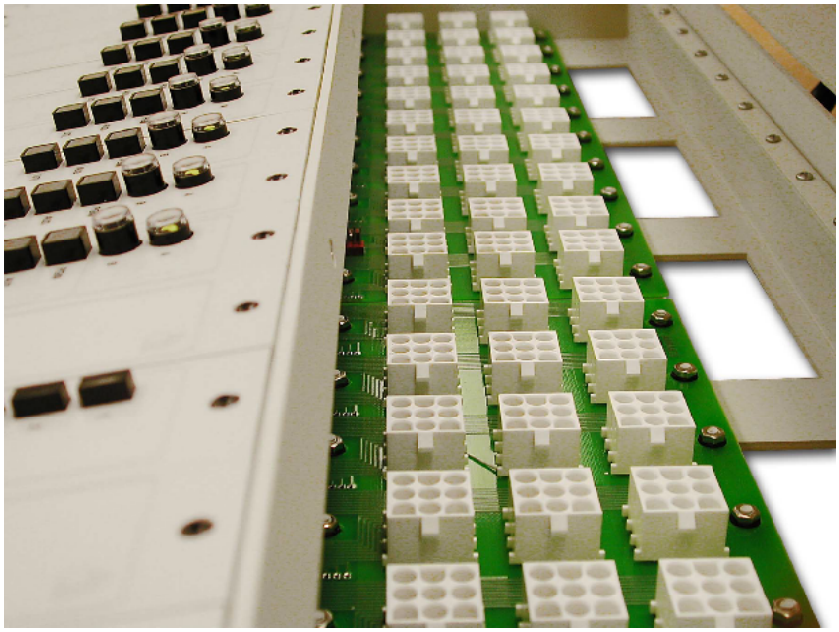
AC Power Systems

Arrakis Systems inc.

application note



Purpose of this Ap Note

This application note is designed as a practical aid for designing, installing, and debugging low noise, high performance audio broadcast studios and facilities. It is intended for use by novice and experienced “technical” people alike, including managers.

The application note focuses on the basic principles of audio “systems” design. Simple mathematical models are used only as they illustrate a principle. We find that it is the proper understanding and application of basic principles that results in a professional audio installation. It is often only through an application of basic principles that a problematic installation can be corrected.

In preparation for writing this application note, we have performed an extensive review of available technical literature and product manuals on these subjects. The review underlined the complexity of modern audio systems design and that this is a field under constant change. Combining audio products from the broadcast, consumer, music, commercial sound, and now personal computer industries into a single facility is a challenge. These different industries have different product design goals that have resulted in an inability to simply “plug and play.” It would be thought that it would be possible to simply purchase equipment and off the shelf interconnection cables to assemble an audio facility. However, variations in audio levels, impedance, connector designs, AC and audio ground systems, and other factors make this difficult. The purpose of this application note is to help to provide enough of an understanding of the underlying principles to be able to overcome these obstacles.

Arrakis Systems has been building professional radio consoles since the late 1970‘s and digital audio source equipment since the early 1990’s. We are a leading manufacturer and innovator in the professional broadcast audio industry. We have accumulated experience with thousands of studios in diverse conditions around the world.

I- Important Information

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Important Disclaimer

Use of the information in this document is entirely at the reader's risk. Although precaution has been taken in the preparation of this document, Arrakis Systems inc. assumes no responsibility for errors or omissions. Neither is any liability assumed for damages resulting from the use of the information contained herein.

Danger- Shock & other hazards

Electronic products may contain potentially lethal voltages and currents and should be serviced by trained and experienced personnel only. Any installation, test, or calibration procedures in this document that require access to the interior of the equipment should be performed by qualified personnel only.

