AES bijeenkomst
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heynen

ANALOG SIGNAL CONNECTION
In The Real World

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We live in a World full of:

- Stray electric fields
- Stray magnetic fields
- “Stray” (and imperfect) human beings

Electric Fields...

- Fluorescent lights, computer monitors, ac mains, sources of high-voltage, RFI, etc.
- Electric fields capacitively couple into any unshielded conductor with a non-zero impedance
  - *Usually high pass filter characteristic*
- Shielding can give near perfect results
  - *Thank Mr. Faraday!*
  - *Separation is also a very effective measure, especially when implemented above a conductive ground plane*

Magnetic Fields...

- Power transformers, CRT deflection yokes, cooling fans, filter capacitor charging currents
- All varying magnetic fields induce electrical potentials within nearby conductive loops
  - *Induced voltage is proportional to the derivative of magnetic field strength*
  - *Induced voltage also proportional to the susceptible circuit's loop area*
- Shielding is less than perfect--depends highly upon the material's nature and thickness

Human Beings...

- Human nature is highly non-linear, and definitely reluctant to let previously bad decisions die
  - *Examples: the RCA phono plug, XLR pin 1*
- In the Bible it is written that the sins of the fathers are visited unto the 3rd and 4th generations…
  - *In other words, we must live with design practices and standards based upon bad technical decisions that are sometimes many decades old*
- NO amount of shielding seems to be effective!

Analog Signal Connections

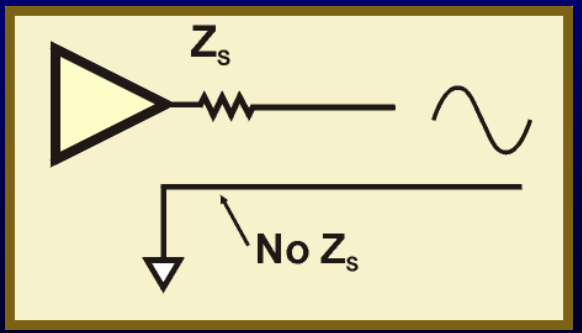
- There are only two basic types of analog signal connection:

- Unbalanced
  - *usually associated with consumer audio or very low impedance applications (power amp outputs)*

- Balanced
  - *usually associated with Pro-Audio and Broadcast*

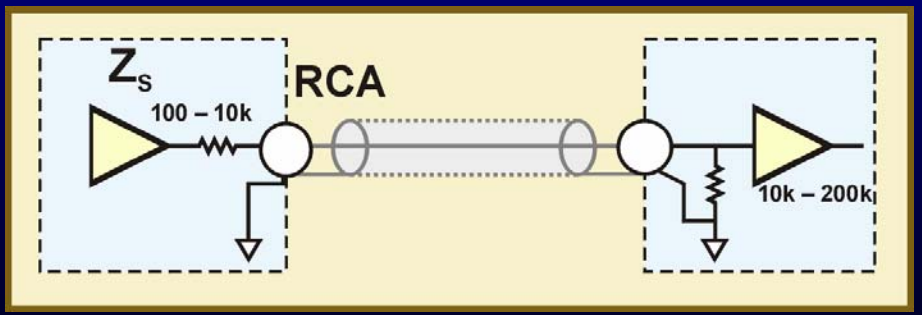
The Unbalanced Connection

- The signal is carried on one line and referenced to the ground line or chassis connection
- Only the signal line has a specified source impedance
  - *The reason it is called "unbalanced"*



Typical Unbalanced Circuit

- Signal is referenced to “ground” as it is perceived by the local output and input circuits
  - *However there is usually ground potential differences between the output and input circuits (V_{crap})*



Ground Potential Differences Are Often >1 mV

- With a 1 V audio signal and 1 mV of V_{crap} the typical S/N ratio of an unbalanced connection is only 60 dB
  - *300-1000 V signal levels would be needed to achieve a S/N equal to the dynamic range of today's converters!*

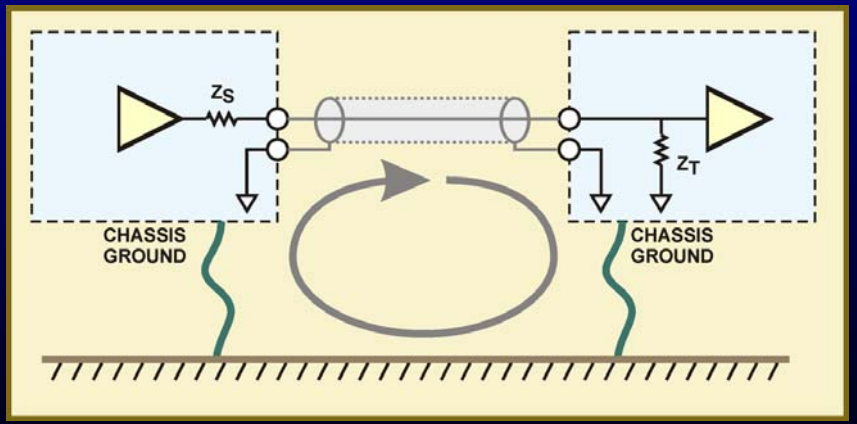
- There are two significant sources of ground potential differences

