Computer to Rig Interfacing – You Don't Need to Buy an Interface!

Jim Brown
K9YC
Santa Cruz, CA
http://audiosystemsgroup.com

Interconnections Needed

- Audio from the computer
  - Transmit RTTY, PSK31, WSJT
  - Playback contest messages to radio
- Audio to the computer
  - Decode RTTY, PSK31, WSJT
  - SO2R operation
  - Mics to sound card
- Mics to radio

Interconnections Needed

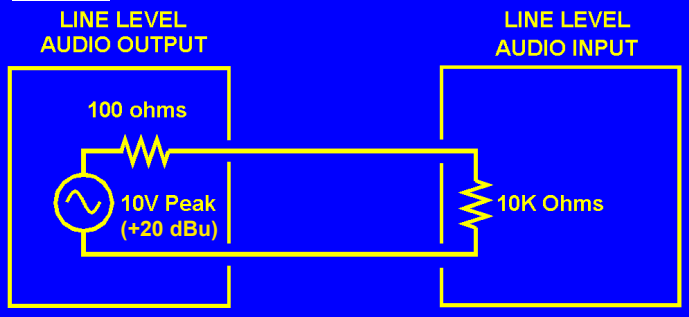
- Sending CW
  - Computer to radio
  - Paddle and keyer to radio
- PTT from computer to radio
- Rig control and data for logging software
  - Frequency readout, band changes

The Elements of the Problem

- Interconnects are unbalanced
  - Noise voltage between equipment grounds
- We must match audio levels properly
  - Avoid overload of transmitter input stage
  - Optimize operation of sound card
  - Avoid distortion in sound card
- We do <u>not</u> need to match impedances
- We must connect the right pins of the right connectors to each other

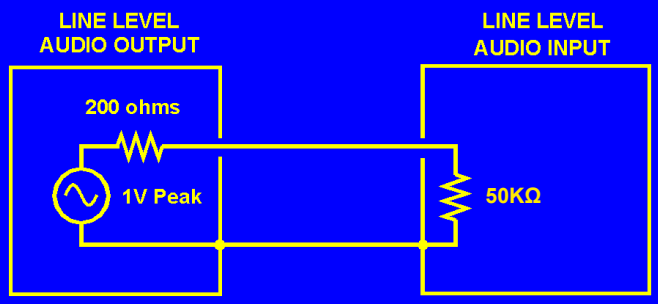
Audio Levels and Impedance

Pro Balanced Line Level



- Almost no audio current flows
- Wire size doesn't matter
- Twisting important for hum/buzz/RFI rejection
- Shield is not necessary!
- Some pro stages are 6 dB hotter (20V peak)

Consumer Unbalanced Line Level



- Almost no audio current flows
- Center conductor wire size doesn't matter
- Shield resistance increases hum/buzz

600 Ohm Circuits are a Myth!

- 600 ohm circuits have not been used in pro audio for more than 40 years!
- In the olden days, telephone circuits loaded and equalized for up to 20kHz bandwidth were used as broadcast studio-to-transmitter links, and for other special uses. These were 600 ohm lines, but they have been very rare for at least 25 years!

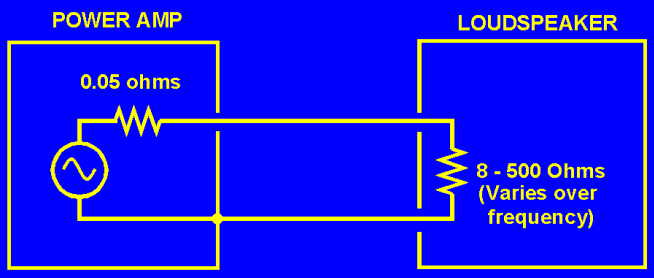
600 Ohm Circuits are a Myth!

- Those who talks about 600 ohms for audio circuits must have slept through the last 40 years!
  - Video people
  - Marketing people (product literature)
  - Hams

In the World of Audio

- We never match impedances
- We must match levels!

Speaker Level (Medium)

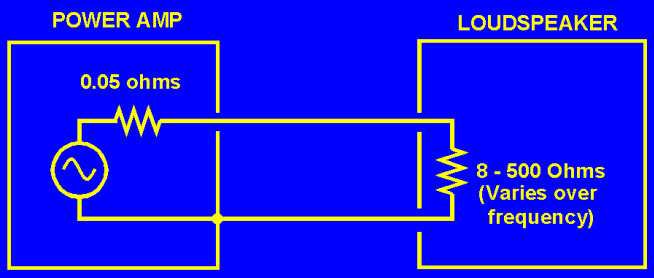


- For a power amp:
  - 8 volts = 8 watts @ 8Ω, 16W @ 4Ω
  - 15 volts = 28 watts @ 8Ω, 56W @ 4Ω
- 8-15 volts is pro line level (+20 to +26 dBu)
  - It drives headphones just fine – just don't turn it up!

Audio Level Matching

- Line level circuits are <u>not</u> designed to provide current
  - That is, they want to see a 10K or 50K load
  - If you load them with 600 ohms, distortion increases!
- Mic level circuits are <u>not</u> designed to provide current
  - Loading them with 600 ohms reduces their output and can increase distortion
- Loudspeaker and headphone outputs <u>are</u> designed to supply power (current)

Speaker Levels (Low)



- For a typical laptop sound card:
  - 1.4 volt = ¼ watt @ 8 ohms, ½ watt @ 4 ohms
  - 1 volt = ¼ watt to 4 ohm speaker
  - 1 – 1.4 volt is consumer line level!
  - It drives headphones just fine too!

Audio Level Matching

- Maximum Level is just before audio clips
- Clipping causes distortion
  - Harmonics, intermodulation
  - Muddy sound
  - Splatter!
- Consumer Line Ins and Outs clip at about 1 volt sine wave
- Mic Inputs may Clip at 50-100 mV
- Good output stages work best near their maximum output

Audio Level Matching

- Computer sound cards may produce less distortion about 6dB below clip
- VERY important for digital modes
  - PSK31
  - AFSK RTTY
  - Distortion produces copies of your signal
  - Run the computer about 6 dB below clip

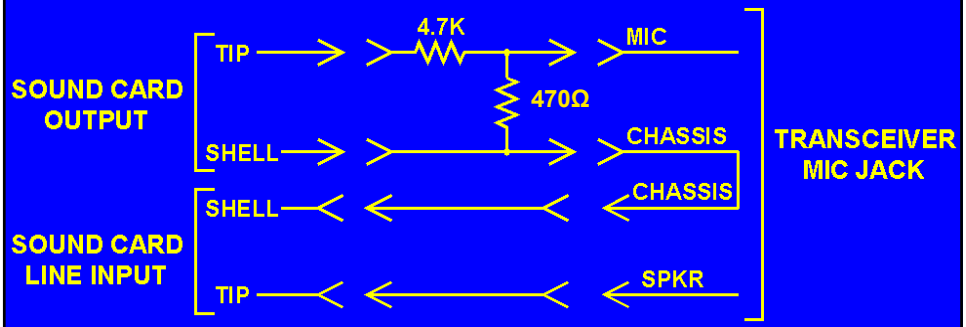
Audio Level Matching

- Why work near maximum level?
  - To keep signal well above the noise floor!
- All audio stages have a noise floor
- Digital converters create more distortion near their lower limit
- Set the computer to transmit PSK31 (or AFSK RTTY) and watch audio on a scope
  - Increase output level until you see clip
  - Turn down output by 6 dB (half the voltage)
- This should optimize the computer

Audio Level Matching

- Use a simple resistive pad (voltage divider) at the input of the radio
  - 2.2K in series, 1K across line input (10 dB)
  - 4.7K in series, 1K across line input (15 dB)
  - 4.7K in series, 470Ω across mic input (20 dB)
- The mic gain for your computer should be set about the same as it is for your mic
- Always use the 20dB pad if computer feeds the mic input
- Use the 10dB or 15dB pad on the line input if needed to put the mic gain in the right place

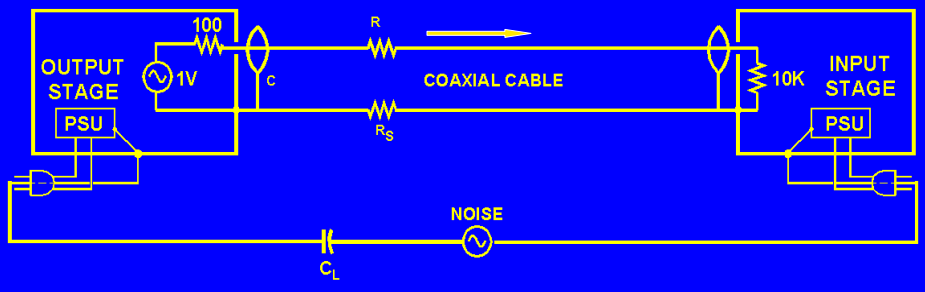
K6DGW Simple RTTY Interface



- Set rig for SSB, VOX operation
- No PTT required
- Do Hum/Buzz steps 1 & 2 for best results
- MMTTY needs serial cable for rig control

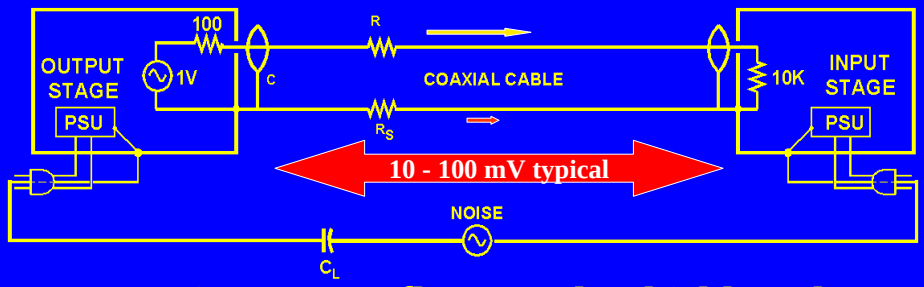
The Unbalanced Interface Preventing Hum and Buzz

A Typical Unbalanced Interface



- Input stage is high impedance, so very little signal current through R and R_S
  - Resistance of center conductor doesn't matter

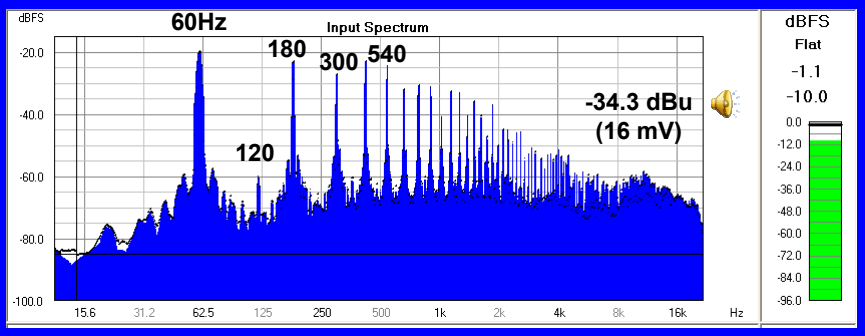
The Problem with Unbalanced Interfaces



Noise current flows on the shield, and the IR drop is added to the signal.

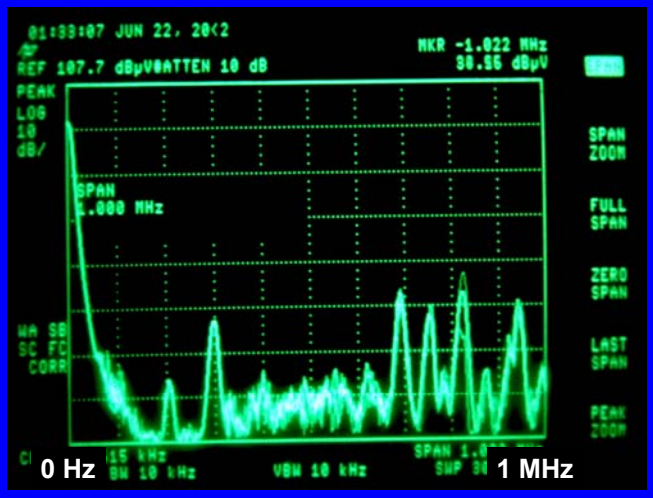
Any voltage between the two chassis is added to the signal.

