Resistance, Impedance, Damping factor, Cables.

Impedances and resistances are not the same but are closely related.
A **resistance** is a **constant value** that does not alter with varying frequencies or power. The current flowing through a resistance has a linear correlation to the voltage across the resistor.

An **impedance** is a **varying resistance** which is different in value for various frequencies and thus the current can NOT have a linear correlation to the applied voltage.
The current may even have a different phase relation to that of the applied voltage.

The **damping factor** is the number you get when the load resistance (headphone impedance) is divided by the output resistance of the amplifier **(R_{LOAD} / R_{OUT})**. It says something about how well the acoustically generated movements (that are not related to the applied electrical music signal) are 'braked' to 'damp' this unintended movement. Impulse response and resonances have a relation with this.

Headphones are specified to have a certain 'Ohmic' value but in reality it has an impedance.
The DC resistance of the voice-coil is, in most cases, equal to the impedance around 1kHz and is specified in Ohm(Ω). You can measure this resistance with a multi-meter in the 'Ohm' setting.
The test current of most multi-meters is low enough, so the driver won't be damaged when you measure it.
A short measurement should be enough to get an idea of the nominal impedance.
Loudspeakers (finished box, not the units) usually are specified to have impedances between 4 Ω and 8 Ω but may have impedances as low as 1 Ω and as high as 100 Ω in certain cases on specific frequencies. This is often caused by badly configured crossover filters in these certain loudspeakers. Most speakers will not drop much below their rated impedance but might increase to several times that of the nominal value at a certain frequencies.
The majority of headphones does not have crossover filters as there is only one driver, so the impedance will only be higher than the Ohmic resistance, which normally is given in the specifications.
Some balanced armature (in-ear) headphones with multiple drivers can have impedance rises and drops at other parts of the frequency spectrum as 'normal' headphones.
Ortho-dynamic headphones usually have a very linear (flat) resistance, this has to do with their construction.
Electrostatic drivers (those with transformers) and 'normal' cone type headphone drivers have 'smoothly' varying impedances.

I*n short*: **Headphones** and **loudspeakers** have **impedances** (i.e. varying resistances dependent of the frequency).
Amplifiers have **constant** output **resistance** (within the audible range).
All headphone amplifiers have a certain output resistance, which is NOT specified in the spec sheets in most cases.
Mostly only the range of headphones that can be used is mentioned, for instance 16 Ω - 600Ω or 32Ω - 300Ω or 16Ω - 64Ω.
The output resistance, however, **CAN** influence the sound signature of the used headphone, in some cases more then others. Cause of all this is the varying impedance of a headphone in relation to the fixed resistance of an amplifier because of voltage division that takes place.

In general:

Low impedance headphones (16Ω to 50Ω) with considerable rises in its impedance (above a factor 2) PREFER low Ohmic amplifiers and definitely sound best on those amplifiers, Low impedance headphones that only have small humps in their impedance plot don't change their sound signature much with different output resistances and might even **sound** better on higher Ohmic amps, certainly if they are designed with a higher output resistance in mind.

For medium impedance headphones (60Ω to 120Ω) the influence of the output resistance is less obvious and more subtle. Again some headphones may sound better from low Ohmic amps, other headphones may sound better from higher Ohmic amps.

Higher impedance headphones (150Ω to 600Ω), also depending on the rise of the impedance in certain areas again may blossom more on higher Ohmic amps than lower Ohmic amps or vice versa.
The T1 was definitely designed for a higher Ohmic amp, The HD800 also benefits and this explains also why some find the HD800 lacking in lows and others have no complaints. Other than a difference in taste it is more than likely the 'synergy' with their amplifiers (read different output resistance)

Which headphones sound best on which amplifier/output resistance may also be of a personal nature as taste and type of music is also important in this case. Some prefer prominent bass, others like it subtle. Some like fierce treble, others like it subdued.

Why are there output resistors in headphone amplifiers in the first place ?

They are there to protect low impedance headphones from receiving too much current and thus too much power, which could potentially destroy certain headphones, when the amplifier section can also deliver higher voltages (above $5V_{RMS}$).

How can headphones be destroyed by some amplifiers ?

