# The Origin of Balanced Power
## by Martin Glasband

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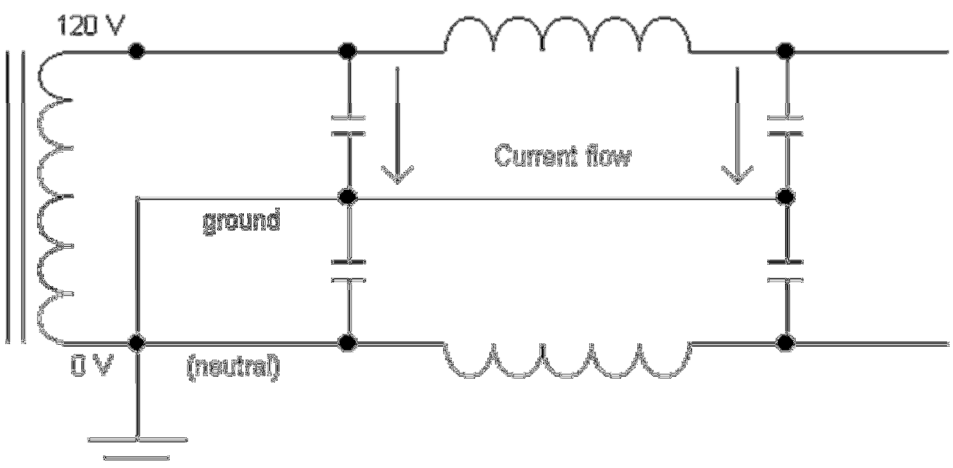
BACK IN THE SPRING OF 1988, I was approached by a good friend, Rick Perrotta (founder of Matchless Amplifiers) and asked to engineer the electrical system of a new multi-million dollar studio complex that was being built in Studio City, California. His main request was that the electrical system be designed in the quietest way possible. I explored numerous avenues of engineering, including chemical earthing, radial grounding and several other possibilities involving use of isolation transformers -- all of the regular "stuff", a considerable task nonetheless by any measure.

All proceeded along the conventional path until one day, an English engineer approached me on coffee break and literally scolded me for being so ignorant about the noise issue. He said, "Look at these filter capacitors. See how they leak current into the ground from the hot side of the AC mains? (Fig. 1) You need to balance the voltage across the filters to get the noise out of the ground." I wasn't offended by his blunt approach. As a matter of fact, I was elated. I could see how simple it was to address the leakage current problem, and if it was true that this was the actual cause of all noise (which it wasn't), certainly this would help me with my engineering project. But there was one issue to resolve, the electrical inspector.

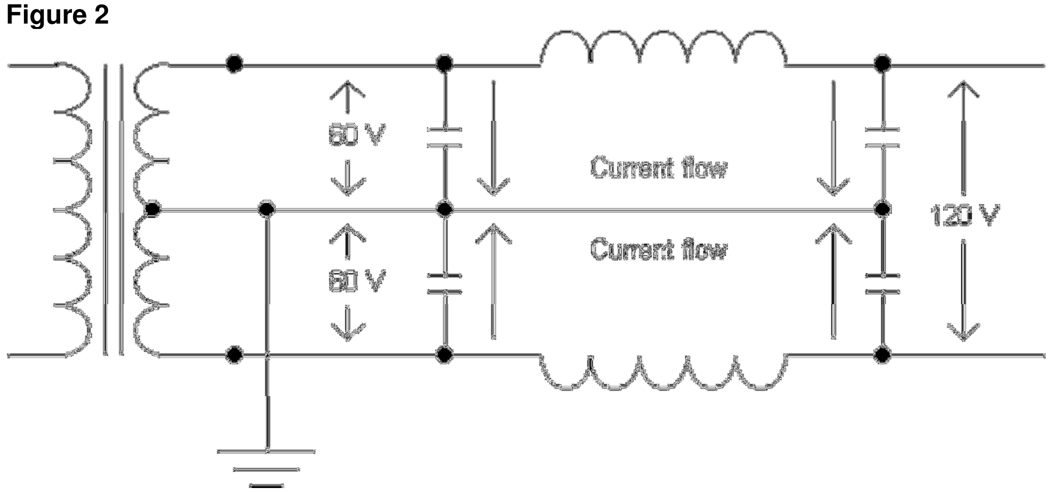
**Figure 1**




*Current leaks into ground through RFI filter capacitors from he hot side of the AC circuit.*

