PHY405-L10

Noise

Acquisition Mode: Normal vs High Resolution?

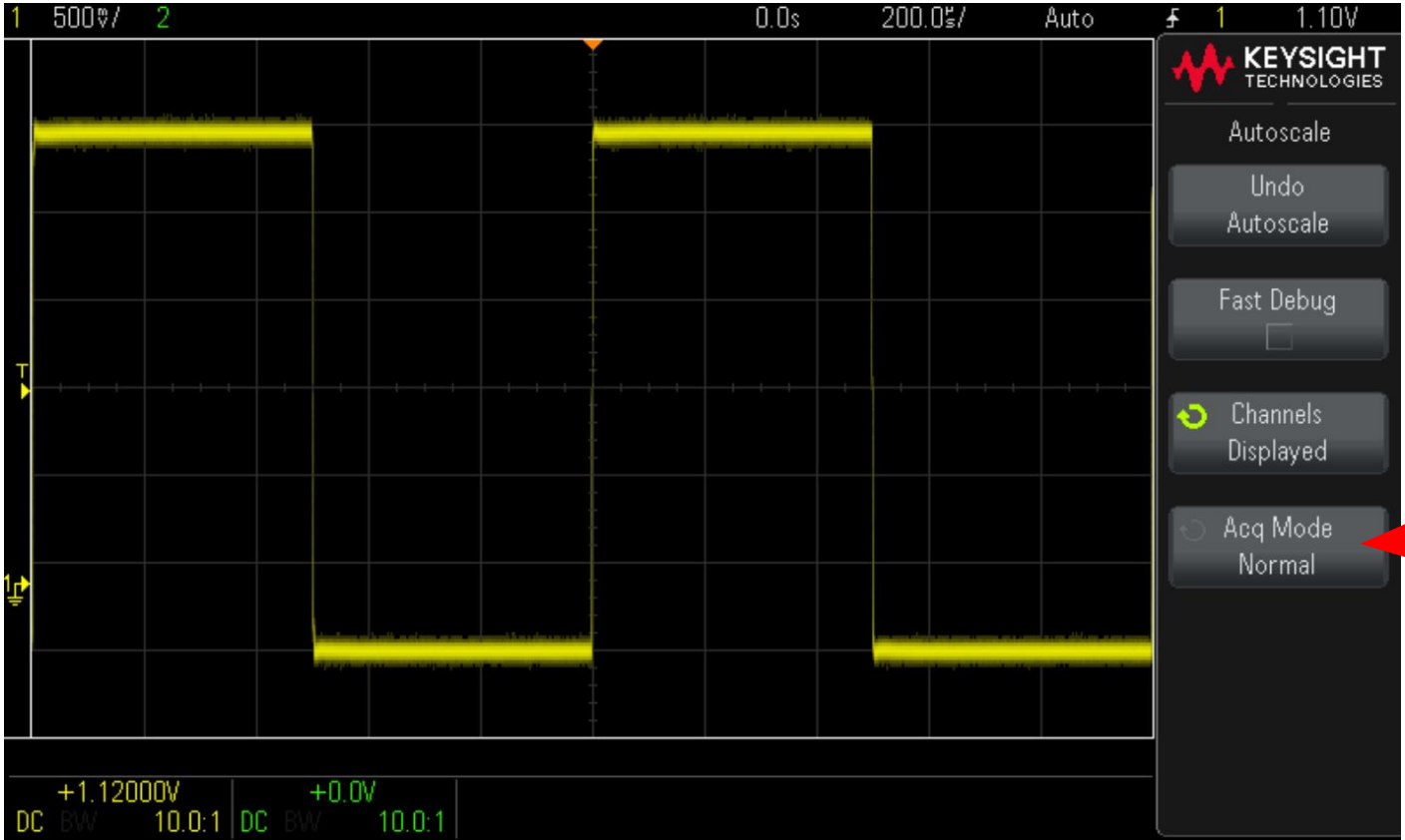


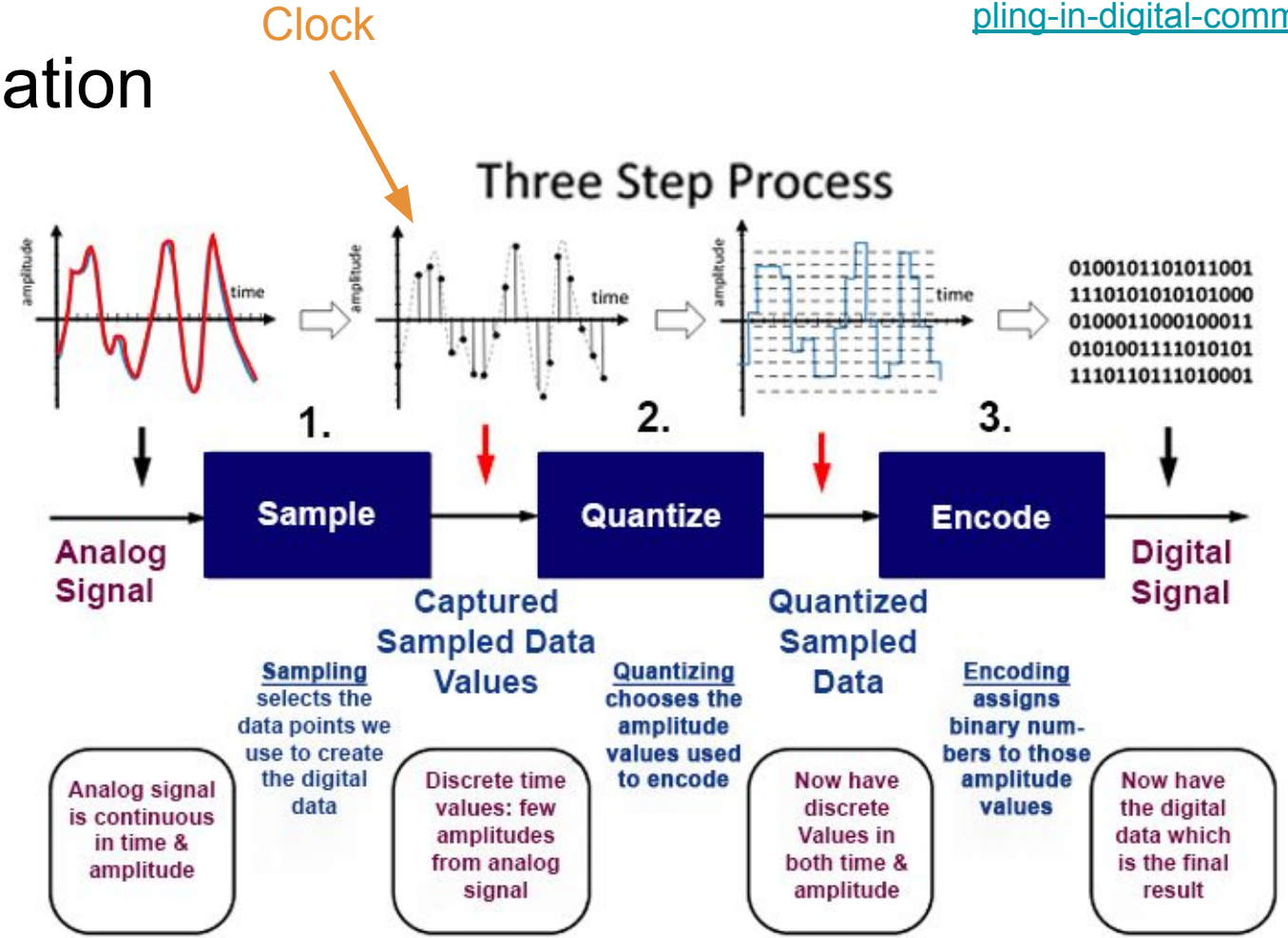
Table 16 Acquisition Features

When selecting the oscilloscope acquisition mode, keep in mind that samples are normally decimated (thrown away) at slower time/div settings.

