GIZMo for DUNE at LBNF

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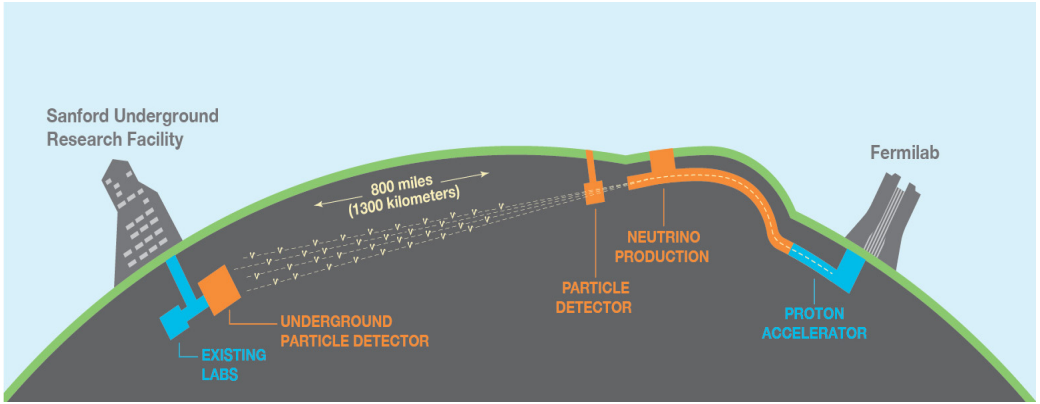
In partnership with:

Deep Underground Neutrino Experiment (DUNE)

Under-construction accelerator and neutrino detectors that analyze long-baseline neutrino oscillations.

Purpose

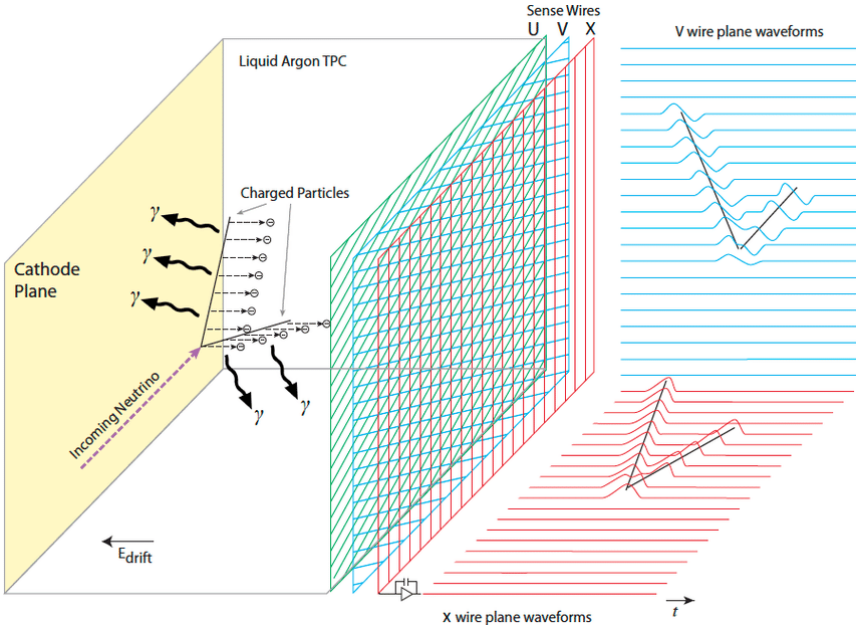
- Study Neutrino-Oscillation
  - Mater-antimatter asymmetry
- Capture neutrino from stellar death
  - Formation of Black Hole
- Study Proton Decay
  - Unification of Forces



DUNE at LBNF

Deep Underground Neutrino Experiment (DUNE)

- Interaction with Argon
  - Photon
    - Scintillation Detector
  - Charged Particles
    - Creates Bipolar Signal in the wire grid



Operation of LArTPC

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Ground Impedance Monitor (GIZMo)

