



Audio Engineering Society
Conventions and Conferences

Atlanta Section - 27 September 2010

Selected Topics on Grounding and Interfacing in Audio-Video Systems

by

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Jensen Transformers, Inc.

Life Fellow, Audio Engineering Society
Life Senior, Institute of Electrical & Electronic Engineers



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About the Presenter

Bill has designed pro audio electronics since 1972 and was head of electronic development for Capitol Records from 1981 to 1988 prior to joining Jensen Transformers.

His landmark paper on balanced interfaces appeared in the June 1995 AES Journal, the best selling issue ever printed. Other writing includes three chapters for the Glen Ballou's "Handbook for Sound Engineers," numerous magazine articles and columns, and Jensen application notes. Since 1994, his seminars have taught tens of thousands at industry trade shows, universities (including MIT in 2007), and professional society meetings. He's active in AES standards and was a major contributor to AES48. In 2009, he was voted NSCA's Technical Instructor of the Year.

His patents include the InGenius® balanced input IC and the ExactPower® waveform-correcting AC voltage regulator.

The Physics Police Rule!

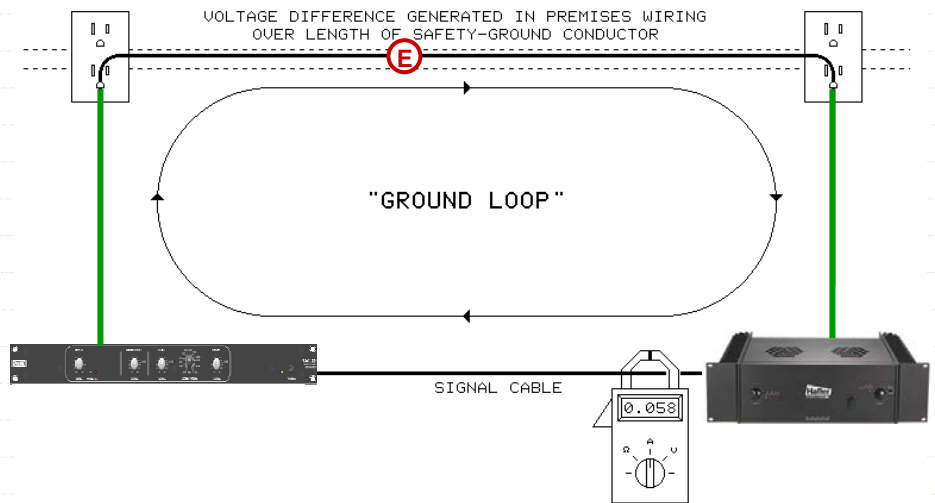


Courtesy of Coilcraft

What is "Ground?"

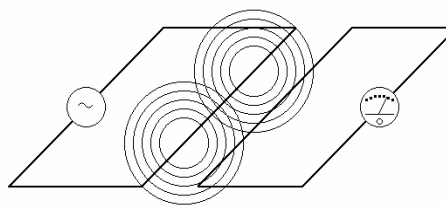
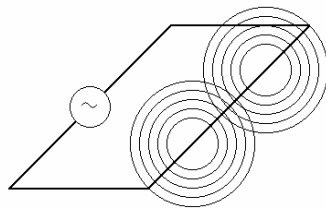
- **Utility Power:** an electrical connection to **SOIL**
- **Electronics:** a common return path for various circuits, *whether or not connected to soil*
 - **A "equi-potential" FANTASY invented by engineers to simplify their work**
 - A "ground" circuit most often serves, either intentionally or accidentally, more than one purpose
- Meaning of "ground" has become vague, ambiguous, and often quite fanciful

Pictorial of a "Ground Loop"



But what creates voltage E ...

Magnetic Fields & Coupling

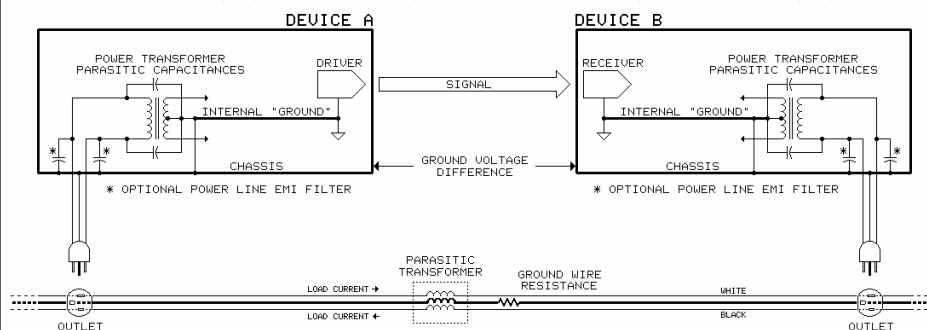


Faraday's Law at work!

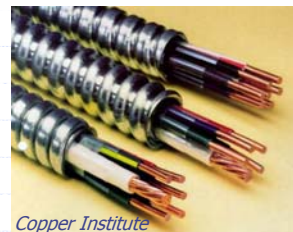
The "Conduit Transformer"

- Load current in line and neutral produces opposing magnetic fields
- Imperfect cancellation **magnetically induces** voltage over length of safety ground conductor
 - **Highest voltages with random wires in conduit**
 - Lower voltages with uniform geometry of Romex®
- 1 volt difference between outlets not unusual
- **Voltage is proportional to circuit load current**
- Mechanism favors harmonics of 60 Hz
 - Induced voltage proportional to $\Delta i/\Delta t$

The "Conduit Transformer"

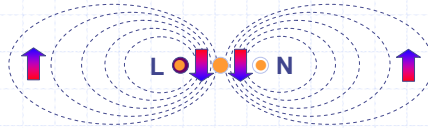


UNCONTROLLED GEOMETRY OF THIS WIRING CAN INDUCE SIGNIFICANT VOLTAGE DIFFERENCES BETWEEN OUTLET SAFETY GROUNDS!



Magnetic Fields in Romex[®]

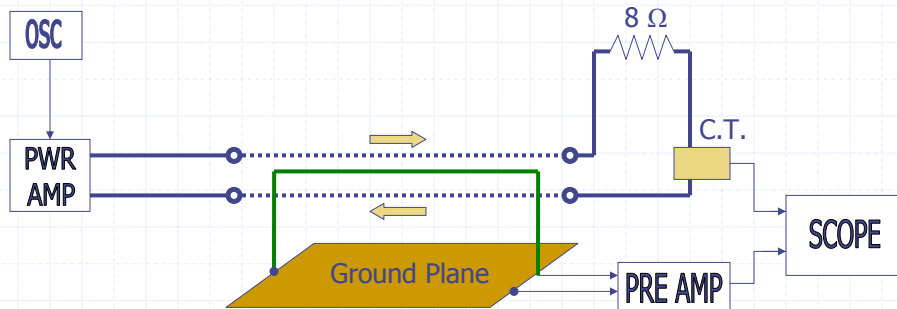
Current in L and N are equal but opposite directions



