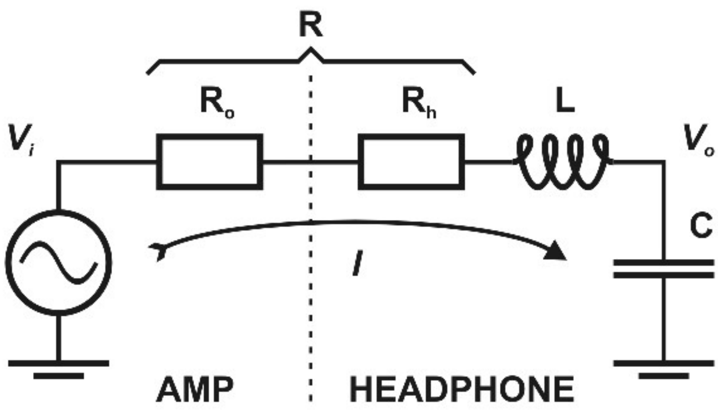
AUDIO SCIENCE GUIDE

Musings on Headphone Amplifier Output Impedance

By Jan Meier Tyll Hertsens • Posted: Nov 18, 2014



Ed Note: Dr. Jan Meier, of Meier Audio, recently submitted this article for me to consider publishing. He and I have had many a discussion, and quite a few disagreements, about the nature and effects of amplifier output impedance over the years. While I still have some concerns with his view brought to light here (I'll intersperse some of my comments in italics through the course of the article), I have moved away from the simple view that lower output impedance is always better. The following article does a lot to show a bit more sophisticated view of factors involved, and I thought it would be useful for InnerFidelity readers.

I also need to note, for ethical purposes, that no compensations have exchanged hands, the article was freely submitted with no promise of compensation or publication. The publication of this article should in no way be taken as an endorsement for Meier Audio Products. (Though, I do have his Corda Rock here, that Skylab reviewed and placed on InnerFidelity's "Wall of Fame", and find it a dandy amp for the price.) I am publishing it because I found it interesting and stimulating to my desire for more knowledge on the topic.

And now, Dr. Meier....

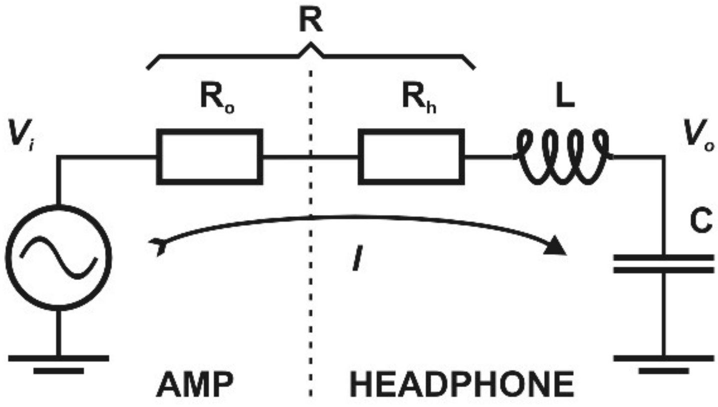
Greetings InnerFidelity readers!

Occasionally I meet people who tell me that a lot of what I do is totally wrong. In my amplifiers I use the wrong capacitors, crossfeed is a hoax, and it is impossible to built a decent amplifier with transistors and without tubes. When I ask them whether they have ever heard one of my amplifiers or ever designed/made an amplifier of their own, the answer is "No". But they have read in this or that article that capacitors of brand X are much better than the ones that I use; that crossfeed only hampers the purity of the signal; and that transistors only create tons of TIM-distortion (whatever that might be). It is written down, it must be true, right!?

But the written word is not all-knowing and, in my experience, sometimes can be quite wrong. Authors are just human after all.

One of these statements repeatedly made in articles on amplifiers and speaker-control is that a low output impedance (high damping factor) should result in the best control over the driver action since energy stored in the driver system should be removed as quickly as possible. However, in those articles a real explanation is never given why a lower output impedance indeed results in faster energy decay. To be honest, thinking about it this statement never made real sense to me. Dumping current into a zero Ohm resistance doesn't dissipate any extra energy at all. So what's really going on?

The network in the figure below presents a (very) simplified model of a driver system that contains three elements only:



- A conductor L that is the equivalent of the inductivity of the driver's coil.
- A resistor R that is of the sum of the coil's ohmic resistance (Rl) and the output impedance of the amplifier (Ro).
- A capacitor C that represents the mechanical elements of the driver that store energy (like the suspension and compressed air).

Ed Note: I'd like to not that this simplified circuit is very far away from what a modled headphone might look like. However, the concept being explored here is about the operating principles of reactive loads, and for purposes of conveying the concept being discussed, I find it perfectly adequate.

The output voltage Vo should follow the applied amplifier voltage Vi as close as possible. The mechanical energy stored in the system should stabilize as quickly as possible after the input signal reaches a fixed level.

The lumped network in the figure is a so-called linear system. Any input-signal can be considered as the summation of a long series of successive impulses. Any output-signal can be considered as a summation of the correlated impulse responses. The response to a single impulse is a good indication how closely the system can follow the input signal.

I will not bother you with a detailed analysis of the network and how we can calculate its response to an input impulse. I will merely present you the final results. Basically there are four different situations to be distinguished:

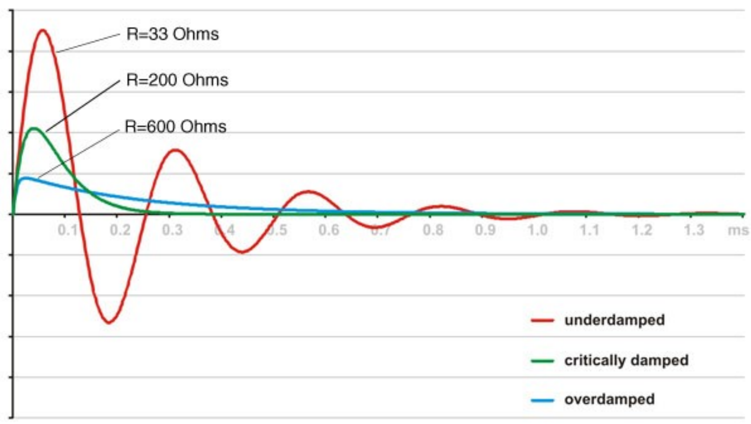
1. The first situation is when the resistor has zero resistance. The network then contains no elements that dissipate energy. The output signal continuously oscillates at a fixed frequency. This is a virtual system as it is not possible to produce a driver/coil that has zero impedance and (normally) amplifiers do have an output impedance that is higher than zero Ohm.

