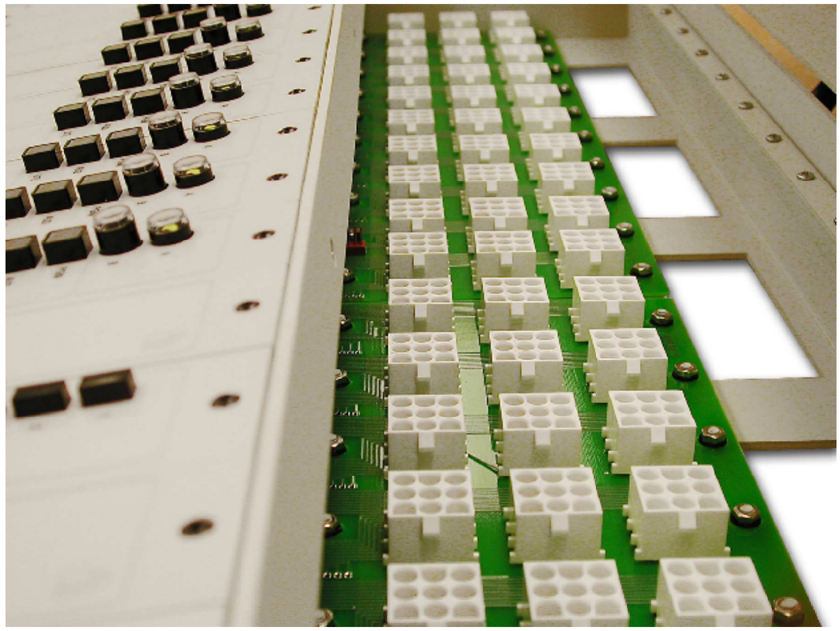
Ground loops & other problems

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

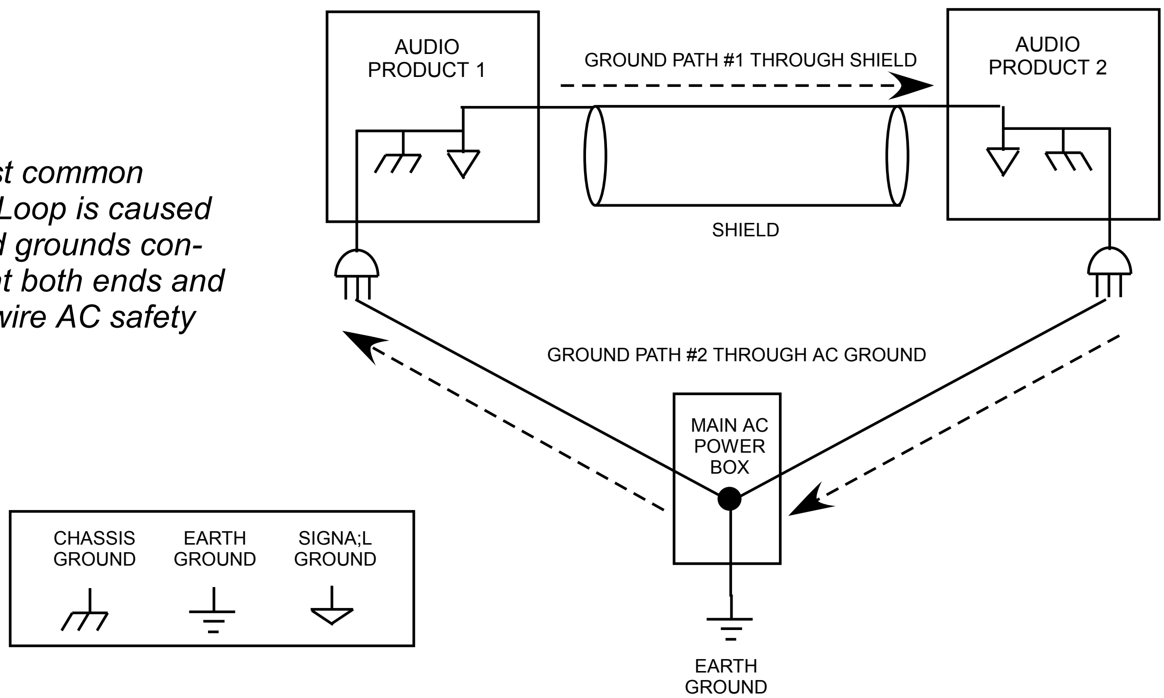
GROUND LOOPS

9.0 More on Ground Loops

a) A GROUND LOOP CAUSES 60 CYCLE HUM

A ground loop exists when there is more than one ground path between two pieces of electronic equipment. The two ground paths form a large loop antenna which picks up noise currents, particularly 60 cycle AC. The resistance in the ground paths converts these currents into fluctuating noise voltage differentials between the two pieces of equipment. If there is an audio signal connection between these two pieces of equipment then this noise is added to the signal voltage.

