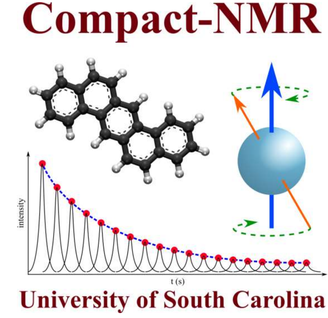
Hardware Development for a NMR Signal Processing Instrument

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

University of South Carolina

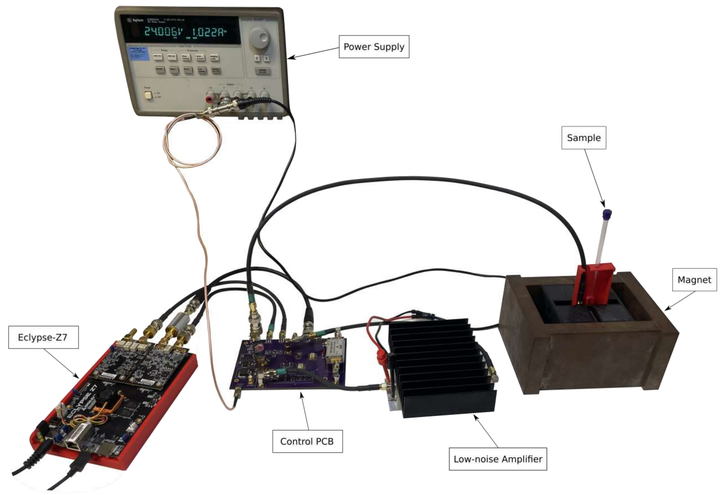


Background

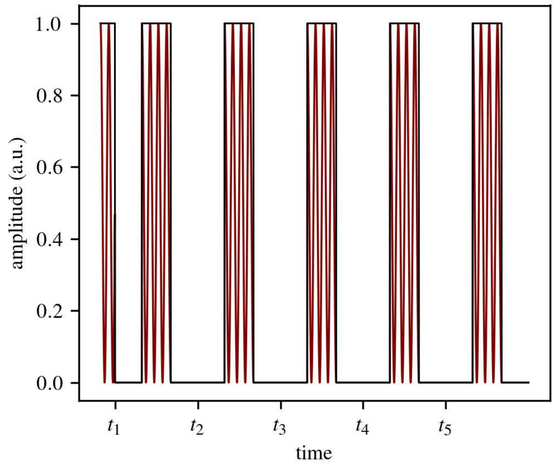
- Nuclear magnetic resonance (NMR) is a phenomenon that occurs when the molecules are placed under a strong magnetic field.
- When applying the radio frequency to the molecule, its nuclei will enter an excited state. As the nuclei relaxes from the agitation, voltage is induced in a coil surrounding the sample which can then be measured and analyzed

Objective

- Develop an FPGA-based system that is more compact and less expensive while preserving or improving the original implementation's performance.

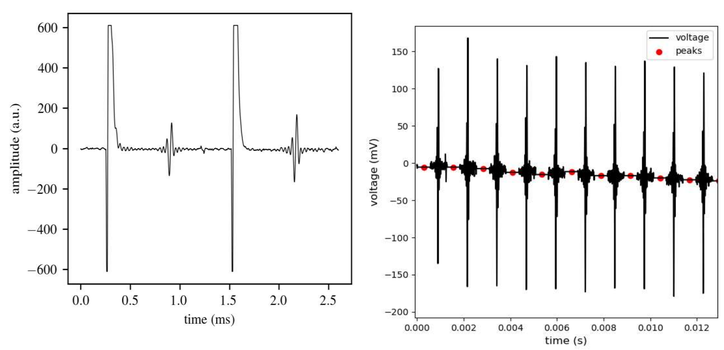


Current Compact NMR System

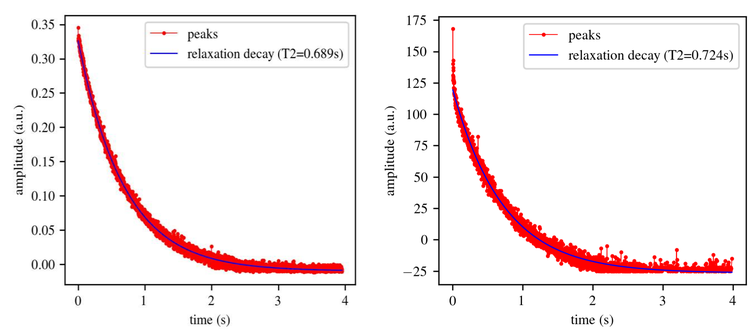


Visualization of the Carr-Purcell-Meiboom-Gill pulse sequence

Results



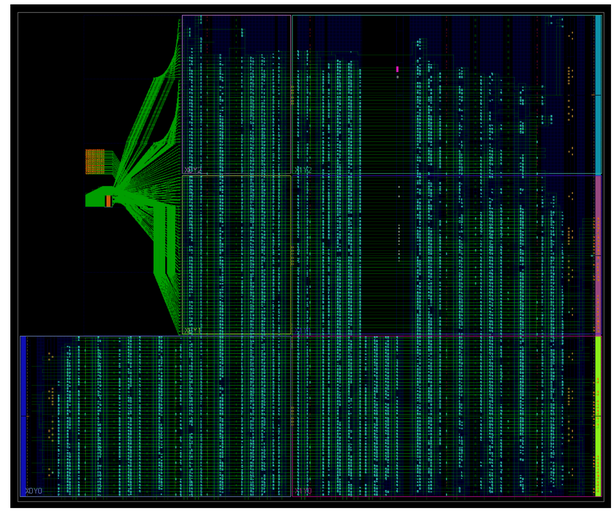
In-hardware peakfinding algorithm for pulse removal



T2 curve extraction using: (left) PXI-1062Q and (right) Eclypse-Z7 FPGA

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.



Internal FPGA hardware description

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

Funding for this project was provided by the National Science Foundation through projects 2152896, 2237696, and 2344357 and by Molinaroli College of Engineering and Computing at the University of South Carolina through the McNair Junior Fellows Program. The authors' opinions, results, conclusions, and recommendations in this material are their own and do not necessarily reflect the views of the National Science Foundation or the University of South Carolina.

UNIVERSITY OF South Carolina