Technical Articles

High and Low Impedance Signals

by Al Keltz

The output from most electronic devices in an audio system will be of low impedance in nature, usually 150 Ohms or less. However, the output from many passive devices, such as a high impedance microphone or passive guitar pickup can have much greater output impedance. What's the difference and why is it important to know how to deal with these signals in an audio system?

Impedance (Z) is the measure of the total opposition to current flow in an alternating current circuit. It is made up of the sum of two components, resistance (R) and reactance (X).

$Z = R + X$

Resistance is essentially constant at all frequencies in an audio circuit and is measured in Ohms.

Reactance is the measure of opposition to the flow of alternating current caused by the effects of inductance and capacitance in a circuit. It is also measured in Ohms but it will vary with frequency.

The following formula for inductive reactance illustrates how its opposition to current flow increases as the frequency and/or the amount of inductance increases:

$$X_L = 2 \pi FL$$

where F = the frequency in Hertz (cycles per second) and L = the inductance in Henrys.

The following formula for capacitive reactance illustrates how its opposition to current flow decreases as the frequency and/or capacitance increases.

$$X_C = \frac{1}{2 \pi FC}$$

where F = the frequency in Hertz and C = the capacitance in Farads.

These formulas also point out the fact that a specified impedance for an audio device is only going to be valid for a single frequency - the actual operating impedance will vary greatly over the audio frequency spectrum.

The Low vs. High Difference

A high impedance microphone or guitar will usually output a greater signal (voltage) than a low impedance microphone. This high impedance signal works fine and even has some advantages in a sound system as the mixer or amplifier doesn't need to boost the signal as much. Therefore, any noise on the line is also not amplified as much and this results in an improved signal to noise ratio.

Keep in mind however, that the impedance of the transmission line (or cable) is affected by the impedances of the devices that are connected to it. A low impedance microphone will lower the impedance of the entire line connected to it. Similarly, if you connect a high impedance microphone, you will have a higher impedance line all the way from the microphone to the mixer. This can become a problem as the length of the cable increases.

High impedance lines are more adversely affected by the inherent capacitance that is present in the cable itself. This capacitance combines with the impedances of the source and destination to set up a filter. As the impedance increases and/or the capacitance per foot increases, the active frequency at which the filter comes into play gets lower. The frequencies above this point actually begin to "short out" across the cable's conductors before they ever get to their intended destination. Keeping impedance low and using quality cables can be important issues for maintaining wide frequency response in long lines.

A high impedance line that is interacting with outside electrical interference will act more like an "antenna" than a low impedance line. This problem can get worse as the cable gets longer. This effect is usually insignificant for a guitar or high-Z microphone plugged into an amp with a 15' cord but it can have a big effect if that same signal is sent 100' down a snake. These are reasons why a high impedance signal is almost always converted to low impedance with the use of a Direct Box (DI) before being sent long distances.

Another reason for the use of a DI is that it takes a two conductor unbalanced line and converts it to a three conductor balanced line. *This is a separate issue, not to be confused with impedance.* It is a common misconception that all lines that use regular tip/sleeve ¼" guitar cord type connectors are high impedance. Not so. The output from a guitar that has a battery operated active preamplifier or pickup system will be low impedance in nature. So will the output of an electronic keyboard, guitar preamplifier or guitar effects processor. The signals are unbalanced but LOW impedance in nature.

Low Feeds High

In order to preserve signal level and frequency response, it's important to drive equipment with a source signal that is lower in impedance than the equipment's input impedance. If the input impedance of a device is not significantly higher than the source impedance, the signal will be reduced or "loaded down" and its signal to noise ratio and frequency response will suffer.

Think of this as having a nozzle at the end of a garden hose. The garden hose is a low impedance source (there is little resistance to the flow of water) and the nozzle is the higher impedance of the input being fed by the hose.

When the nozzle valve is closed (open circuit):

- Input impedance is VERY high
- Pressure (voltage) is at maximum
- Flow (current) is zero

Now open the nozzle just a little:

- Input impedance reduces but remains high
- Pressure reduces but remains high
- Flow is small
- You can hear lots of hiss from the spray (high frequencies)

As you continue to open up the nozzle:

- Input impedance reduces further
- Pressure reduces
- Flow increases
- Hiss from spray becomes less noticeable

With the nozzle open all the way:

- Input impedance is very low
- Pressure falls dramatically
- Flow is greatest
- Hiss from spray all but disappears

In the case of a high impedance guitar output (7,000 to 15,000 Ohms or more) driving a relatively low impedance input of a mixer (2,000 to 10,000 Ohms), it's like connecting a garden hose to a fire nozzle. The hose just can't produce enough flow (current) for the size of the opening to maintain the pressure (voltage).

Splitting Signals

When a signal needs to be split and sent to more than one destination, the impedances of the destinations provide additional paths for the electrical current. This has the effect of *reducing* the overall impedance presented to that signal. In terms of our garden hose analogy, we've now added a second open nozzle which provides an additional path for the water (less resistance to flow causes reduced pressure in the entire system and each opening has a little less spray).

As a general rule of thumb, it's wise to try and maintain an input impedance of at least 10 times the amount of the source impedance.

For example, if we are going to connect the output of a mixer to several amplifiers, calculate the total load provided by the amplifiers by using the formulas below. If that total is approximately 10 times the output impedance of the mixer, then simple passive, parallel splits (like "Y" connections) will usually work fine. The same general principle applies to splitting microphones too. (There can be other issues involving ground loops and isolation - see "Microphone Splitters").

The formula for calculating the total load presented by a number of different parallel impedances is:

$$\frac{1}{Z_{total}} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} \ldots + \frac{1}{Z_n}$$

If there are only two differing impedances, use the following:

$$Z_{Total} = \frac{Z_1 \times Z_2}{Z_1 + Z_2}$$

or "the product over the sum".

If there are parallel impedances of the same value, then just divide that value by the number of impedances.
For example:
Two 10,000 Ohm loads = 10000/2 = 5,000 Ohm total impedance.
Three 20,000 Ohm loads = 20000/3 = 6,666.66 Ohm total impedance.

If a microphone has its signal split to two mixers which have a 5,000 Ohm input impedance each, the total load to the microphone is 5,000/2 = 2,500 Ohms.

If a mixer output with an impedance of 100 Ohms is split to 4 amplifiers, each with an input impedance of 20,000 Ohms, the total impedance of the load is 20,000/4 = 5,000 Ohms. This is well within the 10:1 load impedance ratio and illustrates how a mixer's output can be passively split several times to a bank of amplifiers without the need for an active distribution amplifier.