FURUTECH

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Audio/Video Cable White Paper

The many conflicting claims about cables and interconnects creates a confusing message for high performance enthusiasts who simply want to connect a complete A/V or stereo system together for a wideband, low-noise, harmonic and dynamic presentation. Those upgrading cables and interconnects component-by-component face the same predicament.

At Furutech, we achieve best results with an extremely high level of engineering allied with a total dedication to creating the best, most refined products possible using cutting-edge materials and processes, like our 2-Stage Cryogenic and Demagnetizing Alpha technology. And do it at relatively reasonable prices for the performance available.

We present the following white paper so you may find, as we do, that there is a meaningful and significant correlation between cable design and sound quality. Our emphasis on engineering and quality of materials for each and every element of signal transfer leads us to suggest that subjective listening *alone* may not be enough when choosing cable or interconnect.

First and foremost, Furutech designs each cable and interconnect to accurately meet all required technical specifications using the best design and materials available.

While the quality of the AC mains power significantly influences sound and image quality, Furutech offers a number of power cord, power distribution, and filtering solutions. In this white paper, we will concentrate on interconnect and speaker cable.

Cable Basics

High performance A/V components typically make use of three cable types:

- A/C mains power cords
- Line-level and digital interconnects linking components
- Speaker cables linking amplifiers and speakers

A quality cable design depends on three basic factors:

- Conductor material
- Insulation material
- Cable construction

High performance conductor materials allow significant levels of resolution enhancement, plus tighter and more controlled bass, a more fully textured midrange, sweeter highs, and a greater sense of air, imaging and soundstaging. The combination of a cable’s construction, insulation, and electrical characteristics define its musical accuracy and timbre.

TPC

OFC

μ- OFC

Alpha-OCC

TPC *Alpha-OCC*

Conductors

TPC (Tough Pitch Copper)

TPC is a basic copper wire conductor widely used in power cords and occasionally inexpensive audio cables. Drawing melted, electrolyzed copper through a series of dies, the conductor is cooled to the desired size. Tough pitch copper melted and cooled in open air is laden with about 300~500ppm of oxygen.

OFC (Oxygen Free Copper)

OFC is manufactured in an oxygen-free/inert gas environment, and its 10ppm of oxygen content represents a significant improvement over TPC. As a result, OFC's conductivity is 0.5% to 2% greater than that of TPC.

μ-OFC (Annealed Micro Oxygen Free Copper)

μ-OFC is manufactured by carefully controlling time and temperature constants as well to further inhibit the formation of crystal grain structures.

In 1988 Furutech introduced Furukawa Electric cable products, the first to make PCOCC A/V cables and interconnect featuring high purity single-crystal oxygen-free copper. Ohno Continuous Casting techniques, invented by Professor Ohno at The Chiba Institute of Technology in Japan, result in a very pure copper conductor.

Since then, Furutech's engineers have applied themselves to perfecting every single aspect of signal and power transfer, resulting in today's state-of-the-art *α Alpha-OCC conductor*. We use the Ohno Continuous Casting process, then additionally treat the cable with Furutech's special *2-Stage α Alpha Treatment*. (See below.) We use a high temperature heated mold that produces mono or single crystal ultra-pure copper wire with *insignificant* traces of oxygen and hydrogen, and the process reduces the ratio of stress to strain in the wire. Since *α Alpha-OCC* has greater flexibility, a higher specific gravity, and a higher "Q", its mechanical isolation and resistance to electromagnetically induced vibration within the

conductor is excellent. As a result, our α *Alpha-OCC* monocrystal has *no* crystal grain boundaries within the conductor to interfere with signal flow. Our conductors feature the lowest distortion factor of any others available!

α *Alpha-OCC* is the *only* OCC featuring Furutech's *2-Stage Cryogenic and Demagnetization Alpha Process* resulting in high performance cables at all price points.

Furutech Alpha Process

2-Stage Cryogenic and Demagnetization Treatment

Using cutting-edge technology and materials, Furutech developed a two-stage process that significantly improves every facet of audio and video performance. The treatment begins with a deep, conditioning cryogenic freeze of all metal parts, including conductors and connectors,

Using high-end refrigerants--liquid N_2 or He--Furutech achieves between -196 to -250C. The treated parts change their molecular structure at these extremes of temperature relieving internal stress. The molecules bond together more tightly and the overall structure becomes more stable. Cryogenic treatment enhances electrical conductivity and thus power and signal transfer.

