Constant Current Impedance Testing (CCZT)

for the measurement of audio cable performance

The purpose of this white paper is to explain the methodology and scientific principles supporting Constant Current Impedance Testing (CCZT)™. This proprietary testing method, devised by TARA Labs' Research and Testing Department, is used to measure the differences in cable performance. CCZT highlights the fundamental and primary reason that audio cables sound different, and that is the design (size, shape and configuration) of the conductors themselves.

We can make measurements of different audio cable conductor designs and find that the measurements will correlate with the differences that we can hear. Moreover, with the measurements as a learning tool, we can begin to distinguish conductor designs that are linear and accurate as opposed to designs which soften or color the sound. With sine wave analysis, using a frequency generator and oscilloscope, we can make measurements that will provide reliable predictions about the sound to be heard from the changes of cable conductor design and configuration. At TARA Labs, we have been able to reliably correlate the listening experience to the test-bench experience by developing certain tests described later in this white paper.

The fundamental differences between cable designs have to do with two basic criteria: conductor size and conductor shape. In a conductor with a smaller diameter, the current carrying capability is reduced but linearity with frequency is improved. Linearity here is defined as the least degree of impedance rising with increasing frequency. It is both necessary and important because it directly relates to correct harmonic structure, phase coherency, rise-time and the accurate reproduction of the musical signal. As well as the size or diameter, the shape of a conductor (round, rectangular) can change its linearity also.

We can compare the rising impedance with increasing frequency for different conductors of different sizes and different shape. The self-inductive related rising impedance of the conductors, sometimes referred to as the 'skin-effect', is a phenomenon that can be measured down to as low as @1 kHz with TARA Labs' Constant Current Impedance Testing (CCZT) setup. With these measurements, we have found that for any given conductor, the measured impedance from DC to 1 kHz is the same as the DC resistance of the conductor. At around 1 kHz and above, a conductor will have a rising impedance vs. frequency response. When we compare these responses above 1kHz, as well as noting the phase shift in the different conductors at varying frequency, we can draw conclusions about the sound to be heard from these conductors as used alone or as part of a finished cable design.

In the following tests, we use conductors of equivalent mass, but of differing shapes. The conductors are placed through a Test-Jig constructed of MDF. The conductors form a 10-foot channel run and have the same parallel configuration between the send and return lines. This methodology is valid because it accurately compares the design qualities of the conductors themselves while keeping all other factors identical.

For the sake of brevity, the test results from our Test-Jig and Frequency Generator set-up are shown for 5k and 10k. See "Measurement Summary" to note the measured differences. Then see the graphed results of the four main conductor types after their results were tabled and plotted.

Starting with the 14 AWG round conductor, we note that the has least linearity with frequency. This conductor could be stranded or solid, but even if you assume the best case for the stranded conductor, i.e.: that it had no oxidation between the strands, then the conductor whether stranded or solid will have the same impedance vs. frequency curve for a given diameter and mass. Multiple-stranding does not mitigate the skin effect when the strands are bundled together as one conductor. The skin effect or inductive reactance will be the same for a stranded or solid conductor of the same diameter and conductive mass.

The inductive reactance and the skin effect are reduced when the strands are separately insulated from each other. This leads to Litz-Wire (multiple enamelled wire) construction such as is used in some high-end cable. Look at the entry marked 4 x 20AWG Enamelled, equivalent to a 14AWG conductor. This conductor has superior linearity compared to the 14AWG round conductor. Its linearity is due to smaller size wires being used. But because the construction is 'compact' and not spaced apart, it nonetheless approximates a round conductor in its overall shape. Any compact or uniform shape increases the tendency of the whole conductor to have greater density in the coupling or linkage of electro-magnetic flux, thereby reducing the high frequency linearity. See the notes on 'skin-effect' for a complete explanation.