Leakage Currents into Ground

- Leakage currents from AC Mains or other sources can cause residual voltage potentials between the chassis grounds of difference pieces of equipment
- Usually results from the capacitance between the AC mains circuit and ground
  - *inter-winding capacitance of power transformers*
  - *stray capacitance*
  - *intentional capacitance (EMI filters)*

The Ground Loop Problem

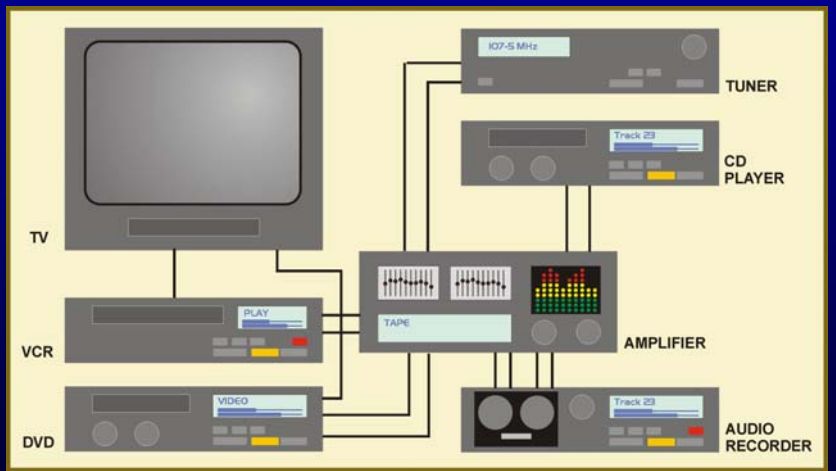
- If a ground loop exists, stray magnetic fields will induce unwanted potentials in series with the ground connection between any two pieces of equipment
  - *loop usually consists of the shields of interconnecting cables and/or the earth safety grounding*



The Simple Stereo Connection of Two Unbalanced Cables Inherently Creates a Ground Loop

- How the stereo cables are dressed significantly affects the loop area
- Twisting stereo cables greatly reduces hum and interference effects from stray magnetic fields
  - *Besides minimizing loop area, it also causes alternating loop polarities*

A Typical Setup has Many Loops

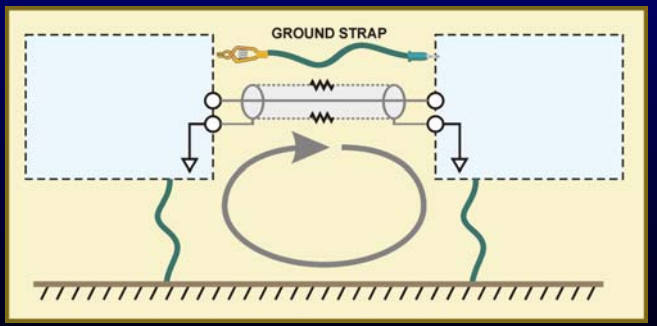


Basic Ways to Minimize Problems with Unbalanced Connections

- Minimize the ground potential differences in the first place
- Minimize the sensitivity of the circuit to ground potential differences

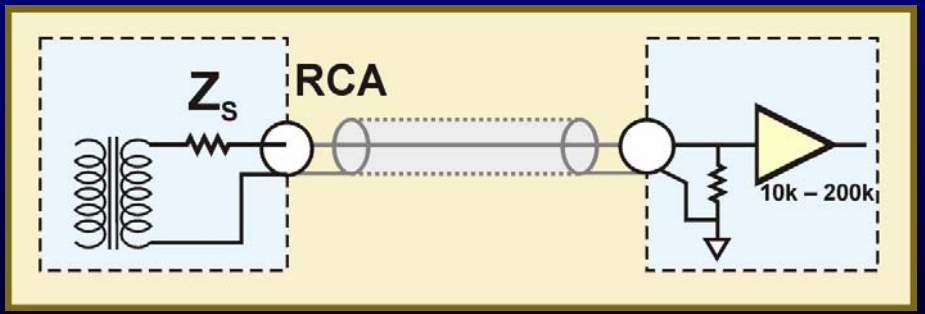
"Brute Force" Grounding

- Idea is to create a much lower impedance connection so any potential differences caused by leakage currents will be carried by a large, multi-strand cable
  - *think of the circuit as a current divider*
  - *may increase magnetic induction problems due to creation of a new loop (watch location of the strap versus the signal cables!)*