Stage two in the Alpha Process exposes these same parts to our patented Ring Demagnetization treatment. Ordinary high power magnets used for this purpose often *increase* magnetization effects; they leave some areas more magnetized than others. Just like a CD spinning over a fixed magnet; when the CD stops the area above the magnet is still exposed to the magnet's field causing audible distortion. The patented Ring Demagnetization Process uses *controlled* attenuation of the magnetic field to eliminate all field effects for immediately more vivid and colorful improvements. Ring Demagnetization further enhances conductivity of all treated materials.

All metal parts used in Furutech products are given the Alpha Process treatment, and Furutech's RD-2 Disc Demagnetizer will keep your interconnect, speaker cable, and power cord connectors in perfect demagnetized condition.

The 2-Stage Cryogenic and Demagnetizing Alpha Process works in tandem with other designed-in features to create the most optimized signal transfer possible. Furutech's total awareness and devotion to detail results in a greater sense of power, dynamics, and resolution, with cleaner, blacker backgrounds and a larger, more stable soundstage, with a vivid tonal colors and deeper extension at both ends of the frequency range. Displays of all types will exhibit greater, sharper resolution with less ghosting, color shift, "snow", or vertical and horizontal lines.

Physical and Chemical Properties of Copper Ingot

		Alpha-OCC	μ-OFC	OFC	TPC
Purity		>99.997	>99.99	>99.99	>99.9
Density	×	8.938	8.928	8.926	8.75
	max	8.940	8.934	8.932	8.88
Gas impurity	O_2(ppm)	<5	<10	<10	200~500

	H_2 (ppm)	<0.25	<0.5	<0.5	>0.3
Hydrogen Embrittlement		None	No	No	Yes

Properties of Materials

	Alpha-OCC		μ-OFC	OFC/ TPC
Conductor diameter	5mm	15mm	1.6mm	0.9mm
Length of grain	>500mm	>50mm	<0.3mm	<0.05mm
Length of grain after drawn to 0.1mm	>1,125.00m		<12cm	<4mm
Number of grains in 2m cable	1		>30	>400

Under Construction

Most high performance cables use either a solid-core conductor or stranded “wire lays” depending on its use. Stranded wire cables are typically available in one of three configurations, each having its own characteristics.

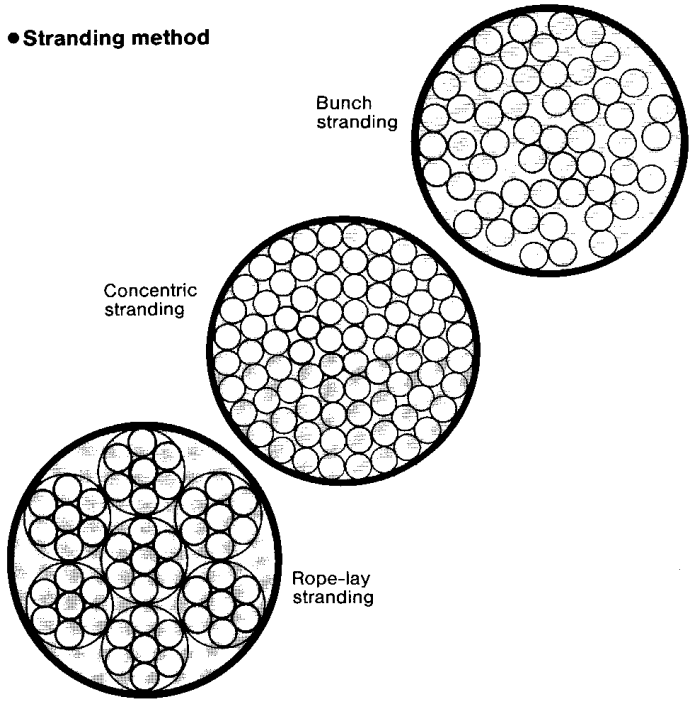
Stranded Conductors

Many basic power cables and interconnect use simple, stranded conductors. They are simple loose copper conductors arrayed in a group or bunch from connector to connector.