Headphone drivers have extremely thin wires in their voice-coils because they need to be extremely light to be able to reach the highest frequencies without much problematic behavior.
Thicker copper wires means more weight, which adds weight to the whole diaphragm construction, all the moving parts as it were. This must be as light as possible to move as dictated by the applied electrical voltage.
Thin wires also means they cannot carry much current. They will glow like a light bulb, burn out or get loose from the material they are wound on, causing the drivers to distort or fail if they receive(d) too much power.
Most dynamic headphones (certainly not all) are specified to have a power handling capacity between 50mW and 200mW regardless of their impedance. They can easily handle short peak values that are 2 to 4 times higher though, but not continuously. Music signals aren't continuous but are varying constantly in amplitude with most of the electric energy being in the lows to lower-mids.
Above the specified powers most headphones do not react linear anymore meaning the excursions of the diaphragm do not accurately follow the applied electrical signal anymore but are smaller then 'expected'.
A form of soft-clipping/distortion/compression.
Output stages of most (solid state) headphone amplifiers provide an output **voltage** and have an output resistance of around 0Ω (between 0Ω and 1Ω in general) BUT the connected headphones may have quite different nominal impedances ranging from 16Ω to 600 Ohm nominally, this would result in considerable different power levels when the same voltage is applied.
High impedance headphones will draw a **low current** at the maximum output voltage of an amplifier.
Low impedance headphones, however, will draw a **high current** at the same maximum output voltage **if** there were no output resistors or some other form of current limiting present.

Some technical math:

10V output voltage on a 300 Ω (**high impedance) headphone** will result in a current of 10V/300 Ω = 33.3mA.
The output power can be calculated as: 10V x 33.3mA = **330mW**.
This is above the 200 mW level but when real music is applied only short peaks will reach these values and the average levels will be MUCH lower so no real danger to 300Ω (and higher) headphones.
10V on a 32Ω (**low impedance) headphone** will result in a current of 10V/32Ω = 312mA, calculating the power gives 10V x 312mA = 3,125 mW (**3.125W** !) in case there is no current limiting.
These levels may certainly burn out the coils of this headphone in an unguarded moment as they can only take about 200 mW (0.2 W) max ! So.. the goal of the output resistors in headphone amplifiers LIMIT the currents that can flow which are determined by the maximum output voltage of the amplifier, output the resistance of the amplifier and the impedance of the headphone. Adding output resistors is a CHEAP way of achieving a form of current limiting so the amplifier cannot destroy low impedance headphones.
When a resistor is in series with the impedance of the headphone the current is limited as I (current) = U (voltage) divided by the total resistance ®, thus output resistance + headphone impedance.

The same amplifier as mentioned above BUT with a 120Ω output resistance fitted in it's output path will result in the following output powers. High Ohmic: 10 V/(120Ω + 300Ω) = 24 mA.
Because of the **voltage division** that occurs, because the output resistance and headphone impedance are in series, the voltage on the headphone is no longer 10V but only a certain percentage of it.
This voltage division that takes place complies to a formula: the voltage across the load (headphone) can be calculated as $U_{HP} = U_{OUT} \times (R_{HP}/(R_{HP}+R_{AMP}))$.
Since U(voltage in Volt) =I(current in Amps) x R(Resistance in Ω), and P (power in Watt) = U(Volt) x I(Amps) the power can also be calculated with the equation: $P=I^2 \times R$ or $P=U^2/R$
The calculated output power in this case will be: $(24mA)^2 \times 300Ω$ = 173mW which cannot destroy high impedance headphones. Low impedance headphone: 10V/(120Ω + 32Ω) = 66mA.
Because of the voltage division the power can be calculated by: $I^2 \times R$ so 66 $mA^2 \times 32$ = 139 mW which cannot destroy the low impedance headphones.
In this example it is clearly shown that in case an amplifier is fitted with a certain output resistor all types of headphones receive about the same maximum output POWER and headphones will not receive powers that are (far) beyond their maximum ratings which could potentially destroy the delicate voice coils of your expensive headphone. *Why was a 120 Ω used in the example ?* This value has been set as a 'standard value' and is described in the 1996 **IEC 61938** standard. How many manufacturers apply this standard is unknown.
The sound of these headphones has been 'tailored' to sound correctly (as intended by the manufacturer) when this output resistance value is used. Many of the more expensive headphone amplifiers, however, have a much lower output resistance which may or may not be optimal with certain headphones.

Why are some amplifier output resistances lower in value, say 30 or 50 Ohm ?

This has to do with the maximum output voltage that the amp can deliver (without a load).
The output voltage that an amplifier can deliver is dependent on the power supply voltage and output stage configuration.

