AUDIO TECHNOLOGY IN GENERAL

Most audio professionals typically work with "balanced" cables and signal processing equipment. This article investigates what balanced lines are all about and how they may affect your choice of cabling.

Hum and interference

First and foremost musicians want to play music.
Plug in, turn on, and then – you hear hum like a buzz saw. It is not very easy to explain how this hum, mostly caused by so-called ground loops, is created. For musicians and roadies it is important to get some idea what causes this annoying by-product in audio systems and what can be done about it.

Wherever we go in our civilized world, dangerous forces lurk in the shadows, ready to disturb the peace of our pure, innocent sound signals. **Running motors, transformers, mobile phones, electric tooth brushes** – in short, a whole army of possible sources of interference. Every cable is being threatened by all kinds of external interference. Some of these hidden forces travel through air in form of radio waves, while others sneak through the normal electrical system in our house, for example when we switch on fluorescent lights, dimmers or the power supply of an amplifier.
With PA systems sometimes you have no other choice but to use long cable runs between stage and mixer. Interference caused by fluorescent lights, for example, can be picked up by these cables and cause "humming", "buzzing" or "crackling".
Typical causes for these problems are the power supplies that are required for most audio equipment.
All electronics, from effect units to instrument amplifiers, require a power source of 115 or 230 V. If you have ever taken a look at a power cable you have noticed that it has three wires, usually black, white, and green: Phase = carries the voltage, zero = grounding at the generating plant, and the protective earth (PE) or equipment grounding conductor = grounding at the house to the foundation earth or ground.

On most units the conductive parts, surfaces and ground connection for the cable are internally connected directly to the PE contact, and thus to the protective earth conductor at the power outlet. The purpose of the protective conductor is to protect. It discharges the voltage if there is a defect in the unit or the phase touches the housing. This should normally trip a safety breaker.

Even though all we want to do is make music, (un)fortunately the subject of required power supply safety standards result from a number of legal guidelines that were not randomly created by some officials just to make our lives more difficult. The opposite is the case, because it could be a matter of life or death!

The voltage of 115 V with 60 Hz in the US, and even more so the 230 V with 50 Hz commonly used in Germany/ Europe will endanger your life if you come in contact with it. This makes the operation of amplifier and PA equipment, and even more so lighting systems that are powered by a so-called three-phase current, dangerous. Here we are dealing with currents of up to 380 V!!! They are guaranteed to be lethal, a fact that is supported by accident statistics.

Everyone who makes music would like to show off his or her talents at public events. To do this, in most cases you need technical equipment. And here the challenges begin. Even a performance at the town hall in front of only 100 – 150 people is a public event.

Such events are governed by conditions and regulations which have only one purpose: to protect the public and performers from injury or worse. The organizer of the event is mostly responsible for ensuring that escape routes and emergency exits are available, the stage is built safely and that appropriate power sources and wiring are used. And now we have come full circle – back to supplying the electrical power.

Protective classes

Nearly all locales in the U.S. adhere to the standards for the safe installation of electrical wiring and equipment specified in the National Electrical Code (NEC). All electrical devices in Germany must be properly equipped to protect the user against electrical shock. Even if there is a defect, the outside parts of the housings must never carry any electrical voltages. In the specifications laid out in Protection Classes I, II or III must be fulfilled.

Protect. class	Meaning	Notes	Symbol
I	Equipments and lights with ground conductor connecting all accessible metal parts that could carry an electrical current in case of a defect.	Connection to ground conductor is mandatory with no exception. The symbol is displayed at the connection point.	
II	Units with no accessible metal parts that could carry an electrical current in case of a defect (protective insulation or double insulation).	Lights that must not have a ground wiring post and must not be connected to the ground.	
III	Lighting for operation with protective extra-low voltage (SELV), i.e. less than 50 V, generated by a safety transformer, according to DIN VDE 0551 (EN60742) or powered by batteries.	The unit must not have a ground wiring post and must not be connected to the ground.	

If you take a close look at your amplifier, mixing board or keyboard you will find a number of manufacturer instructions regarding this subject on the power rating plate or next to where the power cord enters the equipment.

CE

The **CE test symbol** (CE = Conforming to European safety standards) has been in use for a number of years. It states that the manufacturer conforms to the generally applicable engineering guidelines and EMC guidelines (for electro-magnetic compatibility) during production. All units introduced to the market in Europe, meaning they are sold and operated there, must carry the CE test symbol.

What's behind it?

In this particular case not the usual arbitrary nature of public authorities!

Basically, the EMC guidelines adopted by the European Union are very positive. As described above, our environment is full of electro-magnetic interference, partially due to technical developments such as Wireless LANs and millions of mobile phones.

