FPGSZR

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18-500 Capstone Design, Spring 2026
Electrical and Computer Engineering Department
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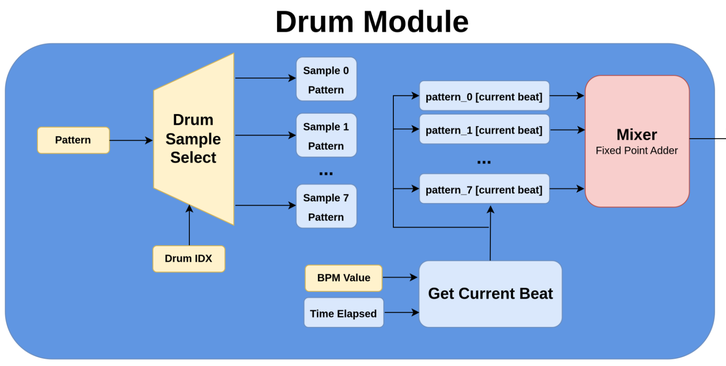
Product Pitch

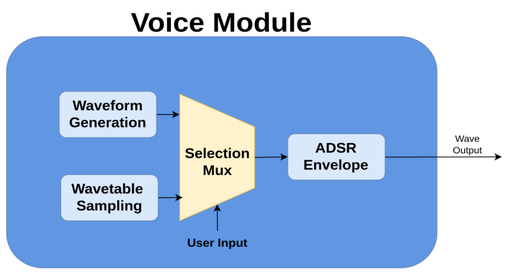
Hardware synthesizers are a pivotal part of modern day music production. However, a capable hardware synthesizer with a built-in drum machine is **not** cheap. Our group solves this problem by providing a modern, capable digital hardware synthesizer with **filtering**, **ASDR, effects**, **wavetable sampling**, and a **drum track**, to lower the barrier to entry for new users who are interested in music production. It features:

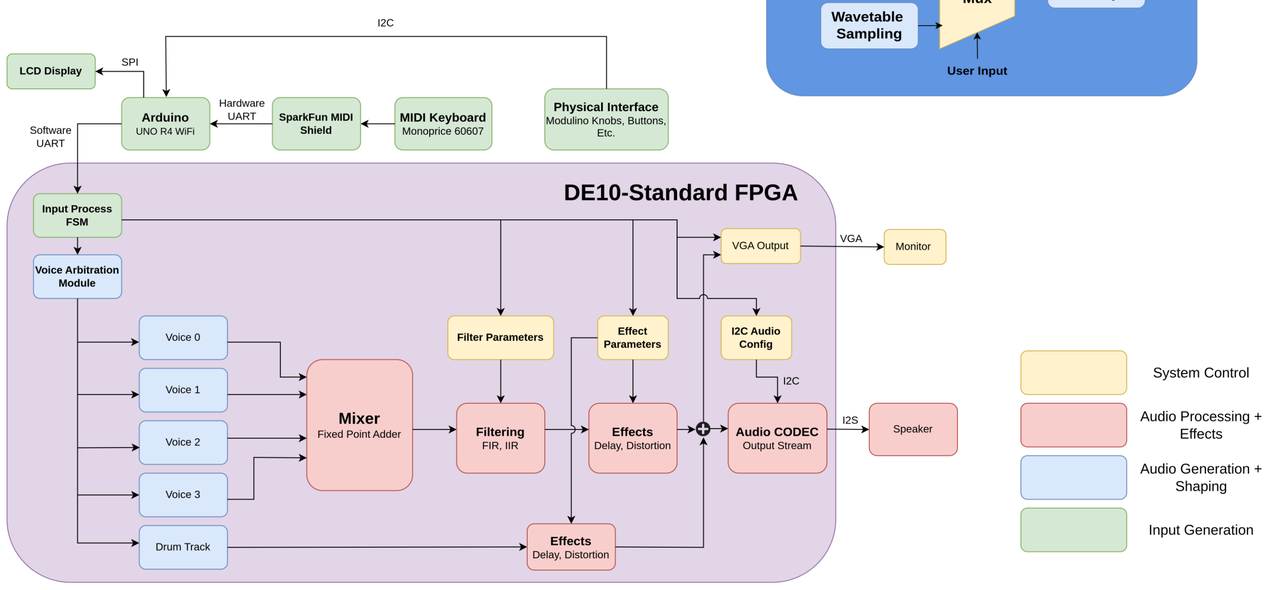
- **Intuitive UI**
- **Lightweight, 5 lb design**
- **Minimal latency (<5 ms)**
- **High Audio Quality (0.33 cent average error)**

System Architecture

User input is captured via MIDI keyboard, buttons, and knobs, and preprocessed by an Arduino microcontroller prior to transmission to an FPGA. In the FPGA, each voice module employs wavetable oscillator synthesis, feeding the resulting waveform through an ADSR envelope, digital filter, and effects chain. The drum module uses stored samples and user patterns for playback. The voice outputs are mixed and transmitted to a CODEC for digital-to-analog conversion. Real-time parameter state is reflected on an LCD display and a VGA output.