Roughly, the output voltage in V_{RMS} (Root Mean Square) is about 1/3 of the total power supply voltage.
So an amplifier with a single 9V battery can deliver about $3V_{RMS,}$ an amplifier with a single voltage rail of 24V can deliver $8V_{RMS,}$ a dual voltage supply rails of +15V and -15V (total 30V) can deliver $10V_{RMS}$ e.t.c.
An MP3 player (or other battery operated device) with 2 (rechargeable) AA batteries for instance only has 2.4V available so can deliver max. 0.8V, provided they don't use an internal DC/DC voltage converter (booster) to create a higher voltage. It is obvious different amps can/will have different maximum output voltages.
IF the maximum output voltage is not high enough (several volts) it will not be able to deliver enough power into high impedance headphones, but can deliver enough power in low impedance headphones, as these don't need much voltage to reach the needed currents (remember: power = voltage **x** current). These lower output voltage amplifiers (C'Moy's for instance) therefore don't need current limiting resistors in the output path.
High voltage amps can drive high and low impedance headphones with a series resistor, low voltage amps can only drive low impedance headphones to considerable SPL (Sound Pressure Level) and do not need output resistors. In practice they still have some resistance, but only a few Ohms (between 10mΩ and 10Ω in general)
Amplifiers with a medium output voltage therefore often have a resistance between 0Ω and say 50 Ω so they can drive low impedance headphones to their maximum value and higher impedance headphones pretty well, though NOT to their maximum power rating, but still to more than acceptable levels.

The technical part above has been about what output resistors are used for in headphone amplifiers. It is has nothing to do with impedance matching, as this is often mentioned in forums to be needed.
Impedance matching is only needed for very high frequency signal transfer (FAR beyond the audible range and way above 100kHz) with cables that have a similar impedance as the in and output resistances of the source and receiving end (mostly 50 or 75Ω).
This is NOT needed nor applicable in the entire audio range, even up to 50kHz. Not even for interlinks.

In short:

1: The output impedance does NOT have to match the impedance of the headphone NOR is this desirable.
2: Output resistors are used to limit output currents to protect low impedance headphones when amps can deliver higher output voltages (say above $5V_{RMS}$).
3: These resistor values are dependent of the range of suitable headphones and maximum output voltage.
4: Current limiting can also be done in other ways but using a resistor is simple and cheap.
5: Needed if the manufacturer of the amplifier wants to meet the IEC 61938 standard (120Ω)

Why are there many different headphone impedances ?

This has to do with the intended usage. Low impedance headphones are designed to be used with portable equipment, which does not have a large output voltage swing. High impedance headphones are designed to be used with higher voltage amplifiers (desktop or studio). Higher impedance headphones can easily be paralleled without the amplifier getting into trouble, which may be of importance in studios.
Because high impedance headphones draw less current at the same power level compared to low impedance headphones, the voice coil wire can be thinner which means lighter. This results in faster transient response and a wider frequency range, the higher impedance versions of the same headphones have been reported to sound more refined because of it. This is often blamed on the damping factor but the lighter weight of the membrane is of greater influence, as that also means less prominent resonances and resonances being higher up in the frequency range.

Some headphones can be purchased (for above mentioned reasons) in different impedances. The different output resistances of the used output amps for these editions can have sonic effects, as does the weight difference of the different impedance driver assemblies.

Is the sound affected by different output resistances ?

The answer is YES, how **much** the sound is affected depends on the value of the output resistors in the amps, the impedance of the headphone and how much this impedance varies with different frequencies.
Also an important ingredient is IF the headphone is optimized to perform as it should with a certain output resistance (IEC 61938). Most headphone and amplifier manufacturers do not mention anything at all about the optimal output resistance of amplifiers or if it meets that specific standard.
Some headphones are designed to have the intended frequency response when this specific output resistance is used, but it is rarely mentioned in the specifications sheet of the headphone itself nor in the specifications of many headphone amplifiers. Other headphones are designed to be driven from low output resistance sources.

What about the damping factor ?

