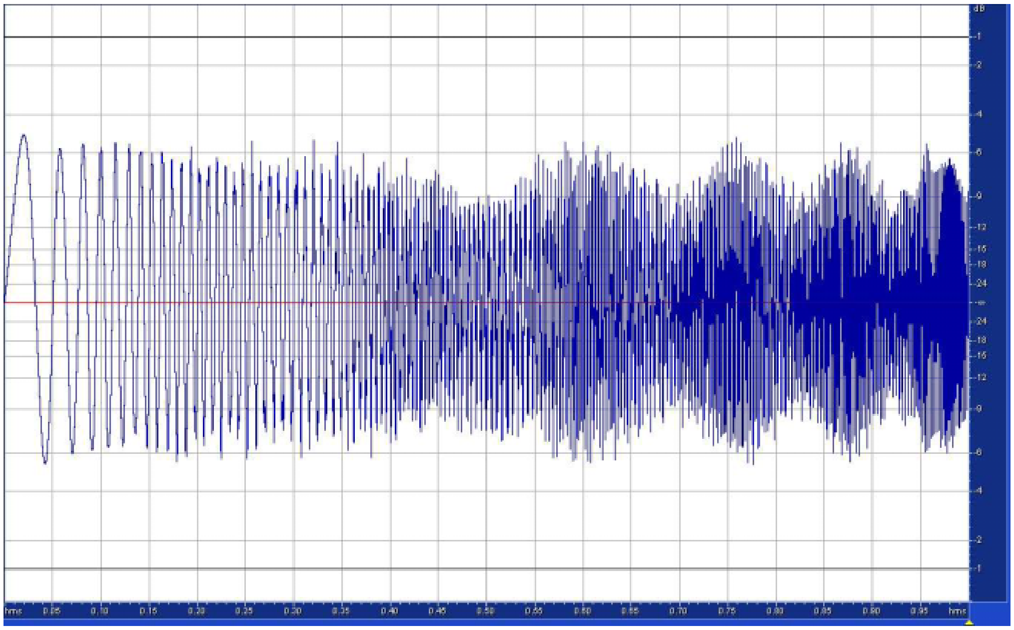


And again, we see a 20Hz wave, but this time it is obviously very soft. The high peaks are not very far away from the lowest peaks. In this way, we can depict small changes in air pressure (and thus a softer volume) even though the pitch is exactly the same.



In real life, there are few things that generate single frequencies at a time. Even musical instruments have a fundamental tone, as well as “overtones”. These other tones are frequencies that are generated in addition to the main frequency that is generated, and help us differentiate a violin from a flute, even if they are playing the same note. These other frequencies give the instrument color and depth. Moreover, other common objects, such as motors or engines generate a host of frequencies all at once…with each moving part generating its own sound and adding it to the other sounds. The resulting sound is called a complex sine wave, and these make up virtually all of the sounds we hear. Complex sine waves are the movement of air back and forth at many frequencies and many volume levels all at once. After these hit our eardrum, our brain is able to recognize and even dissect most of the sounds into things we have heard in the past (such as a violin, a jet engine, a blender, or a child crying).

Below we depict a typical complex sine wave showing many overlapping changes in frequency and volume. Note the general lower frequencies at the start, and higher prevalence of higher frequencies over time.



The important points of this section are:

A) Sound is generated by changing air pressure

B) The pitch is how fast the air pressure changes

C) The volume is how much the air pressure changes

D) Most sounds we hear are complex sine waves

2 What are Decibels?

In the last section, we discussed frequency and volume. We also learned that pitch is measured in Hertz (which is simply how fast the air is changing per second). The volume of a sound is measured in decibels (or dB). Technically, decibels are used to measure a comparison of two sounds, but since we use 0 dB as a reference, we may consider dB as an absolute in the case of sound.

The range of human hearing for frequency (or pitch) is about 20Hz to 20kHz. dB is not quite that simple. First of all the range of volume of sound a human can hear is enormous, from a loud rock concert all the way down to a cricket. It would take millions of crickets to equal the volume of The Rolling Stones live, so scientists developed a scale to measure sound that is logarithmic. The loudest sound the ear can hear without damage is about 10 trillion times louder (in sound pressure level) than the softest sound. Simply put, 3dB is not 1/3rd of 9dB, because the scale is not linear. In fact, noise is cut in half for every 3dB reduction, as measured by actual sound pressure, however our own perceived change in volume is about half as loud for every 10dB reduction. Said another way, each increase of 10 dB represents a 10 times increase in the power in the sound wave, but only a 2 times increase in the perceived volume by the human ear.

