conFFTi - FPGA music synthesizer

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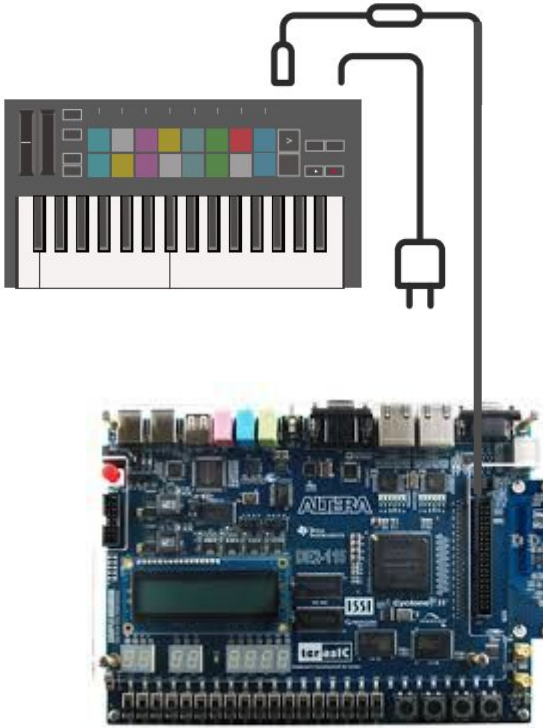
Application Area

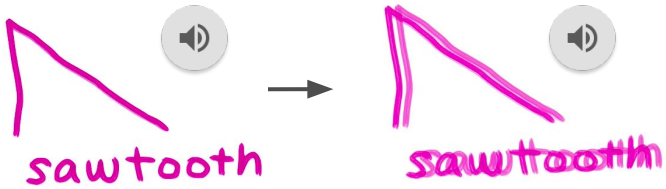
- Accepts real-time input from a MIDI keyboard
- Easy user control over sound generation and mixing on FPGA
  - Waveform generation
    - tri, sin, sqr, saw
  - ADSR Envelope
- Effects that aid music composition
  - **Arpeggiator**
  - **Harmonizer**



Solution Approach

- DE2-115 Cyclone IV FPGA
  - Large number of logic elements and RAM
- Launchkey Novation MINI MkIII
  - Intuitive knobs and pads

- Implementation of **harmonizer**
  - Feedback loop on waveform oscillator



- Interface of **arpeggiator**
  - Arpeggiator mode and normal mode
  - Hardware support

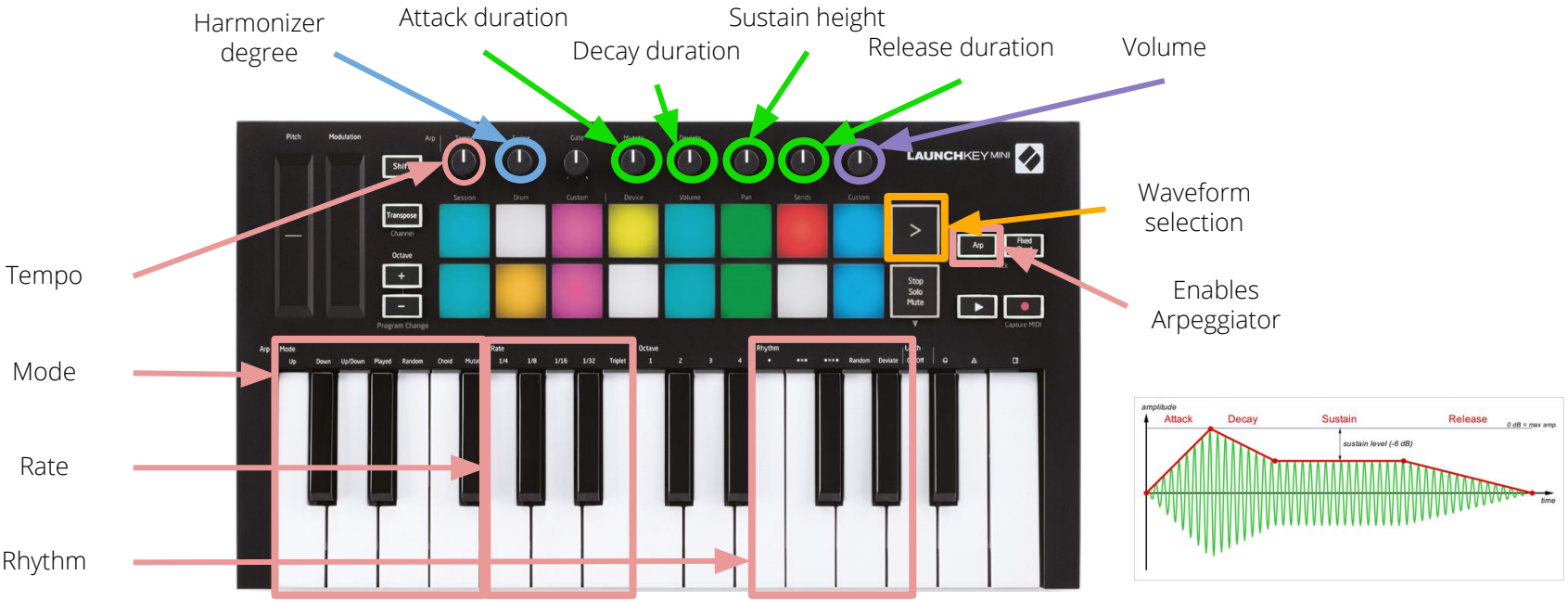
Video reference: https://youtu.be/W_UyQqiocCw

