SHUNYATA RESEARCH

Electrical System Optimization

There are no bells and whistles that describe Shunyata designed products. No buzz words, LED's or velvet-lined boxes. Shunyata Research products are an accumulation of deep engineering and the finest parts, materials and metal treatments in the industry.

All Shunyata products are meticulously tested, designed and manufactured to minimize the in-line AC resistance that measurably detracts from the performance of professional and consumer audio-visual electronics. Shunyata designs also minimize the effects of system and grid generated high-frequency noise. This combination of attributes allows electronics systems to perform free of the constraints normally associated with stock delivery systems or a mixed accumulation of widely differing approaches and designs.

The following is a complete guide to better understand the links in the AC system, why they are of critical importance and how they should be chosen. These recommendations are based on Shunyata's own measurements, engineering principles and years of experience building electrical systems for the world's finest musicians, recording engineers, electronics manufacturers and customers.

Why the Power Cord is Important

A properly designed high-performance power cord should function as a noise-isolated, low resistance interface between a power source and the components power supply. It should fundamentally do two things: provide a highly conductive, linear pathway for DTCD® and minimize induced and radiated electromagnetic interference (EMI). Seen in this manner, their function takes on a more prominent and understandable role. They represent the initial outward electrical interface for each component in the system. If left unaddressed, this initial interface may act as antenna for radiated and ground-borne noise while the conductors, dielectrics, contacts and connection points may imped DTCD®.

Power cords do not represent the last few feet of an AC grid leading to a component; they are the first few feet from the perspective of the component's power supply. The further a potential noise source is from a component, the less impact it will have upon the circuitry within the component. In essence, the component represents the beginning of an electrical interface, not the end.

Given that a power cord is an outward extension of the primary winding within a power supply, literally everything about a power cord's construction will impact performance. Every parameter of a power cords design should be purpose built to optimize the AC interface. It should be constructed from top quality connectors, high quality copper conductors and RFI/EMI shielding or a noise canceling wire geometry. Finally, an exceptional power cord should be designed to have a neutral reactive signature,

meaning minimal capacitive and inductive properties so that it will perform compatibly and consistently across a broad range of electronics.

Power Cords as a System

Power cords should not be viewed as individual standalone items but rather as an integrated system with the goal of optimized DTCD® and minimal RFI/EMI distortions. Power cords interact with one another when they are connected to the same power line circuit (same outlet). This means that when one model or one type of power cord is tested it becomes inextricably linked both electrically and in terms of its performance signatures with other cords in the system. This is one of several reasons why opinions differ when trying a single model of power cord mixed with others of varying designs. Most will find however that when evaluating models from a single maker they will have a uniform performance signature that is consistent across systems. For these reasons, when evaluating power cords attempt get enough of the model you want to try so that you can replace all the cables in the system. It is impossible to gain a good understanding of any single power cord in a mixed system without alternately evaluating it as part of a closed single manufacturer system.

High-End Alternatives

There are so many makes and models of after-market power cords available that it can be a daunting process to choose models that may be worth the time to experiment with. The best method to select likely candidates is simple: do a little homework. Choose designs that have explainable technology, a track record of legitimate commercial success and that appear to be purpose built and well made. The better power cords do not change the fundamental sound from recording or playback systems. They get out of the way and allow the component and system to perform as it was intended to.

The only obvious differences when replacing stock cords with better should be a noticeably reduced noise level and a rather striking improvement in micro-dynamics — audible but subtle shifts in sound pressure and immediacy. Avoid designs that alter frequency balance or push detail forward or back, or those that tilt the delicate spectral balance in sound too far in one or another direction. Commercial after-market power cords do not have to cost thousands of dollars to perform well. Like anything else, time spent gaining experience and exposure is the best teacher in determining the perfect fit between value and performance.

Power Cords and Burn-In

A new power cord needs to “burn-in” to perform optimally. A new power cord will sound relatively blurry and indistinct when first applied to the system. It takes about five days of continuous current draw for a power cord to burn-in. Using an adapter and attaching the power cord to a fan or light is the best method to burn them in without having to listen through the initial annealing process.

Power Distribution and Power Conditioners

Since most homes and studios have only have a single duplex AC outlet along a wall and most A/V systems have more than two components, it becomes a requirement to have some sort of power

distribution. In its simplest form this would be a common power strip. In many cases a power distributor will also include current and surge protection.

