

# **XLO Cable**

## **Sounds Like Nothing At All**

### Cable White Paper

#### Cables as Components

Most people believe that audio and video cables just hook components together and little else. That is correct in theory. Just as any component in a system should do all and only what it is designed to do, the same applies to cables: The theoretically perfect cable should carry signal without affecting system sound or picture quality in any way.

However theoretical ideals are theoretical ideals; in fact making them a practical reality strains current technology. The perfect cable—utterly passive, absolutely neutral—is extraordinarily difficult to design and build in the real world. In fact cables of all kinds almost always have an effect on system performance.

#### Filter Matters: Filters Matter

Creating a simple filter network takes just two components, a resistor and a capacitor, or a resistor and an inductor. If it is a resistor/capacitor combination, the filter is said to be “high-pass”; frequencies below a certain “turnover” frequency are rolled-off, and frequencies above the turnover frequency pass undiminished. A resistor/inductor combo achieves exactly the opposite: A “low-pass” filter rolls off everything above the turnover frequency but passes everything below. The turnover frequency is determined by the values of resistance and capacitance or resistance and inductance present in the network.

This affects the sound because all cables—speaker and interconnect—exhibit, to one degree or another, all three basic elements of a filter. They are all resistive, capacitive, and inductive, capable of robbing a system of its bass foundation, precision, upper frequency shimmer and sound staging.

To make cables that Sound Like Nothing At All, XLO specifically designs each and every cable for the lowest possible resistance, capacitance and inductance. Whatever residual filter effects remain exhibit turnover frequencies either well above or well below the audio frequency spectrum.

#### The Phase Remains the Same

XLO Electric’s proprietary geometry minimizes capacitance and inductance, but there are, in fact, only two ways to reduce resistance: Either use more metal, or metal of higher conductivity. The path chosen is crucial as the wrong choice in solving problems of resistance always creates new problems with phase shift. Phase shift refers to a timing aberration of the positive/negative sequence relationships of the pressure waves that constitute the sound we hear.

To illustrate, consider what happens when speaker cables are wired-up “backwards” (positive-to-negative—“red” to “black”, instead of positive-to-positive—“red” to “red”). When wired “out of phase”, a positive signal from the amplifier produces a negative movement at the speaker (the cone of a “moving-coil” driver pulls in instead of pushing out), and a negative pressure wave is formed where a positive one is called for. Because the sequence of pressure waves produced by the speaker is exactly opposite that it should be, so it is considered 180-degrees “out-of-phase.” Because this

out-of-phase condition applies equally to all frequencies the speaker produces, the speaker is said to be out of absolute phase.

Errors in absolute phase are very easy to hear and should be avoided wherever possible. Yet a much more important consideration—one brought about by improper cable design—is frequency-related phase shift. Instead of all frequencies moving through a cable equally at the same speed, some are “shifted” forwards more than others depending on where they are in the frequency spectrum.

### Frequency-Related Phase Shift

A major cause of frequency-related phase shift is what is known as the “skin-effect.” This becomes most significant in large-diameter conductors as signals at different frequencies do not pass through the conductor in a uniform way. Higher frequencies are carried nearer the conductor’s surface and lower frequencies pass nearer the center. The cause is frequency-related differences in the AC resistivity of the conductor between its surface and center—the thicker the conductor the greater the differences—resulting in frequency-related phase-shift, with the higher frequencies shifted ahead of lower frequencies.

As frequency-related phase shift has a strongly negative impact on a system’s overall frequency balance, sound-staging and imaging capabilities, the means to reduce cable resistance assumes special importance.

The first option is a higher-conductivity metal in the conductors. XLO uses special high performance copper for all of its cables—99.99% pure Oxygen Free High Conductivity (OFHC) copper for all XLO/HT™, XLO/HTPRO™ and XLO Ultra™ brand cables, and 99.99997% (6N or “six-nines”) pure Laboratory-Grade copper for all others. The copper for all XLO cables, regardless of type or series, receives at least two treatments before the dielectric insulation is applied, resulting in reduced resistivity with no increase in frequency-related phase-shift.

The other way to reduce resistance is using more metal in the conductor to make it thicker, or in the case of stranded wire increasing thickness by adding more wires to each conductor bundle. But as above, thicker conductors (or bundles of conductors) have greater surface-to-center AC resistivity differentials and correspondingly greater frequency-related phase-shift.

XLO uses high-metal-content conductors to reduce resistance but maintains excellent phase characteristics with large numbers of individually-insulated, relatively small diameter wires arrayed in either surface-only geometries or proprietary variants on the Litz configuration.

Surface winding of the conductors successfully combats frequency-related phase-shift by reducing both the thickness of each conductor bundle and the diameter of each individual wire within the bundle to no more than twice the penetration depth (the depth within a wire at which signal passes) of the highest audio frequency. This effectively forces all frequencies to pass through all of the thickness of the wire, and because there is no “signal-layer stratification” to react with the wire’s AC resistivity gradient, and there is also no frequency-related phase-shift! We love this stuff...