How to Contact Arrakis

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Having difficulty contacting Arrakis? Refer to the website (www.arrakis-systems.com) for current contact information

AC POWER SYSTEMS

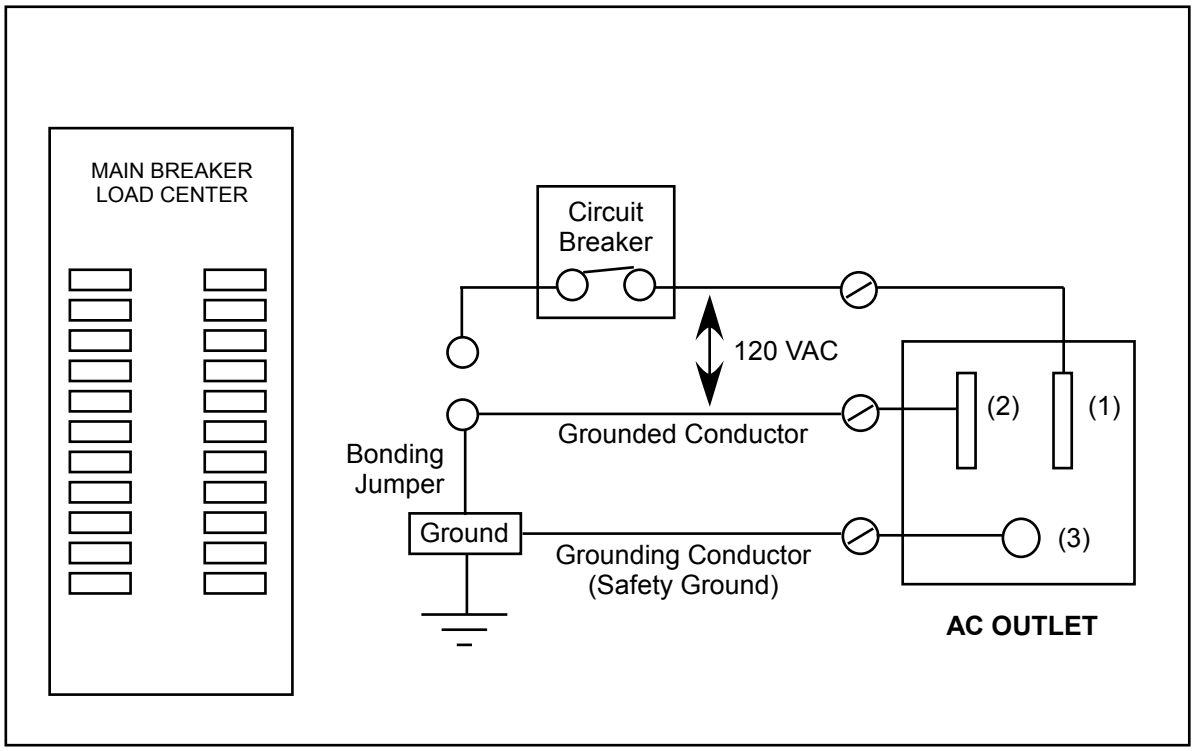
4.1 A Basic 110 volt AC Outlet

A 3 wire AC outlet has:

(1) 110VAC
(2) Ground (return) for 110VAC
(3) Safety AC ground

The large AC power currents are carried by (1) and (2). The Safety ground (3) may be connected to the metal chassis of the product and carries a current only if there is a short between the chassis and power. In the case of a short, the AC breaker will be thrown, disconnect power from the outlet, and remove the shock hazard.

IMPORTANT- . The 3rd prong should NEVER be disconnected by the use of a 3 prong to two prong converter because this creates a potentially lethal hazard.



4.2 Ground Fault Circuit Interrupters (GFCI)

a) Ground fault interrupters are protection for people. Circuit breakers serve two important functions but are not perfectly effective at protecting people. First, circuit breakers protect electrical wiring from overheating and causing a fire by limiting the current in the circuit. Second, as a function of the 3rd wire safety ground system, a circuit breaker will remove dangerous voltage from the metal chassis of equipment and thereby remove a potential shock hazard before a person might be shocked. Circuit breakers are not designed to disconnect dangerous AC voltages and currents quickly enough or at low enough currents to protect people.

b) THE HUMAN BODY & AC CURRENTS

> 5 millamps	painful shock
> 15 millamps	muscle cramp freeze to circuit
> 30 millamps	breathing difficulty
50-100 milliamps	possible ventricular fibrillation
100-200 millamps	certain ventricular fibrillation
> 200 milliamps	severe burns, muscle contractions

c) AVERAGE BODY RESISTANCE (varies based on moisture, muscles, and voltage)

Typical	1000-4000 ohms
120VAC	2800 ohms
240VAC	2100 ohms

d) TYPICAL SHOCK CURRENTS

120VAC	43 millamps
240VAC	114 milliamps

e) GFCI DESIGN PARAMETERS (Class A Device, UL)