Feature	Front Panel Key/Softkey Location (see built-in help for more information)
Acquisition mode	**[Acquire] > Acq M**
Normal acquisition mode	**[Acquire] > Acq Mode, Normal** At slower time/div settings, normal decimation occurs, and there is no averaging. Use this mode for most waveforms.
Peak detect acquisition mode	**[Acquire] > Acq Mode, Peak Detect** At slower time/div settings when decimation would normally occur, the maximum and minimum samples in the effective sample period are stored. Use this mode for displaying narrow pulses that occur infrequently.
Averaging acquisition mode	**[Acquire] > Acq Mode, Averaging, [Acquire] > # Avgs** At all time/div settings, the specified number of triggers are averaged together. Use this mode for reducing noise and increasing resolution of periodic signals without bandwidth or rise time degradation.
High resolution acquisition mode	**[Acquire] > Acq Mode, High Resolution** At slower time/div settings, all samples in the effective sample period are averaged and the average value is stored. Use this mode for reducing random noise.

Digitization

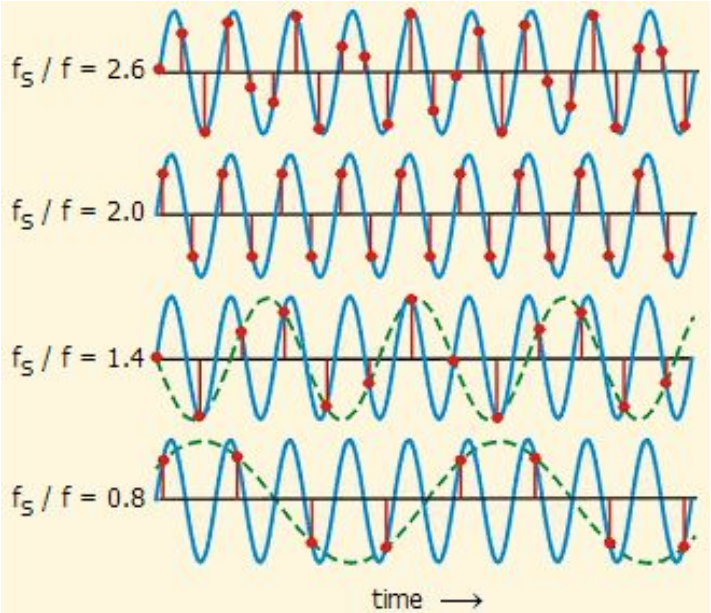
https://www.geeksforgeeks.org/sampling-in-digital-communication/



https://en.wikipedia.org/wiki/Nyquist%E2%80%93Shannon_sampling_theorem

Nyquist–Shannon sampling theorem

- Sampling frequency (f) used when digitizing an analog signal
- Max frequency component can be resolved is f/2
  - → Nyquist frequency
- Frequency components above f/2 are “aliased” below f/2

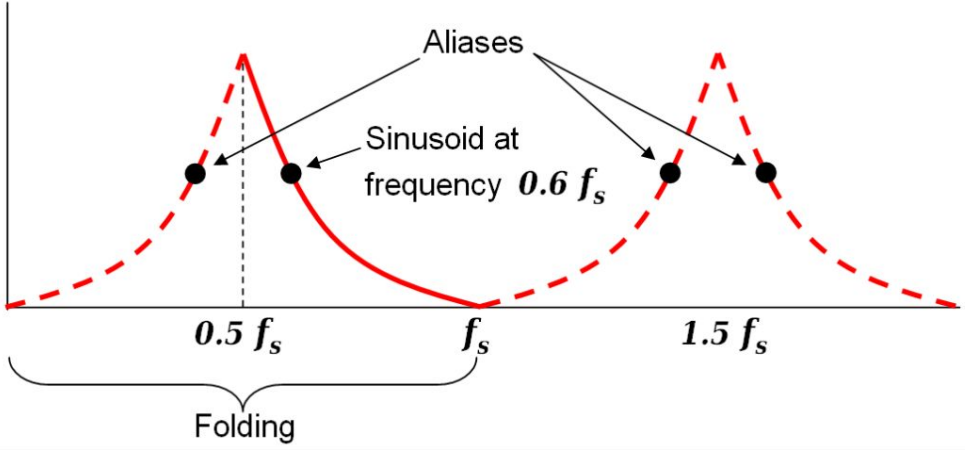


http://webapps.chem.uoa.gr/efs/applets/AppletNyquist/Appl_Nyquist2.html

https://en.wikipedia.org/wiki/Aliasing

Aliasing

- Turn to frequency domain
- Frequency above Nyquist frequency gets “folded” in
- → Unusable information



examples of aliasing

This full-sized image shows what a properly sampled image of a brick wall should look like with a screen of sufficient resolution.

