A4

FMPGA: The Frequency-Modulating Programmable Gate Array

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Application Area

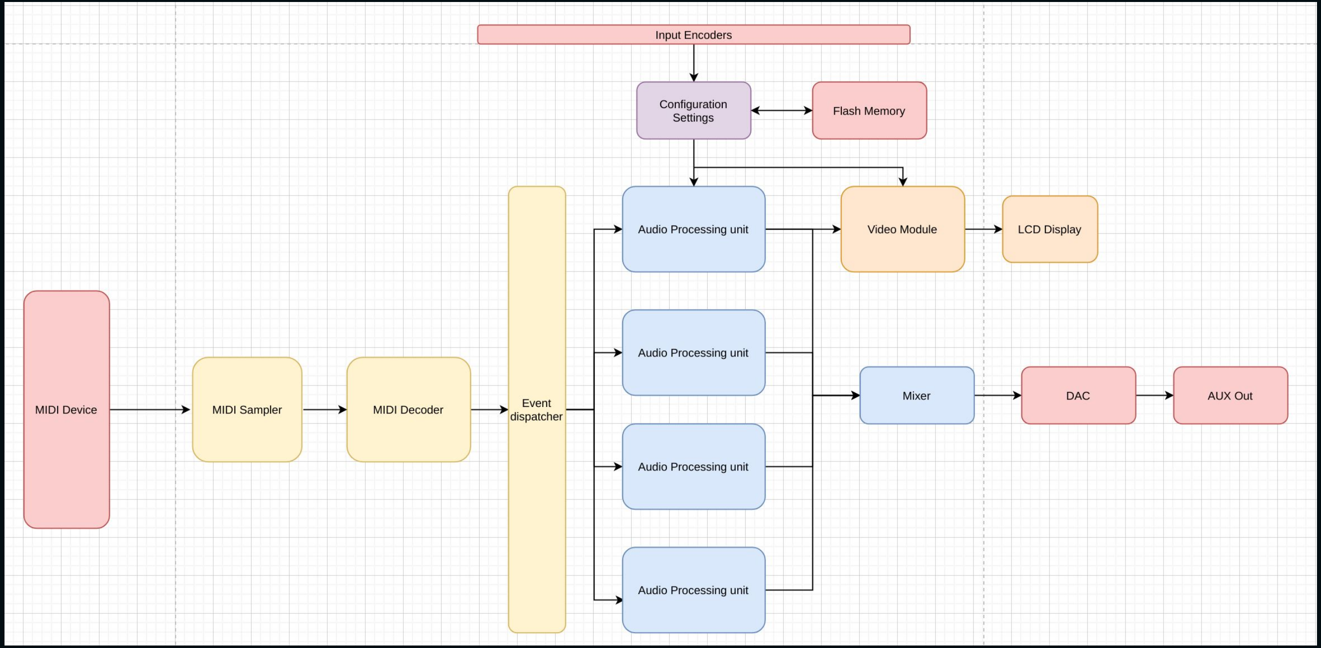
We provide an FPGA solution for on the fly digital audio synthesis.

Unlike previous FPGA solutions, we are providing:

- The ability to generate audio streams, rather than operate on existing streams.
- The ability for a user to modulate pitch, oscillators, amplitude, filters, and distortion in real time.