This may seem a bit complicated, but the important concept here is that a change from 50dB of noise to 47dB of noise is half the noise total energy. So a 1dB change has some real significance, even though it is only 1dB. But again, remember that our ears do not perceive a change in energy the same as perceived volume.

The following table shows various dB levels and the corresponding reduction in actual sound pressure as well as the human perceived volume reduction for reducing noise levels.

dB	Actual Sound Pressure Reduction	Perceived Volume Reduction
3 dB	50.00%	18.77%
6 dB	75.00%	34.02%
9 dB	87.50%	46.41%
12 dB	93.75%	56.47%
15 dB	96.88%	64.64%
18 dB	98.44%	71.28%
21 dB	99.22%	76.67%
24 dB	99.61%	81.05%
27 dB	99.80%	84.61%
30 dB	99.90%	87.50%
33 dB	99.95%	89.85%
36 dB	99.98%	91.75%
39 dB	99.99%	93.30%
42 dB	99.99%	94.56%
45 dB	100.00%	95.58%
48 dB	100.00%	96.41%
51 dB	100.00%	97.08%
54 dB	100.00%	97.63%
57 dB	100.00%	98.08%
60 dB	100.00%	98.44%
63 dB	100.00%	98.73%
66 dB	100.00%	98.97%
69 dB	100.00%	99.16%
72 dB	100.00%	99.32%
75 dB	100.00%	99.45%
78 dB	100.00%	99.55%
81 dB	100.00%	99.64%

Signal to Noise ratio (S/N) is often expressed as the dB difference between the wanted sound (such as someone speaking) and the unwanted sound (such as car background noise). So if a person were speaking at 75dB, and the car noise was 70dB, the Signal to Noise ratio would be 5dB. A few other important points to note:

1. A change of 1dB is generally not perceptible
2. A change of 3dB is just perceptible by most humans
3. Speech is somewhat understandable at S/N ratios of 0dB
4. Speech is highly understandable at S/N ratios of >6dB

5. Background noise becomes generally unnoticeable at S/N ratios of >20dB
6. A 3dB increase in volume requires 2X the power in an audio amplifier

The general range of human hearing is from ~0dB to 120dB. As a quiet library is about 30dB, we are rarely in environments that are quieter than that, so we don't often hear sounds below that level as they would be masked by the other sounds (or one might say noise) in the environment around us. On the other end of the scale at 120dB, this is considered the threshold of pain, where the ears begin to feel pain from the volume and above which, permanent damage to human hearing will occur. Rock concerts often run at 120dB and sometimes over 130dB if you are near the speakers. At 130dB, the eardrum is at its physical limits and is distorting the sound. The sound is getting distorted because the ear drum cannot move back and forth exactly like the air pressure that is hitting it, so it hits its limit and stops swinging until the air pressure reverses, then it hits its limit on that side as well. Hence, your brain is not able to get a perfect sine wave…for example. Instead it gets something that has a clipped top and bottom (approaching what is sometimes refer to as a square wave).

There is also a physical limit to how loud a sound can get in air. This is limited by the ambient air pressure. At approximately 194dB, the sound pressure would have to change more than the ambient air pressure. At this point, the sound wave would have to create a negative air pressure to get any louder than this. Since that cannot happen air itself distorts sound by "clipping" the sound wave. This is also known as a sonic boom. Sound moves in other ways in other materials such as steel and water, and hence sound will travel differently through these materials and have different limits.

