Touchscreen Synthesizer

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Overview

Our project introduces a new alternative in synthesizers – a touchscreen synthesizer. A synthesizer is a sound producing electronic instrument that is used to generate a broad range of sounds and tones, as well as apply different effects, such as filtering and resonance. Although it is usually controlled by an analog interface consisting of buttons, switches, sliders, knobs, and piano keys, our aesthetically appealing product employs these features via a touchscreen, relieving the user from any physical stress.

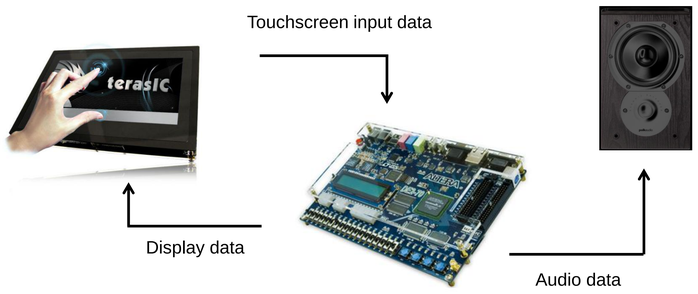
Objectives

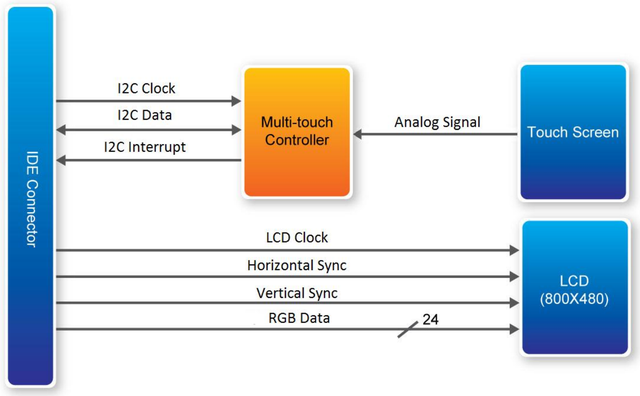
- Read touch input from the Terasic Multi-Touch module
- Generate basic waveforms (up to 3 octaves)
- Read in additional waveforms from memory
- Generate major and minor chords
- Generate and apply band-pass filters to waveforms (equalizer)
- Output graphical user interface to LCD screen
- Output audio signals

System Architecture

The **Altera DE2-70 FPGA** board is the core processing unit of the touchscreen synthesizer. It offers superior performance over a standard microprocessor because its highly parallel operation allows specific filter forms to be run very quickly. Additionally, it offers a wide variety of peripherals to connect input / output and a large amount of memory to store additional waveform samples.

The **Terasic Multi-Touch LCD** module is an all-purpose capacitive touchscreen for FGPA applications. It provides multi-touch gesture and single-touch support. An IDE cable with an IDE to GPIO (ITG) adapter is used to interface with the Altera DE2-70 FPGA board through a 2x20 GPIO interface on the Multi-Touch LCD.





Digital Signal Processing

Sound Generation

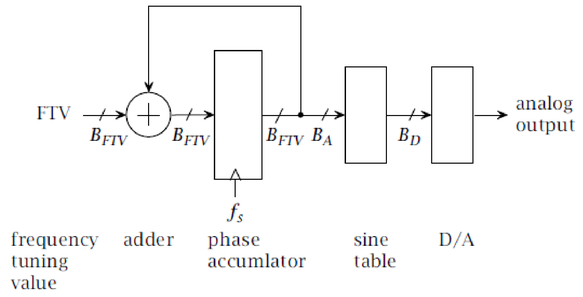
- The synthesizer uses four basic waveforms to generate audio output. The first three waveforms are:
  - Square Wave
  - Saw-Tooth Wave
  - Triangle Wave

  These waveforms are quite easily implemented through mathematical equations.

