White Paper # 5208

What's This About Impedance?

ETA SYSTEMS

Introduction

Among the variety of important elements to consider when selecting an isolation-transformer based power-conditioning solution is the issue of impedance. All transformers are not created equal, and it's crucial that the power conditioner you select uses an isolation transformer with the correct impedance characteristics. Otherwise adverse conditions may arise that lead to unsatisfactory performance.

What is impedance?

Impedance is defined as "opposition to the flow of a changing current." Impedance is similar to resistance, however, resistance is applied only to DC or direct current circuits.

Both types of circuits (AC and DC) contain capacitance, inductance, and resistance. In AC circuits, the circuit current is constantly changing or alternating. In DC circuits, the current changes only when the circuit is turned on or turned off.

In a DC circuit, capacitance and inductance have little affect on the circuit's operation. In an AC circuit, however, the constantly changing current causes the capacitance and inductance to exhibit a factor called "reactance." Like resistance, reactance also opposes current flow, and the effect of reactance must be added to the circuit's resistance to determine the total opposition to current flow. The combination of reactance and resistance is called impedance.

Impedance is also different from resistance in that its value is affected by the frequency of the current in the circuit. In other words, a circuit may offer a low impedance to 60 Hz. current but a higher impedance to a 10 kHz. current, for example.

The issue of impedance vs. frequency becomes important when selecting a power conditioning interface that must function as both a low impedance "source" for AC power and as a high impedance "barrier" to unwanted power disturbances.

Why impedance is important

Audio systems are a good model for understanding the importance of impedance in the world of power quality. Both the system's amplifier and speakers have a specification for impedance. To achieve the best performance, impedance of the speakers must be matched to the output impedance of the amplifier. It's also important to pay particular attention to the quality (impedance) of the audio cables used to connect the components together. If these parts of the system are mismatched, the stereo system will perform poorly and have unacceptable sound quality.

That's because the manufacturer has designed the system to deliver the best audio frequency response at a given output impedance. As long as the impedance of the amplifier, audio cable, and the speakers are matched, the complete range of audio frequencies is transferred to and faithfully reproduced by the speakers. If a mismatch occurs, the audio might sound "tinny", hollow, or muddy. Matching impedance is necessary to reproduce the full range of desired audio frequencies. Impedance and the frequency of a changing current are inter-related, and we can apply the rules of impedance to the world of AC power to create an effective match between an electronic load and its power-conditioning source.

Looking at loads

Just as a stereo system will perform badly if amplifier and speaker impedance is mismatched, so an electronic system will perform poorly if it's attached to a power conditioner with the wrong impedance.

Switch mode power supplies (SMPS) are used in most of today's electronic systems. This technology is more efficient and less costly than the older linear style power supplies that were in wide use in earlier generations of technology.

Switch mode supplies utilize current from the AC power line in a completely different manner than their predecessors. Figure 1 shows the current vs. voltage waveform of a typical switch mode power supply.

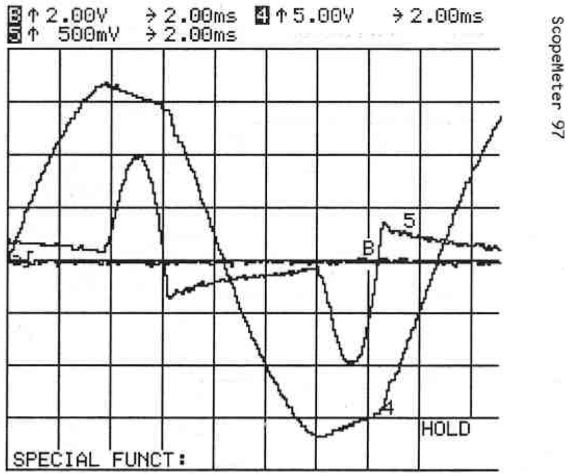

Figure 1 – Voltage vs. Current in SMPS

You will notice immediately that the supply utilizes current from the power line in a discontinuous manner. Most of the current is drawn for just a few milliseconds every one-half cycle. In addition, the peak amplitude of this current is quite high (often three times or more the RMS value).

This is a considerable departure from linear power supplies, which drew current from the power line in a continuous manner and had relatively modest peak current demands.

Power conditioning technology was not a highly critical issue for the older technology of the 1970s and early 1980s. Systems with switch mode power supplies, however, want a power conditioner that places no limitations on their peak current demands. By definition, they require a low impedance source. It's here where the difference in transformer technology becomes apparent.

Look out for high impedance

Several types of high impedance transformers are found in the marketplace today. Perhaps the most popular is the ferroresonant transformer. While sadly outdated, this technology is still promoted as an answer to voltage regulation problems. Switch mode supplies, however, don't need voltage regulation (see Whitepaper #5203). The high impedance nature of a ferroresonant transformer is an inherent part of its voltage regulating capability and cannot be avoided or dismissed.