$$V \sim \sin(wt) \qquad R = 0 \qquad w = \sqrt{\frac{1}{LC}}$$

2. For small values of R during each cycle of the oscillation a little bit of energy is dissipated by the current through the resistor (producing heat). The signal-amplitude of the cycles thereby continously decreases. This is called underdamped oscillation. Amplitudes decay with a time-constant 2L/R. The red line in the figure below shows the impulse-response for R = 33 Ohm, L = 4 mH, C = 40 nF.

$$V \sim a.e^{-at}.\cos(wt+p) - w.e^{-at}.\sin(wt+p)$$

$$R < 2\sqrt{\frac{L}{C}} \qquad a = \frac{R}{2L} \qquad w = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} \qquad p = \arctan\left(\frac{-R}{2Lw}\right)$$



3. When the value of R is increased to a value where in the formula above w=0 the signal no longer oscillates. After an initial bump the signal continously decays and goes to zero relatively quickly. This situation is called critical damping and is shown by the green line. R = 200 Ohm.

$$V \sim t.e^{-at} \qquad R = 2\sqrt{\frac{L}{C}} \qquad a = \frac{R}{2L}$$

4. If R is increased even further the signal decay becomes more slowly. The large resistor value doesn't allow for a fast (dis)charging of the capacitor. We now have overdamping. The blue line shows the situation for R = 600 Ohm.

$$V \sim e^{-(a-w)t} - e^{-(a+w)t} \qquad R > 2\sqrt{\frac{L}{C}} \qquad a = \frac{R}{2L} \qquad w = \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

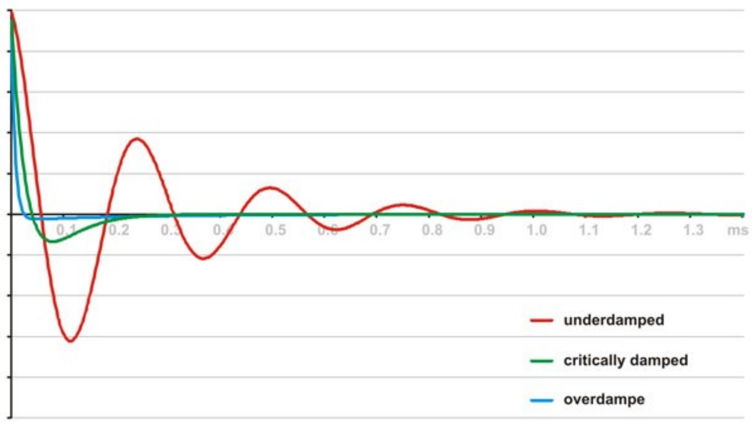
It is easily recognized that critical damping provides the fastest and most stable response to an impulse signal. R should be closely matched to the values of L and C. However, be aware that its value is the sum of the output impedance of the amplifier and the ohmic resistance of the coil. If the latter is (too) small then the system may profit very well from a higher output impedance.

(Note for the mathematicians: the three impulse-responses shown in the figure are scaled such that they will result in the same over-all sound pressure. That is, the surface-integrals of all three curves have the same value!)

Have you ever studied the various headphone measurement diagrams as measured by Tyll? Many headphones show very distinct oscillations when fed with short impulses. However, these oscillations do not necessarily have to be caused by inadequate electrical impedance matching. They could well be caused by factors like driver break-up or cavity-resonances that are not necessarily shown in the electric parameters/characteristics of the headphone. The presence or ringing doesn't necessarily imply inadequate electrical damping. For this we have to investigate any ringing in the electrical current as delivered by the amp.

Ed Note: This is a very important paragraph. What we're talking bout here is the electrical signal going into the headphones. Many headphones do show ringing in various ways, but I do think most of that is due to acoustic issues and not electrical issues. The electrical impedance matching issues talked about here, in my opinion, will have relatively small effects on headphone listening fidelity relative to the acoustic design of the headphone. None the less, based on my past experience with headphones, I would think these electrical impedance matching issues may be audible enough to warrant investigation.

The next picture shows the current responses of the LCR-circuitry discussed above for underdamping, critical damping and overdamping.

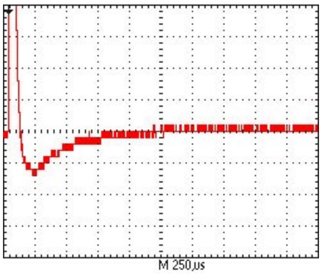


To measure the current response of real headphones an amplifier was build that allows to monitor the current flow while applying a signal to the headphone. The effective output impedance of this amp can be varied in discrete steps, negative output impedances included, and ranges from -81 ohm to 208 Ohm.

Ed Note: As odd as it might seem, there is such a thing as a negative output impedance. See half way down this page.

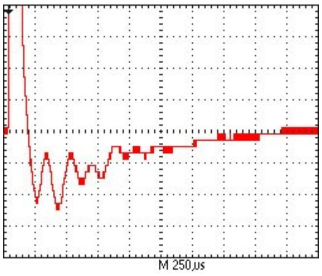
Some results:

Axel Grell, the chief-designer at Sennheiser, once told me that their top-of-the-range headphones are always designed to sound best at a low output impedance. The figure below shows the current flow of a HD-800 with the amplifier having an output impedance of 0 Ohm. There is no oscillation. Just a nice bump after the initial pulse-current, as could be expected from a critically damped system. Increasing the output impedance to 120 Ohm decreases the bump, indicating a slower impulse response, as expected from the theoretical example. This is as good as it can get. True textbook delivery. People at Sennheiser know their stuff!

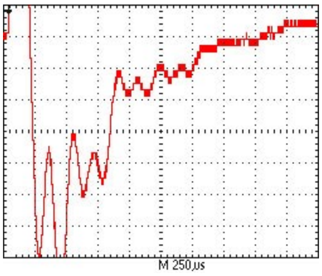


The HD-800 has a relatively high coil-resistance of 300 Ohm. Thus there is enough resistance available for proper damping. However, over the years there has been a clear tendency towards headphones with much lower impedance values. The reason is simple. They go louder with lower signal voltages—the output voltages of modern portable players is very limited...and for many the louder the better.