When the resolution is reduced, aliasing appears in the form of a moiré pattern.

https://en.wikipedia.org/wiki/Noise_%28electronics%29

Types of noise we often deal with

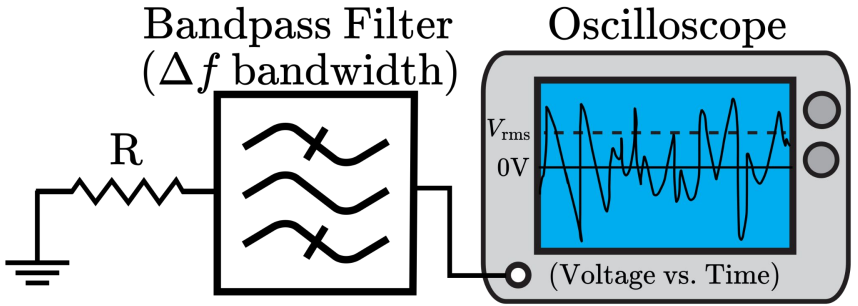
- Johnson–Nyquist noise
  - $v_n = \sqrt{4k_B T R \Delta F}$
  - Irreducible noise
  - From electron random motion
- Shot noise
  - $i_n = \sqrt{2Iq\Delta B}$
  - From “when the charge carriers (such as electrons) traverse a gap”
- Flicker noise (1/f noise)
  - Power vs frequency looks like 1/f
- More often in the lab: **Coupled noise**

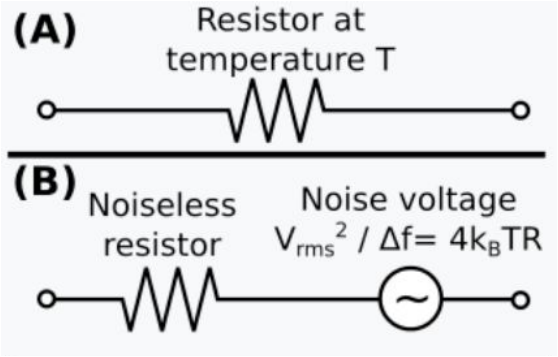
https://en.wikipedia.org/wiki/Johnson%E2%80%93Nyquist_noise

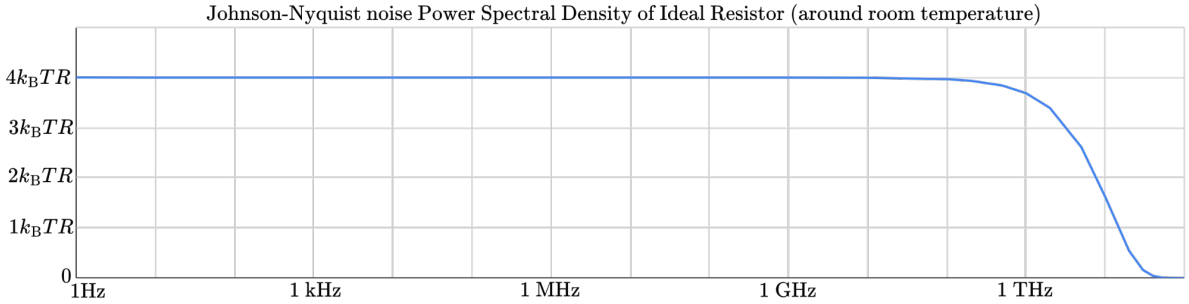
Johnson Nyquist Noise

$$v_n = \sqrt{4k_B TR\Delta F}$$

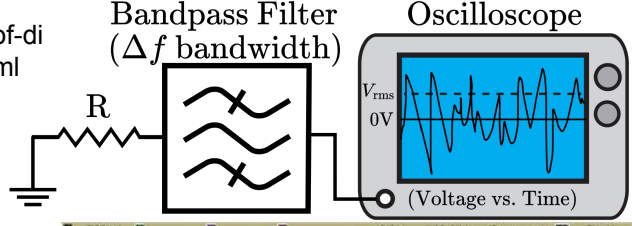
- Resistor is a noise voltage source
- Amount of noise scales with bandwidth