Typical Noise Spectrum on "Ground"



Measured between two outlets on opposite walls of my ham shack and office, into a high impedance

RF Spectrum Analyzer 0 – 1 MHz



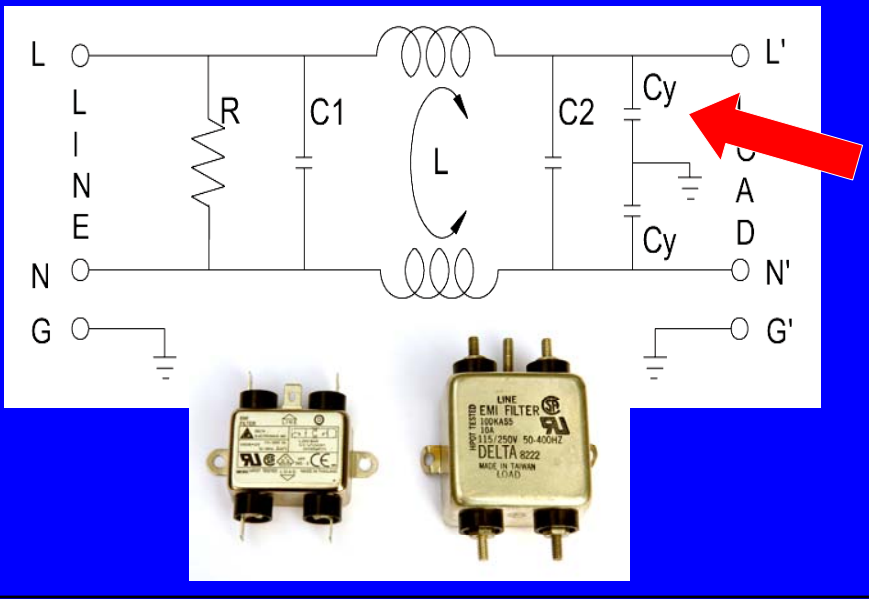
Measured between two outlets on opposite walls of my ham shack and office, into a 75 ohm load

Where Does All That Buzz Come From?

Sources of Noise on “Ground”

- Capacitance from AC “hot” to ground
  - Leakage capacitance in transformers
  - AC line filters
- Magnetic induction
  - Leakage fields from power transformers
  - Wiring errors in buildings and homes
    - Double bonded neutrals
  - Leakage fields from motors and controllers
    - Variable speed drives
- 3-Phase noise current from neighborhood

Line Filters Contribute Noise to the Green Wire

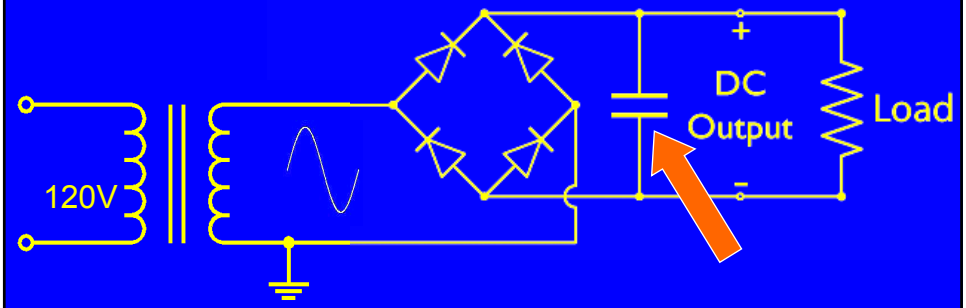


The Harmonic Problem

- Nearly all electronic loads have power supplies with capacitor-input filters
  so:
- Load current is drawn in short pulses at peaks of the input sine wave
  thus:
- **Phase, neutral, and leakage currents are highly distorted**

The Harmonic Problem

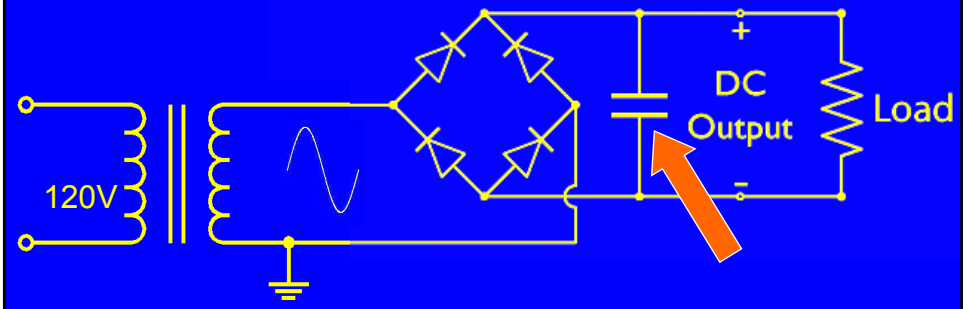
Recognize this power supply?



Something like it is in <u>every</u> piece of electronic gear – audio, video, computers, printers, copiers (even switching power supplies)

The Harmonic Problem

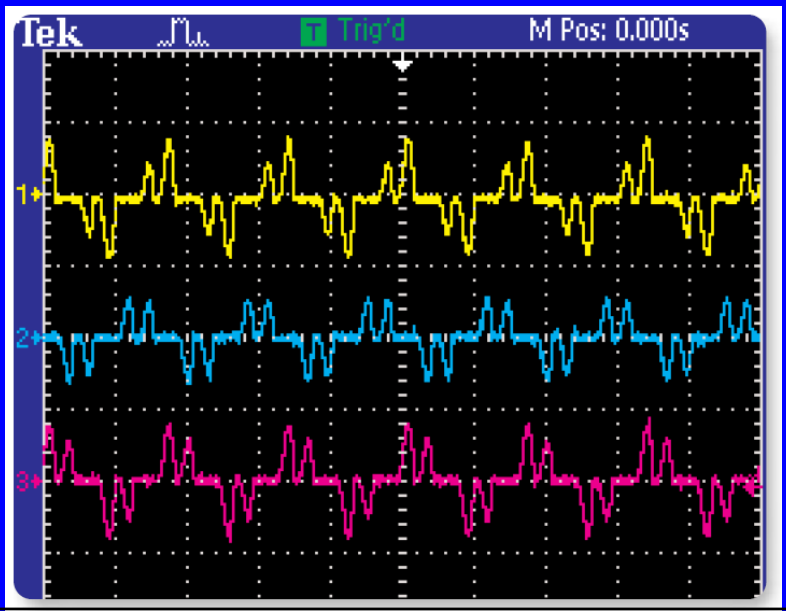
Recognize this power supply?



Current flows in short pulses that recharge the filter caps on each half cycle

Current is not even close to a sine wave

Load Currents in a 3-Phase System



In Single Phase Systems

- 120V – 0V – 120V
- If leg currents are equal, they cancel in the neutral

In Three Phase Systems

- If leg currents are equal, ***fundamental*** and most harmonics cancel in the neutral and in the ground

BUT:

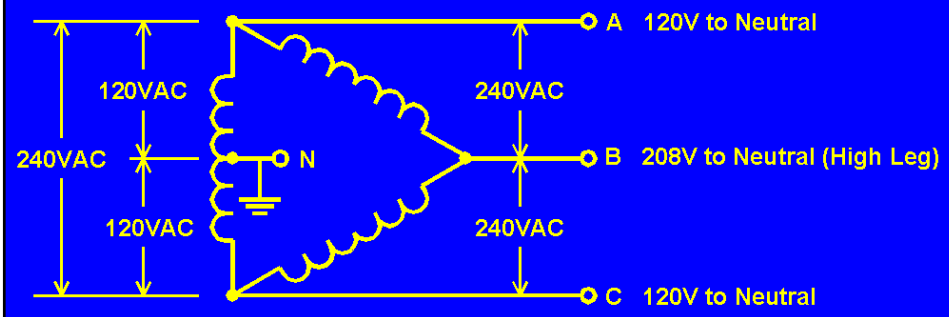
- Triplen harmonics (3^{rd}, 6^{th}, 9^{th}, etc.) ADD in the neutral and in the ground
- This tends to make 180 Hz, 360 Hz, 540 Hz, etc. dominant buzz frequencies

But I Don't Have 3-Phase at Home!

But I Don't Have 3-Phase at Home!

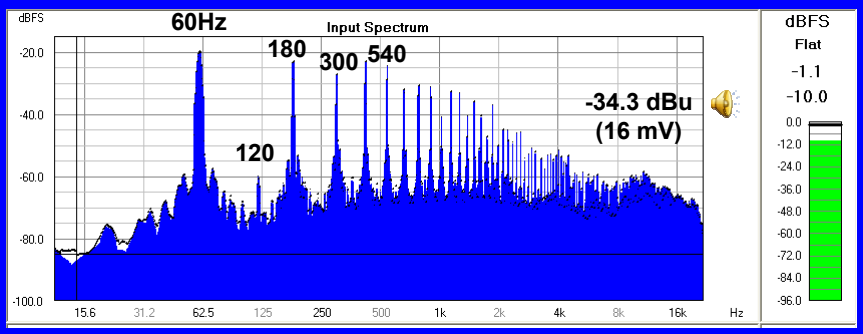
- No, but that factory or business down the street does, so you may get your 120V-0-120V service from the "high leg" of a 240V Delta in your alley!
- Some of their neutral current may flow through your neutral to ground!

"High Leg" Delta



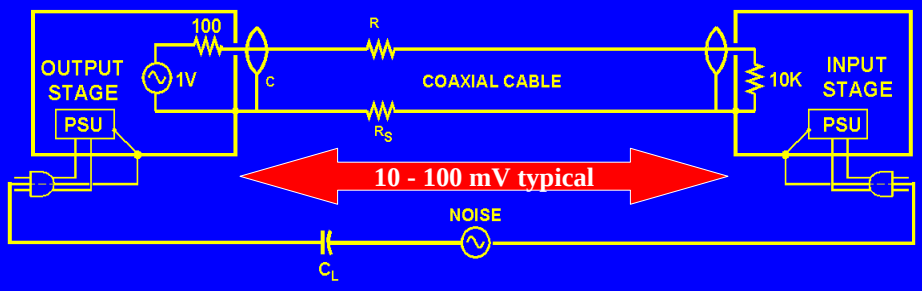
- Common in mixed industrial/residential areas where both single phase and 3-phase power are needed
  - A-N-C feeds residences (120-0-120)
  - A-B-C feeds industrial users (240-240-240)
  - Part of Neutral current from 3-phase system goes to ground through residential ground connection!

3-Phase Noise in Santa Cruz Mountains!



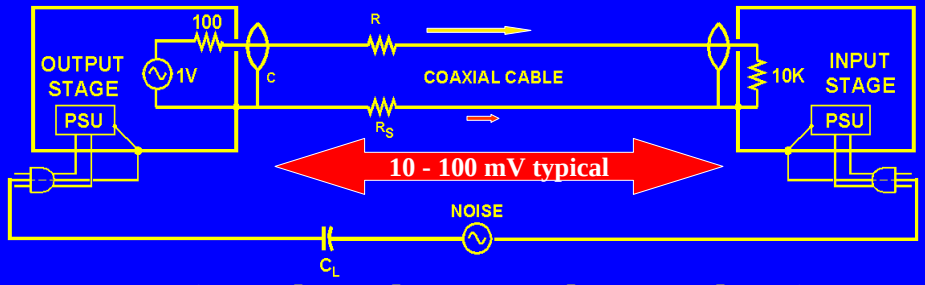
Measured between two outlets on opposite walls of my ham shack and office

The Problem with Unbalanced Interfaces



- **Why we hear more buzz than hum**
  - Noise is leakage through capacitance, so it's a voltage divider between C_L and R_S
  - 3-phase noise is dominated by harmonics

The Problem with Unbalanced Interfaces

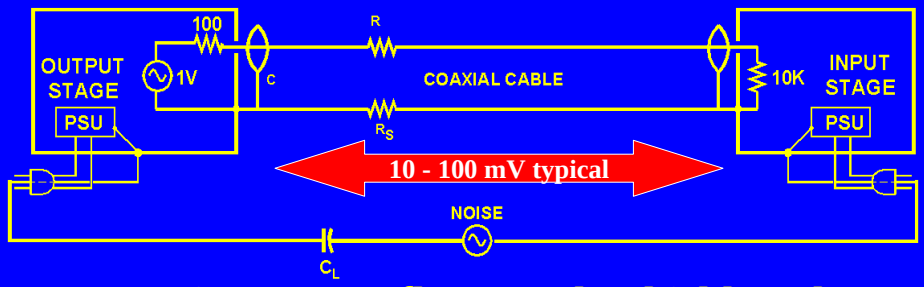


Noise voltage between the two chassis is added to the signal.