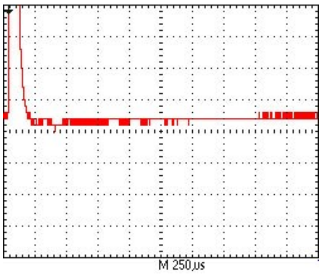
The next figure shows the current response of the AKG K420. This headphone has an impedance of only 32 Ohms and a very high efficiency. At zero output impedance clear oscillations can be distinguished at a frequency of around 5 kHz. This doesn't look nice, does it?



And the situation gets worse at a negative output impedance of -18 Ohm. Brrr. Not pretty at all, right?



On the other hand, when increasing the output impedance the oscillations get smaller and smaller and are completely gone at +88 Ohm.

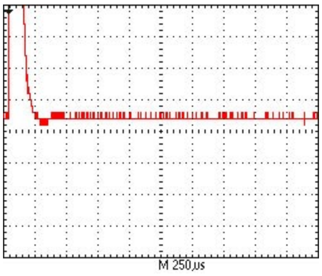


It is clear that an increased output impedance does improve the electrical response of the K420 considerably. Whether it also shows in the acoustic impulse response unfortunately I can't tell. Maybe Tyll is able to do some measurements.

Ed Note: Unfortunately I don't have an AKG K240 to try. I did, however, take a quick stab at measuring output current to headphones to see if I could replicate Jan's findings and was unable to do so. I'm not sure my gear has the appropriate differential inputs to look at the current signal through a resistor. Additionally, I did a quick and dirty look at a couple of mediocre performing headphones to see if I could observe a change in square wave response as I varied output impedance. Just a gross test looking visually at square waves, and didn't observe any changes. That's not to say they weren't there, just that my method wasn't very sensitive. The only thing I can say for sure after doing my experiment is that if electrical ringing is occurring, it's not of a magnitude similar to that of acoustic resonant problems seen in my measurements. I'll take another stab at it one of these days though, because this a pretty interesting subject, in my mind, and Jan's article has gotten me quite curious.

(Note: the three figures above where measured at similar sound levels. The amplitude of the input pulses Vi is increased with increasing output impedance Ro of the amplifier to compensate for changes in sound level created by this impedance.)

The membranes of magneplanar drivers have a large surface and very low mass. Therefore they are already highly dampened by air. Proper electrical damping is of less importance. This figure shows the current for the Hifiman HE-500 driven at 0 Ohm output impedance.



Changing the effective output impedance only had very little effect on the current. It is the reason that current-amplifiers (instead of voltage amplifiers), like the Bakoon, which by nature have an extremely high effective output impedance, do work well with magneplanar headphones.

Summary

From the examples above it becomes clear that the best output impedance is not necessarily a low one. Increasing the output impedance may well reduce any oscillatory behaviour of the driver. Sure, it can slow down the response of the driver but sometimes that's a good thing. If you feel your headphone is a little bit 'hot' then increasing the output impedance using an adapter between headphone and amp (or by soldering resistors into the headphone or the headphone-plug) may well be a solution. I've had various customers who reported very good results with a large variety of headphones. Trust your own ears and experiment with various resistor values. Simply use the one that you personally like most.

With portable players the use of resistors/adapters can have an additional positive effect. Internally these players often have coupling capacitors at the headphone output that prevent offset voltages reaching the headphone. However, in combination with the impedance of the headphone these capacitors make a high-pass filter. Low frequency signals do not reach your headphones at all.

With a capacitor value of 47 uF and a headphone resistance of 30 Ohm the cut-off frequency is a whopping 113 Hz! Adding 47 Ohm to the headphone will reduce the cut-off frequency to 44 Hz. This is as good as a bass-boost. The only drawback is, that you now have to turn-up volume control a little bit further (which actually can be benificial of its own if it is a digital control as this will increase the effective resolution of the digital signal).

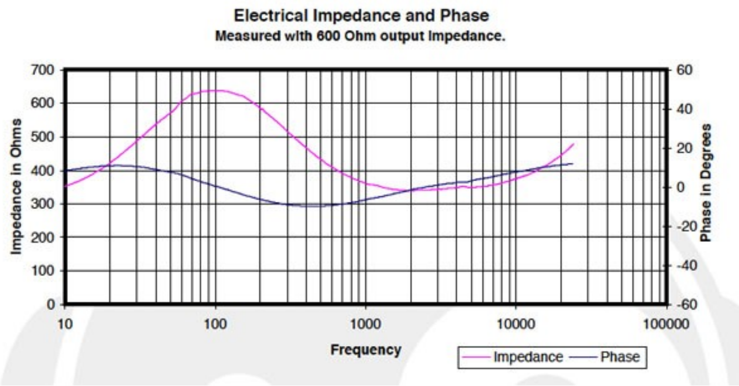
Many headphone-addicts prefer tube amplifiers over solid-state equipment. These preferences may well be (partly) explained by the fact that by nature tube amplifiers do have higher output impedances than transistor amps. With many headphones this slightly slows down responses but also suppresses oscillatory behaviour. These people may well try adapters when using transistor-gear.