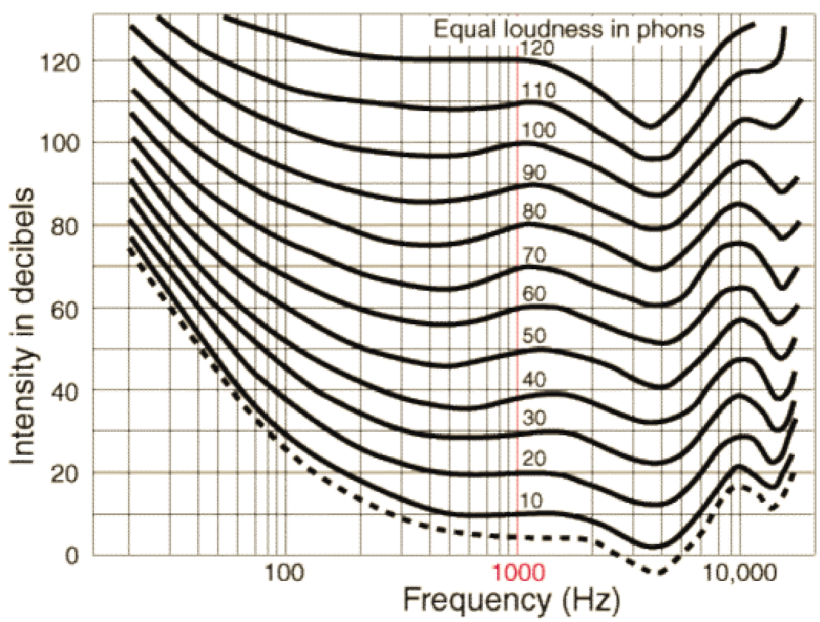
Here are some common generators of sound and their typical Decibel levels as well as OSHA exposure limits:

Maximum Exposure per day (OSHA)	Sound level	Decibel Level	Examples
	No Sound	0	Threshold of hearing…essentially no sound
		10	Breathing
		15	A soft whisper in someone's ear.
	Very Quiet	20	Whisper, rustling leaves
		25	Recording Studio
		30	Quiet rural area, Very quiet library.
		40	Very Quiet Residence
		45	Typical neighborhood.
	Quiet	50	Quiet suburb, conversation at home, Private office
		60	Normal conversation (3-5 feet), sewing machine, typewriter.
	Annoying	70	Freeway Traffic at 50 feet, vacuum cleaner
		75	Typical car interior on highway
	Loud	80	Garbage disposal, dishwasher, average factory, Telephone dial tone, Noisy office
16 hours		85	City Traffic (inside car).
8 Hours		90	Power drill, shop tools, Busy urban street, diesel truck, food blender
6 Hours		92	Clarinet, Oboe at 10 feet
4 Hours		95	Subway train at 200 feet
3 Hours		97	French Horn at 10 feet
2 Hours	Very Loud	100	Jet takeoff 1000 feet, Outboard motor, farm tractor, garbage truck, Very heavy Traffic
1.5 Hours		102	Motorcycle
1 Hour		105	Power mower
		108	Home Theater (loud peaks)
0.5 Hours		110	Chainsaw, pneumatic drill, typical rock concert, Steel Mill, riveting, auto horn at 3 feet
0.25 Hours		115	Jackhammer
0 Hours	Pain threshold	120	Loud thunderclap, typical live rock music
Hearing damage occurring		125	Pneumatic riveter at 4 feet
Ear drum distortion		130	Jet takeoff (300 feet), Noise level during a stock car race.
Permanent hearing damage		132	Very loud rock concert, 50 feet in front of speakers
		140	Gun muzzle blast
		140	Prop aircraft on takeoff, gun muzzle blast, aircraft carrier deck, jet engine at 100 feet
Eardrum rupture		150	Jet takeoff 75 feet
		155	Shot from a handgun (.38 or .44) at 1 foot
		160	Jet aircraft on Takeoff at 30 feet
Immediate death of tissue		180	Jet engine at 1 foot
		194	Loudest sound in air, air particle distortion (sonic boom)

When we measure decibel levels, we often do so using a scale called “A weighting”. It turns out that human hearing is not perfect. We perceive sounds at some frequencies and volume levels louder than others, even though the changes in air pressure are exactly the same. So a “weighting” of the dB scale was devised to better represent the actual way most people perceive sounds. In this way, measurements more accurately represent what you would hear in terms of loudness across the frequency range. This is referred to as dBA, and most noise measurements are done in this way.