The damping factor is the number you get when the load resistance is divided by the output resistance (R_{LOAD} / R_{OUT}). For loudspeakers a value higher than 10 is considered sufficient, meaning the output resistance of the amplifier for an 8Ω speaker should be 0.8Ω or lower. Most people forget the serial resistance of the inductor in series with the woofer (the woofer has the biggest mass and benefits most from damping) and including the wiring, often is around 0.5Ω.
The unintentional movement that needs to be 'damped' is generated by the speaker itself (it acts as a microphone/dynamo) and if the woofer has a DC resistance of say 6Ω, this internal resistance + inductor(s) and wiring determines the actual 'shorting current'. Whether the total resistance of that path is 6.5Ω (amp damping factor 1000) or 7.3Ω (amp damping factor 10) the current is only 10% lower in the case of a damping factor of 10. In case of speakers, the weight of the moving mass is relatively large compared to that of the midrange or tweeter so the woofer generates the most current that can be used as a 'power brake' for unintended movements of this woofer.
Just like when you run your car in stationary and you turn on the lights of the car you can hear the engine turning slower because of the load of the generator (lamps) take away power from the engine through the generator.
Shorting a generator (in this case the voice-coil of the driver) through the output resistance of the amplifier has a 'braking' effect and thus the unintended movement is smaller/shorter and thus damped. The membrane of a headphone driver is considerably smaller than a midrange speaker and even lighter than a tweeter.
Most of the damping of these ultra-light membranes of headphone drivers comes from mechanical compliance and a dampening action by the surrounding air/housing/damping materials.
For headphones the electrical damping is of considerable less importance than in the case of a loudspeaker. The usually considered minimal damping factor of 10 is therefore not really needed for most headphones and may be lower.
A damping factor of around 1 should suffice. Some headphones might need a higher damping but others don't even need a damping factor of 1 to perform well.

Lower Impedance (32Ω) dynamic headphones (mostly intended for portable use) mostly like to 'see' an output resistance between (close to) 0 Ω and 15Ω, also depending on some of their properties.
Headphones designed to work properly on 120Ω also sound O.K. from lower Ohmic amps but sound more pleasant/less edgy/full bodied on amps with output resistances between 60Ω and 120Ω.

Balanced armature drivers (8Ω to 32Ω in-ear), because of their sometimes weird impedance behavior, like to be driven from low Ohmic amps with an output resistance no higher than 1 or 2Ω has nothing to do with damping factor but more with the change in the sonic signature due to (considerable) impedance changes within the 200Hz to 5kHz range making them sound rather poorly/strange.

Higher impedance headphones (above 300Ω) really don't get 'damped' much more with a low output resistance than with a higher one as the current that is needed to 'damp' their own swinging motions are not much different (300Ω vs 400Ω) the differences in current, and thus the 'breaking action' are not that big as the shorting current is mainly determined by the impedance of the headphone.

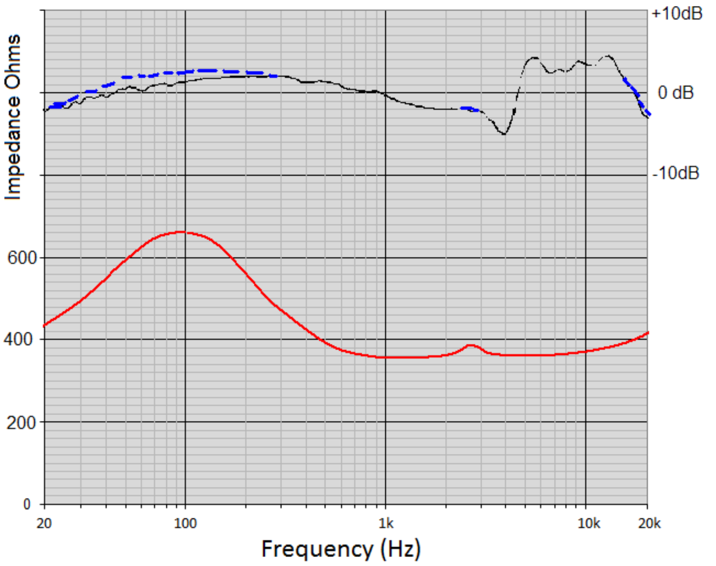
In short: the 'damping' in headphone drivers is mainly achieved by mechanical properties and only a small percentage of the 'damping action' is due to electrical damping. Low Impedance headphones are more affected than high impedance headphones, depending on their impedance graph.

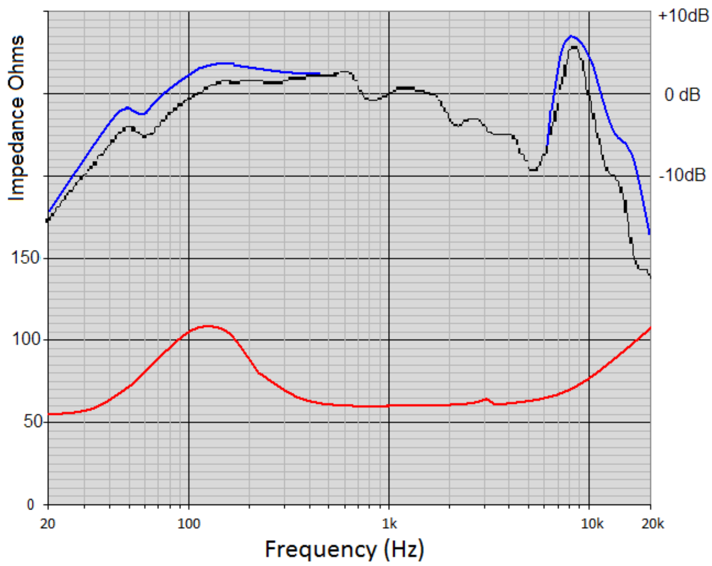
How MUCH does the output resistance of an amplifier influence the sound?