The most common Ground Loop is caused by shield grounds connected at both ends and the 3rd wire AC safety ground



b) REMOVE THE GROUND LOOP BY BREAKING THE LOOP (Full Ground Lift)

To stop the 60 cycle hum, one of the ground paths must be removed. The typical method to remove the second ground path is to have the shield grounded on one end only.

c) PARTIAL GROUND LIFT

Sometimes it is possible to insert a 50-100 ohm resistor between the shield and ground. This will allow the ground to remain connected for audio signal flow but increase the impedance to break the ground loop. This may reduce the problem but will not fix it.

d) EQUIPMENT WITH A GROUND LIFT SWITCH

In some equipment, the ground is part of the connector assembly and a switch is provided to disconnect the ground. If no switch is provided, then a standard cable may need to be modified or a custom cable built with modifications to the shield ground.

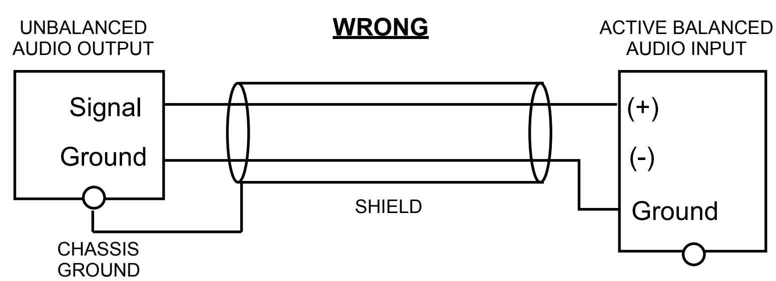
GROUND LOOPS

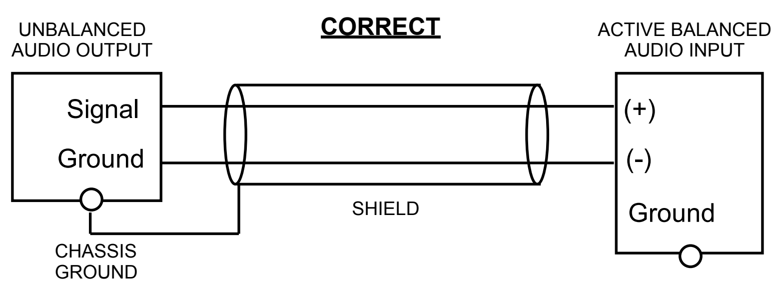
9.0 More on Ground Loops (continued)

e) DIGITAL AUDIO GROUND LOOPS
Some but not all S/PDIF and AES digital audio inputs and outputs have an isolation transformer in the circuit. If there isn't a transformer in the connection, then there will be a ground connection through the audio wiring and the possibility of a ground loop. Refer to Section 14 in this manual for more information on digital audio formats and circuits. A ground loop is broken in a digital circuit in the same way as in an analog circuit. One of the ground paths must be broken.

f) BREAKING A GROUND LOOP WITH AN AUDIO ISOLATION TRANSFORMER
In cases where the ground loop can not be broken due to a 3rd wire safety ground as the second part of the ground loop, an audio isolation transformer can be inserted into the audio signal line. This can be required in unbalanced audio connections with signal and ground. The use of transformers may not be desirable, but is sometimes the best solution.

g) BREAK A GROUND LOOP WITH A BALANCED INPUT
If a ground loop is being completed by the ground in an unbalanced device, it is possible to break the loop by taking the ground of the audio output into the balanced input of another device. If it is not possible to use a transformer to break a ground loop then a balanced distribution amp is a possible solution.





AC COUPLED CURRENTS

10.0 Interchassis AC Currents

AC power transformers have a coupling capacitance from the primary to secondary coils (Cc). Because the capacitances are unequal, an AC current is generated in the centertap of the transformer (chassis ground) that seeks to return to AC ground. The amount of current depends on the size and quality of the AC power transformer. Typical currents in audio equipment range from 5-1000 microamps.