Trip Current	> 5 milliamps
Trip Time	Time = (20 / I) ^ 1.43, where Time is in seconds and I is in milliamps

f) HOW GFCI DEVICES OPERATE

GFCI devices sense the difference in current between the ungrounded load conductor (hot) and the neutral load conductor (ground). When the current imbalance exceeds 5 milliamps then a ground trip solenoid is activated to disengage the hot conductor. Any difference in current between the hot conductor and the ground conductor means that current is returning to earth ground by another path such as a human body.

g) GFCI DEVICES CAN NOT REPLACE 3RD WIRE SAFETY GROUND SYSTEMS

At this time, NEC code requires 3rd wire safety grounds to be used wherever available. GFCI devices may not be used in place of 3rd wire safety grounds or to remove a 3rd wire safety ground to defeat a ground loop.

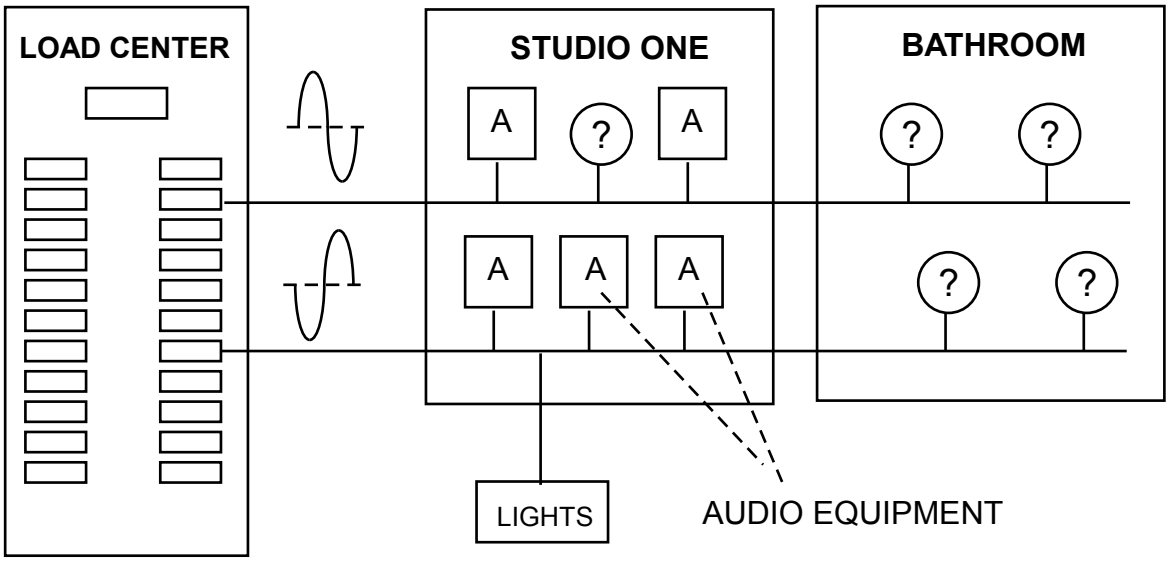
AC POWER SYSTEMS

4.3 A TYPICAL AC Power System

a) TYPICAL AC POWER DISTRIBUTION

In typical “residential” or “commercial” style AC wiring system, there are 8 or more duplex wall outlets on each AC branch circuit. There is usually more than one branch circuit in each room and they may be on opposite AC phases. The branch circuit may include duplex wall outlets and building systems such as lights, control, etc. In a residence, the wire will usually be multipair insulated cable and the safety ground will be a bare wire. In a commercial building, the wire will usually be in a conduit and the conduit itself may be the safety wire.

