Neuralynx ~ TechTips

Noise Debug 101 - Introduction

Noise is any unwanted signal that contaminates your desired signal. It may originate internally from other bioelectric signals or externally from any voltage or magnetic energy source. There are many external noise sources from our high-tech world, many of which are generated by necessary technology such as computers and AC wall power. The challenge for neuroscience researchers is to find solutions that reduce or eliminate the noise source or reduce the coupling of the noise into the recording setup.

Magnitude of Signals

The challenge of noise in the electrophysiology environment is the magnitude of the desired signals from the brain (microvolts to millivolts) to the external noise sources (hundreds of volts) in the laboratory environment. This represents a “100 Million to One” ratio of desired signals to noise sources.

The good news is that noise signals can be greatly reduced or entirely eliminated through proper identification and coupling reduction techniques! Part 5 of this series will cover recording techniques used to eliminate noise signals on our electrophysiology data.

Key Electrical Engineering Concepts & Terms

1. A signal (current) always flows in a complete loop. It is important to keep the “loops” in mind when analyzing the source of the noise and how it is coupled into your recording circuit. The total voltage drop around a loop is always ZERO.
2. Whenever current flows through a conductor, there is a voltage drop because every conductor has resistance.
3. Ohm’s Law is key to this discussion: V = I * R Voltage drop = Current times Resistance.
4. Changing signals (AC signals other than static DC values) will be conducted by capacitance as well as by conductors; there is capacitance between any two metal objects anywhere in space. The higher the frequency of the noise, the better it will be conducted by capacitance.
5. A changing magnetic field will induce a voltage and current flow into a conductor, single wire or a loop of “turns.” The magnitude of the induced signal is based on the number of turns in the loop and the area of the loop.
6. Ground is not absolute! There is no such thing as a “perfect earth ground.” Ground is only a point where measured voltages are relative to: you can measure significant voltages between two different close locations in the earth.
7. Voltage drops in a circuit (loop) are based on the ratio of component impedances of each component.
8. Impedance and Resistance are very similar: Resistance is for “steady state” DC circuit analysis; and Impedance is for the AC frequency circuit analysis. Both are measured in Ohms, but impedance has an

"imaginary or complex component" resulting in a "phase shift."

9. The term "Ground Loop" is often misunderstood. When you have an "extra conduction path" around a circuit, it usually does not result in "magnetic coupling into the ground loop" creating current flows and AC power line frequency noise.

Noise "Sherlocking"

When you observe an external noise signal in your recordings, you must first identify the noise source. This is done by observing the signal and answering such questions as:

- Is it at the AC Power Line frequency or a multiple of the frequency?
- Is it dependent on location?
- Is it dependent on a piece of equipment being turned on or plugged in?
- Does you hear anything unique, like music, when listened to?

These will all provide you with clues about the source of the noise.

After you determine the noise source, you need to run some experiments to determine the external coupling type that is causing the noise to "get into your setup." For example, a florescent light has three possible conduction types: electrostatic from the high voltage (120 or 220VAC), magnetic from the turns of wire in the ballast; and RF from the high frequency "sharp edges" of the florescent tube starting and stopping current flow on every ½ cycle of the power line voltage cycles. Note: "Getting out the aluminum foil" for every noise problem usually doesn't work and the "fix" may be rather inconvenient.

Once you identify the source and coupling type, it is usually easy to implement a solution to resolve your noise problem, delivering clean, recorded signals!

Our **Noise Debug 101** series will examine the physics behind each coupling type and the method(s) for designing an experiment that test for its magnitude.

Parts 1-4 address the four main types of external (environment) noise signals:

- Part 1 - Conducted Noise (common path voltage drop)
- Part 2 - Electrostatically Coupled (voltage coupled)
- Part 3 - Magnetically Coupled
- Part 4 - Radio Frequency Coupled
- Part 5 - Brain Electrode Interfaces, focuses on recording techniques used to eliminate noise signals on your electrophysiology data.

