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Quiet drive electronics for pulse-tube refrigerator rotary valves

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Quiet drive electronics for pulse-tube refrigerator rotary valves

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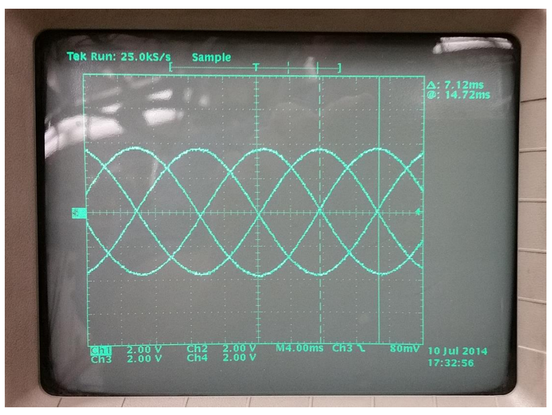
The Idea

- **Our new MMC array was acutely sensitive to noise in the cryostat. We took advantage of this sensitivity to eliminate an important noise source.**

- For sensitive low-temperature experiments, the rotary valve motors and motor drive electronics can be troublesome sources of noise.
- One area where progress can readily be made is in reducing noise from the electronics used to drive the pulse-tube rotary valve motor.
- These are often stepper motors with stepper motor drive electronics.
- However, the stepper motor drive electronics are not required: the stepper motor is simply used as a synchronous AC motor.
- If the drive electronics can be made quiet, the use of a synchronous AC motor is actually a good choice for sensitive experiments:
  - It has no commutator or brushes, and thus none of the associated switching noise, and it is well-suited to being driven by pure sinusoidal currents, minimizing any possible noise-spectrum footprint.
- In this report we describe the development and testing of a fully-linear, fully-differential motor drive electronics. We believe this is the quietest-possible motor drive and may even be compatible with use of a pulse-tube refrigerator in an RF-shielded room.

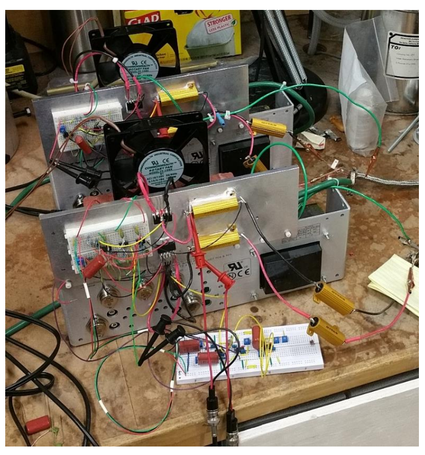
Design and Build

- Fully analog, from the motor to the wall socket
- A low-distortion sine wave is phase-shifted and amplified to create fully differential drives in quadrature.



- Linear power supplies plus an Isolation transformer to reduce noise coming from the wall (our old building has really crappy power)
- Supports only two-phase (4-wire) stepper motors

- Cabling to the cold head uses individually-shielded twisted pair to respect the fully differential drive.
- from idea to prototype in 6 weeks, for less than $1K



Next Steps

We plan to convert the circuit into PCB/enclosure as part of the current MMC project. z

Acknowledgements

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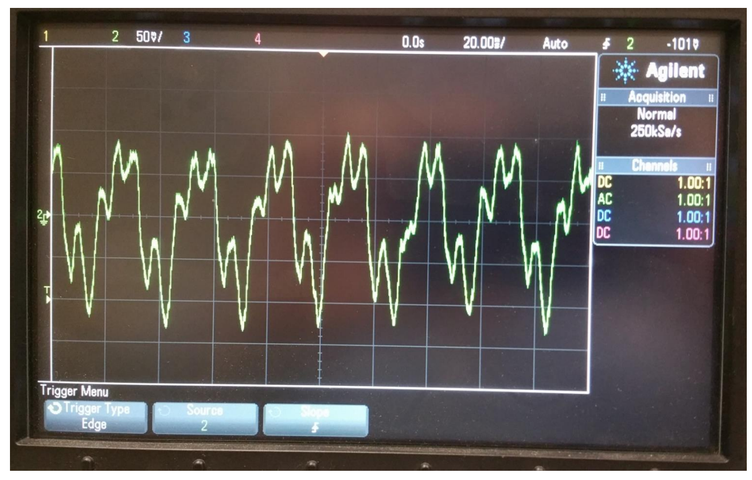
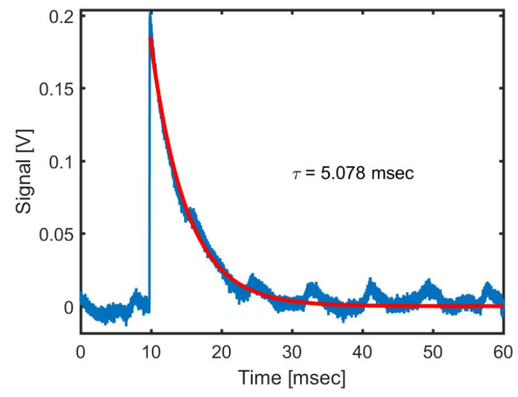
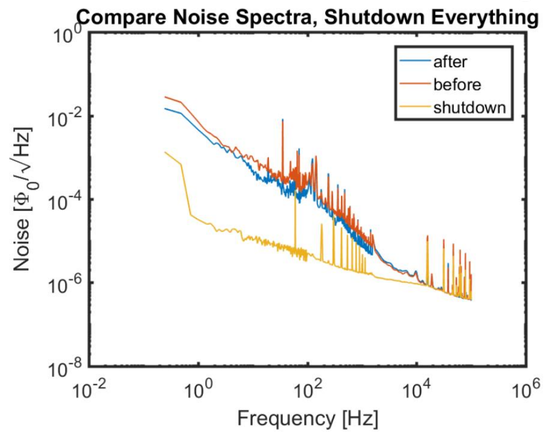
Results

- With the highly-sensitive MMC array, the SQUIDs were unusably noisy





- We invested weeks cleaning up cabling and improving grounding.
- However, the problem turned out to be the pulse-tube refrigerator
- Here was the noise difference between PTR running and not running



- The first time we ran the new drive electronics, we thought the SQUIDs had gone to the voltage rail and needed resetting (they were so quiet we thought they had stopped working). From the SQUIDs we now cannot tell if the pulse-tube is running or not.
- As a result of our new quiet cryostat, it quickly became clear that remaining noise pickup by the MMC array was due to our commercial temperature readout. We have readouts from Lakeshore (370 and 340), SRS, LR 700. ALL OF THEM INJECT NOISE INTO THE CRYOSTAT.
- For this reason we are developing a monolithic SQUID-based paramagnetic thermometer, described in **3EPo1B-06 [E14]** in this conference.

Quiet Enough for an RF-Shielded Room?

- The circuit we built to solve our problem has no digital or high-frequency components: it is analog from the motor to the wall socket.
- This drive approach should be compatible with the use of an RF-shielded room.
- The circuit described creates sinusoidal drive voltages with low total harmonic distortion to minimize the potential noise-spectrum footprint.
- The feedthrough that could still occur into sensitive experiments should show up in the noise spectrum as a single line at the motor drive frequency, which for us is about 35Hz.