Floating Unbalanced Source

- Requires a transformer or complex output stage design
  - *uncommon in consumer gear*
- Removes the ground loop possibility, but signal is still susceptible to other common mode influences

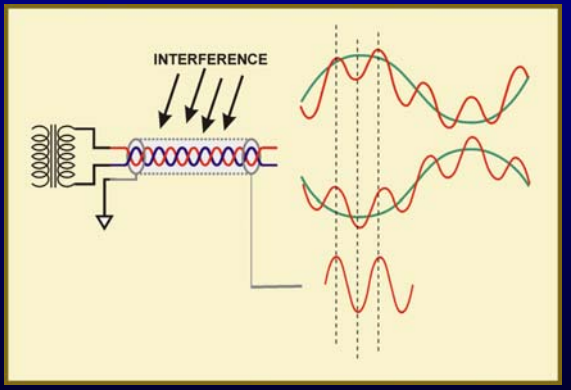


Quasi-Floating Input Design

- If the input unbalanced connector can be isolated from ground, differential input design can give big improvements
  - *Generally need HF bypass capacitor to prevent EMI susceptibility problems (typ 10-100 nF)*
  - *Also need some DC shunting resistance if source is truly floating (typ 10-500 Ohms)*
  - *Used in Audio Precision analyzers*
- Quasi-floating outputs are also possible

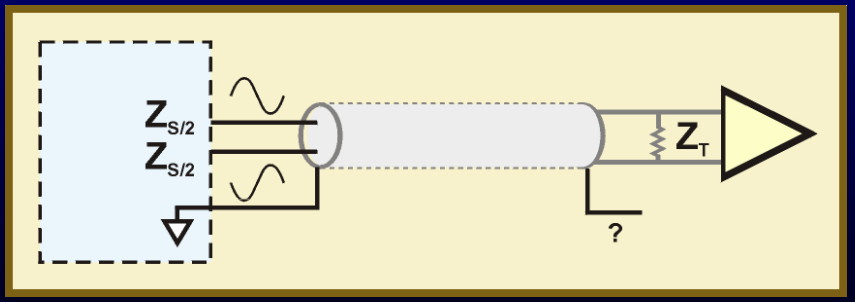
The Balanced Connection

- The signal is transmitted using two signal lines having equal source impedance (Z_S).
  - *Voltage symmetry is NOT a requirement!*
- The signal path does NOT include ground
- Ground loops involving cable shield do not affect the differential signal (in theory)



Typical Balanced Circuit

- Gives best possible immunity to ground potential differences provided both source impedance and input impedance are well balanced
  - *Cable construction is also a factor*

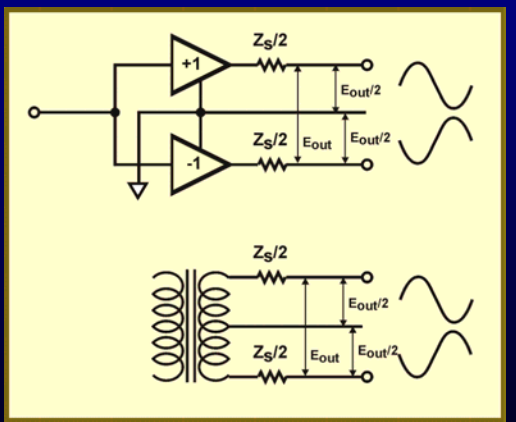


Balancing Offers Vastly Improved Rejection of Ground Potentials

- Typical component tolerances give 40-50 dB CMRR without circuit trimming or matching
  - *Capacitive balancing is usually more difficult to achieve resulting in some loss of S/N performance above 2-10 kHz*
- 60 dB S/N with an Unbalanced connection can easily improve to 100-110 dB S/N with a Balanced circuit having the same signal amplitude