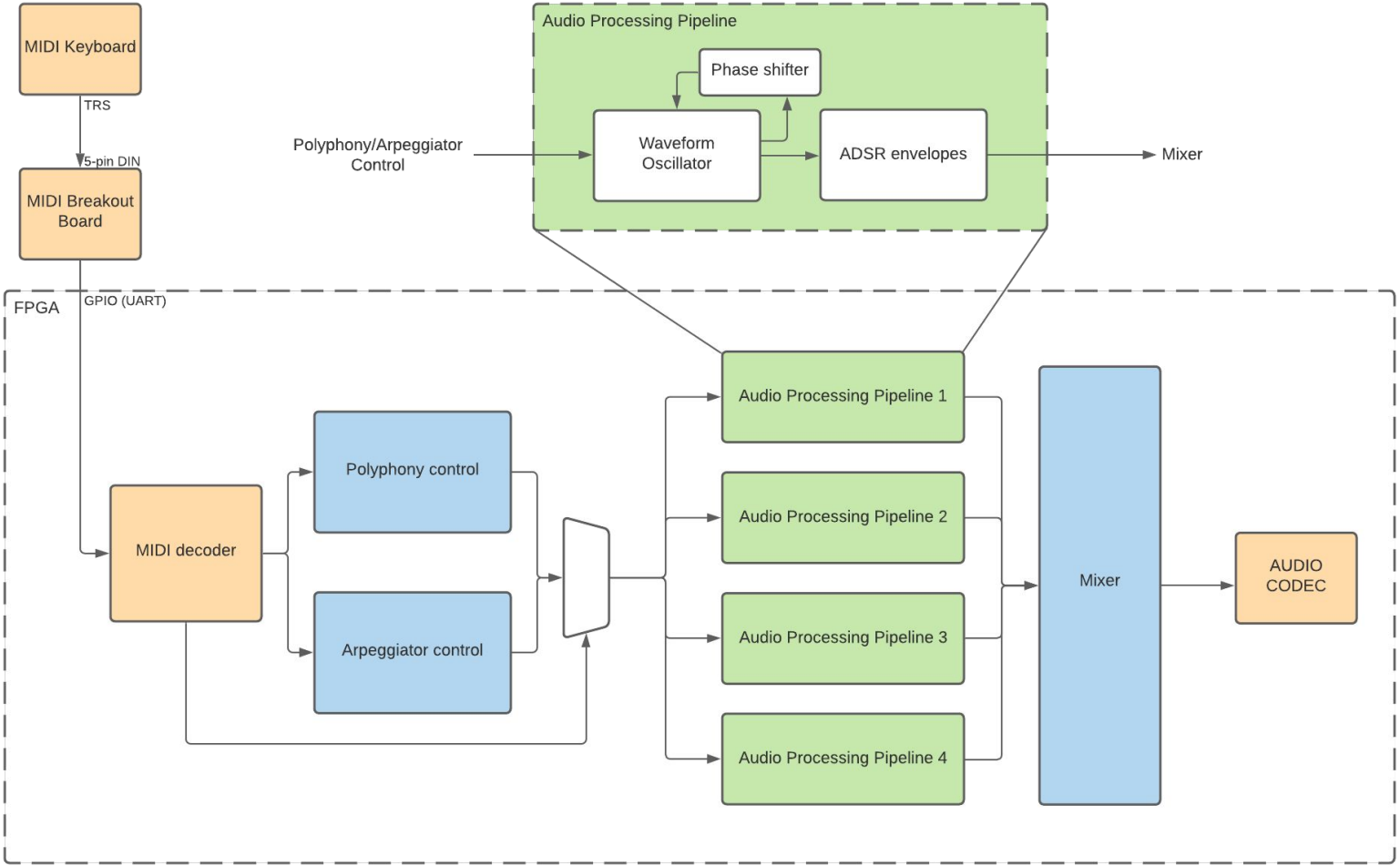
System Specification - User Interface

Arp mode: Holding the Arp key allows for Arp configurations

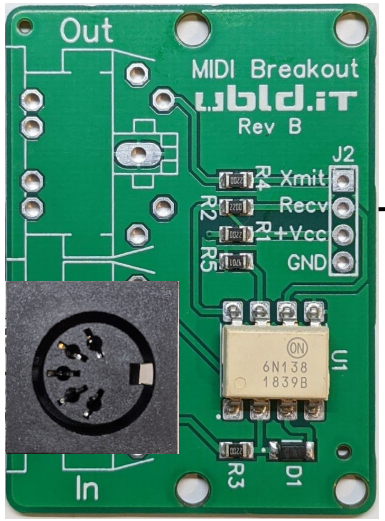
Normal mode: Adjust other effect parameters (ADSR, harmonizer)

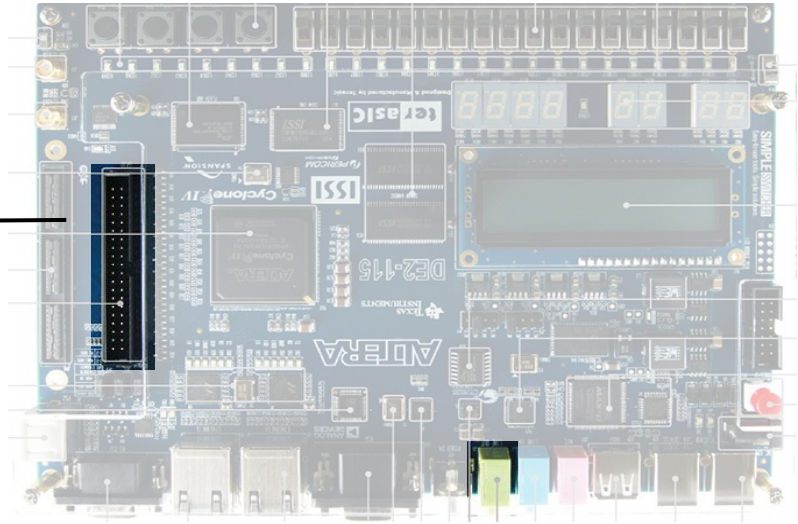
Across both modes: Volume, waveform type




MIDI Keyboard
TRS
5-pin DIN
MIDI Breakout Board
Audio Processing Pipeline
Phase shifter
Polyphony/Arpeggiator Control
Waveform Oscillator
ADSR envelopes
Mixer
FPGA
GPIO (UART)
Audio Processing Pipeline 1
Polyphony control
MIDI decoder
Audio Processing Pipeline 2
Mixer
AUDIO CODEC
Audio Processing Pipeline 3
Arpeggiator control
Audio Processing Pipeline 4


Sustain
MIDI Out
novation


Out
MIDI Breakout
ubld.it
Rev B
J2
Xmit
Recv
+Vcc
GND
R4
R2
R1
R5
U1
6N138
1839B
R3
D1
In


DE2-115
ALTERA

Line out

Metrics

- **Industry standard audio quality**
  - 44.1kHz, 24-bit, single channel output
- **Low latency**
  - < 10 ms, from MIDI input to codec
- **Low frequency distortion**
  - < 5 %
- **Low pitch deviation**
  - < 1 %

UART	3 byte/MIDI message * (8 + 2) bits/byte / 31250 baud rate	0.96 ms

Decoder	Combinational	Order of ns
Polyphony	Single cycle	Order of ns
Oscillator	Single cycle	Order of ns
ADSR	Single cycle	Order of ns
Harmonizer	Single cycle	Order of ns
Mixer	Single cycle	Order of ns

Total		< 1 ms

Verification

- Correctness
  - **Oscilloscope:** Take data points (t, v) from waveform generated by FPGA
  - **Matlab scripts:** Take data points (t, v_ref) from reference waveform
    - Ensure that v_ref == v
  - If a test fails?
    - Use oscilloscope for debugging code
- Latency
  - **Oscilloscope:** Quantitatively measure latency using the screenshot function
- Frequency distortion
  - **Oscilloscope:** Apply FFT to waveform generated by FPGA
  - Calculate percentage of distortion of each frequency
  - Calculate total distortion
- Pitch accuracy
  - **Commercial tuner**