So, being from that school of discipline, I took the matter up before the Chief Electrical Inspector of the City of Los Angeles, a fellow named Gary Wilson who I had known professionally for some 18 years. I pointed out sections of the code where a pseudo-system of balanced AC had been used in hospitals and when I asked for permission to try it out in a sound recording environment, I received a resounding NO. The reasons he cited were instability and the inherent dangers of using an ungrounded AC system. He was right. So I went back to the drawing boards and sought out a way to ground the system to his liking without unbalancing the voltage. That didn't take long. I figured that placing a common terminal between the voltage outputs of an isolation transformer and grounding that would likely solve everyone's concerns. (Fig. 2) Fortunately, it did. And after a few more discussions, Mr. Wilson and I came up with a few installation procedures and wiring methods that would satisfy his department's safety concerns.

**Figure 2**




*Grounding the center tap on an AC transformer provides for both safe grounding of the AC system and also balances leakage current to ground which in turn reduces objectionable grounding currents.*

The project was completed a short time later. When the investors showed up for a test run, a studio guitarist panicked when he plugged in his Marshall Amp and announced to all that his amp was broken. He went back to his rig and played around with the guitar then nearly blew out all of the glass in the room. After the initial trauma had passed, he calmly announced to all present that this was the first studio he had ever been in where his amp made no noise. He only thought his amp was broken. This event was a harbinger of things to come.

That's how balanced power was born. The irony of it was that it was conceived in its present form just to satisfy the grounding concerns of an electrical inspector -- reminiscent of "Mr. Watson, come here. There's been an accident."

Little did I realize at that time that there was literally an entire power quality industry awaiting something new and different to "step out of the box." And so it has. Balanced power is a revolutionary concept rapidly approaching its day of reckoning as more and more experts in the field are educating themselves in its theory, effectiveness and in its simplicity.

## About Power Quality

Beyond the obvious filter capacitor problem, there are a host of other power quality issues and noise problems that balanced power seems to solve in a most elegant fashion. And herein also lies the simple truth about electrical interference.

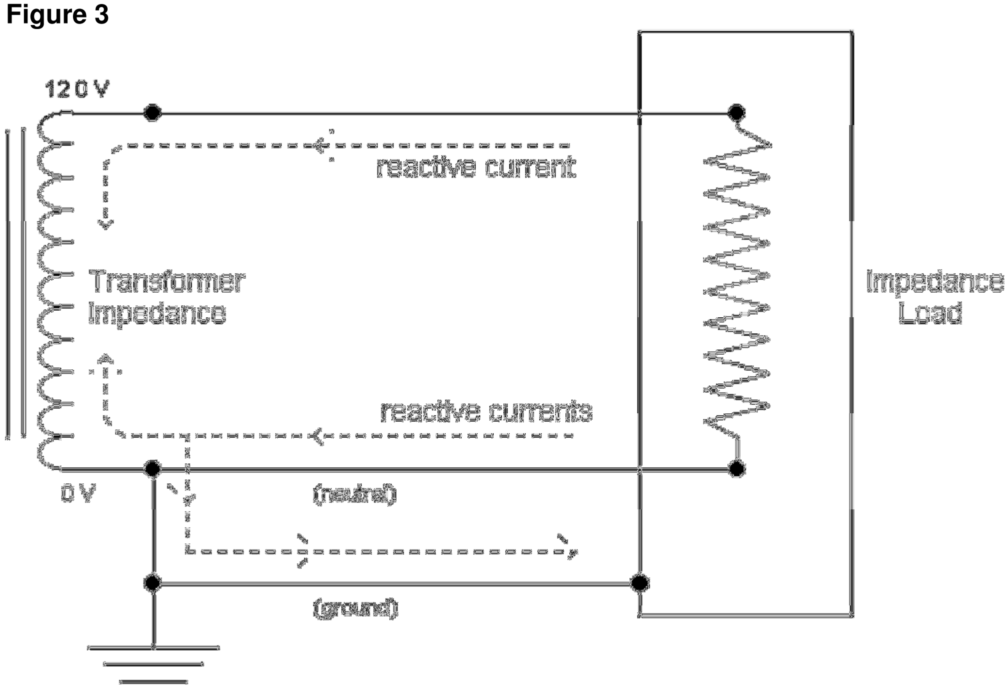
Just where exactly does electrical interference come from? This is the age-old question that has confronted many of the best engineers who have responded with a very perplexed and frustrated "shoot from the hip" attitude about the subject. Most everyone blames power or power related components such as harmonic distortion, power supplies, grounding systems, isolation transformers, non-linear loading and so on when investigating the causes of noise. There seem to be a myriad of issues involved -- apparently enough to keep busy for quite some time with one's education alone.