Cheers,

Jan Meier

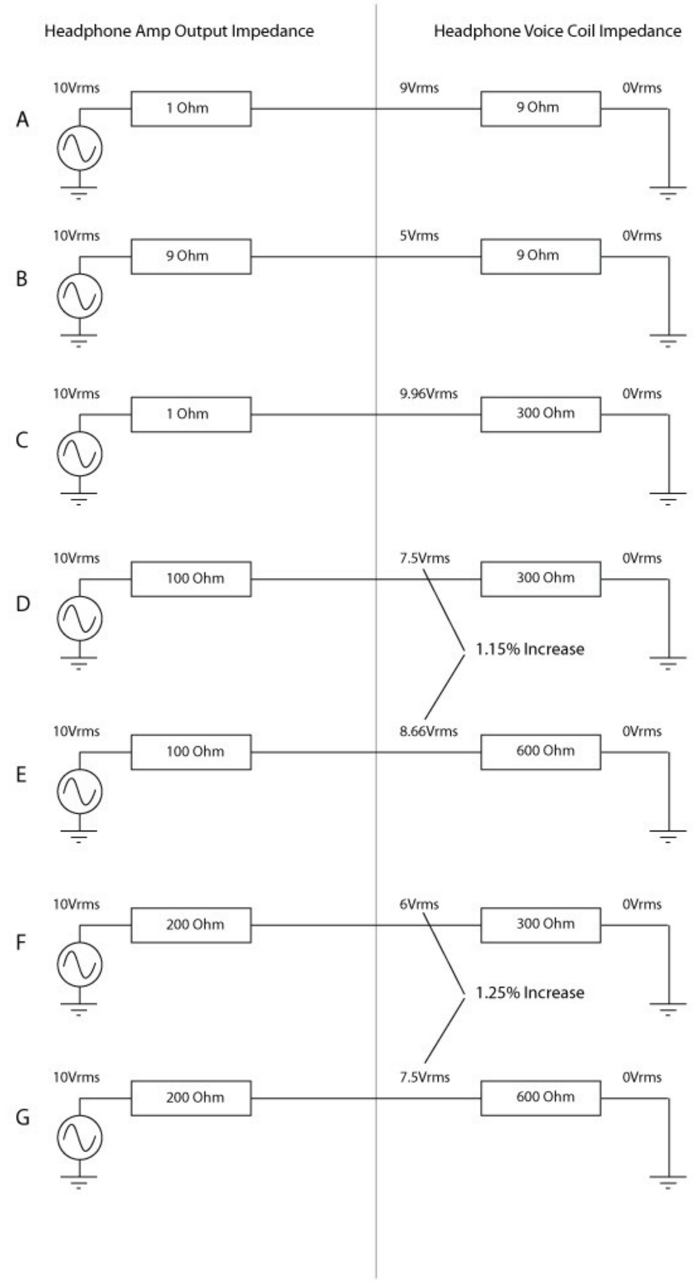
Ed Note: While I agree that the suggestions in Jan's summary have significant merit, I think there are mitigating circumstances that may argue against that approach. The most important one to my mind is the case of headphones that have widely varying impedance with changes in frequency. Let me explain...

First, let's have a look at the impedance response of a Sennheiser HD800.



In the above plot, you can see that the Sennheiser HD800 has a peak impedance of about 650 Ohms at 100Hz, and a low impedance of about 350 Ohms at 3kHz. I'm going to try to keep the math easy here for illustrative purposes, so let's say it's 600 Ohms at 100Hz and 300 Ohms at 3kHz.

Now, you're going to need to know about how a voltage divider works. here's an illustration.



Here's a series of very simple circuits. The left side is the headphone amp and the resistor models the output impedance of the amp, and on the right is the headphone with the resistor modeling the headphone impedance. To the far left of each circuit is a signal generator putting out a 10Vrms signal. The 10Vrms signal has to go through both resistors to get to ground on the other side.

In case "A", there is a total of 10 Ohms resistance between the two resistors. With a 10Vrms signal across 10 Ohms it will loose 1Vrms for every Ohm. So it will loose 1 Vrms across the 1 Ohm resistor and 9Vrms across the 9 Ohm resistor. so there will be 9Vrms between the two resistors. This is called a voltage divider.

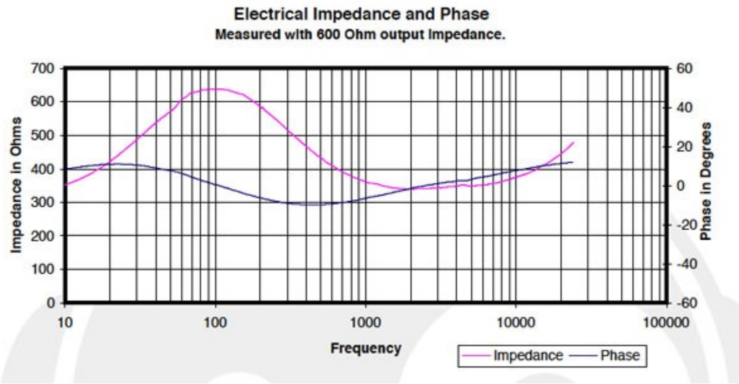
In case "B", the value of both resistors is the same at 9 Ohms. Because they're the same each will loose half the total voltage, so there will be 5Vrms measured between them. Now if each resistor was 18 Ohms, or 100 Ohms, you would still get 5 Vrms between the two resistors because it's the ratio or resistances that count, and not the absolute value.

Case "C" is to model a typical low output impedance, solid-state amp with 1 Ohm output impedance driving an HD800 at 3kHz and 10Vrms. (10Vrms is way too high, but it's a convenient number so let's just use it for now.) Because the output impedance is so low, almost all the voltage is dropped across the headphones. This is good because it means all the drive from the amp is going to the headphones and little energy is being lost as heat across the output impedance of the amp. (The power lost as current goes through a resistor is done so in the form of heat.)

Case "D" would be typical of an output transformerless (OTL) tube amp that have output impedances in the range of 100 Ohms. Here, about 1/4 of the voltage is dropped within the amp across the output impedance, and only 7.5Vrms is left to drive the headphones.

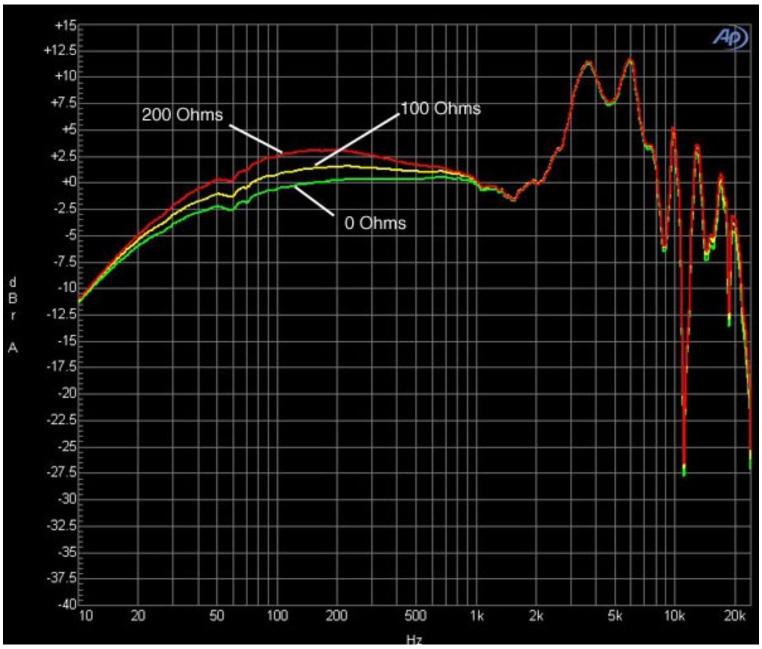
Case "E" is the same amp, but this time is putting out 10Vrms at 100Hz. At 100Hz the impedance of the HD800 is 600 Ohms, and now there is 8.66Vrms across the headphone coil. In other words, because of the high output impedance of the amplifier and the changing impedance of the headphones, they get more drive voltage when their impedance is higher...without any change to the volume control.

