### Impedance Because Resistance is Futile

Presented by Dr. Dennis Noson, Colin Isler, Dana Olson & Mark Rogers and

The Pacific Northwest Section of the AES

Monday, March 20, 2017





## Outline

Introduction - some basics - Steve

### Acoustic Impedance - Dr. Dennis Noson RAIN CHECK - THIS FALL?

- Impedance of Audio Interfaces Colin Isler
- Break
- Loudspeaker Impedance Dana Olson
- Distributed Loudspeakers Mark Rogers







### **Bob Smith**

**impedance:** the complex combination of DC resistance and frequency dependent reactance in an AC circuit.

**reactance:** the non-resistive component of impedance in an AC circuit, arising from the effect of inductance or capacitance or both and causing the current to be out of phase with the electromotive force causing it.

### **Merriam-Webster**

- : something that impedes : hindrance: such as
- **a**: the apparent opposition in an electrical circuit to the flow of an <u>alternating</u> current that is analogous to the actual electrical resistance to a direct current and that is the ratio of effective electromotive force to the effective current
- **b**: the ratio of the pressure to the volume displacement at a given surface in a sound-transmitting medium
- **c** : opposition to blood flow in the circulatory system

### Encyclopædia Britannica

**Electrical impedance**, measure of the total opposition that a circuit or a part of a circuit presents to electric current. Impedance includes both resistance and reactance.

Acoustic impedance, absorption of sound in a medium, equal to the ratio of the sound pressure at a boundary surface to the sound flux (flow velocity of the particles or volume velocity, times area) through the surface.

#### AES - Pro Audio Reference aes.org/par

**impedance** A measure of the complex resistive and reactive attributes of a component in an alternating-current (AC) circuit. Impedance is what restricts current flow in an AC electrical circuit; impedance is not relevant to DC circuits. In DC circuits, resistors limit current flow (because of their resistance). In AC circuits, inductors and capacitors similarly limit the AC current flow, but this is now because of their *inductive* or *capacitive* <u>reactance</u>. Impedance is like resistance but it is more. Impedance is the sum of a circuit, or device's resistance AND reactance. Reactance is measured in ohms (like resistance and impedance) but is frequency-dependent. Think of impedance as the complete or total current limiting ohms of the circuit — the whole banana. Since AC circuits involve phase shift -- i.e., the voltage and current are rarely in phase due to the storage effects (think time; it takes time to charge and discharge) of capacitors and inductors, the reactance is termed "complex," that is there is a "real" part (resistive) and an "imaginary" part (bad terminology, but it means the phase shifting resistance part). To summarize: resistance has no phase shift; *reactance* (capacitors & inductors in AC circuits) includes phase shift; and *impedance*, is the sum of resistance and reactance. Just that simple.

### **Impedance** Audio Dictionary 3rd Ed: PAGE 1 of 2

Impedance: In an electric circuit containing direct current, the magnitude of the current is determined by the voltage across the circuit divided by the resistance of the circuit. This is known as ohm's law. In a circuit containing alternating current, the situation is more complex; the "resistance" presented to the current is a function of frequency. This "AC resistance" is called impedance and is also measured in ohms. Impedance is the sum of resistance, capacitive reactance, and inductive reactance. (See Appendix 11 for more information on the definition of impedance.) Alternating currents are affected by resistance the same way as direct currents, and Ohm's law can be used for AC if the reactances are zero, that is, if there are no capacitors or inductors in the circuit.

In audio circuits and components, many different impedances are encountered. A loudspeaker, for instance, is a low-impedance device, usually about 8 ohms. This means that a given voltage across it will result in relatively large amounts of current in it. The power accepted by the speaker is equal to the voltage multiplied by the current. A condenser microphone, on the other hand, is a very high-impedance device, generally several billions of ohms. The voltage generated by a condenser microphone results in vanishingly small amounts of current because of the high impedance. In general, impedances are relatively low where large amounts of power are being transferred, and are relatively high when power levels are low. An exception to this is found in low-impedance microphones, such as dynamic microphones, where power levels are also very low.

Low-impedance circuits are less susceptible to electrical interferences such as 60-hertz hum than are high-impedance circuits, and they are used to transmit audio signals over cables.

#### Audio Dictionary 3rd Ed: PAGE 2 of 2

Most audio transmission lines used in the broadcast industry are of 600 ohms impedance, except for speaker lines, which are much lower in impedance. It is interesting that 600 ohms would be chosen as a working impedance for commercial sound and broadcast work.

Four reasons can be stated:

- 1 Shunt capacitance found in long cables has negligible effect on high-frequency response.
- 2 Line resistance in long lines is not an appreciable fraction of 600 ohms, so losses are low.
- 3 Higher impedances are much more sensitive to electrostatic interference, and lower impedances are more susceptible to magnetically induced interference.
- 4 The capacitors and inductors needed for building equalizers at 600 ohms are of modest size and low cost. There is a common misconception that impedances of interconnected audio equipment must be "matched," and one is constantly hearing about problems caused by an "impedance mismatch." The fact is that impedances are almost never matched in audio systems. For instance, an amplifier designed to operate with an 8-ohm loudspeaker will have an output impedance of a small fraction of an ohm, in fact as low an impedance as the designer can manage. There are two reasons for this, one having to do with efficiency and one with damping factor. If the amplifier driving an 8-ohm load had 8 ohms of output impedance, one half of all the power generated by the amplifier would be dissipated in the amplifier itself and would never reach the load. This is because the output current supplied by the amplifier passes through the amplifier output stage as well as the load, and the same power would be dissipated as in the load. For the same reason, the wires connecting the speaker to the amplifier should be of very low impedance to reduce power loss in them as well. When the output terminals of an amplifier say "8 ohms," this simply means that its maximum current and voltage capabilities are such that it will deliver maximum power to an 8-ohm load. See damping factor for a discussion of the other effect.
- In radio frequency and video transmission, impedances are matched to avoid signal reflections from the ends of the lines. Such reflections cause double images, or "ghosts." This effect is due to the relatively short wavelengths of the signals involved. Such reflections could be a problem at audio frequencies if the transmission lines were hundreds of miles long. They were sometimes heard in analog long-distance telephone circuits as an echo, but the effect is of no consequence to normal audio circuits. Today long distance telephone lines are almost exclusively fiber optics, and they are not susceptible to this type of echoing. See also Appendix 11.

#### Alternating Current: The Water Analogy





### **Cable Length vs Signal Length**









### **Audio Waves**





**Electrical Signals** - Propagation speed approaches speed of light! (300,000,000 m/s or 186,000 mi/s) **Audio Signals** - Electrical signals that fall within the bandwidth of the human hearing system



Courtesy: Synergistic Audio Concepts - prosoundtraining.com



Acoustic Signals - Propagation speed depends on medium



#### Speed of Sound (air) - 344 m/s or 1130 ft/s or ~ 1 ft/ms



Courtesy: Synergistic Audio Concepts - prosoundtraining.com