Safety Ground "Sees"
Zero Magnetic Field at
Exact Midpoint

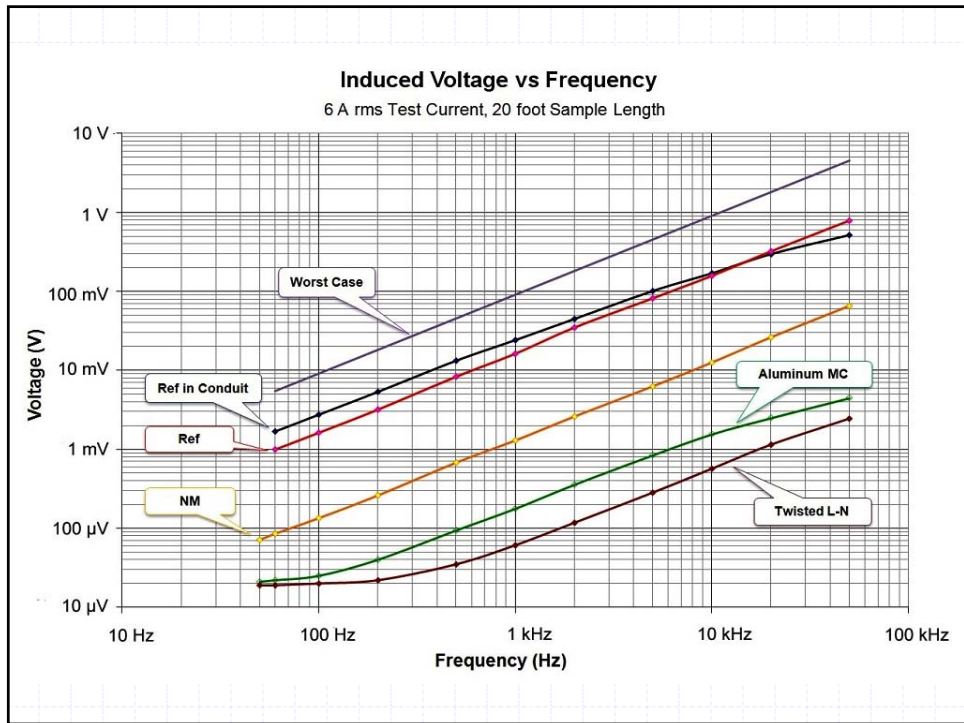
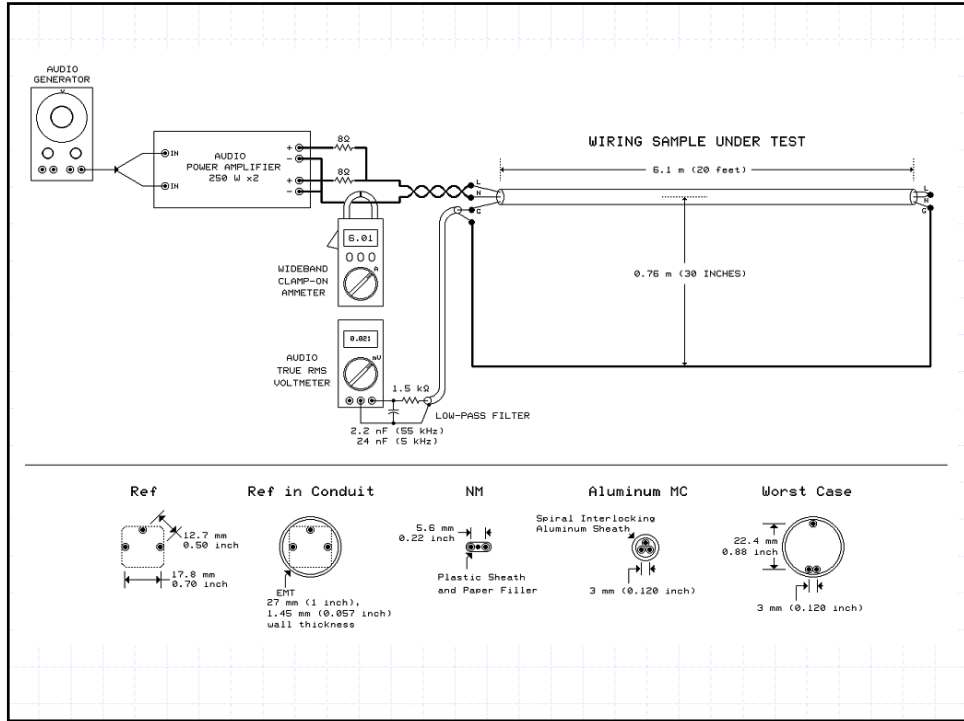
(cross-section view)

Instantaneous L and N currents are
flowing into page and out of page



PARASITIC TRANSFORMER DEMONSTRATION

(Syn-Aud-Con 2007)



It's Not Just 60 Hz

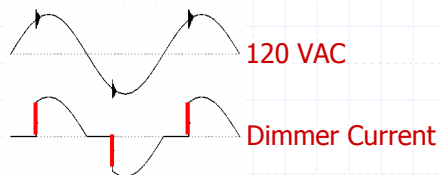
- Many power-line loads, especially electronics, draw current non-uniformly during each cycle
- 120 VAC distortion typically 2% to 6% THD
- High harmonics caused by abrupt current step
- **Leakage current** and **conduit transformer** each favor high frequencies (+20 dB per decade)

High-Frequency Noise Sources

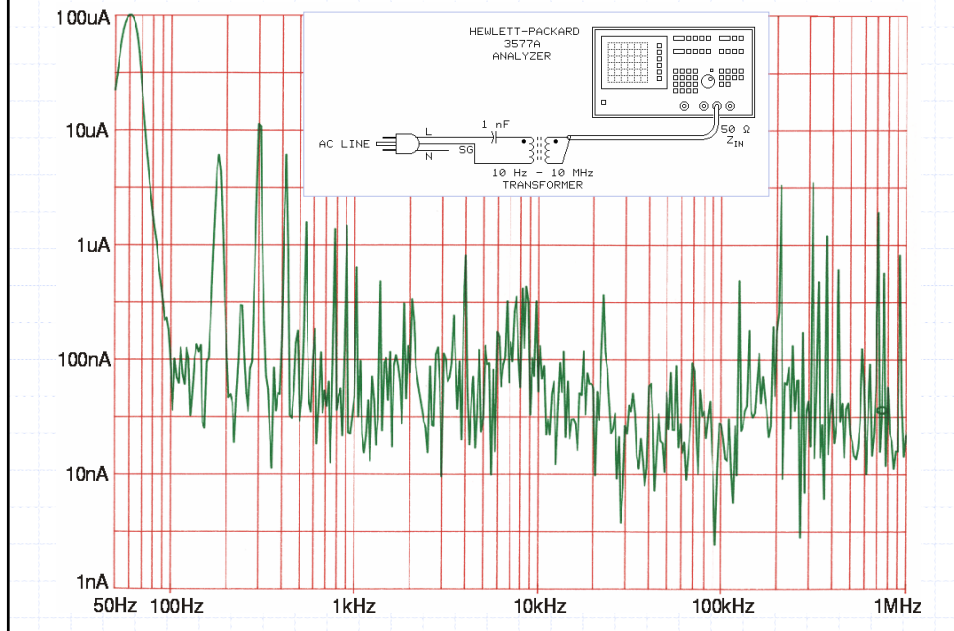
- **Light dimmers** →

- Risetime $\approx 5 \mu\text{s}$

- Fluorescent lamps
- Electronic power supplies
- Arcing of switches, relays, or motors
- Power-line insulator corona discharge
- AM radio (power lines are huge antenna)



Typical Leakage Current Spectrum



The Facts Of Life



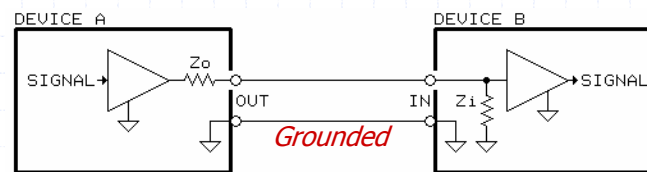
- Harmless voltage differences will **always** exist between grounds of properly wired outlets
- Harmless leakage currents will **always** flow in signal cables connected to equipment with 2-prong plugs
- Problems arise only at vulnerable points in our systems!



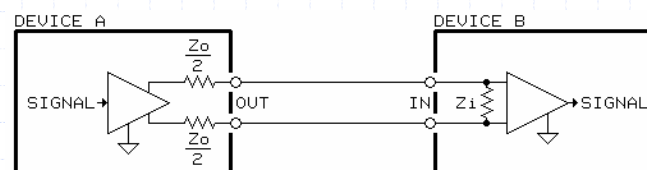
Unbalanced vs Balanced Interfaces

- An *interface* consists of a line **driver** (device output), the **line** or cable, and a line **receiver** (device input)
- **Two** conductors are always required to complete a signal (or any) current path
- Status depends **ONLY** on the **impedances** (to ground) of the two signal conductors
- In **unbalanced** interfaces, one impedance is zero (grounded) and the other is higher
- In balanced interfaces, both have nominally **equal** (and non-zero) impedances
- Requires that driver, line, and receiver each maintain nominally equal impedances to ground

Unbalanced vs Balanced Interfaces



Unbalanced



Balanced

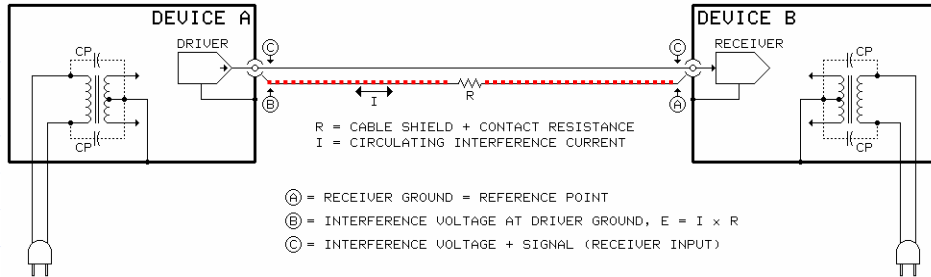
The Unbalanced Interface

- **Extremely susceptible to noise coupling**
- After 50 years, consumer audio still uses it, in spite of ever-increasing dynamic range needs
- Virtually all **video** interfaces are unbalanced
 - Power line coupling results in classic "hum bar"
- The RS-232 **digital** interface is unbalanced
 - Symptoms usually called "unexplainable"

Big Problem with Unbalanced

- When two devices are connected, ground loop current will flow in signal cable
- Virtually all flows in the grounded conductor, typically the shield of audio/video cables
- Its resistance creates a small **noise voltage** drop over the length of the cable
- Noise is **directly added to signal** seen by receiver (the interface is a series circuit)

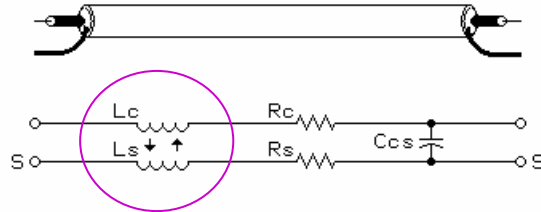
Common-Impedance Coupling



Two currents (power-line and audio) flow in the same impedance, which allows them to couple!

