Direct Digital Synthesis (DDS)

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Milestone 1 - Project Description and Prototyping

Direct Digital Synthesis (DDS) is an upcoming product, with the goal of allowing the user to dynamically adjust the frequency, phase and amplitude of a reference signal. One of the key draws of this product is that it will be implemented on an FPGA to allow for rapid prototyping and development. An interesting video to watch on the topic is *The Basics Of Direct Digital Synthesis (DDS)* [1].

Project Description

The DDS system is comprised of three stages of operation: **Input**, **Processing**, and **Output**.

The **input stage** handles the user's selection of parameters, through a series of buttons and switches, of the note(s) to be played and the chosen waveform. **The processing stage** is the most complex, and contains most of the software functions of the system. This stage handles the storage of different preset waveforms (sine, triangle, saw, square) in lookup tables, while mixing the output levels if more than one note is played simultaneously. This data is then sent to the output buffer. The **output stage** reads from the output buffer and converts the digital data to an analog signal via PWM and a low-pass filter.

To adjust the frequency of a signal, a look-up table of the signal is created. The speed at which this lookup table is then traversed determines the frequency of the output signal. The phase can be adjusted by by providing an offset to the starting point in the lookup table. The amplitude of the signal can be amplified or attenuated through the application of digital gain before the output stage, or at the output stage itself. These are not guaranteed to be the final methods used, but give us a set of specifications to work towards, as well as a good idea of the means to implement them. Presenting an overview of the system (Figure 1) is crucial to understanding how the different modules of the system fit together. The three modules, Input, Processing, and Output, can be developed concurrently.

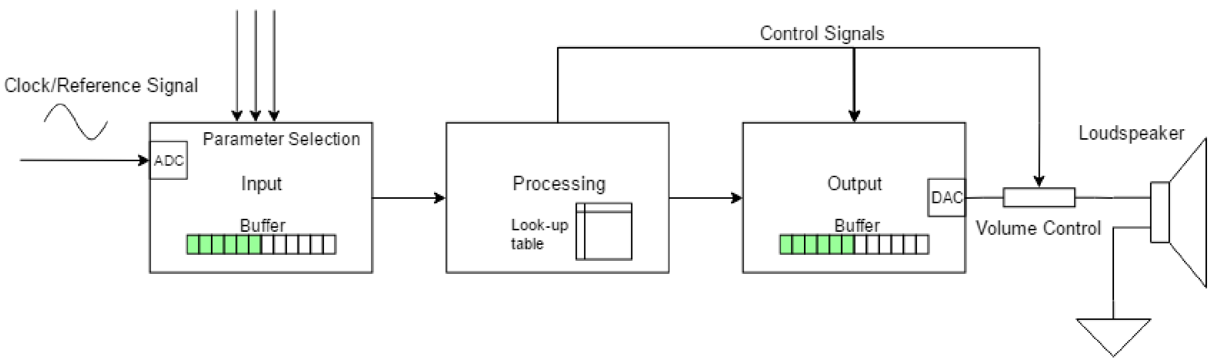

Figure 1: Overview of the system

Defining "Success"

Measuring the success of the product is crucial in guiding the development process. Having clear goals towards which we can work allows the development team to shift emphasis from certain aspects of the design to others needing more work. This also allows us to gauge our progress and consequently allocate our team's resources more efficiently. Throughout the project, we will make use of software to develop our fundamental waveforms. These waveforms will be our test inputs to the system in lieu of analog input; this allows a more modular workflow, as the development of the system is not bottle-necked by the implementation of the input section. We will use cross correlation [3] between our "input" and output signals to determine their similarity, as well as using oscilloscopes to visually ascertain their similarity.

Prototype Specification

- A system shall be developed to generate an analog signal at the output of the FPGA
- This signal should be generated by iterating through the values of a lookup table and sending them to the output
- Different lookup tables for a set of predefined waveforms (sine, saw, square and triangle) must be created
- The system must accept user input to select the parameters of the system (pitch, octave, amplitude, and waveform)
- Multiple notes should be able to be played simultaneously
- The system parameters should be displayed on a digital display

Formal Design Criteria

- Less than 1% frequency drift when generating signals compared to their base frequency
- Less than 100ms of delay between input and output
- Less than 0.1V of quantization error on a 3.3V/440Hz sine wave
- Polyphony allowing three notes to be played simultaneously
- Dimensions of the final product should not exceed 20cmx20cmx20cm
- Less than 1kg in overall weight
- Less than 200mW (FPGA) (5W if including amplifier)

Stretch Goals

- Use an external amplification circuit to drive a loudspeaker
- Digital filtering of input signal to reduce noise
- Peak/zero crossing detection to determine frequency of input signal
- Adding a DC offset to input signal before ADC
- Dual channel Output
- Frequency and/or amplitude modulation of two signals

References

1. "The Basics Of Direct Digital Synthesis (DDS)." YouTube video, 12:32. Posted by "HWDSPSolutions," April 1, 2013. https://youtu.be/tYzYok3Vo9c.
2. Bhagat, K.,University of Illinois at Urbana-Champaign,2012-12, http://mathworld.wolfram.com/Cross-Correlation.html.
3. Weisstein, Eric W. "Cross-Correlation." From MathWorld--A Wolfram Web Resource. http://mathworld.wolfram.com/Cross-Correlation.html.