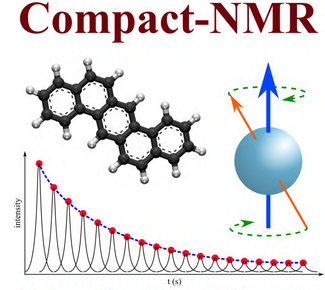
Excitation Signal Generation for a Compact Nuclear Magnetic Response Sensor

Jackie Wang, David Wamai, Jason D. Bakos, Austin R.J. Downey

University of South Carolina

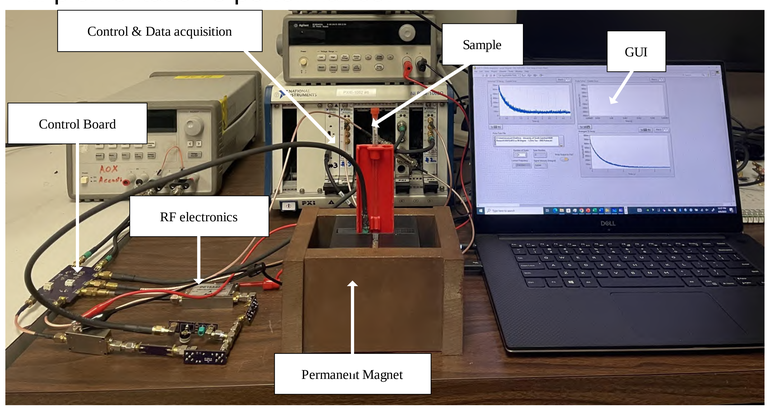


Background

- Nuclear magnetic resonance (NMR) is a phenomenon that occurs when the molecules are placed under a strong magnetic field.
- When applying the radio frequency to the molecule, its nuclei will enter an excited state. As the nuclei relaxes from the agitation, voltage is induced in a coil surrounding the sample which can then be measured.
- The measured voltage can then be used for particle analysis where the properties of a sample under analysis could be understood.
- For example, the NMR data from the analysis of a fuel sample can be used to identify its hydrogen deposition. From this, the combustibility of the fuel can be determined.

Objective

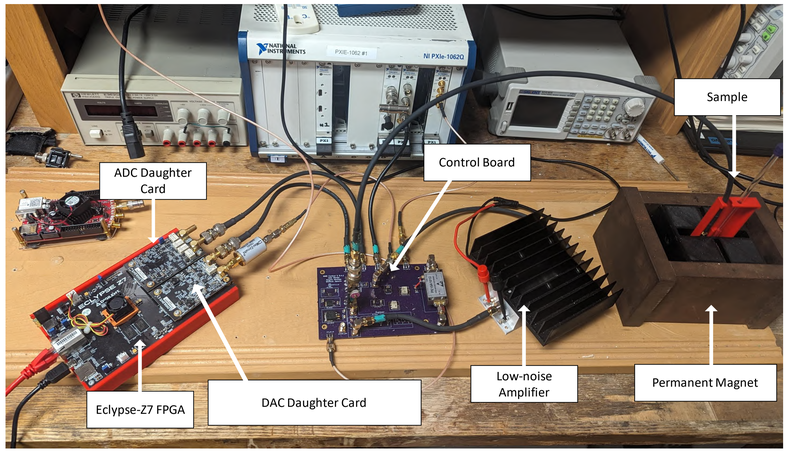
- The current NMR setup is expensive and cumbersome to be brought outside of the lab for in situ testing.
- Develop a system that is more compact and less expensive while preserving or improving the original implementation's performance.



Current Compact NMR System

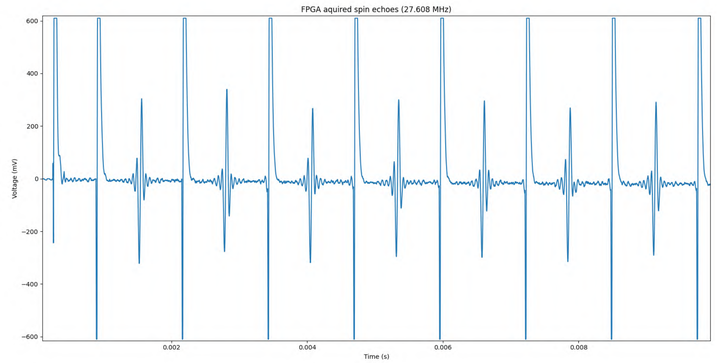
Methodology

- The digital to analog converter on the FPGA sends a sinusoidal waveform at 20-30 MHz in specific timings to agitate the sample. The trigger delay between the initial and following waveforms being sent is half of the delay between the rest of the waveforms being sent.
- The ZMOD1410 Analog to Digital Converter collects the Free Induction Decay response signal from the NMR sample. A scatter-gather engine sends the samples from memory to a host computer.