Signal received (C to A) consists of signal sent (B to C) from device B **plus** ground-loop noise (A to B)

LP Model of Coaxial Cable



Magnetic Coupling

100% for Coaxial

(60-70% for Unshielded Twisted-Pair)

"LP" = lumped parameter

Cable Physics from Another Universe?

- Double-blind tests prove that when audible differences among cables actually exist, they're entirely explainable
- Marketing often hypes transmission line theory as critically important
- Real physics confirms that audio cables only begin to exhibit subtle transmission line effects at **4,000 feet**



Audio, especially the "high-end," abounds with pseudo-science, anti-science, and mysticism

My Take On Exotic

- **Exotic cables, even if double shielded, made of 100% pure un-obtainium, and hand woven by virgins, have no significant effect on hum and buzz!**
- Truly high-performance unbalanced audio cables combine very low shield resistance, low capacitance, and reliable connectors
 - I like Belden 8241F (they call it video cable)
 - Very low resistance shield, low capacitance, very flexible, and available in lots of pretty colors!



THE BALANCED INTERFACE

- Highly immune to noise coupling – the **only** technique used in phone systems to this day
- **Its true nature is widely misunderstood:**

“Each conductor is always equal in voltage but opposite in polarity to the other. The circuit that receives this signal in the mixer is called a differential amplifier and this opposing polarity of the conductors is essential for its operation.”

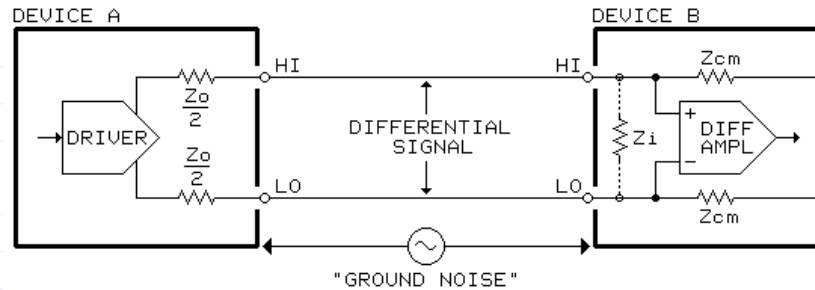
Like others in print, this explanation is not only **WRONG, but fails to even mention the defining property of a balanced interface!**

Signal Symmetry ~~≠~~ Balance

“Only the **common-mode impedance** balance of the driver, line, and receiver play a role in noise or interference rejection. This noise or interference rejection property is independent of the presence of a desired differential signal. Therefore, it can make no difference whether the desired signal exists entirely on one line, as a greater voltage on one line than the other, or as equal voltages on both of them. Symmetry of the desired signal has advantages, but they concern headroom and crosstalk, not noise or interference rejection.”

*from "Informative Annex" of
IEC Standard 60268-3*

Balanced Interface Circuit



Signal is "differential-mode" or "normal-mode"
Ground voltage difference is "common-mode"

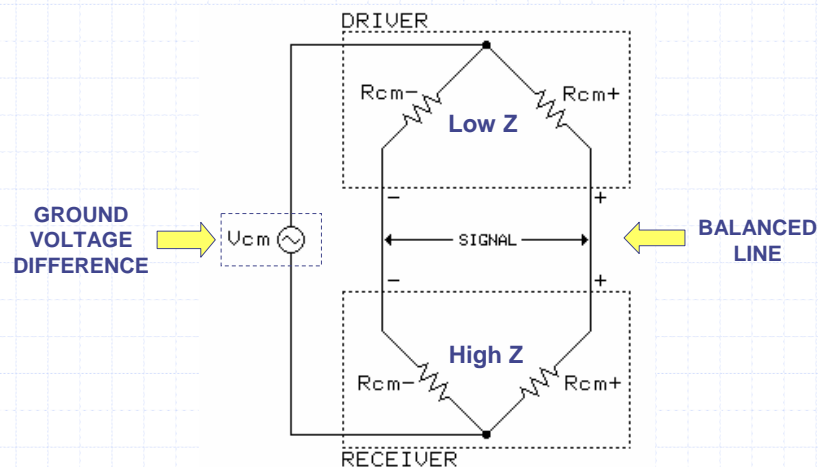
Common-Mode Rejection

- Ideal receiver responds only to difference voltage and has no response to common-mode
- Real-world receiver is "diff-amp" or transformer
 - Limited common-mode rejection
- Common-Mode Rejection Ratio or **CMRR** is the ratio, in dB, of **differential** to **common-mode** gain
 - Higher CMRR figures mean better rejection
- **CMRR is exquisitely sensitive to impedances at both the driver and receiver!**

A Wheatstone Bridge

- Common-mode impedances (to ground) of driver and receiver form a Wheatstone bridge
- If not *balanced*, a portion of the ground noise V_{cm} will be *converted* to differential signal
- Balance critically depends on ratio match of driver and receiver common-mode impedance pairs
 - Most sensitive to tolerances when all arms are same impedance
 - Least sensitive if upper and lower arm impedances widely differ
 - Standard practice is low Z at driver and high Z at receiver

Balanced Interface = Wheatstone Bridge



Poor Common Mode Rejection

- **The other common design defect that tarnishes the reputation of balanced interfaces**
- In theory, all external noise sources generate common-mode voltages at the balanced input
- Three sources of Common-Mode voltage:
 - **Voltage between grounds of driver and receiver**
 - Voltage induced in cable by **magnetic** field
 - Voltage induced in cable by **electric** field
- High CMRR was taken for granted before simple, and cheap, IC diff-amps appeared around 1970
 - Suddenly, all transformers became “ugly iron”
 - **Manufacturers never talked about, or likely even realized, how CMRR varied widely, depending on the signal source!**

CMRR: Marketing vs Reality

- Zo of **real** drivers typically set by $\pm 5\%$ series resistor and $\pm 20\%$ (or worse) series capacitor
 - Zo **imbalance** is typically about $10\ \Omega$ at 60 Hz
- Zcm of conventional “active balanced” receivers typically range from $10\ \text{k}\Omega$ to $50\ \text{k}\Omega$
 - Low Zcm means actual interface CMRR is easily degraded by normal, real-world driver Zo imbalances
 - **SSM-2141 CMRR drops 25 dB with only a $1\ \Omega$ imbalance**
- Zcm of good input transformer or the InGenius[®] IC is typically $10\ \text{M}\Omega$ to $50\ \text{M}\Omega$... 1,000 times higher
 - **Their CMRR unaffected by a $500\ \Omega$ imbalance!**

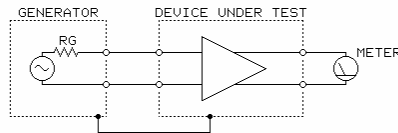
CMRR and Testing

- **Noise rejection in a real interface depends on how driver, cable, and receiver *interact***
- Traditional CMRR measurements **ignore** the effects of driver and cable impedances!
- Like most such tests, the previous IEC version “tweaked” driver impedances to **zero imbalance**
 - IEC recognized in 1999 that the results of this test did not correlate to performance in real systems ...
- My realistic method became “IEC Standard 60268-3, Sound System Equipment - Part 3: Amplifiers” in 2000
- **The latest generation Audio Precision analyzers, APx520/521/525/526, support this CMRR test!**

Audio Precision Model APx525

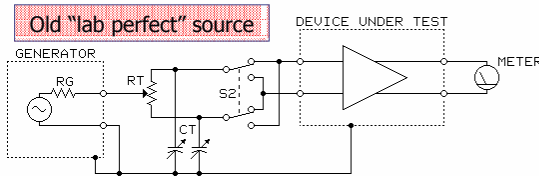


IEC CMRR Test – Old vs New



IEC Normal-Mode Test

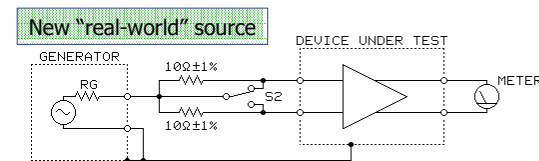
0 dB reference to which common-mode gain is compared



Old "lab perfect" source

IEC Common-Mode Test 1988 Ed 2

RT and CT are trimmed for same reading as S2 is toggled. This "perfect" reading is used to calculate CMRR.