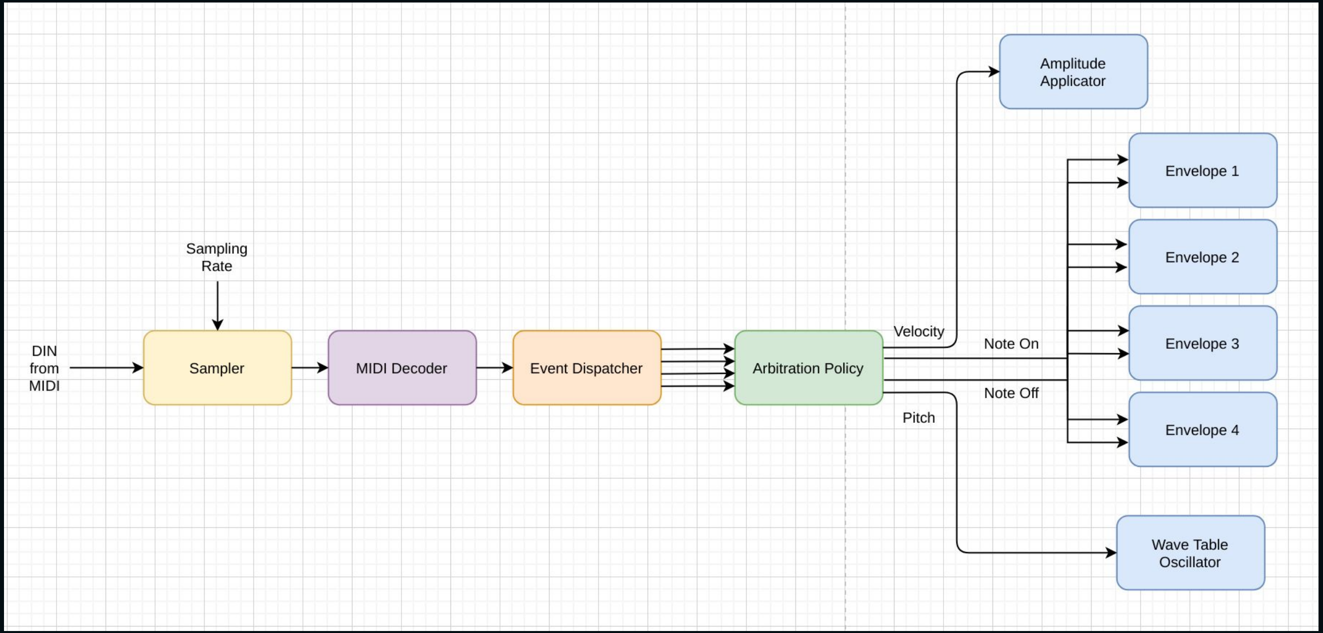
Unlike commercial solutions, we are combining extremely low latency with a very high level of control over sound synthesis while maintaining 4 note polyphony.

System Specification



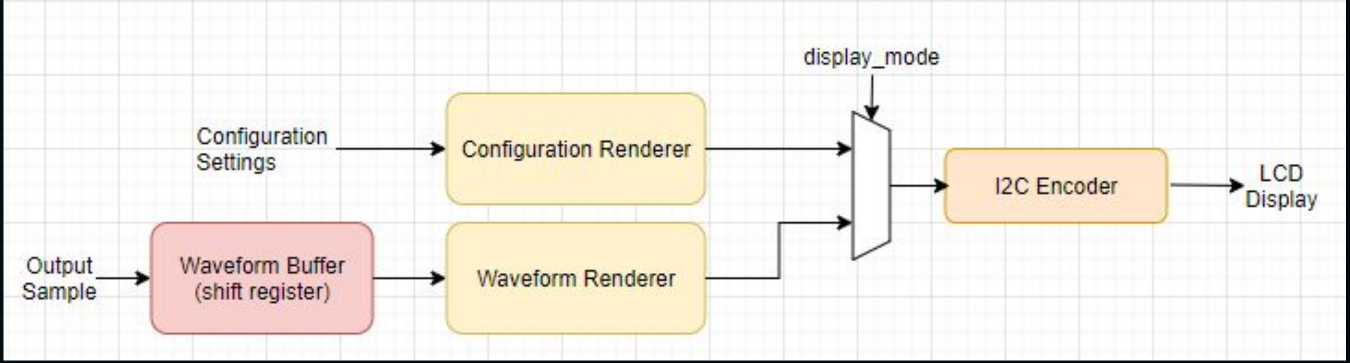
- MIDI Layer
- Audio Processing Layer
- Video Layer
- External components