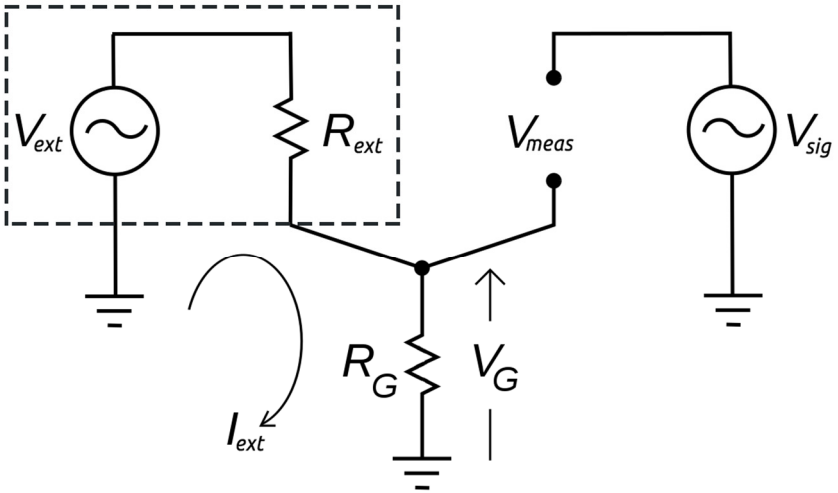
Ground Impedance Monitor system monitors the integrity of the **single-point-grounding** configuration required for low noise operations of the DUNE detector.

Motivation

- It is important that signal is noiseless
- Building Ground is noisy

Single Point Ground

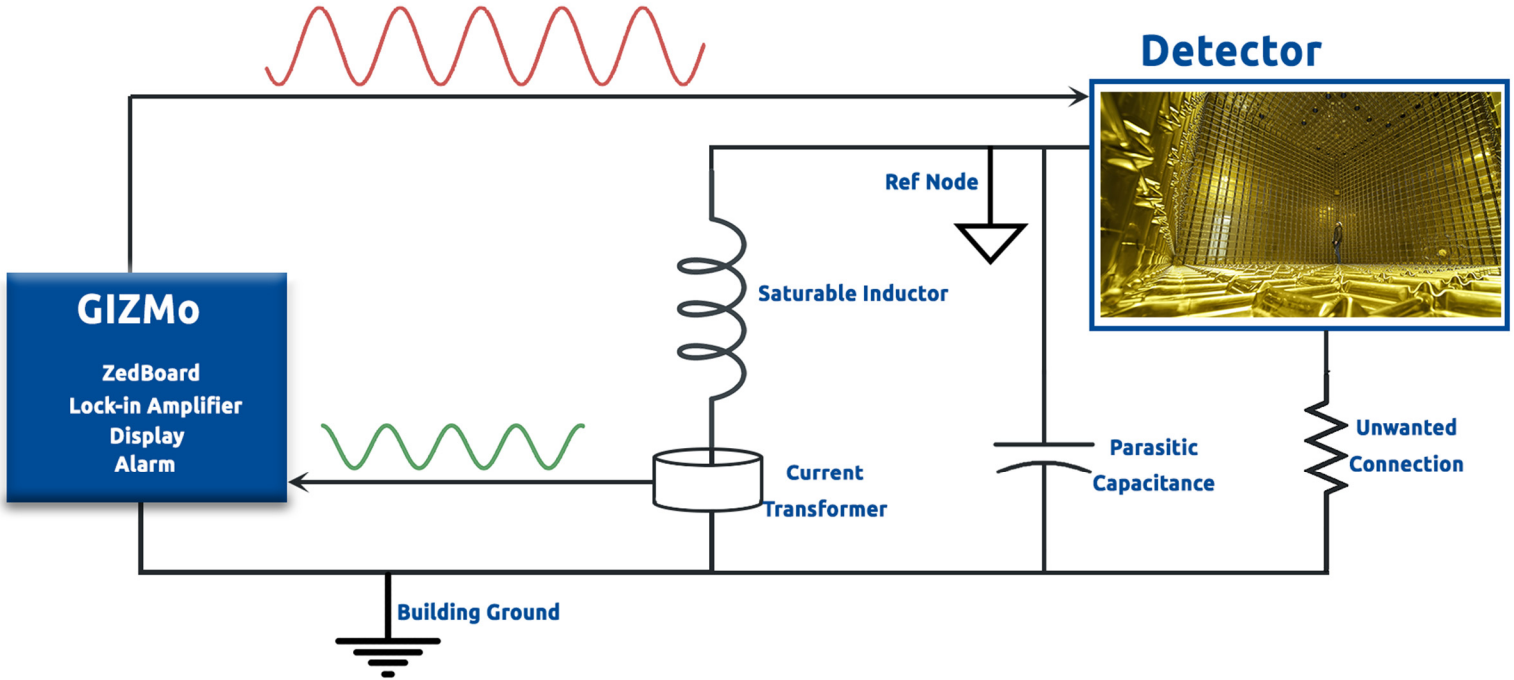
- Isolates the detector from the ground
- Uses Saturable Inductor for safety