Noise Debug 101

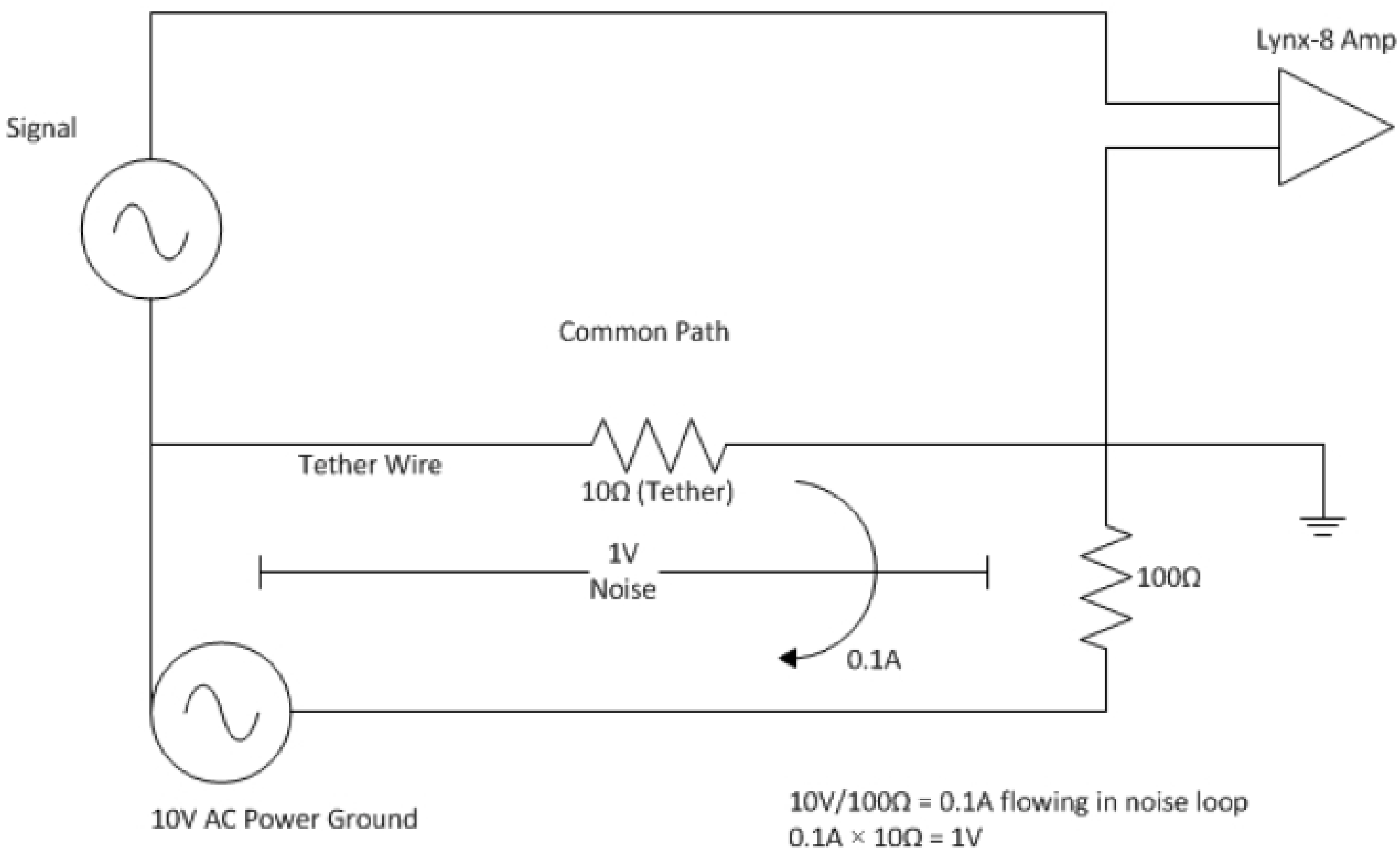
Part 1 - Conducted Noise (common path voltage drop)

Remember that current ALWAYS flows in a loop/circle; the electrons MUST return back to the source.

Conducted noise coupling occurs when the expected signal path (usually in the return portion of the loop) is in common/contact with the noise source's signal path.

