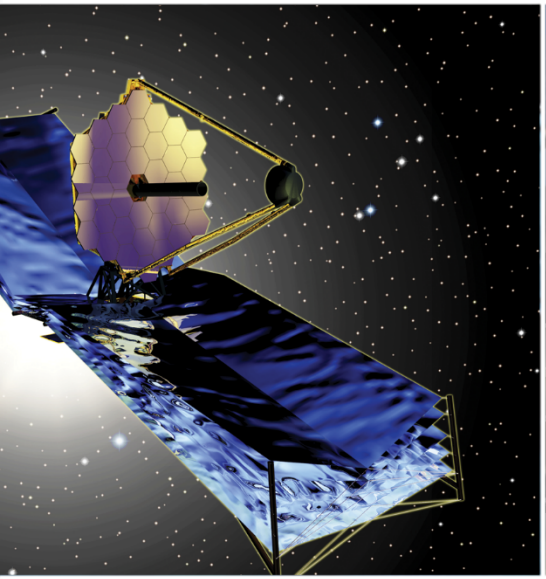
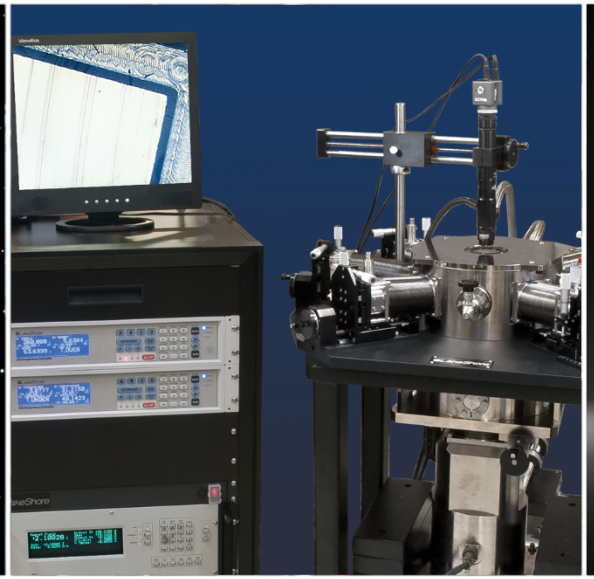
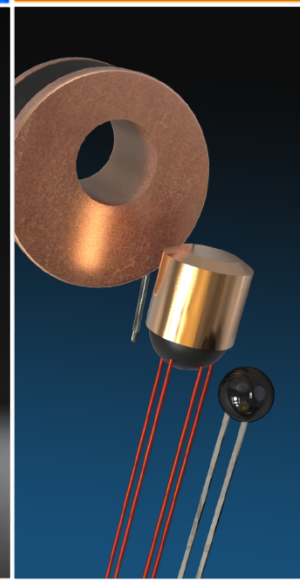
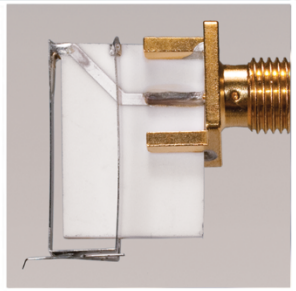
Lake Shore CRYOTRONICS