Example- A Studio and a Bathroom are on the same branch circuits. Also, the lights in Studio One are on a branch circuit with audio equipment. Turning an appliance on in the bathroom or the lights on or off will create a transient in the AC power and possibly a pop in the audio equipment. Another problem is that some audio equipment is on one phase of the AC power while other audio equipment is on the other phase of the AC power. This can cause 60 cycle AC hum.



b) TYPICAL PROBLEMS

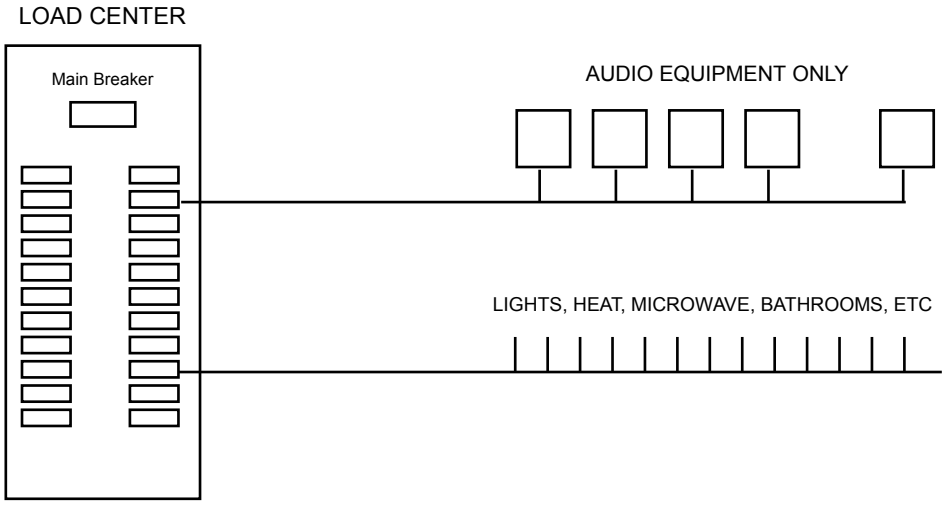
In this situation, typical problems are 60 cycle hum and various noises due to building equipment or equipment in other studios. There may be no problems on one day and significant problems on another day. This is all due to equipment interactions through the AC power and ground systems. Turning on equipment in one studio can introduce hum in another studio. Adding a new piece of equipment to a studio can change the problems in that studio and in another studio.

AC POWER SYSTEMS

4.3 A TYPICAL AC Power System (continued)

c) HOW TO BEST USE EXISTING "TYPICAL" WIRING

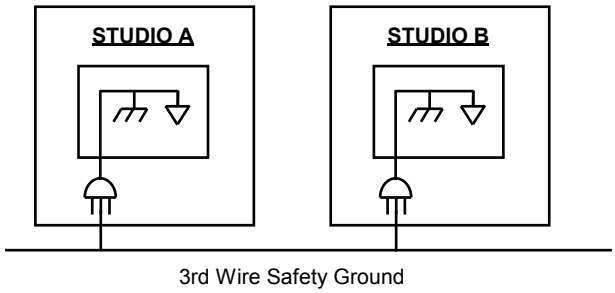
Using the existing wiring, remove all non-audio equipment from an AC branch circuit in the studio. (Use the circuit breaker to turn power on and off to a circuit to find the equipment on that circuit. Remember a circuit can power equipment in several rooms.) Connect all audio equipment to that clean AC power branch. Preferably, connect an AC terminal strip to a single AC outlet on that "clean" branch and power all equipment in that studio from that AC terminal strip. Do this for each studio in the facility.



d) REMAINING PROBLEMS

By following the guidelines above, the audio equipment in each studio is connected to a single AC branch circuit and a single phase on the AC power. This is a huge improvement. Problems can still exist however because of the 3rd wire safety ground interacting with other AC systems. In commercial buildings, the 3rd wire safety ground is often the conduit itself which can then connect multiple AC branches and phases. In residences, the 3rd wire is usually not insulated and can touch ground wires from other AC branches and phases. This type of wiring is safe, but creates a randomly connected ground system for your audio. If problems remain, it may be necessary to rewire the AC power for the audio equipment in your studios.

EXAMPLE- The audio ground of an audio device in Studio A is connected to the audio ground of an audio device in Studio B through the 3rd wire safety ground. In buildings not designed for audio systems, you will have random ground connections throughout your facility that will cause unpredictable noise problems as various combinations of equipment are used.