Ground Loop

Ground Impedance Monitor (GIZMo)

Design



Simplified Circuit of GIZMo and DUNE Far-side Detector

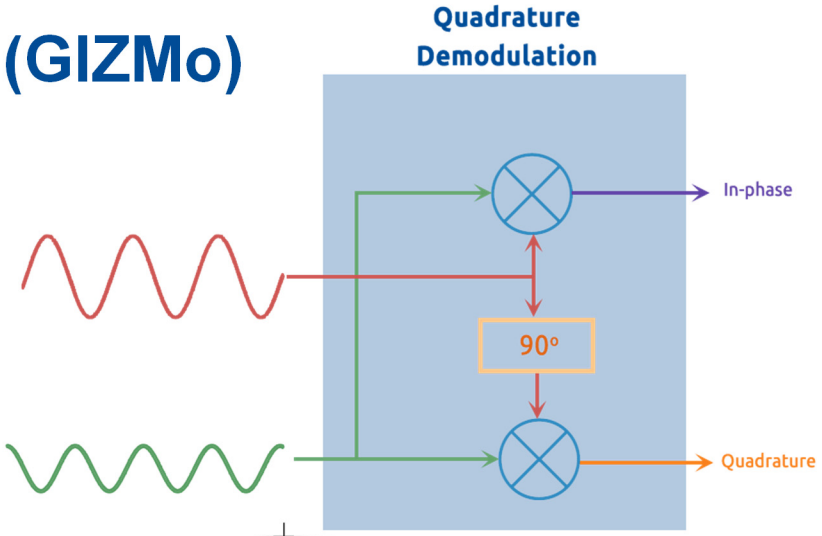
Ground Impedance Monitor (GIZMo)

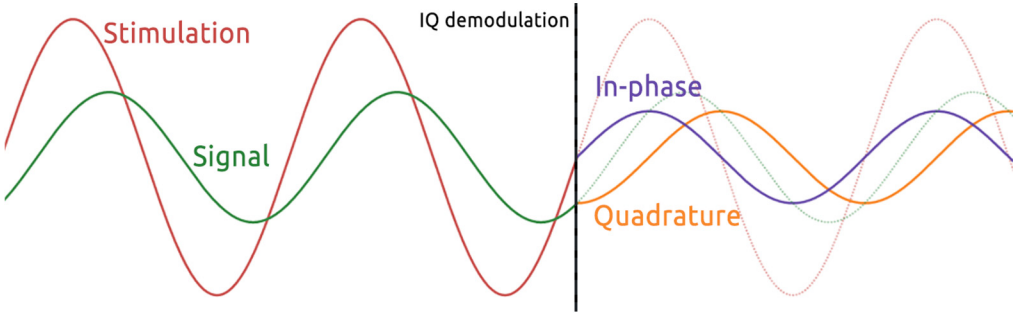
Impedance Estimation

$$S_{RF}(t) = I \cdot cos(\omega t) + Q \cdot sin(\omega t)$$

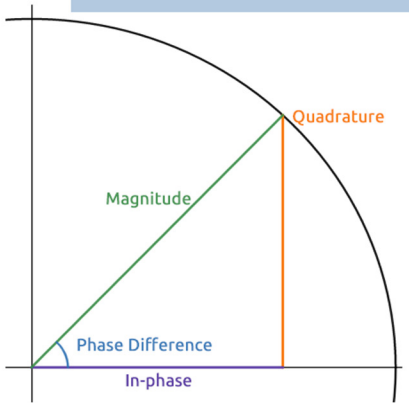
$$\int_0^\tau S_{RF}(t) cos(\omega t) dt \sim I$$