The impedance for low frequencies is mostly determined by mechanical properties of the driver.
Everything in nature wants to vibrate on their preferred frequency or even on multiple preferred frequencies. When these resonance point(s) is neared, or reached, there is less power needed to get the same excursions as would otherwise be needed, as the driver also acts as a generator at this point and generates a 'counter voltage'. Less power is needed when the same voltage is applied and this can only result in less current drawn. Less current with the same voltage across it means the resistance has to be higher.
So at lower frequencies (the resonance point of speakers and headphones) the impedance is higher.
A similar thing happens at higher frequencies (upper midrange) if the driver has certain resonance points. These can be seen as little peaks/bumps in the impedance graph and means the driver resonates at this frequency. This is not a good thing in general but may not make it sound bad.

On the next page the influence of a 120Ω output resistance on the frequency plot of various headphones is made visible. The red trace is the impedance plot, the black trace is the measured frequency response (assuming a low Ohmic amplifier was used to create the frequency plot) and the drawn blue lines represent the expected changes in frequency curve. Because of sonic properties the lows in general should have an amplitude about 5dB higher than the middle of the graph (300z to 3kHz) to sound realistic.

2 examples of the effect of a 120Ω output resistance amplifier on the frequency spectrum of 2 headphones. On the left the Sennheiser HD800 (300Ω) and on the right the AKG K271-II (60Ω)



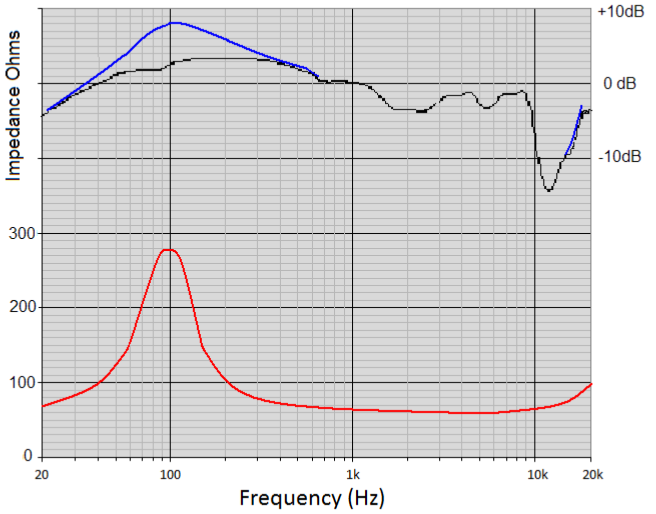


What are the sonic consequences ?

What can be observed is the (wide) hump in the 100Hz region of the Sennheiser HD800 which almost doubles in impedance around that frequency to well above 600Ω. There are little resonances seen in this graph. The impedance rises again the higher the frequencies go from 10kHz and up. At 20kHz the impedance is already 450Ω. The rising of the impedance above 10kHz is not due to resonances but is caused by the inductance of the voice-coil that starts to play a role as well as the mechanical properties of the membrane.
The Sennheiser HD580, HD600 and HD650 show quite similar behavior, but slightly less prominent.
These headphones will therefore give slightly more 'warmth' and 'body' when played through a higher resistance amplifier. The HD650 can do with a little less warmth so low-Ohmic amps are recommended for the venerable HD650, The HD580 and HD600 may sound better to some people on higher Ohmic amplifiers.

The AKG K271 is a low impedance headphone and has considerable less bottom end frequencies and highs as well, when used with a low Ohmic amplifier. The blue line shows how the graph alters when a 120Ω output resistance is used. It can be seen that lower frequencies are more present and the highs extension is also better.

Orthodynamic (planar) headphones usually have an impedance characteristic that looks like a straight line due to their construction and is, beside the obvious drop in SPL due to voltage division, not affected in the frequency domain nor is the damping factor of great importance in these types of headphones. Maximum power levels, however, are restricted with higher Ohmic amps. For ‘dynamics’ reasons and the much higher power handling capacity the Ortho-dynamic headphones can best be driven with low-Ohmic amplifiers.