Conclusions & Additional Information

https://course.ece.cmu.edu/~ece500/projects/s26-teamd0/

Overall, we are happy with the project. While we had to create workarounds for some components, we feel that we achieved our goal of creating a capable hardware synthesizer at an affordable budget. In the future, we hope to expand the system and add more features such as additional voices and filters.

System Description

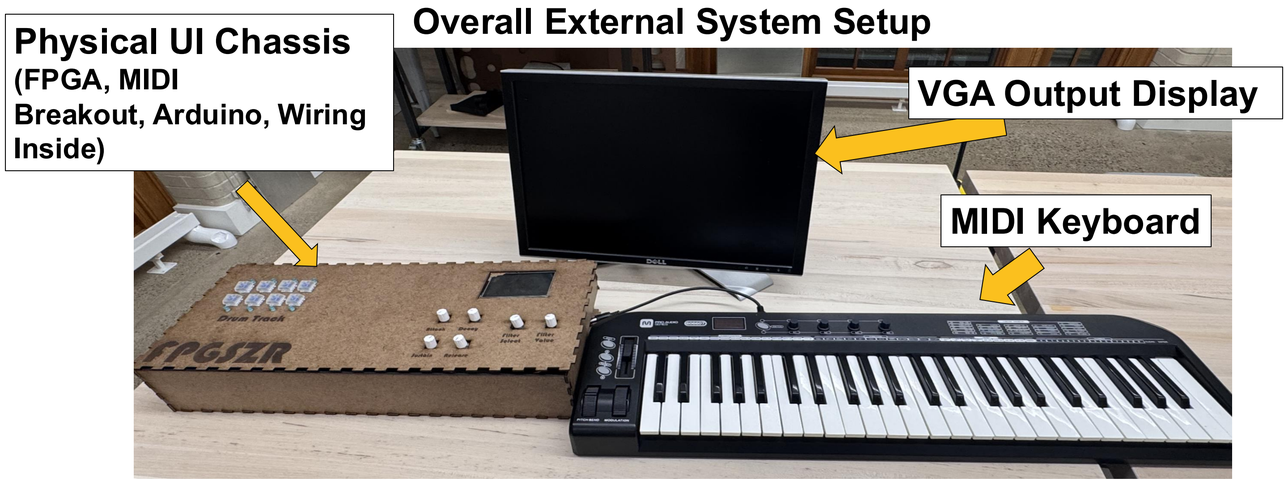
DE10 Standard FPGA
- Wave Generation
- ADSR (Attack, Decay, Sustain, Release)
- Filtering
- Effects (Delay, Saturation)

Arduino + MIDI breakout board
- Captures user + MIDI input
- Forwards input to FPGA
- Talks over I2C, UART, and SPI

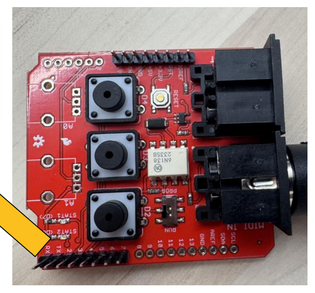
Physical UI
- Knobs (ASDR, filter, and menu control)
- Buttons (drum programming)
- LCD (menu display)
- VGA (Oscilloscope and ASDR visual)

MIDI keyboard
- Modular
- Standard keyboard interface

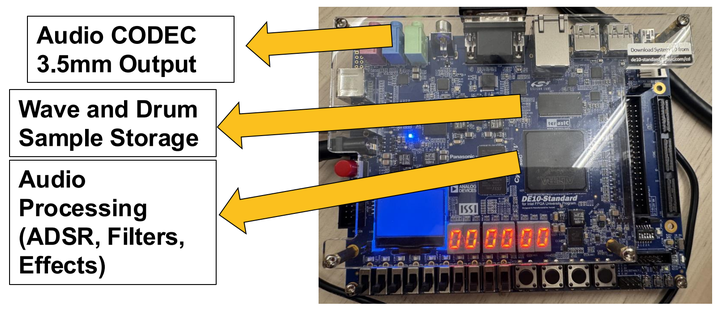
Overall External System Setup



SparkFun MIDI Breakout Board



Internal DE-10 Standard FPGA



System Evaluation

A three-level approach was taken, testing at the module, subsystem, and system levels. SV testbenches were compared against golden models for the first two, while physical measurements were taken for system evaluation.

Testing Results for Audio Quality as of 04/17

Wave Type	THD (dB)	SQNR (dB)	SFDR (dB)
Sine Wave	-55.29	+44.99	+59.32
Square Wave	-6.31	+30.10	+9.54
Saw Wave	-1.90	+25.33	+6.02
Triangle Wave	-18.33	+108.37	+19.08

Use-Case Requirements:

Metric	Target	Actual
System Latency	≤ 5 milliseconds	≤ 2.741 milliseconds
Audio Accuracy	< 5 cent difference	0.33 cent avg, 1.45 max
Audio Quality	≥ 40 dB SQNR	* Varied Results

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