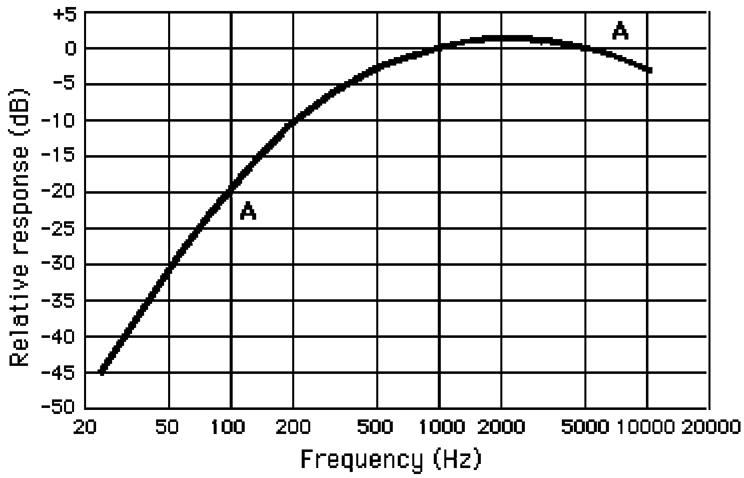
Our ears are not as sensitive to low frequencies (bass) as we are for speech (around 1kHz). The sensitivity of our ears can be plotted showing, for instance, that to sound as loud as a 1kHz tone at 60dB would require a 102dB 20Hz tone to sound as loud to us. Note also that our sensitivity not only changes with frequency, but also with volume levels.

Human Ear Equal Loudness Curves:



The result of understanding the ears sensitivity gives us a reverse curve, which is used for the dBA measurements. By using this curve as a correction value to a flat measurement, dBA measurements more closely approximate how humans will perceive the sound or noise they hear.

dBA Contour:



When we consider decibel levels in a room for instance, we often look at the loudness of the sounds we want to hear as well as those we don't. For instance, we might be in a quiet library at 30dBA (referred to as the noise floor because it is the background noise in the room) and we want to know if installing a certain copier will increase that noise level. When we run the copier, we find that in chairs nearest the copier, the noise level goes to 52dBA, and this might be unacceptable to patrons and staff. In this case, the copier is 22dB above the background noise level.

Now lets consider a typical condo, which might have a background noise level of 45dBA on a very quiet day. You like to watch TV at a moderate volume of about 60dBA, which is 15dB above the background noise. A new neighbor moves above you and has a home theater, which he plays loudly every night. When he is playing it you cannot hear the TV because his sound is getting into your space and resulting in a sound level in your room of 75dBA, which is 15dB louder than your TV. We might also consider a typical factory, with many motors moving belts, HVAC, and vibratory feeder bowls, all of which raise the noise level in the factory to 90dBA. When the factory is empty and the machines are off, the background noise is 52dBA. Here, the noise is 38dBA above the background level, and at 90dBA, exceeds recommended long-term exposure levels for workers. We will look at how these, and many other noise problems are solved in coming sections.

3 Noise Propagation

We have reviewed how sounds are generated, how they move through the air, and how we perceive them. Also, we learned how rapid changes in air pressure caused by a vibrating object can be measured, both in pitch (Hertz) and in volume (decibels). Sound waves move through the air with some natural loss (about 6dB for every doubling of the distance in the open over the ground). Also, sound waves reflect off of other surfaces, some more, and some less depending on the material, so the sound coming from one source can easily fill every corner of a room by propagating out in all directions and by reflecting off of the surfaces in the room. So we can picture these waves moving through the air, but how does the sound get into one room from another above it? Simple.

The first thing to understand is that changes in air pressure not only move our eardrums back and forth (that is how we hear), but also move other objects back and forth. For instance, if we were to make a wall out of cellophane (thin plastic wrap), and stretch it from floor to ceiling in a doorway, sealing off all the airflow from one side to the other, do you think you could hear someone banging a bass drum on the other side? The answer is, of course you can! Even though no air is flowing between the bass drum and you. That means that the bass drum vibrating generated rapid changes in air pressure (sound waves) that hit the cellophane, vibrating the cellophane in an almost identical fashion. The cellophane vibrating creates rapid changes in air pressure on your side (just as the bass drum would have directly done), which travel and hit your eardrum. Because the cellophane essentially reproduced the vibrations of the bass drum, you hear the bass drum, as if the cellophane were not there. Now… we said *essentially*.