Some headphones don’t react well to higher output resistances. Examples are the Sennheiser HD555, HD595 and HD598 for instance. It’s impedance rises from 60Ω to 270Ω at 90Hz which will give an increase of over 6dB around 90Hz, making it sound bloated and fat. This headphone really needs a low Ohmic source.
It was clearly designed to be driven from low Ohmic amplifiers and portable equipment.

Headphones like Grado’s for instance do not change much in frequency response so these headphones will sound quite similar from most amplifiers regardless of their output resistance.

Headphones that have a 'bathtub' type frequency graph (boosted highs and lows) might benefit from a low output impedance amplifier as well, because the bass will be reproduced lower in level which will make the bass sound tighter which isn't a bad thing for these types of headphones. Of course this is also depending on impedance plot, taste and preferences.

What is the influence of cables on the sound ?

Headphones cables may have some influence in channel separation with certain headphones/cables.
This could potentially influence stereo imaging.
Often it is said bass reproduction and or highs have improved (sometimes even dramatically) according to those that have changed the headphone cable.
Reasons for these sonic improvements have been debated often, but decisive technical evidence is not yet presented. Very small differences can be measured in capacitance, inductance and resistance between various cables, but the question remains in what extend these differences are audible.

Some properties of headphone cables that should be present:

1: Supple (so not stiff)
2: Low in microphonics, so tapping on the cable doesn't end up in mechanical coupling of sounds to the ear-cups.
3: low resistance of at least the 'return' conductor/wire in case a 3 wire cable is used with common return wire.
4: the diameter small enough to be supple/lightweight, yet big enough to be sturdy/handle pulling on it.

Length is dependent on the application, short for portable gear, 1 to 3 meters for stationary use.
In some cases a longer cable (or extension cable) may be needed.

Often capacitance and inductance of cables is mentioned as the reason for cables sounding different.
Because headphone impedances and output resistances are relatively small the influence of capacitance is extremely small. Large capacitances (long cables, meaning 5m or more) MAY in some cases cause some, not well designed, low output resistance amplifiers to oscillate. Amplifiers with a minimal output resistance of 10 Ohm usually are not afflicted with this problem as the output resistance works as a load for very high frequencies. Even with an output resistance of 120Ω the capacitance of a cable doesn't cause roll-off at higher frequencies. Low capacitance headphone cables have a capacitance of around 100pF/m, screened cables may reach a value of 250pF in worst case. Exotic cables usually have a low capacitance.
So an amplifier with 120Ω output resistance and 5 meter of worse case capacitance (250pF/m) will have a high frequency cut-off of 1MHz (1,000kHz) so capacitance is of no importance for rolled off highs.

The inductance of the cables is MUCH smaller than that of the voice-coil and even long distances of cable do not come near that of a driver. A cable has an inductance of around 1µH/meter. The inductance of a voice-coil is in the mH region so at least 1000x higher and therefore also is not of importance as a sound determining parameter. Since the cable inductance is in series with that of the driver the increase by the cable is negliable.

In short: the cable inductance and capacitance have virtually no influence on the audible frequency spectrum, even far beyond what is considered audible (way above 20kHz).

How about resistance ?

The resistance of a headphone cable may have some influence on the stereo imaging IF the headphone has a very thin cable which is quite long also (thus a noticeable resistance) AND the amplifier has a low output resistance AND the impedance of the headphone is low AND the efficiency of the headphone is high.
Higher impedance headphones are far less sensitive because this effect has to do with voltage division.

Some numbers:

The thin cables found on portable headphones and such have a resistance of around 0.5Ω/m.
Note these cables are usually short (max 1m) as they are intended for portable gear.
Cheaper cables from budget class headphones have a resistance between 0.1Ω/m and 0.2 Ω/m
Cables from the better headphones have between 0.04Ω/m and 0.1Ω/m.
Screened cables have core-conductors with resistances between 0.05Ω/m and 0.1Ω/m and screens have a resistance of around 0.03Ω/m.

Copper vs Silver:

Silver has a better conductivity than copper (in case the silver is not corroded). The difference is not much, about 6%. Solid silver wire and copper, however, do not change their conductance with frequency at different points so the bandwidth of a silver cable is not bigger/wider than that of a similar copper constructed lead.
The skin effect (electrons traveling at the edges of the wire and thus increasing in resistance) starts from around 10khz and above 100kHz becomes noticeable in an increase of resistance.
The theory is that copper cables coated with a 6% better conduction edge would increase the higher frequencies. Since it is a question of simple voltage division the effect can be calculated.
Worst case scenario: 16 Ohm headphone, a very long 3 meter of thin cable, amplifier assumed a perfect 0Ω.