But as is true with most major issues, the problem itself is not the problem but rather a symptom or consequences of a chosen architecture. To effectively deal with the problem of electrical interference, one must think differently -- one must look deeper at structure. So the first thing one must do to cure the problem of electrical interference is to be willing to wander off the beaten path where conventional norms and conventional thinking have provided us with conventional problems.

## The Structure

So let's look at structure.  Here is a typical AC circuit connected to an impedance load: (Fig. 3)  Note the components.  There is a "hot" conductor (120 V.), a neutral wire (0 V.) and a ground wire.  Along with the load, these are the essential components of an AC circuit.  Also indicated in the diagram are reactive currents that are typically present in the power circuitry with every non-linear load application.  Reactive current is basically capacitively discharged energy that is keyed to a modulating AC source -- a "backwash" of non-active power.  This is wasted energy that is not being actively processed by the load.  The important thing to understand here is that reactive currents are natural phenomena.  Unfortunately, the thrust of modern power quality engineering has been to methodically "undo" what nature has done without examining structure which is at the root of the problem.

**Figure 3**

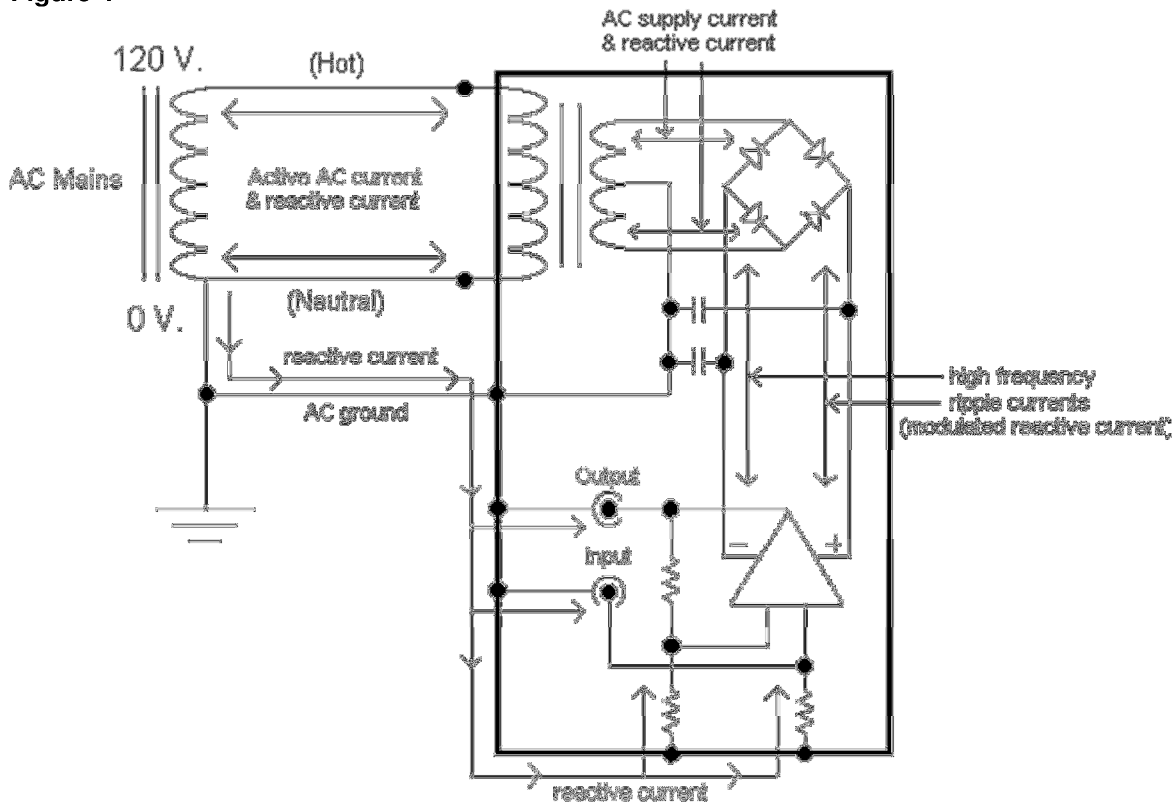



*Reactive currents from non-linear loads are present on the ground in proportion to the AC transformer's impedance.*