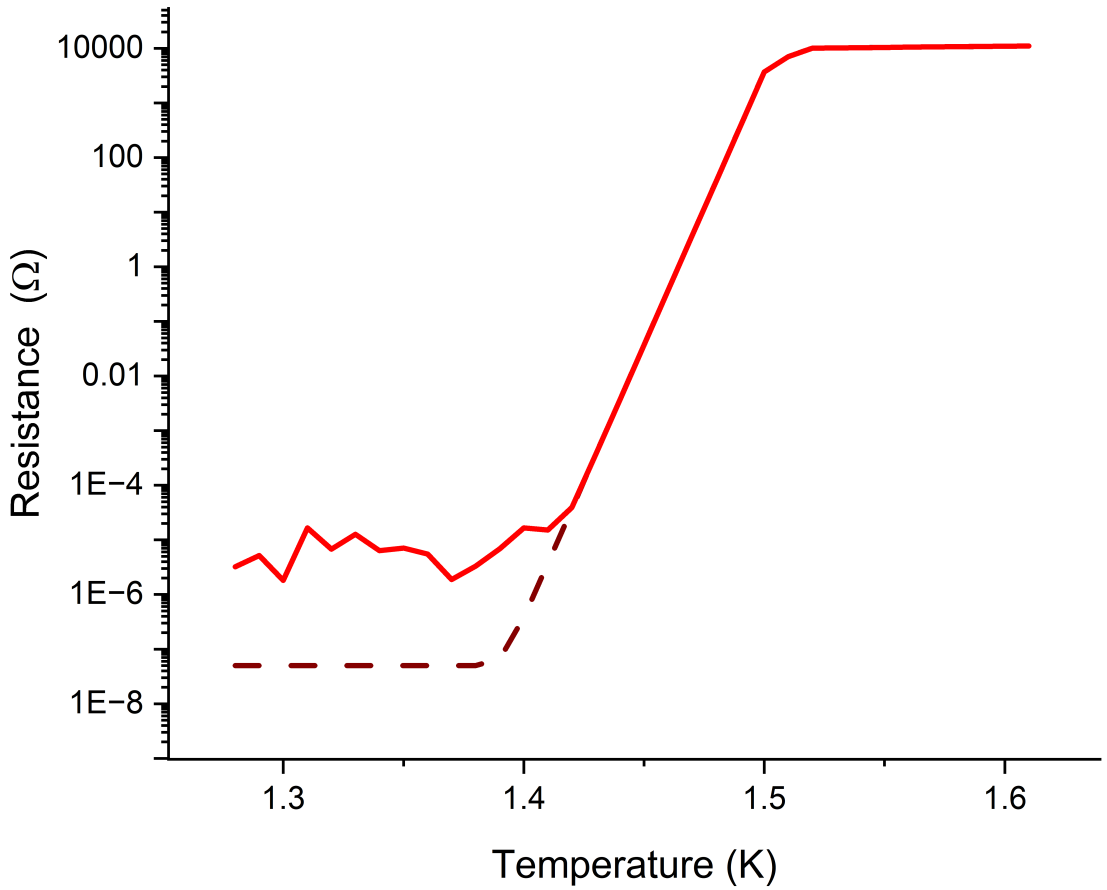
Really, Real

David Daughton

Problem Statement

"The resistance of my device should be about 50E-9 Ohm in the superconducting state. With a four-wire set-up and my M81, I'm measuring a resistance of about 1E-5 Ohm in my cryostat. Can I test such small resistances?"