EMC means **e**lectro-**m**agnetic **c**ompatibility, and the EMC guidelines, legally adopted in 1992 (EMCG 1992), obligate manufacturers to produce products resistant to electro-magnetic interference. Furthermore, manufacturers must acknowledge adherence to EMCG and their technical guidelines in a Declaration of Conformity (VDE 0100; VDE 0800; etc.). Only then are they allowed to apply a clearly visible CE test symbol onto the unit.

That's great, because if the unit starts humming and crackling the manufacturer is at fault! ...or not?

No, of course not! The manufacturer is only responsible for the unit he supplies and will specifically state the environmental requirements and intended purpose in the respective documentation. Interfaces, environmental temperature and other operating conditions must comply with manufacturer requirements. Other factors are the sole responsibility of the operator. Smart manufacturers will list faulty operating conditions and warn us of the specific situations in which humming and crackling will occur. So, the buck is passed back onto the operator, the user or the musician.

There is no doubt that you can hit a tree with your car. Of course, efforts are taken to prevent just that by driving and operating a car in compliance with the technical specifications of the vehicle. Besides, we learned the traffic rules when we got our licenses and most of us drive accordingly. Those who drive through a red light or are caught driving 65 miles an hour in a 35 mile-an-hour zone must suffer the consequences. In traffic we all know that hitting a tree is the result of negligent driving and a traffic ticket is documented proof that we have violated valid traffic rules.

The same is true on stage. If the system hums or we suffer an electrical shock, it will be due either to faulty operation or non-observance of the rules. And the consequences of an electrical shock can be much more severe than the ticket and 4 weeks without a driver's license after running a red light.

If you're not sure whether the sound system you use is in proper shape electronically, and safe, you should hire an electronics specialist to test it. The cost for such a service is far less than the subsequent costs of a power failure in public. Everyone who makes music to earn a living must have their electrical equipment checked periodically!

This short explanation makes clear that the sonic quality of audio systems does not only depend on brand names and the manufacturers behind them. Each mixing board and each speaker system (PA) can only operate optimally to the extent that external factors also play along. Since sound equipment has to be cabled together for the system to work, anyone interested in producing pristine sound without hum and other noise should first check and possibly upgrade their multicore system, the stage cables for the instruments and the power cables.

Music free of noise is more fun!

How does the audio signal reach the speaker, or...

The proper cable!

Let's first start with the instrument, the guitar, the bass, and the keyboard. On stage, the kind of cables that are usually used to connect instruments and amplifiers are single-wire audio cables with shielding. Interference from external sources can cause trouble even if short cables are used. The cable shielding consists of a wire mesh or foil that completely surrounds the actual conductor. The shielding protects the sound-carrying wire against interference caused by electrical and electro-magnetic waves.
But the problem for a single-wire shielded cable is that we only have one dedicated positive signal "hot" wire (+), while the negative "cold" phase (–) is shared with the outer shielding. This works fine as long as outside interference is low. The shield functions simultaneously as the second conductor that is required to complete the circuit.

For the transmission of audio signals through single-wire shielded cables, interference-free transmission is limited to cables that are only a few meters long.

Unbalanced cable connections

Unbalanced cables (such as your typical guitar cord) are single-wire audio cables with an inside conductor and outside wire braiding. The plug only requires two contacts (positive "hot" phase and shielding).

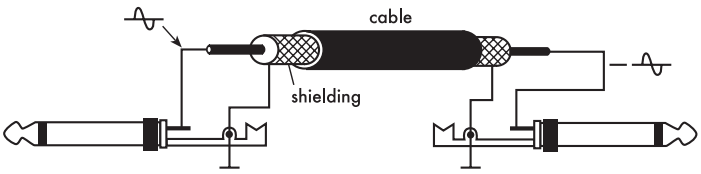

Fig. 1: Schematic view of an unbalanced audio cable

The phase ("hot") transmits the audio signal from the source to the destination. The shielding serves as protection and as the negative or "cold" phase.

Application:

Unbalanced outputs	Unbalanced inputs
Electrical guitars and basses	Instrument amplifiers
Keyboards, Amplifier line-outs	Mixing boards line-ins (mostly)
Speaker connections	DI boxes
Aux-send-paths (mostly)	Effect pedals
Direct-outs (mostly)	

Because instrument cables are usually connected to the inputs of amplifiers, they not only amplify the sound of the instrument, but also the interference noises. For example, it is not a good idea to run an audio cable next to power cables. The electro-magnetic field of the power cable (115 V/60 Hz or 230 V/50 Hz) will leak the 60/50 Hz humming noise into your audio cable, which will then be substantially amplified by the amplifier properly amplified.

Another cause for hum is the fact that each instrument cable works as a so-called R-C-element (R = resistance, C = capacity) and, under certain circumstances, acts like an antenna. This occurs especially if there is an impedance mismatch between the instrument output and the amplifier input. Some musicians have wondered why a radio station all of a sudden was audible through their sound system.