There is a major problem with his design, however. When examining it in cross section, it’s easy to see that the circle of wires at the perimeter of the bundle isn’t perfectly circular. This results in signal degrading reflections caused by fluctuating impedance.

Concentric Lay Stranded Conductors

A concentric lay stranded cable consists of multiple layers of concentrically wound stranded conductors. In this configuration, the center of the middle conductor coincides with the center of all the other conductors. Most importantly, the uniform layout of the conductors form a perfect circle when viewed in cross section, making it more suitable for signal transmission as it stabilizes impedance fluctuations.



Rope Lay Stranded Conductors

Rope lay stranded conductors are composed of concentric lay stranded conductors consisting of bunched or concentric lay stranded wires. Rope lay stranding is a superior design often used in better quality speaker cables which need a large cross section but needs to be

flexible.

Solid-Core Conductor

Solid-core Alpha-conductors are the ultimate in signal transfer conductor materials. Furutech's perfectly circular solid-core conductor, produced in a variety of sizes, eliminates every compromise mentioned above.

Understanding Cable Performance
Essential Electrical Characteristics

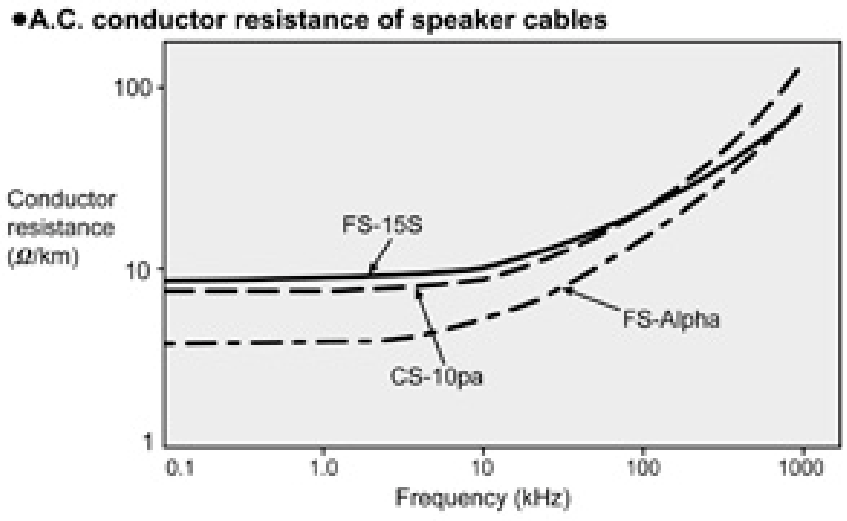
Resistance (R)

Resistance (R) is one of the big three most recognized characteristics describing cable performance. It is normally expressed as LCR: impedance, capacitance, and resistance.

Resistance causes signal loss--attenuation—that is directly proportional to the conductor's resistance. Attenuation represents the energy consumed by the cable as signal passes through it. This is especially important in speaker cable where a high resistance factor causes a decreased damping factor. The voice coil of the driver generates an "electromotive force" that feeds back through the speaker cable and can, in extreme cases, damage the power amplifier. DC resistance is in direct proportion to the conductor's cross sectional area and purity of materials. Keep the cable's diameter as large as possible, use the highest purity wire possible, and DC resistance will be low.

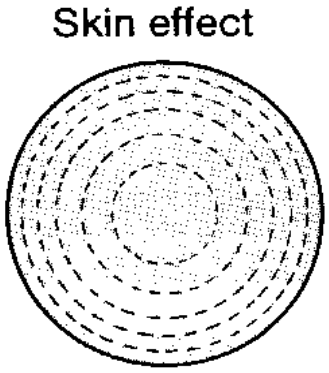
The conductor's resistance also increases because of the *Skin Effect*, the *Proximity Effect*, and *Eddy Current Losses*. Illustrated below are frequency characteristics of three Furutech speaker cables, CS-10pa, FS-Alpha and FS-15S. The first two are stranded designs with 2mm square and 5.5mm square conductors respectively, while the third is 1.5mm square solid-core conductor.

Notice that from 20Hz to 20kHz--the audible frequency range--all three cables remain relatively flat. However, as frequency increases from DC to AC conductor resistance increases. It may be argued that these frequencies are inaudible, but they directly affect timbre, air and ambience, focus, detail, and imaging.