Next, note the conductor made of two round solid wires whose mass together is equivalent to 14AWG. This conductor has slightly better linearity than the 4 x 20AWG Enamelled wire conductor even though the individual gauge size of each of the two solid wires is greater than 18AWG. The reason is that this conductor construction has less coupling or flux linkage between the two solid wires due to their spacing and overall shape. This is an important point and leads us to make conclusions about compactness in multi-solid core conductor designs. Spacing conductors apart increases linearity. Compactness in a design reduces linearity. Finally, the rectangular conductor is inherently more linear than any of the round conductor types due to its shape and diminished flux linkage.

The sound...

(1) 14AWG Round conductor.

The highs are definitely softened and rolled off. The mid-range and upper bass are warm and colored, and the bass is full but not distinct or clear.

(2) 4 x 20AWG Solid Enamelled conductor.

The sound is more linear; the highs are a little soft and dark sounding. The mid-range and upper bass are more natural sounding, though slightly warm or colored. The mid-bass and bass are cleaner and clearer sounding than the 14AWG Round.

(3) 2 x Round Solid conductor.

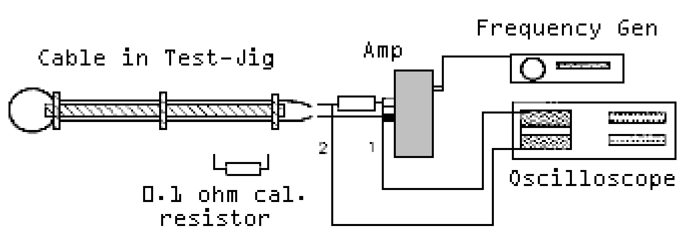
The sound is linear and natural; the highs are softened slightly. The upper mid-range, mid-range and upper bass are coherent, clear and natural. The mid-bass is less distinct or clear than the 4 x 20AWG but cleaner and clearer than the 14AWG Round.

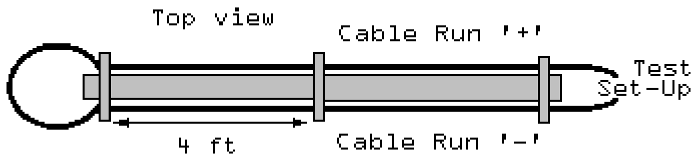
(4) 2 x Rectangular conductor.

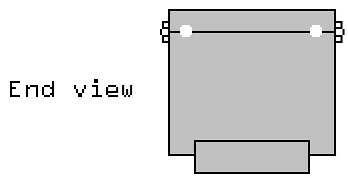
The sound is remarkably different. The highs are extended and clear. The upper mid-range, mid-range and upper bass are clear, natural and very coherent. The natural harmonic structure of the music is very apparent. By comparison to the other conductor types, every aspect of the mid-bass and bass is perfectly distinct and clear.

Notes on Skin Effect:

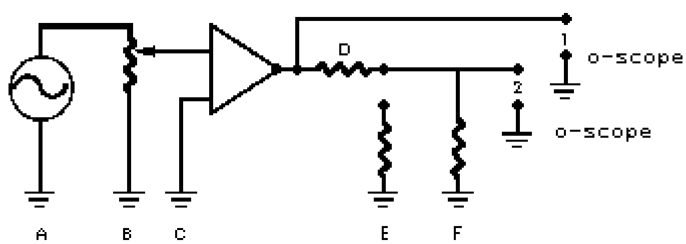
The phenomenon known as the "Skin Effect" (higher frequencies tend to travel toward the skin of the conductor) causes high frequencies to be attenuated as compared to lower frequencies, which travel more uniformly within the conductor. For any conductor with a uniform diameter or uniform thickness, there will be more coupling or linkage of electromagnetic flux at the center of the conductor as compared to the surface. As a result, there will be more opposition to AC current at the center of the conductor. Also, as the AC frequency increases, there will be an increasing rate of change of flux. This causes increasing counter-EMF to be generated nearer the center of the conductor, reducing HF energy as frequency increases. The conductor can be compared to a series inductor: the high frequencies are attenuated more and more as the diameter or thickness of the conductor increases and as frequency increases also.







