**Why do we need to consider the use of high-quality power cables?**

Traditionally there has always been an assumption that any power cable will be satisfactory for use with a hi-fi or home theatre system provided that it will handle the current drawn and provided that it is electrically safe. As a result, it has been quite common to find that users have spent large sums of money to build up a high-performance entertainment system with good quality interconnection cables yet have powered the components through the same cables they would use to power a general purpose electrical accessory. Similarly, many systems can be found to be plugged into low-cost extension sockets purchased from the nearest supermarket.

There are two problems with this level of "false economy". First it is the case that you cannot get out of the loudspeaker cables what you cannot take in through the power supply cables. Although we all accept the improvements that good quality interconnects (analogue and digital) and speaker cables can bring to our hi-fi and home cinema systems there is far less acceptance of the potential benefits of the changes that can be made on the mains power side of the equipment. Which is odd as the sounds that emanate from the loudspeakers are generated via the power from the wall socket modified and controlled by the input signal. And even amongst designers who should know better there has been an assumption that the mains supply is near enough a perfect 50Hz sinewave or at least good enough to do the job. But in practice the supply suffers from several problems including mains borne and radio-frequency interference; transient spikes; an asymmetrical wave-shape with consequent distortion harmonics; an unwanted dc component and fluctuations in level.

It is worth noting that the generator companies generally do an excellent job in providing a supply that is reasonably clean and stable in terms of voltage and frequency. The problems usually start in the immediate locality of the home and many of these problems are caused by neighbouring users. The street supply is shared so any unusual loads in other buildings will affect the quality of the supply. Unwanted harmonics and interference can be added by old motors (central heating pumps are popular culprits) whilst some appliances draw power in a way that clips the tops off the originally pure sine-wave waveform of the supply.

Many hi-fi enthusiasts stick with the power cables that came with the equipment and plug the system into the nearest wall socket often via one or two extension sockets purchased at an attractive price from the nearest superstore. The system appears to work fine so why make any changes?

Well, let's start with the socket on the wall. In the UK it is likely to be fed from a ring main which is a power cable which starts at the main distribution box (circuit breaker) and continues from socket to socket in a daisy chain until the cable arrives back at the main distribution box. The primary advantage of the ring main is that no single outlet can load down the supply to the detriment of any other outlet in another room; every outlet gives the same output voltage. The disadvantage of the ring main is that if one appliance, like an old laptop or a WiFi router, injects interference onto the mains line then it will appear on each and every socket.

Mains supply power is subject to electromagnetic interference (EMI) and radio frequency (Rf) pollution from extraneous effects, such as interference from wireless and Bluetooth networks. Also internal interference generated from other electrical equipment connected to the household ring-main, which then transmits noise to every socket outlet throughout the household. Regulated power management is critical to ensure the effective distribution of clean and consistent power to sensitive audio equipment to reduce variability in the supply and limit the effect of signal noise and interference.

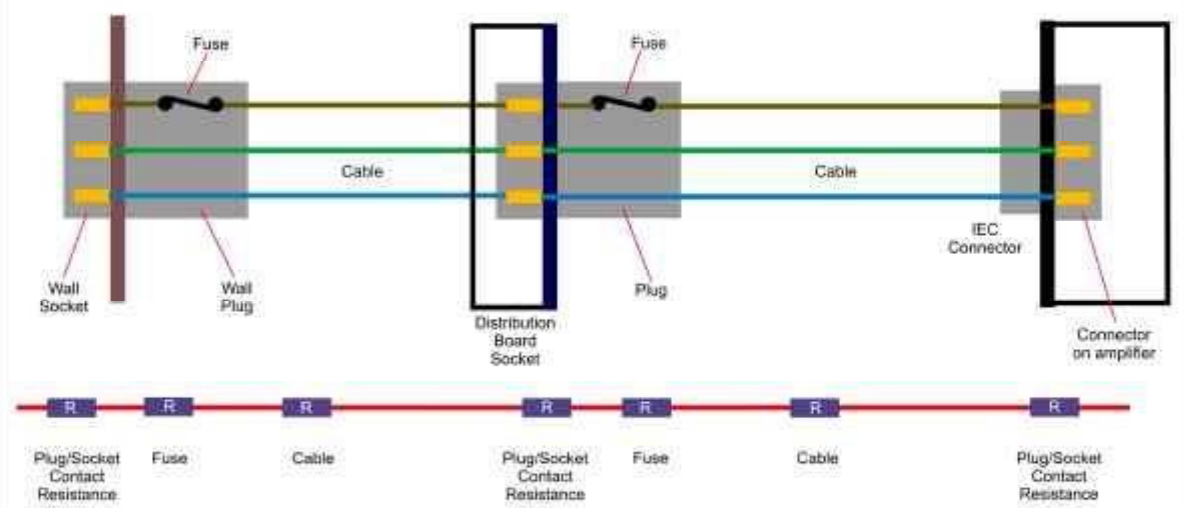
So, the power cables ideally need to be shielded from each other and from the other sensitive audio/video cables. As we describe later this is usually achieved by having an outer shield of braided copper wire, foil, graphite loaded fabric or combination. Not only are there unwanted "interference" signals on the mains supply but there are also many such signals being transmitted through the air, so the shielding of the supply conductors is very important.

