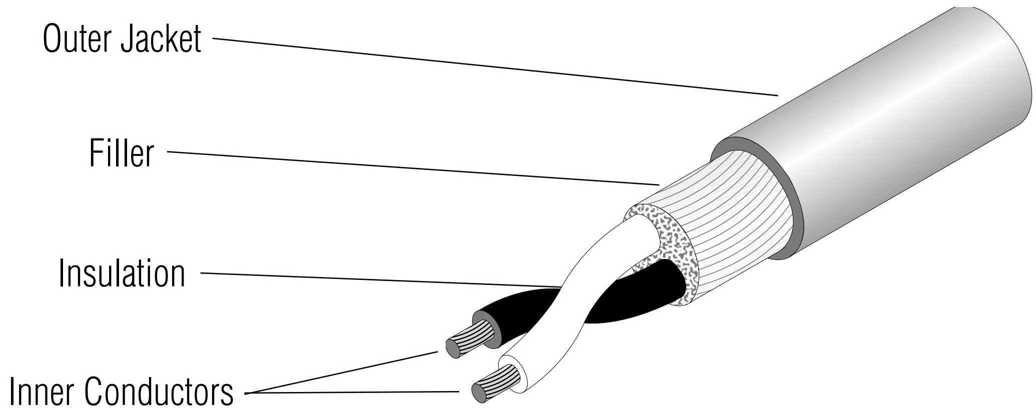
CABLE ANATOMY I: UNDERSTANDING THE SPEAKER CABLE

What are the main parts of a speaker cable and what does each one do?

Typically a speaker cable has two stranded copper ***conductors***, covered with ***insulation***, twisted together with ***fillers*** and sheathed with an ***overall jacket.***



How big should the conductors be?

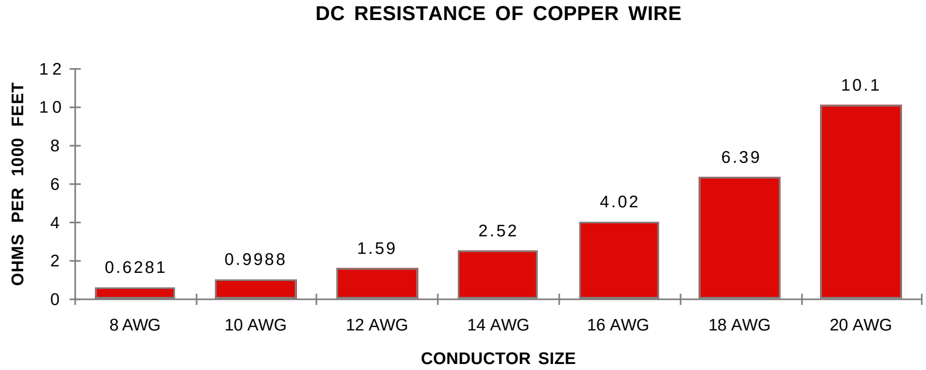
The required size (or ***gauge***) of the conductors depends on three factors: (1) the ***load impedance***; (2) the ***length*** of cable required; and (3) the ***amount of power loss*** that can be tolerated. Each of these involves relationships between ***voltage*** (volts), ***resistance*** (ohms), ***current*** (amperes) and ***power*** (watts). These relationships are defined with ***Ohm's Law.***

The job of a speaker cable is to move a substantial amount of electrical ***current*** from the output of a power amplifier to a speaker system. Current flow is measure in ***amperes.*** Unlike instrument and microphone cables, which typically carry currents of only a few ***milliamperes*** (thousandths of an ampere), the current required to drive a speaker is much higher; for instance, an 8-ohm speaker driven with a 100-watt amplifier will pull about 3-1/2 amperes of current. By comparison, a 600-ohm input driven by a line-level output only pulls about 2 milliamps. The amplifier's output voltage, divided by the ***load impedance*** (in ohms), determines the ***amount of current*** "pulled" by the load. Resistance limits current flow, and decreasing it increases current flow. If the amplifier's output voltage remains constant, it will deliver twice as much current to an 8-ohm load as it will to a 16-ohm load, and four times as much to a 4-ohm load. ***Halving the load impedance doubles the load current.*** For instance, two 8-ohm speakers in parallel will draw twice the current of one speaker because the parallel connection reduces the load impedance to 4 ohms.