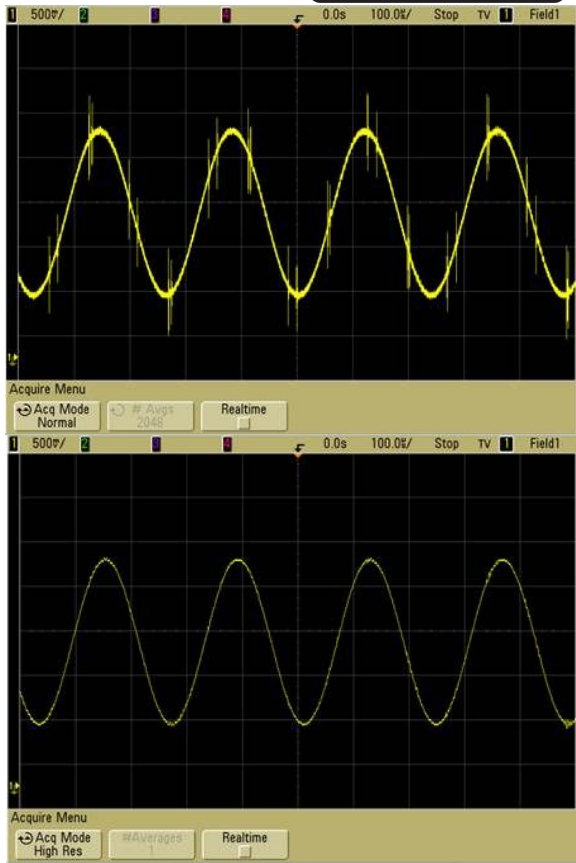


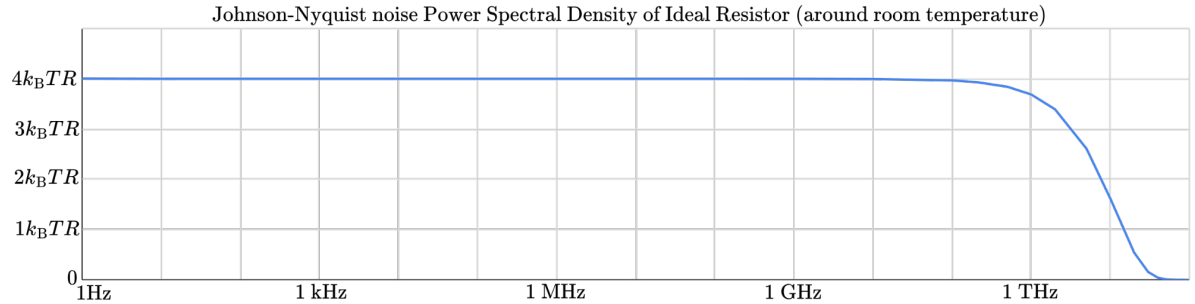
https://docs.keysight.com/kkbopen/the-difference-of-different-oscilloscopes-in-hires-mode-577943002.html



Oscilloscope “wiggles”

- Normal mode doesn’t limit bandwidth
  - → Aliasing, and showing unnecessary noise beyond frequency region of interest
- “High Res” mode reduces bandwidth with an averaging filter
  - → More proper frequency range, less noise

