Wavetable Synth

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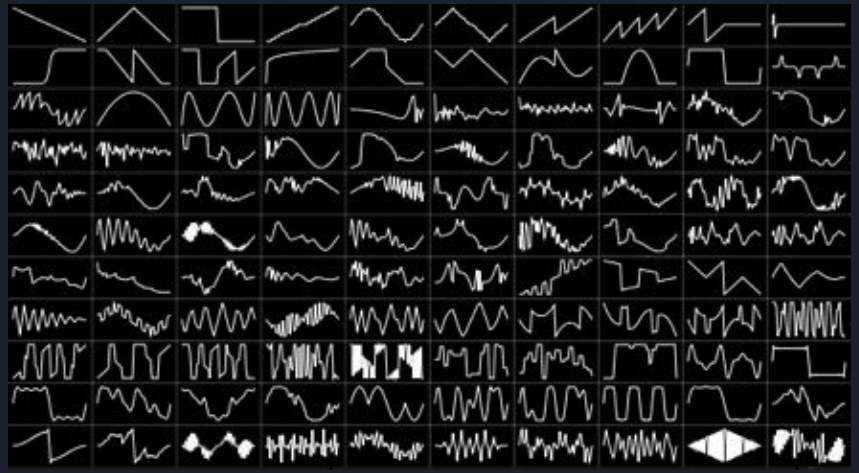
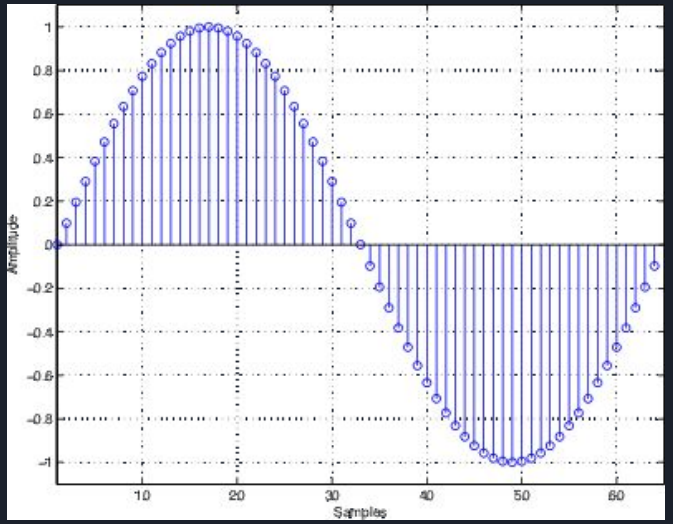
Advisor: John Hui

Overview

Wavetable Synthesis

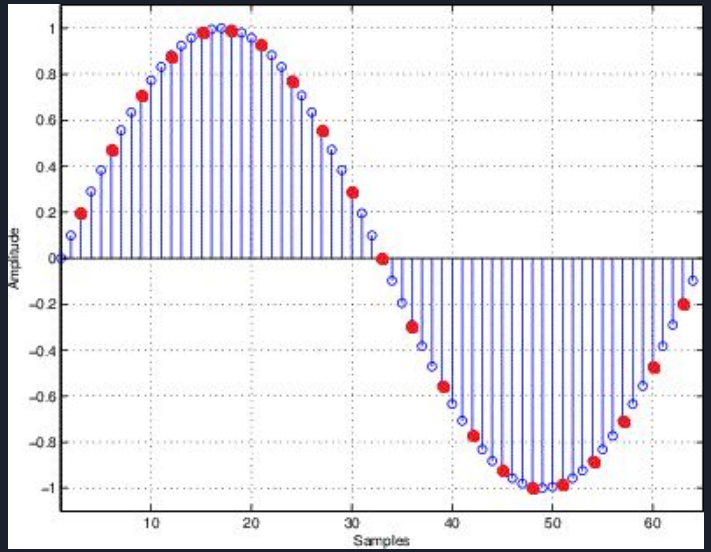
- A sound wave signature is stored in memory
- Loop through this wave to make a sound





Different Notes

- Suppose a wave is sampled at 440 Hz and stored
- To sample at 880 Hz, skip every other address
- 1320 Hz = every third