All the power cables of the system generally go to one set of outlets, and they are usually tied together or laid on top of each other. They also tend to physically crossover sensitive audio interconnects and speaker cables so giving the opportunity for mains borne interference to be injected directly into the audio signal with predictable and undesirable results. A few minutes spent routing the interconnect; loudspeaker and power cables into separate neat groups usually gives immediate benefits to the performance.

Finally, the power cable must use large enough conductors to allow adequate power to flow to your equipment and it needs to make a good connection to both the wall outlet and the product through the use of low contact resistance, high-quality connectors on both ends.

**The incoming Mains Primary Circuit**

When audio engineers design power supplies they go to great lengths to keep the internal supply voltages as stable and predictable as possible. In doing so most engineers assume that the incoming supply (230 volts at 50Hz in Europe) will be stable. So, you will see amplifiers with very large toroidal power transformers and oversized reservoir capacitors all of which keep the impedance of the supply (its resistance to the follow of electricity) at virtually zero. However, there is a constant rule in the design of power supplies; you can only get out what you put in. This doesn't just refer to the power you can draw it also refers to the circuit losses.




This drawing shows the potential losses in the circuit from the wall socket to the entry into the amplifier for a typical installation

In the primary circuit, the incoming mains supply circuit; there are a number of losses. These include the losses of any cables or wires; the losses through any connections; the losses introduced through fuses or contact breakers and the losses through and filters in the power supply lines. Now these losses may seem small but they do add up and start to have an effect. This can be shown by doing some simple calculations. Imagine we have a typical domestic supply chain to an amplifier comprising the power socket on the wall; the power plug (with perhaps an internal fuse); a length of cable into a distribution board; the internal wiring of the distribution board and its output sockets; the power plug; another length of cable and the IEC type plug and socket. Now for our example imagine that the total end to end impedance is 2.5 ohms and the current drawn by the amplifier varies between almost zero and 6 amps depending upon the music level.

At the peak current level, the voltage loss in the primary circuit will be 6 x 2.5 = 15 volts so the supply voltage into the amplifier will drop an appreciable 6.5%. This loss will also dissipate some power = 6 x 15 = 90 watts. This power dissipation may cause a temperature rise which in turn will cause the resistance of all the copper components and wires to rise. Imagine now that the internal temperature of the copper cables rises from 20 degrees C to 8o degrees. The resistance will increase to 3.1 ohms; the voltage loss to 18.6 volts and the power loss to 112 watts. As more power is dissipated so the temperature will rise causing the vicious circle to continue. Now a voltage drop of under 10% may not seem much but with many amplifier designs it can cause a very audible compression of the sound so such losses must be minimised.

There is a very simple test that can be made to check some of the losses of the primary circuit. Play music at a fairly loud level for an hour or two and then switch the power off and touch accessible items in the primary chain such as the mains power plugs. If they are warm to the touch then you have significant losses because where you have losses you will have power dissipated and when power is dissipated the temperature will rise. So if the power plug is hot to the touch you will reveal very significant loss problems which need to be addressed.