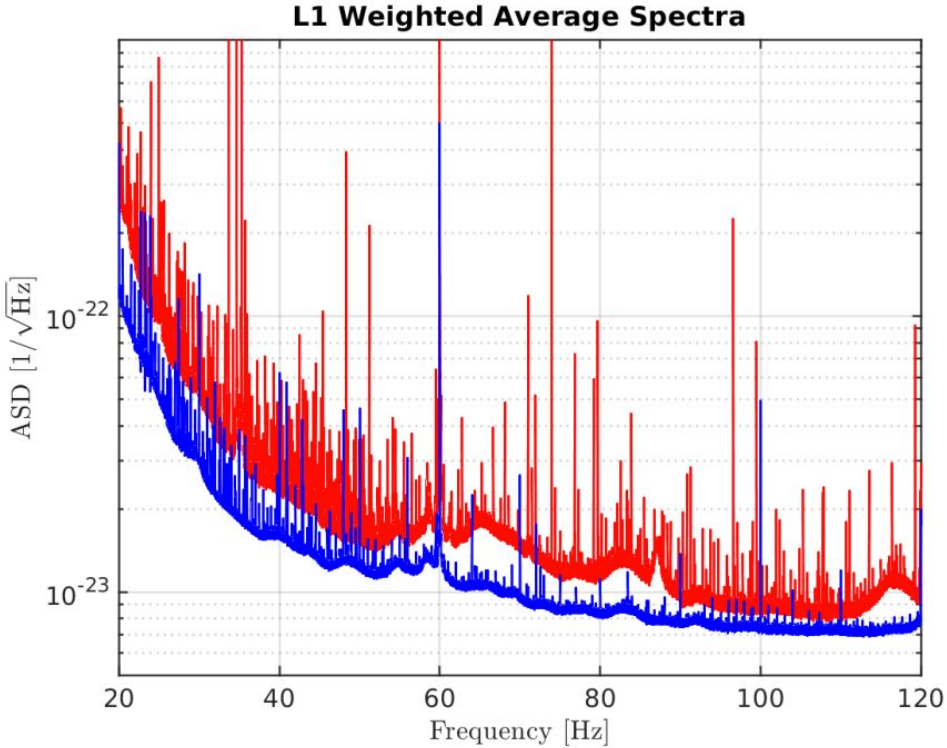




https://arxiv.org/pdf/1801.07204

Typical “noise hunting” experiment

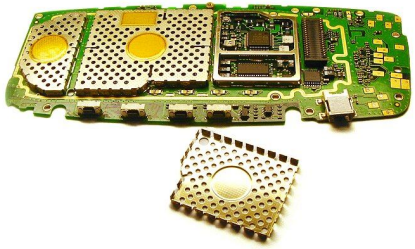
- LIGO noise spectrum
  - Red: Observation 1
  - Blue: Observation 2
- Expect smooth intrinsic noise
  - Can calculate theoretical noise
- Peaks in noise spectra usually from external E&M wave Coupling in
  - Eg. 60 Hz is from electricity
  - 120/180 Hz are harmonics of 60
- The paper details the investigation and mitigation of every line

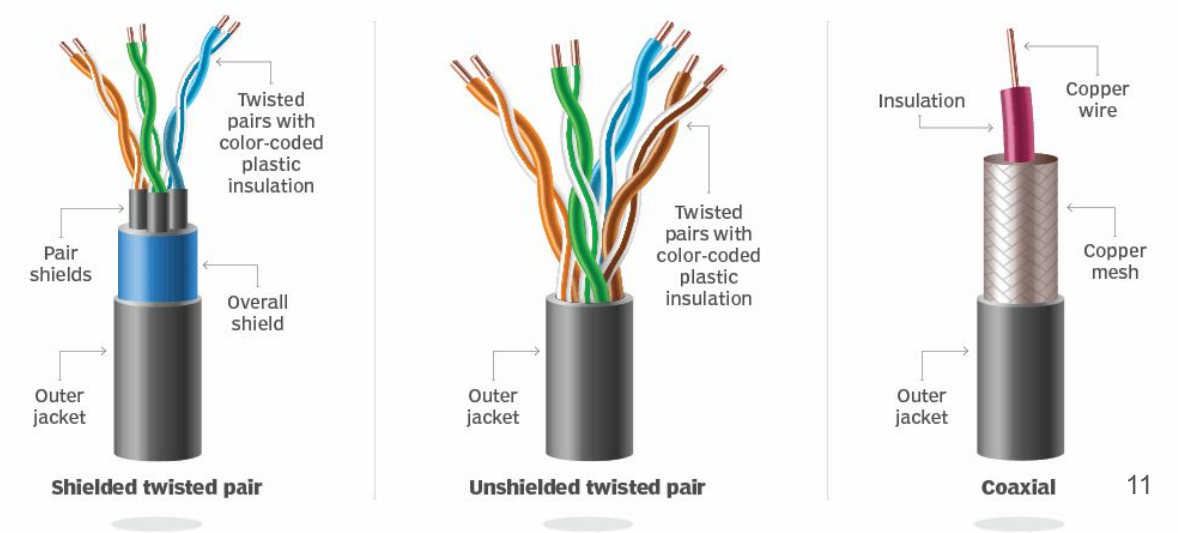


https://www.techtarget.com/searchnetworking/definition/shielded-twisted-pair
https://en.wikipedia.org/wiki/Electromagnetic_shielding
https://en.wikipedia.org/wiki/Faraday_cage

