Chapter 1: An Introduction to Transformers in Audio Devices

A White Paper from Lundahl Transformers
www.lundashl.se

Presented by ProSoundWeb
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LUNDAHL
– TRANSFORMERS –

Introduction

In the dawning days of audio, transformers played a vital role in the functionality of first-generation all-tube based electronic circuitry. It was circa 1920 and radio broadcasts for the general populace had just begun, generating a rapid rise in the demand for broadcast audio systems, all of which needed transformers to function.

Later, as equipment for live sound reinforcement began to emerge, transformers again proved indispensible as the only means of matching microphone impedances to vacuum tube preamplifiers. Transformers were also used as inter-stage devices in amplifiers, for line output drivers, and for matching a power amplifier's output stage to the impedance of a loudspeaker voice coil – just as they are still used today in audiophile tube-based amplifiers and musical instrument amps.

Eventually, widespread use of transistor-based preamps and power amplifiers lessened the need for transformers, but as any electric guitarist will tell you, tubes "just sound better."

Insurance Policy

However, transformers do much more than just impedance matching. They can differentially balance a microphone or line-level signal at the source, and then de-balance the same signal at the destination (or more properly stated, the "load"). In the process, electromagnetic interference (EMI), the cause of all-too-familiar hum and buzz, is cancelled out as a function of the transformer's common-mode rejection ratio (CMRR or CMR).

The term "common mode" refers to any stray field that is common to both the plus and minus poles of a balanced line. Add the word "rejection" and it describes exactly what the transformer is doing: it phase-cancels the EMI because the poles are 180 degrees opposed to each other, thus rejecting any unwanted field induced in the cable.

This is pretty important stuff. When a line is not balanced, it becomes vulnerable to picking up all kinds of stray energy. Usually this takes the form of 60 Hz (or 50 Hz in Europe), along with related harmonics. The interference is induced in the cable from nearby alternating current (AC) power cables or from AC rectifiers in electrical devices.

Problems can also be caused by radio transmitters and other high-power devices that generate unwanted energy fields, such as diathermy machines and wood welders (yes, there really is such a thing as a wood welder). In the case of higher frequencies, the invasive energy may not be audible, but it can wreak havoc in a sensitive broadband mic preamp if the energy is not cancelled out by a precision-grade transformer (or by other means).

High-grade audio transformers, such as those manufactured by Lundahl in Sweden and Jensen in the U.S., exhibit high CMRR values across a broad spectrum of frequencies; low-grade transformers may help reduce hum and buzz a bit, but their CMRR is rarely sufficient to solve any significant problem. When it comes to hum and noise rejection, precision high-grade transformers are an invaluable insurance policy.

Ground Control

Audio transformers not only provide differential balancing of signals, they eliminate ground loops as well.

In fact, very well.

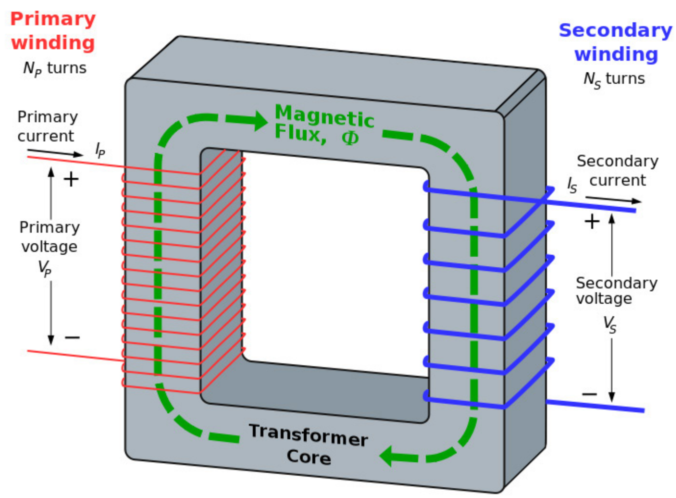
Ground loops occur when two points should be at the same ground potential, but aren't. They're caused by improperly installed equipment (or sometimes improperly designed equipment), with the result being noise and interference in a system. Merely plugging AC power cords into outlets that do not share the same ground path can create a ground loop when one piece of equipment is connected to another.

When many devices are interconnected, or when devices are far apart, the likelihood of a ground loop increases significantly. Ground loops are what keep audio professionals working through the dinner break. They can be difficult to sort out because different manufacturers of consoles and signal processing gear use different grounding techniques.

Enter the transformer. It stops ground loops cold, without resorting to the dangerous practice of lifting the AC ground pin on (one or more) power cords. Those who know this carry a handful of "barrel" style line-level transformer isolators to gigs.

Matter Of Magnetics

A unique feature of transformers is the ability to transfer a signal from the primary winding to the secondary winding without any galvanic connection, thus the input and outputs are said to be galvanically isolated from one another.



Power (VI) applied to the primary coil is magnetically transferred to the secondary coil, hence the galvanic isolation.

Galvanic isolation refers to isolating one branch, or section, of an electrical system from another, preventing current flow. No conductivity is permitted between the sections, yet energy and information are still exchanged. This perfectly describes the function of an audio transformer. Instead of a galvanic connection, the input signal induces a magnetic field in the transformer's primary, which in simple terms is a coil of wire wrapped around an iron core. The transformer's secondary consists of another coil of wire wrapped around the same core, but insulated from the primary coil.