- So we have 1v signal (on peaks) and 10mV – 100 mV of noise
- Average value of speech is 10 dB below peak

  So only 10dB - 30 dB S/N ratio!

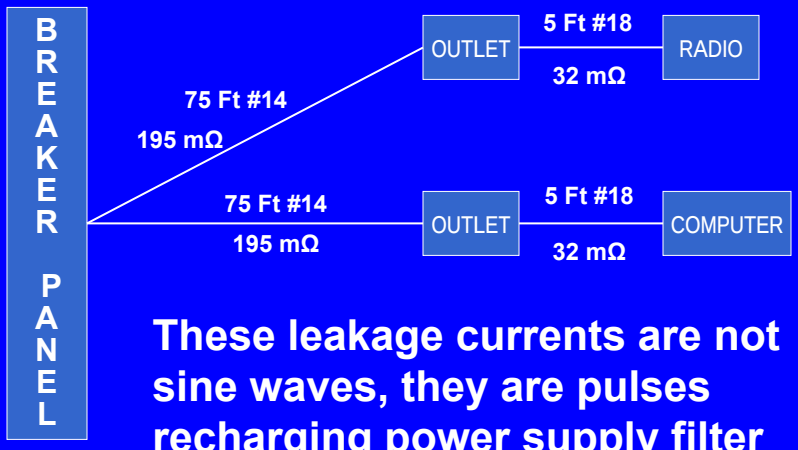
The Problem with Unbalanced Interfaces



Noise current flows on the shield, and the IR drop is added to the signal.

- **Reduce the noise voltage between the ends of the cable**
- **Use a "beefy" cable shield**
  - **Minimizes the drop**

Power System Ground Wiring (The "Green Wire")



These leakage currents are not sine waves, they are pulses recharging power supply filter capacitors!

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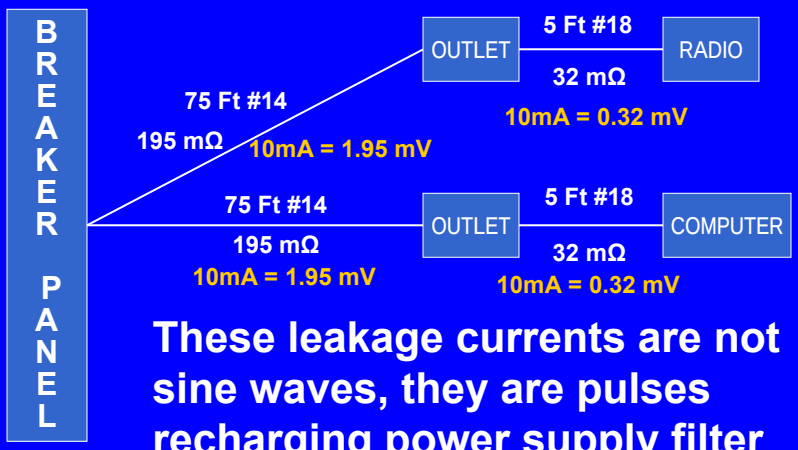

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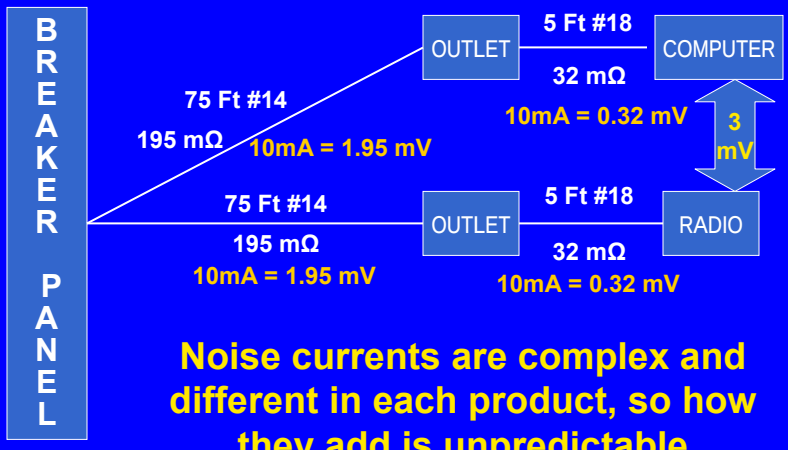
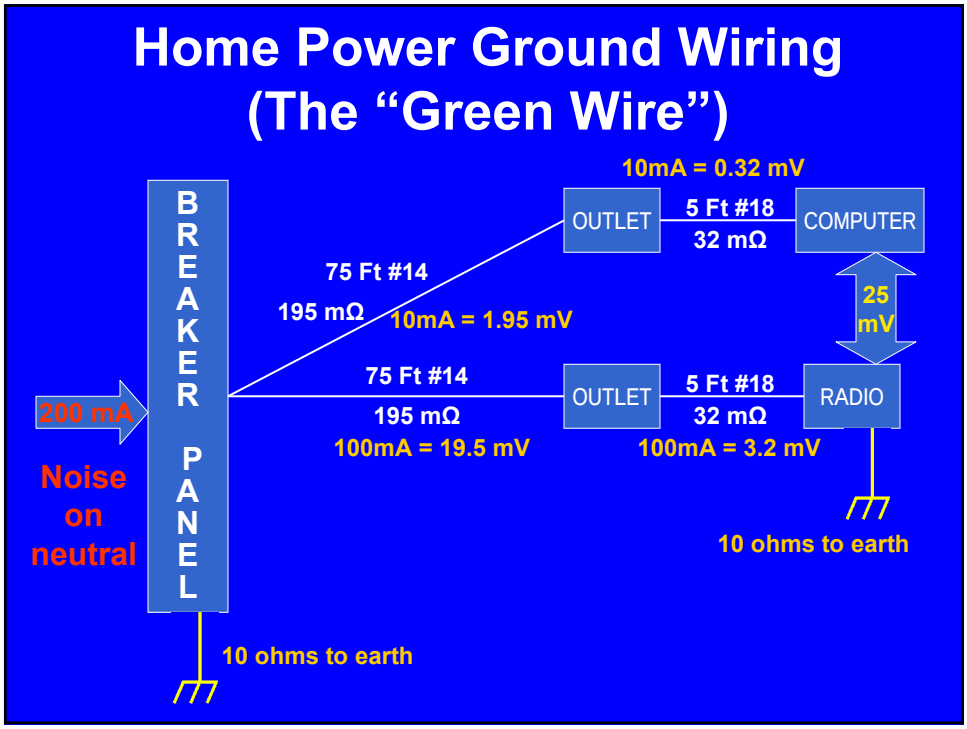
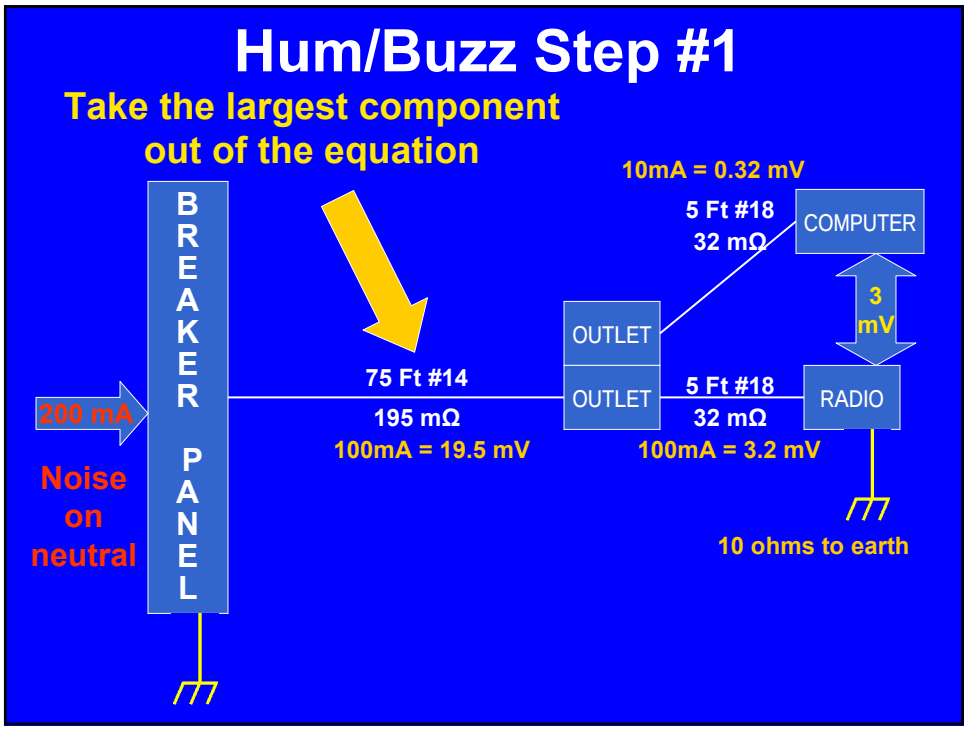


Noise currents are complex and different in each product, so how they add is unpredictable


Home Power Ground Wiring
(The "Green Wire")
10mA = 0.32 mV
OUTLET
5 Ft #18
32 mΩ
COMPUTER
75 Ft #14
195 mΩ
10mA = 1.95 mV
25 mV
BREAKER PANEL
200 mA
Noise on neutral
75 Ft #14
195 mΩ
100mA = 19.5 mV
OUTLET
5 Ft #18
32 mΩ
100mA = 3.2 mV
RADIO
10 ohms to earth
10 ohms to earth

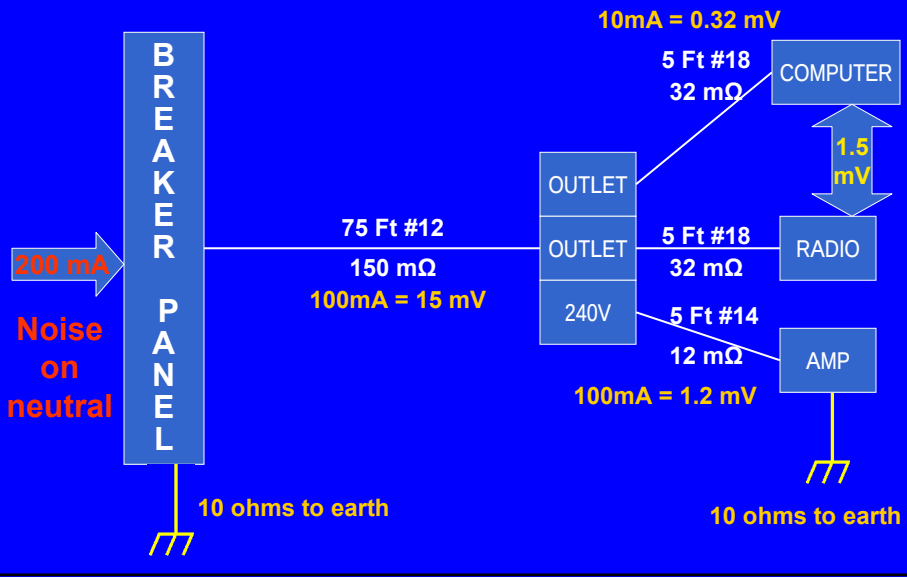

Hum/Buzz Step #1
Take the largest component out of the equation
10mA = 0.32 mV
5 Ft #18
32 mΩ
COMPUTER
3 mV
OUTLET
BREAKER PANEL
200 mA
Noise on neutral
75 Ft #14
195 mΩ
100mA = 19.5 mV
OUTLET
5 Ft #18
32 mΩ
100mA = 3.2 mV
RADIO
10 ohms to earth

Hum/Buzz Step #1

- Get all the power for your ham station from outlets connected to the same "green wire"
  - A 15A circuit can run three 100W radios (transmitting simultaneously) and two computers
  - If you need more outlets, bolt multiple quad boxes together
- Put 240V outlet in a backbox bolted to the 120V box(es)

A Quad Box

Home Power Ground Wiring (The "Green Wire")



