Digitally Programmable Variable Gain Amplifier for Wireless Communication Applications

Gaurav Jha, *M.S. Student, Northeastern University*
Mengting Yan, *Ph.D. Candidate, Northeastern University*
Rohit Chopra, *YSP Student, Community Charter School of Cambridge*
Brian Estevez , *YSP Student, Urban Science Academy*
Marvin Onabajo, *Department of Electrical and Computer Engineering, Northeastern University*

Abstract

Analog circuits play a key role in devices for the wireless transmission and reception of information. They have to be designed with high performance and reliability. However, the quality of analog circuits depends strongly on variations of electronic component parameters and manufacturing processes. A general research approach aimed at improving analog circuits in the presence of random variations involves the measurement of key performance parameters in combination with automatic tuning for optimum performance through the aid of circuits in the same system. To allow the tuning of analog circuits with digital control, programmable elements have to be incorporated into the analog circuits. This approach will be investigated in this research project by prototyping a digitally controllable variable gain amplifier.

Introduction

Variable gain amplifiers play an important role in wireless receivers, they serve 2 main functions. The first is to boost the output signal level based on the level of strength from the received signal, this amplification is known as the gain. The second function of the VGA is to optimize the signal level at the input of the analog to digital conversion allowing for less information loss through the conversion. Within this project we have constructed a digitally controllable variable gain amplifier using an Arduino Uno microcontroller and a prototype board with discrete electrical components.

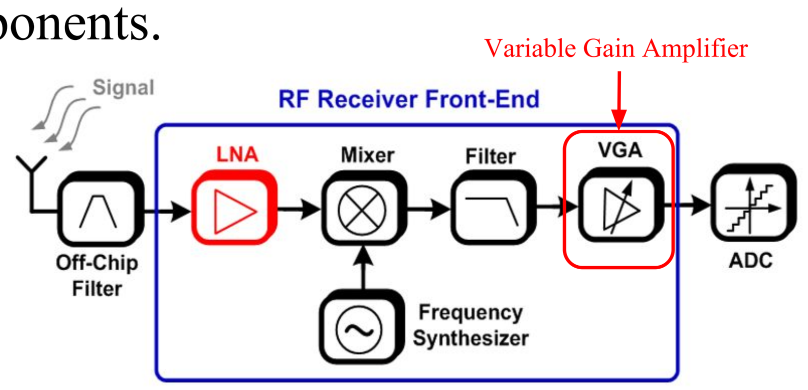


Figure 1: Radio Frequency Receiver Front-End

Development of Variable Gain Circuit

The design process of this project consisted of 3 main stages of development, starting with simulations, floor planning, then assembly via soldering.

- Simulations are done through LTSpice with diagrams that allow for simulated signal testing throughout the circuit diagram.
- After tests are completed on the simulated circuit, a floor plan is made to show where specifically on the board the discrete electronic components go.
- Once the floor plan is approved we move the electrical components to the prototype board and are connected by solder.