(For simplicity's sake we are using the terms resistance and impedance interchangeably; in practice, a speaker whose nominal impedance is 8 ohms may have a voice coil DC resistance of about 5 ohms and an AC ***impedance curve*** that ranges from 5 ohms to 100 ohms, depending on the frequency, type of enclosure, and the ***acoustical loading*** of its environment.)

How does current draw affect the conductor requirements of the speaker cable?

A simple fact to remember: ***Current needs copper, voltage needs insulation.*** To make an analogy, if electrons were water, voltage would be the "pressure" in the system, while current would be the amount of water flowing. You have water pressure even with the faucet closed and no water flowing; similarly, you have voltage regardless of whether you have current flowing. Current flow is literally electrons moving between two points at differing electrical potentials, so the more electrons you need to move, the larger the conductors (our "electron pipe") must be. In the ***AWG*** (American Wire Gauge) system, ***conductor area doubles with each reduction of three in AWG;*** a 13 AWG conductor has twice the copper of a 16 AWG conductor, a 10 AWG twice the copper of a 13 AWG, and so on.

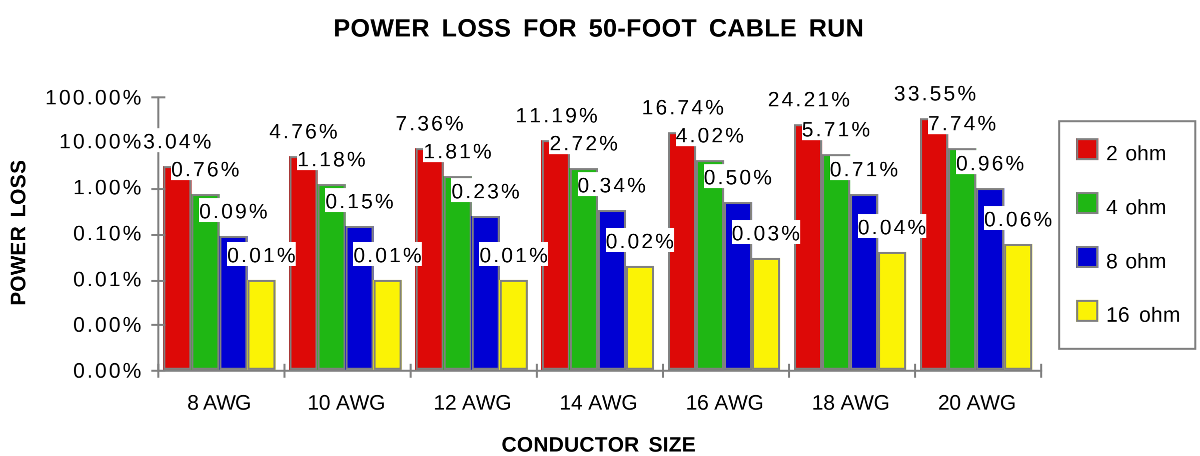


But power amp outputs are rated in watts. How are amperes related to watts?

Ohm's Law says that ***current*** (amperes) times ***voltage*** (volts) equals ***power*** (watts), so if the voltage is unchanged, the ***power is directly proportional to the current,*** which is determined by the impedance of the load. (This is why most power amplifiers will deliver approximately double their 8-ohm rated output when the load impedance is reduced to 4 ohms.) In short, a 4-ohm load should require conductors with ***twice*** the copper of an 8-ohm load, assuming the length of the run to the speaker is the same, while a 2-ohm load requires ***four times*** the copper of an 8-ohm load. Explaining this point leads to the following oft-asked question:

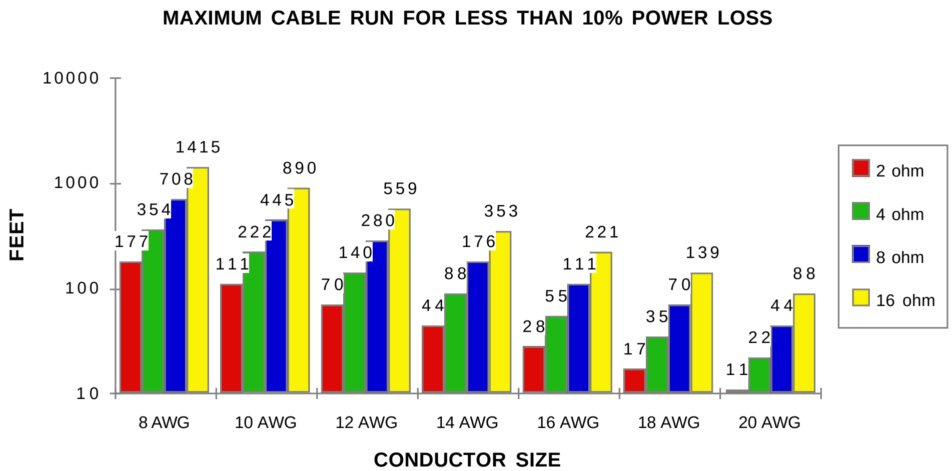
How long can a speaker cable be before it affects performance?

The ugly truth: ***Any length of speaker cable degrades performance and efficiency.*** Like the effects of shunt capacitance in instrument cables and series inductance in microphone cables, the signal degradation caused by speaker cabling is always present to some degree, and is worsened by increasing the length of the cable. The most obvious ill effect of speaker cables is the ***amount of amplifier power wasted.***



Why do cables waste power?

Copper is a very good conductor of electricity, but it isn't perfect. It has a certain amount of resistance, determined primarily on its cross-sectional area (but also by its purity and temperature). This wiring resistance is "seen" by the amplifier output ***as part of the load;*** if a cable with a resistance of one ohm is connected to an 8-ohm speaker, the load seen by the amplifier is 9 ohms. Since increasing the load impedance decreases current flow, decreasing power delivery, we have lost some of the amplifier's power capability merely by adding the series resistance of the cable to the load. Furthermore, since the cable is seen as part of the load, part of the power which is delivered to the load is dissipated in the cable itself as heat. (This is the way electrical space-heaters work!) Since Ohm's Law allows us to calculate the current flow created by a given voltage across a given load impedance, it can also give us the ***voltage drop*** across the load, or part of the load, for a given current. This can be conveniently expressed as a percentage of the total power.



How can the power loss be minimized?

There are three ways to decrease the power lost in speaker cabling:

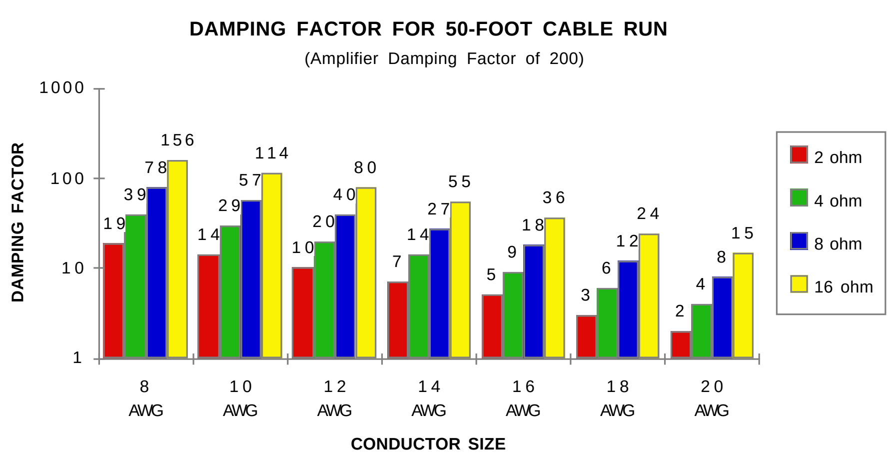
First, ***minimize the resistance*** of the cabling. Use larger conductors, avoid unnecessary connectors, and make sure that mechanical connections are clean and tight and solder joints are smooth and bright.