New "real-world" source

IEC Common-Mode Test 2000 Ed 3

S2 is toggled and highest reading noted. This reading is used to calculate CMRR.

How Much CMRR is Necessary?

- Professional reference signal level is +4 dBu = 1.23 V
- A 1.23 V ground voltage difference (common-mode voltage) might exist in a hostile electrical environment
- In this case, signal-to-noise ratio = **Interface CMRR**
- Total dynamic range is SNR + "headroom"
- Assuming 20 dB of headroom (clip at +24 dBu):
 - 80 dB CMRR gives 100 dB dynamic range (comparable to CD)
 - 60 dB CMRR gives 80 dB dynamic range
- If ground voltage difference were a more benign 123 mV (20 dB less), we'd gain an extra 20 dB
 - 60 dB CMRR gives 100 dB dynamic range (comparable to CD)
- **50 dB is rarely adequate in most systems!**

An Example of Bad Design Advice!

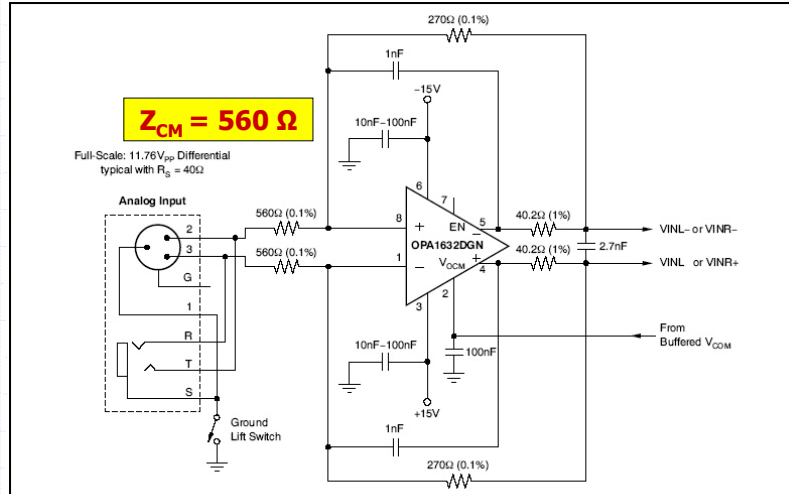
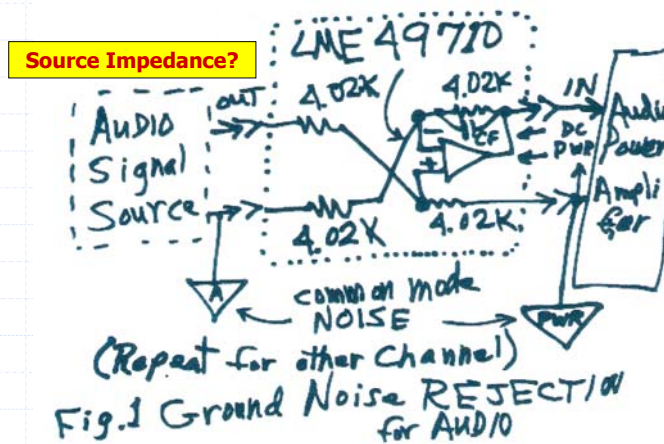


Figure 50. Differential Input Buffer Circuit Utilizing the OPA1632
Texas Instruments, PCM4222 Data Sheet, March 2007

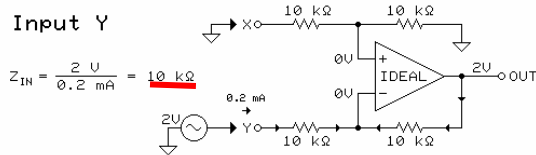
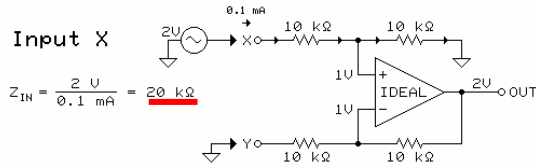
And Another ...



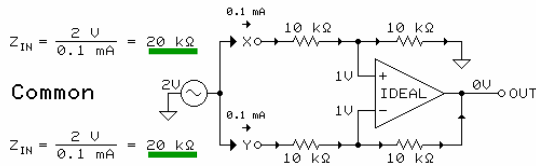
Bob Pease, "What's All This Noise Rejection Stuff, Anyhow?" Electronic Design, 1 Oct 2009

MYTH: The Diff-Amp Needs "Fixing"

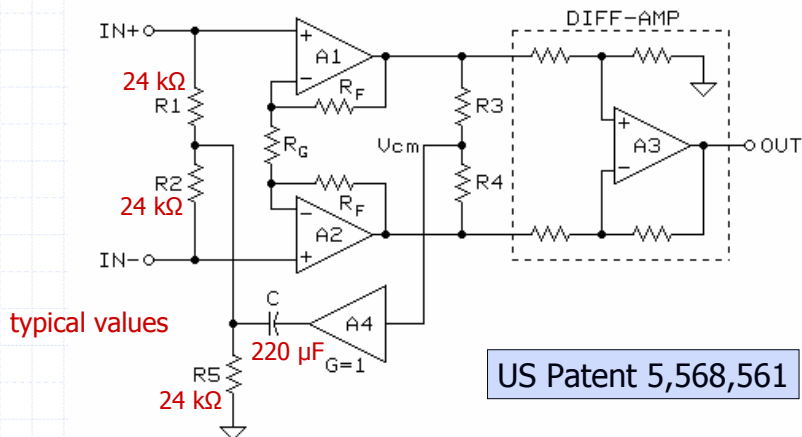
Driven separately,
input impedances
not equal ...
NO PROBLEM!



COMMON-MODE
input impedances
are equal ... **OK!**



Bootstrapping the Common-Mode



InGenius® IC

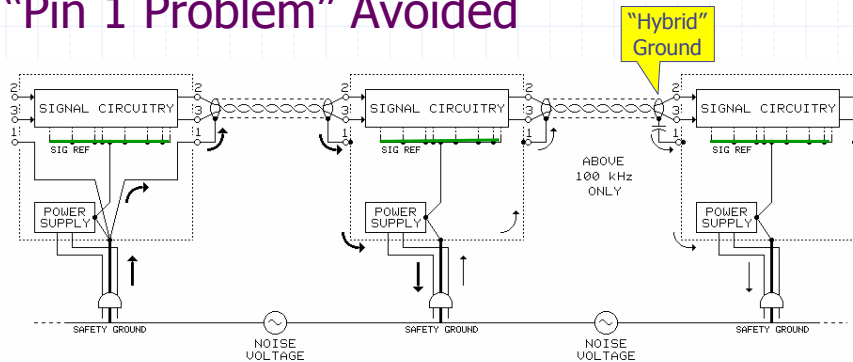


- R1, R2, and R5 necessary to supply amplifier bias currents (sources may have no dc path)
- CM voltage extracted by R3 and R4
- A4 buffers CM voltage and “bootstraps” R1 and R2 via external C, typically 220 μ F
- **Common-mode input impedances increased to 10 M Ω at 60 Hz and 3.2 M Ω at 20 kHz!**
- R_F and R_G covered by patent for high-gain applications like microphone preamps
- Allows bootstrapping of RFI suppression capacitors, too
- Matches SSM2141 footprint
- Cost in \$2 to \$3 range

Pin 1 Problems - “Designed-In” Defects

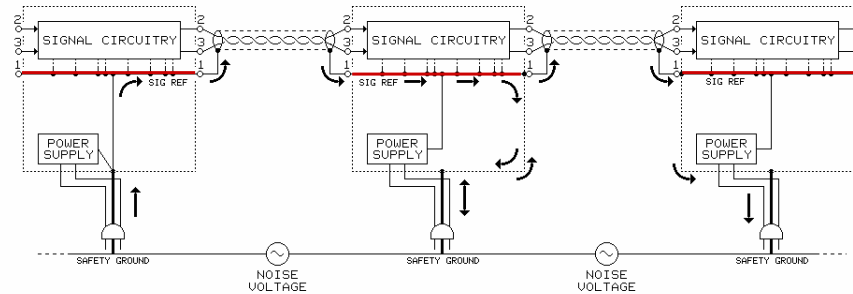
- **One of two common design defects that tarnish the reputation of balanced interfaces**
- Common-impedance coupling inside devices effectively makes the shield connection a low-Z audio input!
- Dubbed “the pin 1 problem” (XLR pin 1 = shield) by Neil Muncy in his 1994 AES paper
- The problem has been inadvertently designed into a surprising number of well-known products
- **Shield current (power-line noise) is allowed to flow in wires or PCB traces shared by amplifier circuitry**

"Pin 1 Problem" Avoided



Problem is avoided by making shield currents flow in paths NOT shared by signal circuitry inside equipment

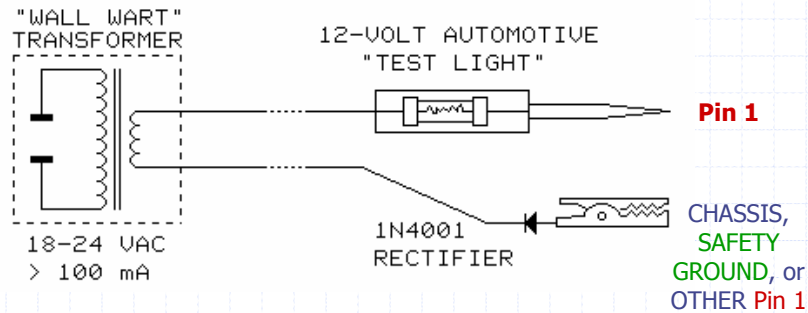
"Pin 1 Problem" Designed-In



Problem occurs when shield current flows in signal reference "ground" inside equipment

Note the power supply connections in devices 2 and 3. Power-line noise will couple to the signal path this way, giving the box a **"sensitive equipment"** reputation!

