

HOW TO ELIMINATE NOISE SUCCESSFULLY

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Many Thanks to Larry Robinson

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Rules to eliminate noise in small signal applications:

1. DO use shielded cable or a twisted pair. Shielding a twisted pair is best.
2. DON'T use the shield as a signal conductor.
3. DO keep the shield at a FIXED potential relative to the circuit being protected.
4. DON'T ground the shield at both ends.
5. DO twist the signal pair.
6. DON'T splice low-level signal cables.
7. DO minimize the enclosed AREA exposed at the end of a twisted pair.
8. DON'T put other connector pins between the pins of a twisted pair.
9. DO put the shield pin next to the signal pins.
10. DON'T leave extra pins floating. Make a guard by grouping them around the signal pair and connecting them to the cable shield.
11. DO separate low-level signals from noisy signals, at right angles and as far apart as possible.
12. DON'T leave unused shielded conductors in a cable disconnected. Ground the signal conductors at the load, ground the shield at the source.
13. DO use a source with a low output impedance if possible.
14. DON'T use an unbalanced line if you can avoid it.
15. DO select a source with a center tapped output if possible.
16. DON'T make signal lines longer than necessary.
17. DO float all inputs with respect to ground.
18. DON'T ground a signal at more than one point.
19. DO tie all grounds together at a single point.
20. DON'T allow ground loops.
21. DO ground the signal at its source if possible.
22. DON'T use a common ground return for 2 or more signals.
23. DO put any surge protectors ahead of any ground fault circuit interrupters.

24. DON'T plug equipment in indiscriminately. Plug all signal handling equipment into a power strip, with one cord to the wall socket.

25. DO connect shielded equipment in the following way:

- If the source can be grounded, and the amplifier has a floating input guard shield, connect the cable shield to the source ground, and to the amplifier guard terminal.
- If the amplifier input shield is grounded internally, connect the cable shield to the source ground. Leave the other end disconnected.
- If the source cannot be grounded (mobile source), use a separate conductor in the cable to provide the ground reference for the source. Connect the cable shield to this conductor only at the source end.

Techniques for sources with single-ended inputs or outputs:

1. Make special cables with two conductors inside a shield. Connect one conductor to the signal terminal of both connectors. Connect the other conductor to the shield terminal of both connectors. Connect the shield to the shield terminal of one connector. Label that end of the cable "source." Do not connect the other end of the shield.
2. Where several low-level, shielded, unbalanced line cables run between the same two pieces of equipment, bundle and tie the cables together. This is better than using ground loop interruption when it works.
3. Do not bundle noisy or high-level signals or power in with low-level signals.
4. Where necessary cabling creates ground loops, make ground loop interrupters using short cable extensions. Cut the cable insulation at one end, and cut a gap in the shield conductor. This way, the shield is connected at only one end. Use these on all cables except those sufficient to ground everything together. Use the special cables mentioned earlier for those.
5. If disconnecting a grounding cable can cause damage to equipment from lack of ground, modify the ground loop interrupters as follows: Connect a 10 ohm resistor across the gap in the shield conductor. This is a good idea anyway.
6. Where a balanced line is necessary due to distance, a special amplifier can be placed at the source to make a balanced output from an unbalanced input.
7. For AC signals, use transformers to balance and unbalance signals.
8. Use a transformer to isolate an AC signal from ground for safety.
9. Where a source must be isolated from ground for safety, feed a DC coupled signal into a voltage-to-frequency converter. Send its output through a transformer or an optical link to provide the isolation. Then use a frequency-to-voltage converter to restore the original signal.

Audio techniques:

1. Do not use the shield as a signal conductor for phonograph and microphone signals. Connect the shield to the arm headshell, and the motorboard of the turntable. Run a separate ground wire from the motorboard to the

preamplifier. Connect the microphone cable shield to the preamplifier or mixer shield connection.

2. Use a balanced line where possible for a microphone. Use balancing transformers at each end, with the shield connected to the center tap and the short length of unbalanced line ground wire. (Do not use external transformers if phantom power is needed by the mic.)
3. Group and bundle stereo, quadraphonic, and surround sound cables.
4. Group and bundle record and play lines for the same tape recorder.
5. Group and bundle effects send and return lines.
6. Avoid ground loops where not bundled.
7. Make ground loop interrupters as follows.
 - Use a male and a female connector.
 - Connect the signal lines to the corresponding pins in each connector.
 - Connect a 10 ohm resistor from one shield terminal to the other.
 - Make sure any mounting box does not short the shield terminals together.
8. Keep speaker, power, phonograph, and microphone cables separated from each other.
9. Where microphones pick up breath noise, place the mic to one side of the vocalist, aimed at the mouth. This way, the breath misses the microphone, but the sound does not.
10. Use cup cozies to keep extraneous sounds out of microphones. Stick the handle of the mic through the hole in the bottom of the cozy, until the open end surrounds the sides of the mic element. These can also partially correct for room effects on mic placement.
11. Put a preamplifier before a long cable run, not after it.
12. If acoustic feedback from monitor speakers is a problem, and mic placement cannot be altered, reverse the phase of one or more of the speakers. It might be a good idea to put a phase switch on each speaker.
13. Sometimes it is better to use one set of mics for sound reinforcement, and another set for recording.
14. Distant mic placement is better for recording if done right. One good technique uses three mics. Aim two for left and right stage pickup, and the third for surround.
15. Ground everything at the mixer or control preamp.
16. Use one power cord, with a power strip, to power all of the audio equipment.
17. If a snake is used, run a power cord alongside to supply equipment at the other end. Separate the power cord from the snake by at least 30 cm (1 ft). This way, all of the equipment can be supplied through the same ground. It is better to have the main supply cord at the power amp location, rather than at the other end of the long cable run.