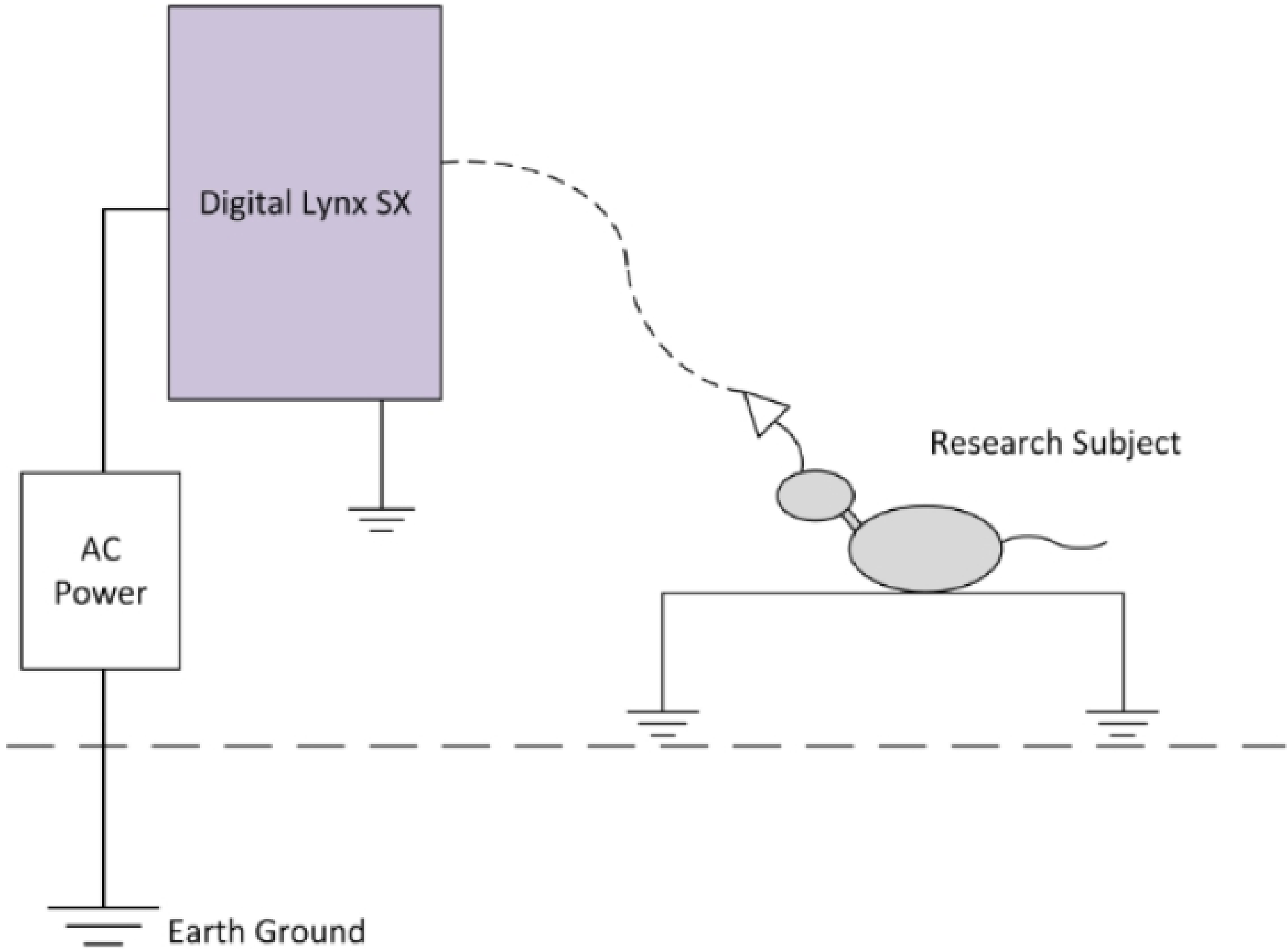
Because the desired signal and the noise signal share a common section of each one's path, the voltage drop on the common section will be the summation of voltage drop of the two signals' paths.

Schematic of Conducted Noise Path Coupling



Ohms Law yields 10V/110ohms ~= 0.1A flowing in the bottom noise loop. The tether has a resistance of 10 ohms, 0.1A*10ohms = 1V.