"Pin 1 Problem" Testing



"Hummer" forces about 50 mA of rectified 60 Hz through suspect shield connections

(concept by John Windt, June 1995 AES Journal)

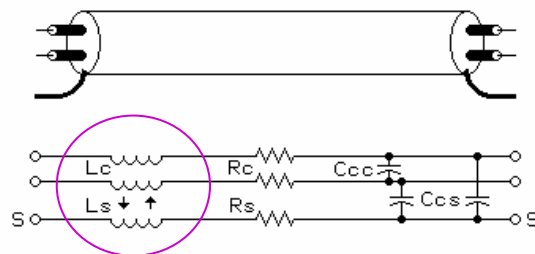
Cable Immunity to Magnetic Fields

- Voltage is induced in conductors exposed to ac magnetic fields, but for pairs it may be unequal
 - **Twisting** improves match by averaging physical distances to external field source
 - **Star-Quad** improves another 40 dB by paralleling pairs of wires to create zero magnetic cross-section
- Effective **magnetic** shielding, especially at power frequencies, is very difficult to achieve
- Only magnetic materials like steel conduit provide significant audio frequency shielding — ordinary shielded cables have no effect

Shield Current Induced Noise

- Current flow in cable shield creates a magnetic field ***extremely close*** to the twisted pair
- Imperfections and manufacturing tolerances in real cables result in **unequal** induced voltages
 - Dubbed SCIN in 1994 paper by Neil Muncy
 - **Best** cables use braided or dual counter-wrapped spiral shields and **no drain wire**
 - **Worst cables use a drain wire**, regardless of other construction details [*Brown-Whitlock paper*]
- Can be eliminated, regardless of cable type, by simply not allowing current to flow in shields
 - **Ground shield directly at driver end only**
 - Receive end may float or be capacitively coupled to ground

LP Model of Shielded Pair Cable

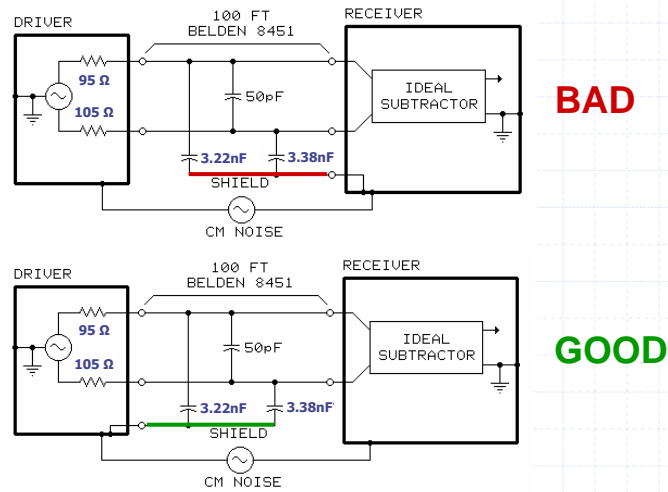


Magnetic Coupling

100% for inner conductors to shield

60-70% between twisted inner conductors

Send or Receive, Which End to Ground?



Send vs Receive End

- Grounding only at receive end forms pair of **low-pass filters** for common-mode noise
 - Driver Z_0 imbalances and 4% to 6% typical cable C imbalances create mismatched filter pair
 - Mistracking of filters causes **conversion** of common-mode noise to differential (signal), degrading CMRR
- Grounding only at send end **completely eliminates the filters!**
 - All filter elements move together (with driver ground) with respect to receiver ground

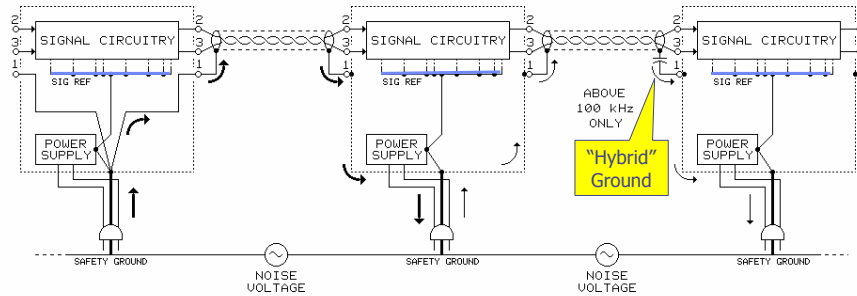
Connections and Crosstalk

- Signal asymmetry and capacitance mismatch cause **signal current** flow in the shield
 - Grounding only at receiver forces current to return to the driver via an **undefined** path – **can result in crosstalk, distortion, or oscillation**
 - Grounding only at driver allows current to return **directly** to the driver – **NO PROBLEMS**
- The **driver** end of a balanced cable should **always** be grounded, whether or not the receiver end is grounded

Shield Grounding Tradeoffs

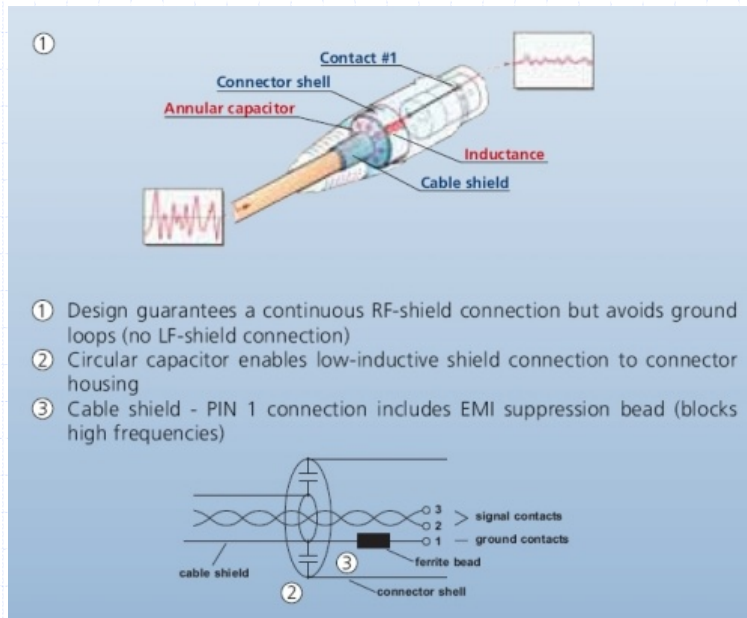
- Conflicting goals for balanced audio cables
- Grounding shields only at the send end produces best possible interface CMRR
- Grounding shields at the receive end often reduces RF interference problems
- “Hybrid” grounding uses a capacitor to ground receive end only at RF frequencies
 - AES Standard on Interconnections, AES48, issued in 2005 (after almost 10 years of agonizing debate) includes this method

"Hybrid" Stops SCIN and Pin 1 Problems



Capacitive grounding of shield stops audio-frequency current flow, preventing SCIN and Pin 1 problems, but effectively grounds it at frequencies >100 kHz

The Neutrik EMC Connector



What To Do? – Code Violations

- More than one N-G bond
 - Sub-panels the most frequent culprit
 - Neutral wire pinched (shorted) at a metal J-box
 - Causes abnormal ground voltage differences and subsequent noise problems in audio systems
- Neutral-safety ground swaps
 - Most common at outlets or outlet strips
 - No effect on ordinary appliances
 - Causes abnormal ground voltage differences and subsequent noise problems in audio systems
- Other outlet miswires
 - Can be found with \$10 outlet testers



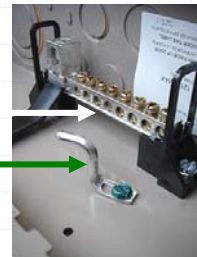
The Neutral-Ground Bond

- One incoming utility wire, often bare, is the *grounded* or **neutral** conductor
- NEC requires 120-volt AC premises power distribution using a 3-wire system (since about 1960)
- **Line** (black) and **neutral** (white) are intended to carry the load current, typically up to 15 or 20 A in branch circuits
- The “safety” **ground** (green) normally carries no current
- Neutral and **ground** are **bonded** at the main panel