The cellophane can cause some distortions in the original sound. This occurs for many reasons. First of all, the cellophane has a certain mass that, like most materials, is larger than air. It requires some energy (ie more energy than simply moving air) to move the cellophane back and forth, and that energy is dissipated as (or converted to) heat energy. While this small amount of heat is impossible to measure, it fits within the requirements of “conservation of energy”, which states that energy cannot simply disappear, but must be converted into another form of energy (ok, for those true physics majors, energy could be converted to mass theoretically, but we will forget about that for the purpose of this paper, since it won’t happen at the speed of sound).

Now, as we move farther away from any sound source, that sound generally gets softer. This is due to sound waves not only spreading out in every direction, but also the fact that the rapid changes in air pressure that make sound dissipate energy through the air, because even air has some mass. This loss of energy, through air, and more so through objects, causes the sound to get softer due to energy converting to minute amounts of heat, and thus, a lower dBA level.

In our cellophane example, we still hear the bass drum through the cellophane, but it should be a bit softer (due to the mass of the cellophane) than if we had no cellophane in the way.

Now lets suppose we remove the cellophane from the doorway and close the door. The door likely has much more mass than the cellophane, and thus will dissipate more energy. Yes, the door itself will vibrate as the bass drum does, re-generating the bass drum sound on the other side. However, the loss through the door will be more than the cellophane, which was more than air. Thus, we might suppose that standing 6 feet from the bass drum, we would hear a sound measured at 90dBA through air, 89dBA through the cellophane, and 75dBA with the door.

There are other distortions of the sound that occur in addition to volume reduction due to mass. Many materials simply cannot faithfully reproduce sounds at certain frequencies. They, in essence, overload (just as our ears do at high volume levels) and do not reproduce the sound waves faithfully. Hence, they may shift the frequency, or have certain frequencies that "resonate". Every material has a resonant frequency (or often several) where they naturally vibrate. It not only depends on the material type, but also on the size and thickness of the material. A gong for instance is a certain size and shape and of a certain thickness and material to produce a strong fundamental frequency just by being hit by a mallet. However, when a gong is struck by other sound waves, it will naturally want to also produce its fundamental, or resonant, frequency. Just as it has a resonant frequency, it has other frequencies that it cannot produce well, as it has a difficult time vibrating at a particular frequency. Hence, when struck by sound waves, it will take some of that energy and convert it to its resonant frequency, take some and reproduce it, and take some and convert it to heat energy. So if one could construct a door out of gong material (size and shape as well), one would not hear the bass drum reproduced faithfully, but instead have a variety of additional frequencies not part of the original, as well as others that have been softened significantly. As such, walls, floors, metal housings and the like all affect sound in a variety of complex ways, not only by potentially reducing the volume (due to increased mass) but also by adding to the original sound. If these materials add to the original sound in certain ways, it can actually sound louder to the person than the original sound was. How can this be? Two reasons.

First, as all objects have resonant frequencies, much of the original sound energy can be converted to a fundamental resonant frequency when passing through the barrier (such as metal or wood etc.). So while other frequency components will lose volume, one or more could gain volume, resulting in passive amplification. To the unappreciative listener, the noise just got louder, even though there is a barrier between you and the noise source. This property is sometimes referred to as frequency shifting.

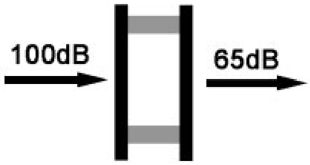
Second, remember we talked about A-weighting in the decibel scale? A-weighting exists because our ears are more sensitive to certain frequencies than others, and attempts to weight the dB scale to accommodate this. So, if some if this "frequency shifting" occurs in such a way to shift more of the energy into frequencies that are more sensitive to our ears, you will perceive it as being louder than the original source.

Beyond the mass of objects, there are other properties that can shift or dissipate energy. Most solid objects are just that—solid. That is, as a metal panel is deformed by a sound wave, it almost immediately returns to its original form and can easily continue to "vibrate" at a rapid speed. Provided the metal has not been deformed beyond repair by the sound (it would probably be nearly impossible to deform metal that far with sound alone… a hammer would be more likely), it is always ready for the pressure to reverse and swing in the other direction.