$$\int_0^\tau S_{RF}(t) sin(\omega t) dt \sim Q$$



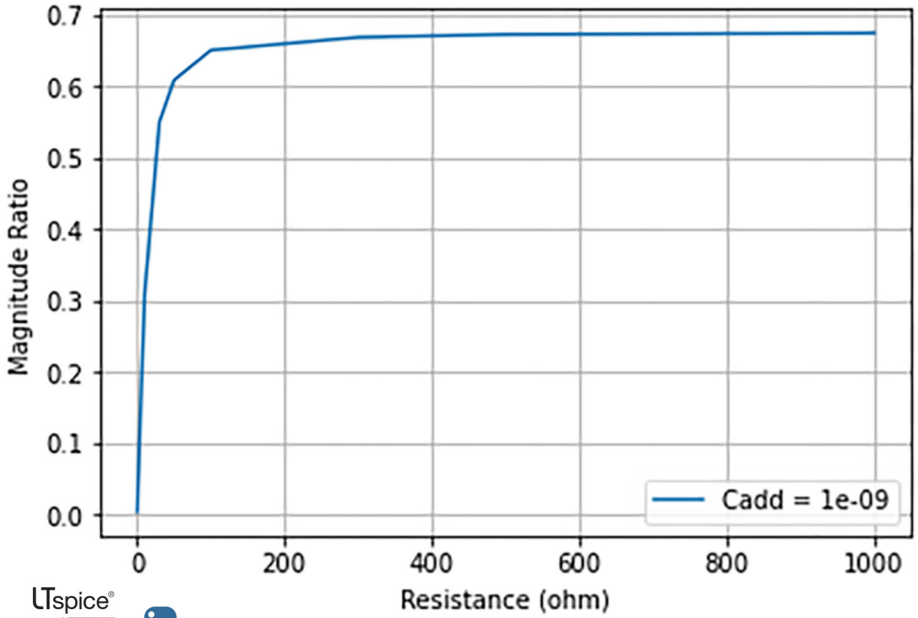


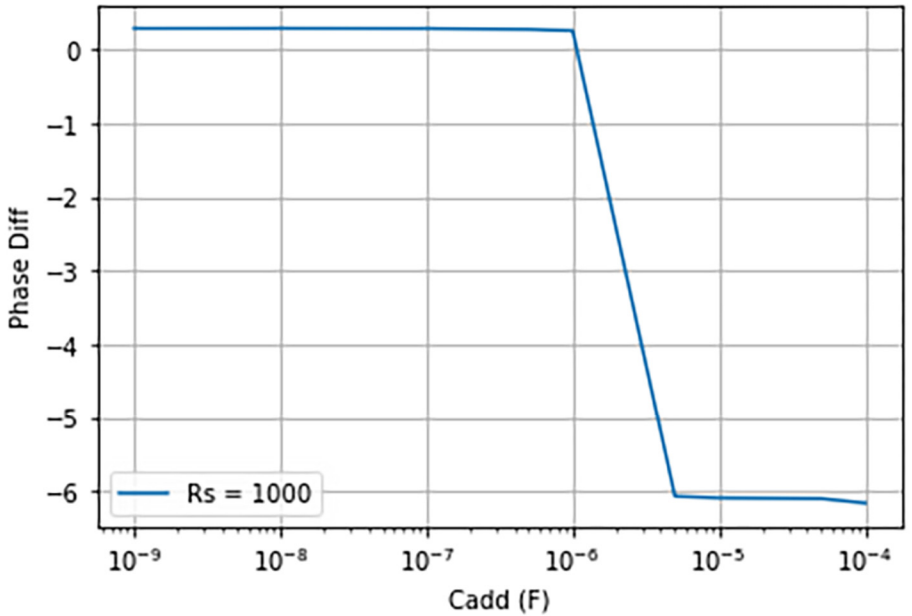
Quadrature Demodulation



Ground Impedance Monitor (GIZMo)