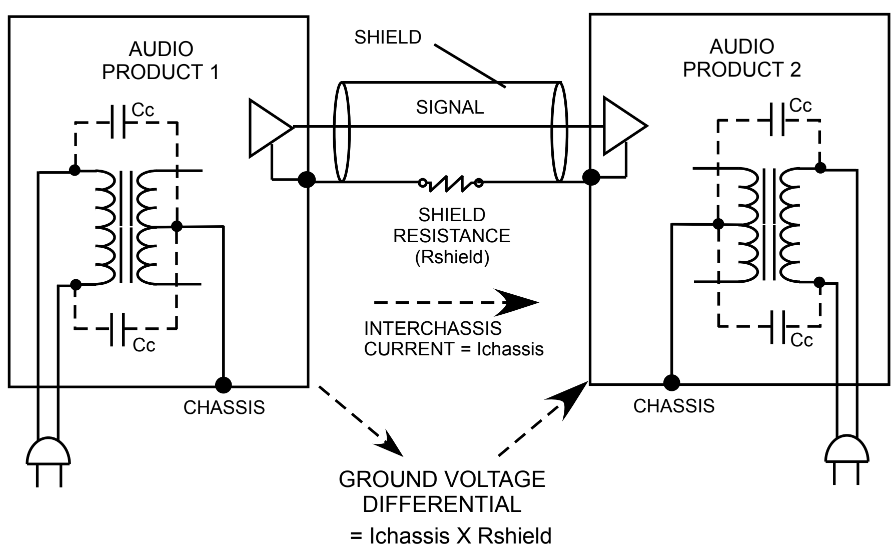
When the chassis grounds of two audio devices are connected together, the current from each device will seek AC ground through the other device. In the unbalanced system illustrated below, the current passes through the shield resistance. In unbalanced equipment, noise voltages on the ground can not be distinguished from signal and therefore appear as noise in the audio.

In a real world situation, a 10 ft shielded cable can have a 0.1 ohm shield resistance and 0.1 ohm contact resistance. This can create a voltage differential between the two devices of 0.001-0.2 millivolts. This produces a 60 cycle hum only 62-108 dB below -10dBu. In 100 feet of cable, this can be 42-88dB below -10dBu. Clearly, this can be very objectionable.

PRACTICAL SOLUTIONS

1) Reduce Cable Ground Resistance- use high quality audio cable with low shield and contact resistance.
2) Connect the Two Devices together with a Low Resistance Ground Wire- this works if the equipment has a chassis screw that is connected to ground. Use the screw on each piece of equipment to connect the wire to.
3) Reverse the AC Plug in the AC socket- one direction will be lower noise than the other because the phase of the AC current in the product will change.
4) Use an Audio Transformer to Break the Ground Path- insert an audio transformer in the audio path to break the signal and ground connection between the two products.

UNBALANCED AUDIO EQUIPMENT



TYPICAL INTERCHASSIS CURRENTS

EQUIP	AC PWR	CHASSIS CURRENT
CD players	<20W	~5 microamps RMS
Power Amps	20-100W	~100 microamps RMS
High Power	>>100W	~1000 microamps RMS

RF INTERFERENCE

11.0 RF Interference

a) RF SHIELDING IS CRITICAL

Most modern audio equipment is very high performance and has little or no RF filtering. This is because the filtering would limit frequency response and common mode rejection. As a result, most modern audio equipment depends on proper ground and AC power design to reduce RF interference. Therefore, RF Interference is most often caused and cured by the grounding system in the facility. If shielding and grounding are done well, then the RF is drained away from the electronics and there is no RF interference.

b) TYPES OF RF INTERFERENCE

Most RF interference is due to a radio transmitter being on site. AM interference is more common than FM interference.

The AM band is low frequency (~1MHz) and amplitude modulated. AM frequencies are too close to the audio band to be filtered and require shielding, ground, or transformer solutions to reduce interference.