The manner in which a signal or voltage is applied to a load and referenced to ground is the structure of which we speak.  This can also be called "mode."  How are the voltage and current phases referenced?  Where does active current flow?  Where does reactive current flow?  In the case of single-phase applications, where is zero, where is it not and where is ground?  And, how does one incorporate this "modality" into practical terms so that structure can be modified to provide for a different outcome.

Lets look again at Figure 3.  Notice that reactive currents have invaded our (assumed) zero reference potential (the ground.)  Now let's jump to Figure 4.  This is called the common mode noise circuit.  Here we are relying heavily on the power supply's transformer for common mode noise rejection.  This is essentially the boundary where modern methods of noise suppression end.  Beyond common mode noise, there is also transverse mode noise which is essentially noise that is not referenced to ground.  Its primary domain is the ground.  Perhaps more accurately stated, the "hot" side of the reactive current circuit is the neutral conductor which, in electrical industry parlance, has been appropriately named "the grounded conductor."

**Figure 4**




*The common mode noise circuit. Reactive currents present on the AC mains is transmitted into signal circuits via the grounding system.*

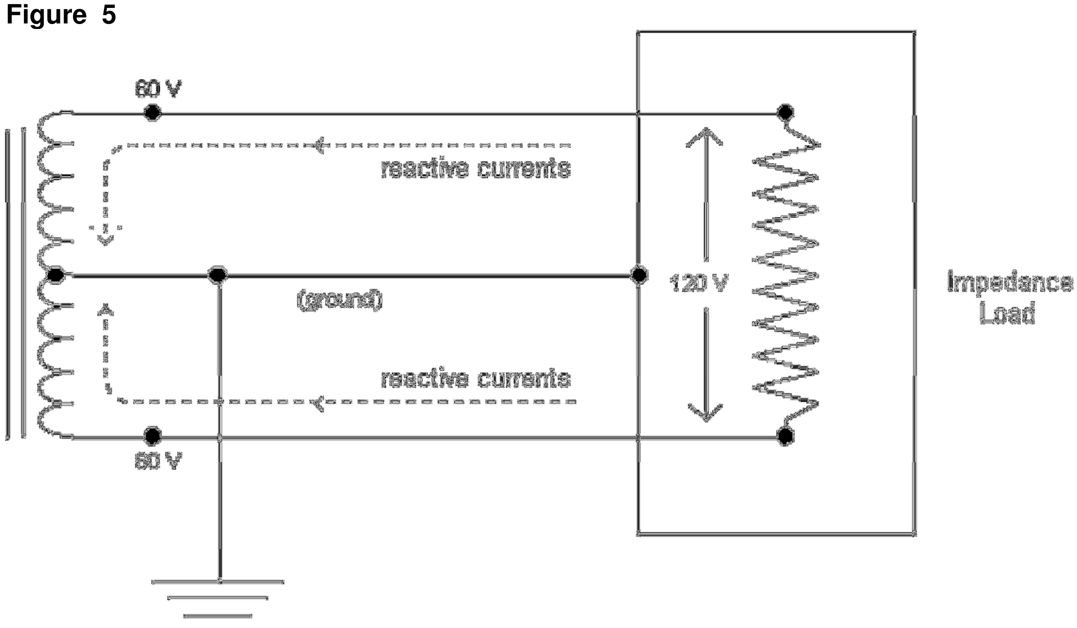
Where it was assumed that there was no voltage present on the neutral, only active current, there is also reactive current present. And, as reactive current from the load is applied across the source transformer's impedance, reactive voltage is also quantified. In tandem, reactive current times reactive voltage equals reactive power or "KVAR" (kilovolt-amperes reactive.) There is how a reactive voltage potential presents itself in the grounding system of an AC circuit -- via the neutral-to-ground connection at the AC mains. This explains why lifting the AC ground to equipment chassis eliminates noise.