The majority of multi-outlet power distributors or active conditioners act as an entertainment systems' common interface and contact point for distributed power. Due to the convergence of multiple electronics at this single junction, the crucial role of the power distributor or conditioner becomes clear.

Special attention should be paid to literally every aspect of a distributor's construction with the principles of DTCD® and CCI™ in mind. An ideal distributor will use of heavy gauge wiring, top quality outlets, connections and termination points that preserve contact integrity and DTCD®. Another ideal distributor attribute would be an ability to filter not only the small amount of noise from the power grid but more importantly a means to filter the back-wave of noise generated and propagating from the system itself.

Taking a simple view, a power distributor should act as nothing more than an extension of the power cord in terms of current delivery. The power cords help isolate components from radiated CCI™ that surrounds electronics. The power distributor should act as a zero point for power line conducted rectifier noise and digital hash. The power cord and power distributor work symbiotically to isolate the two most damaging forms of CCI™ while maintaining the continuity of instantaneous current. Obviously, a power distributor should also have surge protection to protect from catastrophic spikes — though these elements are more ideally placed at the electrical panel — more about that in the electrical panel section.

High-End Alternatives

The key to choosing the ideal power-distributor system lies within the concept of keeping things simple and uncomplicated. For the best performance in the context of recording or reproducing sound, choosing a distributor that optimizes DTCD® is preferable over a design that emphasizes external noise isolation at the expense of DTCD®. Designs that use transformers, coils and baluns are inductive and by their nature impede instantaneous current delivery. This may cause a loss of phase and time coherence (PraT), losses in perceived voice and instrument weight and overall compression of dynamics.

If the designers of top performing recording and playback electronics wanted another inductor in line with the primary coil of their transformer, they would have put it there. If they wanted another type of reactive device, it would already be within the design. Manufacturers of today's finest sound and recording components designed their power supplies to interface with the original AC wave-form, not one that has been processed, re-directed or impeded.

Outlets

Similar to power distributors, an outlet at the wall is often a critical common contact, or current interface point for multiple electronics in a system. Outlets represent another open contact that can increase line impedance and create losses in connectivity and conductance that affect performance. Even the tightening and termination of the wire behind the outlet to its hot, neutral and ground

terminals is of significance. Keep in mind that multiple, or even a single loose connection point can severely impair the performance expected from any top tier system.

Most outlets that are installed into homes are the lowest cost models available. Low cost outlets retail for about 50 cents while a high quality commercial grade unit will go for more than $20. Obviously, there is no incentive for a residential developer to install quality outlets. The superior contacts are invisible to the user. For the audiophile this is a low cost opportunity to improve power system performance. Replace the outlet powering the audio system with a good heavy-duty commercial grade outlet. If your power circuit has multiple outlets you will need to replace all the outlets with quality units even if the audio system is not connected to the other outlets on the circuit — Leviton and Hubbell both make suitable products.

Isolated Ground Outlets?

An "isolated ground outlet" is a term that comes from commercial buildings' power systems. Commercial buildings often require the use of metal conduit to contain the power lines within a building. Without getting too technical, the term isolated outlet has no relevance unless your AC power circuit is contained within metal conduit and has a metal outlet box. It is NOT necessary to use an isolated ground outlet in a home environment and it has no performance advantages whatsoever.

High-Performance Alternatives

Outside of top quality commercial outlets such as Spec grade Leviton and Hubbell, there are now many brands of specialty "Audio-Grade" outlets on the market, some costing hundreds of dollars or more. These outlets often have special contact plating, polished surfaces, unique material and metal treatments. What's notable about all of them is that they will invariably sound different from one another and subjective preferences will often play a role in choosing one over another. Just as with after-market power cords, more expensive does not necessarily mean better no matter how precious the metals are.

The critical elements in selecting an outlet for applications related to sound and recording are covering the basics of conductivity and a secure connection. This means that there should be high quality conductive base metals used for the contact points and that there are broad heavy gauge contact surface areas internally. Contact points for wire should also have generous space for 10 gauge wire termination and broad brass or copper base metal surface areas. Outlets with wide internal chassis are preferable for their better air cooling properties and reduced heat at contact points.