18. Do not run speaker wiring in the same snake as the microphones, unless sufficient internal shielding is provided. It is even better to put the power amps at the speaker end of the snake.
19. Use three-wire power cords throughout the system.
20. Keep the signal and power (chassis) grounds separate except at the mixer or control preamp. Use ground loop interrupters where separating grounds would cause an electrical code violation.
21. Make sure that rumble (mechanical noise) is not being mistaken for hum (electrical power line pickup). When the noise is present in the last silent grooves of a record, but not when you lift the pickup arm with a toothpick, it's rumble. If the noise disappears when the microphone is lifted, it's rumble.

Varying signal connections and how to interconnect them.

	Source		
Load	Grounded single ended source	Floating single ended source	Single ended source above ground
Grounded single ended load	<ol style="list-style-type: none"> 1. Use single conductor shielded cable with ground loop interrupter at load end.* 2. Use isolating transformer and single conductor shielded cable if DC not needed. 3. Alternately, use two conductor single ended shield cable, and isolate one of the grounds.* 	<ol style="list-style-type: none"> 1. Use single conductor shielded cable.* 2. Alternately, use two conductor single ended shield cable.* 	<ol style="list-style-type: none"> 1. NO! Above ground voltage shorted out through load ground. 2. Use a balancing transformer if DC not needed. 3. Alternately, use a balanced input amplifier.*
Balanced to ground load	<p>:</p> <ol style="list-style-type: none"> 1. Use balancing amplifier and two conductor shielded cable. 2. Use isolating transformer (or a direct box) and two conductor shielded cable. 	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable.* 2. Connect shield to source ground if available, or to load ground. 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable. 2. Watch the load offset!

	3. Alternately, feed only one side of the input (terminate the other side).*	3. Better if source impedance is low.	
Single ended floating and guarded load	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable.* 2. Connect shield to source ground, signal low to guard. 	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable.* 2. Connect shield to source ground, signal low to guard. 3. May have to ground the guard through a resistor. 	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable. 2. Connect shield to source ground, signal low to guard. 3. Load common mode rejection must be quite high.
Balanced floating guarded load	<ol style="list-style-type: none"> 1. Use two conductor shielded cable.* 2. Connect shield to source ground and guard. 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable.* 2. Connect shield to ground and guard. 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable. 2. Connect shield to source ground and guard.
	Source		
Load	Grounded balanced source	Floating balanced source	Balanced source above ground
Grounded single ended load:	<ol style="list-style-type: none"> 1. NO! Connecting both sides shorts out one side of source. 2. Alternately, use one side and terminate the other.* 3. Use two conductor single 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable.* 2. Connect shield to the load ground. 	<ol style="list-style-type: none"> 1. NO! Above ground voltage shorted to ground through signal source. 2. Alternately, use a balanced

	ended shield cable.		input amplifier.*
Balanced to ground load	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable. 2. Connect the shield at the source. 3. This is the second best arrangement. 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable. 2. Connect shield to load ground, and source center if available. 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable. 2. Connect shield to load ground. 3. Source impedance must be low. 4. Watch the offset. 5. If load is an amplifier, its gain must be low.
Single ended floating and guarded load	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable. 2. Connect shield to source ground, signal low to guard. 3. Source impedance must be quite low.** 4. Watch the offset. 5. Load common mode rejection must be quite high. 	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable. 2. Connect shield to source ground, signal low to guard. 3. If no source ground, connect the shield to the guard and ground it. 4. May have to ground the guard through a resistor. 	<ol style="list-style-type: none"> 1. Use two conductor single ended shield cable. 2. Connect shield to source ground, signal low to guard. 3. Source impedance must be quite low.** 4. Watch the offset. 5. Load common mode rejection must be quite high.
Balanced floating guarded load	<ol style="list-style-type: none"> 1. Use two conductor shielded cable. 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable. 	<ol style="list-style-type: none"> 1. Use two conductor shielded cable.