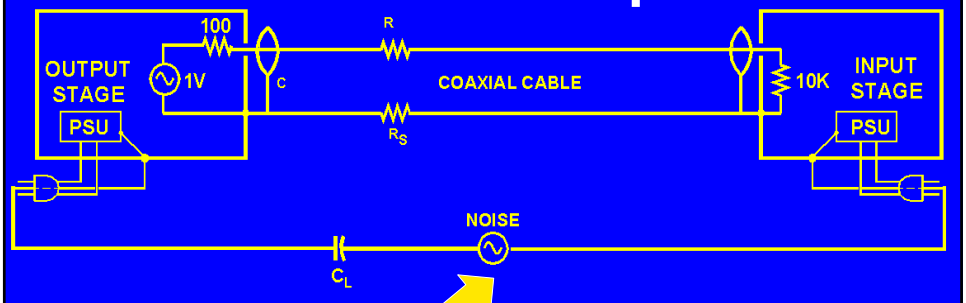
Hum/Buzz Step #1

- This reduces the voltage between outlets to a few microvolts
- What's left are the IR drops on line cords within your station
- Step #1 is typically good for 20 dB

Hum/Buzz Step #1 for Multi-Multi

- Get all the power for as many stations as possible from outlets connected to the same “green wire”
- Bolt more boxes together as needed
- When outlets can’t be bolted, bond them together with steel conduit or heavy braid

Hum/Buzz Step #1



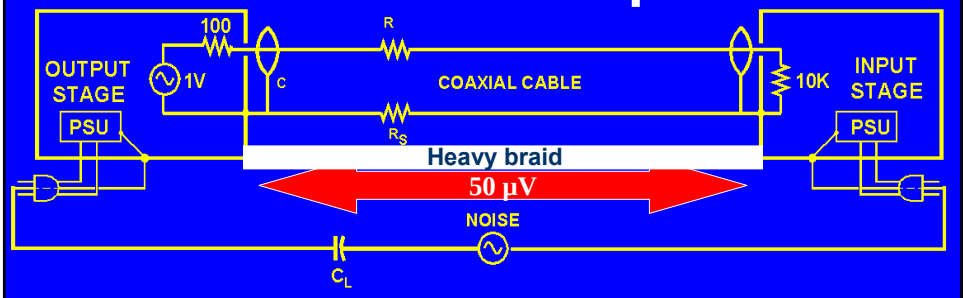
Hum/buzz step #1 reduces this voltage, but not enough

So we need step #2

Hum/Buzz Step #2

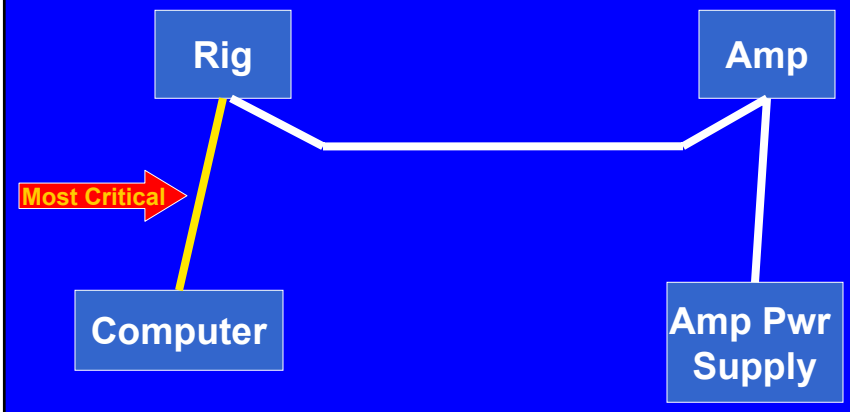
- Bond all interconnected equipment together with heavy copper braid
  - Radio to power supply
  - Radio to computer
  - Radio(s) to SO2R box
  - Radio to other band decoder, etc.

Hum/Buzz Step #2

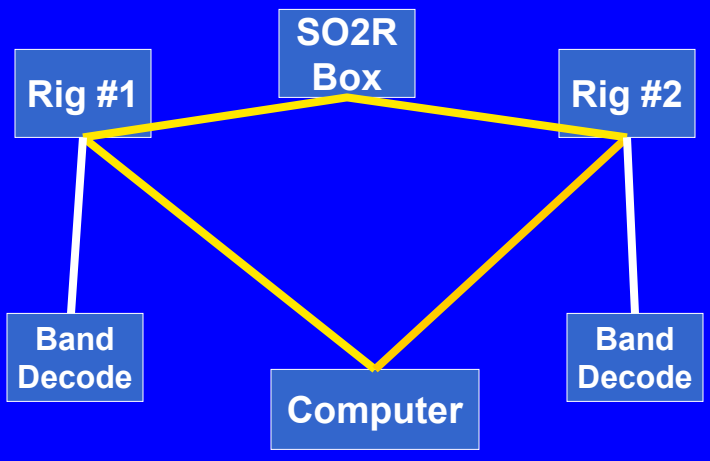


- Short out the remaining noise (or reduce IR drop) by adding a BIG conductor between the two chassis
- 50µV would yield 76 dB S/R ratio

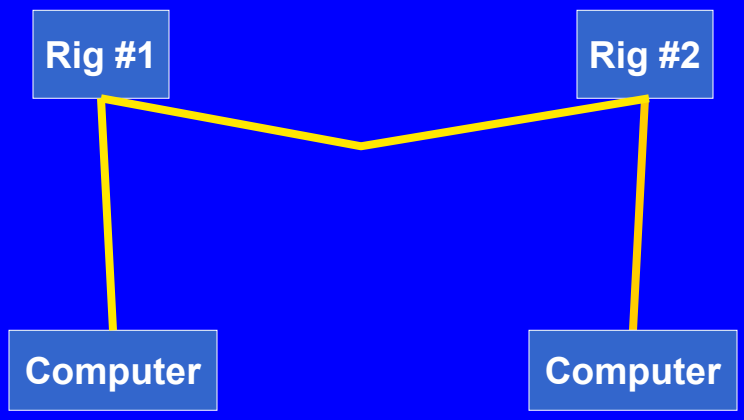
Equipment Bonding – A Basic QRO Station



Equipment Bonding – SO2R Station



Equipment Bonding – SO2R Station



Guidelines For Bonding

- Add bonding in parallel with every audio path
- Bonding should be #10 copper or larger
  - Strip braid from transmitting RG8, RG11
  - Or buy braid if you see it cheap enough
  - #10 THHN stranded is OK, but stiffer
- Bond to chassis of rigs and computers
  - Retaining screw of D-connector on laptops
- Keep bonding conductors short

Guidelines For Bonding

- Noise is proportional to resistance of the bonding path
- Make conductor BIG
  - Double the size = 6dB
  - Two conductors in parallel = 6dB
  - Four conductors in parallel = 12 dB
- Make bonding conductor SHORT
  - Half the length = 6dB

SO2R Box Bonding

- Bond transmitters together
- Bond SO2R box or power supply to computer(s) or transmitters
- Bond computer(s) to transmitters

Multi-Transmitter Bonding

- Bond all transmitters together
- Bond all power outlet green wires together
- Use bigger braid for longer runs
  - Multiple RG8/RG11 braids in parallel

When There's No Metal to Bond To

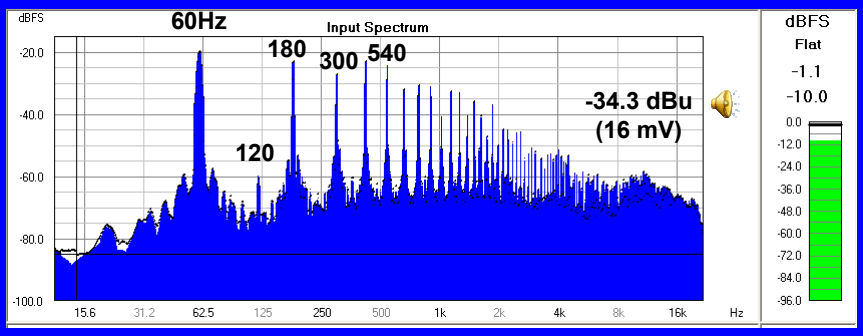
- Power that unit from a good DC power supply and bond the chassis of the supply
- Bond to a D-connector retaining screw

Hum/Buzz Steps #1 & #2

- Should eliminate most hum and buzz
- No need to replace cables
- AND it puts a band-aid on power-related pin 1 problems!
  - No shield current, no pin 1 problem (at audio)
- RF pin 1 problems still possible
- Still have hum/buzz?
- Suspect Magnetic Fields
- Move on to Step #3

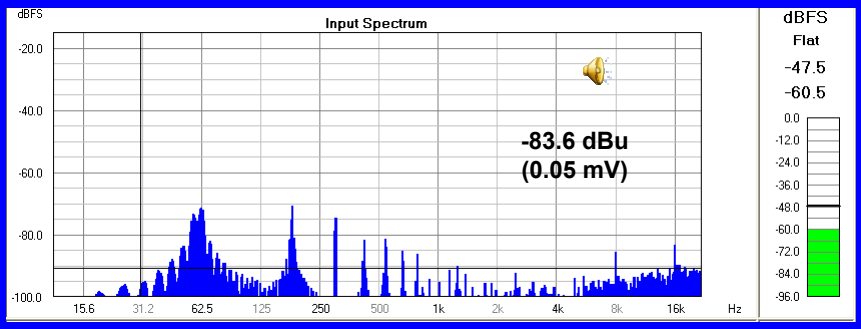
How Well Does This Work?

We Started With This



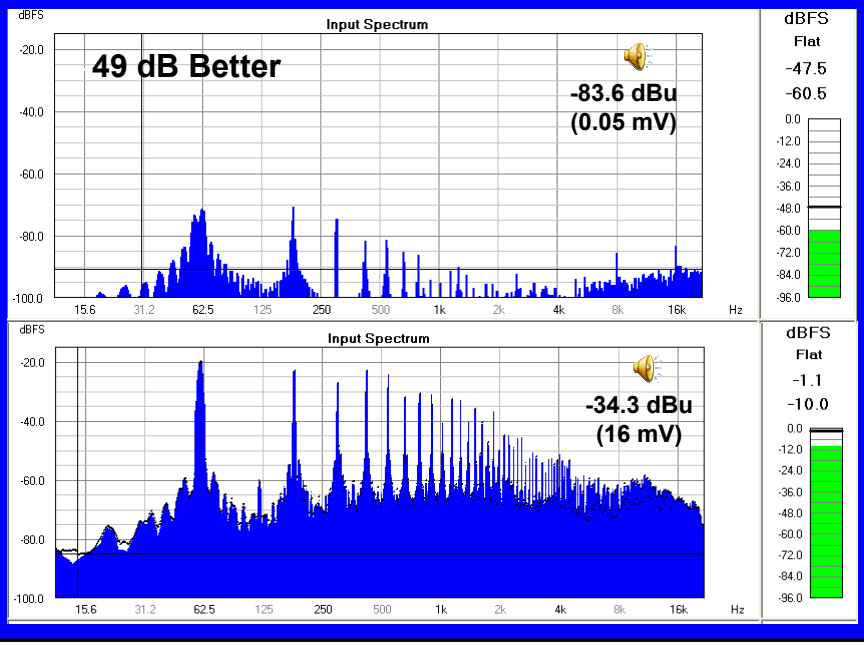
Measured between two outlets on opposite walls of my ham shack and office, into a high impedance

Noise Spectrum on “Ground” After Bonding



Measured between computer and FT1000MP with heavy braid bonding their chassis together

Noise Reduction From Bonding



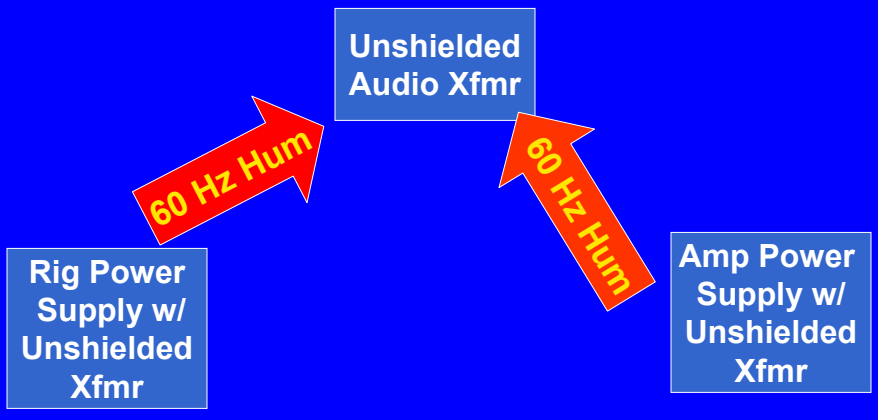
Still Have Hum/Buzz?