Constant Current Impedance Testing (CCZT)™



A=Signal Source	D=Current Limiting Resistor
B=Signal Level Control	E=Calibration Resistor
C=Amplifier	F=R(Z) to be measured

If Resistor D is expected to be much larger than Resistor E, and higher than Resistor F will be over the entire frequency range, then the current passing through R_D and R_E is largely determined by R_D.

For example, let us say that $R_D = 1000$ and $R_E = 1$ ohm and the expected resistance of R_F is about 1 ohm.

Changes in R_F or Z_F resulting from changing the input frequency will have little (about 1%) effect on the current in the circuit. Therefore, the voltage across R_E(calibration) or R_F (impedance to be measured) will be proportional to the impedance of R_E (or R_F).

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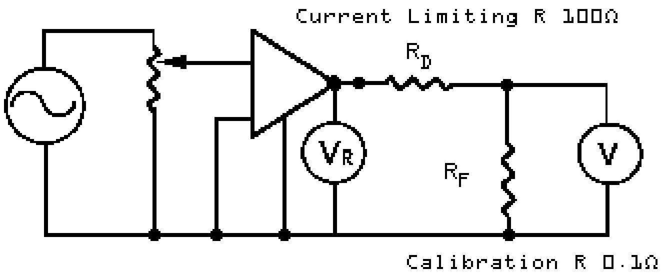
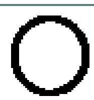
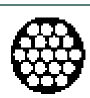
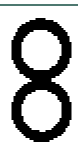
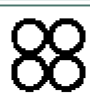
Procedure -- Conditions



1. Connect resistors as shown.
2. AC voltmeter or Oscilloscope is connected at V.
3. Signal source (frequency generator) is set at desired frequency. For all practical purposes, measurements of Z in wire or cable are the same from DC to about 1kHz. Signal level control is adjusted until meter or scope reads at 1 division, preferably 1/10 full scale. The sensitivity will need to be high due to 1/1000 voltage division of circuit. After the 1 division deflection is made, do not adjust the signal level or scope sensitivity.
4. Substitute Resistor R_F or cable to be tested for the calibration resistor, after the meter or scope has been calibrated. The number or division of the deflection on the meter or scope will be proportional to the resistor R_F or the cable under test and read as the impedance at the input frequency.

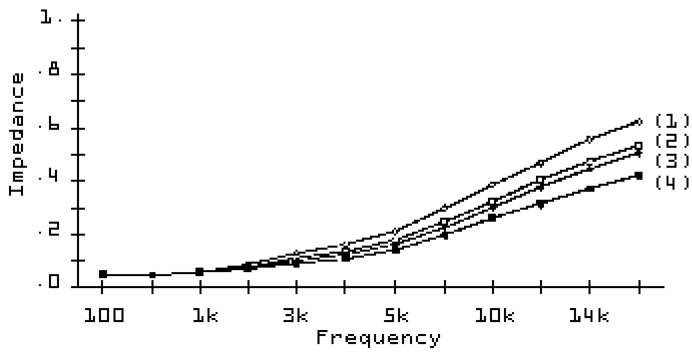
NOTE: Phase shift can be seen with a dual trace scope by connecting the other channel at V_R. The shift in phase of the sine wave traces will be that caused by the capacitive or inductive reactance of the cable under test R_F.

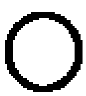
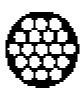
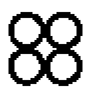
Measurement Summary

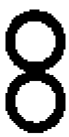
Diagram	Area	Type	Z(ohm) @ 5 KHz	Z(ohm) @ 10 kHz
	14 AWG	Solid Core	0.19	0.39
	14 AWG	Stranded	0.20	0.41
	14 AWG	2x Round Solid Core, PE insulated	0.16	0.31
	14 AWG	4x Round Solid Core enamelled	0.16	0.33

	14 AWG	2x Rectangular Solid Core®, PE insulated	0.14	0.28

CCZT Test Results



(1)   **(2)** 

(3)  **(4)**