Shield your electronics

- Rely on Faraday cage concept
- Hole size on cage depends on frequency to shield against

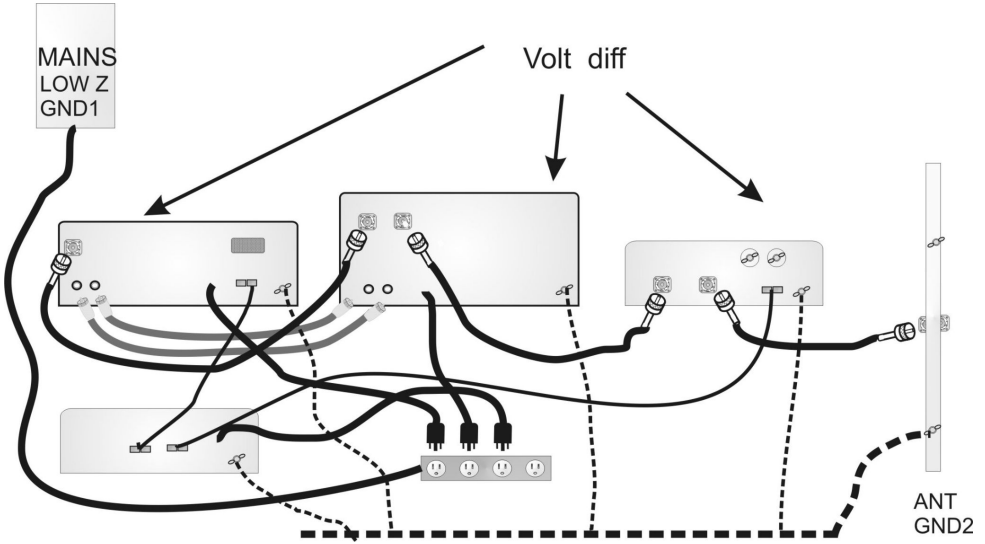


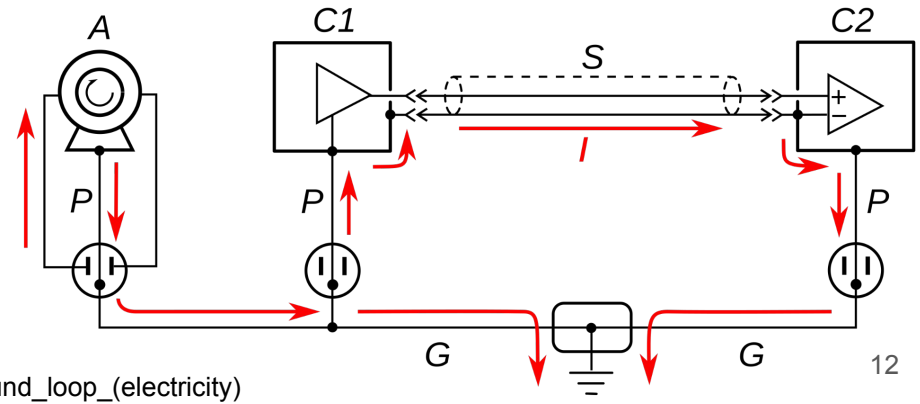


https://www.w8ji.com/ground_loops.htm

Ground loop

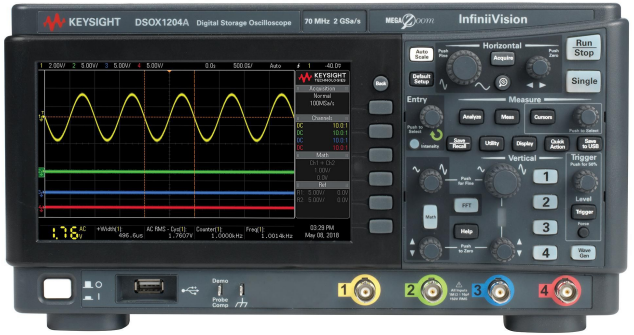
- Happens a lot in our lab
- Often from wave generator → BNC cable → bread board → BNC cable → oscilloscope
- Low impedance loop subject to EM noise pick up