Project Management and Risk Factors

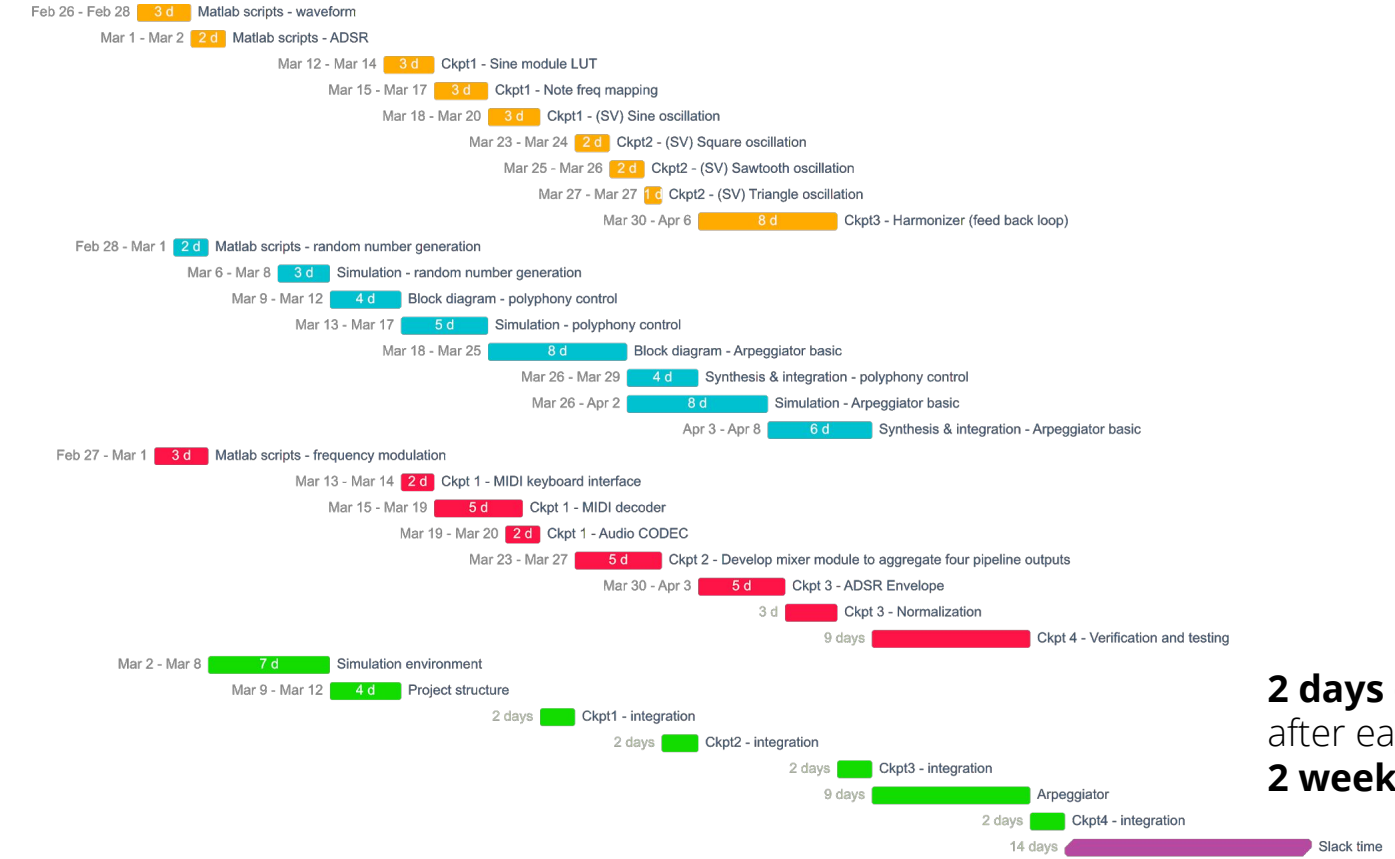
- **Checkpoint 1 (3/20):** Single key input produces single output sound
  - MIDI keyboard, FPGA interface; Sine waveform generation
- **Checkpoint 2 (3/27):** Maximum 4 key input produces mixed sound
  - Polyphony, mixer; Square, sawtooth, triangle waveform generations
- **Checkpoint 3 (4/6):** Effects, basic arpeggiator
  - Harmonizer, ADSR; Arp mode note capturing, looping
  - (risk 1) Arp mode: extensive test cases for FSM
  - (risk 2) Harmonizer: datapath and FSM for feedback loop
- **Checkpoint 4 (4/17):** Arpeggiator effects, verification
  - Control mode, control rhythm

Risk control: System integration test and verification performed at the end of each checkpoint.

Division of Labor and Collaboration

- Michelle
  - LUT and mapping setup
  - Waveform oscillator
  - Harmonizer
- Hongrun
  - MIDI keyboard interface
  - ADSR
  - Audio output
  - Waveform verification
- Jiuling
  - Polyphony control
  - Random number generation
  - Arpeggiator set up

- Collectively
  - Set up local environments for simulation and synthesis
  - Advanced arp features



2 days of integration
after each ckpt
2 weeks of slack time