Second, ***minimize the length*** of the cabling. The resistance of the cable is proportional to its length, so less cable means less resistance to expend those watts. Place the power amplifier as close as practical to the speaker. (Chances are excellent that the signal loss in the line-level connection to the amplifier input will be negligible.) Don't use a 50-foot cable for a 20-foot run.

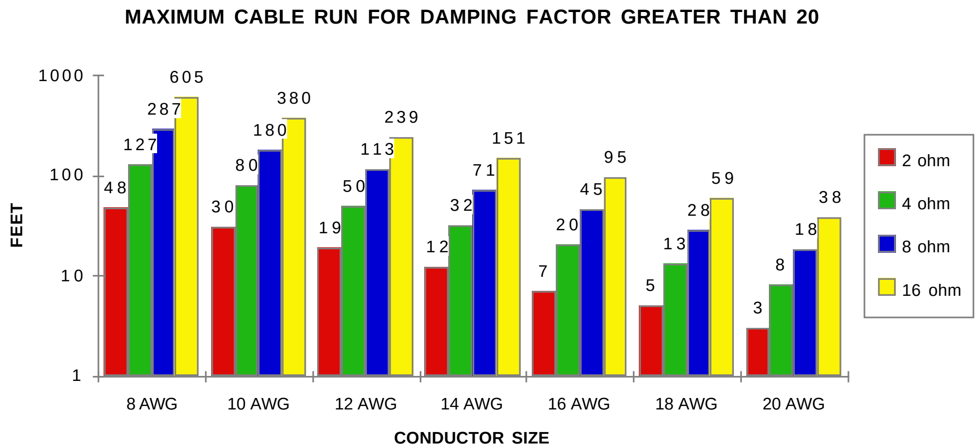
Third, ***maximize the load impedance.*** As the load impedance increases it becomes a larger percentage of the total load, which proportionately reduces the amount lost by wiring resistance. Avoid "daisy-chaining" speakers, because the parallel connection reduces the total load impedance, thus increasing the percentage lost. The ideal situation (for reasons beyond mere power loss is to run a separate pair of conductors to each speaker form the amplifier.

Is the actual performance of the amplifier degraded by long speaker cables?

There is a definite impact on the amplifier ***damping factor*** caused by cabling resistance/impedance. Damping, the ability of the amplifier to control the movement of the speaker, is especially noticeable in percussive low-frequency program material like kick drum, bass guitar and tympani. Clean, "tight" bass is a sign of good damping at work. Boomy, mushy bass is the result of poor damping; the speaker is being set into motion but the amplifier can't stop it fast enough to accurately track the waveform. Ultimately, poor damping can result in actual oscillation and speaker destruction.



Damping factor is expressed as the quotient of load impedance divided by the amplifier's actual source impedance. Ultra-low source impedances on the order of 40 milliohms (that's less than one-twentieth of an ohm) are common in modern direct-coupled solid-state amplifiers, so damping factors with an 8-ohm load are generally specified in the range of 100-200. However, those specifications are taken on a test bench, with a non-inductive dummy load attached directly to the output terminals. In the real world, the speaker sees the cabling resistance as part of the source impedance, increasing it. This lowers the damping factor drastically, even when considering only the DC resistance of the cable. If the reactive components that constitute the AC impedance of the cable are considered, the loss of damping is even greater.



Although tube amplifiers generally fall far short of sold-state types in damping performance, their sound can still be improved by the use of larger speaker cables. Damping even comes into play in the performance of mixing consoles with remote DC power supplies; reducing the length of the cable linking the power supply to the console can noticeably improve the low-frequency performance of the electronics.

What other cable problems affect performance?

The twin gremlins covered in "Understanding the Microphone Cable," namely ***series inductance*** and ***skin effect,*** are also factors in speaker cables. Series inductance and the resulting ***inductive reactance*** adds to the DC resistance, increasing the AC impedance of the cable. An inductor can be thought of as a resistor whose resistance increases as frequency increases. Thus, series inductance has a ***low-pass filter*** characteristic, progressively attenuating high frequencies. The inductance of a round conductor is largely independent of its diameter or gauge, and is not directly proportional to its length, either.