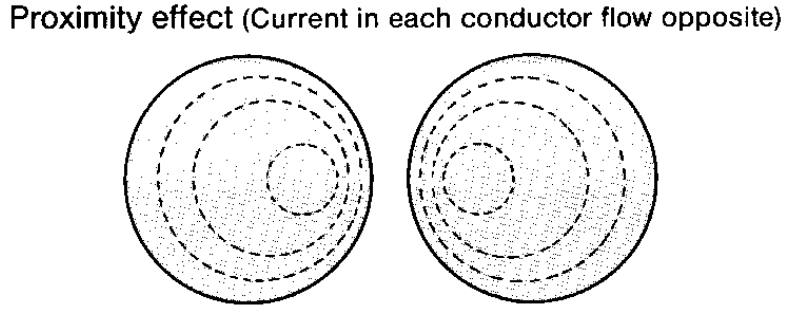
Skin Effect

Flowing current tends to migrate towards a conductor's surface as frequencies rise. Traveling across a conductor's peripheral surface changes the effective cross-sectional area. That results in greater resistance, and that means signal loss and degraded sound and image quality.



Proximity Effect

When conductors are positioned side by side and high frequency currents flow, the currents tend to flow with a certain distance between them when both conductors' signal flow is the same direction. When the current flows are opposite each other, the current tends to flow towards each other. This explains the increase in conductor resistance when current flow is not uniform.



Insulation

The most popular insulation materials are PVC (polyvinyl chloride) and LDPE (low-density polyethylene). You'll find PVC in commercial low-voltage applications of 600 volts or less. LDPE, with its improved dielectric characteristic, is preferred for high voltage power applications, as well as video and digital cables.

FEP (Teflon) and PP (polypropylene) are also used as insulation material. Teflon has excellent dielectric characteristics along with superior heat resistance. That's helpful when you consider that insulation is applied at extrusion temperatures of about 400 to 500 degrees centigrade; at these temperatures, the conductor surface oxidizes.

PP (polypropylene) is a pure, stable material with excellent insulation characteristics, including its

dielectric constant. PP also exhibits better mechanical isolation from vibration. It is Furutech's favored insulation for speaker cables and line-level analogue interconnects.

The efficiency of the insulation's dielectric constant determines the signal transmission velocity, so it is easy to understand how important a factor that is. Engineered as they are, all Furutech cables and interconnect have low dielectric loss and therefore stable frequency response throughout the audio spectrum.

Insulation Materials' Electrical Characteristics

Material / Properties	Low Density Polyethylene (LDPE)	PVC	Polypropylene	FEP
Specific volume resistance (Ω·cm 20℃)	$>10^{17}$	10^{12} ~10^{15}	6.5 X 10^{14}	$>10^{18}$
Dielectric constant ($50\sim10^{6}$Hz)	2.3	4~8	2.25	2.1
Dielectric loss tangent ($50\sim10^{6}$Hz%)	0.02~0.05	8~15	0.02~0.06	0.02~0.07

˙ Teflon is a trademark of Du Pont.

Electrical Characteristics of Insulation Materials

Insulating materials have four electrical characteristics that are critical to the transfer function. These are:

Specific Volume Resistance

- The resistance per unit area of DC (direct current)
- Used as an index of insulation performance

Dielectric Strength

- The voltage at which 1mm of insulation breaks down

Dielectric Loss Tangent

- A guideline for dielectric loss when AC is applied to insulation material

Relative Dielectric Constant

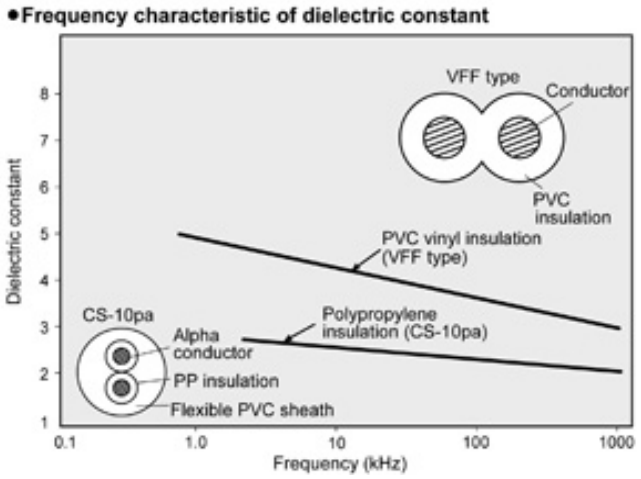
- Probably the most important element in a cable's design.