MAYBE



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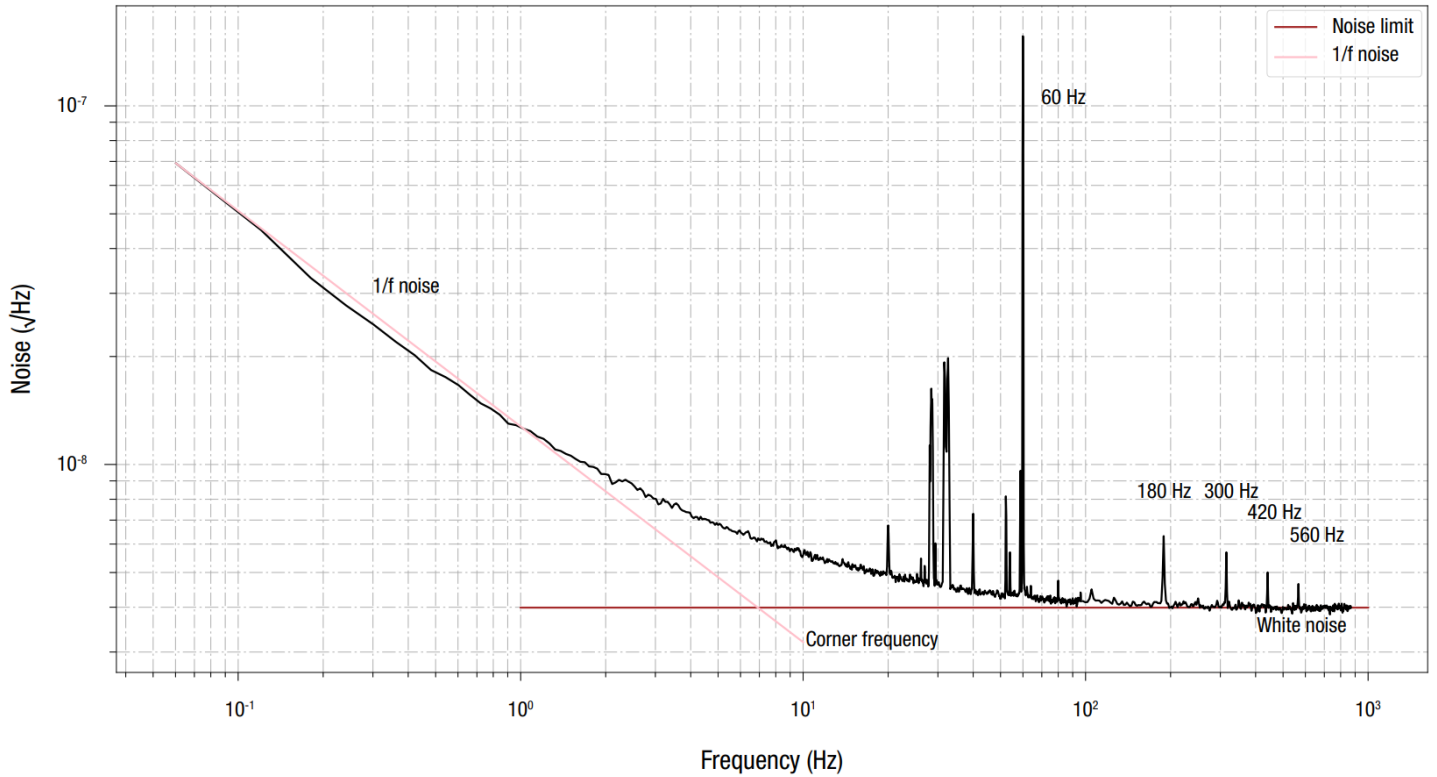
$$V = I\,R = 50\ \text{mA} \times 50\ \text{n}\Omega = 2.5\ \text{nV}$$

10 : 1 SNR for somewhat reliable results

0.25 nV noise floor

Noise Spectral Density

Range	Differential operation
	Voltage noise at 1 kHz
10 V	170 nV/√Hz
1 V	50 nV/√Hz
100 mV	4.5 nV/√Hz
10 mV	4.1 nV/√Hz