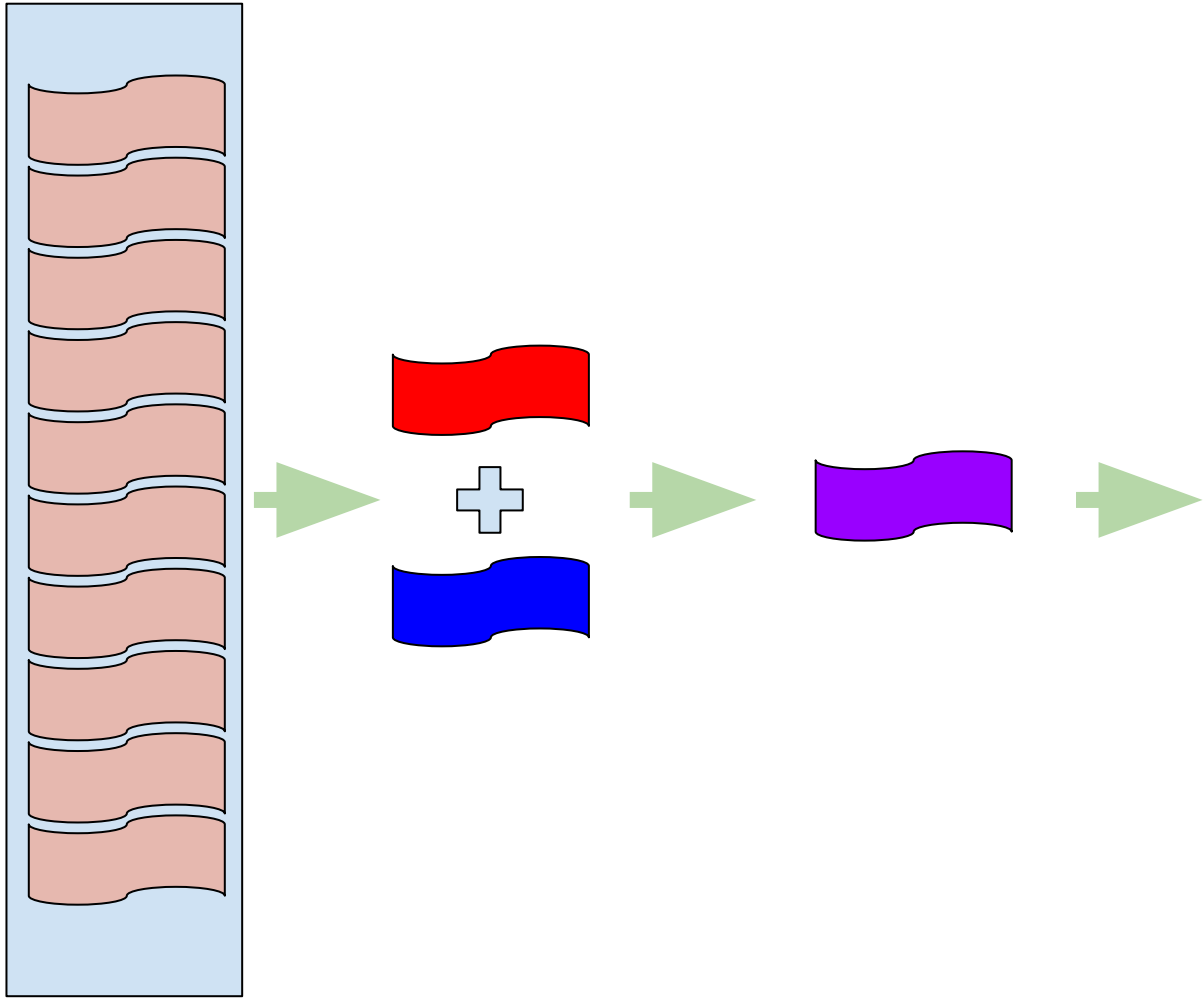
MIDI Instruments

- Send status of key press and release

Table 1: MIDI 1.0 Specification Message Summary		
Status D7----D0	Data Byte(s) D7----D0	Description
1000nnnn	0kkkkkkk 0vvvvvvv	Note Off event. This message is sent when a note is released (ended). (kkkkkkk) is the key (note) number. (vvvvvvv) is the velocity.
1001nnnn	0kkkkkkk 0vvvvvvv	Note On event. This message is sent when a note is depressed (start). (kkkkkkk) is the key (note) number. (vvvvvvv) is the velocity.

Our Design

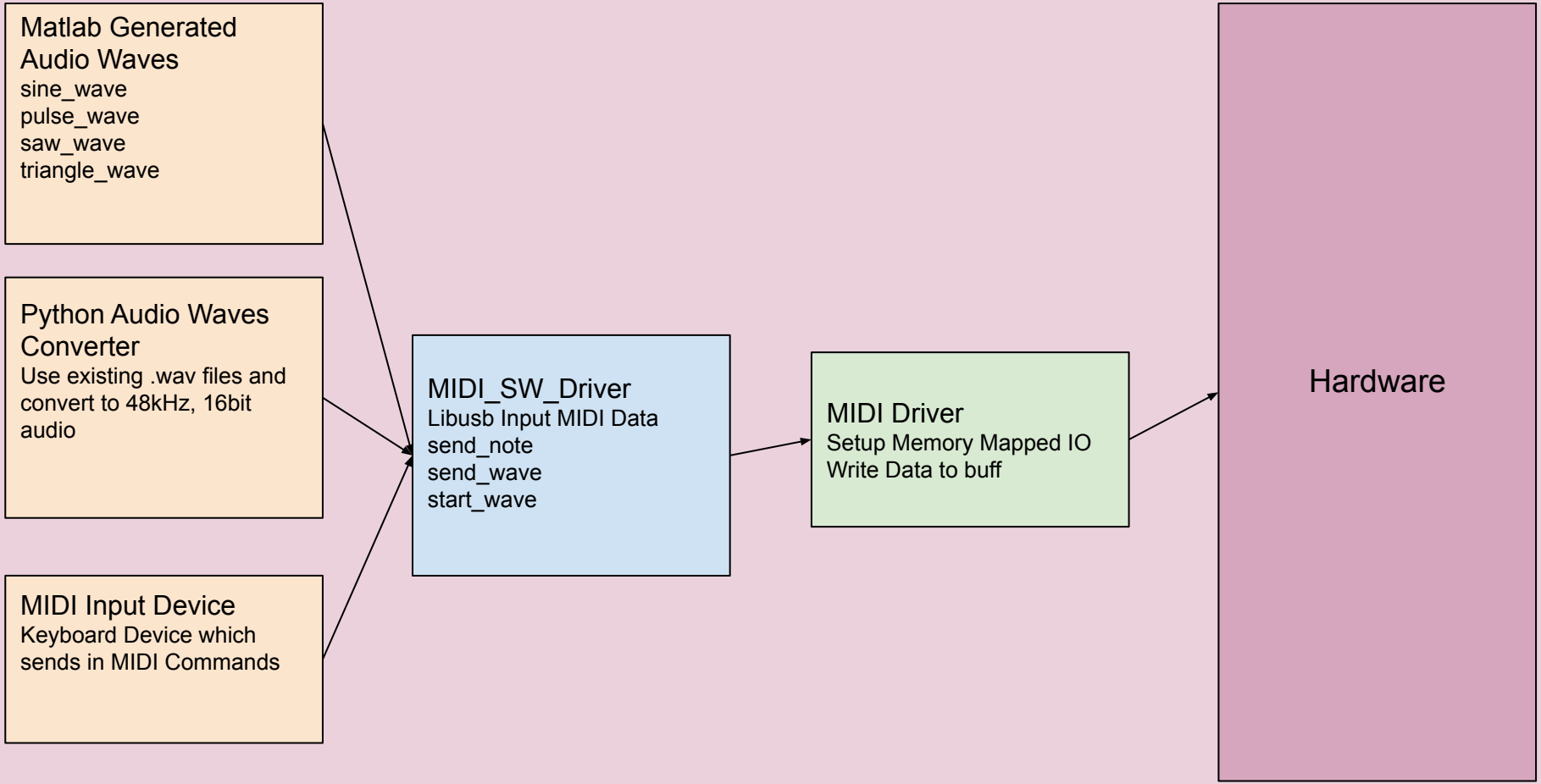
- Send MIDI packets over USB to software synth program
- Synth converts MIDI signal data into calls to a hardware driver
- The driver accepts configuration of pitches (up to 10 notes)
- Each note requests samples from sampler
- Sampler can take samples from 2 wavetables and combine them with different coefficients
- The current samples can be configured from the software program
- The samples from all the 10 notes are combined and sent via interface to audio codec



