UNIVERSITY OF NOTRE DAME NDnano CENTER FOR NANO SCIENCE AND TECHNOLOGY

NDnano Undergraduate Research Fellowship (NURF)
2014 Project Summary

1. Student name: Katherine Sanders

2. Faculty mentor name: X. Sharon Hu and Michael Niemier

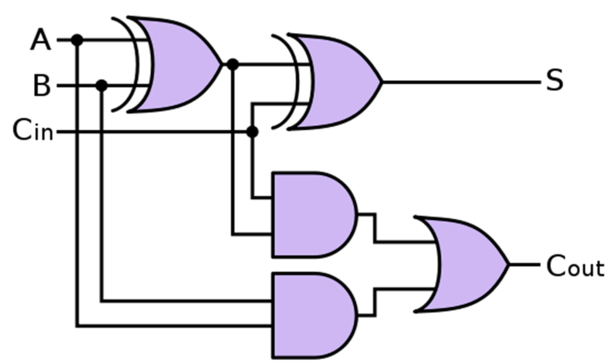
3. Project title: Stochastic computing and nanomagnet logic (NML)

4. Briefly describe any new skills you acquired during your summer research: Using new coding systems. Making a concise and engaging presentation of the work completed.

5. Briefly share a practical application/end use of your research: My critical thinking skills have increased by basing simulations off prior results. I am able to summarize my work and present it in an engaging fashion. Coding skills will be instrumental in my education as an electrical engineer.

Project Summary to describe problem and project goal and your activities/ results:

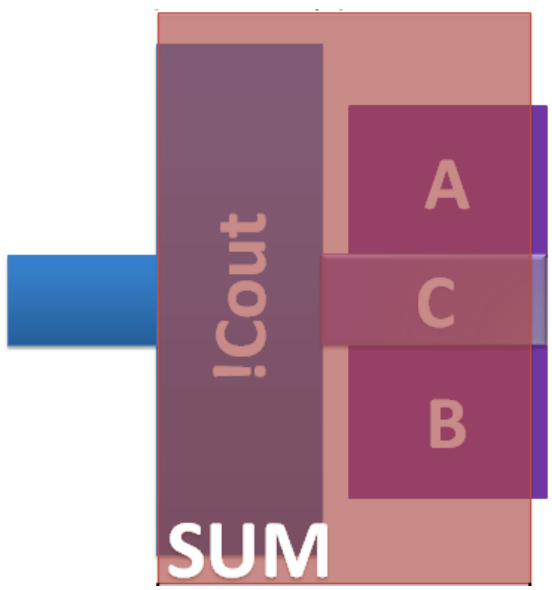
Leveraging stochastic computing (SC) paradigm and nanomagnetic logic (NML) devices, we are working to create a counter. Starting with an adder of five bistable magnets from an existing work we change different parameters to allow for correct logical computation. Using micromagnetic simulation tools, simulations are run to compare the effect these parameters have on different logic cases and on the adder as a whole (based on the clocking margins), test different NML structures, and use the results to create a functional counter. Unlike most NML research we focus on devices that use perpendicular magnetic anisotrophy (pNML) to process binary data. The clocking technique used allows us to compute the data and to reach a logically correct, computational ground state. Two important aspects of our adder are the majority gate and focused ion beam (FIB) irradiation. The majority gate is what causes both Cout! and the SUM magnets to reach logic '0'or '1' based on the input magnets A, B, and C. FIB irradiation can be employed to establish a direction of dataflow by changing the nucleation center of the magnet.



The image above is the gate diagram of a full adder. It shows how the logic state of the input magnets produce the logic state of the SUM.

The majority of our research relies on determining parameters of the adder to test, either in isolation or in tandem. To test these parameter changes we use Object Oriented MicroMagnetic Framework (OOMMF). This program creates 3D array of the magnetic fields of the adder.

For my work with the adder I ran simulations testing changes in the SUM magnet on the logic states. The adder has eight possible logic states, based on the three input magnets (A, B, and C). That is an excessive amount to simulate for every change, so only three (000,001, 010) are simulated for every parameter change. Typically five to six sets are run when testing a parameter. For example, when changing the width of the SUM magnet, if the width is changed in increments of 10nm then the final set will be a 60nm change in the width. Over the summer I completed approximately 70 simulations with the parameters listed: Increasing/ Decreasing the width of the SUM magnet (on both sides, above ABC, and about Cout!), Increasing/Decreasing the length of the SUM magnet, and Increasing/ Decreasing the height of the SUM magnet.



The image above is the full-adder used for our research. It is shown in the X-Y plane to highlight the shape. The adder is approximately 170x170nm.

However, when working with the counter I ran simulations testing changes in the C magnet on the logic states of the Cout magnet. The counter only has four possible logic states since one of the input magnets (B) is held constant. Still, only three (000, 001, 100) are simulated for every parameter change. Over the summer I completed simulations with the parameters listed: Increasing the length of C by 10nm, Decreasing the thickness of C, adding a FIB to C. For our counter, we want the largest positive margin and the smallest switching field magnitude possible. Our simulations have decreased the field magnitude and we have maintained a similar margin for the A and B magnets, but the Cin margin has reduced to zero for the most promising parameter changes. It is important to find a way to increase the margin of the Cin magnet as we continue to work toward a correct logical state.

Publications (papers/posters/presentations): Participation in the Notre Dame Summer Undergraduate Research Symposium.