Skin effect is a phenomenon that causes current flow in a round conductor to be concentrated more to the surface of the conductor at higher frequencies, almost as if it were a hollow tube. This increases the apparent resistance of the conductor at high frequencies, and also brings significant phase shift.

Taken together, these ugly realities introduce various dynamic and time-related forms of signal distortion which are very difficult to quantify with simple sine-wave measurements. When complex waveforms have their harmonic structures altered, the sense of immediacy and realism is reduced. The ear/brain combination is incredibly sensitive to the effects of this type of phase distortion, but generally needs direct, A/B comparisons in real time to recognize them.

How can these problems be addressed?

The number of strange designs for speaker cable is amazing. Among them are coaxial, with two insulated spiral "shields" serving as conductors; quad, using two conductors for "positive" and two for "negative"; zip-cord with ultra-fine "rope lay" conductors and transparent jacket; multi-conductor, allegedly using large conductors for lows, medium conductors for mids, and tiny conductors for highs; 4 AWG welding cable; braided flat cable constructed of many individually insulated conductors; and many others. Most of these address the inductance question by using multiple conductors and the skin effect problem by keeping them relatively small.

Many of these “esoteric” cables are extraordinarily expensive; all of them probably offer some improvement in performance over ordinary twisted-pair type cables, especially in critical monitoring applications and high-quality music systems. In most cases, the cost of such cable and its termination, combined with the extremely fragile construction common to them, severely limits their practical use, especially in portable situations. In short, they cost too much, they're too hard to work with, and they just aren't made for rough treatment. But, sonically, they all bear listening to with an open mind; the differences can be surprisingly apparent.

Is capacitance a problem in speaker cables?

The extremely low impedance nature of speaker circuits makes cable capacitance a very minor factor in overall performance. In the early days of solid state amplifiers, highly capacitive loads (such as large electrostatic speaker systems) caused blown output transistors and other problems, but so did heat, short circuits, highly inductive loads and underdesigned power supplies.

Because of this, the dielectric properties of the insulation used are nowhere near as critical as that used for high-impedance instrument cables. The most important consideration for insulation for speaker cables is probably heat resistance, especially because the physical size constraints imposed by popular connectors like the ubiquitous 1/4" phone plug severely limit the diameter of the cable. This requires insulation and jacketing to be thin, but tough, while withstanding the heat required to bring a relatively large amount of copper up to soldering temperature. Polyethylene tends to melt too easily, while thermoset materials like rubber and neoprene are expensive and unpredictable with regard to wall thickness PVC is cheap and can be mixed in a variety of ways to enhance its shrink-resistance and flexibility, making it a good choice for most applications. Some varieties of TPR (thermoplastic rubber) are also finding use.

Why don't speaker cables require shielding?

Actually, there are a few circumstances that may require the shielding of speaker cables. In areas with extreme strong radio frequency interference (RFI) problems, the speaker cables can act as antennae for unwanted signal reception which can enter the system through the output transistors. When circumstances require that speaker-level and microphone-level signals be in close proximity for long distances, such as cue feeds to recording studios, it is a good idea to use shielded speaker cabling (generally foil-shielded, twisted-pair or twisted-triple cable) as “insurance” against possible crosstalk form the cue system entering the microphone lines. In large installations, pulling the speaker cabling in metallic conduit provides excellent shielding from both RFI and EMI (electromagnetic interference). But, for the most part, the extremely low impedance and high level of speaker signals minimizes the significance of local interference.

Why can't I use a shielded instrument cable for hooking an amplifier to a speaker, assuming it has the right plugs?

You can, in desperation, use an instrument cable for hooking up an amplifier to a speaker. However, the small gauge (generally 20 AWG at most) center conductor offers substantial resistance to current flow, and in extreme circumstances could heat up until it melts its insulation and short-circuits to the shield, or melts and goes open-circuit, which can destroy some tube amplifiers. Long runs of coaxial-type cable will have large amounts of capacitance, possibly enough to upset the protection circuitry of some amplifiers, causing untimely shut-downs. And of course there is enormous power loss and damping degradation because of the high impedance of the cable.

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