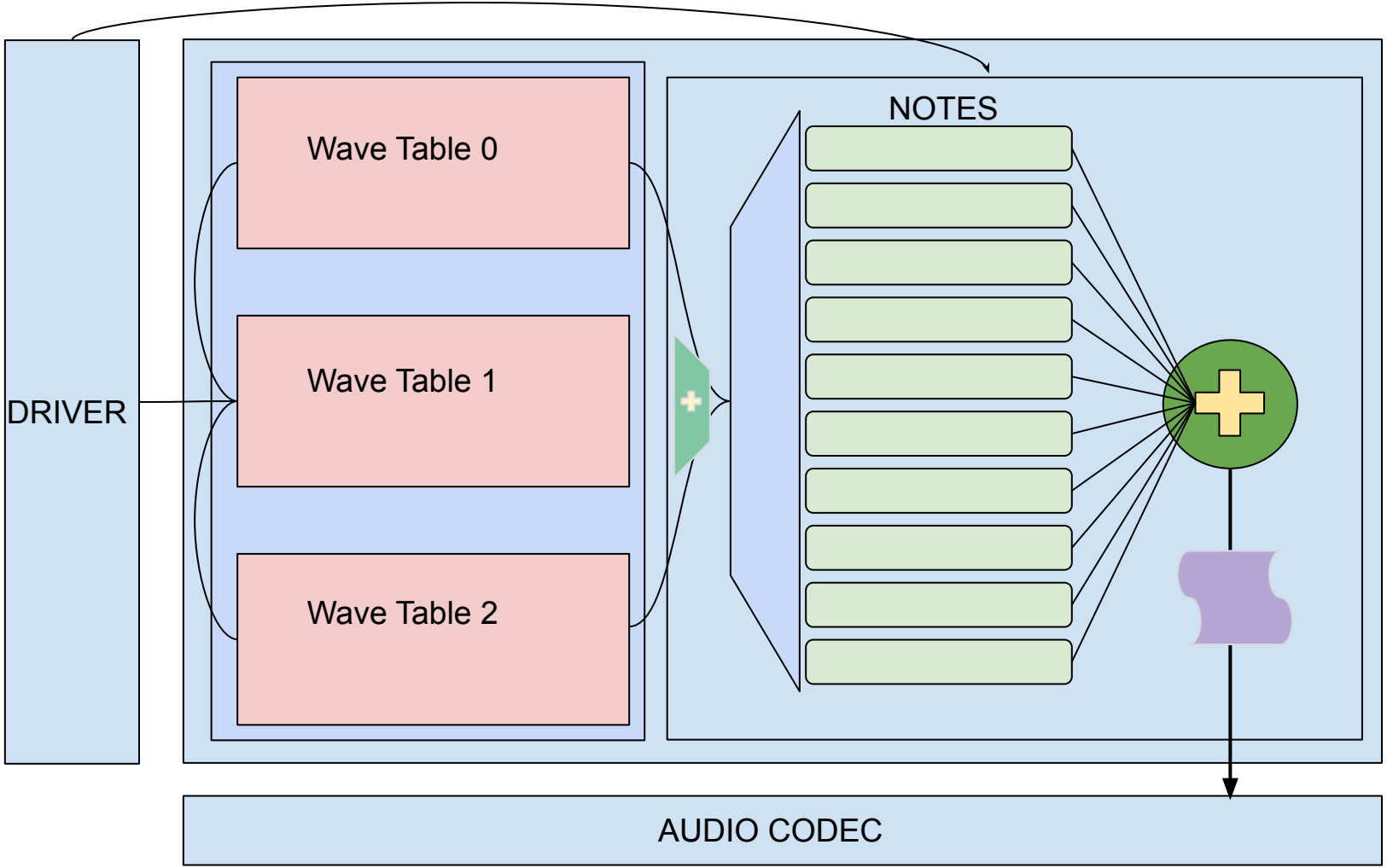
Synth Software

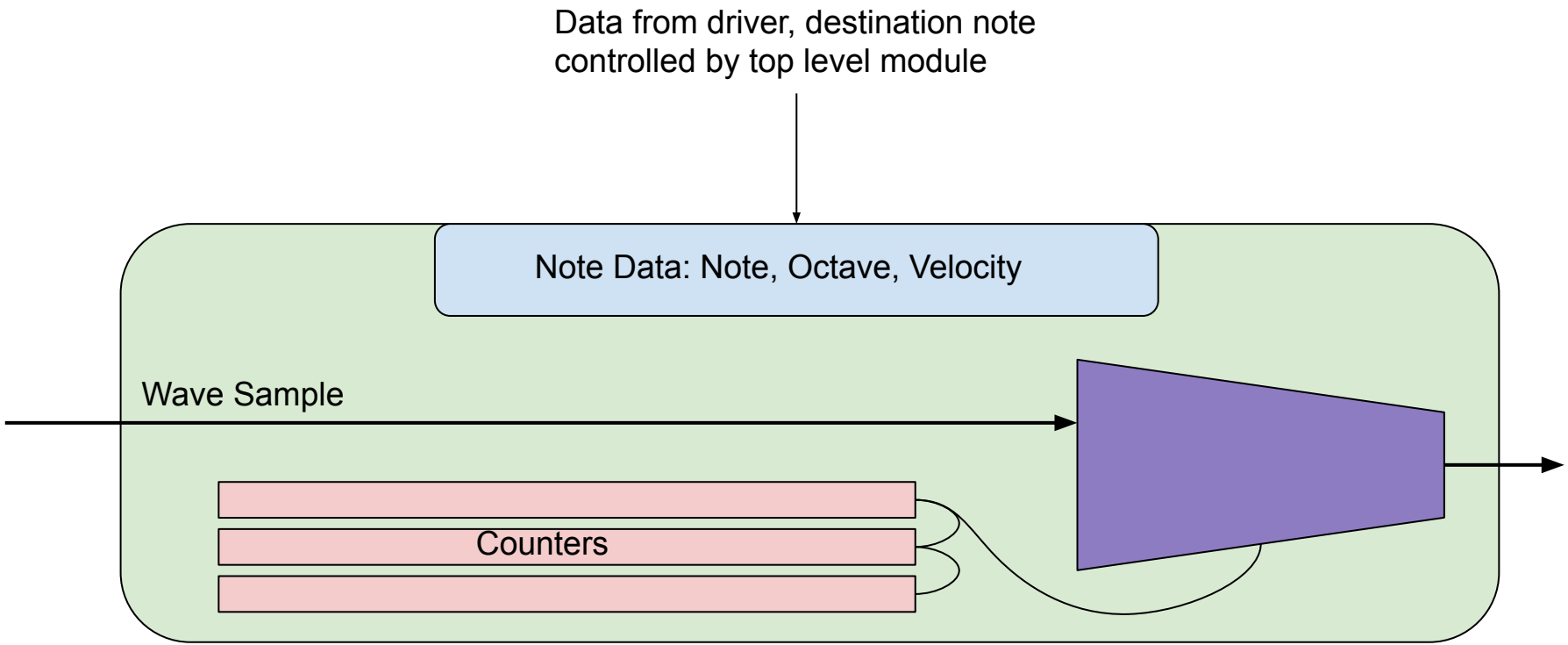
Software: MIDI Decoder

- The MIDI decoder program is responsible for taking the MIDI Protocol messages utilizing the Libusb software library and translating the instructions into logic output:
  - MIDI Packets are 64 bytes
  - note, attack velocity, modulation
- Wave tales generated through Matlab and conversion script in python for any .wav files which normalizes the audio format..
  - 48kHz
  - 16bit


Matlab Generated Audio Waves
sine_wave
pulse_wave
saw_wave
triangle_wave
Python Audio Waves Converter
Use existing .wav files and convert to 48kHz, 16bit audio
MIDI Input Device
Keyboard Device which sends in MIDI Commands
MIDI_SW_Driver
Libusb Input MIDI Data
send_note
send_wave
start_wave
MIDI Driver
Setup Memory Mapped IO
Write Data to buff
Hardware