**Mains Power Connectors**

Most people pay little attention to the mains power connections for after all a plug is a plug is a plug. However, even though they should all meet the electrical safety standards they do vary considerably in the quality of the metal conductors and plating used; the design and effectiveness of the clamping of the wires to the conducting pins and in the design and effectiveness of the mating between the pins and the contacts inside the matching socket. Many low-cost UK style power plugs and sockets (13A fused style) have a contact area totalling less than 0.5 $cm^2$ yet these will be found in many designs of many extension leads which handle high levels of current. It should also be remembered that the supply voltage may pass through a fuse link built into the power plug so this component should also be of the highest quality and designed to ensure a clean low-loss connection within the plug.

The UK 13 Amp 230-volt power plug and the IEC power plug are typical of the Atlas range and feature copper bronze pins which are highly polished then deep silver plated to ensure a low and consistent contact resistance which ensures an excellent connection and hence better overall performance. The care in design extends to the substantial bodies which are precision moulded in heavy duty Polycarbonate.

**The function & design of cable shielding and screening.**

The home of today is flooded by electromagnetic waves; radio frequencies of numerous kinds from short transients created by machinery and burst transmitters such as is used for speed trap radar, automatic door opening systems to the Wi-Fi and Bluetooth wireless systems used throughout most homes. Although we cannot hear this interference directly it does have effects that can severely degrade the quality of the audio signal we are listening to. Many of the circuit components used at audio frequencies do behave as resistors, capacitors and inductors. But at higher RF frequencies the so-called "parasitic" properties of many components come to dominate, and some capacitors turn into inductors; some inductors turn out to behave as capacitors and so on. Furthermore, such RF frequencies and fast interference spikes can be transmitted across circuit board without any need for direct wires, so they are very difficult to control. If such interference enters, say, an amplifier it can get into the sensitive stages through an input; a feedback connection or a power supply line and be able to overload the input transistor stage with noise. During the time it takes for the amplifier to recover it will not be operating correctly and the sound quality may be severely degraded although not in a way that is easy to describe.

RF and interference signals can be reduced by adding screening or shielding the complete cable. A cable shield may be composed of braided strands of a metal such as copper or a non-braided spiral winding of copper tape, or a conductive carbon loaded fabric. This is the type of shielding used for Atlas EOS em power cables and the shield acts as a Faraday cage so that any electrical signals on the outside of the cage will not be present on the inside of the cage. The shield works by shunting unwanted electromagnetic energy (the RF or interference signal) directly to the ground. To do this effectively a shield needs to cover the conductors completely, so that RF energy cannot readily pass through any gaps in the shield; it must have good conductivity so that energy can be easily conducted to the ground; and naturally there must be a good connection to the ground at the end of the cable via the connector.

During development of the Eos em screened power cables experimentation on different screening techniques identified that variability in the contact points and intervals between each twist (or rotation) of the generic drain wire provided an entry point for interference within the system. The company investigated manufacturing processes to reduce the level of variability to provide greater consistency and reduce errors.

Further experimentation and iterative testing and prototyping resulted in an alternative approach using two screen ground wires configured in a double helix arrangement along the length of the cable. Following testing, the increased contact area was determined to significantly reduce Rf load on the cable and thereby limit resistance build up. As a result, Atlas "Dual Drain" technology has significantly increased the screening capability of power supply (and audio) cables for HiFi equipment, thereby limiting the potential for degrading interference and noise signals to enter the system and impact audio fidelity.