Impedance Estimation

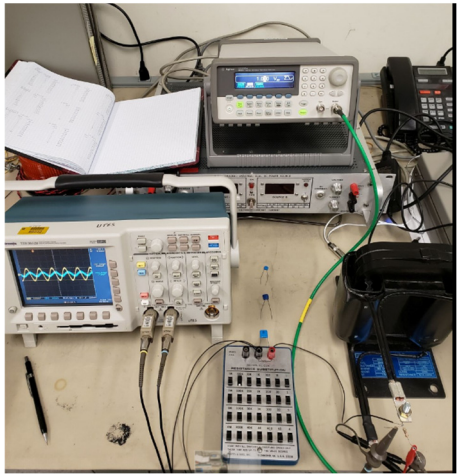


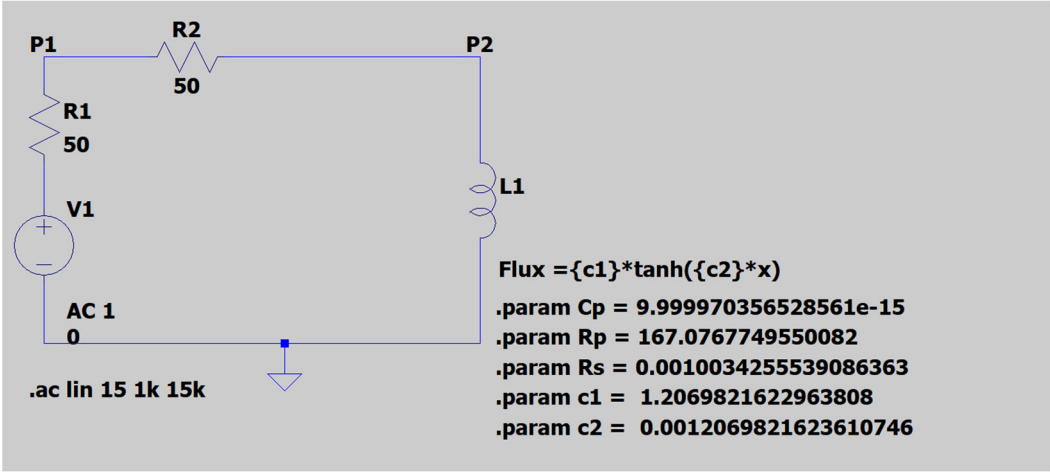


LTspice

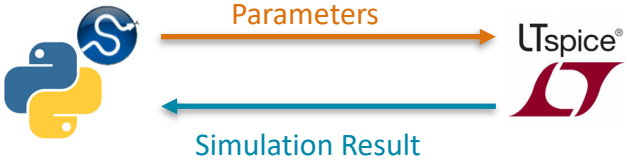
Calibration Curves for stimulating current at 3000Hz

Circuit Element Optimizer





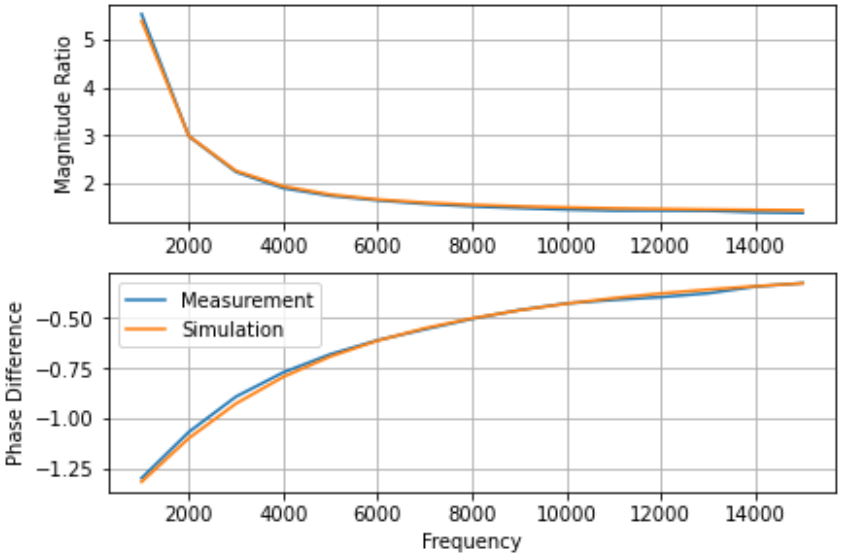
Circuit for estimation of parameters for Saturable current
(a) real implementation, (b) LTSPICE Schematic

