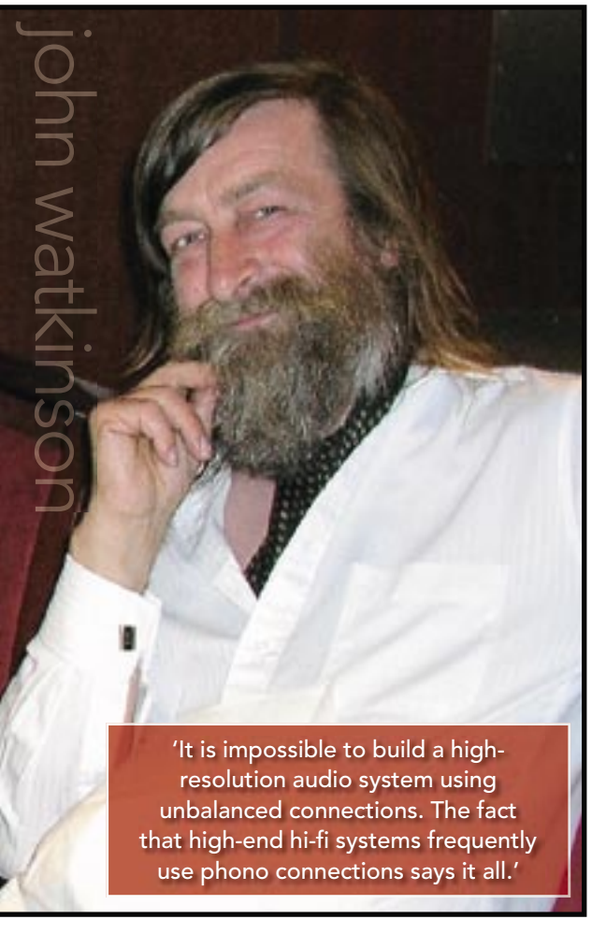
Grounding

Good grounding is vital for safety and for sound quality, but is often neglected because it's not exciting and/or because it's not understood. JOHN WATKINSON argues that it deserves more attention.



'It is impossible to build a high-resolution audio system using unbalanced connections. The fact that high-end hi-fi systems frequently use phono connections says it all.'

ALTHOUGH THERE'S ONLY one type of electron, there are two categories of electricity as far as audio is concerned. There's the type that works the lighting, the air conditioner and the coffee machine, and the type that carries the sound waveforms from one place to another. Unfortunately electrical signals have no idea of their purpose and simply obey the laws of physics.

As a result we can inadvertently mix the two categories. I can't recall a case where the audio signals interfered with the power. One milliWatt of audio isn't going to have a big impact on a ten kiloWatt air conditioner. It's always the other way round. Thus achieving good sound quality in an electrically powered environment is like achieving harmony in a relationship where one partner trains circus elephants and the other collects porcelain.

Electrical power uses voltages high enough to kill, whereas with audio signals the biggest health risk is nausea. From an electrical power standpoint, safety has to be paramount and that is where grounding comes in. If the metal cases of all electrical devices are connected to ground, then no-one standing on the ground can receive a shock from them. If a live wire comes off inside the device and touches the case, then it will fry the fuse instead of the operator. Devices like this need three-core power cords. There is another category of device that is constructed in such a way that it is physically impossible for the body to become live even in the worst case. These devices are referred to as double-insulated and can use a two-core lead. For example, an electric drill with a plastic body simply needs a plastic gear in the transmission so that the chuck can't become live if the motor insulation breaks down.

In all electric power systems there will be currents in the grounding system. All devices have finite leakage resistance, so some leakage current flows to ground. All devices have some capacitance and the power is alternating. In many devices, there is an interference filter at the power inlet. This will often have capacitors between the power leads and ground, guaranteeing ground currents. Even a double insulated device can have ground currents due to capacitance.

Thus if the grounds of two devices are connected, the chances are that some ground current will flow. Every time we connect up a lead having phono plugs we take that risk. The screen of the phono cable is the common terminal of the audio signal, yet we are allowing ground currents to flow through it. Unless the screen has zero impedance, the ground currents create a potential that is added to the audio waveform: the common-impedance effect.

Consequently it is impossible to build a high-resolution audio system using unbalanced connections. The fact that high-end hi-fi systems frequently use phono connections says it all. The use of audiophile phono cables with massively over engineered gold plated plugs and exotic wire makes about as much sense as gold-plating a cow pat.

From a linguistic standpoint, the term audiophile is derived from the Greek philos, meaning love. However, in the conventional English usage, it can mean love of an unwholesome or perverted nature. I think there should be a register of audiophiles so we can keep our children away from them.