MIDI Layer



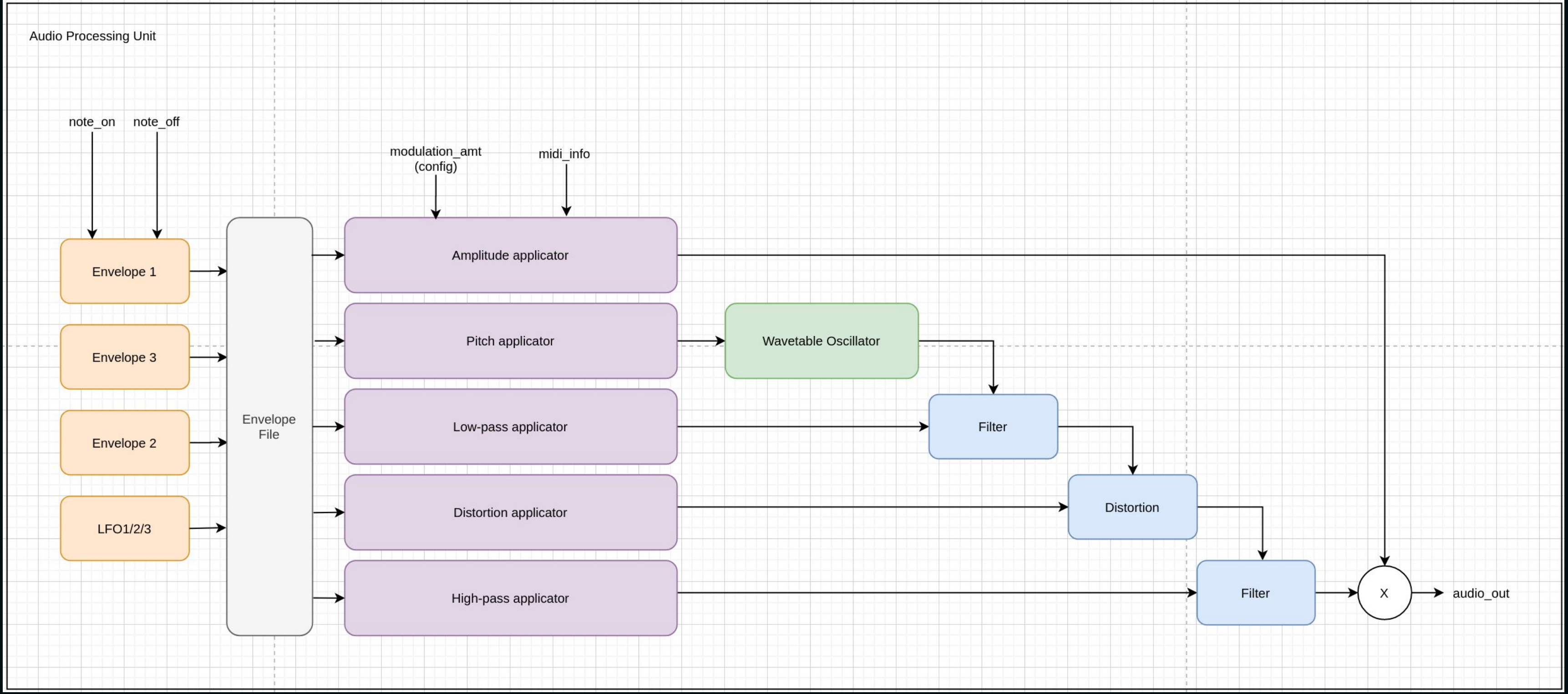
- Sampler: samples the MIDI input at a dynamic rate
- MIDI Decoder: converts bitstream to a list of distinct “events”
- Event Dispatcher: determines the destination and handling of events
- Arbitrator: fairly distribute the load and balance 4-note polyphony

Video Layer



- Waveform Buffer - stores the history of samples so that an image of the waveform can be rendered
- I2C Encoder - Converts the rendered display buffer into a stream of bits to communicate with the display
- Waveform Renderer - Converts the waveform to an image
- Configuration Renderer - Displays settings for the current sound

Audio Processing Layer



Audio Processing Unit

- Envelopes: allow user to on-the-fly adjust/modulate arbitrary parameters
- LFO: low frequency oscillator, allows user to apply a periodic modulation to arbitrary parameters.
- Applicators: apply an envelope to a particular parameter
- Wavetable oscillator: generates a wave at an audible frequency
- Filters/distortion: modulated audio effects that can be applied to the sound

