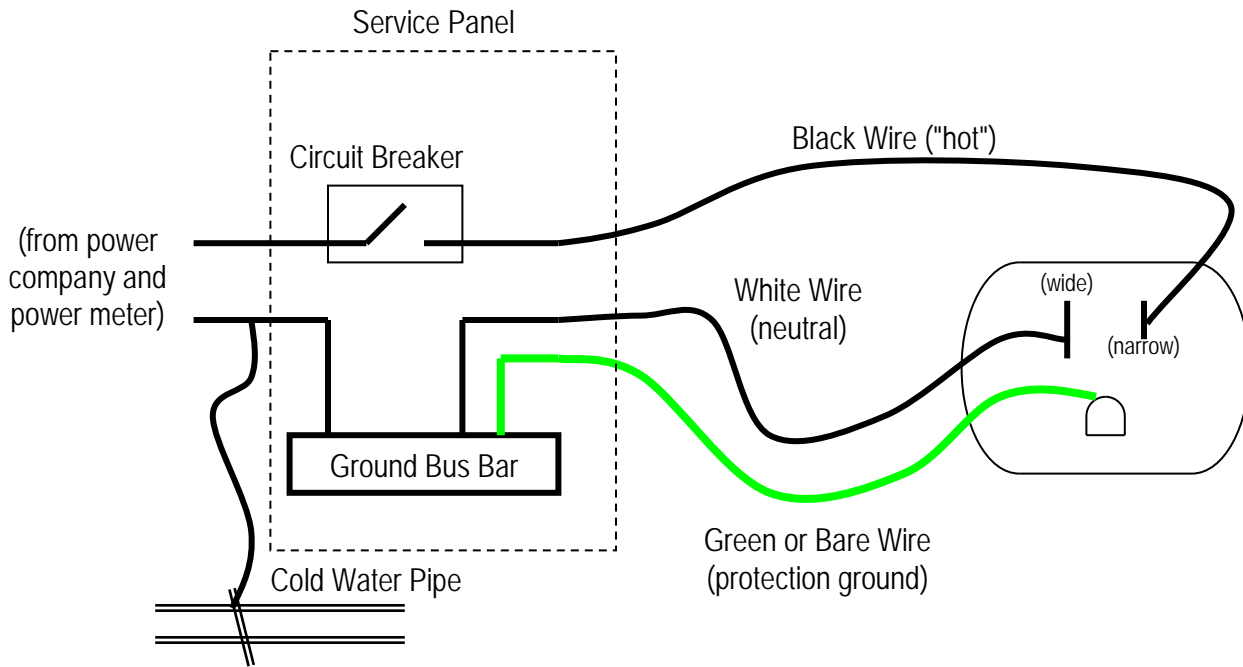


## Audio Electrical Wiring Considerations

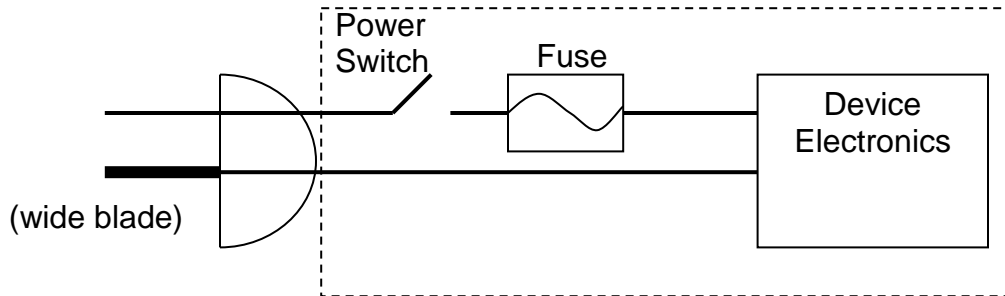
### Basic branch circuits in homes and businesses (U.S.)



IF the outlet is wired correctly (never EVER risk your life on this assumption!!), the white wire ("neutral") should be the wide blade and the electrical potential should be near zero potential. In the U.S. the black wire ("hot") is 120 volts RMS (root-mean-square) sinusoid, 60 Hz repetition frequency, with peaks  $\pm 170$  volts respect to the neutral. Keep in mind that the colors are purely customary: the color itself doesn't influence how the electricity flows in the circuit!

