ND*nano* Undergraduate Research Fellowship (NURF)
2014 Project Summary

1. Student name: Robert L. Frame III

2. Faculty mentor name: Gyorgy Csaba, Wolfgang Porod

3. Project title: Non-Boolean Computing Using Nanodevices

4. Briefly describe any new skills you acquired during your summer research:

This summer my research exposed me to the theory and use of the Van der Pol oscillator, and how to physically implement one using operational amplifiers and passive components. I learned how twenty such oscillators interact when coupled together in different configurations. Implementing an Arduino micro-controller I was able to figure out how to automate the control of the coupling and frequency of each oscillator. The final circuit I designed allowed me to further improve my programming code writing and pcb layout/design skills.

1. Briefly share a practical application/end use of your research:

The coupled oscillator circuit that I designed and constructed will be used in the field of cryptography. It performs what is referred to as a physically uncloneable function, or PUF. The fundamental idea behind PUF's being that even if one was to reverse engineer the exact same circuit and build it, the random interactions of the different oscillators, component tolerances, manufacturing inaccuracies, etc. would cause the final result to not perform the exact same way. The waveform produced by coupling multiple Van der Pol oscillators together at various frequencies appears random, but can be used to perform calculations and encrypt data in a non-Boolean method as the circuit is analog in nature operating under the digital control of a micro-controller.

Begin two-paragraph project summary here (~ one type-written page) to describe problem and project goal and your activities / results:

The problem and project goal I was presented with was to design and construct a working coupled Van der Pol oscillator circuit that could be used in multiple configurations for further research in cryptography and analog non-Boolean computing. The basis for the design called for twenty such oscillators, with each having the ability to be varying in frequency and coupled and decoupled as desired. The circuit was to be controlled from a computer with the implementation of an Arduino micro-controller development board and associated programming code. With these circuit parameters established, I began to create and design the resulting electronic circuit that consists of analog oscillators under digital control.

The Van der Pol oscillators were created by implementing an operational amplifier based circuit. The frequency control was implemented using digital potentiometers that could be programmed using the serial peripheral interface, or SPI bus, of the Arduino MEGA 2560 development board. This allowed for a frequency range varying from approximately 5 kHz to 65 kHz for each oscillator. The oscillator coupling was decided to be controlled by CMOS switching integrated circuits, also controlled by signals sent from the micro-controller. An external breadboard allowed for the coupling of the oscillator outputs in any configuration needed, individually or in multiple groups. The outputs of the individual oscillators, as well as the coupled output can also be monitored on an oscilloscope via BNC connectors on the front panel of the device. The final circuit performed as expected with additional options to independently modulate the frequency of any oscillator and auto-couple the outputs by the micro-controller.

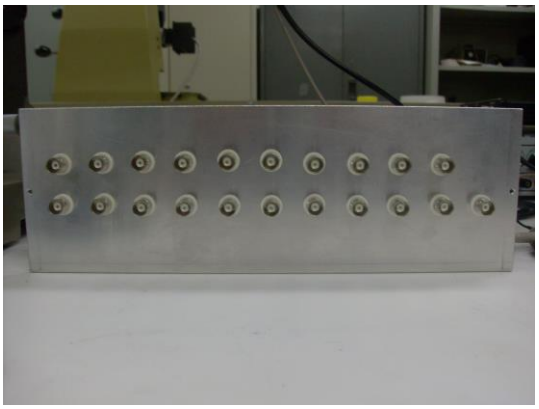

Figure 1: Final Device Front Panel

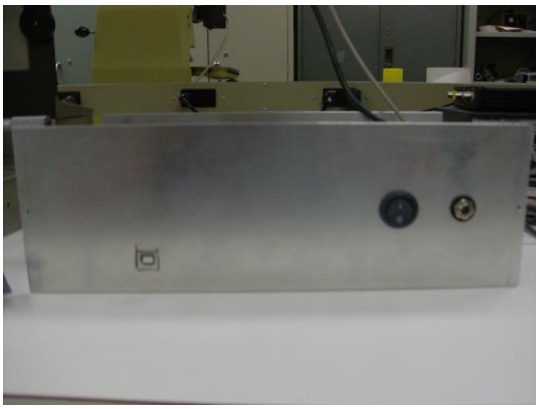

Figure 2: Final Device Rear Panel

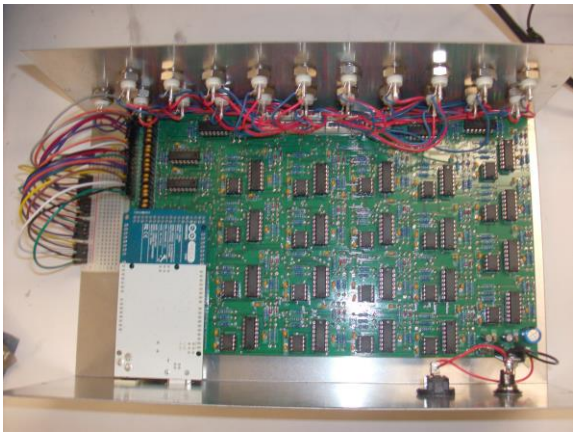

Figure 3: Final Device PCB and Internal Wiring

Publications (papers/posters/presentations):
Coupled Oscillator Manual (User's Guide)