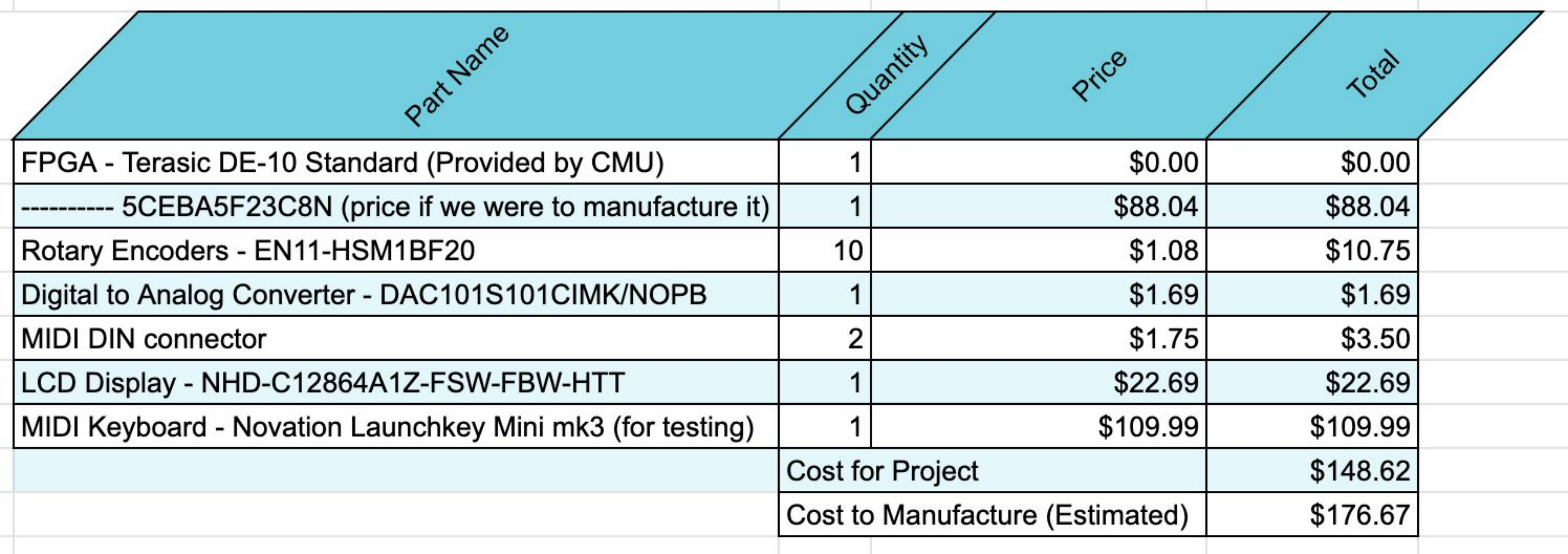
Implementation Plan

- We are designing all FPGA components, including the MIDI, audio processing, and video layers.
- We are buying the FPGA itself, the external display, the control knobs, and the DAC. We are also buying a MIDI keyboard for testing.
- We have designed a robust system for testing SystemVerilog against Python models.

Metrics & Verification

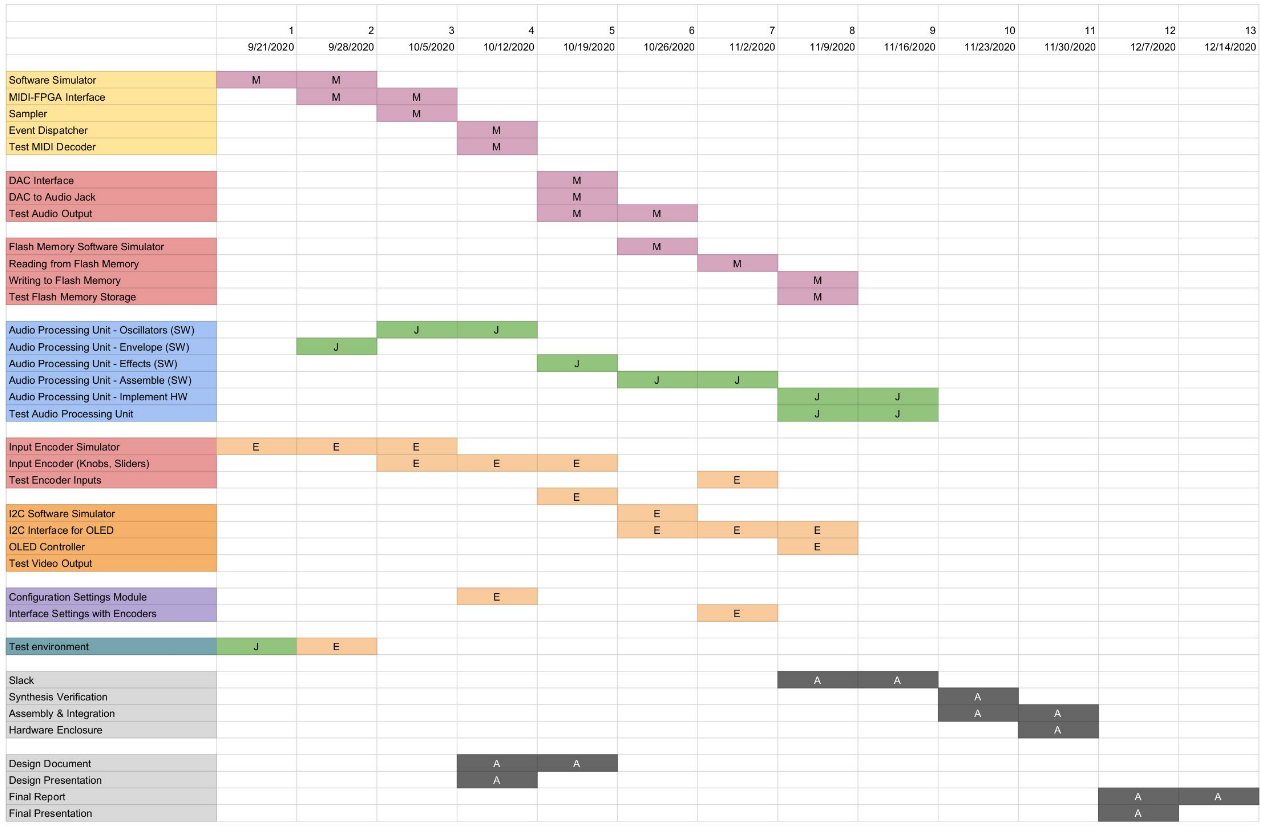
- Software simulators & unit tests for each module in design
- Software simulator of entire MIDI layer, audio layer, and video layer
  - Verify accuracy of MIDI processing
  - Verify accuracy of modulations and effects on pitch
  - Verify video functionality and communications
- Physical verification: verification of latency using high speed audio capture, tuner to measure intonation