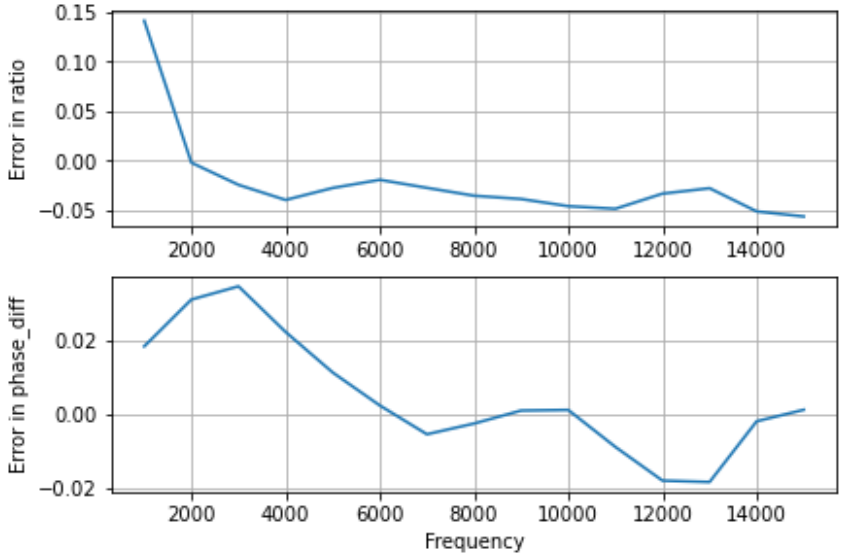


Optimization Algorithms Method Used

- Newton Conjugate Gradient
- Broyden–Fletcher–Goldfarb–Shanno

Circuit Element Optimizer





Saturable Inductor Parameter matching using Newton CG Algorithm

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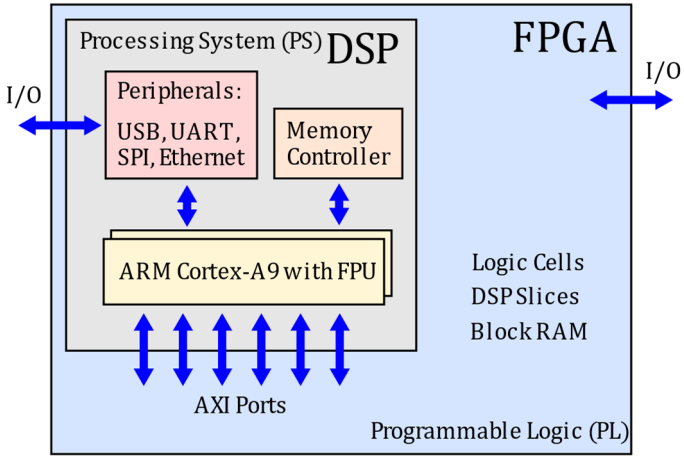
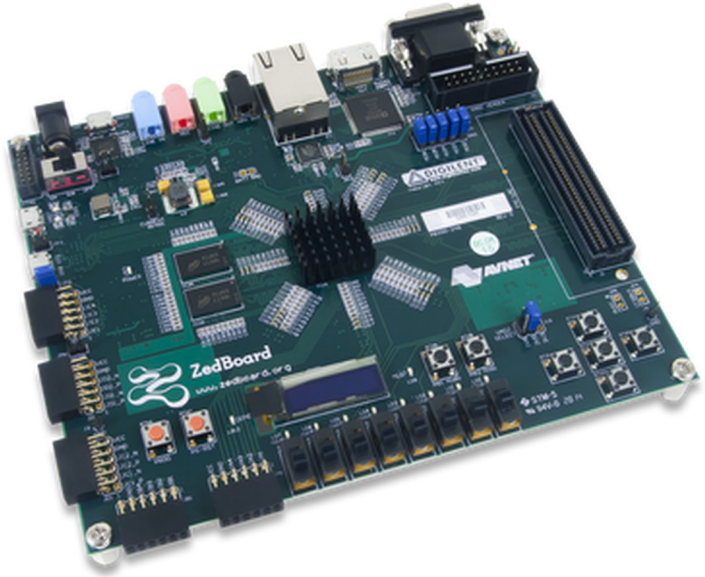
Embedded System Implementation