The green (or bare) wire is the protection ground, and the internal wiring of an appliance will have this conductor connected it to the metal chassis of the appliance. The green wire does not conduct any current under normal circumstances, EXCEPT if there is a fault in the appliance that allows the "hot" wire to come in contact with the chassis. In the case of a fault the ground wire short circuits the "hot" wire through the chassis and back to ground, which should draw enough current to trigger the circuit breaker to open, de-energizing the outlet. This protection is important, because without it a fault could energize the chassis, and then a person could get shocked by simultaneously touching the chassis and a nearby grounded surface, inadvertently completing the circuit.

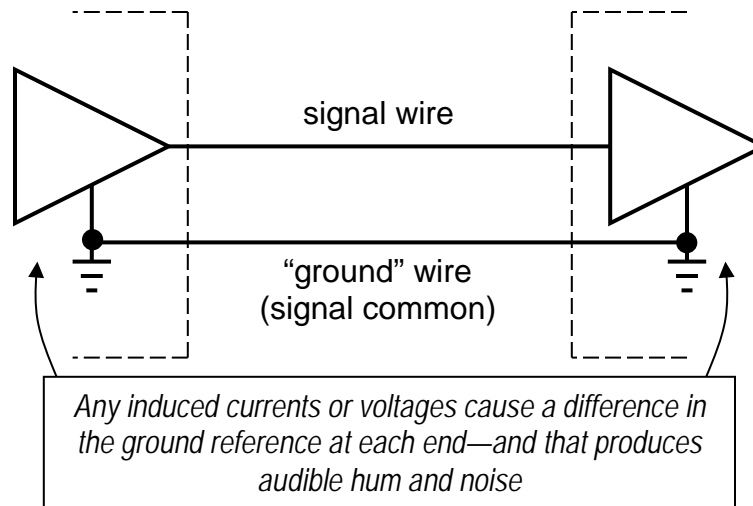
Appliances with a polarized (wide blade) plug should be designed so that the exposed conductors (like the metal ring of a screw-in light bulb) are connected to the neutral wire, and the "hot" conductor has the power switch, as shown below. This arrangement has the power switch positioned to de-energize all the components down-stream from the switch, making it less likely a user would get a shock if changing a light bulb or an internal fuse with the appliance inadvertently left plugged in. The appliance will still work if the outlet is not wired with the proper hot and neutral orientation, but it is safer with the correct wide-blade neutral orientation.



Homes and businesses may also have *GFCI* outlets. GFCI stands for *ground fault circuit interruptor*, which describes special circuitry inside the outlet itself that monitors the current in the hot wire and in the neutral wire: if there is even a small difference between the hot and neutral current, it means current is leaking somewhere in the appliance (like as a shock current going from the appliance through a grounded person!) and the device will quickly turn off the outlet. GFCI outlets usually have a reset switch and a test switch on the faceplate. If the GFCI trips, don't just reset it, but check out what might be triggering the imbalanced current. Sometimes electric motors will trip the GFCI even without a fault condition.

### **Unbalanced and balanced audio wiring**

*Unbalanced* audio interconnects, also known as *single-ended* connections, use two wires between the source device and the receiving device. One of the wires is the electrical ground (zero potential) and the other wire carries the analog voltage representing the audio signal with respect to the ground wire. Thus, the source device (such as a CD player) and the receiving device (like an audio amplifier) have their electrical grounds connected together via the interconnection cable.



Unbalanced connections are inexpensive and work reasonably well for consumer devices that are located close to each other, like a stack of gear in a stereo cabinet. However, the unbalanced connection is susceptible to both electric field pickup and magnetic field coupling.

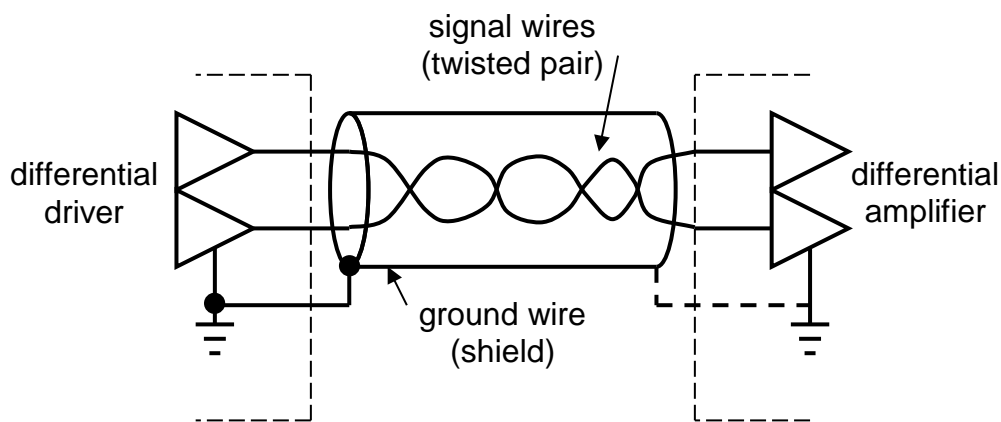
Electric field pickup is due to the presence of electromagnetic waves, particularly broadcast radio and TV signals, but also emanations from computers and other devices with high