**Why all the power cables should be screened.**

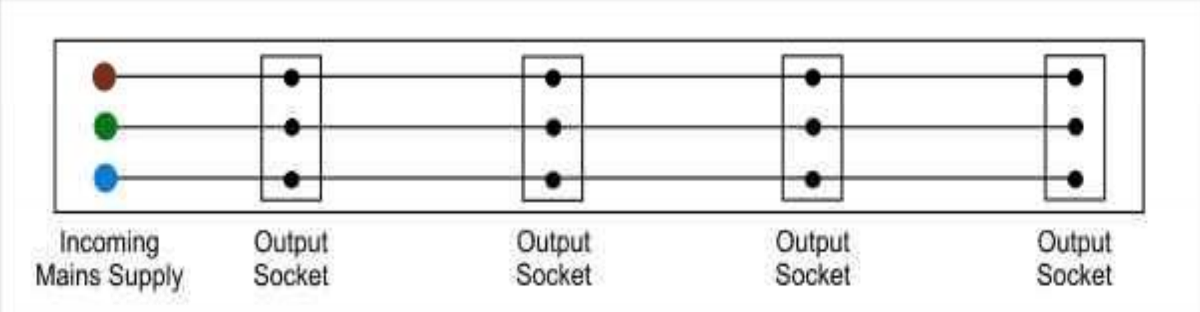
So far, we have explained that a high-performance power cable should allow the electrical current to be delivered to the equipment; be it an amplifier or high resolution streamer; with the minimum of electrical losses and with the minimum pickup of any unwanted signals which could distort or colour the sound.  Yet sometimes users, for perfectly understandable reasons, may chose to change just some of the power cables in a system and then find that the improvements are not as clear as were expected.  RF and mains borneinterference signals will always find their way into an electronic system if they are given an entry point and once inside, they can pass freely from unit to unit because there is nothing to impede their progress.  The only way to avoid the audible degradation they bring is to deny them an entry into the system and that means shielding every single power cable.

**Power Distribution for your Hi-Fi system**

In an ideal world the best way to connect a hi-fi system to the electrical power supply would be to provide an unswitched output socket on the wall for each individual piece of equipment; each socket being directly wired into the ring main supply or wired on a direct spur to the consumer distribution unit where the mains power enters the home.  However, with many systems needing, say 8 to 12 outlets, this is too big a step for most people and can often require expensive re-wiring of the home.  So, in practice most people use extension sockets and because such products all look much the same most people finish up using relatively inexpensive extension sockets bought at the local supermarket.

But the use of such cheap extension sockets can degrade the performance of a good hi-fi system and will certainly undo all the benefits of using good quality power cables. By contrast a well-designed Power management system, such as the Eos Modular 4.0em, 16A and Eos Modular 2.5em that use high quality low loss output sockets with matching power plugs can significantly improve system fidelity. The Atlas Eos Modular em is internally wired with exactly the same high purity and gauge OFC conductors as used in the award-winning Eos em screened power cables ensuring continuity from the wall socket to each and every product in a system.

The picture below shows the wiring of an Eos Modular 2.5em and all the output sockets are wired in a “bus bar” configuration (2.5mm2 conductors), that is each conductor goes from one low contact resistance socket to the next with no filtering whatsoever.




This means that the current being drawn by every unit in the system passes down the same uniform and consistent conductors. So practically that would mean that you should always place your higher current devices (e.g. power amplifiers) in the sockets nearest the IEC input connector. Screening is further enhanced by being enclosed within a solid Aluminium extrusion to maintain and protect the integrity of the unit.

The top performing Eos Modular 4.0em, 16A optimises this "bus bar" design even further by utilising 4mm2 OFC conductors, stabilise PVC dielectrics as well as a new Sequential Socket Decoupling[1] technique to provide additional pathways for unwanted RF on the unfiltered outputs. Additionally, three of the six low contact resistant sockets can also be assigned to be actively filtered, that is a controlled roll off filter whose intention is simply to strip any unwanted "power line" ethernet signals from sensitive or high-resolution devices that may exist on your phase of the mains power.

**In Summary**

In many ways it is fair to say that much of the investment in a high-quality hi-fi system is potentially wasted if attention is not paid to the quality of the mains supply it is powered from. The supply must be clean and free from any noise; interference and radio frequency signals all of which can degrade the performance of the system.  To get the best results from a hi-fi system the user should follow some simple rules to ensure that the supply feed (the sockets on the wall) and each and socket outlet is powered through a high quality screened power cable such as the Atlas Eos em cable family and, where a means of power management is required, only to use a matched and purpose build product such as the Atlas Eos Modular em.

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