Development of an FPGA-based signal processing system for a compact NMR measurement system

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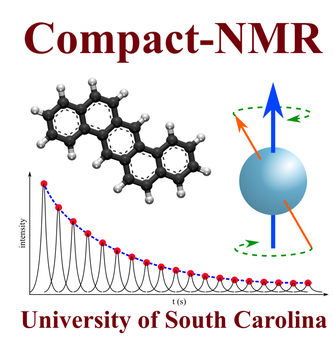
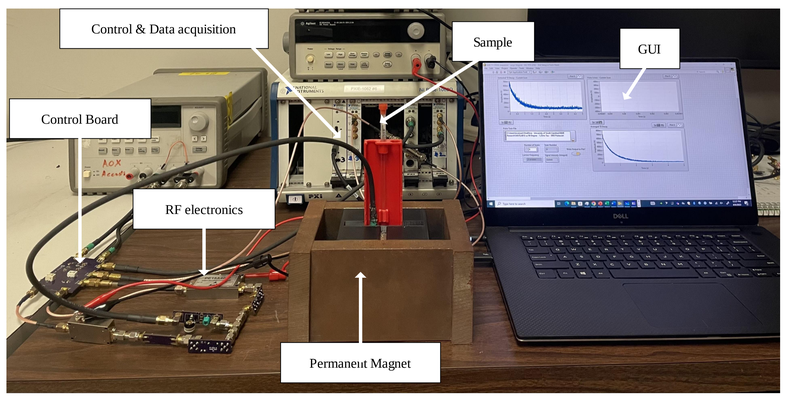


Background

- 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.

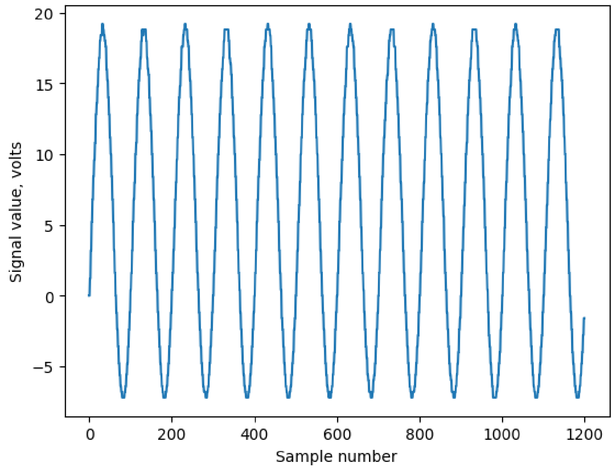


Current Compact NMR System

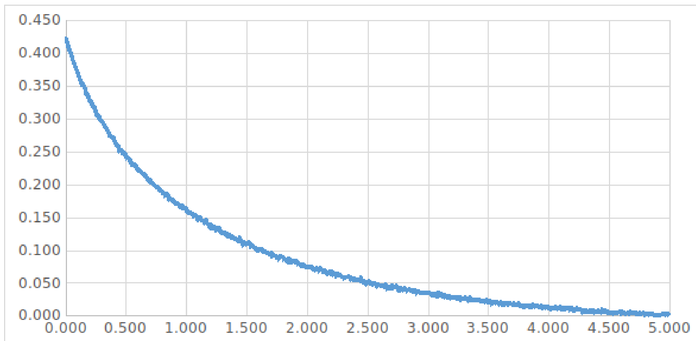
Methodology

- A DDS Compiler generates a continuous and stable sinusoidal wave without the use of the processor on the board.
- 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.

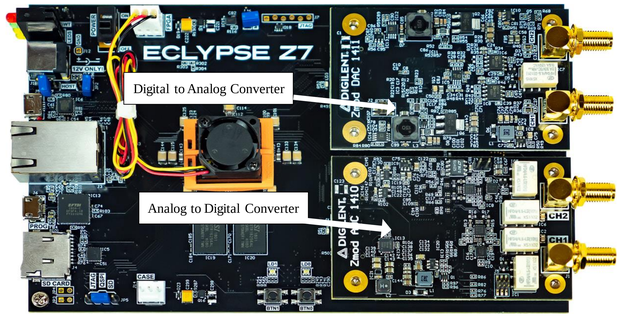
Results



20 MHz Sine Wave From Eclypse FPGA



Transverse Relaxation Curve



Eclypse Z7 Platform
(ZYNQ7020 FPGA)

Conclusion and Future Plans

- The Eclypse Z7 might not be the best platform to implement the compact NMR system due to its inability to produce two waveforms at different frequencies.
- The board does not allow for fast enough data transfer rates for the data Acquistion portion of the compact NMR.
- In the future we plan to use an Arduino DDS signal generator for wave form generation and a Speedgoat for data acquisition. We hope that these tools will alleviate the current limitations we have with the Eclypse Z7 FPGA.

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

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