Silver, gold and nickel plating may seem like a plus but "premium metal plates" often have obvious or overt sound characteristics — one warm and rich while others are sharp, cool and lean. Contact platings do not enhance DTCD® nor do they provide measurable noise reduction. Most often these simply act as tone-shifting elements rather than an enhancement to connectivity. As is often true in high-performance markets where price extremes exist — more often the best value and performance solutions lie in the more reasonable price ranges and with the more explainable science.

Dedicated and Isolated Power Lines

For those that are able to have dedicated lines installed, these are perhaps the greatest gift you can give to the DTCD® performance of a recording or playback system. There is a lot of confusion surrounding dedicated lines and isolated outlets among audiophiles. Let's start with the definition of a dedicated line. Most power circuits in a home are daisy chained with multiple outlets on a single circuit. When you "flip"$\frac{7}{8}$ the circuit breaker to the outlet powering your audio system go check the other outlets in the room and adjacent rooms. You will find that several other outlets are being powered by a single circuit breaker. A "dedicated line" is a term used to describe a circuit breaker that is dedicated to a single outlet. It is not connected to any other electrical outlet or switch. The in-wall wires are all dedicated to that single outlet and cannot be shared with any of switch or outlet.

Why They Matter

In layman's terms, any "less crowded" circuit will allow the electronics on that circuit better access to the instantaneous current impulses that are inextricably linked to the system's signal "output". This is especially true for amplifiers, whose full-wave bridge rectifiers pull extremely "hard" on the AC line. In fact, taking almost any amplifier off of a shared line (with other electronics) and placing it on its own dedicated line will render immediate and unmistakable benefits (largely dynamics) — in sound, proving how short-duration current-transient sensitive electronics really are.

Whenever possible, installing separate lines should be a primary consideration when building an electrical delivery system for studio, home or recording. Adding two or three dedicated lines is ideal — allowing for the separation of high-current and low-current electronics. In terms of overall performance, isolating high current electronics such as amplifiers, projectors, recording panels or powered speakers from source or low current electronics is far more beneficial than the separation of analog from digital. The availability of separate circuits also confers many options in terms of multi-outlet distribution units. Amps could connect directly to outlets for example while line and source components use some type of non-peak current limiting distributor.

Installing an individual dedicated circuit, or better two dedicated lines, will dramatically improve total available current capacity and associated system DTCD® . This does not discount the other elements in an AC system chain. To the contrary, adding a dedicated lines only enhances and punctuates improvement in electrical efficiency or reductions in CCI™ elsewhere. It's the open "system" of AC that matters most. All other parts should serve the same open-channel theme.

Avoiding Ground Loops

With the positives of dedicated lines can come the risk of the dreaded ground-loop, which is often accompanied by subtle to loud 60 cycle hum heard from the speakers. This can occur when multiple dedicated lines are installed without any attention being paid to grounding issues. Without getting into great technical detail, the solution is to ensure that the dedicated lines are all equal in wire length and that the ground wires for each are the same wire gauge. You want to achieve an equivalent impedance to ground through each of the respective lines.

If necessary the electrician can cross and fasten the wire from side to side in a ceiling joist or between the walls to insure that the wire from the closest outlet to the panel is as long as the farthest wire run from the panel. This is a far better alternative than the band-aid solution of floating the ground pins from electronics to the outlets.

Over-rated

Everything about a dedicated line from the breaker, outlet, panel and power-system should be electrically over-rated for best performance. It is not a waste of time or money to use 10 gauge wire, a 20A or 30A breaker, 20A outlets and, when possible in a new home construction — a dedicated system sub-panel. Electricity does not behave like water that flows calmly through a hose under moderate pressure. AC power is dynamic and complex as it pulses and reacts with the various types of power supplies.

An End Point: Electrical Panel

The electrical panel is where all the circuit breakers are located. From a realistic perspective, the panel represents the end point of influence over the sound of a recording system. Once again, dedicated and over-rated breakers at the electrical panel are a good starting point in maximizing the DTCD® to a high performance A/V system. Placing the breakers on the same phase of the AC panel will also render a benefit in sound and system performance. Select the electrical phase that has the fewest number of electrically noisy devices. For instance, avoid using the phase that has constant running electronics such as refrigerators, freezers, aquariums or other noise-producing motors etc.