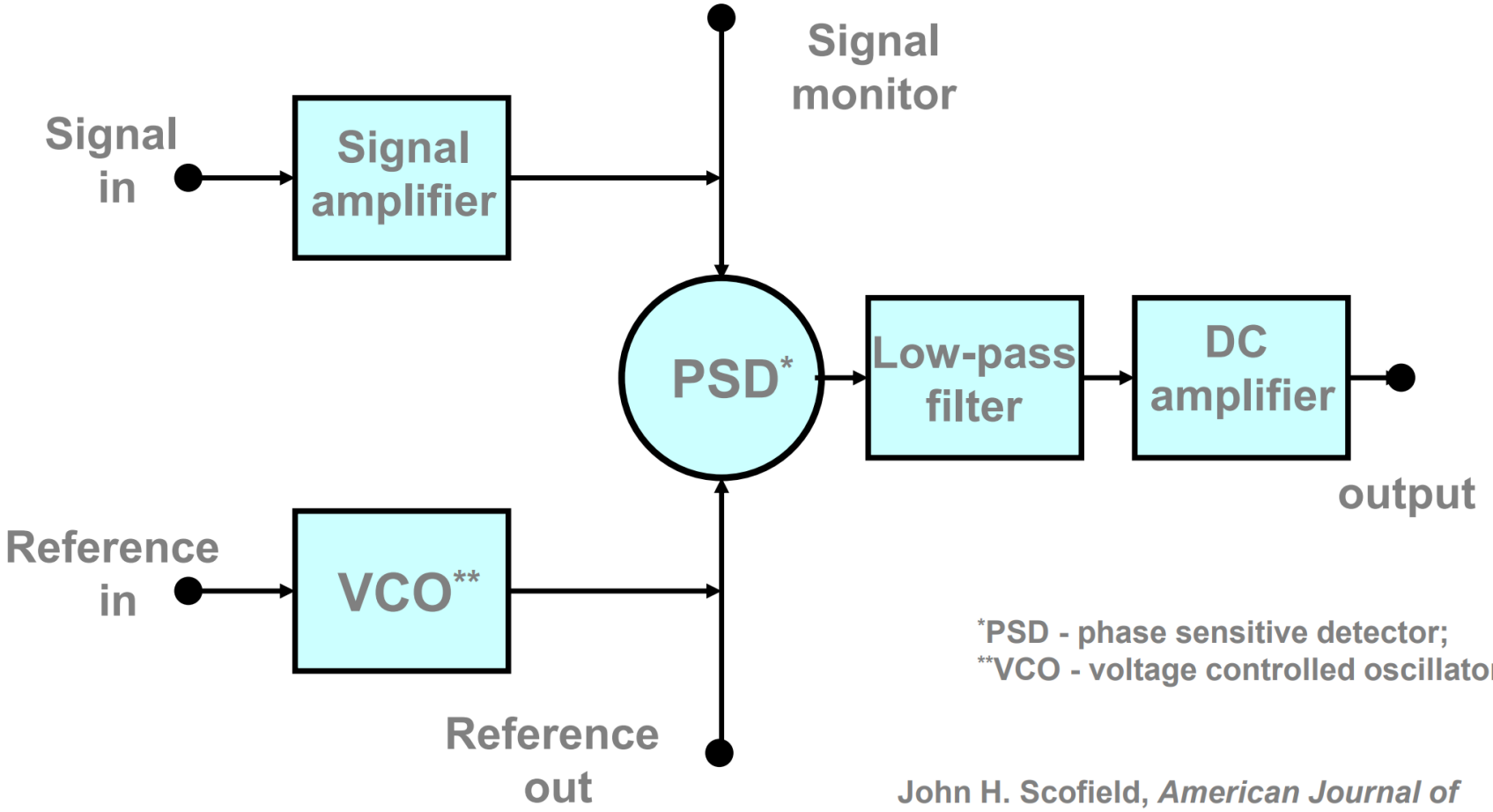


Voltage noise spectral density is a measurement of root-mean-square (rms) noise voltage per square root Hertz

RMS voltage noise = 4.1 nV/$\sqrt{Hz} \times \sqrt{ENBW}$

"ENBW" – equivalent noise bandwidth

ENBW in a lock-in



Roll-off	ENBW
dB	τ is time constant
6	$^1/(4\ \tau)$
12	$^1/(8\ \tau)$
18	$^3/(32\ \tau)$
24	$^5/(64\ \tau)$

IIR output filters

*PSD - phase sensitive detector;
**VCO - voltage controlled oscillator

John H. Scofield, *American Journal of Physics* 62 (2) 129-133 (Feb. 1994).