	<ol style="list-style-type: none"> 2. Connect shield to source ground and guard. 3. This is the best arrangement of all. 	<ol style="list-style-type: none"> 2. Connect shield to source ground and guard. 	<ol style="list-style-type: none"> 2. Connect shield to source ground and guard.
<p>* Common mode noise not rejected in this mode.</p> <p>** To prevent common mode noise.</p>			

Troubleshooting:

- **Power source or other signal picked up inductively:**
 1. Use a separate shield, connected at the source only.
 2. Twist the signal pair.
 3. Magnetically shield the source.
 4. Shorten the cables.
 5. Separate the cables or cross them at right angles.
 6. Minimize area at ends of twisted pair.
 7. Use separate ground return for each signal.
 8. Put an amplifier at the source, before the cable run.
- **Power source or other signal picked up capacitively:**
 1. Use lap-foil shield with low impedance drain.
 2. The shield must be at a fixed potential relative to the source.
 3. The shield pin must be adjacent to the signal pair pins.
 4. Make a guard around the signal pins with extra pins in the connector.
 5. Connect the shield to the floating guard of the load (if provided).
 6. Ground unused signal wires at load end, unused shields at source end.
 7. Connect all source and amplifier power cords to power strips plugged into the same cord.
- **Power source or other signal picked up by ground loops:**
 1. Only one ground per circuit.
 2. Use differential amplifiers with floating inputs.
 3. Ground the shield only at the signal source.
 4. If the source is mobile, supply a grounding conductor in the cable (in addition to the twisted pair), connect to the shield at the source end.
 5. Connect all grounds at the same point, a proper system ground.
 6. Keep other grounds away from the system.
 7. Group and bundle related single-ended cables together.

8. Connect all source and amplifier power cords to power strips plugged into the same cord.
- **Mechanical noise picked up by transducer or pickup.**
 1. Use carpets with pads to minimize vibrations from people walking nearby.
 2. Float all motors on damped resilient mounts.
 3. Don't work on an unsteady floor. A concrete slab is best.
 4. Eliminate the source of mechanical noise.
 5. Float the transducer on a vibration reducing mount.
 6. If possible, tune the mountings with weights and damping to remove the most noise.
 7. Rigidly mount the transducer to a large unmoving mass.
 8. If the transducer must be able to move (example: a phonograph pickup), dynamically balance all of the moving parts, so a motion imparted to the mount is not transferred to the transducer.
 9. Float the entire experiment on a massive concrete pad with damped resilient mounting.
 10. Use hanging curtains, acoustic ceilings, bass traps, stuffed items, and styrofoam to eliminate air vibrations.
 11. Move to a location away from forklift, truck, train, and low air traffic.
 - **Inadequate common mode rejection:**
 1. Pay attention to the specifications of the source and load.
 2. Use a center-tapped signal source.
 3. Use a balanced line.
 4. Confine all paths for the same signal to the same cable.
 5. Connect the shield to the floating guard of the load (if provided).
 6. Ground the signal circuit only at the source.
 7. Provide a good ground.
 8. Connect all source and amplifier power cords to power strips plugged into the same cord.
 - **Signal source loaded down:**
 1. Make load impedance at least 1000 times source impedance for maximum voltage transfer.
 2. Load impedance must equal source impedance for maximum power transfer.
 3. Where maximum power transfer is needed, don't tap off to other loads.
 - **Ineffective temperature compensation:**
 1. Pay attention to the specifications.
 2. Use 3 or 4 wire temperature compensation cable for any bridge system.

3. Arrange circuits physically for proper compensation.
 4. Don't forget the reference junction of a thermocouple and its location.
- **Thermo-electric drift:**
 1. Strip down to bare metal.
 2. Use cadmium solder.
 3. Pay attention to the specifications.
 4. Avoid junctions between different metals without corresponding reverse junctions at the SAME temperature.
 - **Variable contact resistance:**
 1. Solder, fuse, weld, or screw down the connection if possible.
 2. Use spring pressure and wiping action on moving contacts.
 3. Use compression connectors.
 4. Keep everything clean.
 5. Amplify before the connector.
 6. Use sufficient voltage to overcome oxides.
 7. Use an impedance that minimizes contact problems.
 - **AC line transients get into signal:**
 1. Connect all source and amplifier power cords to power strips plugged into the same cord.
 2. Use power line filter.
 3. Use spike suppressor.
 4. Use isolation transformers with faraday shield.
 5. Use tuned transformer-capacitor combination.
 6. Eliminate the source of the offending transients.
 7. Use a motor-generator set.
 8. Use a power conditioner.
 9. Use an uninterruptable power supply.
 - **Line transient filter trips ground-fault circuit interrupter.**
 1. Place the transient filter upstream of the ground-fault circuit interrupter.
 2. Use a choke-input filter.
 3. Filter only the hot and neutral of the power line, not the equipment ground.
 4. Use a combination line-filter-GFCI made for the job.
 5. Make sure harmonics from discharge lighting are filtered out ahead of the GFCI.

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