Fortunately there is a solution that works perfectly and it is, of course, balanced signalling using twin wires, twisted and screened. In such a system, the ground conductor acts only as a screen and if ground currents flow in it they have no effect because the signal is carried differentially in the twisted pair.

Consequently the ground connection of twisted screened cable should always be made at both ends, otherwise the screening ability will be compromised. In a well engineered system, each device is enclosed in a metal case that connects via pin 1 of the XLRs to the screens of all the cables so that circuitry and signal paths are surrounded by continuous metal screening. Inside a device, the common terminal of the circuitry is connected to metal in one place only. Such a single point connection prevents the formation of ground loops.

I often hear cases where the screen was disconnected at one end and the problem went away, thus 'proving' my theory wrong. However, if disconnecting the screen removes a problem, there is a design fault. Pin 1 of an XLR connector should go directly to the metal enclosure and nowhere else, unless that one XLR has been designated as the single ground point for the internal circuitry. Modern XLRs have an insert that connects pin 1 to the mounting screw. Often XLRs are grounded to the printed circuit and then earth currents can flow in the circuit board where common impedances with the audio signals exist. Thus in an adverse ground current environment lifting the screen at one end would reduce the hum. However, in an adverse RF environment, lifting the screen would make it worse.

It is easy to check XLRs for proper bonding to chassis by injecting a high AC current between pin 1 and chassis with the connector active. If the system hums when the ground current is injected, there is a design fault. A solder gun of the type where the heating element is a copper rod running from a single turn transformer secondary makes an excellent current injector if the element is removed and short leads with clips are fitted.

Large installations may have a separate grounding system, called technical ground or technical earth, which is used as the safety ground for all of the technical equipment. A separate grounding system is used for all other electrical devices. In principle the idea is a good one because the magnitude of ground currents can be reduced in the technical ground. However, it requires constant vigilance to ensure the technical ground is not compromised by connection of inappropriate devices. Also there will be a ground potential between technical ground and non-technical ground.

I remember well the case of a large digital mixing console in Paris whose sound quality varied throughout the day. It transpired that the building had a superb technical ground installation. After two days of tearing the place apart, I found that the main ground of the mixing console went to non-technical ground. A major load on the non-technical ground was the restaurant. When they started cooking, the difference in ground potential between technical and non-technical grounds grew and with it the apparent jitter on the AES-EBU signals received from the console.

Thus although digital systems have more immunity to the environment than analogue systems, it is as well to remember that the immunity isn't necessarily total and good grounding practice is still needed in digital systems.

Grounding and screening are related subjects. Unwanted signals can be picked up from alternating electric and magnetic fields. In the case of electric fields, typically radiated from power wiring, the coupling mechanism is capacitive and an electrically conductive screen that is grounded will block the pickup. This is the purpose of the braided wire

screening around audio cables. However, conductive screening will not stop magnetic fields induced by currents in power wiring or leaking from transformers. True magnetic screening requires ferrous metal so that the flux prefers to pass through the metal rather than the device being screened. However, for a magnetic field to induce a voltage, there has to be a conducting loop with a finite area. Balanced wiring is twisted so that the loop area is effectively zero. Thus differential mode pickup is near zero. Common mode pickup is rejected by the balanced receiver.

On the subject of balanced receivers, they will only reject interference if they are operating as true subtractors. The problem is that many balanced inputs only have this characteristic over part of their frequency band. At higher frequencies true subtraction fails and the common mode signals get added to the signal path.

A correctly engineered differential receiver has identical impedance on both inputs at all frequencies. The CMRR must be tested to find the highest frequency at which it is maintained. Low pass filters must be placed in the inputs to remove signals for which true subtraction is not possible.

Naturally audiophiles would want those filters removed because they reduce the bandwidth of the audio system from absurdly ultrasonic to mildly ultrasonic. Go ahead, remove them and then wonder why the local taxis break through on the audio.

I suppose that brings us to further meanings of grounding. Marketing people, who frequently don't have a grounding in audio, can come out with the most preposterous statements that are, intellectually speaking, a form of noise. People who are grounded are better equipped to identify and reject that noise. ■

DO

Use balanced signalling wherever possible.

Ensure screen is connected to pin 1 of XLRs at both ends.

Check pin 1 of XLRs goes direct to enclosure metal and not via the PCB.

Keep technical and non-technical grounds just that.

DON'T

Use unbalanced signals.

Disconnect grounds randomly, you may fix one fault and introduce another.

Give credence to any audiophile marketing nonsense.