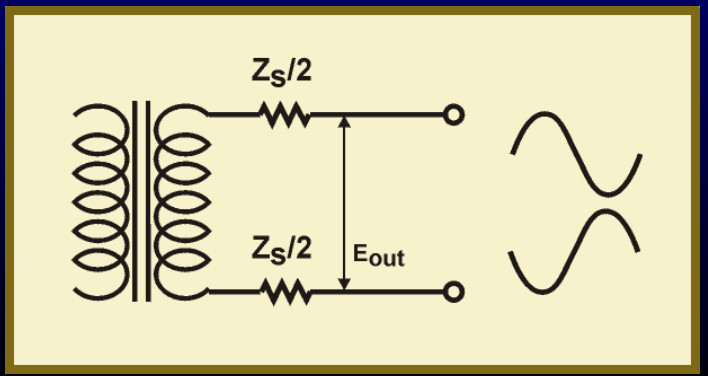
The Grounded Balanced Source

- Examples
  - *Active balanced driver*
  - *Transformer with grounded center-tap*
- Symmetrical or equal output voltages
- Ground loop in signal path is not possible
  - *But the cable shield can be part of other loops*



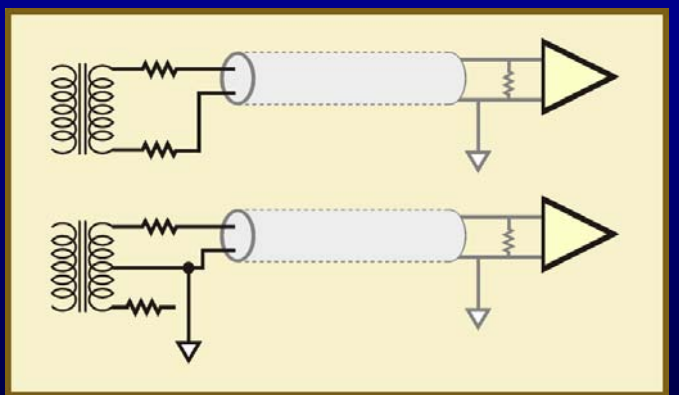
The Floating Balanced Circuit

- No explicit ground reference--*but it's still there!*
- Common mode capacitance is usually present
- Output voltage symmetry not assured
  - *measuring one side to ground gives spurious readings*
- Ground loop in the signal path is not possible
  - *but the cable shield can be part of another ground loop*



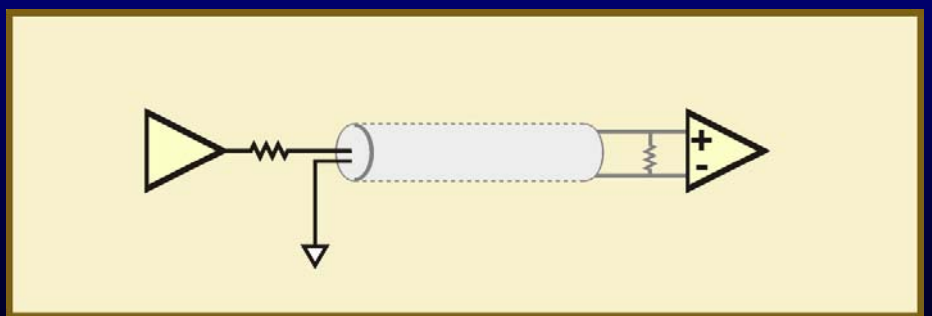
Interfacing Balanced Outputs to Unbalanced Inputs

- No problem with truly floating sources
- Try using only 1/2 of the output with grounded or ground referenced sources



Interfacing Unbalanced Outputs to Balanced Inputs

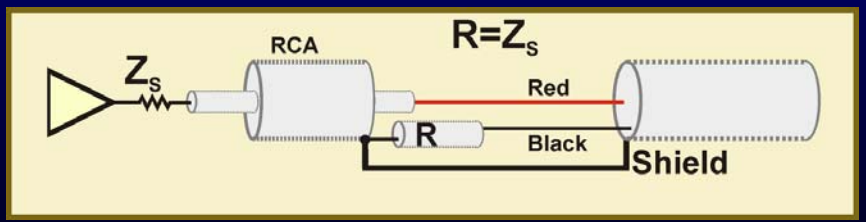
- Not a serious problem as long as the cable is balanced and the input impedance greatly exceeds the source impedance
  - *Cable capacitance imbalance will cause problems*



Tip for Connecting an Unbalanced Output to a Balanced Input

- Add a resistor equal to the source impedance in the ground segment of the unbalanced output to create a balanced output

- Voltage symmetry is <u>not</u> a requirement of balancing!