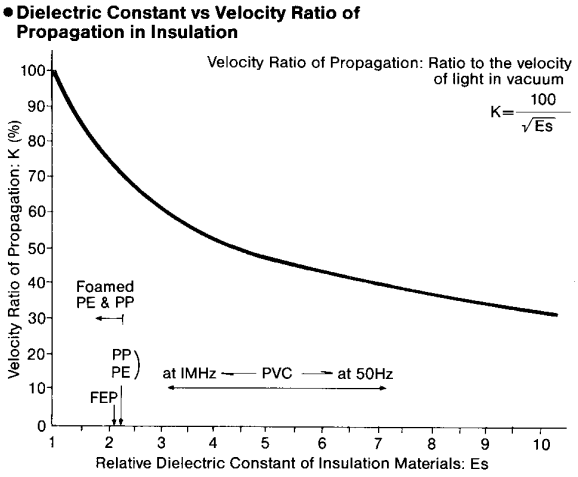
The relative dielectric constant (Es) is defined as the ratio between the electrostatic capacitance for parallel plate condensers in a vacuum (Co) and the electrostatic capacitance when an insulation material is interposed (C). It is expressed as Es=(C/Co). The relative dielectric constant may be interpreted as the magnitude of

polarization for the vacuum (Es=1).

As seen in the graph below right, an insulating material containing a large volume of ions such as PVC *polarizes* when voltage is applied. The altered structure of the insulation surrounding the current-carrying signal conductor causes dielectric loss, resulting in reduced transmission velocity based on the insulation's relative dielectric constant.

The graph lower left illustrates the frequency characteristics of relative dielectric constants (Es) between two sample cables, Furutech VVF, a power cable using PVC insulation, and Furutech CS-10pa speaker cable, with PP insulation and a PVC sheath.



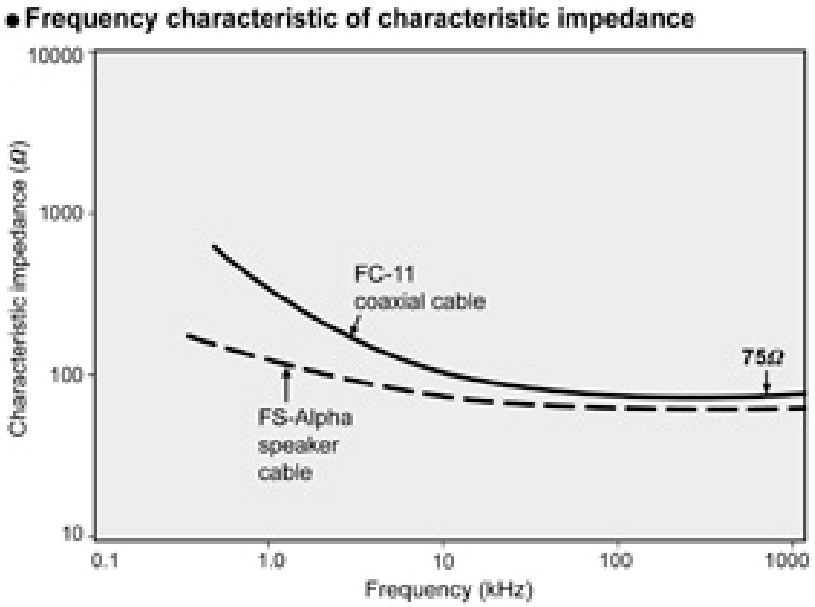


Capacitance (C)

Another of the big three cable characteristics expressed as C. The electrostatic capacitance of a cable is determined by the relative position of the two conductors and the dielectric constant of the insulation. Foamed polyethylene and polypropylene are employed in low capacitance cable like Furutech's FC-11, and FA-220, where foaming reduces the dielectric constant thereby stabilizing the frequency characteristics. Within the audio range, the amount of capacitance together with conductor resistance governs the level of attenuation, and the lower the better.