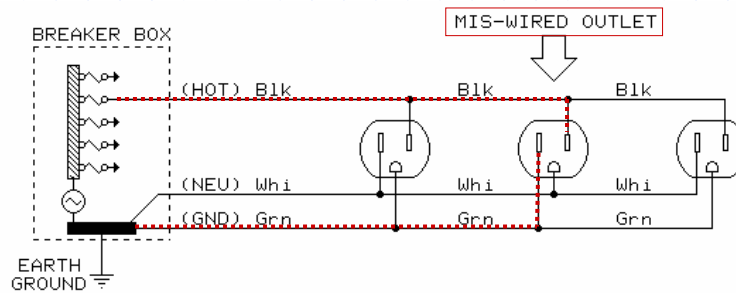
CODE PROHIBITS NEUTRAL TO GROUND CONNECTIONS ANYWHERE ELSE

NEUTRAL BUS

N-G BOND LINK



The Neutral-Ground Swap



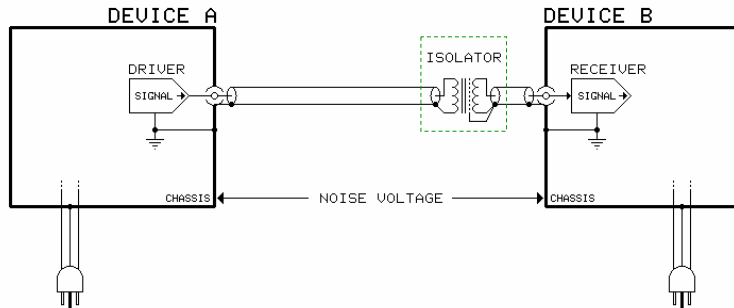
Load current now flows in **safety ground** wiring. Its voltage drop, up to 3 volts, appears as a ground difference voltage to the system – creating truly **severe** noise problems! The swap is **not** detectable with outlet testers, but a clamp-on ammeter on safety ground will find it!



What To Do? – Equipment

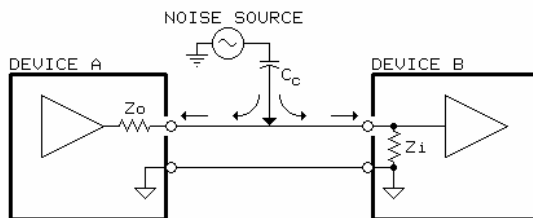
- Buy the “right stuff”
 - Look for mention of AES48 in “specs” or ask if the manufacturer has tested for “pin 1 problems”
 - Test it yourself with the hummer and complain to the manufacturer if it fails!
 - Demand meaningful CMRR specs instead of the usual “no test conditions specified” bullshit
- Pay attention to cables
 - For cables grounded at both ends, avoid cables that use a drain wire
 - For existing cables with drain wires, consider using the Neutrik EMC connector with pin 1 disconnected at the receive end

Ground Isolator for Unbalanced

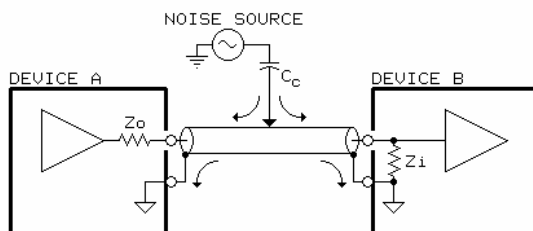


Signal transfers with **no electrical connection** between driver and receiver – ground loop broken

Electric Field Coupling



Current couples to signal

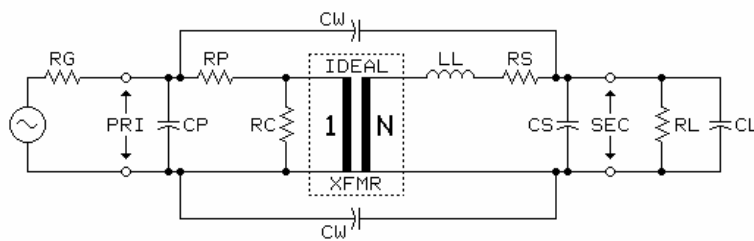


Current diverted to ground

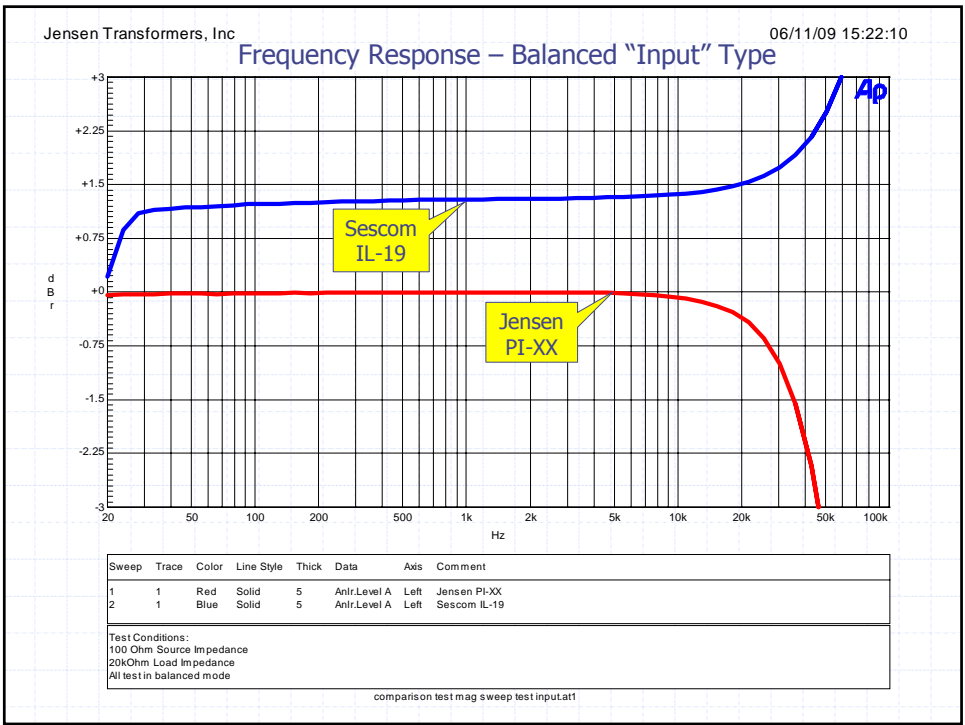
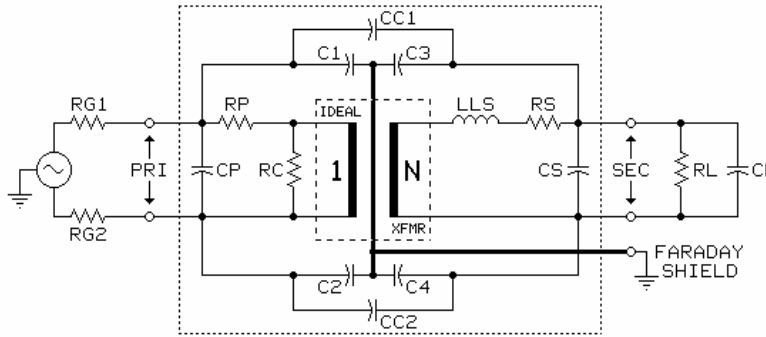
Transformer Faraday Shields