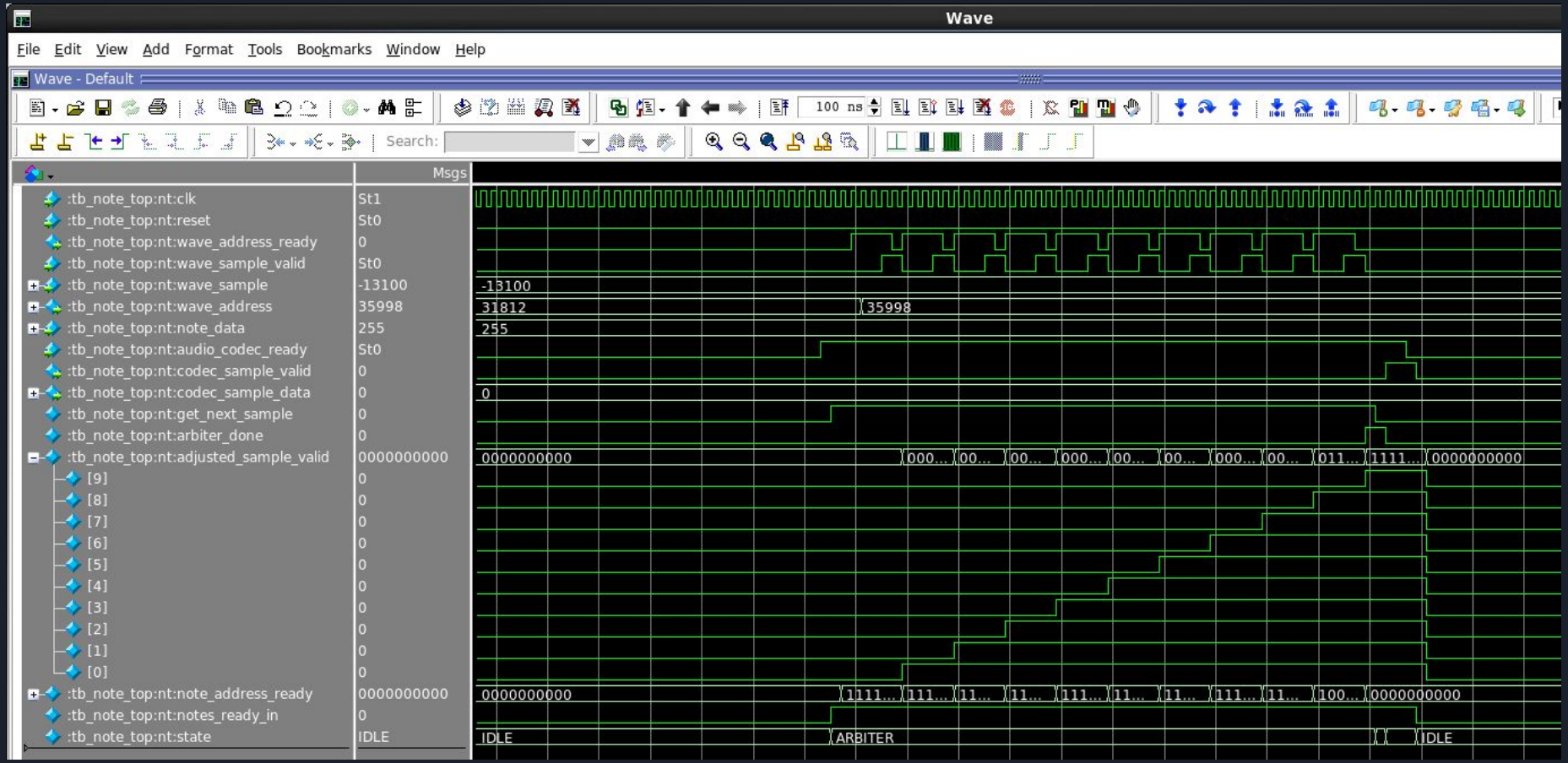
Synth Hardware

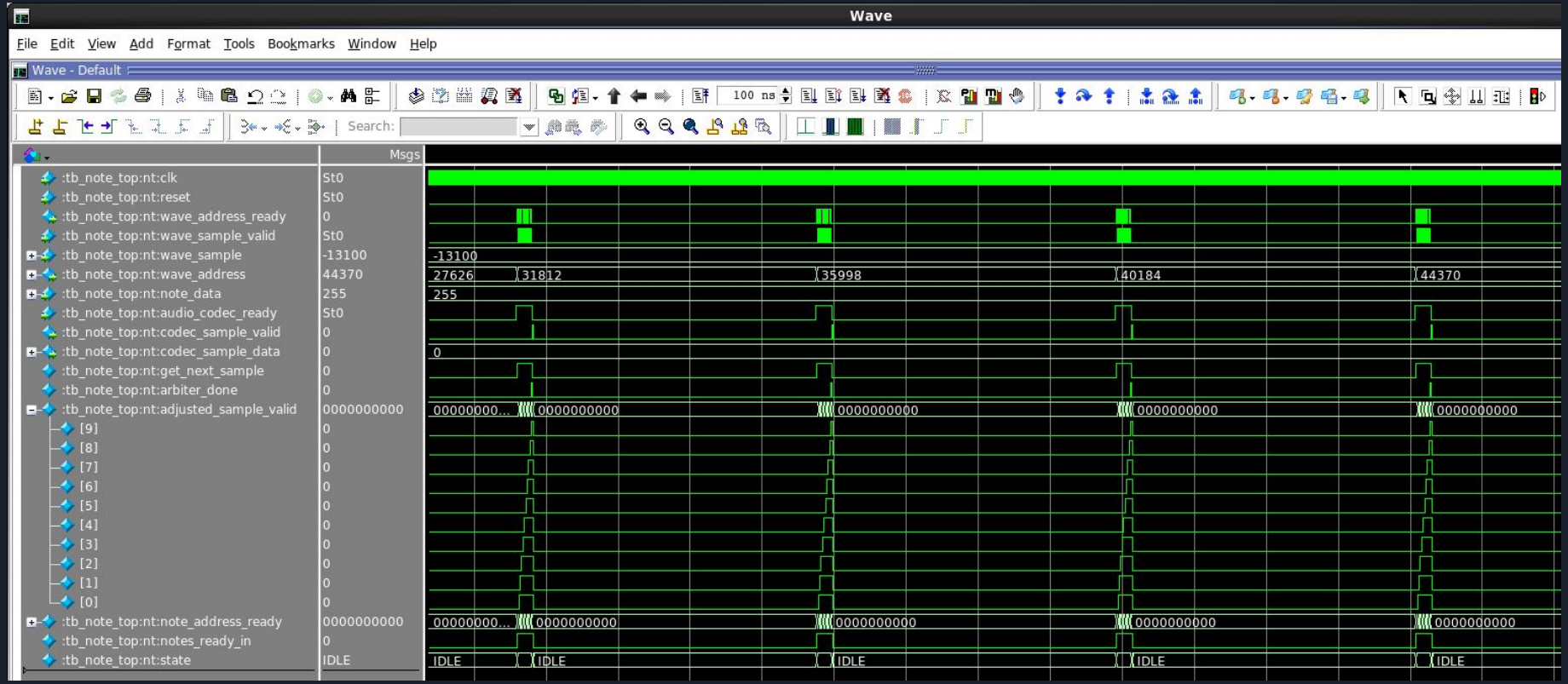

DRIVER
Wave Table 0
Wave Table 1
Wave Table 2
NOTES
AUDIO CODEC