Characteristic Impedance (L)

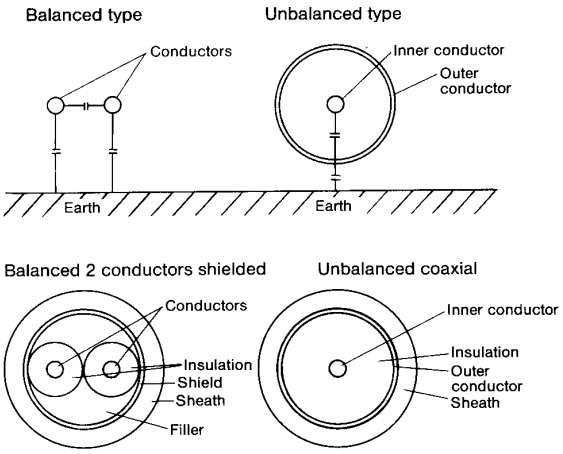
The last of the big three electrical cable elements Impedance, is more easily explained with digital connections. Maintaining characteristic impedance from one tip of the cable to the other is paramount for unimpeded high frequency signal transfer. The best cable for this application is 75 ohm coaxial. When other constructions are used there is more likely to be reflections from a connection point, like an RCA connector, for example, which causes timing errors and jitter. This interferes with the clean transmission of digital's step rise/fall time so the waveform becomes "jittered" degrading the signal transfer function.



Balanced and Unbalanced Cables

Balanced configuration cables use conductors at the same characteristic impedance, capacitance, and resistance (LCR), as found in Furutech's FA-13S and FA-220 conductors. Both conductors are at equal ground potential and do not reference ground. Balanced cables may feature a separate shield to eliminate radiated noise. In some cases the shield is connected to a flying lead--an external wire--for connection to chassis ground.

Unbalanced single-ended cables, usually on RCAs, have hot and cold conductors that are *not* equivalent in terms of construction or electrical characteristics, such as Furutech's FC-11 and FX-Alpha Ag cables. These are coaxial designs where the shield is tied to the cold signal path--the outside barrel of an RCA connector. In general, the resistance of the shield is lower than that of the conductor enhancing its effect.



The Shield

Interconnects are shielded to protect the signal from external radiated noise. There are two types of shield, one rejects electrostatic induced noise, the other magnetically induced noise.
Damping electrostatic noise calls for a metalized shield with a high conductivity constant, such as copper or aluminum foil. Since the shield's effect is in reverse proportion to its resistance, reducing resistance increases current flow, creating a more effective barrier against external noise. Furutech balanced cables use copper wire braid and aluminum foil shields. Underneath the insulated conductors are twisted around each other.

Some type of ferrous material must be used to shield against magnetic interference, but cable can quickly become very thick and unwieldy unless carefully engineered. Generally speaking, twisting the insulated conductors around each other in a "hum-bucking" lay suppresses magnetic fields. But

Furutech's engineers do not accept this as a proper *magnetic* shield, which usually denotes an effective ferrous-based solution.

Formula GC-303 is a special material that Furutech layers and bonds to the interior bottom-plate of our power distribution and filtering units. It absorbs EMI (Electromagnetic Interference), and can be found in the outside module of our Reference Line of cable products.

Jacketing
Furutech's attractive jacketing material mechanically dampens external vibration as well as electromagnetically-induced resonance. It even bends with relative ease to increase placement options.

Furutech Audio Cables Are Scientifically Designed and Engineered
A few precautions for optimal performance:

- Do not wind, bundle or bind cables
- Do not stretch
- Do not bend excessively
- Do not place signal carrying cables in parallel with power cables
- Do not place audio cables in parallel with ferrous materials
- Do not leave one end of any cable connected with the other not
- Do not allow hot and cold signal paths to touch and short circuit
- Disconnect unused cables
- Do not attempt to fix a solder connection within the cable
- Periodically clean any oxidation from the contacts
- Do not use in unnecessarily long runs where possible

Furutech dealers will be pleased to assist with an obligation free, in-home demonstration of the very special sonic improvements of Furutech cables.

Make a More Powerful Connection with Furutech