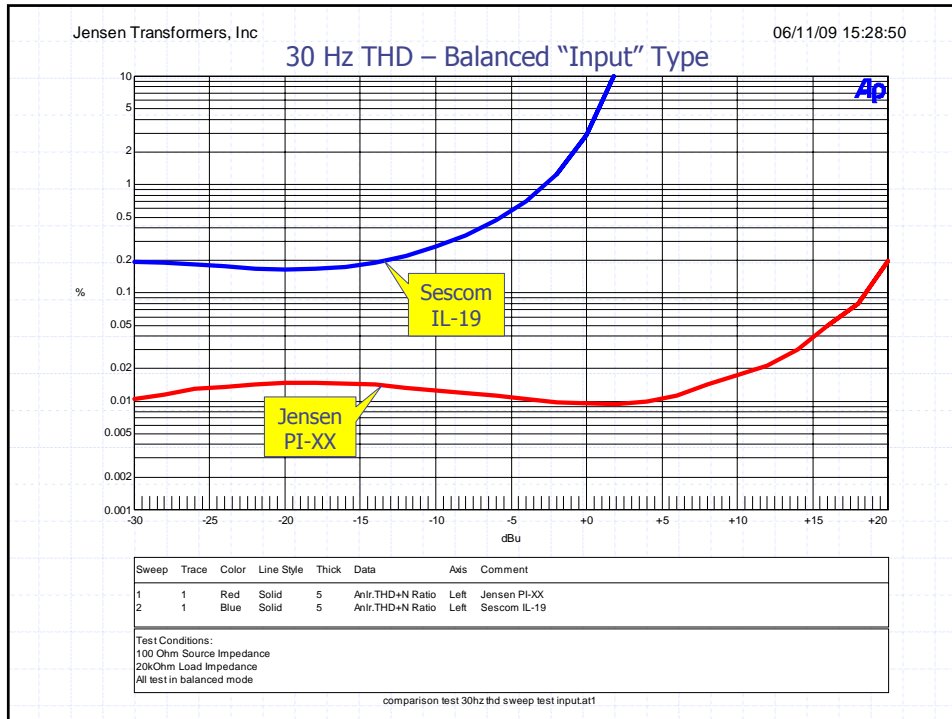
- Low inter-winding capacitance often necessary
- Virtually eliminated by **Faraday shield**
 - Often called "electrostatic shield"
 - Generally a sheet of copper foil between windings
 - Requires shields between adjacent layers
 - Intercepts capacitive current between windings when grounded
- Achieves common-mode rejection of "ground noise"
- CMRR depends on match of capacitances $C1$ and $C2$
- Match of $C3$ and $C4$ less critical because secondary usually unbalanced
- "Sneak" capacitances $CC1$ and $CC2$ are low but affect HF CMRR

HF Transformer Model



HF Model with Faraday Shield





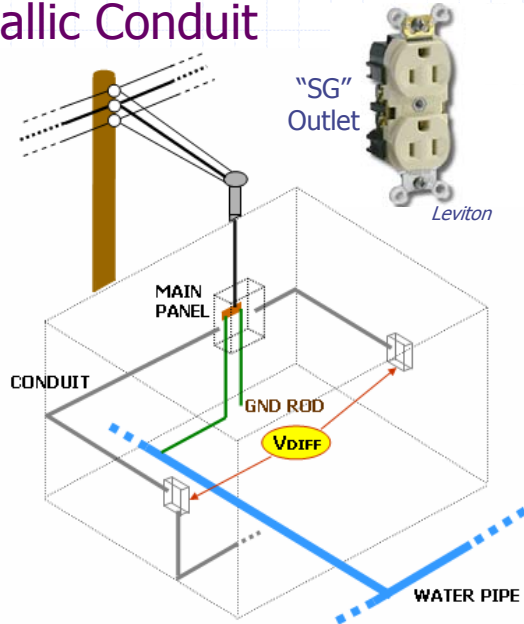
What To Do? – Powering New Installs

- Twist all "line" and "neutral" pairs (not Romex)
 - **Vastly reduces ground voltage differences!**
 - Twist as tightly as practicable for wire size
 - Untwisted safety ground must be in same conduit
- Use separately-derived power transformer
 - Especially if using a 3-phase feeder
 - Locate as close as possible to equipment
 - Faraday shield prevents noise coupling from primary feeder
 - **"Power White Paper" at Middle Atlantic Products website has great info on this and other power topics**
- Consider "isolated" or "technical" grounding
 - Especially in large commercial buildings
 - Requires user discipline to prevent "violations"

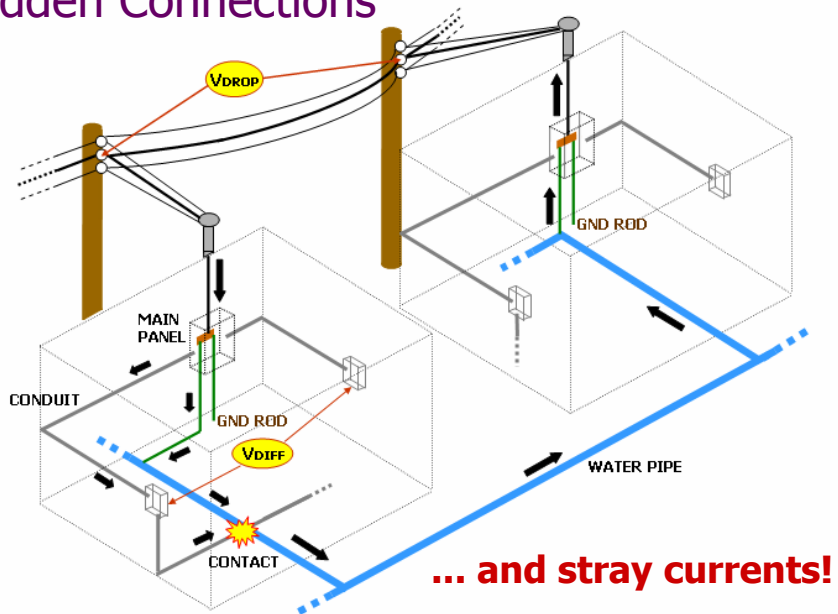
Building with Metallic Conduit

V_{DIFF} is magnetically induced into safety ground wires as current flows in other conduit wires. It is this voltage that drives ground loop currents through our signal cables.

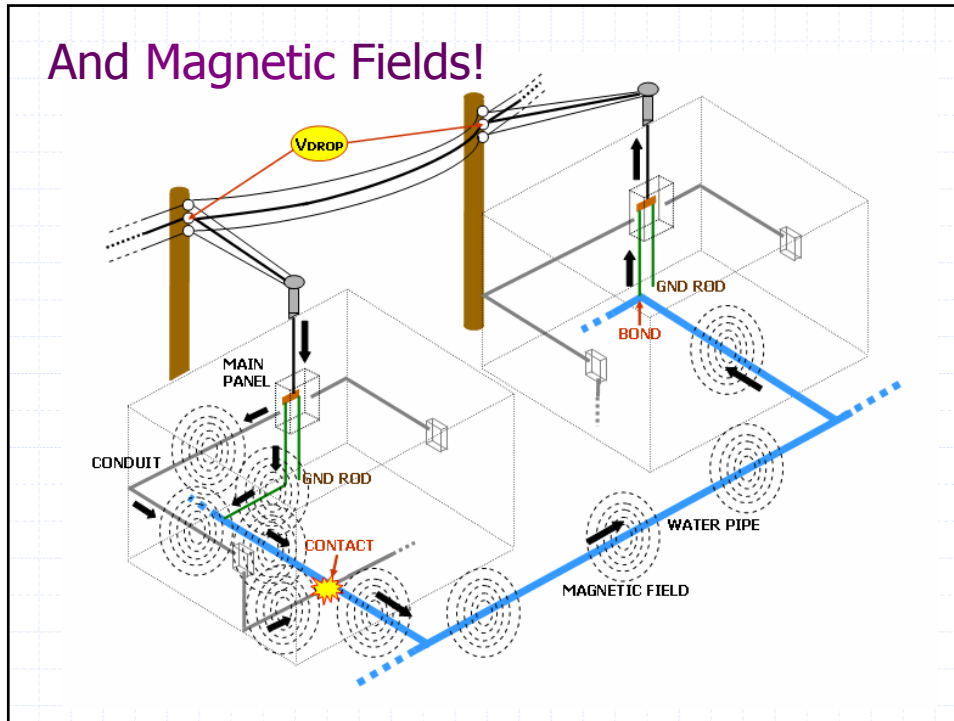
Normal saddle-ground outlets connect safety ground to conduit when J-box mounted.



Hidden Connections



And Magnetic Fields!



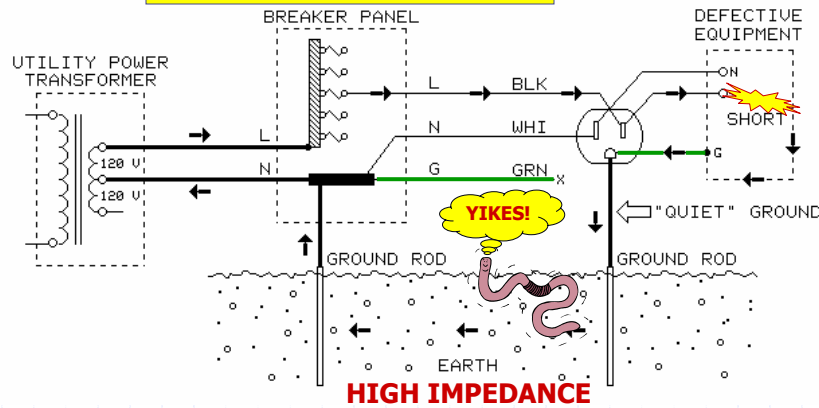
“Technical” or “Isolated” Grounding

- **Conduit touching ANY separately-grounded metal causes new noise currents in safety ground system**
- Isolated-ground outlets do **not** connect safety ground to their mounting saddle but only to the **green wire**
- IG outlets reduce extraneous, and often intermittent, ground noise problems
- Covered by NEC Article 250-74
- Does **not** apply to premises wired with Romex® and/or plastic J-boxes
 - It's already an isolated ground system!