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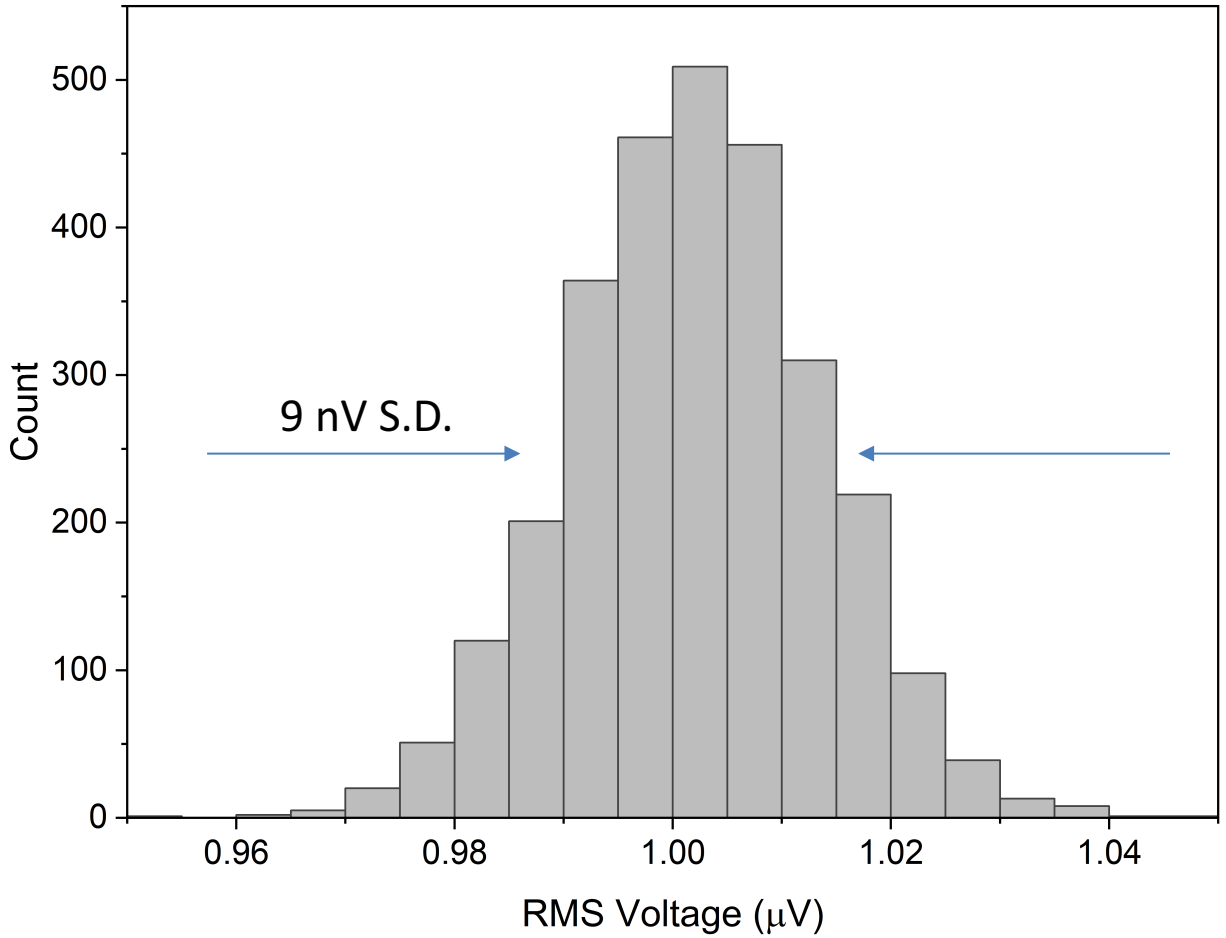
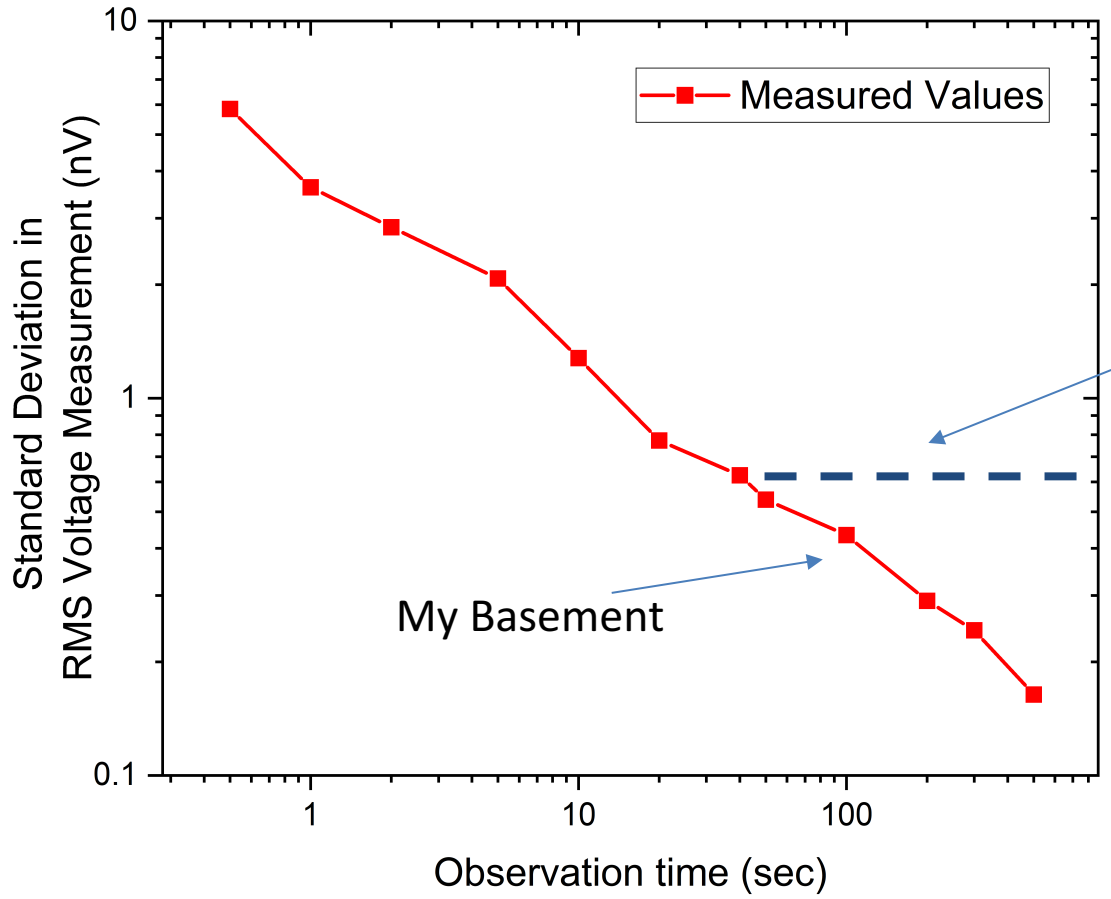
RMS noise