Litz-variant winding approaches the problem of phase-shift differently, but no less effectively: Rather than concentrating on individual wires, XLO’s proprietary Litz-variant construction deals with phase-shift effects in the entire conductor bundle. By providing for controlled quasi-random movement of each wire from the center of the conductor grouping to the surface, and back again, it ensures that no wire will have any “normal” position within the grouping or any “normal” phase-shift characteristics. Topologically the cable has neither surface nor center, and frequency-related phase shift is therefore effectively canceled.

Mentioning the quasi-random distribution of individual wires at any given point leads to the subject of cable geometry. In fact, how it is wound—the “cable lay”—has as much to do with the sound as any other factor in cable design.

### Resistance is Futile

The simplest proof of this is to look once again at DC resistance; DC this time, not AC resistance as with the skin effect. If we consider any wire, of any gauge, of any material and any length at all, it will have a certain amount of DC resistance as one of its basic characteristics. Just for convenience, say that that amount equals “1”. If we add another wire, of exactly the same kind and length, the total resistance for the pair will be exactly halved (“1/2”), and it will be halved again every time we double our total number of wires (“1/4”, “1/8”, “1/16”, etc.).

Now, to make it interesting, let us take all our wires—16 long lengths, for example, with a total DC resistance of 1/16—and, after individually insulating them (which will not affect their total resistance), bind them together to make a cable. In fact, let us cut our insulated wires into equal shorter lengths, and make several cables, all with different geometries.

For one just twist all of the wires together in a single bundle. For others, braid the wires into a cylinder, or flat like webbing. We can twist and braid the cable to produce any number of different arrangements.

The most important elements of all these cables are: 1) All will have exactly the same DC resistance, and 2) All will sound completely different from each other! Given that all are made of the same number of the same lengths of the same wire, the differences in sound quality must be down to the winding geometry, and to the differences that makes in each cable’s capacitance and inductance.

We have mentioned capacitance and inductance as important elements in determining a cable’s filtering characteristics. Another aspect that makes these two characteristics important in audio cable design is that the degree to which a cable is capacitive or inductive strongly affects how well it interfaces and performs with the equipment to which it is connected. (Yes, you have to really want to be in the cable business!)

Generally less is best, but, for conventionally engineered cables this is a problem: Capacitance and inductance are normally considered to have a reciprocal relationship; reducing capacitance results in increasing inductance, and vice-versa. Because of their proprietary geometry, XLO cables offer both remarkably low capacitance and inductance. This means that our cables work better with more kinds and brands of equipment than most.

### Proprietary Field-Balanced™ Winding

Proprietary Field-Balanced winding is among XLO’s most significant core technologies. The braiding and winding geometries—how each signal-bearing conductor is arrayed relative to the others—optimizes and balances the relationship between two fields that are formed around a cable’s conductors and its insulating dielectric as an audio signal passes through.

It is no surprise that passing current through a wire produces an electromagnetic field around it. That is the basis of electromagnetic operation and the way in which a cone or moving-coil loudspeaker works.

What comes as a surprise to most people is that when current runs through an insulated wire, two distinct fields are formed: A current-controlled electromagnetic field around the wire itself, and a voltage-controlled electrostatic field around the insulating

dielectric. The interaction of these two fields has a considerable influence on the passing signal and strongly affects the system's sound. And that is why managing these fields forms an important part of every XLO Electric cable design.

### Capacitive Discharge Effects

Even the dielectric material coating the metal conductor affects the sound of your system. Not all the cable's passing signal energy is directly transmitted. Instead, some of it "charges" the dielectric insulation, exactly as if it were the dielectric of a capacitor.

Most of this energy is stored until the signal reverses polarity (every 180-degrees of a Sine Wave, for example) and then it is "dumped" back into the signal path out-of-phase, thus canceling some portion of the transmitted signal and creating noise. The rest of the diverted signal energy is converted into heat and lost. How much energy an insulating material stores is described by its dielectric constant. The amount of energy stored that is lost as heat is the dielectric's dissipation factor.

The dielectric constant is expressed as the ratio of energy storage capability of a volume of the material under test to that of the same volume of the very best (lowest energy storage) dielectric possible, a "hard" vacuum. The dielectric constant of vacuum is stated as 1.0, so a material with a dielectric constant of 3.5, for instance, would be capable of storing 3.5 times as much energy as a vacuum, on a volume-for-volume basis.

The dielectric constants of plasticized PVC compounds used by many manufacturers for cable insulation can range from 4.0 to more than 8.0. Thermoplastic rubbers (TPRs), another commonly used insulating material, can run as high as 15.0.

PTFE (the only insulating dielectric material used in XLO Electric cables even in our outer jackets has a dielectric constant of only 2.0—the lowest available. Other materials used in the XLO/HT™ and XLO/HTPRO™ brand speaker cables and interconnects are ethylene polymers and copolymers. As a group these are the next best thing to PTFE and offer dielectric constants as low as 2.1.