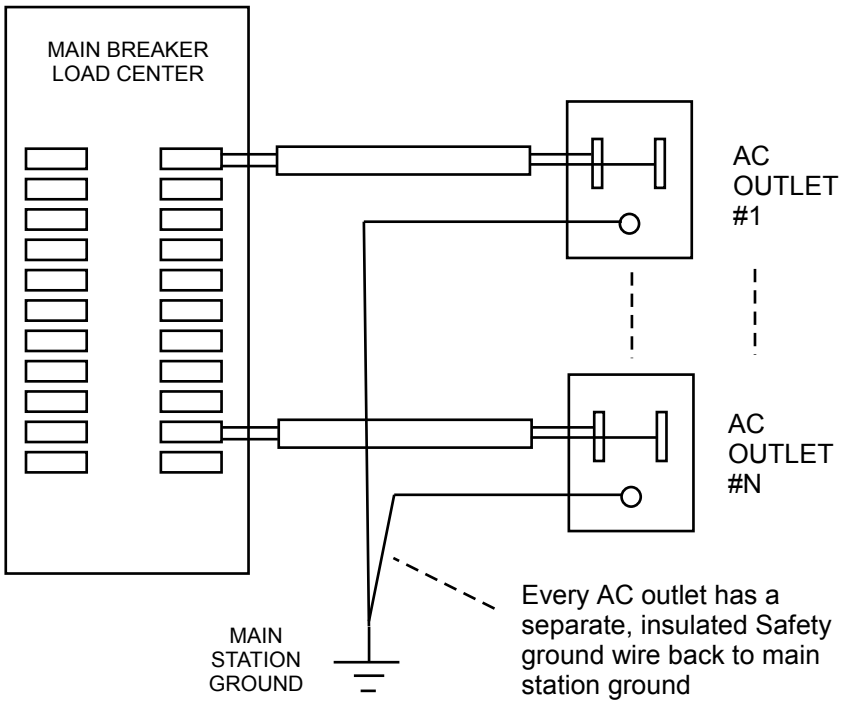


AC POWER SYSTEMS

4.4 A BETTER AC Power System

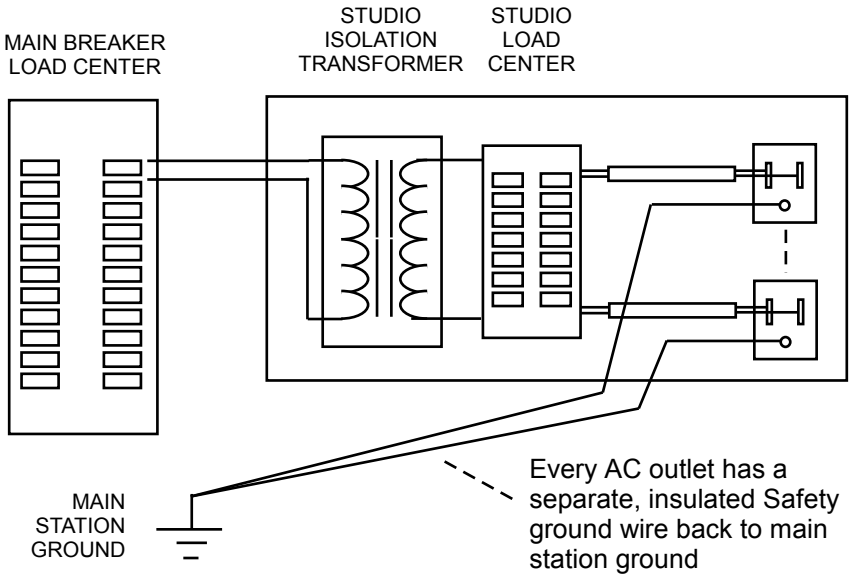
a) ISOLATED SAFETY GROUND (Better)

In this type of system, AC branch circuits are run for the audio equipment separate from ALL other building systems or uses. On these special AC branch circuits, the 3rd wire safety ground to EVERY AC outlet has an individual, insulated ground wire (green) return all of the way to the main AC breaker box. This provides a clean “star” ground to every AC receptacle and therefore every piece of audio equipment.



b) AC ISOLATION TRANSFORMER & SAFETY GROUND (Better Still)

In this type of system, a separate AC isolation transformer (on its own individual AC branch circuit) is located in each studio. The 3rd wire safety grounds follow the same isolation rules described above where EVERY AC outlet has an individual, insulated ground wire (green) return all of the way to the main AC breaker box. This provides a clean “star” ground to every AC receptacle and therefore every piece of audio equipment.