- Suspect Magnetic Fields
- Move on to Step #3

Hum/Buzz Step #3

- Fix magnetic field problems
  - Big transformers in power supplies can couple hum into audio transformers
  - Move power xfmr away from audio xfmr
  - Rotate the power supply to put the field at 90° to the audio transformer's field
  - Rotate the audio transformer
  - Get rid of the audio transformer (you don't need it!)
  - Shield the audio transformer

The Problem with Audio Transformers



An unshielded audio transformer can <u>cause</u> a hum problem!

Audio Transformers

- An expensive fix for "ground loops"
- Sitting duck for magnetic fields
  - Must be well shielded!
  - Shielding is expensive (typically $50-$70)
- If you've done Hum/Buzz steps #1 and #2
  - You don't need a transformer!
  - You don't need an optoisolator!
- An ***unshielded*** audio transformer can cause more problems than it solves!

Audio Transformers

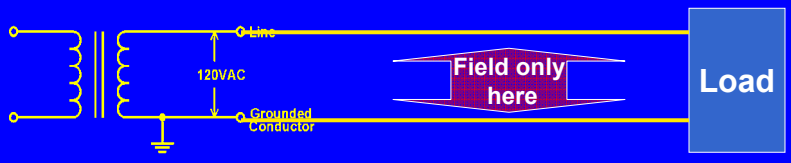
- You do need a transformer to bring audio in from another building
  - Remote operation, etc.
  - Need ***mu-metal shield*** to reject magnetic fields
  - Need ***dual Faraday shields*** to reject RFI
- Lundahl
  - http://lundahl.se
- Jensen
  - http://jensen-transformers.com

Hum/Buzz Step #3

- Fix magnetic field problems
  - Double-bonded neutral
    - Neutral must be bonded to ground ONLY at the breaker panel, NEVER anywhere else
    - Use AC voltmeter to look for zero volts between neutral and ground (that's bad – it indicates an extra bond)
    - "Normal" is 20mV – 2 volts
    - This will be ***buzz***, not ***hum***

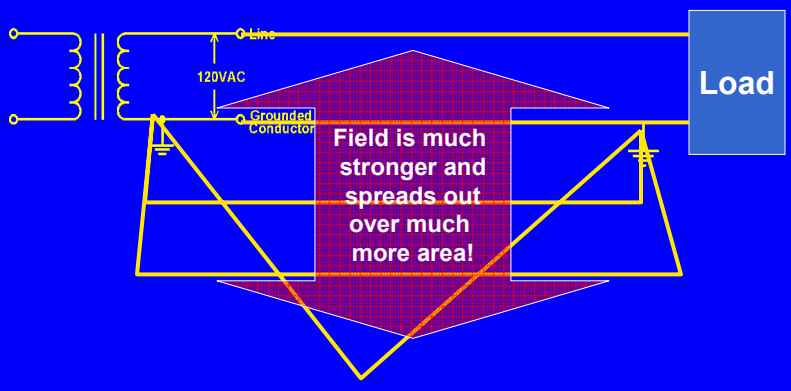
A Double-Bonded Neutral Creates An Interfering Magnetic Field

Field with Single-Bonded Neutral (Right)



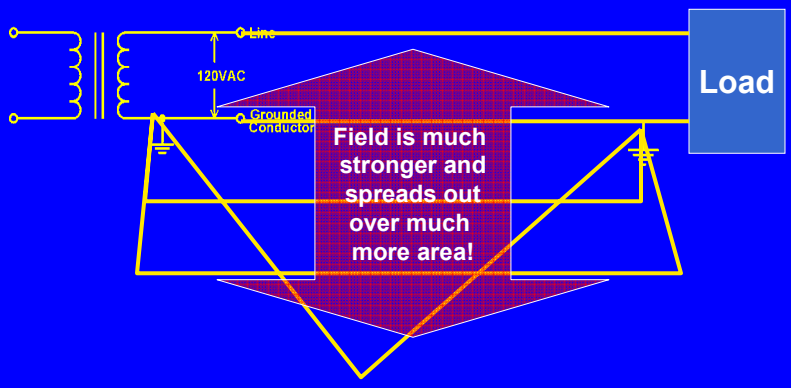
- Field mostly confined to the very small area between conductors – that is, between the wires

Field With Double-Bonded Neutral (Wrong)



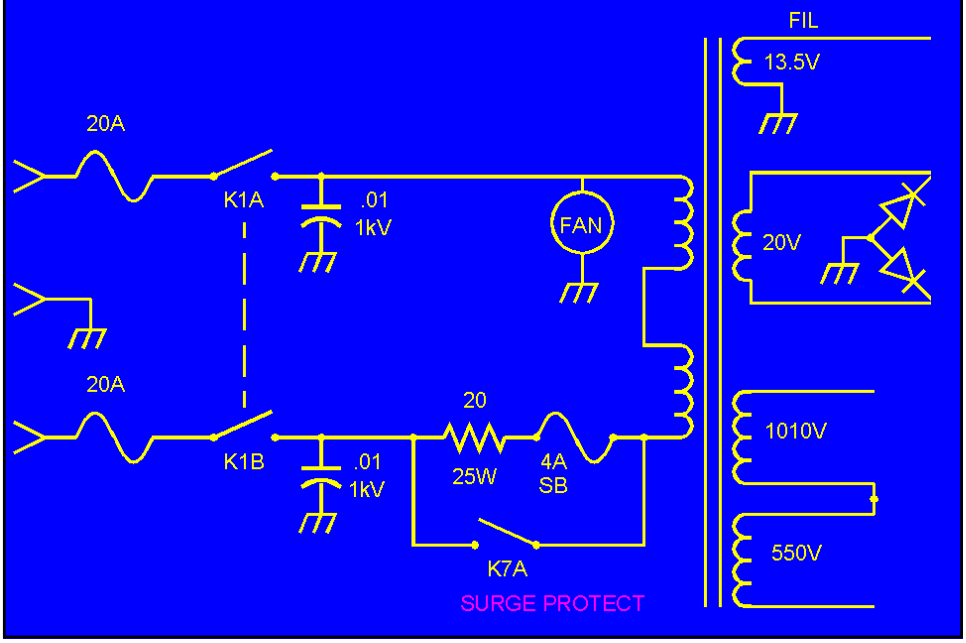
- Field may engulf large areas of a building!

Load Connected Hot to Ground (Also Wrong)

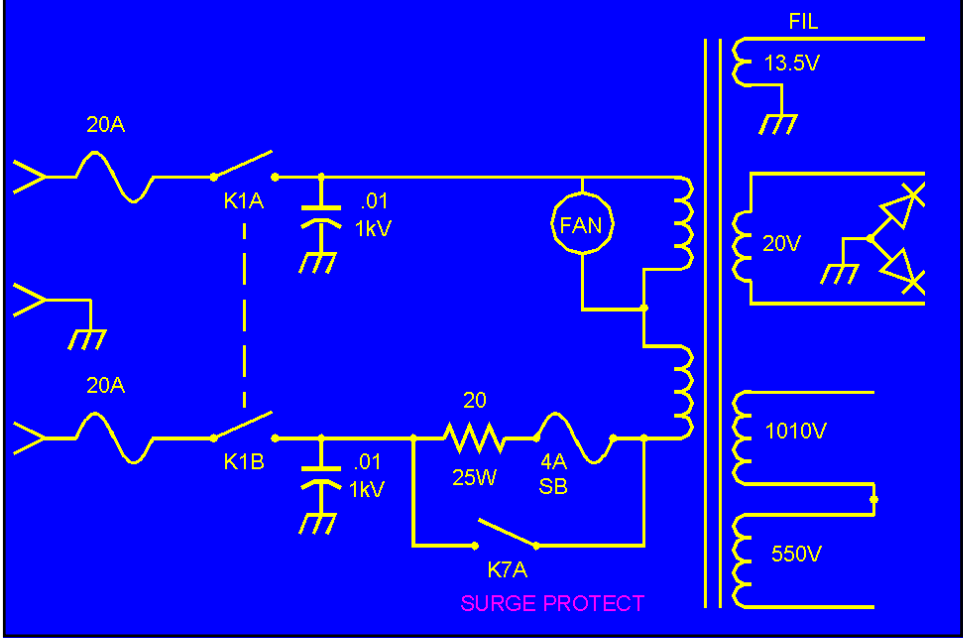


- Field may engulf large areas of a building!
- Puts hum voltage on green wire (chassis)
- Fans in some older power amps

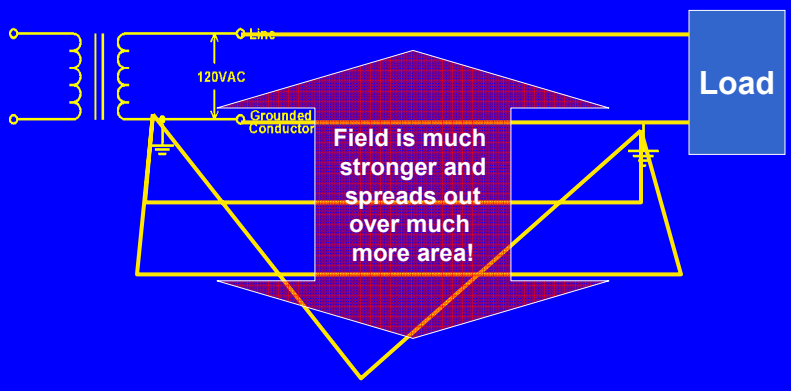
120V Fan in Power Amp - Wrong



120V Fan in Power Amp - Right



Load Connected Hot to Ground In Alpha 77, 500 mA



- Field may engulf large areas of a building!
- Puts hum voltage on green wire (chassis)

Hum/Buzz Step #3

- Finding big ground currents
  - Use AC voltmeter to measure voltage drop on green wire between outlet and the chassis
  - Use Ohm's law and the wire resistance to find the current (measure the length – 5-6 ft is typical)
    - 5 ft of #18 = 0.032 Ω (most IEC line cords)
    - 5 ft of #16 = 0.020 Ω (a few heavier IEC line cords)
    - 5 ft of #14 = 0.0126 Ω (maybe on your power amp)
  - 6 mA is maximum leakage permitted by NEC; more is illegal, and should trip a GFCI

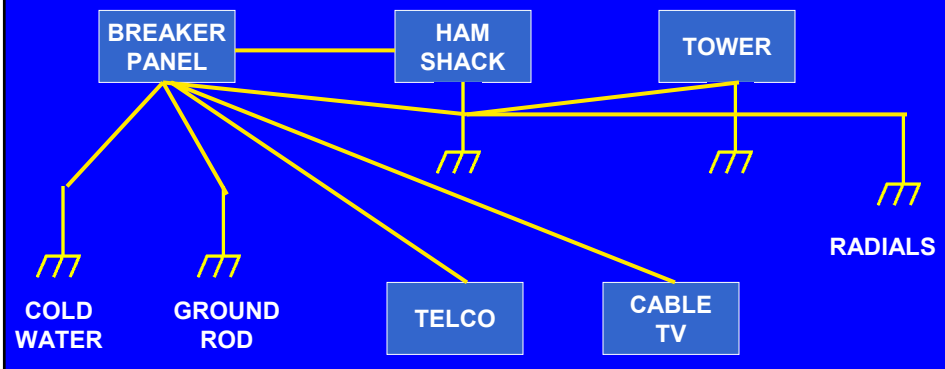
Hum/Buzz Step #3

- Fix magnetic field problems
  - Hot to ground loads
    - NEVER do this – causes current to flow on ground
  - Current on green wire to station ground
    - Station ground better than power system ground?
    - Power system ground not bonded to station ground?
    - Power system not properly grounded?