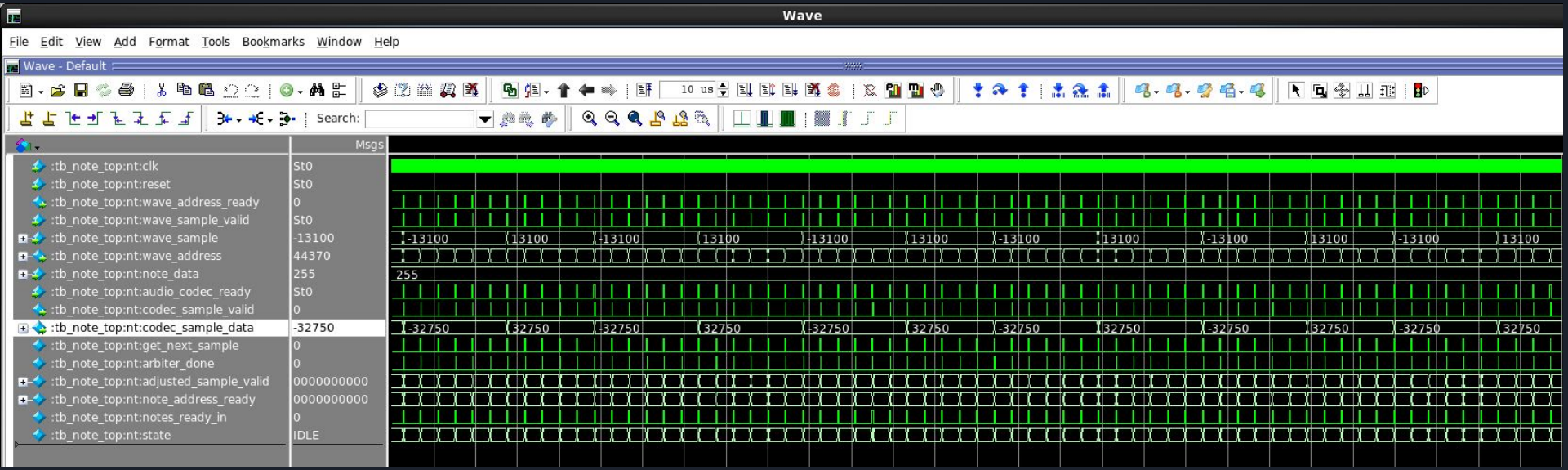

Data from driver, destination note
controlled by top level module
Note Data: Note, Octave, Velocity
Wave Sample
Counters