Case "F" and "G" show the same headphone impedances, but this time with a 200 Ohm output impedance. The important thing to note here is that the higher the output impedance of the amp, the more effect changes in headphone impedance with frequency will have.

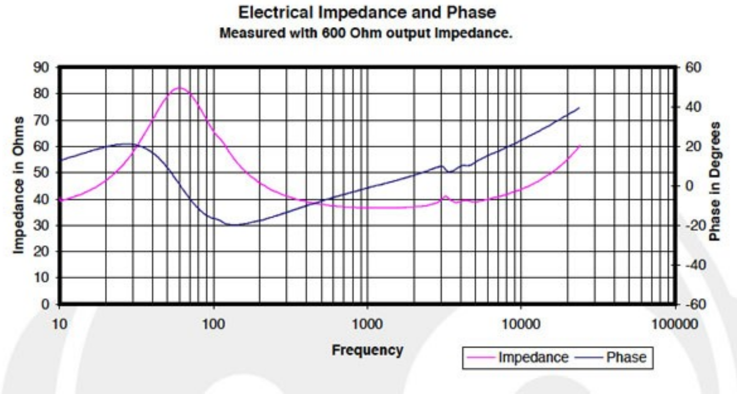


Again, look at the impedance plot of the HD800. With a high output impedance amp, the headphones will get a little more gain as the impedance goes up. Therefore, you can think of the impedance curve as an EQ curve with high impedance amplifiers. The higher the amp output impedance, the more the headphones will be EQ'd toward the shape of the impedance curve. In the case of the HD800, the higher the output impedance of the amp, the more you'll get a mid-bass boost centered at 100Hz.

To prove that I measured an HD800 with 0, 100, and 200 Ohm output impedances. You can see in the plot below that as the headphone amp output impedance changes, you get an ever increasingly large bump in the bass that's related to its impedance curve.

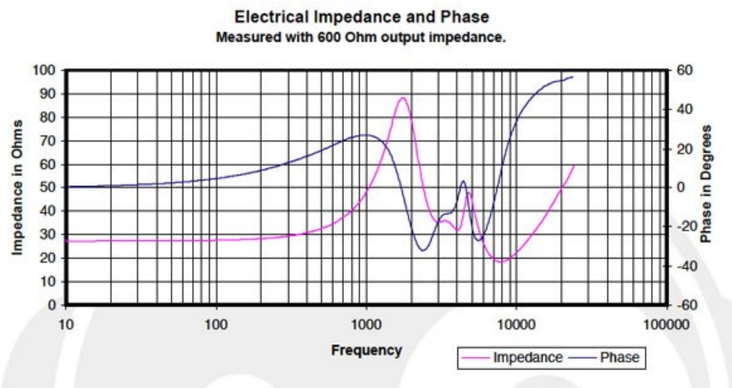


Fortunately, the HD800 has a very high impedance to start with, but, as Jan mentioned, many of todays portable headphones have very low impedances, and that means that they'll be even more sensitive to amplifier output impedance. For example, here's the Sennheiser PX100 impedance curve.



It's roughly 10% of the impedance of the HD800, and therefore you're likely to see changes in the frequency response curve like the HD800 with the differences in output impedance of only 0,10, and 20 Ohms... and that's near the normal variation of portable devices. Fortunately the PX100 could probably use a little more bass.

But it does get worse, here's a somewhat typical multi-balanced armature IEM. You can see that because of the crossovers and multiple drivers of varying impedance, the overall impedance curve (violet) swings wildly any where from 19 Ohms to almost 90 Ohms. Put a 30 Ohm resistor in series with that bad boy and your going to have a pretty severe peak in response at 1.8kHz.



What I'm trying to get across here is that simply increasing the output impedance of your amplifier by putting series resistance in line with the headphones (which is effectively the same thing) has many effects and those effects will vary based on a variety of issues. It's a fairly safe thing to do when the impedance response of your headphones is very flat, but if your headphones have large swings in impedance (usually multi-balanced armature and open dynamic headphones) you need to be careful.

My Summary
Jan's idea is quite stimulating to me. (Thanks so much for writing this, Jan.) I can see someone building a headphone amp that has a built in analyzer that is able to optimise electrical impulse response to the headphones—not only by varying output impedance but possibly also adjusting the reactance (inductance and capacitance) of the output. In fact, you might be able to vary the output impedance for EQ and then adjust reactance to critically damp.

My current guess, however, is that the built-in acoustic damping of the headphones is dramatically more responsible for headphone's acoustic impulse response than is the damping of the electrical drive signal. I'd love to investigate this further, but until then I'm betting the acoustics are far more important.

None the less, you are now armed with a little more knowledge. I'd suggest a little box with an in and out jack, and a variable resistor mounted in it that you can adjust between zero and about 200 Ohms in series with the signal. And then play around a bit. It is a hobby after all, nothing wrong with a little playing around.

| | Share

Log in or register to post comments

COMMENTS

Lovely read

Submitted by ashutoshp on November 18, 2014 - 5:07pm

Thanks Jan and Tyll. Good, fun read. Could be wrong but my oft fatigued ears

serve as proof that impedance matching is probably the most critical, but often overlooked factor when matching equipment. Based on my limited experience with looking/matching equipment with impedance curves of loudspeakers (and Tyll's article on the Beyer DT880 Ohm variants), one measure I use to know if there is an impedance mismatch in my signal chain is to listen for high frequency 'ear darts'.
Having said that- now this may sound funny to an engineer- in the past, I have bought EXTREMELY long cables to increase the impedance if one of my components (eg, DAC) is too bright rather than plunking down a few hundred more to buy another component! So I got excited by these mythical (to me) 'adapters' you talk about. Where can I get those things and are they universal, i.e., can be applied before/after any component?

Log in or register to post comments

this is the David Lynch of

Submitted by castleofargh on November 18, 2014 - 6:52pm

this is the David Lynch of damping explanation. you get in thinking you know what it's going to be, and you get out lost but enjoying the surprise.