"Quiet" Grounding Scheme

Circuit Breaker Will NOT Trip!



This "solution" was offered by a "sales engineer" for a well-known power conditioning company at a CEDIA trade show seminar a few years ago ... some engineer!!

"Power Conditioning" as a Cure?

"Today's residential systems contractors face un-precedented challenges where high resolution, trouble-free operation is required. From inducing AC **ground loops, video hum bars**, static bursts, damage from AC line surges and variable audio and video performance, comprehensive control and conditioning of AC power is no longer an option." *[actual ad copy, emphasis added]*

- Transient voltage "spike" protection (usually MOV clamps)
- Long-term surge, swell, and sag protection (regulation)
- Isolation transformers ("common-mode" noise reduction)
- So-called "balanced" power (leakage current reduction)
- Filters (common and normal mode noise reduction)
- Other "bizarre" (for lack of a better term) noise eliminators

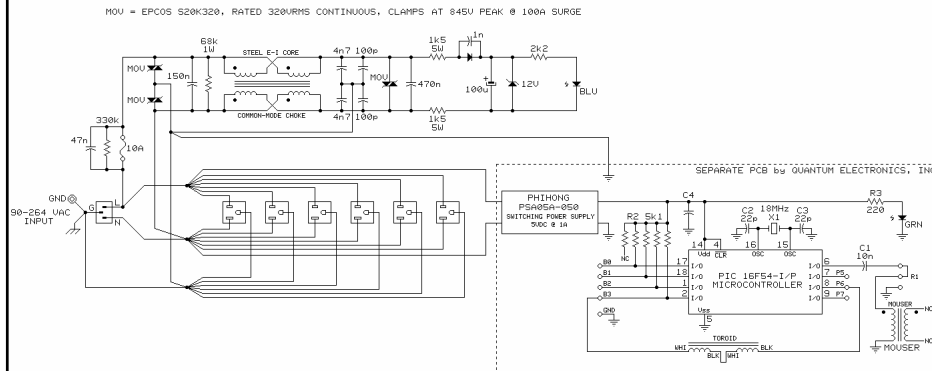
A \$3,000 Power Conditioner



Nordost "Thor" Specs:

- Internally wired with Nordost Valhalla
- Silver Solder used throughout
- Polaris-X technology
- Number of outlets: 6
- Type of outlets: High End Audiophile Grade un-switched outlets.
- Standard mains inlet: Audiophile Grade IEC fused
- Mains AC voltage: 100-140 VAC
- Surge Protection: Full Surge & Spike Protection
- Total maximum current: 18 Amps
- Total maximum current: 18 Amps
- Dimensions: (W x H x D) 17.4" x 3.34" x 12"
- Weight: 13.2 pounds

What's Actually Inside



**Note that the output of the elaborate filter only powers the blue LED and that the micro-controller circuitry apparently does nothing at all!
This schematic was generated from an actual production unit.**

Background Facts ...

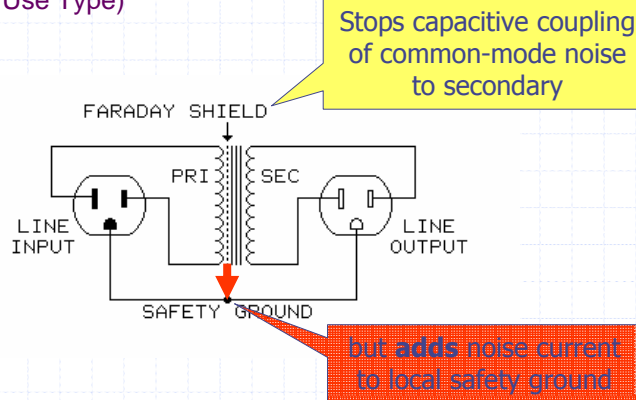
- **Ground voltage differences** are **the** driving force behind nearly all audio (and video) noise problems
 - **Generated by magnetic induction in the premises wiring**
 - **Difference approaches zero between equipment powered from closely-spaced AC outlets**
- **Many benefits attributed to "power conditioning" are actually due to their closely-spaced output outlets!**
- The coupling in signal cables that causes hum and buzz becomes negligible beyond about 30 kHz
 - Conditioner filters typically work only at frequencies above 50 kHz
- Power-line "common-mode" (neutral to ground) noise is **zero** at the N-G bond in the main panel

Power Filters and Isolation Transformers

- **Neither can legally interrupt safety ground connection**
 - Applies to cord-connected filters and isolation transformers
 - Both add noise to safety ground, often making system noise worse
 - Only a transformer configured as a **separately-derived system** per Code can establish a new N-G bond to improve system noise
 - ♦ See Middle Atlantic Products white paper "Integrating Electronic Equipment and Power into Rack Enclosures" for excellent info
- Touted noise reduction specs are unrealistic
 - Measurements made in lab on low-impedance **ground plane**
 - Real-world grounding is via high-impedance **wires** or conduit
- **Filters may be beneficial if installed at N-G bond**
 - All common-mode noise is generated on **load side** of N-G bond

Power Isolation Transformer

(Point of Use Type)



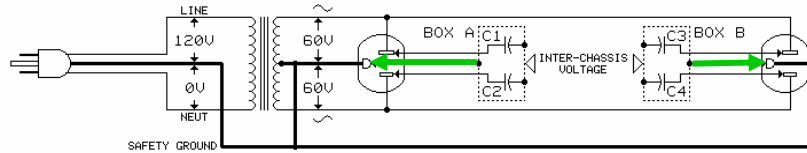
Understanding, Finding & Eliminating Ground Loops

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So-called "Balanced Power"

- Properly called **symmetrical** power
 - Has seductive intuitive appeal
 - **NOT similar to balanced audio lines in any way!**
 - Transformer with 120 V center-tapped secondary
 - ◆ **Both line and neutral blades are energized at 60 V**
 - Use **restricted** by Code - ads often imply *endorsement*
 - ◆ **Only** for professional use
 - ◆ **Cannot** be used with lighting equipment
 - ◆ **Must** have GFCI at output
- Only benefit is to reduce leakage currents
 - Leakage currents are a trivial system noise issue
- **Noise reduction generally less than 10 dB**
 - Likely due to powering system from clustered outlets

Symmetrical AC Power



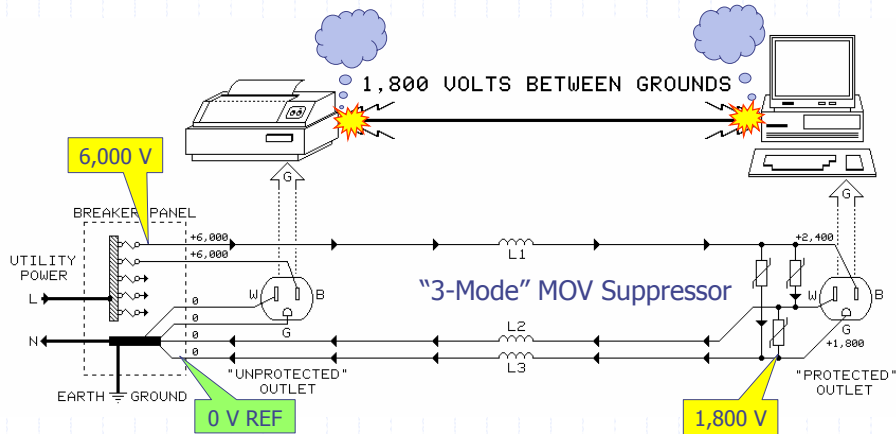
In theory, net leakage current to safety ground is cancelled. But this would require that equipment parasitic capacitance pairs, shown as C1/C2 and C3/C4 above, be precisely matched – **not** likely to happen!

About Surge Suppression

- Fear and pseudo-science are often used to sell surge protection devices
- **Mindless use of conventional suppressors can actually increase equipment damage risk!**
- The most widely-used suppressors employ three MOV (*metal-oxide varistor*) devices that divert surges into the safety ground system
- Surges generate brief but **extreme** voltage differences in the safety ground system!
- Equipment interfaces are often damaged ...



DANGER Will Robinson!



Understanding, Finding & Eliminating Ground Loops

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Think Different ...

- Protect from the biggest threat, lightning-induced surges, with a "whole house" device at main power service entry
- For branch-circuits or in the equipment rack, use only **series-mode** suppressors
 - Present a **high impedance** to the surge energy
 - **They do NOT dump surge currents into safety ground**



SurgeX

Understanding, Finding & Eliminating Ground Loops

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Thanks for Your Attention!

See the "Handbook for Sound Engineers,"
Glen Ballou editor, for more on these
subjects in three chapters by Whitlock

Think of a question? My e-mail is
whitlock@jensen-transformers.com

New 4th edition, 2008