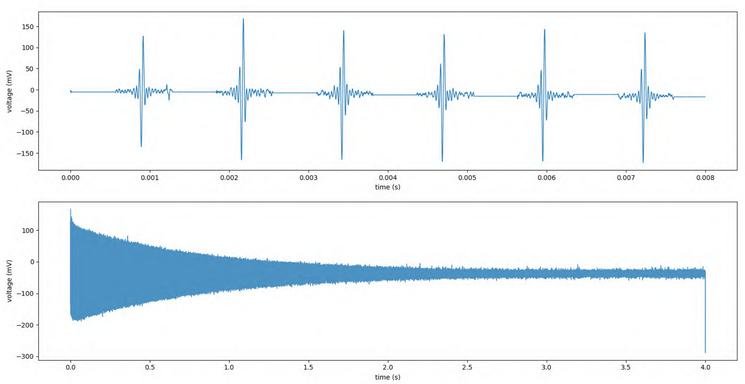


Eclypse-Z7 FPGA Compact NMR System

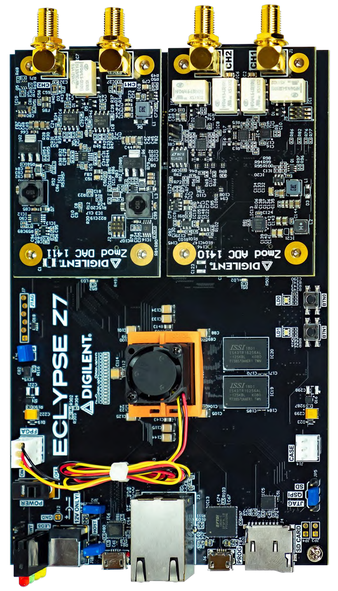
Results



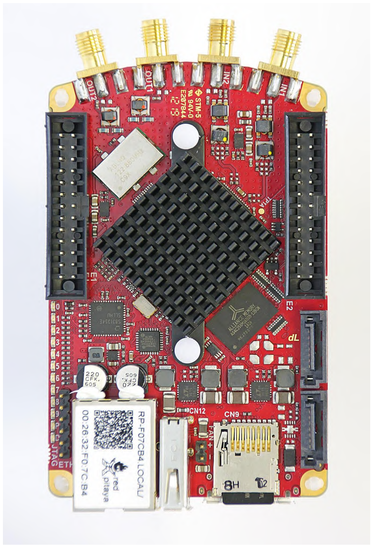
Spin Echo acquisition via Eclypse-Z7



Post-processed Spin Echo and T2 curve extraction



Eclypse-Z7 FPGA



Red Pitaya FPGA

Conclusion and Future Plans

- Due to the difficulties imposed by the Eclypse-Z7 involved with Linux applications; we plan on using the Red Pitaya FPGA moving forward.
- The Pitaya have similar specifications in comparison to the Eclypse-Z7 such as both boards being powered by the same Zynq SoC.
- The Pitaya offers several other advantages over the Eclypse-Z7, such as a smaller form factor, more flexible sampling rates for data acquisition, and more extensive documentation.

References

[1] Downey, Austin, & Huggins, Parker, & Martin, Jake, & Won, Sung Hee, (2022). Machine Learning for NMR-based Fuel Classification. University of South Carolina Research Poster. http://www.me.sc.edu/Research/Downey/publications/Posters/Huggins2022MachineLearningNMR.pdf

[2] Downey, Austin, & Martin, Jacob, & Won, Sung Hee, (2022). Compact Time Domain NMR Design For The Determination of Hydrogen Content in Gas Turbine Fuels. ASME IDETC-CIE, 2022. http://www.me.sc.edu/Research/Downey/publications/Conference_presentations/Martin2022CompactTimeDomain_presentation.pdf

This work is supported by the National Science Foundation, United States Grant Numbers 2152896 and 2344357. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

UNIVERSITY OF South Carolina