frequency switching circuits. The interconnection wiring acts like an antenna, and small radio frequency (RF) currents are induced capacitively into the wiring by the electromagnetic fields. Since the receiving device is observing the voltage between the single signal wire and the ground wire, these RF currents can cause a noisy signal in the audio frequency range due to nonlinear mixing in the wiring and the circuitry.

Magnetic field pickup is often caused by nearby wiring in the building's power system. The currents flowing in the building's wiring cause magnetic field loops encircling the conductors, and if the magnetic field passes through the loop created by the two conductors of the unbalanced connection, a 60 Hz hum can be picked up. The problem can also be caused by *ground loops*. A ground loop occurs when different devices are interconnected by unbalanced wiring, forcing the ground reference of each device to be shared. Any currents induced in the ground wire cause a difference in electrical potential at each device, and the receiving device interprets that difference as part of the audio signal. Magnetic field pickup and ground loops can be avoided by keeping interconnection wiring as short as possible, twisting the conductors in the unbalanced cable, and keeping any loops in the grounding system as small as possible.

*Balanced* audio connections, also known as *differential* interconnects, avoid several of the problems inherent in unbalanced wiring—at the expense of more complicated audio circuitry and three wires instead of two in the interconnect cable.

A balanced audio connection has the signal presented as the voltage between two wires, neither of which is the ground potential, and the receiving device has a differential amplifier that looks only at the voltage difference between the two wires. The two signal wires are usually twisted around each other during the manufacturing process so that any stray magnetic fields will not couple very well into the signal wiring: each twist would couple the magnetic field in the opposite direction as the prior twist, thereby canceling out any induced signals. A third wire is the ground wire, and typically the ground is used as an electric field *shield* by incorporating a conductive foil or mesh wrapping inside the cable that surrounds the two signal wires.



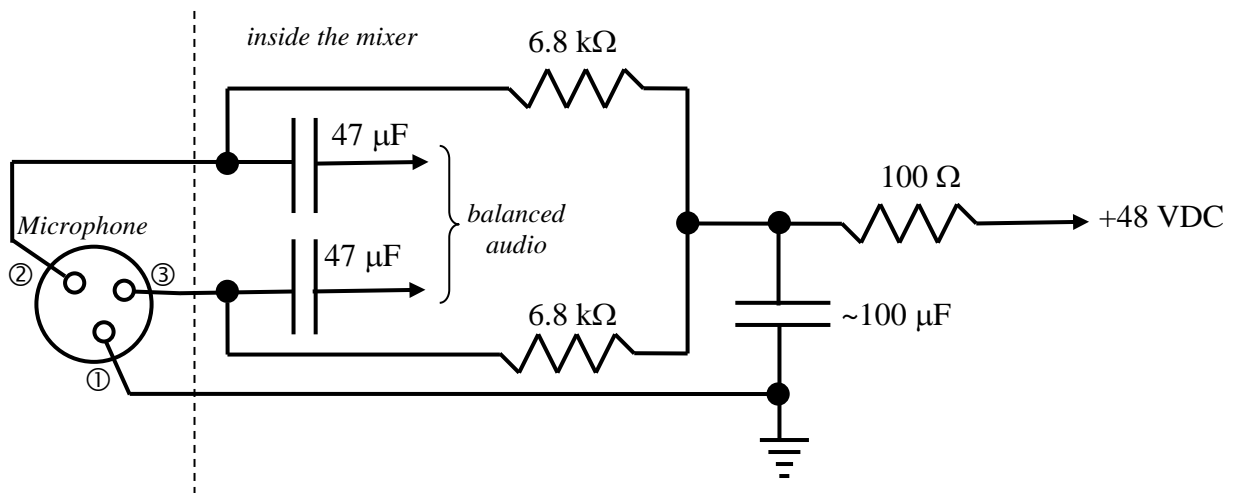
*The signal is the difference in voltage between the two signal wires, and NOT referenced to ground. Induced ground currents do not corrupt the signal.*

Most professional audio gear is designed with balanced interconnections in mind. Most consumer gear (and even most "audiophile" stereo and a/v equipment!) uses unbalanced

interconnections, probably because it is less expensive. Care must be taken when using a system in which some devices are balanced and some are unbalanced: it is generally best to use an audio transformer or a "direct box" when hooking up unbalanced gear to balanced system in order to avoid electromagnetic interference and ground loop issues.