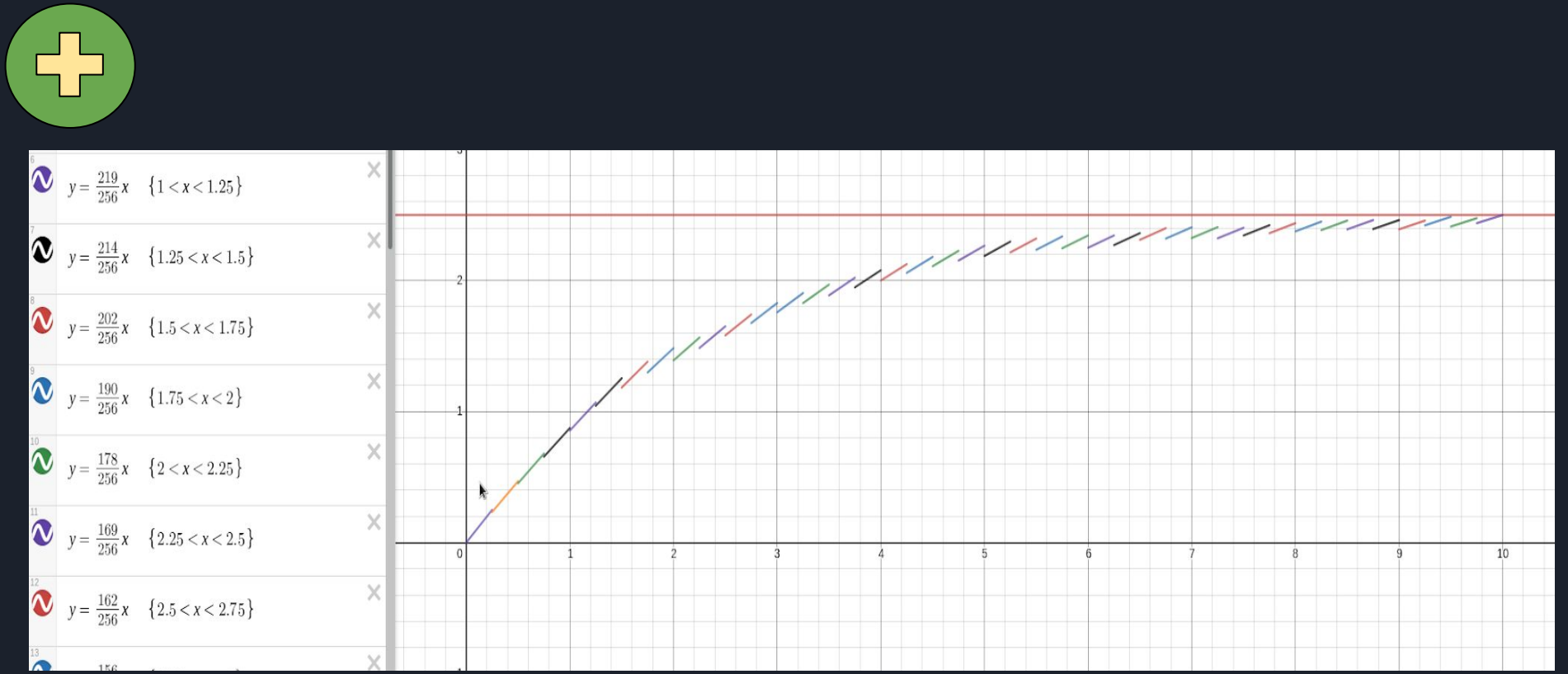
ADSR enveloping

- Attack
- Decay
- Synthesis
- Release


Wave
File Edit View Add Format Tools Bookmarks Window Help
Wave - Default
100 ns
Search:
Msgs
:tb_note_top:nt:clk St1
:tb_note_top:nt:reset St0
:tb_note_top:nt:wave_address_ready 0
:tb_note_top:nt:wave_sample_valid St0
:tb_note_top:nt:wave_sample -13100
:tb_note_top:nt:wave_address 35998
:tb_note_top:nt:note_data 255
:tb_note_top:nt:audio_codec_ready St0
:tb_note_top:nt:codec_sample_valid 0
:tb_note_top:nt:codec_sample_data 0
:tb_note_top:nt:get_next_sample 0
:tb_note_top:nt:arbiter_done 0
:tb_note_top:nt:adjusted_sample_valid 0000000000
[9] 0
[8] 0
[7] 0
[6] 0
[5] 0
[4] 0
[3] 0
[2] 0
[1] 0
[0] 0
:tb_note_top:nt:note_address_ready 0000000000
:tb_note_top:nt:notes_ready_in 0
:tb_note_top:nt:state IDLE
-13100
31812
35998
255
0
0000000000
0000000000
IDLE
ARBITER
IDLE


Wave
File Edit View Add Format Tools Bookmarks Window Help
Wave - Default
Search:
Msgs
:tb_note_top:nt:clk St0
:tb_note_top:nt:reset St0
:tb_note_top:nt:wave_address_ready 0
:tb_note_top:nt:wave_sample_valid St0
:tb_note_top:nt:wave_sample -13100
:tb_note_top:nt:wave_address 44370
:tb_note_top:nt:note_data 255
:tb_note_top:nt:audio_codec_ready St0
:tb_note_top:nt:codec_sample_valid 0
:tb_note_top:nt:codec_sample_data 0
:tb_note_top:nt:get_next_sample 0
:tb_note_top:nt:arbiter_done 0
:tb_note_top:nt:adjusted_sample_valid 0000000000
[9] 0
[8] 0
[7] 0