Superior System Protection

Very few people are aware that a relatively low cost protection system that can be installed easily by a qualified electrician at the AC panel. This protection system is loosely termed “whole house surge and spike protection”. This is a low-cost installation that protects not only home or commercial recording systems, but everything in the home or business that is connected to the electrical panel. These devices come with an LED system that alerts the customer if the system has been compromised, at which time an inexpensive replacement system is available. What this means is that once again, there are low cost options available to consumers that allow the focus to fall on performance rather than concerns over protection. Even though almost all power conditioner or distribution devices protect systems to some extent, the BEST surge protection is at the electrical panel where the path to ground has the least impedance.

The Best Low Cost Improvement to the Power SystemSince DTCD® is the most critical element to any power system’s performance and effectiveness, the many connection points in the system become paramount. If any of the connections in a power circuit are loose or compromised they will limit DTCD® and introduce noise onto the AC line. It is worthwhile to have a qualified electrician check and tighten the screws to the breakers and the buss bars. While he is there have him replace the AC outlets with heavy-duty units and check the wires for corrosion.

It will also be helpful to replace breakers that have tripped because they can become degraded and trip below their intended rating; they can develop carbondeposits which can introduce power line noise. With these simple maintenance tasks there will be an immediate and pronounced improvement to total power system performance.

The Importance Of Electrical Delivery To Recording And Sound Systems

Before examining methods of setting up an ideal electrical delivery system for recording, music and sound reproduction, it helps to understand why electrical conditions have a profound impact on sound. Too often, the AC system is misunderstood in its relationship to the performance of recording or playback systems. This can lead to the misapplication or over-application of AC treatments — or the extreme of ignoring the power-delivery system as inconsequential altogether. In both cases a corruption of the system's most fundamental signal will be the result.

The Source of Sound

When referring to a playback or recording system's "source" most people will make a reference to the actual media, whether it is voice, instrument, a record, CD or tape. However, from the perspective of electronics systems there is a far more fundamental, underlying "source" than the media being transported through a recording or replay system.

The actual source of what we hear in any recording or playback system is the power as supplied from the wall after being rectified by the power supply into a ;relatively stable DC source. It is this DC power source that is the fundamental energy source that makes soundpossible. For example, in an amplifier it is the DC source current (modulated by the signal source) that drives the coils in a speaker. If the powersource is unstable or contaminated then the output will be as well regardless of the information in the signal source. If the AC power varies or if there's some anomaly in the power source it will show up clearly in the audible range. The assumption that power supplies provide perfect noise-free DC voltage that does not vary under load, is fanciful at best, complete fiction at worst. There is no such thing as a perfect power supply capable of filtering, blocking or managing multiple forms of high-frequency EMI and RFI interference produced by electronics systems. In the simplest terms, alternating current represents the foundation of reproduced sound in recording, sound and music systems.

A Historical Brief

For years, the predominant approach to an AC system was to install a large, usually heavy, multi-outlet box with some type of massive low-pass filter ie: transformer, choke or coil. These were designed with the view that AC delivery is a simple, low-frequency event requiring protection onlyfrom external, grid-related sources of high-frequency noise, line spikes and voltage surges. These boxes were viewed as virtual brick walls, keeping out all grid-borne noise, surges or spikes that posed challenges to the performance and safety of electronic systems. However, two principle issue were overlooked. The primary issue with the low-pass filter or regenerator approach lies in their inability to deliver instantaneous peak current impulses to full-wave bridge-rectifier or digital switching power supplies in the time in which they would normally receive them from the wall. The second and equally important

consideration is the fact that these one-way noise rejecting designs also block noise generated by the components themselves, reflecting that noise back to the other components in the system.

Upon Close Inspection

Electronic power supplies don't pull current in a linear fashion like a light bulb, fan or simple motor would. The full-wave bridge rectifiers and digital switching supplies in electronics draw hard on the AC line, pulling instantaneous bursts of current off the highest and lowest peaks of the sine-wave. This happens within milliseconds in order to fill power supplies storage capacitors. Both full wave bridge rectifiers and digital switching supplies create a significant amount of noise during this process that extends in frequency to the 50th harmonic of the line frequency. What this means, is that from the perspective of power-supply, AC transmission is a near-field, high-frequency occurrence not a low frequency 50-60Hz event.

With this basic understanding of the role AC plays in sound and the high frequency noise electronics systems create, two key elements emerge that are paramount in building an ideal power-system: Dynamic Transient Current Delivery™ (DTCD®) and Component to Component Interference™ (CCI™).