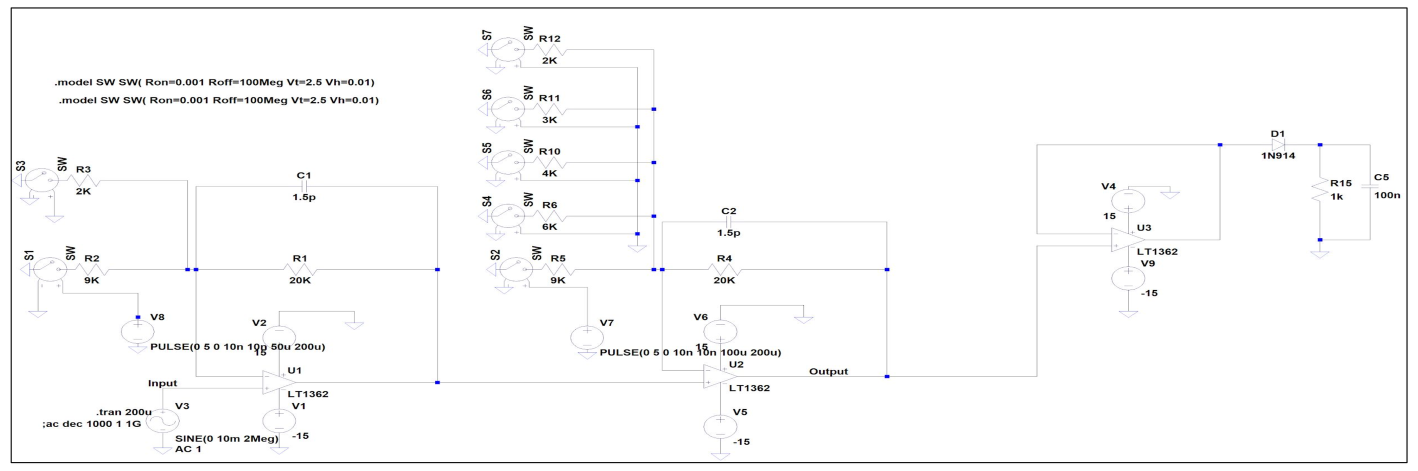


Figure 2: LTspice Simulation Circuit

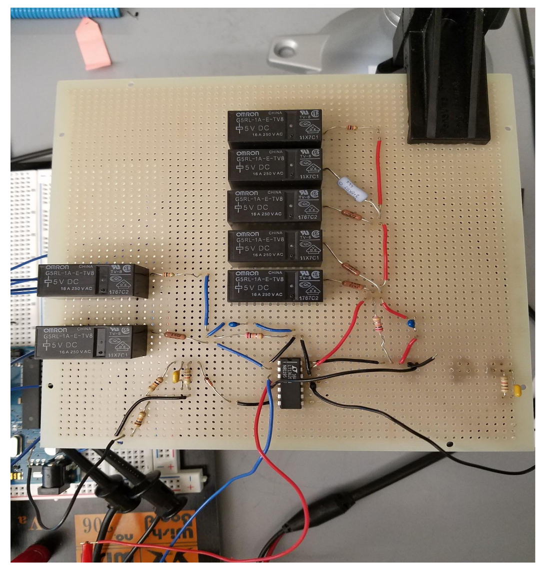


Figure 4: Finished Circuit

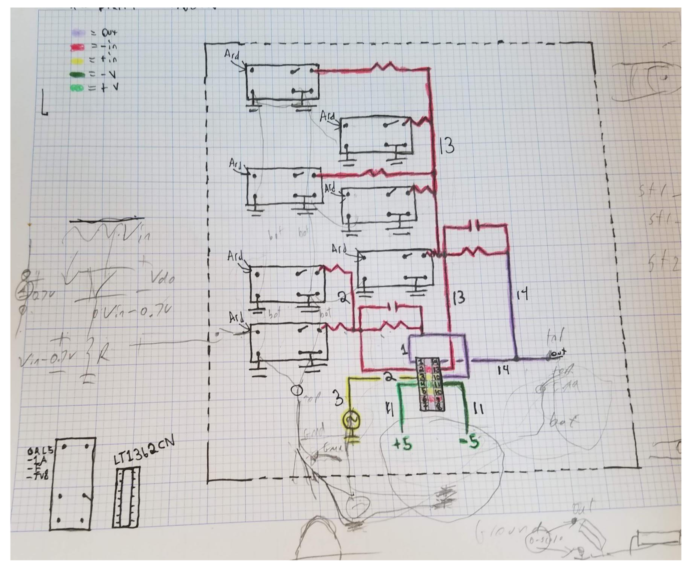


Figure 3: 1st Floor Plan Draft

Development of Gain Calibration Software

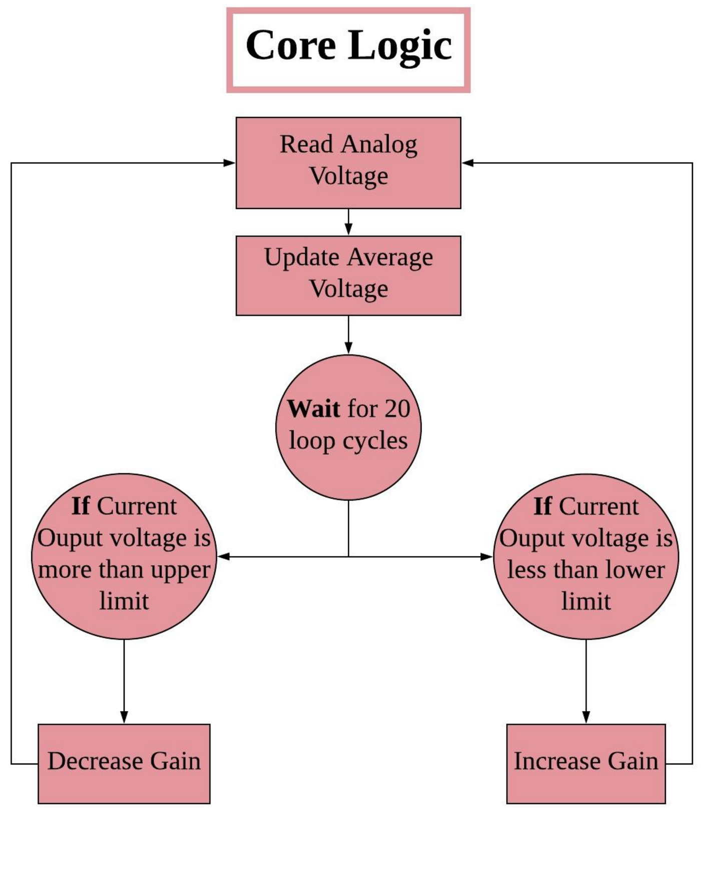


Figure 5: Code Flow Chart

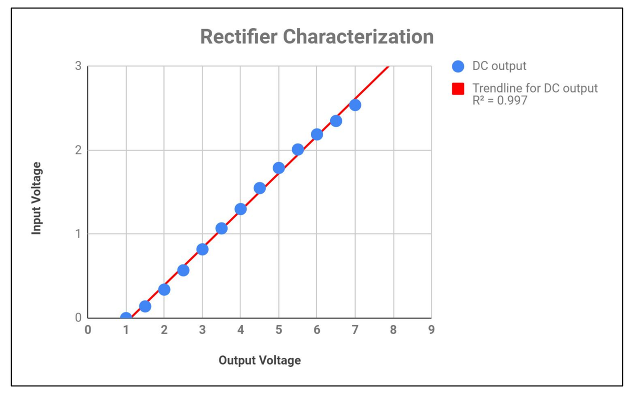


Figure 6: Rectifier Characterization

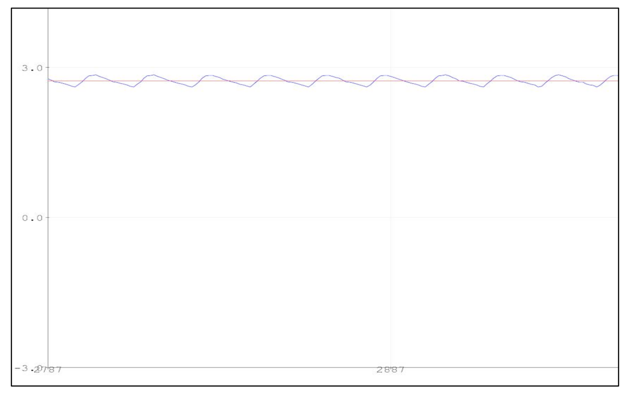
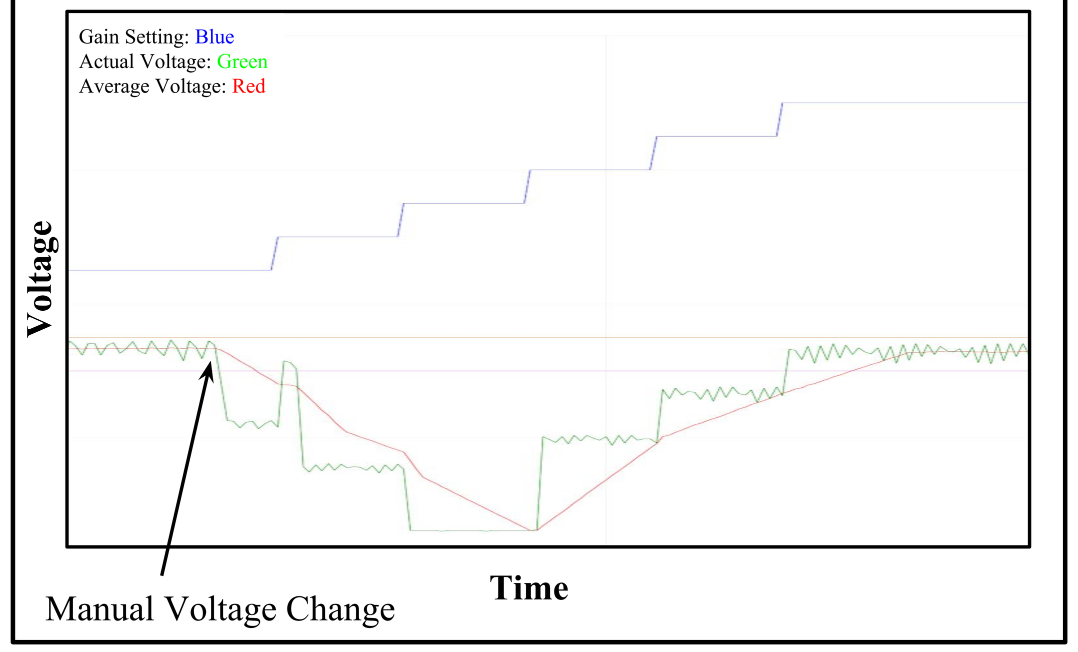


Figure 7: Average Voltage Function

An Arduino Uno microcontroller was utilized to measure the voltage and control the gain. A full wave rectifier was used to convert the AC voltage to DC voltage. A table mapping the input voltages to the output voltages had to be made as the rectifier transforms the output. The relation found by the table allows the output being read from the Arduino to be translated back to the input of the rectifier. Another result of using the rectifier is a ripple in the output voltage. The true DC voltage is the midline of this ripple and an averaging method is used to find the midline. In order to maximize output, the Arduino is used to keep the gain as high as possible without clipping. The Arduino is able to control the gain settings of the VGA by controlling which relays are closed, or which resistors are connected to each operational amplifier.

Conclusion

As shown with the graph below, the Arduino calibrates the gain within the desired values as expected. Once the voltage is manually changed, the gain settings automatically increase until the voltage settles inside the desired range. A delay was added to allow the average to settle before the gain could be changed again. This prevents the Arduino from constantly overshooting or undershooting the desired range.



Future Work

Moving forward, additional relays will be added for a more precise tuning. Further optimization of the delay between changing gain settings will allow for faster tuning as well. Hopefully in the future the circuit could be moved to a smaller chip for more efficiency.

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