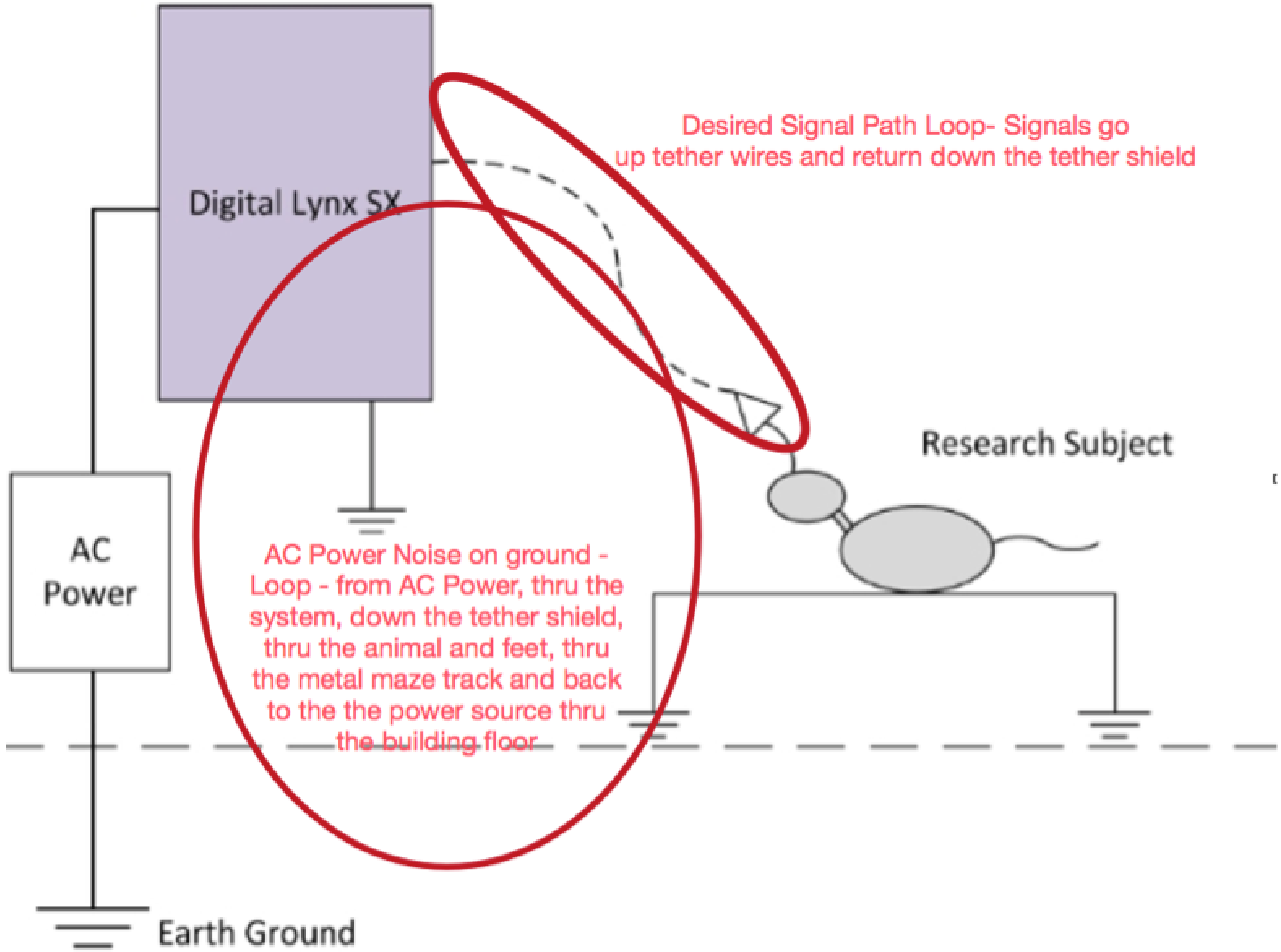
Lab Setup Example: Common Conducted Noise



The diagram above demonstrates a conducted loop situation that has occurred in several laboratories. The subject is placed on a metallic track that has been "well grounded." AC power line noise of a few millivolts is observed on the neural signals from the subject's headstage as recorded on the Digital Lynx SX system.

Note: In most large buildings, currents will flow through the building structure (even through concrete) because electrical power circuits are connected to the building's metal structure.

When we examine and model the possible signal flow "loops," we identify two that can flow through the subject's tether. On first observation, there should not be any current flowing from the connections to ground because there "should not" be any voltage difference in the grounds. But 1) because any current flowing through the conductors to ground will cause a voltage drop on the conductors; 2) because of the current flowing through the building; and 3) because there may be a long distance between the power outlet for the system and the main power distribution panel where the system's "power ground" would be connected to the building, several volts may be present between the grounds in this diagram. Therefore the voltage between the metal track ground and the Digital Lynx SX ground may be significant. The signals between the subject track and the system will add to the buffered neural signals from the headstage.



Solution: Insulate the subject track from the floor with a good non-static, non-conductive material, such as wood or synthetic rubber mat material. This will break the conduction path of the current in the AC Power Ground loop. Also, all equipment, computers, amplifiers, behavior control apparatus, etc. connected for the experiment should be plugged into the same power strip.

This is one instance where the term “Ground Loop” is applicable.

Read our Frequently Asked Questions Check out more TechTips Contact support@neuralynx.com with any noise debug questions!