DTCD® — Dynamic Transient Current Delivery

Maximizing the unimpeded instantaneous and continuous flow of current to electronics is critical to recording and playback systems performance. Recording and sound playback electronics are designed to perform optimally through an unrestricted interface with current. This is as true for source electronics as it is for amplification. Placing anything in front of an electronics system that restricts, impedes or slows the DTCD® of AC power will degrade the ultimate performance of the system. This is why most electronics manufacturers discourage the use of power conditioners that interfere with instantaneous current flow. Starting at the AC panel there are simple methods and measures anyone can implement to improve their entertainment system's instantaneous access to its power source without compromising protection or performance.

CCI™ — Component to Component Interference

A primary concern when building an electrical delivery system for recording or sound should be the isolation of individual components from the high-intensity fields of EMI and RFI noise that saturate the space surrounding electronics systems.

The power supplies of sound and recording electronics are by nature interconnected and in close proximity to one-another. All components in these systems have a unique electrical footprint and output noise from their digital switching or bridge rectifiers within the power supplies. Power supplies generate significant EMI primarily from the switching rectifiers. Digital equipment also generates high frequency RFI.

Both RFI and EMI may be transmitted from one component to another in several ways. The first is through conduction via the power cord connections and through interconnects. The second is through inductive coupling via power cords and other electronics connections.

Not only do power supplies emit a back-wave of noise energy through the ground system and power cords, their digital switching supplies or rectifiers radiate intense fields of gigahertz EMI. This affects all electronics and cabling within their immediate environment.

By far the most effective means of minimizing the impact of this noise lies in treatment of the initial outward points of electrical interface for each component — the power cord and the system's main distribution points, the AC distribution buss/power conditioners.

A properly designed power cord can act as the first line of defense by isolating the power-supply port and IEC area from the radiated energy that surrounds electronics. They should also act as low-impedance path for the back-wave of power supply noise to reach an exit path from the system. Power cables that have low measurable impedance, resistance and reactance are preferable because they can provide a neutral connection for reactive power supply signatures and allow the cleanest exit path for ground noise to be dissipated/filtered at the connection with the distributor.

The primary role of the power distributor — outside of providing optimal DTCD® and simple protections from spikes and over-voltage — should be to provide a passive exit path for system-generated noise. The best distributors will offer individual component isolation so that the ground noise flowing out from one component does not affect other components plugged into the same AC distributor. It may sound simple and that is the goal. Power distribution should be an uncomplicated delivery path for the instantaneous AC impulses that allow electronics to perform at peak efficiency.

Contrary to popular theory, grid related or external noise generated outside of a systems immediate environment is vastly over-rated as a threat to system performance. Most if not all quality electronics have built in power supply elements that are more than capable of filtering or re-directing incoming noise — which pales in its effect to the massive amount of noise that is generated within the system. Given that the most sensitive electrical elements lie within recording and playback systems, this is a good place to start in building an ideal power-supply chain; one designed to deliver maximum current and minimum AC related distortions.

The fundamental design of interconnects, power cords and power distribution can radically affect EMI and RFI contamination — which in turn will dramatically affect the resolution and detail in recorded or reproduced sound.

Keeping It Simple

If we accept that electronic power supply's interface with current is a high-frequency, dynamic (short-term) event then it becomes clear that the ideal signal path for current should be direct, with minimum added complexity. Providing simple, unobstructed, low-impedance pathways for current using solid connections and high quality materials will yield by far the most consistent and desirable results. The closer the signal navigates toward electronics the more critical these elements become. Conversely the more complex, obstructed the path, or the more reactive elements that are used between the panel and a system of electronics, the more compromised and unpredictable the results will be. Keep in mind that reducing perceived noise is only valuable if it can be done without restricting or impeding DTCD® .

Some may value a reduction of perceived noise to a degree that makes losses in timing, immediacy and dynamics tolerable but when compared to sound that is uncompromised with regards to dynamic content and has noise isolation, the choice is clear.

The power-system components that are easiest to control, such as power breakers, grounding, dedicated lines, outlets, power distributors and power cords should perform two simple functions. Each part of the AC chain should be treated or selected to provide Dynamic Transient Current Delivery™ (DTCD®) to the electronics or when close to the system itself, to isolate the effects of radiated or conducted electromagnetic interference generated by associated system components.