I thought that if the headphone impedance wasn't the bigger one, then it wouldn't get all the current that could otherwise pass through it. because the current would be limited by the higher impedance component in the circuit. so in the suggestion to add impedance, the added resistor of 47ohm would "current limit"(if that means anything?) the 30ohm headphone?
am I all wrong about that? and if by chance I'm not, what are the consequences of the source not sending "enough" current to the headphone?

other question: with headphones having lower impedance we often seem to get impressive increase in crosstalk in the measurements of sources. what is the cause for that? and would an added resistor solve the issue?

ok I'll stop here for now and if you're nice to me, maybe I won't come back ^_^.

Log in or register to post comments

Etymotic ER4PT adapters..

Submitted by Seth195208 on November 18, 2014 - 7:19pm

..add about 70 ohms. You can find them on Ebay.

Log in or register to post comments

Other impedances available

Submitted by rasmushorn on November 19, 2014 - 12:56am

Other impedance can be selected (50, 100, 120, 240, 300ohm) if you buy this one.

http://www.ebay.com/itm/271644098644?_trksid=p2060778.m2749.l2649&ssPage...

Log in or register to post comments

nah.

Submitted by Grave on November 18, 2014 - 7:48pm

nah.

Log in or register to post comments

Yay for higher distortion and

Submitted by Grave on November 18, 2014 - 8:13pm

Yay for higher distortion and bad designs?

So, no relevance to Sennheisers then, which is arguably the top headphone brand, unless you want to EQ in a pathological way.

This seems like a flimsy excuse for bad designs to me but it does not surprise me from two people who believe in cables.

Log in or register to post comments

Impressive piece of work !

Submitted by tony on November 18, 2014 - 9:59pm

Hello Tyll ,

Once again , you impress with your reporting , I read this article , marked it for re-reading and study work .
Are you an American Reviewer ? , you read like a Euro Researcher Type !
I've encountered those Sennheiser people and quite agree , they seem to be fluent in things we here are only now realizing , they do seem to be way out in front of the pack on most of what they do . Among others , I have three of the Sennhieser better headphones , they are like having one of Dave Wilson's Big Speaker Systems hanging on a hook , within reach , ready to perform , like a fine musical instrument , they are the finest transducers I've ever owned !
Thank you for reporting on this , it shows a strong benefit to being up there in Hibernation Country , you may-not feel the pressures of coping with the "Big City Rush" leaving you valuable time to ponder these forces of nature , lucky you .
I feel compelled to book some Lab Time .
Tony in Michigan

Log in or register to post comments

Tyll it creates another issue

Submitted by xp9433 on November 18, 2014 - 10:13pm

Tyll it creates another issue for reviewers of headphones and IEMs because of the potential impedance mismatch between amp and speaker. It perhaps puts an obligation on reviewers to try a variety of headphones when reviewing amps and vice versa.

Log in or register to post comments

Comments

Submitted by ultrabike on November 19, 2014 - 2:18am

Thanks for this article Tyll. It made me think about the electrical network formed between the headphone and the amp.

I have a few comments:

1) "The lumped network in the figure is a so-called linear system. Any input-signal can be considered as the summation of a long series of successive impulses. Any output-signal can be considered as a summation of the correlated impulse responses. The response to a single impulse is a good indication how closely the system can follow the input signal."

Though not necessarily wrong, this IMO can be very misleading. The bottom line is that if we were to decompose an input signal into multiple signals, a linear system would yield the same output if we feed it with the original signal or it's multiple signal elements.

2) Once all things are factored (electrical network, mechanical stuff, and sensitivity) end of the day I would probably just look at the acoustic step response (not square wave response) to see the actual damping of the whole system. Results may depend on where the poles and zeros of the system are. The electrical and mechanical damping idea might be useful for cabinet or maybe cup construction though, but may also have it's limitations.

3) I would probably look more for the voltage drop on the cans, than the current drop. And then that may not give much out because it neglects the frequency dependent sensitivity and mechanical stuff.

4) My understanding is that if the resistor went to 0 on the RLC circuit, it would not oscillate forever at a fixed natural frequency and amplitude. LC circuits are passive. Feed a finite energy signal to that and one will get a finite energy signal out. However, on non ideal cases were thermal dissipation is considered, power through the network would be less than power feed in.

5) "Note for the mathematicians: the three impulse-responses shown in the figure are scaled such that they will result in the same over-all sound pressure. That is, the surface-integrals of all three curves have the same value!"

AFAIK sound pressure level is given as a power number. If we are integrating voltage or current maybe that statement is right. But probably not power.

6) In terms of what matters in resistances and power transfer, one probably has to look at both voltage and current. If we keep the output impedance fixed, but increase the load impedance we might get a higher voltage drop at the load, but we decreased the current. So power transfer will be lower.

7) "The membranes of magneplanar drivers have a large surface and very low mass. Therefore they are already highly dampened by air. Proper electrical damping is of less importance."

I think mechanical and electrical characteristics might be independent. The probable reason why electrical damping is of less importance with some planars is that they present a resistive load effectively. Which is probably an example of where the 2nd order RLC model breaks.

Anyhow, I do appreciate this. Makes me think.

Log in or register to post comments

Great Article

Submitted by Bill Brown on November 19, 2014 - 8:09am

I have a large interest in this subject, but have refrained from commenting anywhere as my findings are dissimilar to the current trend for very low Zout ("the lower the better").

I use HD650's and experimented with EQ. I found that I like a small rise in the bass, then realized that the shape and magnitude were very similar to the impedance curve of the HP's. I speculated that perhaps they were designed with the old industry standard Zout in mind (Mr. Meier's comments seem to dispell this notion).

I built a dual mono Buffalo II DAC and drove the headphones through transformers or direct, knowing the Zout in each case. When I adjusted my EQ curve to compensate for the Zout for the same frequency response at the ears (using the HP impedance curve, output impedance, and the voltage divider principle), I found I preferred higher Zout.

I would love to hear current drive (Zout approaching infinity).

It would be interesting to see acoustic measurements of the HD650 or 600 from a higher Zout amplifier applied to your current, preferred, similar-to-Harman FR curve. I suspect it would be closer to ideal....

Thank you for the article,

Bill

Log in or register to post comments

Impedance

Submitted by ultrabike on November 19, 2014 - 9:21am

Meier said:

"Axel Grell, the chief-designer at Sennheiser, once told me that their top-of-the-range headphones are always designed to sound best at a low output impedance."

However, the HDVD 800 seems to have 16 ohms of output impedance. Relative to Sennheiser's TOTL headphones, that may qualify as "low" output impedance, but that's not necesarily a low output impedance amplifier.