[6] 0
[5] 0
[4] 0
[3] 0
[2] 0
[1] 0
[0] 0
:tb_note_top:nt:note_address_ready 0000000000
:tb_note_top:nt:notes_ready_in 0
:tb_note_top:nt:state IDLE
-13100
27626
31812
35998
40184
44370
255
0
00000000...
0000000000
IDLE


Wave
File Edit View Add Format Tools Bookmarks Window Help
Wave - Default
Search:
Msgs
:tb_note_top:nt:clk St0
:tb_note_top:nt:reset St0
:tb_note_top:nt:wave_address_ready 0
:tb_note_top:nt:wave_sample_valid St0
:tb_note_top:nt:wave_sample -13100
:tb_note_top:nt:wave_address 44370
:tb_note_top:nt:note_data 255
:tb_note_top:nt:audio_codec_ready St0
:tb_note_top:nt:codec_sample_valid 0
:tb_note_top:nt:codec_sample_data -32750
:tb_note_top:nt:get_next_sample 0
:tb_note_top:nt:arbiter_done 0
:tb_note_top:nt:adjusted_sample_valid 0000000000
:tb_note_top:nt:note_address_ready 0000000000
:tb_note_top:nt:notes_ready_in 0
:tb_note_top:nt:state IDLE
-13100 13100 -13100 13100 -13100 13100 -13100 13100 -13100 13100 -13100 13100
255
-32750 32750 -32750 32750 -32750 32750 -32750 32750 -32750 32750 -32750 32750

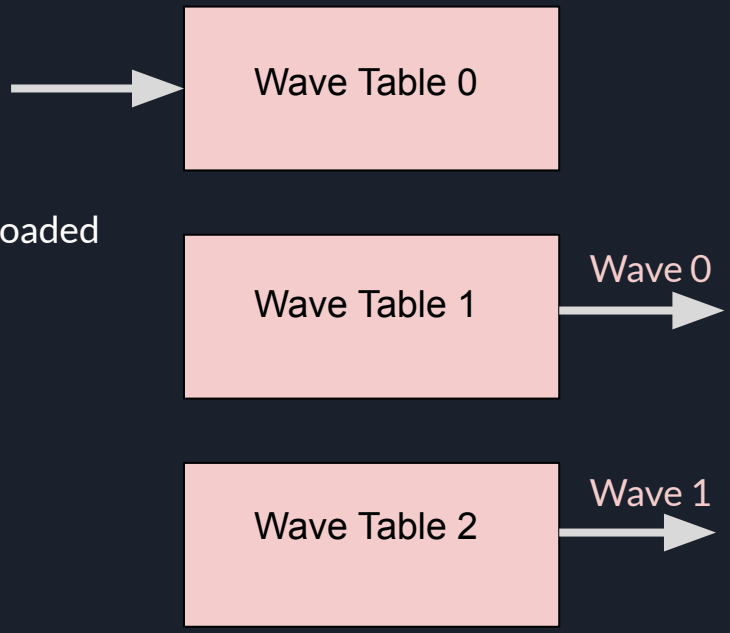

$y = \frac{219}{256}x \quad \{1 < x < 1.25\}$
$y = \frac{214}{256}x \quad \{1.25 < x < 1.5\}$
$y = \frac{202}{256}x \quad \{1.5 < x < 1.75\}$
$y = \frac{190}{256}x \quad \{1.75 < x < 2\}$
$y = \frac{178}{256}x \quad \{2 < x < 2.25\}$
$y = \frac{169}{256}x \quad \{2.25 < x < 2.5\}$
$y = \frac{162}{256}x \quad \{2.5 < x < 2.75\}$
0
1
2
3
4
5
6
7
8
9
10

