**Identify clearly the exact subject of the experiment.**

Todays experiment will focus on the characterization and mitigation of signal noise.

**Give readers the necessary context and background required to understand your results and analysis method.**

Noise is the result of the often unintentional coupling between signals (Ott, pg. 22)

Noise is quantified using a metric called the **signal-to-noise ratio (SNR)**. This can be computed using either the amplitude of the signal, or the peak-to-peak signal. Often SNR is measured in decibles (dB).

There are two types of signal noise, electrical and magnetic.

Electrical noise is caused by any wire acting as an antenna.

Electrical noise can come from power cables, other equipment, or radio signals (Otto, pg. 1)

Magnetic noise can be caused by nearby motors and transformers.

Methods of reducing interference involve (Ott, pg. 26)

1. Shielding
2. Grounding
3. Balancing
4. Filtering
5. Isolation
6. Separation and orientation
7. Circuit impedance level control
8. Cable design
9. Cancellation techniques.

Noise can be reduced by using shorter wires, shielding, twisting wires, or implementing a differential amplifier.

Shorter wires reduce the effectiveness of the unintentional antenna.

Shielding adds an additional grounded antenna that works to intercept interfering radio energy and drain it to ground. Shielding can take the form of a foil or metal braid raped around the wire, and in some cases is as simple as a single bare wire that makes loops long the length of the signal wire.

The effectiveness of a shield against electrical interference can be measured (Ott pg. 165)

Twisting wires is the first technique attempting to specifically limit the effects of magnetic interference. As the flux lines of a magnetic field move into the area of a loop of wire, a current is produce in that wire according the right hand rule. Tightly twisiting the signal wires is an attempt to reduce the loop area, and proportionally reduce the interference. Additioanlly, the direction of the area is reversed with each twist, so any noise in one loop is canceled out by the next.

Finally, a differential amplifier is a way to eliminate the effects of noise without directly attenuating the noise. Interference is expected to affect all signal wires in a cable the same way and by a similar amount. A differential amplifier takes the signal as the difference between the signal and ground wire voltages. In this way, if the voltage in the signal and ground wires is raised equally due to noise, the signal measured at the output of the differential amplifier will not change. This is called **common mode noise rejection**.

An additional source of noise can arise from poor grounding techniques. If large currents are being dumped into the ground plane in one portion of the circuit, any resistances in the ground plane will cause the voltage of the ground plane in that portion of the circuit to rise. In this way, the ground become different between the source of a signal, and where it is received. Often, this can be mitigated using what is called a **mecca ground**. A single point in the circuit where all ground connections are wired together.

**Provide motivation and importance/applications.**

A transducer is a device that converts a physical quantity such a pressure to an electrical signal. Often this signal is an analog voltage or current proportional the quantity being measured by the transducer.

Transducers are subsequently connected to a data acquisition unit (DAQ) that converts the electrical signal into a form the computer can record and understand.

When noise is enough to prevent normal sensor operation it is called **interference** (Otto, pg. 4).

**Present a list of objectives that are expected to be accomplished at the end of the experiment.**

This report has three goals.

Practice the techniques of singe variable statistics.

Understand and characterize sources of noise in measurement.

Understand and implement common noise reduction techniques.

**Materials and Methods**

The voltage reference was powered with 5.0 V using the voltage source output of the Analog Discovery II (Digilent, National Instruments Edition Part# 750290-01)

Cable lengths were 1 m, 3 m, 5 m (39”, 118”, 196”)

3 m cable is (40 TPM, 15 TPM, 7 TPM)

3 m cable, unshielded, shield, grounded shield.

Four noise reduction techniques were used to reduce the noise in a pair of signal wires. In each setup, one wire was connected to the positive oscilloscope input, and the other to one of the grounds. The oscilloscope was set to acquire 5 seconds of data at 1 V/div totaling 8,192 data points. For all experiments type MTW, 20 AWG, 10-strand, 600 V copper wire (AutomationDirect Part# MTW20WB) was used.

To test the effect of wire length, pairs of wire were cut to 1, 3, and 5 m.

To test the effect of shielding, a 3 m length pair of wires was wrapped in a single wrap of aluminum foil (Simply Done brand). The experiment was repeated once with the shield bonded to ground, and once without.

To test the effect of twisting, 3 m pairs of wire were inserted into a drill chuck and twisted until the desired twist-per-meter (TPM) was reached. Twist densities of 7, 15, and 40 TPM were used.

To test the effect of single versus differential ended input, the 3 m control was tested once with the ground wire bonded to the Analog Discovery II ground, and once with the ground wire inserted into the negative oscilloscope input.

For Part II a 400 mV DC signal was generated on the Analog Discovery II and read by a single-ended oscilloscope input. A standard 3 m, untwisted, unshielded wire was used.

**Results and Discussion**

**Part I**

Describe the accuracy and precision of the two multimeters that you used

Compute the mean and standard deviation of the measured voltage signals

Should any data points be eliminated?

**Part II**

Compute the mean and standard deviation of the measured voltage signals

**Part III & IV**

**Log**

**September 15th 2 PM – 7 PM**

Repeated experiment at home with different wires and Analog Discovery II

Plotted histograms in python

Wrote out procedure that was followed.

**September 16th 12:30 PM – 1 PM**

Reproduced parts II and IV on Analog Discovery II

**September 16th 12:30 PM – 3:30 PM**

Refractored data analysis code in Python

Tweaked and plotted graphs.

Performed FFT

Produced histogram of *pure* sine wave to demonstrate non-normal distribution

Experimented with box-and-whisker plots.

**September 17th 7 PM – 8:30 PM**

Developed tools for testing normality

**September 18th 12 PM – 1 PM**

Worked on discussion.

**September 18th 6 PM – 8:30 PM**

Started typing up report in LaTeX and inserted figures.