Any high impedance source alters the operation of the switch mode power supply, and it begins to function in a different manner than its design originally intended. Figure 2 illustrates the changes. Note how the high impedance of the ferroresonant transformer has caused the

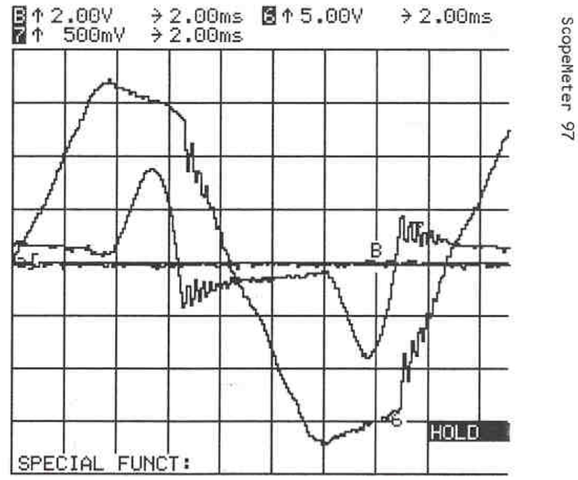

Figure 2 Voltage vs. Current – Ferro transformer

voltage waveform to "flat-top". In addition, it's also limited the peak current demands of the power supply while at the same time increasing the duration of the current draw. This makes the power supply work harder, adds stress and generates more heat.

When impedance is mismatched with an audio system, it's easy to hear the difference. Unfortunately, in the power quality world, the ill effects of an impedance mismatch are more subtle. Because they can't readily be seen or heard, their existence is often overlooked or ignored. With the right tools, however, it's easy to see the results when impedance is mismatched between a power conditioner and a power supply. Figure 3 illustrates the noise generated as the result of such an impedance mismatch.

In addition to the ferroresonant voltage waveform from Figure 2, this photo also shows the normal mode noise present on the ferro transformer output. This noise is a direct result of the interaction between the switch mode supply and the ferro

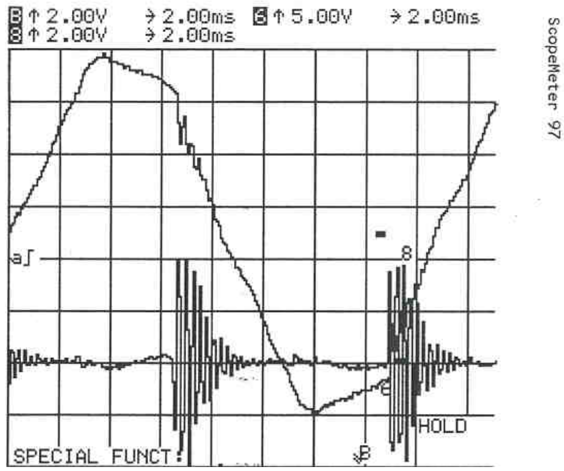

Figure 3 – Noise due to Impedance Mismatch

transformer. If an installation shares several electronic loads on the same ferroresonant power conditioner, the noise will be communicated to the inputs of all the shared loads

To be fair, almost all the negative aspects of high impedance sources can be mitigated by employing two tactics. First, the use of multiple devices will prevent the noise "crosstalk" just mentioned. Second, many of the current limitation issues (poor crest factor, limited inrush, etc.) associated with high impedance devices can be mitigated by selecting a larger conditioner than is required for the operating amperage of the load. Both actions have negative economic consequences.

So what's the right solution?

Switch mode power supplies in modern computer systems use current from the power line in large, brief "gulps". They want little or no opposition to their demands for current. By definition, this makes switch mode power supplies a "low impedance load."

Like an audio system, low impedance loads need to be matched with their power source. In the case of a system with a switch mode power supply, this source must be low impedance at power line frequencies but offer high impedance to noise and unwanted power disturbances. These modern power supplies should never be mismatched with a high impedance power conditioner. That means staying away from ferroresonant transformers, or other products that promise "high isolation", "super isolation", "ultra isolation" or something similar.

The appropriate solution for today's modern systems is a power conditioner that uses a low impedance isolation transformer. This will permit the switch mode supply to work as it was designed and will eliminate any negative interaction between the power conditioner and the electronic system. At the same time, the rules of electricity dictate that the same transformer will offer increasingly higher impedance as the frequency of the current increases into the range of damaging or disruptive power disturbances.

Finally, the application of low impedance power conditioners is more economical. It's not necessary to oversize low impedance devices or to use multiple power conditioners to eliminate noise crosstalk.

Conclusion

Modern systems require low impedance power conditioning solutions if they are to perform as designed. Ferroresonant and other high impedance transformer designs are obsolete and should not be used. Low impedance isolation transformers also present a high impedance barrier to prevent noise or other power disturbances from reaching the electronic system.