## Phantom Power

Condenser (capacitor) microphones generally require a preamplifier to be located in the microphone housing very close to the capsule. This is because the capsule itself generates insufficient power to drive a signal into the microphone cable. The preamplifier needs to be powered somehow. Some mics have a battery inside, while others use an external supply. A common way to power condenser mics in professional systems with balanced wiring is to use *phantom power*, which is a circuit that provides an equal DC voltage with respect to ground to both of the balanced signal wires. Because the balanced receiver is designed to respond only to the *difference* between the two signal wires, including the same DC voltage to both signal wires does not disrupt the audio signal. In the microphone a circuit receives the DC voltage from both signal wires and uses it to power the microphone's preamp.



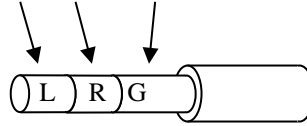
## Audio Connectors

The audio field has a very large number of connector types, and many types come in both male and female configurations. Not all manufacturers choose to wire their connectors in the same manner, so it's a good idea to look at the users' manual or technical diagrams to ensure different gear will interconnect as expected.

Unbalanced connections are typically RCA cinch connectors or phone plugs. RCA refers to "Radio Corporation of America," a well-known 20<sup>th</sup> century audio manufacturer. The RCA connectors generally have the inner conductor as the signal wire and the outer conductor as the ground. Phone plugs come in several sizes and diameters, such as 2.5mm, 3.5mm, 1/8", 3/32", and 1/4".

A typical unbalanced phone plug has a "tip" conductor (signal) and a "sleeve" conductor (ground). NOTE that some phone plugs and cables have three conductors and can be used to carry a stereo pair of signals (e.g., left channel and right channel), using the three wires: the "tip" is generally—but not always—the left audio channel, the "ring" is typically the right audio

channel, and the "sleeve" is the common ground for both channels. The three conductor phone plugs are often called "TRS" plugs, meaning "tip, ring, sleeve".

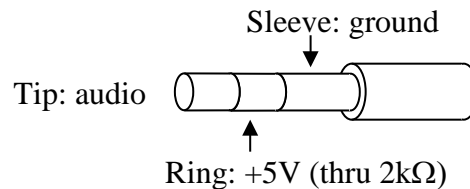


Some "TRS" plugs may have four conductors, tip, two rings, and the sleeve, or TRRS. These are found on cables that provide three channels of unbalanced audio with respect to ground, such as a headset with a stereo pair for the earpieces and a third channel for the headset microphone. One common type (iPod, iPhone, etc.) has left-channel on the tip, right-channel on ring 1, ground on ring 2, and microphone on the sleeve.



Balanced audio connectors are commonly TRS connectors or XLR connectors. TRS connectors typically use the tip and ring for the two balanced audio wires, while the sleeve is the ground (shield) conductor. XLR was originally the part number of a particular style of Cannon-brand audio connectors, but now it has become the generic name for the round, 3-terminal connectors used for balanced audio interconnections. XLR connections use pin 1 for the ground/shield, and pins 2 and 3 are the balanced audio signal wires.

To make things even more complicated, there are some situations in which the TRS cable and connector is used as a powered microphone cable, as in personal computer microphone inputs (see below), and other situations in which it is used as an "insert" cable for an effects send/receive in some audio mixer applications.



## Audio Polarity

Audio signal *polarity* refers to the phase relationship between an increasing analog voltage and the pressure disturbance of the corresponding acoustical wave in the air. It is generally a good idea to maintain consistent polarity when interconnecting various audio devices so that an acoustic wave that caused the microphone diaphragm to move *inward* will go through the audio chain and ultimately cause the loudspeaker cone to move *outward*, thereby creating the same acoustic phase in the listening room that was present in the original recording space. Unbalanced interconnections usually don't present a polarity problem because the signal is always referenced to ground, but the two wires of a balanced interconnect allow a choice of signal reference. Most manufacturers have chosen to use XLR pin 2 or TRS "tip" to be the positive polarity reference, and XLR pin 3 and TRS "ring" to be the negative reference, so connecting pin 2 to pin 2 or "tip" to "tip" should maintain polarity. HOWEVER, some manufacturers have chosen to make XLR pin 3 the positive polarity reference, so you must be careful to look at the equipment documentation to make sure "+" is connected to "+".