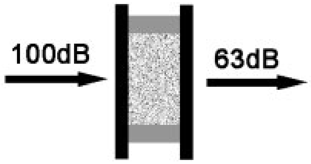
There are some materials however that, when deformed within a certain range and at a certain speed (i.e. frequency), prefer to stay there for a while, yet are not deformed beyond repair. These materials will come back to their original shape and position in some period of time. This property is called viscoelasticity, so the material is said to have viscoelastic properties. There are few naturally accruing materials like this, however you may have seen or used a “Tempur-Pedic” mattress, which uses a viscoelastic foam material that is deformed by weight and heat (of your body), yet will return to its normal shape in 5-10 seconds. This material is viscoelastic in a certain temperature range and across a certain frequency range (which is very low, <1Hz in the case of the mattress). That is, the mattress may not demonstrate any viscoelasticity at high sound frequencies (such as 20kHz), and may revert to just being a solid mass at those frequencies.

Of course, liquids and other gases have their own sound propagation properties, but in most cases in homes and commercial environments, we are usually dealing with solid objects, so we will limit our focus to solids for now.

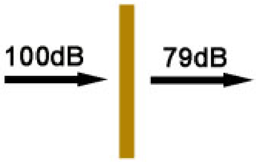
The diagrams below demonstrate a variety of sound propagation through common materials and the amount of sound on 1 side versus the other:



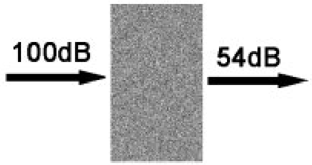
Typical wall



Wall with insulation



Plywood



8" thick Concrete Wall

Noise propagating through any solid object is further complicated by the fact that few objects are complete barriers. For instance a door likely does not make a perfect seal around the edges and may have a large opening at the bottom to keep from hitting the floor. Metal housings, unless fully welded on all sides, likely have many places where air can get through. And walls and floors are far from airtight seals. Sound waves, like water, will find any leak to get through. Since air offers less resistance to sound (air pressure changes) than a piece of metal, much of the sound energy will exit any structure through air openings in the barriers. So, a 5-foot square 1" thick lead wall might reduce the noise traveling from 1 room to another by 50dBA. However, if there were three ½" holes for wires in the lead wall, the majority of sound will exit through those holes, reducing the effectiveness of the wall from 50dBA to 20dBA. Hence, the total system must be considered in any noise reduction problem.

4 Reducing Noise

When considering reducing noise in any system (from a lawnmower to a car to a machine to a home to an apartment), four major tradeoffs need to be considered. These are primarily weight, space, cost, and aesthetics. Given enough money, and unlimited weight and space, one could construct a 10-foot thick lead barrier, welded on all sides. Given the mass of this barrier, it would take considerable sound energy to make it vibrate, so the loss through it would be significant, likely exceeding 120dBA (meaning that a 120dBA sound on one side would be reduced to 0dBA on the other). In construction, this is called Sound Transmission Class (or STC rating). For machines and other industries, it is measured in other ways, primarily as a loss factor, and is not as easily converted to an actually dBA sound loss without further measurement on the machine itself. However the concept itself is called “mass loading”. The idea (in essence) is to place extra mass between the noise source and you. One could also weld lead onto many metal surfaces of a car to mass load the vehicle and make it quieter. Remember, more mass is harder to push and pull (with air pressure), so the energy is converted to heat.

However, few applications have an extra 10 feet to spare, let alone the cost (exceeding a few hundred thousand dollars) and the weight (exceeding 20 tons). It also turns out that to achieve reductions above 5-8dBA in any system requires significant additional mass. In fact, mass loading, while 200+ years old (technology wise), is not a very efficient method of dissipating noise and vibration. And most applications cannot afford the significant cost or weight it requires.