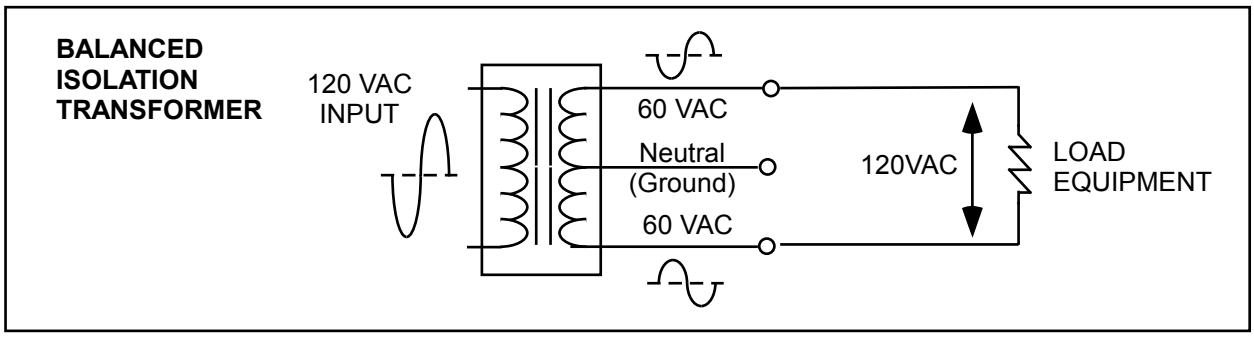


AC POWER SYSTEMS

4.4 A BETTER AC Power System (continued)

c) BALANCED ISOLATION TRANSFORMERS

While not NEC approved and therefore requiring local inspection and approval, balanced isolation transformers are becoming increasingly popular. A standard isolation transformer has 120 VAC and neutral (ground). Large currents must flow in the ground line. In contrast, a balanced isolation transformer is centertapped (ground) and has (+)60 VAC and (-)60 VAC. The equipment still receives 120 VAC but there is almost no current flow in the ground (centertap). This dramatically reduces AC and ground noise in the audio equipment.



d) REMAINING PROBLEMS

While an isolated AC and Safety Ground system is the best possible form of AC power distribution for your audio equipment, all of the audio equipment still has a single common ground path from the Main AC power box to the AC earth ground. If there are large currents in this common path, then there can still be AC hum in your audio system. The only solution in this situation is to create a separate audio “Technical” ground system with its own earth ground stake. This type of system defeats the standard 3rd wire safety ground system, is not NEC approved, and therefore requires local inspection and approval.

TECHNICAL GROUND (a.k.a. technical earth ground)

A specific “ground” reference point in a facility.

The technical ground is generally the point where all audio equipment is grounded in a studio. This could be the standard AC service safety ground, but many times is not. In many large studios the standard AC safety ground is avoided for the audio equipment because of possible problems, which could include poor connection to ground, noise on the line from other equipment in the facility, and unpredictable ground loop problems. In those cases a separate Technical Ground is established specifically for the delicate audio equipment. This may involve a separate grounding rod (a copper rod driven deep into the earth, thus creating a ground “reference” for all the equipment). All audio equipment grounds are tied to this, which when done properly can help prevent ground loops and all but eliminate noise from entering equipment over its electrical cables.