Dielectric dissipation factors also vary widely. As with dielectric constant, PVCs and TPRs have loss factors as great as 0.15 (15% of the energy stored will be lost.) PTFE has the lowest dissipation factor—as little as 0.00002 at 1 kHz. The ethylene variants are also very low, ranging from a high of about 0.01 (1% stored energy loss) to as low as 0.0001, depending on frequency and the specific formulation of the insulating dielectric.

The importance of the dielectric characteristics of insulating material—and why we pay so much attention to them—is that the proper function of a cable is to pass signal unchanged, with no additions or cancellations. Dielectric losses change the signal and represent one of the primary reason cables "sound" the way they do, when in fact they should have no sound of their own.

### The Truth About Damping Factor

One of the most obvious examples of this is the way speaker cables can affect an amplifier's Damping Factor. Simplified somewhat, the damping factor of an amplifier is an expression of its ability to control the movement of a loudspeaker. All loudspeaker drivers have mass, and the greater the mass and the greater the movement of the cone in a moving-coil driver, the greater the inertia that must overcome in accelerating and decelerating to follow the audio signal from the amplifier. Because the biggest (most massive) drivers in a speaker system are its woofers, and because bass signals require the most cone movement to produce, it is to accurate bass reproduction that amplifier damping is most important.

The calculation of amplifier damping factor (as typically stated on amplifier specification sheets) is very simple: It is just 8 ohms, the nominal "standard" loudspeaker impedance, divided by the output impedance of the amplifier. As an example, an amplifier with an output impedance of 0.01 ohm would be said to have a damping factor of 800 (8 divided by 0.01 = 800), which is very good but not exceptional for solid-state amplifiers.

In reality the calculation method just given overlooks two very important facts: First, not all (or, presently, even most) loudspeakers have a nominal impedance of 8 ohms; and second, and even more importantly, no true calculation of amplifier damping factor can be done without consideration of the speaker cable.

### It Is Not What You Think

There are actually three elements involved in powering a loudspeaker: The speaker itself, the speaker cable, and the amplifier. All of these must be considered in calculating true amplifier damping factor.

To make things even more interesting, the three elements act as if they were just two, and, surprisingly, the two are not what you might think: Instead of the loudspeaker and the cable being one element, and the amplifier being the other, in reality it is the loudspeaker that stands alone, and the combination of the speaker cable and the amplifier that comprises the other element.

This means that, for purposes of calculating amplifier damping, the figure that must be used as the effective amplifier output impedance is the sum of the output impedance of the amplifier plus the resistance of the speaker cable.

To understand how this affects the amplifier's true damping factor, and thereby the sound of the system, consider this: The resistance of a 10 foot run of a typically cheap 24-gauge "speaker cable" is about 0.51 ohms. Adding this to the 0.01 ohm output impedance of the amplifier mentioned earlier, we come up with an effective output impedance of 0.52 ohms. Dividing this into the "standard" speaker impedance of 8 ohms, we get a true damping factor of only 15.4, instead of the 800 shown on the specification sheet. Making matters even worse, if the speaker's true nominal impedance is 4 ohms instead of the "standard" 8, the true damping factor is reduced even more to just 7.7! (4 divided by 0.52 = 7.7) And that is why using cheap and badly-made speaker cable results in flabby and uncontrolled bass...because it is uncontrolled!

By contrast, a 10 foot run of XLO Ultra 6, which is a 10-plus gauge cable, has a total resistance (both legs) of just 0.02 ohms. This, plus the amplifier's output impedance of 0.01 ohm is only 0.03 ohms, which, divided into the 8 ohm standard speaker impedance gives a true damping factor of 267 – better than 17 times the speaker control available from the lesser cable!

Interestingly, it is not just audiophile equipment that good cables benefit. In fact, because less expensive amplifiers and receivers tend to have lower specified damping factors, good cable, by making the most of what damping there is, can actually be of more benefit to less expensive gear than to the very best equipment available. For an even deeper analysis of AC/DC conductor basics, why silver conductors are best for video, issues of self-inductance, impedance, reactance, more on capacitive discharge effects and winding geometry, plus a treatise on the importance of AC power cords, visit the [www.argentumacoustics.com](http://www.argentumacoustics.com) multimedia page and download the Technical White Paper.

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About Ultralink/XLO Products, Inc.

Ultralink/XLO Products, Inc., headquartered in Ontario, California is an industry-leading manufacturer of high performance audio and video cables and UltraPower™ AC power products, Canada's market share leader in the field.

In early 2002 Ultralink Products Inc. acquired XLO Electric Co., Inc. a well-known brand of audiophile reference cables and interconnects. Ultralink also introduced the elegant "Engineering Truth" Argentum Acoustics™ line of cables and accessories. Ultralink is a member of PARA, CEDIA and the CEA.

For more information on Ultralink/XLO and their product brands call (909) 947-6960 or find them at [www.ultralinkproducts.com](http://www.ultralinkproducts.com) or learn more about XLO at [www.xloelectric.com](http://www.xloelectric.com).

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