The two coils may have the same number of turns, or one coil may have greater or fewer turns than the other. This is known as the "turns ratio" and determines whether the transformer steps-up the applied voltage, steps-down the applied voltage, or does not re-scale it at all, but serves only to isolate.

When an AC signal is applied to the primary coil, it generates a field that is magnetically induced in the secondary windings, thus reflecting the properties of the applied signal, but not making direct electrical contact. This is the means by which ground loops are broken and unwanted current is prevented from flowing between two or more units that share ground conductors.

For this same reason, no transformer will ever pass direct current DC, because DC does not generate an alternating magnetic field. Note: DC blocking does not apply to auto-transformers that are sometimes used in 70-volt/100-volt distributed loudspeaker systems, because the primary and secondary windings of auto-transformers are connected galvanically.

Sonic Characteristics

It's important to understand that even though transformers are passive devices, they are actually quite complex with internally distributed resistance, capacitance and inductance. Thus they still exhibit varying electrical and performance characteristics, just as active circuits do. They are, in fact, not dissimilar to loudspeakers – except there are no moving parts.

Earlier, we referred to CMRR (common-mode rejection ratio), which is one of the most important performance characteristics that audio product designers and system integrators look for when specifying transformer-coupled interconnects. But an impressive value of CMRR does not fully define a transformer's overall performance. It must also get high marks in each of the following characteristics if the end result is to be clean and transparent sound quality.

Distortion. Like an active circuit, a transformer will inevitably introduce a measure of distortion. In a high-grade design, distortion will be quite low, but present nonetheless. Transformer distortion is a function of level and frequency; the lower the frequency and the higher the signal level, the more distortion. In particular when operating limits of the transformer are exceeded (high level at low frequencies), and core saturation is eminent, distortion will increase rapidly. Core saturation occurs when a transformer's iron core cannot absorb any additional magnetism, thereby "clipping" the signal.

Linearity. Rarely published as a specification, linearity describes how the other parameters (frequency response, distortion, phase response and transient response) will stay stable (or not) under a range of input levels.

Level. This specifies the maximum input and/or output levels at a specified frequency (normally 20 Hz or 50 Hz) before saturating and becoming non-linear.

Frequency Response. Like any other audio device, there is an upper and lower response limit. Within those limits the response may be perfectly flat – or it may deviate a little – or a lot.

Phase Response. This parameter describes any deviation from a flat phase response within the specified frequency range. Even among the leading transformer manufacturers, phase response data is not always available. When it is, it's usually presented as a graphical plot, often with the frequency response depicted on the same graph, as they are proportionally related. In low-grade products, usually very little data is supplied.

Transient Response. Specifies how fast the transformer can respond to a short signal burst (or the leading edge of a continuous signal), and how quickly it stops emitting energy after the applied signal has stopped. Like phase response, this data is not always available, but can be extrapolated by examining frequency response and self-resonance data (pulse transformers for digital audio may delve into this specification more deeply).

Transformers that generally exhibit good frequency response and effective CMRR can still color the sound, sometimes dramatically, due to a slow initial response and significant overshoot at the tail end. Sometimes this can be pleasing to the ear, providing a sense of "warmth," but most times it is not. In any case, it's an inaccurate representation of the signal.

It's better to use a plug-in, or a signal processor intended for such an effect, rather than to infect the system with a sub-optimal transformer. As with everything else in audio, when evaluating a transformer, it pays to spend time listening.

Key Applications

Many microphone types utilize transformers, either for step-up (typically ribbon transformers) or step-down (typically tube microphones), or 1:1 for dynamic microphones. Some manufacturers, such as Cascade, offer upgraded transformer options for many of their ribbon mics. The company even specifies the transformer brand and model, which indicates how important the transformer's contribution is in achieving optimal sonic quality.

Another common stage source is the direct box, or DI. For many years, all DIs were transformer based, and with good reason. An instrument plugged into a DI has one ground reference through the instrument amplifier, while the sound system has a different ground reference. As a rule, a transformer-based DI will solve a ground-loop problem faster and easier than an active DI.

Transformer-based mic splitters incorporate specialized transformers, with one primary and one, two, three, or more secondaries. We mentioned transformers as a form of insurance policy earlier. Nothing equates to more "audio insurance equity" than a well designed and built transformer-based mic splitter.

Mic preamps are another key application. While many brands offer only electronically balanced inputs, a good number of premium products are either transformer-based from inception, or offer transformer versions as an option.

Moving along the signal path, some high-end consoles employ transformers, and/or offer transformer options on lineoutputs. Considering that the console is where all signals come together, this is a good place to consider specifying transformer options, when available.

The console, in turn, feeds signal processing of all types: loudspeaker management systems, outboard equalizers and limiters, and/or banks of self-powered loudspeakers. All are candidates for transformer usage, especially in situations that vary from day to day, when there's little time available to solve induced EMI or ground loop problems.

Conclusion

Present day audio transformers are appreciated and revered for their unique problem solving capabilities; they are perhaps more valuable now than ever before. Today's audio systems have become incredibly complicated, with many interconnected devices comprising even a small system, and a staggering number of devices in large-scale systems.

In the past, transformers were the only way to get things done; now, in many cases, they may be the only right way.

About The Author

Ken DeLoria is senior technical editor for ProSoundWeb and Live Sound International magazine, and has had a diverse career in pro audio over more than 30 years, including being the founder and owner of Apogee Sound.