AC POWER SYSTEMS

4.5 A <u>BEST</u> AC Power System ("Technical" Ground)

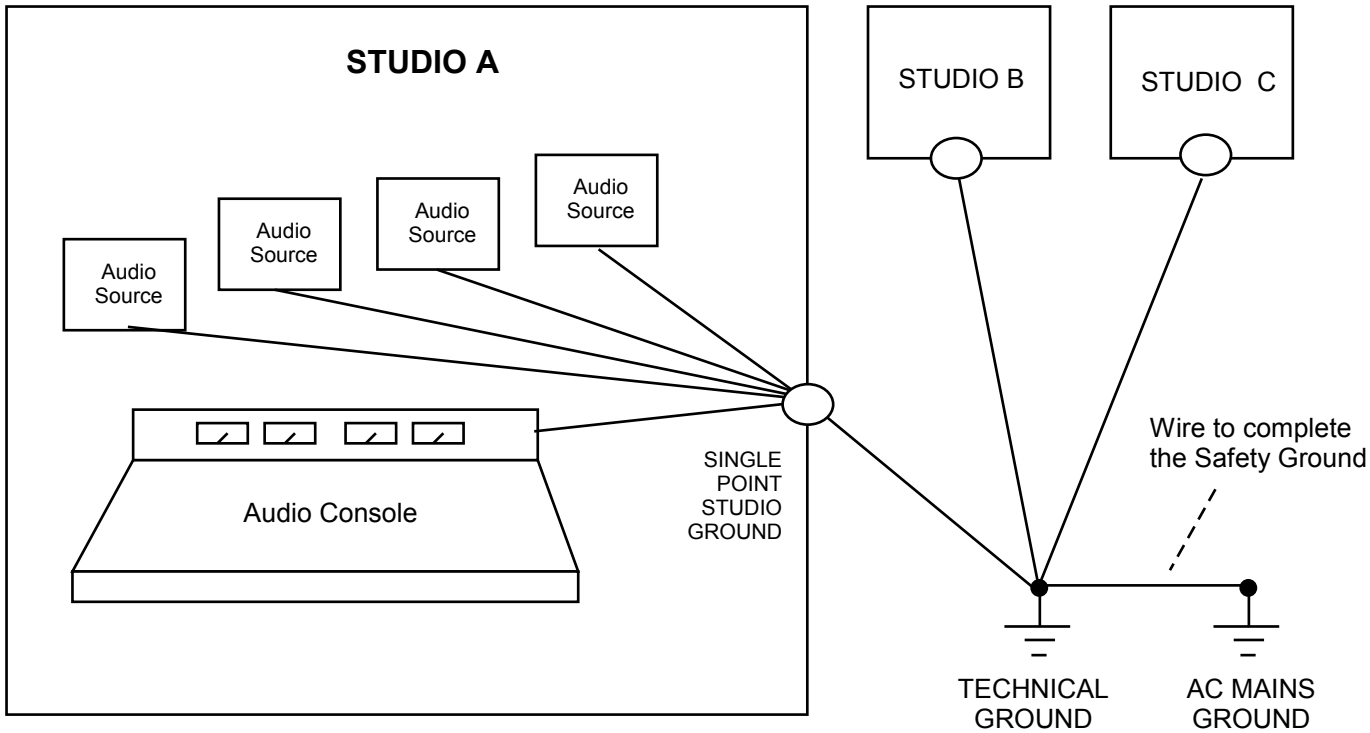
In the best possible circumstance, a "Technical" ground system is built entirely separate from the AC ground system. The standard 3rd wire AC safety ground, which returns to the AC main breaker box and then AC earth ground, is not connected to any audio equipment. Instead, a ground wire is taken from each piece of equipment to a central ground in each studio. This creates a "star" ground for each studio. The central ground of each studio is then taken individually to a central "technical" ground for the facility. This forms a "star of stars" ground. The central technical ground is an earth ground separate from the AC earth ground. The technical earth ground should be connected to the AC earth ground with a ground cable so that the technical ground system will also function as the 3rd wire safety ground. A properly built technical ground system has no AC currents and no AC noise.

A technical ground system is not NEC approved and requires special approval from your local building inspector.

<u>ISOLATED AC FOR AUDIO EQUIPMENT IS STILL REQUIRED</u>

Use of a technical ground system does not remove the need for an AC feed for the technical equipment that is separate from all other AC feeds. In the best circumstance, the technical equipment would be powered from an AC isolation transformer located in each studio. If this can not be done, the next best choice is to be certain that the audio equipment receives its AC from its own AC branch and that no equipment is on that branch except for the audio equipment.

NOTE- the ground cables from each studio are typically 2" or 4" copper ground strap.



5.0 Facility AC & Ground

The discussions about Ground and AC power systems in the previous Sections describe general principles and provide basic examples for typical broadcast audio facilities.

Many facilities have unique site conditions such as being located in multistory buildings, being saturated with very high RF fields, having a poor earth ground, etc. Sometimes these types of site conditions require significant extra effort and cost. However, even in these situations, good quality audio can be achieved if the basic principles are followed.

As always when working with AC power systems, local electrical code, qualified electricians, and proper inspections must be followed.