- Real-time monitoring
- Batch processing
- Low power consumption



ZedBoard Architecture



ZedBoard

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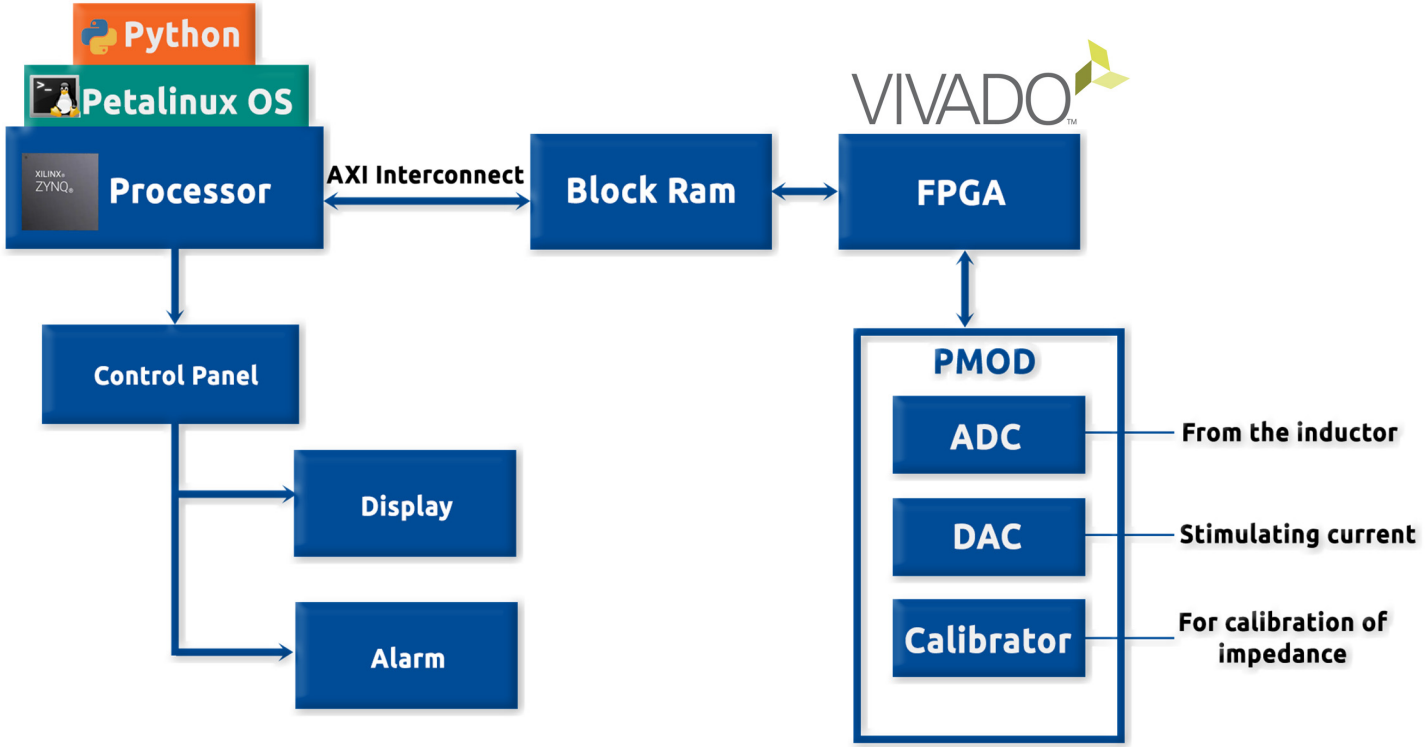
Embedded System Implementation