- The fourth basic waveform is:
  - Sinusoid

  The sinusoid was created through Direct Digital Synthesis. Direct Digital Synthesis stores one full period of a sinusoid in an internal array. By indexing through this array at a specific frequency, a sinusoidal waveform is generated. In order to increase or decrease the sinusoidal frequency, index values are skipped over or held, respectively, while iterating through the array.

$$output\ frequency\ f_0 = FTV\frac{f_s}{2^{B_{FTV}}}$$

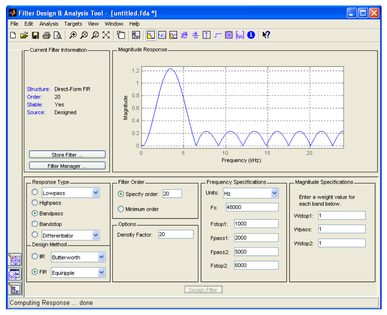


- The synthesizer allows for the generation of both major and minor chords.
  - Major chords are generated by combining the base note with the corresponding major third and perfect fifth
  - Minor chords are generated by combining the base note with the corresponding minor third and perfect fifth.

- The synthesizer allows for 3 distinct octaves to be generated. The possible notes range from C to B for frequencies from 131 Hz to 988 Hz

Filter Generation

The synthesizer's equalizer strengthens or weakens the energy of a signal in specific frequency bands. The equalizer uses band-pass infinite-impulse-response (IIR) filters to tune the gain in the different frequency bands.



The filter coefficients for the equalizer were generated with MATLAB's fdatool. Fdatool allows a filter designer to select the type of filter (high-pass, low-pass, band-pass, or band-stop) type of impulse response (FIR or IIR), type of design method (Butterworth, Equiripple, etc), cutoff frequencies, gain, and order.

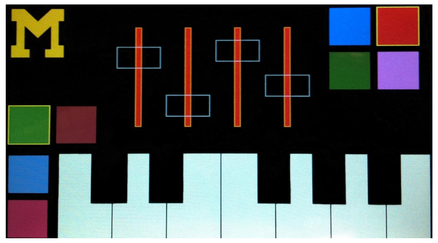
Multi-Touch LCD

Touchscreen Input

The Multi-Touch LCD is a capacitive, 2-point touchscreen. When a person touches the screen, the X and Y coordinates and gesture type (click, north, south, east, west, etc) of the touch(es) are determined by the touchscreen controller. These X and Y coordinates are then analyzed to determine which buttons, keys, or sliders have been pressed.

Graphic User Interface

The Multi-Touch LCD display is 800 x 480 pixels and uses 24-bit color. The display is generated by sending the RGB color data and the horizontal / vertical sync signal to the LCD.

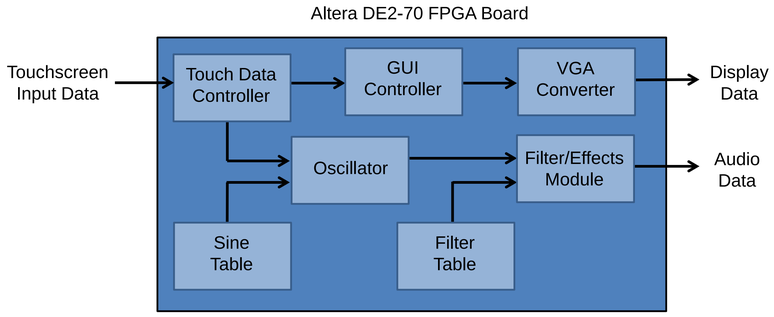


Function libraries for parameterized shapes were programmed to ease in the design and layout of the synthesizer display. Functions for drawing the following items were created:

- Rectangles
- Circles
- Lines
- Text (A-Z, 0-9)
- Colors (name addressed lookup table)

For the rectangle and circle functions, the width and length (or radius), X and Y coordinates, and color taken as inputs. Similarly, lines are drawing by specifying the X and Y coordinates of the endpoints. The line function was based off of the Bresenham line algorithm.

Software Module Design



Touchscreen input data is first sent to the touch data controller to determine what button, key, or slider was pressed. The processed data is then fed into both the visual and audio data paths. The visual data path updates the LCD display, and the audio path generates the selected waveform / frequency and applies any selected filters.