Bill of materials



Part Name	Quantity	Price	Total
FPGA - Terasic DE-10 Standard (Provided by CMU)	1	$0.00	$0.00
---------- 5CEBA5F23C8N (price if we were to manufacture it)	1	$88.04	$88.04
Rotary Encoders - EN11-HSM1BF20	10	$1.08	$10.75
Digital to Analog Converter - DAC101S101CIMK/NOPB	1	$1.69	$1.69
MIDI DIN connector	2	$1.75	$3.50
LCD Display - NHD-C12864A1Z-FSW-FBW-HTT	1	$22.69	$22.69
MIDI Keyboard - Novation Launchkey Mini mk3 (for testing)	1	$109.99	$109.99
	Cost for Project		$148.62
	Cost to Manufacture (Estimated)		$176.67

Updated Schedule



	1	2	3	4	5	6	7	8	9	10	11	12	13
	9/21/2020	9/28/2020	10/5/2020	10/12/2020	10/19/2020	10/26/2020	11/2/2020	11/9/2020	11/16/2020	11/23/2020	11/30/2020	12/7/2020	12/14/2020
Software Simulator	M	M											
MIDI-FPGA Interface		M	M										
Sampler			M										
Event Dispatcher				M									
Test MIDI Decoder				M									
DAC Interface					M								
DAC to Audio Jack					M								
Test Audio Output					M	M							
Flash Memory Software Simulator						M							
Reading from Flash Memory							M						
Writing to Flash Memory								M					
Test Flash Memory Storage								M					
Audio Processing Unit - Oscillators (SW)			J	J									
Audio Processing Unit - Envelope (SW)		J											
Audio Processing Unit - Effects (SW)					J								
Audio Processing Unit - Assemble (SW)						J	J						
Audio Processing Unit - Implement HW								J	J				
Test Audio Processing Unit								J	J				
Input Encoder Simulator	E	E	E										
Input Encoder (Knobs, Sliders)			E	E	E								
Test Encoder Inputs							E						
					E								
I2C Software Simulator						E							
I2C Interface for OLED						E	E	E					
OLED Controller								E					
Test Video Output													
Configuration Settings Module				E									
Interface Settings with Encoders							E						
Test environment	J	E											
Slack								A	A				
Synthesis Verification										A			
Assembly & Integration										A	A		
Hardware Enclosure											A		
Design Document				A	A								
Design Presentation				A									
Final Report												A	A
Final Presentation												A	

Conclusion

We will design a system that allows real time frequency modulation and effects to be applied to a standalone MIDI keyboard.

Thanks for your attention!