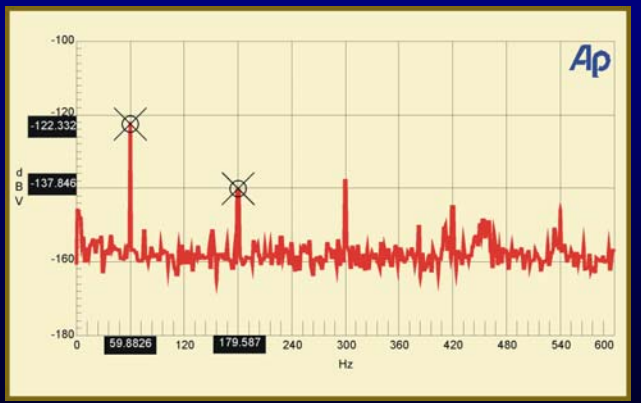


Testing for connection problems:

- Analyze noise spectrum
  - *requires a high dynamic-range FFT analyzer*
- Try a "Brute Force Ground"
  - *use an additional, separate, better ground connection*
- Use the 400 Hz High-Pass filter as a quick check of improvement
  - *compare noise readings with and without filter*

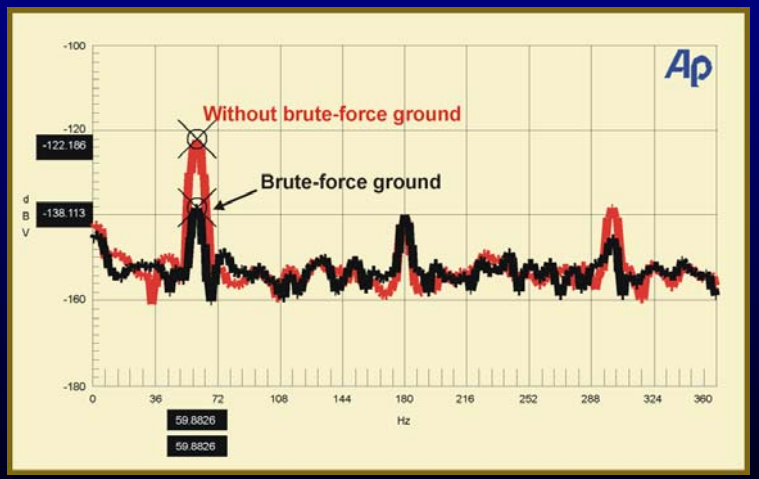
Noise Spectrum Analysis

- Will almost always show some AC mains frequency
- 2nd harmonic (100/120) can indicate full-wave or bridge rectifier filter inadequacy
- 3rd harmonic (150/180) caused by magnetic fields of power transformers
- Higher frequency noise and spurious spikes can be created by motors and lamp dimmers



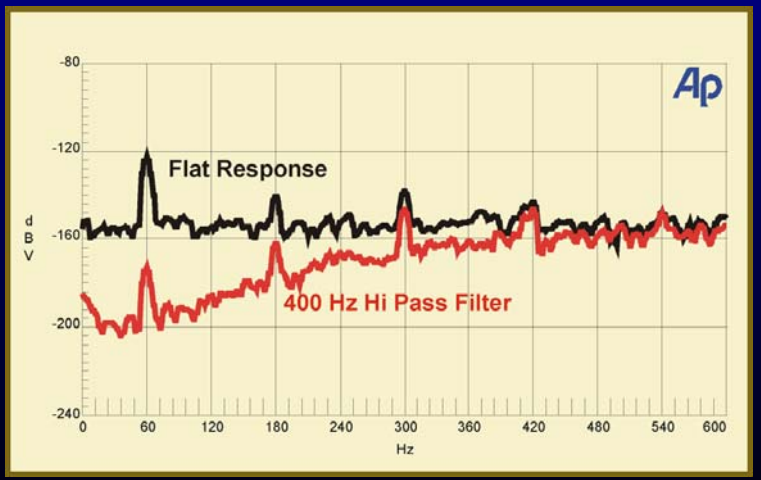
Brute Force Ground

- Provide a very low resistance ground connection between the devices and see if the problem is reduced.
  - *use #12 or #10 with many strands*



THD+N or Noise vs. Hi-Pass Filter

- Compare Noise or THD+N readings in absolute units (V, dBu, dBV, etc.) with and without 400 Hz high-pass filter
  - *An improvement of more than about 0.4 dB is usually an indication of significant hum (AC mains related products)*



The XLR Pin 1 Problem

- NEVER connect Pin 1 to the signal circuit ground or circuit board ground plane
- ALWAYS connect Pin 1 directly to chassis ground at both ends of cable
  - *use the lowest possible resistance and inductance*
  - *leaving Pin 1 floating at either end of the cable invites serious EMI problems*

Summary

- High quality analog signal connection requires:
  - *(1) understanding of basic electronic principals*
  - *(2) careful attention to detail*
- High quality analog signal connection does not happen by chance!

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