Station Grounding

ALL GROUNDS MUST BE BONDED TOGETHER FOR SAFETY

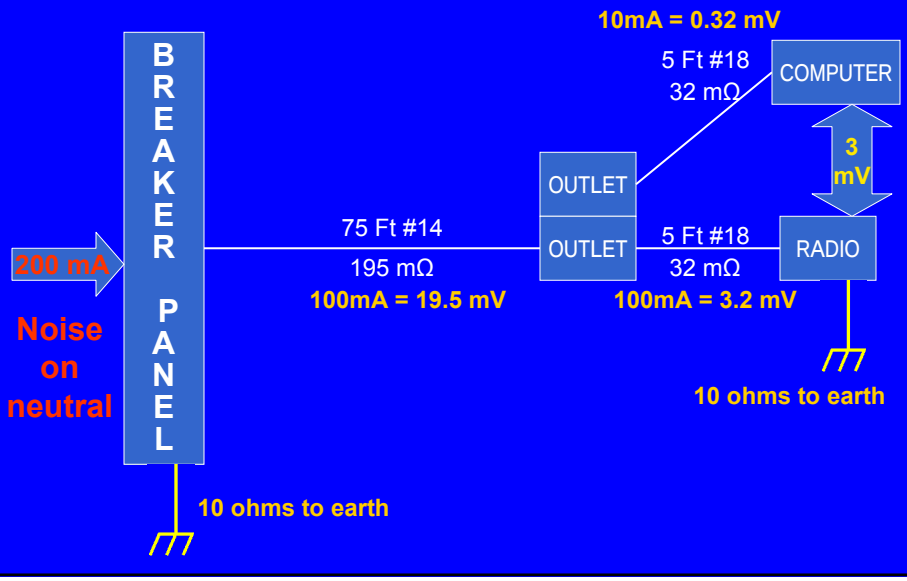
Station Grounding



Grounding is for SAFETY
- Lightning protection
- Blow a breaker if a power system short

Connections should be big copper and short

Home Power Ground Wiring (The "Green Wire")



Now that we've eliminated hum and buzz, we can talk about

Audio Levels and Impedance

Now Lets Talk About Mics

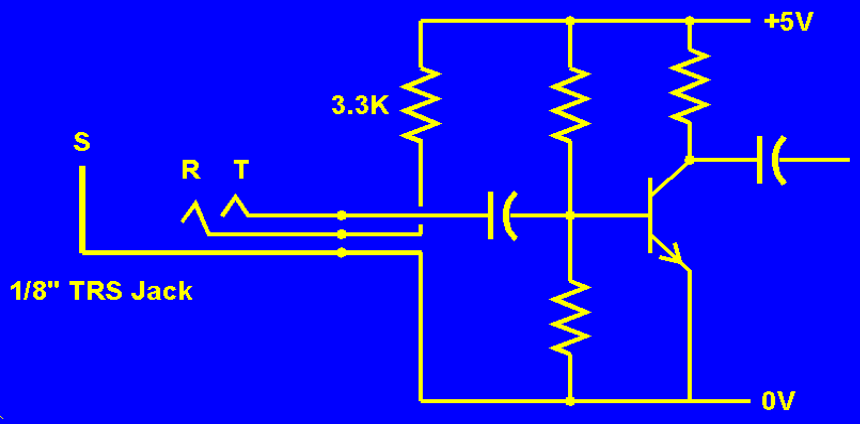
Audio Levels and Impedances

- Audio circuits operate on voltage
- Unbalanced line level is 1 volt sine wave on peaks
- Audio is quite dynamic. A low impedance mic may produce less than 1 mV with soft sounds, but 2 volts with very loud music
- Low impedance mic outputs are 150-250Ω
- Low impedance mic input stages are typically 1,000 – 4,000Ω
- Most ham mics are low impedance mics

Dynamic and Electret Mics

- Mics convert sound vibrations to voltage
- ***Electret*** mics have a pre-polarized capacitive diaphragm connected to a FET "follower" impedance converter. The FET needs a small DC voltage to operate.
- ***Dynamic*** mics have a diaphragm attached to a coil that vibrates in a magnetic field. These mics should not see DC voltage.
- Most modern ham mics are electrets, but dynamic mics work well with ham gear too

Laptop Mic Input (Conceptual)



- Tip is audio input
- Ring provides DC to FET in electret mic

Ham Mic to Laptop

- Most ham mics are electrets
  - Need power for the FET
- If a 3-wire 1/8-inch connector
  - Wire mic audio to Tip (audio input)
  - Wire mic "power" to Ring (+5V)
  - Wire mic audio ground to Shell
  - Wire mic shield to Shell
- In laptop, turn on mic pre-amp
  - Called "mic boost" in my Thinkpad
  - Not all sound cards have a mic pre-amp!
  - If no preamp, it may not be loud enough

Good Low-Cost Headset Mics

Pro Dynamic Mic to Laptop

- No power required
- Pro mics use XLR connector
  - Wire mic audio to Tip (audio input) (XLR pin 2)
  - Wire mic audio return to sleeve (XLR pin 3)
  - Wire shield to sleeve (XLR pin 1)
- In laptop, turn on mic pre-amp
  - Called “mic boost” in my Thinkpad
  - Not all sound cards have a mic pre-amp!
  - If no preamp, it may not be loud enough

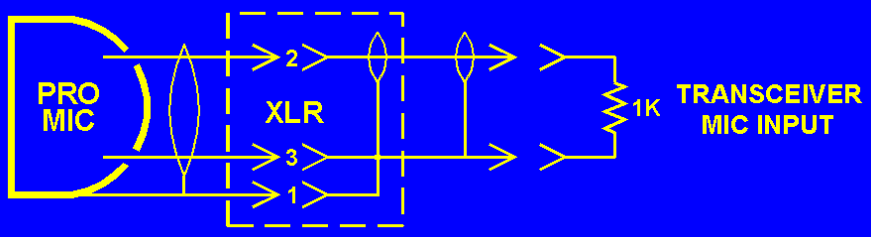
Pro Balanced Electret Mic to Laptop

- Balanced *Phantom power* is required
  - Cannot plug directly into computer
  - External phantom power supply and transformer are needed
  - Wire transformer output like a dynamic mic

Pro Pigtail Electret Mic to Laptop

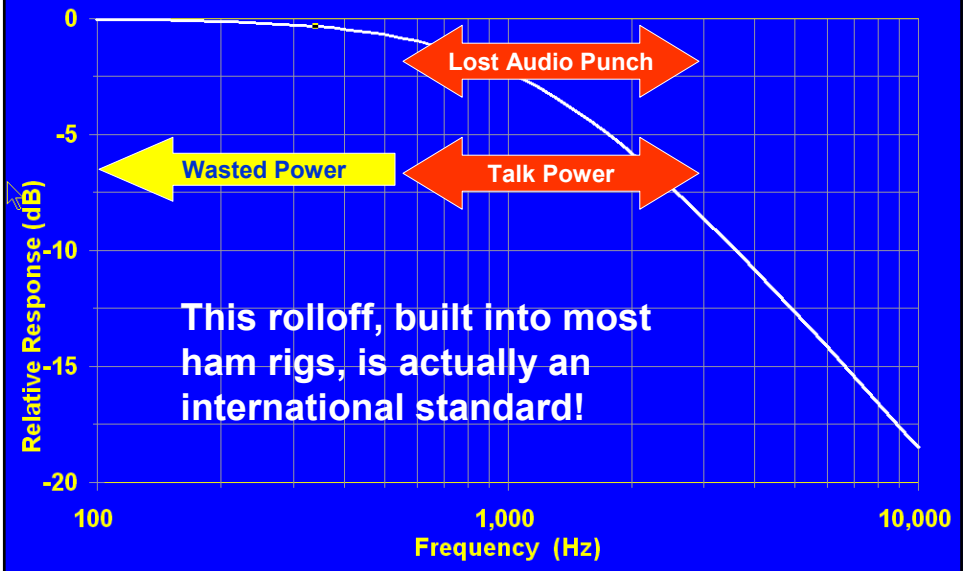
- Unbalanced electret mics with pigtail leads are built for use with wireless mics
  - Can work fine with a laptop
- On 1/8-inch TRS plug
  - Wire audio to Tip
  - Wire power to Ring (resistor may be needed)
  - Wire shield (audio return) to Shell

Pro Dynamic Mic to Ham Gear

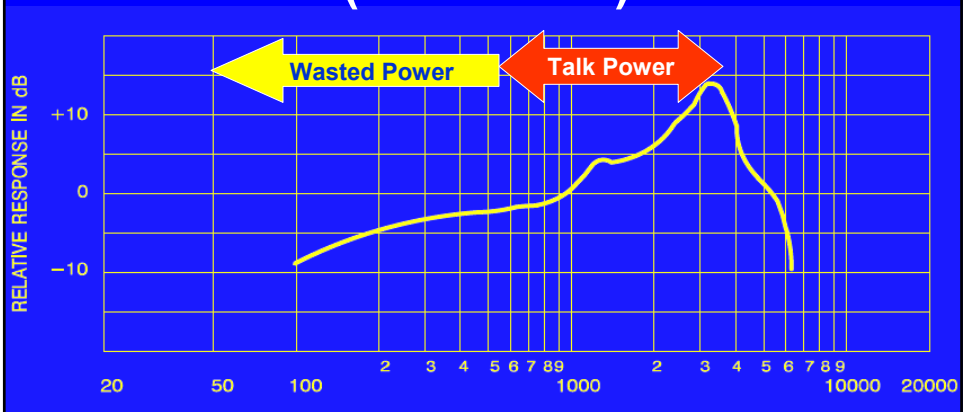


- Plenty of good clean audio
- But also a lot of low end we don't need!

The Frequency Response Problem

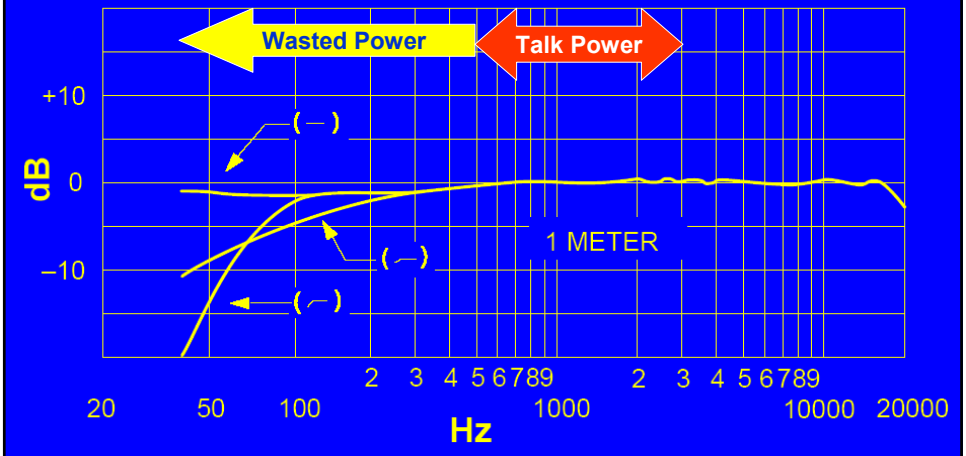


Typical Communications Mic (Shure 450)



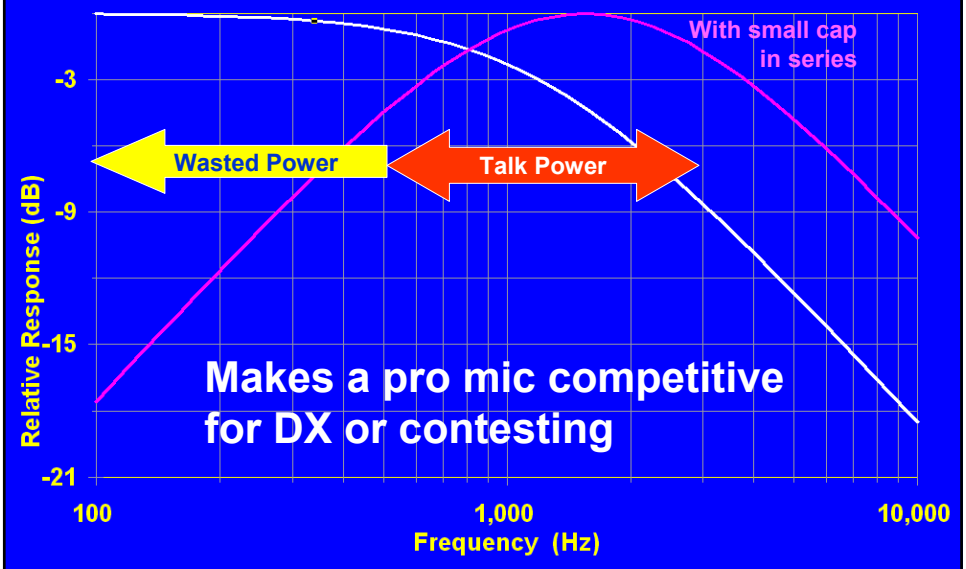
The response of the mic is tailored to correct for the lousy standard!