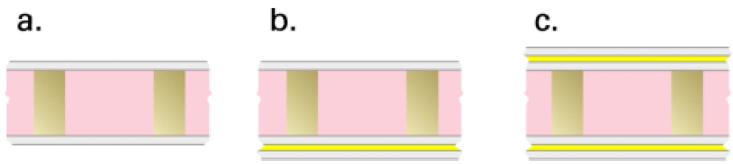
There are many examples of mass loaded materials for soundproofing however including mass loaded vinyl (typically at 1 pound per square foot) as well as asphalt based mats. It is possible with good mass-loaded vinyl to achieve stand-alone isolation reductions of 27dBA, resulting in 5-8 dBA of loss in a wall system.

Another method is by creating many surfaces for the sound to vibrate, each one having little loss, but in aggregate, absorbing a fair amount of sound. Closed-cell foams are popular for this, however they are good for reducing sound WITHIN a room, they rarely have much transmission loss through them. So they do not make good barriers. One can imagine the sound waves passing (and vibrating) each little cell of foam. There may be hundreds of cells that need to be vibrated before the sound has passed all the way through the material, thus causing a small amount of reduction, but a large amount of reduced reflections.

The newest technology in the noise-barrier field exploits the viscoelastic properties of some materials. By formulating special chemicals that are very viscoelastic, they can be deformed by sound waves, take time returning to normal, and within a range of temperatures and frequencies, reduce noise and vibration by 10-20dBA per layer or more. There are two types of viscoelastic materials. Free (unconstrained) layer damping is the simplest way of introducing damping into a structure. The treatment consists of a layer of damping material bonded to the surface of the sound generating source or a sound barrier (such as metal or plastic). The coating goes through tension/compression deformation, along with the bending of the metal, resulting in dissipation of energy. The material is low cost, typically 1mm think, and low weight. Constrained layer viscoelastic damping is among the most efficient ways of introducing damping into a structure. This requires the viscoelastic material to be placed between 2 other rigid materials (such as metal, plastic, wood, drywall etc.). It must also have adhesive qualities to bond directly to both outer layers to work effectively.

There are also materials (typically foams and fabrics) for sound absorption within a room. These work primarily by reducing reflections of sounds from surfaces (such as walls and ceilings). They do not stop sound from passing through them. Materials that work well for reducing reflections often are not very good at reducing sound transmission (through them). For instance, while some foams make excellent sound absorbers within a room, they don't make a very good sound barrier. Vinyl (mass loaded), makes a fine barrier, but a poor absorber. So the right material needs to be chosen for the right result.

As we saw in the last section, various materials (such as concrete or gypsum) have a certain amount of sound transmission loss. This loss is mostly due to its mass. But what about adding some viscoelastic material, rather than mass? The results can be excellent. For example:



The above diagram represents typical inside wall construction (2x4 studs with 5/8" gypsum wall).

a. Represents existing/typical construction. This wall has an average STC rating of 34 with R11 Insulation

b. Represents that same wall with viscoelastic glue between drywall on one side. The STC rating (the amount of sound isolation from one side to the other) is improved by 10-15 dB over (a), to 44-49 dB (with R11 insulation)

c. Represents that same wall with viscoelastic glue between drywall on both sides and R11 insulation. The STC rating can be improved by 15 to 20dB over (a) to 49-54 dB.

Because the yellow layer is a viscoelastic glue, it works by converting acoustic and vibrational energy into minute amounts of heat. This is very different than mass-loading or wall-fill techniques, and is easily achieved in existing construction at a low cost.

It is critical in every noise reducing application that all air gaps are filled. Otherwise, noise will always take the path of least resistance, which inevitably will be the air. In sheet metal applications (such as machines and auto) this may be done in a number of ways, including adding metal, sealing with rubber or self adhesive patch, or using gaskets to seal doors etc. In construction, a good acoustical sealant (one that never skins over… i.e. never dries) is the best bet. Every wall seam must be completely airtight, between panels, and between floor and ceiling, as well as around wall outlets.

In conclusion, there are a variety of techniques to reduce noise and vibration in a variety of structures today. Every method relies on 1 of 2 principals, mass or viscoelasticity. Both methods can be effective, depending on how much material one would want to use. However, noise propagation is very complex, and even though materials are tested to absorb structural vibration does not mean it will eliminate any particular noise problem. As noise becomes airborne near the source, the sound will travel through the air with little to stop it. The more the source can be treated, or isolated with air-tight barriers treated with viscoelastic or mass-loaded techniques, the opportunity to meet your needs for quiet are enhanced.