Source: http://www.headphone.com/products/sennheiser-hdvd-800

I also don't know if one is going to get a similar-to-Harman FR curve from the HD650/600 when using an curent drive amplifier such as the Bakoon. Probably not. However, mid-bass will increase quite a bit. IMO a bit too much.

Log in or register to post comments

I agree

Submitted by Bill Brown on November 19, 2014 - 10:28am

I think you and the engineer are right, 16ohms definitely is low relative to a 300ohm headphone, but it isn't low in absolute terms or to a 32 ohm headphone.

You are also right about the mid-bass; I calculated then applied an ~ 2.5 db reduction starting at 0db where the impedance begins to rise circa 1khz and back to 0db at 20-30hz, q ~ 0.8 to mitigate the frequency response changes based on Zout for subjective comparisons with low output Z. The boost I enjoy subjectively is a small amount below 100hz. (I have read about the bass distortion in the HD650 but feel it is subjectively benign).

Comparing the HD650 raw frequency response with something like the VISO HP 50 in the ranges below 100Z relative to the midbass and 1kHz level is interesting, though.

Log in or register to post comments

"Resistance is Futile...but Important!" - Borg Audiophile

Submitted by Three Toes of Fury on November 19, 2014 - 9:20am

Jan.....Thank you so much for taking the time to put together and share this information with we headphone enthusiasts. This site is continually evolving which is evident in the increased volume of recent postings dedicated to headphone education. My take away from your article was not so much in your conclusion or challenges but an overall better understanding of key variables in headphone and amplifier speak. I absolutely appreciate that. Additionally i have looked at your website and offerings and it sounds like you have some great amps...some of which are targeted towards my demographic (audiophile lover but budget driven consumer). I wish you and your company lots of success!!

Tyll...your comments and, especially, end-of-article additions are outstanding. I love your approach..you are not trying to refute so much as further educate and shine light on the many many variables at hand. One quickie follow up question based on your HD-800 example...if the amp resistance is fixed and the headphone impediance varies across its frequency spectrum..wouldnt that result in drastic volume changes when listening to music which moves throughout the frequency range (due to the shifting voltage division)? Or is the net result just that some of the frequency ranges within what we are listening too are louder than other and thus the overall sound differs accordingly?

Thanks both....wonderful lesson for the day.

Peace .n. Living in Stereo

3ToF

Log in or register to post comments

"...if the amp resistance is

Submitted by Tyll Hertsens on November 19, 2014 - 11:33am

"...if the amp resistance is fixed and the headphone impediance varies across its frequency spectrum..wouldnt that result in drastic volume changes when listening to music which moves throughout the frequency range"

Sort of, that's what an EQ change is though.

Log in or register to post comments

Dear InnerFidelitiers,

Submitted by Jan Meier on November 19, 2014 - 1:45pm

Dear InnerFidelitiers,

yep, Tyll is very right in that the frequency response also changes when changing the output impedance of an amp. I kept it out of the article because I didn't want to complicate reading.

I also agree that acoustic issues may well cause for a lot of the ringing shown in his diagrams. Even the HE-500 shows clear ringing although this is not reflected in the current-plot.

The intention of this article is to make people aware that technically a lower outputimpedance isn't always a better solution and that there is a lot of room for experimenting. If you're not entirely satisfied with the sonic balance of your phone or do feel the phone to be a little bit harsh, then make yourself a simple adapter and try different values of output impedance. It may well solve your sonic problems and is much cheaper than trying different amps and/or headphones.

And above all, it can be real fun!

(Actually, such an adapter can contain more elements than just a resistor and can well be used to (slightly) bend the frequency response in any direction you want. But that is another story ......).

And the most important lesson: You shouldn't believe everything that you read in the papes (West Side Story).

Enjoy your listening,

Jan

P.S.

Yes, I do hear (small) differences between cables! But you don't have to believe that either!!

:-)

Log in or register to post comments

Thank you, Jan!

Submitted by Tyll Hertsens on November 19, 2014 - 3:02pm

Thanks for popping in to say "hi", and thanks for this article. It seems to me one under-expored by enthusiasts, and I personally found it quite stimulating. I think this subject will come up more often.

Log in or register to post comments

This is kind of off topic..

Submitted by Seth195208 on November 19, 2014 - 4:47pm

As we all know, Audeze is coming out with a high impedance planar magnetic. All things being equal(In reality, that's obviously never completely the case) what would be the difference "sonically" between that, and simply adding a resistor to a lower impedance version that makes up the difference? Anyone?

Log in or register to post comments

You're confused

Submitted by elmura on November 20, 2014 - 3:03am

Adding a resistor (or network) in between amp and headphones doesn't change the headphone internal impedance. Without seeing the new Audeze in the flesh, I assume they have made a very fine electrical path on the diaphragm to reduce weight, increase transients, improve treble etc. Placing any resistance in front of a LCD-2 etc won't make any such improvement.

Log in or register to post comments

Yeah..

Submitted by Seth195208 on November 20, 2014 - 8:46am

I was thinking of an Er4s/ Er4p analogy, which is nothing like the Audeze situation. Thanks for de confusing me.

Log in or register to post comments

Simple Example

Submitted by cookiejar on November 19, 2014 - 4:53pm

Quite the long complicated discussion of output impedance, damping factor and all. Lot's of room for mistakes.

A much simpler explanation is the example of an electric motor (after all, dynamic speakers are a type of electromagnetic motor).

Let us say we have a 12VDC electric motor running at speed. Here's two ways we can stop it.

The first is to simply remove the voltage and the motor will coast to a stop. That's an example of applying 0V through a high source impedance.

The second would be to remove the 12V and short out the motor. It will stop a lot faster. That's an example of using a low impedance driver. It's also an example of the motor running as a generator with a heavy load slowing it down.

So given the choice between a very low driving impedance and a high driving impedance, the low impedance drive will give better control.

Log in or register to post comments

Inductive loads are sometimes counterintuitive

Submitted by bcarso on November 19, 2014 - 5:48pm

The example given by cookiejar is somewhat misleading. When another somewhat simpler system is considered, such as a solenoid or relay, the fastest dropout will be effected by allowing the voltage to fly back with the switch turning off and the flyback catch diode dumping the inductor energy into a resistor. The limitation on this technique is the breakdown voltage of the switch.

This approach can result in much faster relay dropout. One is still limited by the mass and spring effects, like any electromechanical system, but the improvement is quite noticeable. I used the approach for a muting relay in a switcher among multiple amplifiers and speakers.

Without the series resistance added, the coil will dissipate the L(I^2)/2 energy eventually, but via its own resistance and some diode losses.