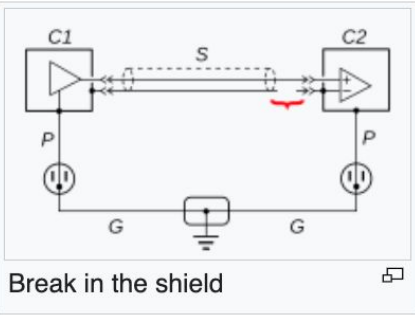


https://en.wikipedia.org/wiki/Ground_loop_(electricity)

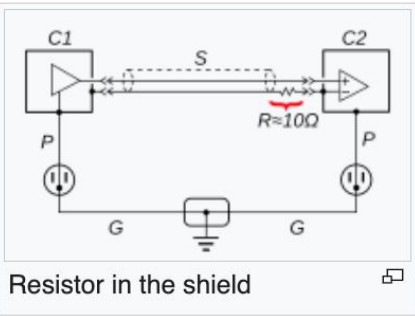
Ground loop mitigation



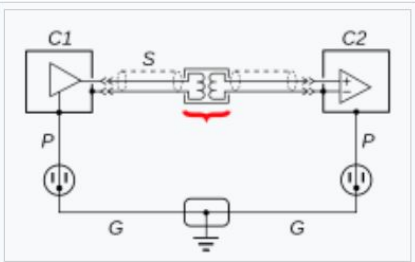
- Dilemma
  - Want to shield as much as possible
  - Connect shield on both ends causes ground loop
    - → Makes noise worse
- Solutions:
  - Gently break shield with tiny gap, or add a resistor
  - Put part of the circuit in floating ground
    - Eg. multimeter
  - Battery power
  - Floating scope
  - Pay an expert
  - …



Break in the shield



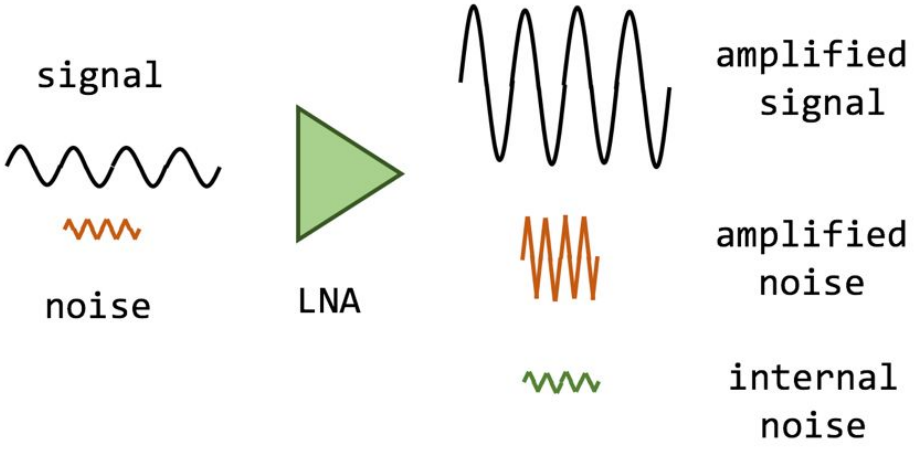
Resistor in the shield



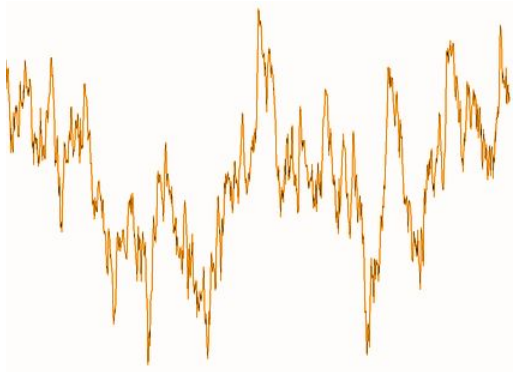
Isolation transformer

Low Noise Amplifier (LNA)

- Often use LNA to enhance Signal to Noise Ratio
- Key is to amplify before more noise couples in
- First stage amplifier needs to be **quiet** and **nearby**



More coupled noise



Questions?