Dataflow in Embedded System Implementation

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Summary

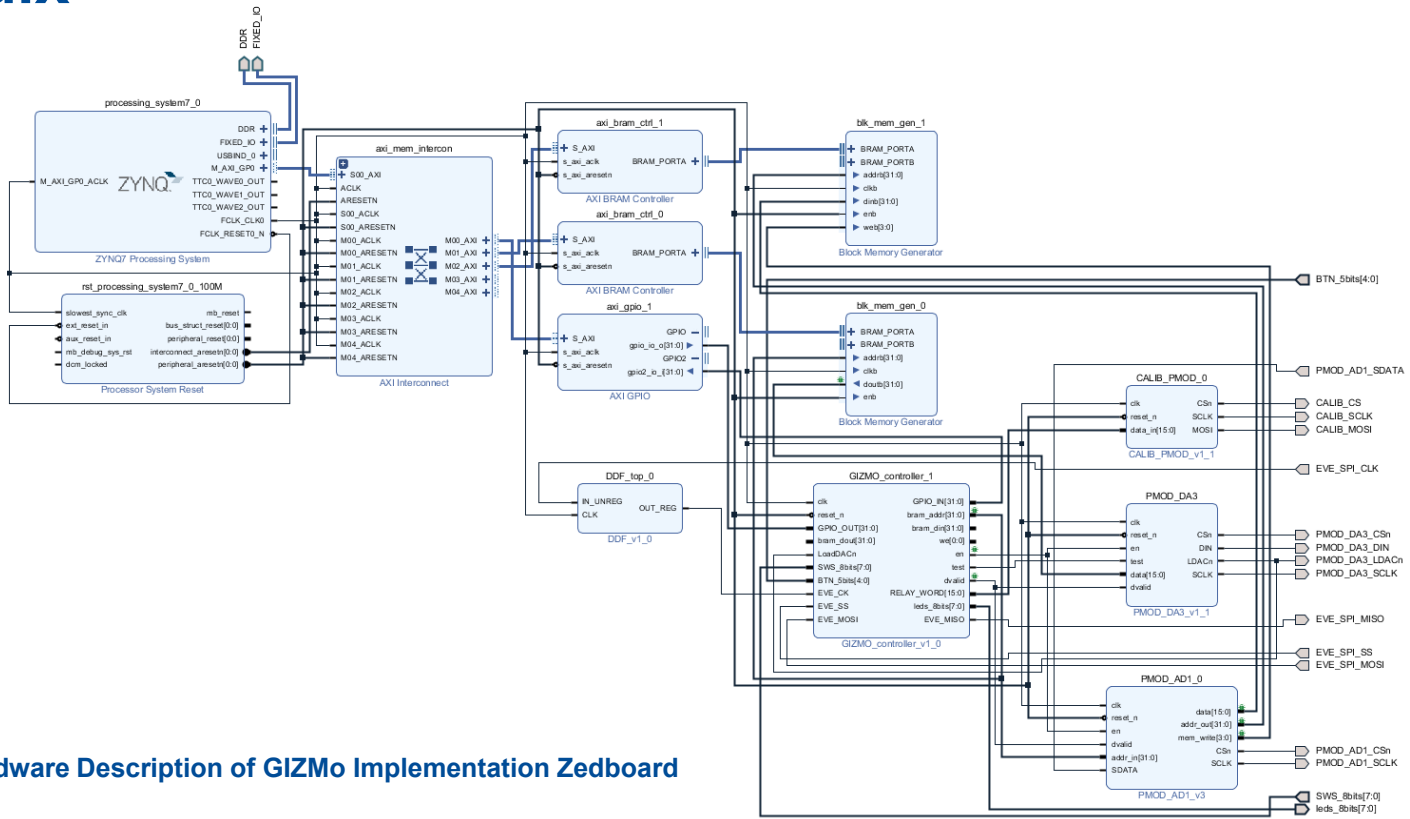
- Created scripts for estimation of impedance using IQ demodulation
- Created a Python package for to optimize parameters for circuit element
- Built images for embedded system
- Further works
  - Publish the python package
  - Finalize the boot image and implement it in the hardware
  - Expand Capabilities

Acknowledgement

I would like to thank my supervisors Michael Utes and Paul Rubinov. Special thanks to my mentors Michael Geelhoed, Ahmed Syed and, and Linden Carmichael. Additionally, I would like to thank everyone who made this internship possible.

Thank you

Appendix



Hardware Description of GIZMo Implementation Zedboard

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