Wave Tables

2 wavetables for reading

1 wavetable for writing

Swap these around whenever a different wave is loaded



Wave Tables

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1 wavetable for writing

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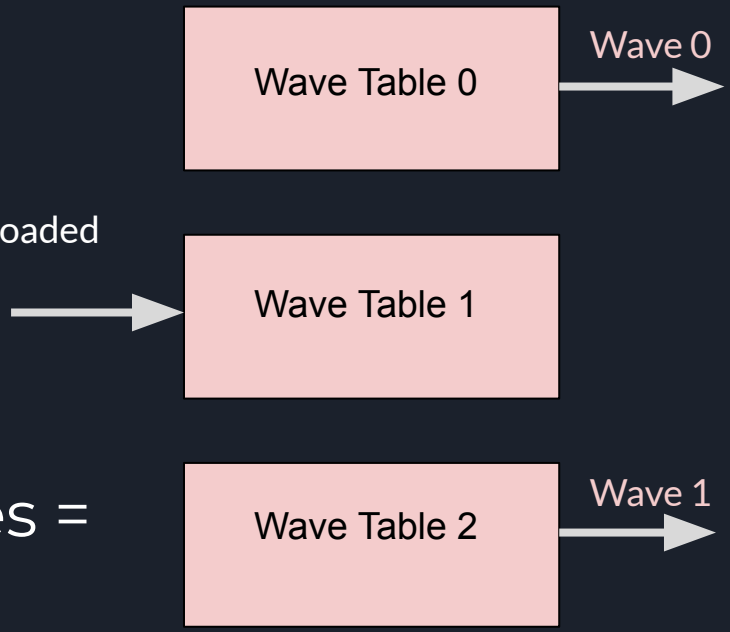
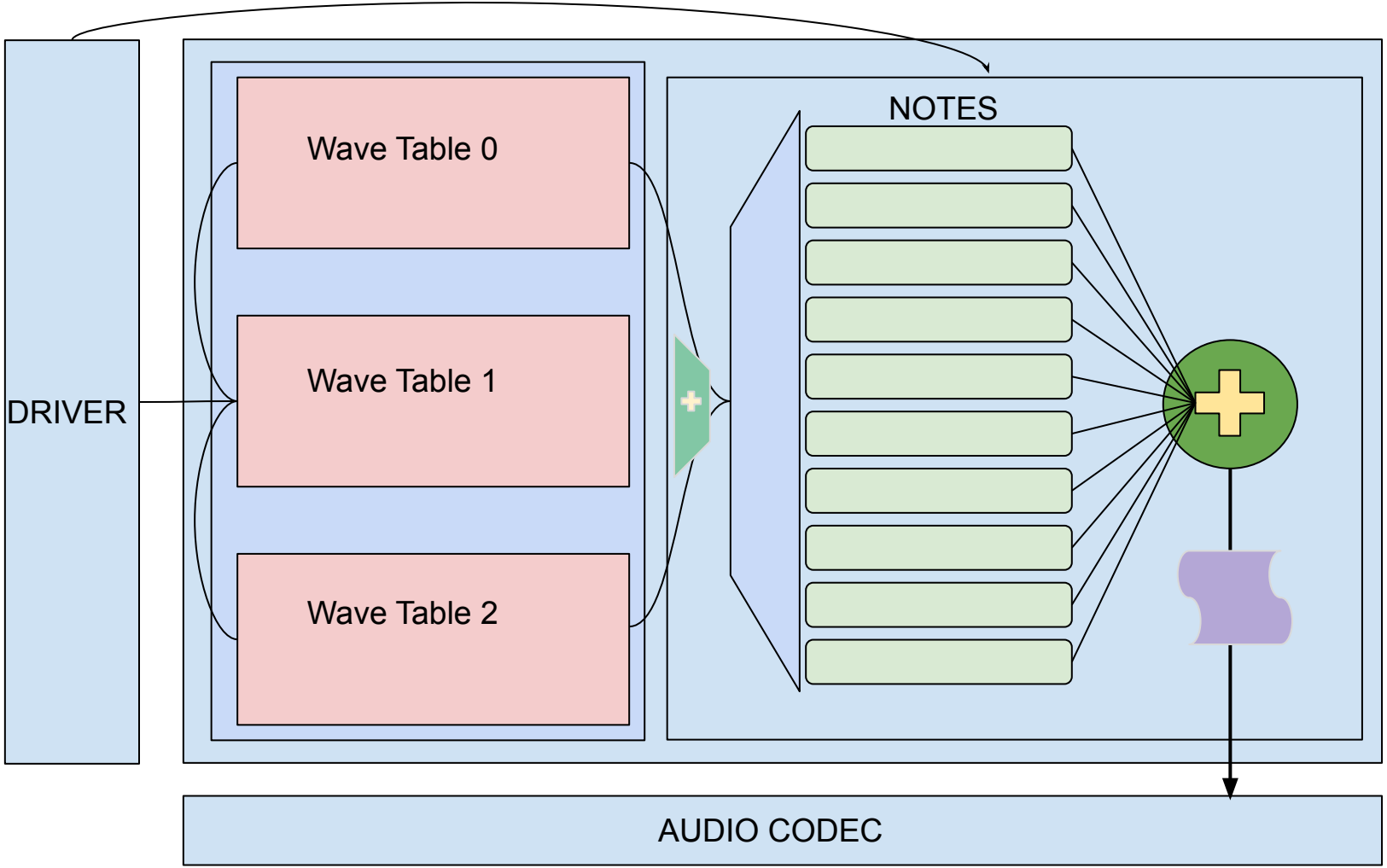


16 bits * 48,000 samples * 3 waves =

288kB used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Performance Constraints

Time to write from memory to wavetables in BRAM is negligible

Longest portion of hardware is taken by the arbiter

Still responds to Codec requests about ~10 times faster than necessary

What works:

Testbenches for each individual module

Testbenches for each major module (wavetables, note_top)

Software for interpreting MIDI signals

Software driver for the synth hardware

Interfacing with the Audio Codec

What doesn’t:

When they all come together