And lastly, in any musician's sound system you typically have a number of different electronic devices that are interconnected through cables that all meet at a mixing console. With unbalanced cables, any interference present is passed on via the common ground to the amplifiers and boosted in the amp, resulting in those annoying ground loops we know so well.
But if you wish to prevent this interference from contaminating the signal, you can use balanced cables with their separate ground.

Balanced cable connections

Balanced cables are made of two conductors and a shield. The signal is exclusively transmitted by the two inner conductors ("hot" positive and "cold" negative), whereas the jacket only serves as the shield. The plugs used here are either XLR or 3-pin Tip-Ring-Sleeve connectors.

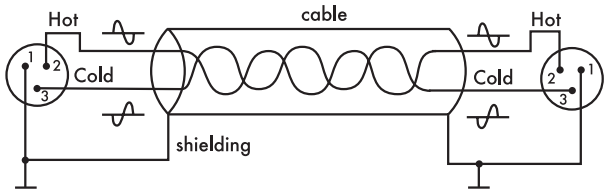

Fig. 2 Schematic view of a balanced audio cable

Application:

Balanced outputs	Balanced inputs
DI boxes	Mixing board XLR inputs
Stage microphones	Mixing board balanced line-inputs
Mixing board L/R master outputs	Mixing board returns
Mixing board sub groups	Microphone pre-amplifiers
Mixing board matrixes	Effect units
Mixing board monitor paths	
Aux paths	

Balanced cables even very long ones are immune to electro-magnetic interference and ground loops.

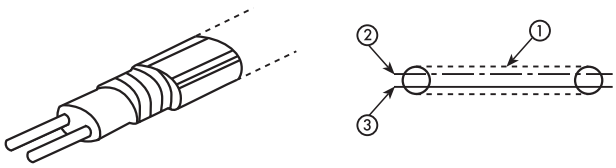

Fig. 3 Construction of a balanced audio cable

Balanced cables consist of shielding (1) and two conductors (Fig. 3).
The audio signal is transmitted independently from the shield and ground. Interferences that are intercepted by the shield and ground wire do not affect the audio signal, thus the term ungrounded. The two conductors are wired phase inverted.

This means that the phase in one conductor is inverted by 180 degrees. Due to this opposite phasing, the electro-magnetic interference signals that affect the cable from the outside reach both conductors simultaneously and cancel each other out.

For ungrounded balanced transmission to work, it is necessary that the inputs and outputs on the connected devices are both balanced. This can be accomplished electronically, i.e. through the use of balanced input amplifiers with common mode rejection or output amplifiers with optimized unbalanced output voltage (a-conductor to b-conductor).

Today we can assume that electronically balanced inputs and outputs are superior to most transformer-balanced ones regarding transmission parameters such as frequency response, distortion factor, common mode suppression, and resistance to over-modulation. Nevertheless it is often necessary to use balanced cables without ground.

Genuine ungrounded balanced audio transmission is only possible through the use of audio transformers. These transformers are optimized to handle low-frequency audio signals. But despite the fact that a vast selection is available on the market many of them can only be used for the ungrounded transmission method.
Those who want genuine transmission quality with the best possible common mode rejection have to depend on toroidal core transformers.

Microphone cables connected to mixing boards carry very low voltage levels (milli-volt range) and are therefore extremely sensitive to interference. This is why it is very important that they always be ungrounded-balanced.
But with return cables leading from the mixing board to the amplifier, the risk of interference is not quite as high, because the strength of the signal can reach several volts. Therefore, using ungrounded balanced cable to route the signal to the amp is not absolutely required.

However, the only way to completely eliminate all possibility of interference is by insisting that all cables incorporate an ungrounded balanced design.

Explanation for abbreviations

RoHS

The RoHS-Guidelines (Restriction of certain Hazardous Substances) issued by the European Union (EU) regulate the restricted use of hazardous substances. Since July 2006, EU Guideline 2002/95/EC has been prohibiting the use of cadmium (Cd), quicksilver (Hg), hexavalent chrome (Cr (VI)), polybromated biphenyl (PBBs), and polybromated diphenyl ether (PBDEs) and lead (Pb) in electrical and electronic units.
SOMMER *CABLE* converted the production of all their bulk cable, ready-made cables, and systems to comply with EU guidelines 2002/95/EC (RoHS) and 2002/96/EC (WEEE) prior to 2006.

VDE

For electro-technical products and products governed by the Unit and Product Safety Law (GPSG)
The VDE symbol verifies conformity with VDE guidelines or European and International Harmonized Norms and confirms compliance with the safety requirements stated in the respective guidelines. The VDE symbol stands for product safety regarding electrical, mechanical, thermal, toxic, radiological and other dangers.

WEEE

(Waste Electrical and Electronic Equipment – EU guideline) A guideline to reduce electronic waste from discarded electrical and electronic units. The goal is to avoid and reduce the steadily increasing amount of electronic waste in an environmentally friendly manner by placing additional responsibility for recycling of the products on the manufacturers.