- Set-up lock-in filter
- Calculate ENBW & settle time
- Acquire a lock-in measurement every settle time period
- Take 750 to 1000 samples
- Look at the statistics

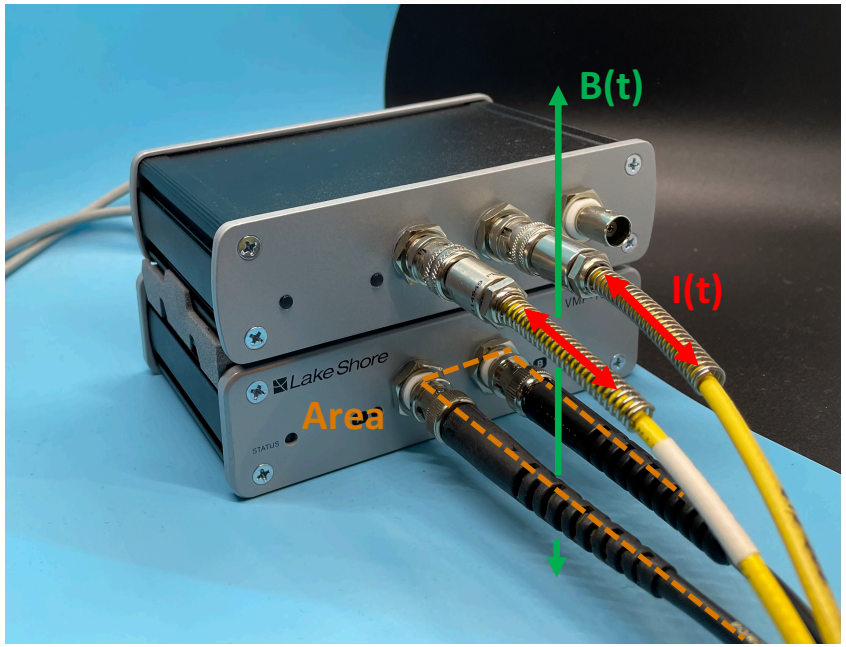
Allan deviation



Fluctuations in the system, electronics & environment may limit the noise floor

Hybrid Filter, 12 dB IIR, 10 to 1 FIR to IIR ratio

Cautionary tale – Cross talk



50 mA + ~ 1000 Hz → ~40 nV

Pick-up increases with:

- Current Amplitude
- Frequency → Reduce Frequency
- Proximity → Isolate Twisted pairs
- Size of magnetic aperture → Look for loops, especially at instruments, feedthroughs, and at sample holders

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