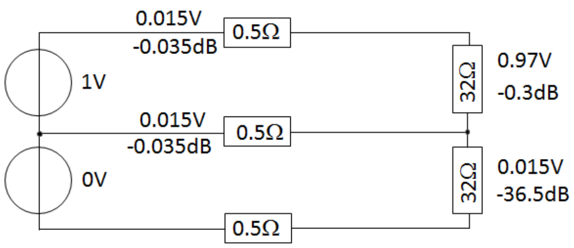
In case copper wiring is used the voltage division dictates a loss of 1.5dB compared to the condition where ideal wire was used. In case a pure silver wire is used the loss would be 1.4dB. This is to say that the attenuation is the same across the whole frequency area, the silver does not have a relatively lower resistance at say 100kHz.
In essence the pure silver wire will play 0.1dB louder over the entire frequency range in this extreme case.
In case a copper wire is used which has a silver coating and following the rule that electrons choose the path of least resistance the theory is that when the skin effect sets in (above 10kHz) more electrons will only travel though the silver and thus the resistance of the highest frequencies will be relatively lower and the top highs will not 'suffer' that much.
At 100khz (for those that believe these frequencies matter) the increase in a wire is only 10% and at 20kHz this is no more than 2%.

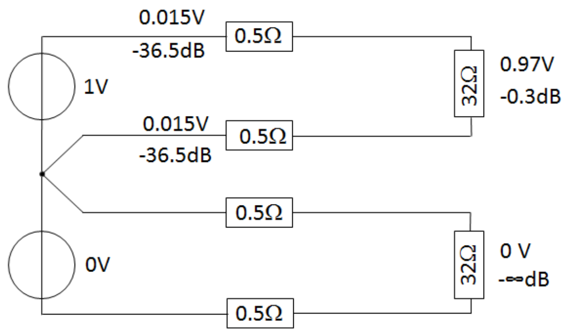
This means that at 20 kHz in the above circumstance the 20kHz signal (because of skin effect) in a copper or pure silver cable will only give an attenuation (with respect to 1kHz) of 0.03dB
The differences between a solid/stranded silver or copper wire opposite and a silver-coated copper cable will be very small and the attenuation of 20kHz will become 0.028dB approximately. A whopping difference of 0.002dB at 20kHz ! and this is WORST CASE scenario.
16 Ohm headphone, a very long 3m of VERY thin wires and a perfect 0Ω amplifier.
The differences become increasingly smaller as the impedance of a headphone increases and normal wires are used.
A quick calculation for a modest 60 Ohm headphone on a perfect amplifier with a 3 meter standard quality headphone cable, differences between a copper and pure silver cable amount to: 0.007dB louder silver wire over the entire frequency range. The audibility of a 0.007dB increase in overall amplitude cannot be perceived. Research has shown that a decrease of smaller than 0.1dB is already inaudible. A decrease of 0.3dB at 20kHz (compared to 0dB at 1kHz) also cannot be detected by hearing.

In short: the audibility of silver versus copper versus silver-plated copper wires for headphone applications cannot be scientifically attributed to conductivity improvements in the HF area.

How can the cable influence the stereo image?

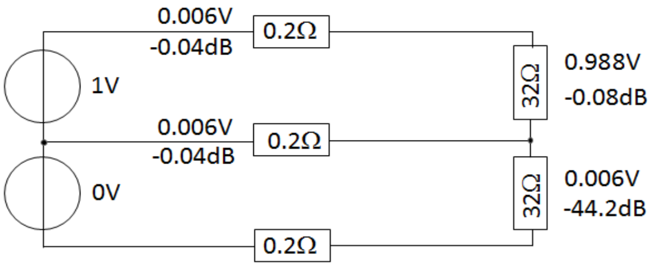
Those who have experienced a dodgy ground connection or a broken common wire might be familiar with the effect, but in this case it is a HUGE exaggerated version of it. What one hears is the absence of voices and instruments that are normally placed at the center of the stereo image (bass among those) and only reverb and strange sounding 'thin' instruments with no clear 'placement' in a weird 'mono' sound is heard.
This is because only the differences between the left and right channel are now reaching the drivers.
The same effect but only a VERY TINY amount of this is also present in 3 wire cable constructions.
These cables are mostly found in single entry headphones, where the cable enters only 1 ear-piece and the other ear-piece is fed via a short cable (or rods) through the headband construction.
Dual entry headphones usually have 4 wires where the return wires (the common of the plug) only are connected inside the headphone plug.
These dual entry headphones are not 'afflicted' with this effect and thus changing of the cable won't lead to a technical improvement. Any perceived differences cannot be traced back to electrical improvements.



