




conFFTi - FPGA music synthesizer

Team D8 - Michelle Chang, Hongrun Zhou, Jiuling Zhou

Use Case


- Synthetic musical instrument for electronic music production
- Fast, configurable and portable solution
 - **Software synthesizer:** cheap, configurable, but high latency
 - **Hardware synthesizer:** fast, but expensive, with limited configurability
 - **FPGA synthesizer:** (potentially) best of both worlds



Serum
by Xfer

Serum by Xfer Records - Advanced Wavetable Synthesizer for Mac/Windows
\$189.00
ADSR
Free shipping, no tax

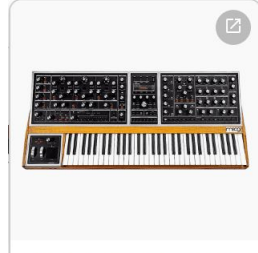
Software
Synthesizer



Korg Opsix Altered FM Synthesizer
\$799.99
Sweetwater
Free shipping

For most items:
30-day return policy

Hardware
Synthesizer



Moog One Polyphonic Analog Synthesizer 16 Voice
\$8,499.00
Guitar Center
Free shipping

For most items:
45-day return policy

State-of-the-art
Hardware
Synthesizer

conFFTi

- Accepts real-time input from a MIDI keyboard
- Generates audio output with subtractive, wavetable and frequency modulation synthesis on FPGA
 - Waveform generation (tri, sin, sqr, saw, wavetable)
 - Filter - Finite impulse response, Infinite Impulse response
 - Distortion - Compression, overdrive
 - Frequency Modulation
 - ADSR Envelope
 - Arpeggiator

Requirements

- 44.1kHz, 16-bit, single channel audio output
- 4-note polyphony
- Low latency (< 10 ms)
- UI for parameter manipulation utilizing keyboard faders and knobs

Technical Challenges

- Memory requirement
 - Arpeggiator is RAM heavy
 - 4-notes polyphony x 4-note arpeggiation x 44.1k sample/s x 16 bit/sample x 2 s/note x $\frac{1}{8}$ byte/bit = 2.8MB
- Fix point division
 - unsupported by SystemVerilog
- Random Number Generation for Arpeggiator
 - Needs a low latency yet good (pseudo-)random generator

Solution Approach

- Memory requirement
 - FPGA with large RAM (brings more logical elements as well)
 - External RAM (cheaper)
- Fix point division
 - Look up tables
- Random Number Generation
 - Linear-feedback shift register
 - CRC generator

Solution Approach

- MIDI keyboard
 - DIN port for interfacing with the FPGA
 - Have a good number of knobs and faders (~8) for parameter control
- FPGA
 - Large RAM and Large number of logic element
 - 4 audio processing pipelines for 4 note polyphony
 - Use RAM to store high fidelity wavetables for 44.1kHz, 16-bit audio output
- Audio Output Unit
 - Microphone for realtime audio output

Testing, Verification and Metrics

- Waveform Comparison
 - For each effect, compare reference waveform generated by Matlab scripts to that of the waveform generated by the FPGA measured by an oscilloscope
- Metrics
 - Aim for high FPGA logic unit and memory utilization
 - Lowest possible latency

ECE Areas

- Software (Embedded Systems)
- Hardware (FPGA, SystemVerilog)
- Signals (Filter Design, Fourier Transform, Sampling)

Tasks and Division of Labor

- Michelle

- Waveform generation
- Filter design
- Distortion
- ADSR
- Mixer

- Hongrun

- MIDI keyboard interface
- Audio output
- Frequency Modulation
- Arpeggiator
- Waveform verification
with Oscilloscope output

- Jiuling

- Polyphony control
- Random number
generation
- Delay
- Echo

Schedule