Well, if all of the above seems confusing, don't worry about it. The important thing to understand is that ground wires are dirty because non-linear loads create a condition where zero (ground) is not truly zero. But as originally stated, these are the consequences of a chosen architecture.

## Back to the Drawing Board

So it's back to basics. Let's examine a restructured AC circuit where we have tossed out the conventional hot-neutral-ground architecture and have instead adopted a balanced circuit configuration. (Fig. 5) Reactive currents which are the primary source of electrical interference are now balanced at the grounding point.

**Figure 5**




*With balanced power, reactive currents null (cancel) at the center tap of the AC transformer thereby eliminating reactive current in the ground as a source of interference in signal circuits.*

Basically, what has been done here is to redefine zero. Actively, zero is now defined as the mean voltage differential of the AC sine wave. Reactively, zero is defined as the sum of everything around it. And, herein lies the magic behind clean electronic circuit operation in a balanced power environment. Simply stated, it works like this: By virtue of the equal presence of inversely phased reactive power elements on the ground, noise is eliminated. Ground is now a zero sum equation. There are no longer any stray potentials around to corrupt signal circuit operations.

It sounds almost too simple, but numerous testimonials bare the validity of the balanced power theory. Balanced power has been applied in numerous audio application environments with great success. Commonly, an additional 16dB to 20dB of dynamic range is realized on a system-wide basis where multiple inputs and channels are mixed.

## The Digital Domain

In the digital domain, balanced power creates a more subtle change in noise characteristics but an equally dramatic improvement in performance. The major issue in digital signal processing is high frequency noise -- noise that approximates the frequency of various digital operations. For example, the sampling rate of digital recordings is 44.1kHz. That times the bit rate equals the rate of the data stream (approximately 700kHz in 16 bit audio.) It has been found that digital jitter is reduced by approximately 1/3 to 1/2 in equipment that has been tested first without and then with balanced AC. High frequency interference (caused primarily by switching power supplies and other half-current-pulse semiconductor devices) is eliminated by balanced AC architecture in a manner analogous to removing the carrier frequency from an FM broadcast. In the case of balanced power, nulling low frequency harmonic current is in essence "knocking the legs out from under" the high frequency harmonics in the AC system. Everything collapses.

## The Future

Looking down the road at the progress of modern electronic systems, the need for ever cleaner signal circuit operations is becoming more and more a critical factor in performance situations. Accuracy and precision are the key elements in the creation of effective technical systems of every sort. For example, MPEG2 and the newer fractal data compression algorithms are highly sensitive to background interference. Expansion of corrupted data streams that are so highly compressed make for unacceptable error conditions.

Every day harmonic distortion from switching power supplies has been known to cause unspeakable calamities. System crashes are often caused by AC interference and poor power. In one instance a well known chip manufacturer lost literally a billion dollars worth of product in one run due to excessive harmonic AC distortion in their automated manufacturing plant. With such consequences, it's no wonder that many manufacturers have become vigilant on the subject of power quality. That can become a real distraction from the more creative tasks at hand. In dollars and cents, the cost of poor power is almost incalculable.

In audio and video production, the concerns are not much different. How many live mixes have been ruined by background hum? How about nuisance hum bars and something less than black video? How many hours have been wasted by engineers troubleshooting ground loops? And what about the subtle veil of IM distortion that has been ever present, noise that we have adjusted our senses to tolerate? What would it be like to have a truly clean background with which to work? What sort of quality could we create? How much productivity and time could we gain?

With the inclusion of balanced power in the 1996 National Electrical Code (Art. 530 Part "G"), the technology is no longer a myth. The advantages of using balanced power are a proven fact. When at one time a technician might have asked, "Do I dare use balanced AC to keep the system clean? The question today is different. The question today is, "Do I dare not use balanced AC?"

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*Martin Glasband is president of* ***Equi=Tech*** *Corporation based in Selma, OR. Formerly, as an electrical engineer in Southern California, he designed and built AC power distribution systems for the Post Complex, ABC Radio, New World Pictures and Baby'O Recorders.*