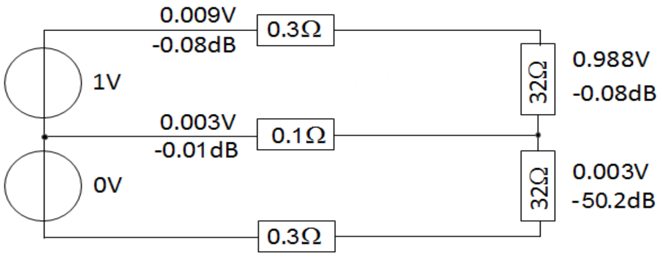


Above a realistic situation, a 3 meter cabled budget 32Ω headphone connected to an ideal 0Ω amplifier that puts out $1V_{RMS}$. On the left in a 3 wire cable where the cable resistances of 0.5Ω and their associated voltage levels and dB level drops are given. Only 1 channel has a voltage, the other one is silent (0V). The voltage that drops across the common return wire falls effectively over the 0V/0Ω amplifier, 0.5Ω cable resistance and 32Ω driver of the other channel. Practically the whole voltage on the return wire effectively, due to voltage division, falls across the driver that is supposed to be silent. It now puts out a -36.5dB sound that is opposite in phase with the signal on the other side. On the right picture one can clearly see the separated path of the 4 wire configuration and it shows the voltage drop on the return wire does not fall across the other driver.
Note that the key ingredient here is the **RETURN** wire (the common wire).

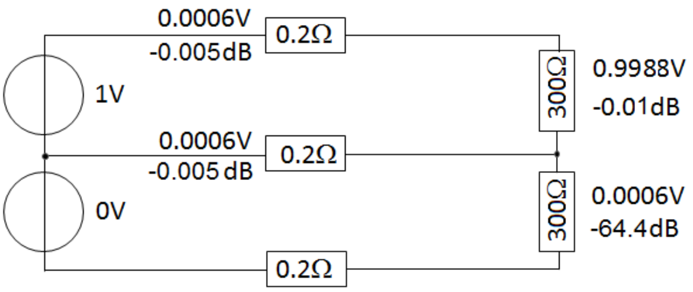
The numbers for a better cabled 3 wire, 32Ω headphone are improving.



The same headphone but using a screened cable, where the common screen is used as a return wire:



A 300Ω headphone with a good quality 3 wire cable:



A channel separation of -40dB is considered to be ‘sufficient’ by many.
Most recordings, vinyl, tapes don’t even manage that, so the audible effect might be very limited.
Technically speaking, a 4 wire headphone cable, where the **return wires** are joined in the headphone plug is measurably better though.

For higher impedance headphones, or in case the output resistance of the amplifier is higher than that of the headphone the advantages for a re-cable job to 4 wire is questionable since it is not likely to be audible in real life situations, where one channel is not silent but has the same signal as the other channel.
With a normal stereo signal level the drop in SPL due to crosstalk is merely a 0.01 to 0.2dB.
This is for both channels at the same time !

A good reason to re-cable a headphone would be to use a cable that is more supple or a less microphonic, so you won’t hear or reduce the friction/touching sounds from the cable via mechanical coupling. Perhaps a change of color scheme, looks or to replace a broken/worn cable might also be a good reason.
Changing the cable to win on sound quality, based on technical improvements, seems a pointless exercise.

The improvement, shown above, of the 4 wire return cable being technically better than a 3 wire cable can be completely undone if the connection between the headphone plug (the common/return connection) is oxidized, is dirty, makes band contact or the wiring inside the used amplifier is very thin or has a bad solder joint.
Short thick internal wiring or the headphone jack soldered directly to a ground-plane of the amplifier's PCB would be optimal.

Also note that people who make their living on selling (very expensive) cables, headphones all have a great (financial) interest in selling their wares so are likely to come up with evidence or testimonies that prove the stuff THEY sell DOES make a difference.
Everyone is free to choose what they believe is the truth or what they feel might be true based on their observations. Above is just my simple view on things, not hindered by yet undiscovered aspects.

Frans de Gruijter
Solderdude (Rockgrotto)