As far as the proper output drive impedance for headphones, the point is well taken if the most important variable to be optimized is transient response. But this is less easy to hear (unless it is just awful) than the attendant frequency response variations as shown by Tyl. The manufacturer has, we hope, achieved the best of both worlds by developing the phones with a given output resistance in mind.

BTW, there is an interesting self-published book on current drive of loudspeakers: Merilainen, Current-Driving of Loudspeakers. The author is passionate about the subject (to say the least), and he anticipates virtually every objection that voltage-drive devotees will throw up. I'm personally a bit dubious that the stated improvements are entirely objective, but to do a proper test one needs the almost-impossible, namely loudspeakers that are optimized for current drive that can be validly compared to ones identical in acoustical behavior (at least frequency response and radiation pattern) to conventional ones.

Brad

Log in or register to post comments

Model is wrong?

Submitted by dguillor on November 19, 2014 - 6:34pm

Drivers are usually designed to have flat frequency response for a voltage applied at the driver input terminals, but in the simplified circuit Vo is shown after the voice coil impedance. It seems to me that this invalidates the analysis.

Log in or register to post comments

Differing ways to view Complex, Dynamic relationships…

Submitted by johnjen on November 20, 2014 - 2:27am

MOAR intriguing food for thought! :thumb

I especially like to contemplate several different approaches and how they 'model' the dynamics involved with the physical/electrical/acoustic variables.

Yeah its complex.

Kudos to all involved!

It will be interesting for me to hear what an amp with a Zout of ≥0.1 Ω running into 800's will yield…
This is probably as close to 0Ω as I'll ever see.

JJ

Log in or register to post comments

For even more food for thought

Submitted by elmura on November 20, 2014 - 3:17am

Here is an objective article that shows phase and distortion to also be affected by damping factor (impedance ratio)

http://benchmarkmedia.com/blogs/white-papers/11653109-the-0-ohm-headphon...

Log in or register to post comments

Here's the error with Jan's approach

Submitted by xnor on November 20, 2014 - 6:57am

Here's the error with Jan's approach:
>"To measure the current response of real headphones an amplifier was build that allows to monitor the current flow while applying a signal to the headphone."

Current only tells you a part of the story. There seems to be a major misconception about voltage, current and back-EMF.

After the impulse, the diaphragm and therefore voice coil keeps moving, but it shouldn't.
The driver will produce back-EMF (*voltage*) trying to counter that motion. Now there are two options here:

a) The back-EMF is shorted out (0 output impedance) resulting in high current that will stop the driver from continued ringing.

b) The back-EMF faces a high resistance resulting in little current that will not stop the driver from ringing.

That is exactly what you can see in the figures above.

Log in or register to post comments

Thanks for the article but I have some doubts

Submitted by Sree on November 20, 2014 - 9:29pm

I started experimenting with in-line resistors few years back on my Denon AH-D7000 powered by Just Audio AHA120. When I added a 75 Ohms adapter to the Denon's, the sound signature changed drastically. Instead of improvement in bass as explained in the article, the Denon's showed better control (restraint) in the bass region but improved the midrange. I tried using a 300 Ohm resistor and the sound signature didn't change much. I tried reading quite a few articles on the impact of Output impedance of amplifiers on the sound signature and it confused me quite a bit.

Since that experiment, I have tried adding resistor adaptors to various headphones with not so satisfying results. This got me thinking. May be, just like the Denon's, there is a sweet spot with the resistors and I had been on the lookout for variable resistance adaptors ever since.
I however have a question. Does adding resistance adaptor decrease the decay of the instruments? The article mentioned about the resistors changing the frequency response of the headphone, which I could sense, but I also felt that decay of the instruments reduce significantly. Do you also feel this in the measurements?

Thanks
Sree

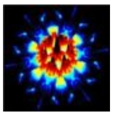
Log in or register to post comments

Impedance adapters

Submitted by stv014 on November 21, 2014 - 7:04am

Did you make sure the levels on the headphones are matched when you compared the adapters ? Adding a serial resistor makes the sound quieter, and that by itself changes the perceived frequency response.

Log in or register to post comments



Isn't a driver with an

Submitted by thune on November 20, 2014 - 11:56pm

Isn't a driver with an electrical tank resonance at 5khz either badly designed or broken? Damping it would seem to be the least of the issues.

I've been led to understand that high-impedance outputs can be beneficial to harmonic-distortion by bypassing the inductance modulation [Le(x)] distortion mechanism (see Klippel). Certainly the frequency response differences are real, but I think this is more an issue of preference.

Log in or register to post comments

Re: distortion

Submitted by stv014 on November 21, 2014 - 7:01am

The previous comment was not saved correctly (apparently because of the HTML links), so I post it again:

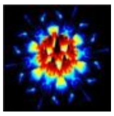
While an amplifier will drive a dynamic transducer and serial resistor with lower distortion than the former alone, it does not necessarily mean that the distortion in the acoustic output will also be lower. Distortion from the driver - which is affected by electrical damping - can easily be much higher than from the amplifier.

The previously already mentioned Benchmark Media paper (http://benchmarkmedia.com/blogs/white-papers/11653109-the-0-ohm-headphon...) shows increased distortion on the voltage signal on the terminals of the driver when the source impedance is high, but the acoustic output was not tested.

These measurements (http://www.head-fi.org/t/607282/headphone-amp-impedance-questions-find-t...) I have posted on the Head-Fi forums on the other hand show higher acoustic distortion for a full size dynamic open headphone when driven by a high impedance source, even though the frequency response is equalized to match the low impedance case.

Unfortunately, it is not easy to find similar measurements that test the effects of output impedance on headphone or speaker distortion, but I found one more at InnerFidelity: DT48 driven by a low impedance (http://www.innerfidelity.com/images/BeyerdynamicDT48.pdf) and 120 ohms (http://www.innerfidelity.com/images/BeyerdynamicDT48E120Ohm.pdf) source. Again, the distortion is slightly higher in the latter case.

Log in or register to post comments



From my reading, people using

Submitted by thune on November 21, 2014 - 2:15pm

From my reading, people using high-impedence outputs to reduce distortion are usually talking about very high impedance (high enough to be called current-source amplifiers.)
[I hate that benchmark paper, it just shows that you can measure the distortion in the current waveform if you put a resistor in there, but the distortion is still with zero-impedance outputs, you just aren't measuring it.]

Log in or register to post comments

1 2 next › last »