The FM band is very high frequency (~100MHz) and frequency modulated. Filtering is possible but is not very practical and shield, ground, or transformer solutions remain the best approaches to removing interference.

c) CONSOLE GROUND

The console metal chassis is generally the main console ground. It should be connected to the main studio ground by a large copper ground. If floating, the console audio ground should in most cases also be taken to the console chassis ground.

d) AUDIO CABLE SHIELDING

The drain wire from the cable shields should be taken to the console chassis ground, not through the console audio ground to the chassis ground. In the best case, the drain wires go directly to the chassis ground and do not connect to the console input or output connectors at all.

e) MIC BOOM

Some large metal objects in a studio can re-radiate RF energy in a studio. The mic boom is a frequent cause of this problem. The boom itself (not the mount), should be grounded to the main studio ground to drain RF energy off the boom.

f) MAIN STATION GROUND

In high RF fields with transmitters on site, the transmitter ground will have a large amounts of RF on the ground systems itself. In these cases, a separate “Technical Ground” system may be required.

Section 12

LONG AUDIO CABLE RUNS

12.0 Long Audio Interconnections

“At what length does my audio cable become a limiting factor in the performance of my studio?” This is an important question in broadcast facility design. This is a complex topic relating to the output impedance of the source amplifier, the terminating load resistance, the desired maximum signal level, the desired audio bandwidth, and the capacitance of the shielded cable.

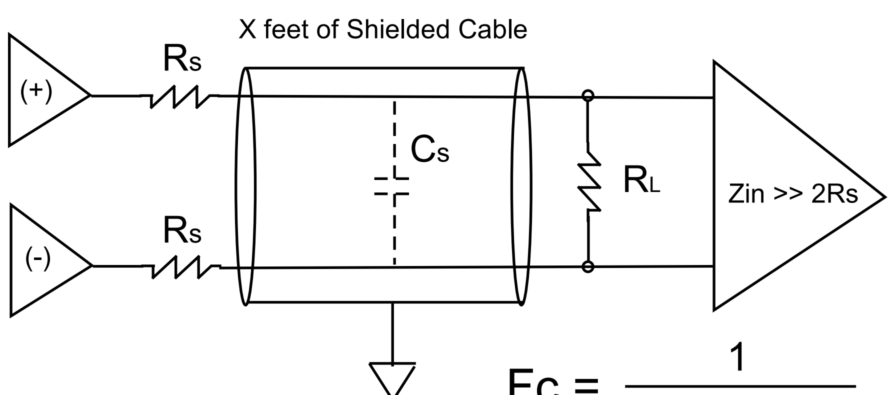
The basic circuit below illustrates that the issue can be modeled as a low pass filter. This model helps to understand the tradeoffs that effect long cable audio systems.

The telephone industry set the early standards for long distance analog audio systems. In the telephone industry, cables lengths are often many miles and therefore form wave guides requiring equalization and proper terminations. Because 1/10th the wavelength of a 20kHz frequency is over 3,000 feet, an audio cable under 3000 feet need not be considered to be a wave guide requiring matching impedance or equalization. At cable lengths under 3,000 feet it is desirable for the load resistance (RL) be very high (>> Rs) so as to not reduce the signal. Also, it is desirable for the source impedance (Rs) to be low (< 100 ohms) to not reduce the signal as well as to increase the high frequency response. This use of low source impedance and high load impedance is contrary to the 600 ohm source and 600 ohm matching load impedance traditional in broadcasting. However, the replacement of audio transformers with active balanced circuits over the last 20 years has changed the design rules for long audio cable interconnection.

REAL WORLD ESTIMATES

Most broadcast quality audio products use a minimum of an NE5532 op amp as an output driver. It can be demonstrated that an NE5532 can drive a maximum +26dBu into ~30pF/ft cable for over 300 feet while maintaining full bandwidth, large signal response. Cable capacitance is the limiting factor, so use of low capacitance cable can extend that cable length to over 1500 feet. This assumes a low output impedance from the output stage (< 100 ohms) and high input impedance at the destination circuit (>= 10,000 ohms). If these rules are followed, most broadcast facilities have cable runs significantly less than 300 feet and need not give serious consideration to this issue. If there is a concern about cable lengths longer than 300 feet, then low capacitance shielded cable is one easy answer.

LONG CABLE RUN LOW PASS FILTER



$$F_c = \frac{1}{2\pi (2R_s) C_s}$$

(assume RL >> 2Rs)

Shielded Cable

(1) Standard	~30pF/ft
(2) Medium	~12pF/ft
(3) Hi Quality	~6pF/ft