High Quality Professional Mic



Broad, flat response to sound great on music and voices

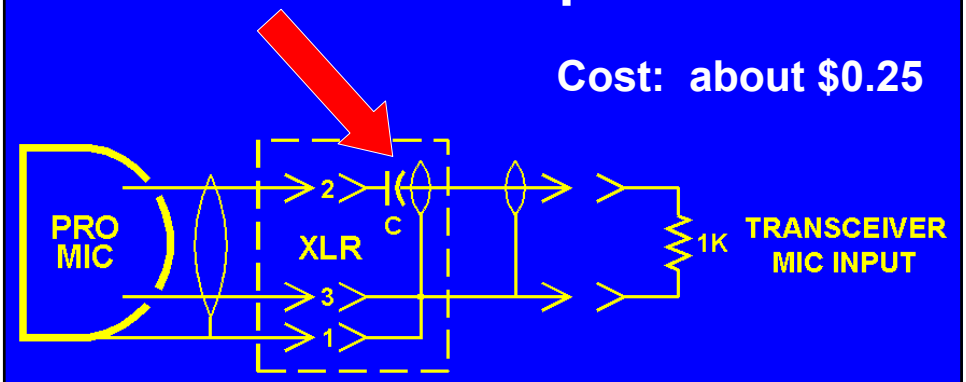
The K9YC Mic Equalizer



Makes a pro mic competitive for DX or contesting

The K9YC Equalizer

Cost: about $0.25

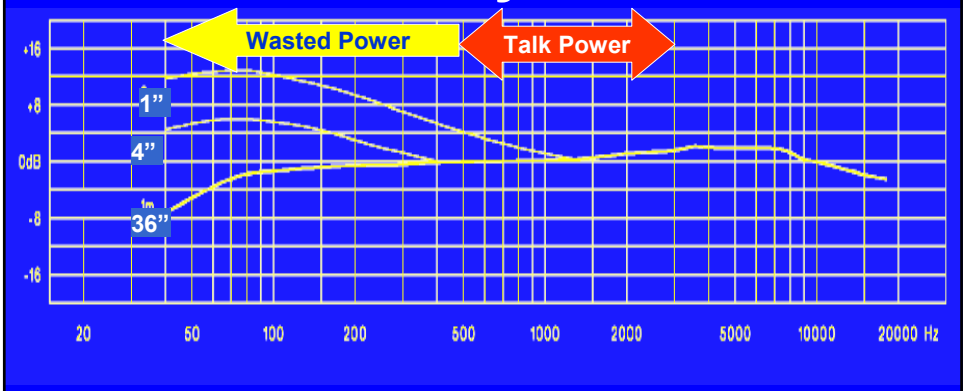


- Add capacitor in series with audio
  - C = 1 / (2πf R)
    - f is 3,000 Hz
    - R = (input Z of input stage) + (Z of mic)
    - In this example, C = 0.047µF

Directional Mics

- Most ham mics are omni-directional – they pick up sound from all directions
- Most performance mics are unidirectional
  - Pick up best from the front, reject room noise
- Most directional mics have proximity effect – bass is boosted for sounds very close to the mic
  - Breath pops
  - Very "bassy" sounding
  - Not good for communications!

Proximity Effect



- Bass boost when you talk very close to it
- Present in almost all directional mics
- K9YC equalizer will reduce it!
- Most pro mics have some low cut built-in

Directional Mics without Proximity Effect

EV RE20, RE27

EV RE11, RE16

AKG D202

AKG D224

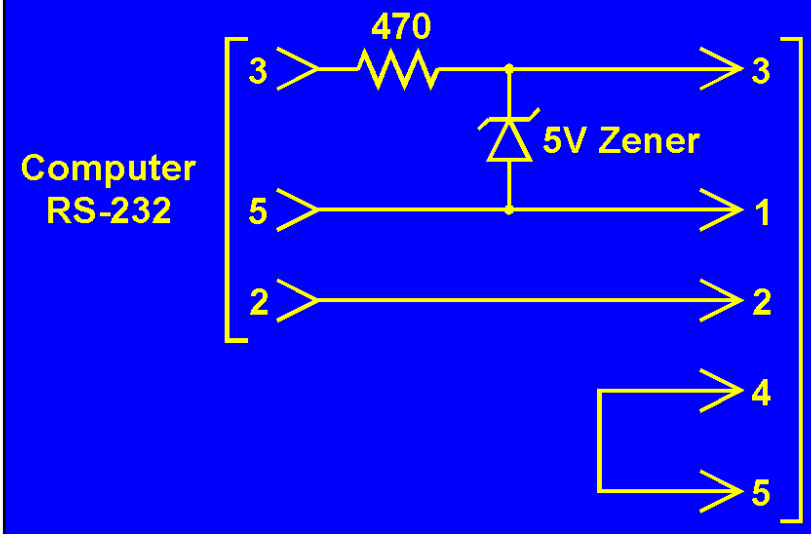
Control Functions

- Radio control
  - Read frequency, mode for logging
  - Remote control – change frequency, radio settings, filters, etc.
  - Elecraft, Kenwood, Yaesu have a serial port
  - Icom is proprietary, needs special adapter
- CW, PTT
  - Can be on same serial port used for control
  - Can be on a parallel port
  - Require a simple NPN inverter/level shifter
  - RTTY requires 2nd serial port for PTT

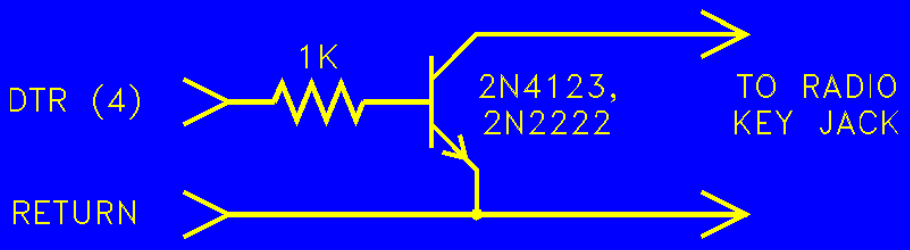
Control Wiring

- Interconnect is unbalanced
  - We must eliminate the noise voltage on equipment grounds
  - Only two circuits for radio control (pin 2, pin 3, return)
  - Twisted pair (CAT5) has best RFI rejection
- Send CW on COM DTR (pin 4)
  - Need simple NPN inverter/level shifter
- Send PTT on COM RTS (pin 7)
  - Same simple NPN inverter/level shifter
- Can use parallel port for CW and PTT

Low Cost Kenwood Interface

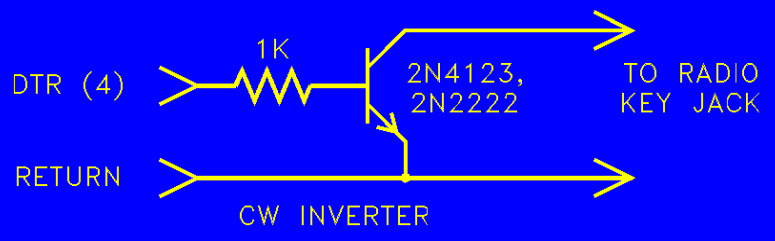


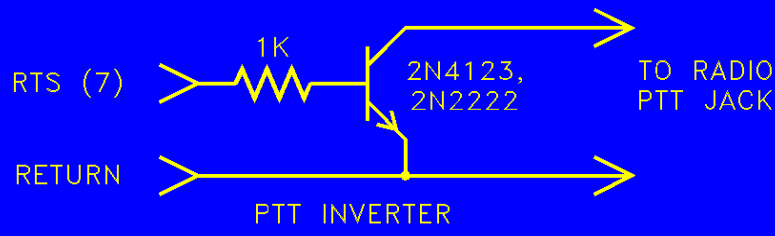
The CW Inverter



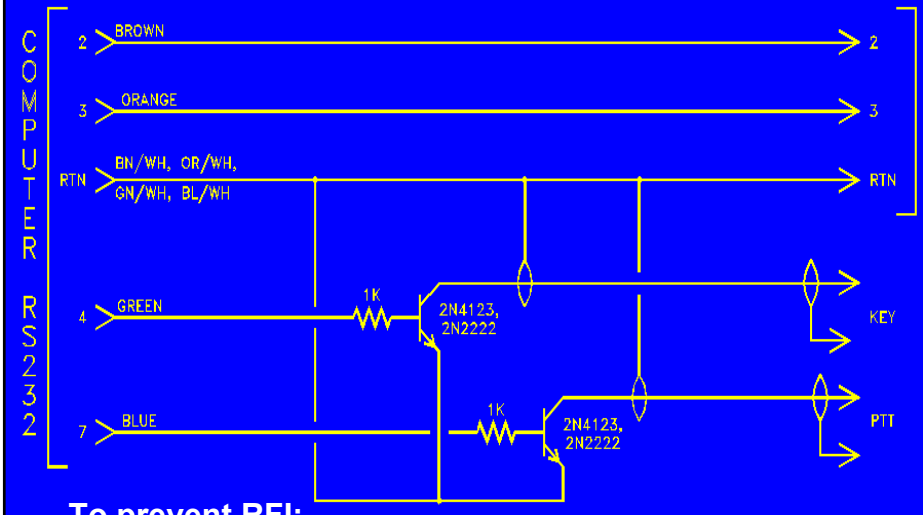
- Almost any small signal NPN works
- Can fit inside a DB9 M/F adapter
- Build a "thru" adapter to work with any radio
  - Carry control signals through it (pins 2, 3, common)
  - Break out CW and PTT (4, 7, common)

The Inverters





Serial Port Connections

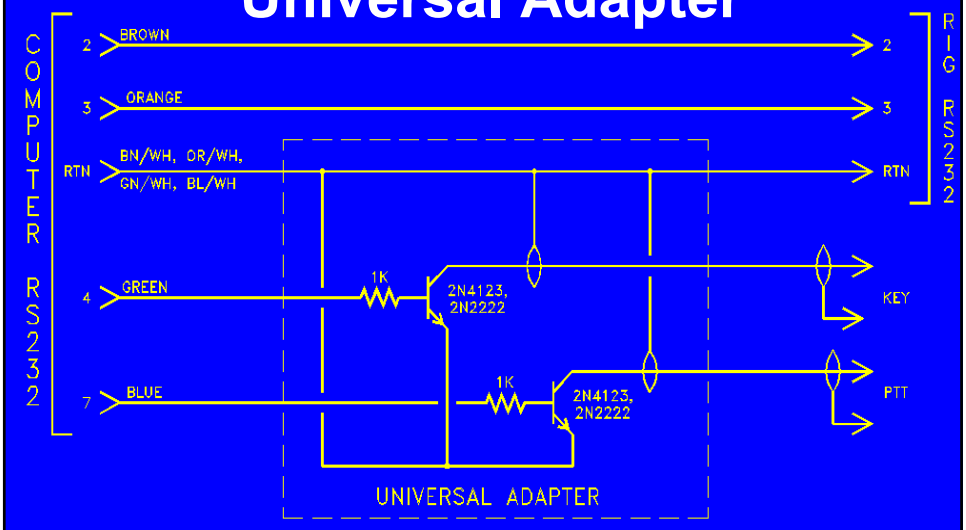


To prevent RFI:

Use CAT5 for computer to radio interface

Use chassis (DB9 shell) as return, not pin 5

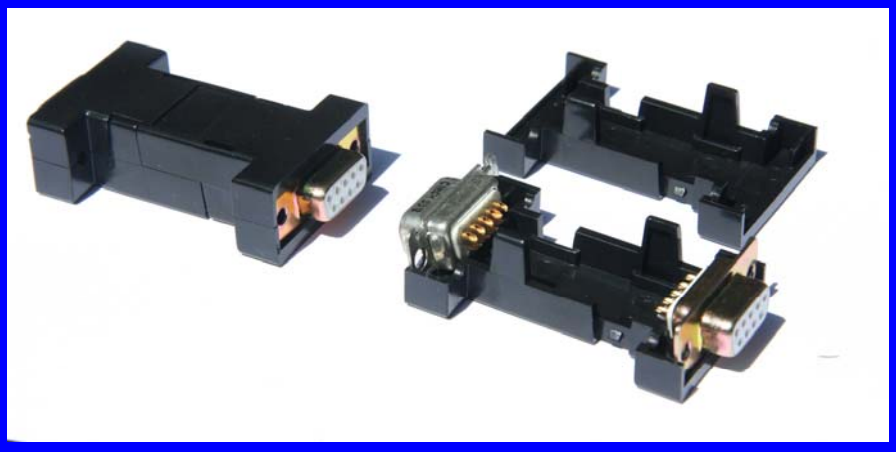
Universal Adapter



To prevent RFI:

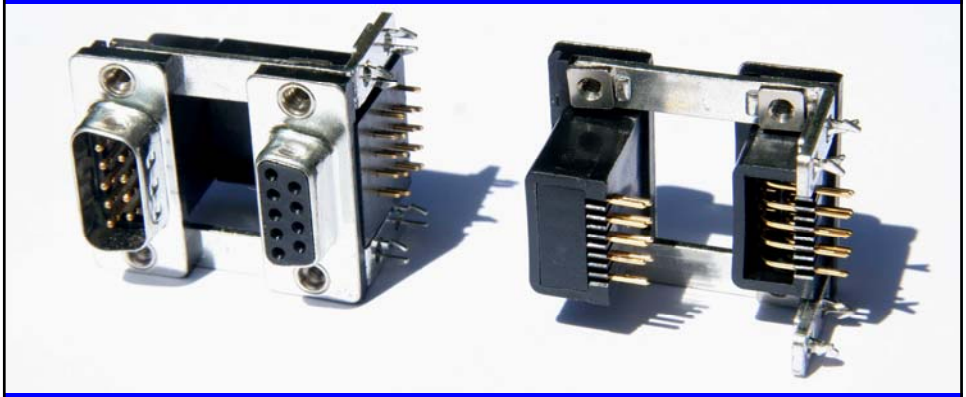
- **Use CAT5 for computer to radio interface**
- **Use chassis (DB9 shell) as return, not pin 5**

Universal Adapter



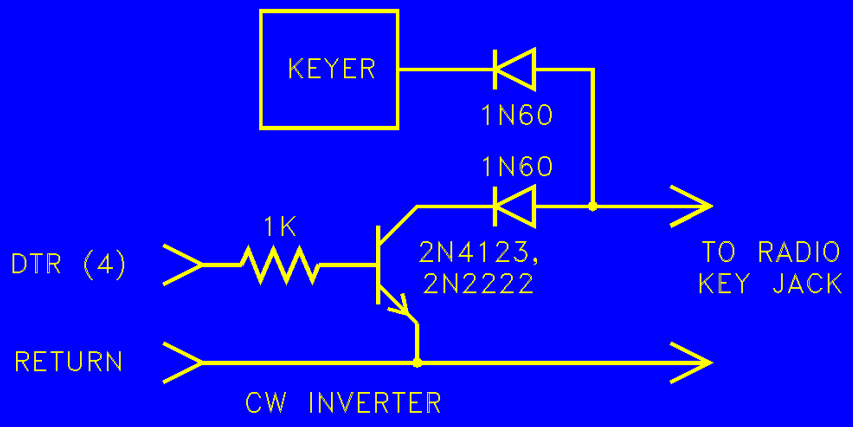
Jumper pins 2, 3, and 5
Add transistors, resistors for Key, PTT
Drill hole(s) for Key and PTT cables to exit

Universal Adapter



This costs about $1 at HSC
Remove jumper block between connectors
Add transistors, resistors, and jumps for 2, 3, 5

Adding a Keyer

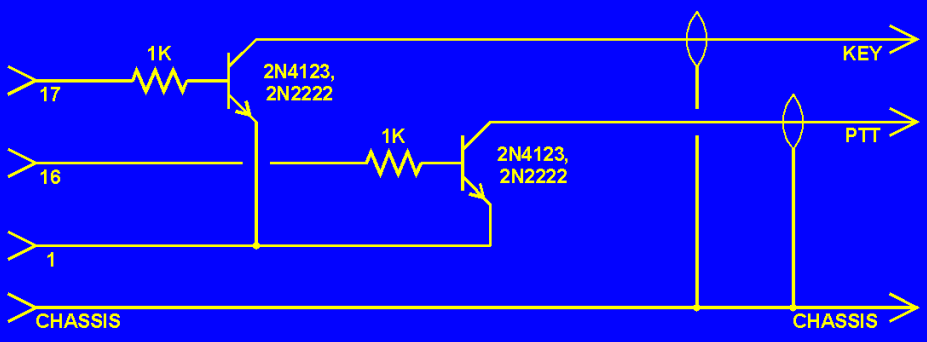


- Works with almost any keyer
- Si diode works with most radios
- Lower voltage of Ge diode may be needed

Adapter – Cost of Parts

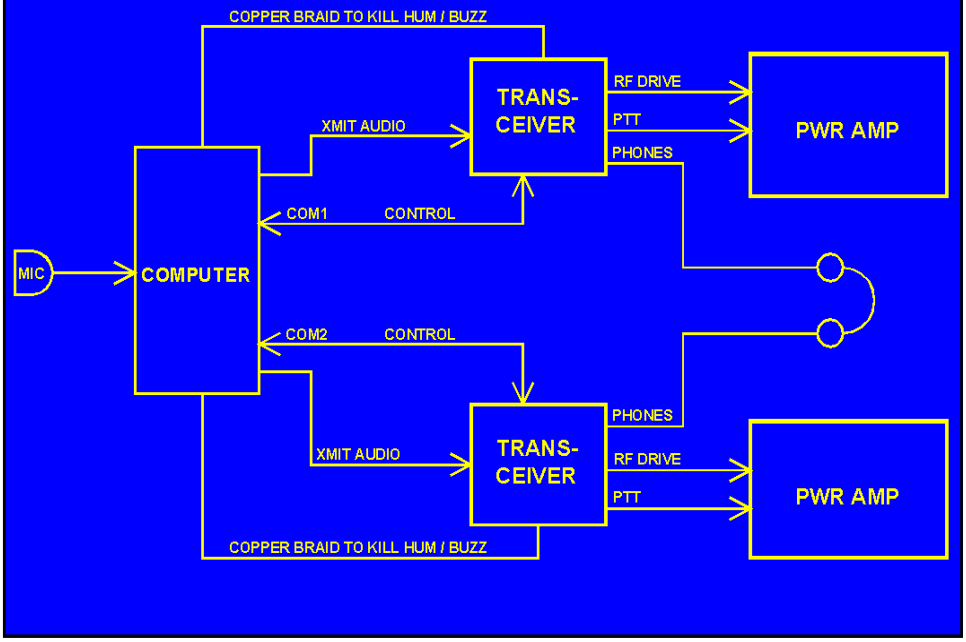
- Connector to hold adapter $1 - $2
- Transistors $0.20 at HSC
- Diodes $0.05 at HSC
- Resistors $0.01 at HSC
- DB9 Connector for Computer $1 at HSC
- DIN connector for radio $7 for a good one
- Plug for key input
  - RCA phono male $1
  - 1/4-inch stereo plug $2

LPT1: Inverters

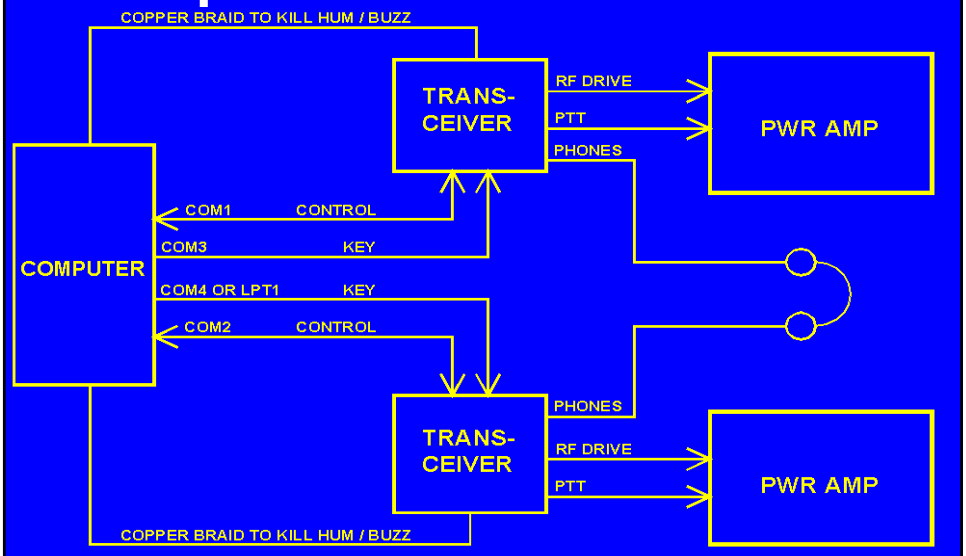


- Almost any small signal NPN works
- Can fit inside a DB25 shell or M/F adapter

Simple SSB SO2R with N1MM



Simple CW SO2R with N1MM



- **Due to limitations within N1MM, this does not work with all computers**

Audio Cables

- Miniature shielded twisted pair
  - Gepco XB401FB (foil/braid shield)
  - Gepco XB401 (braid shield)
- Unshielded twisted pair (CAT5, CAT6, etc.)
- Unbalanced cable
  - RG58 with braid shield

Junk DIN Connectors

- Virtually all DIN connectors sold to hams are JUNK (but they're CHEAP – about $1)
  - Contact metal doesn't take solder
  - Body of connector melts with heat
- Some guilty parties (Hams are cheap)
  - RF Connection
  - HSC
  - Digikey
- The good ones cost $5-$7 each
  - Switchcraft, Tuchel
  - Buy from Allied, Newark, etc.

Good DIN Connectors
buy from Newark, Allied, $5 - $7 each

Configuration	Switchcraft Part Nr
4 pins at 210°	09BL4M, 09GM4M
5 pins at 180°	05BL5M, 05GM5M
5 pins at 240°	12BL5M, 12GM5MX
6 pins at 240°	12BL8M, 15GM6MX
7 pins at 270°	15GM7MX
8 pins at 262°	20BL8M, 20GM8M
8 pins at 270°	15BL8MX, 15GM8MX

Choosing a Computer

- Use a modern computer for Windows
  - Windows 2000 Pro, XP Pro
- Use enough RAM (512MB)
- Consider a recent vintage laptop!
- Thinkpads work well for ham radio
  - Decent sound card, with mic preamp
  - T20-series, T30-series have a real serial port
  - T40-series and later have no serial card
    - Port extender adds serial port, stereo line inputs
    - Quatech PCMCIA card adds two real serial ports

Stuttering CW??

- Use a modern computer for Windows
- Use enough RAM (512MB)
- My 5 year old IBM T22 with W2K Pro runs
  - N1MM or WriteLog
  - DXKeeper
  - DXView (map)
  - Browser with Propagation
  - Browser with qrz.com
  - VE7CC Cluster software
  - Zone Alarm
  - Quattro Pro Spreadsheet

References

- *A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing* by Jim Brown
  http://audiosystemsgroup.com/RFI-Ham.pdf
  - *Chapter 8 – Solving Problems in the Shack*
  - *Appendix 6 – Audio For Ham Radio*
- *Ham Interfacing* (this presentation)
  http://audiosystemsgroup.com/HamInterfacing.pdf
- *Power and Grounding for Audio and Video Systems – A White Paper for the Real World* by Jim Brown
  http://audiosystemsgroup.com/SurgeXPowerGround.pdf

Computer to Rig Interfacing
–
You Don't Need to Buy an Interface!

Jim Brown
K9YC
Santa Cruz, CA
http://audiosystemsgroup.com