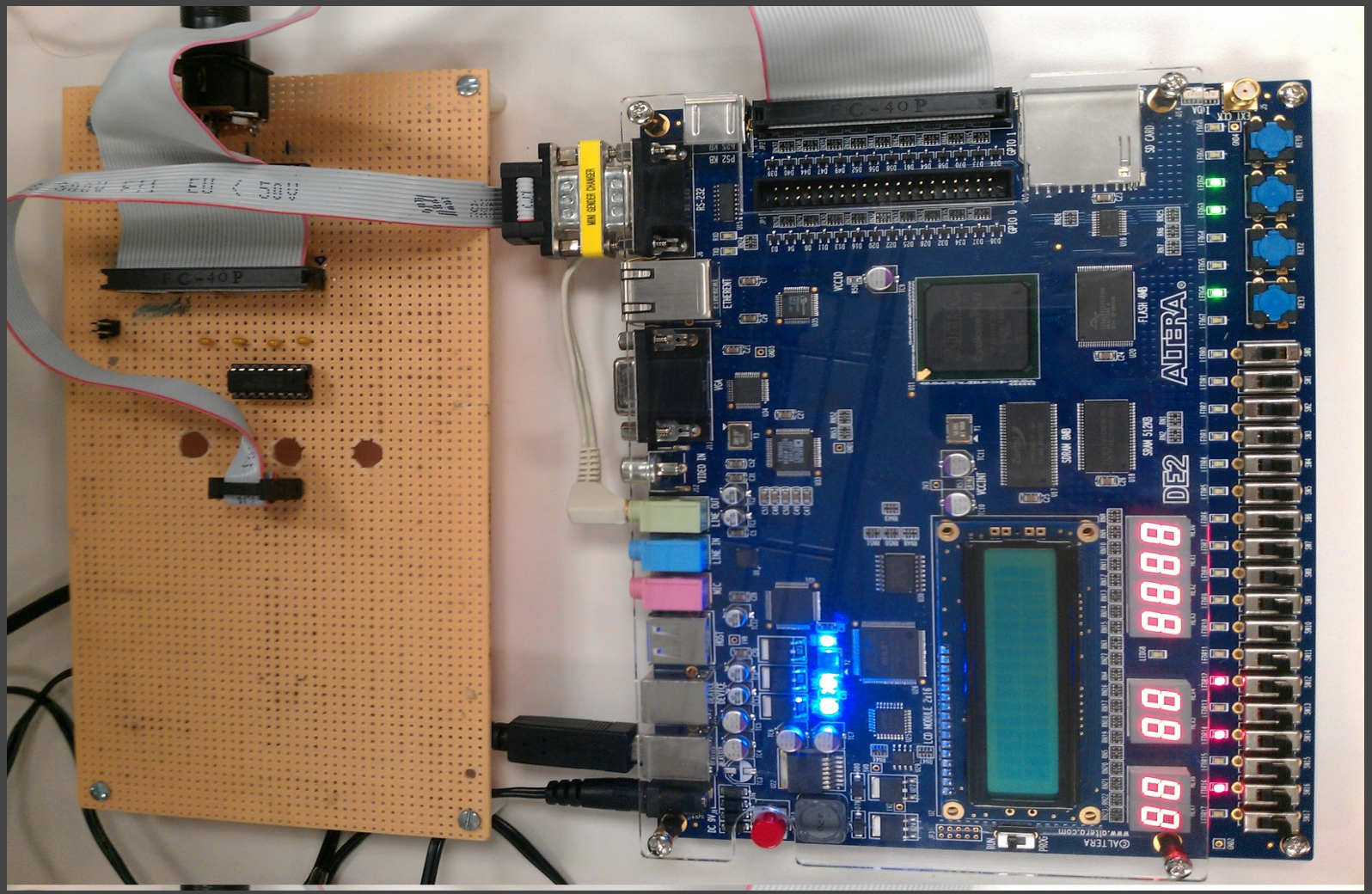
MIDI Synthesizer

Kyle, Peter, and Eric



Motivation

- Interest in digital audio applications .
- A good way to learn about the hardware and software aspects of system design
- Interactive and fun demo.
- Nice way to learn about an industry standard interface.

Overview

- Up to six simultaneous notes playable at once
- Software supports all 128 MIDI note frequencies (8.175 Hz up to 12.5 KHz)
- Ability to play different waveforms, including: Sine, Triangle and Square
- Realistic ADSR envelope generator
- Uses sine table lookup to generator output

Midi Notes

NOTE	0	1	2	...	126	127
NAME	C -2	C# -2	D -2	...	F# 8	G 8

MIDI format has 128 notes, ranging from a C -2 to a G 8. Both of these values aren't really in the range of normal hearing/music. The lower values are useful for effects such as tremolo and vibrato

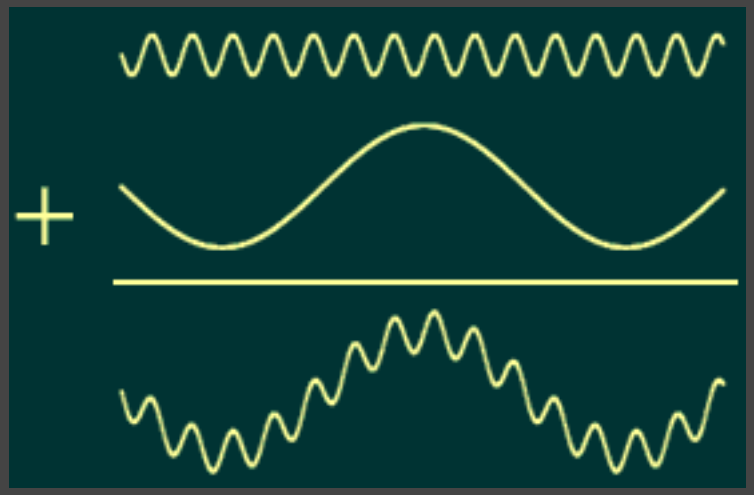
MIDI Protocol

- MIDI is implemented as a Serial Communication Protocol
- MIDI Messages are 1 control byte and 1+ parameters

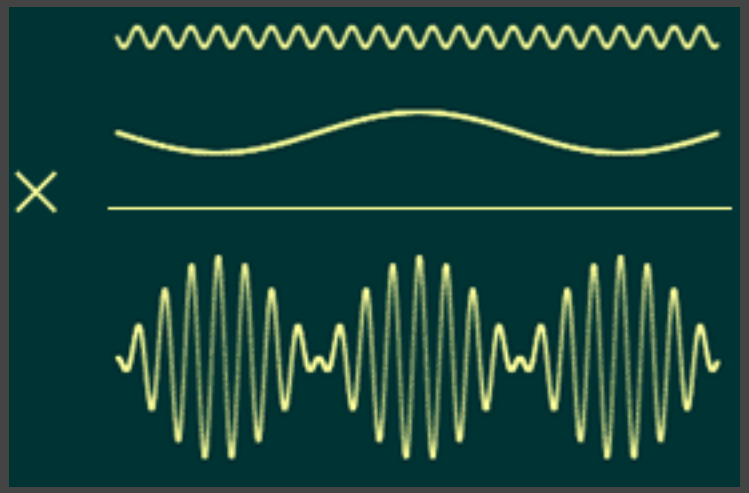
INCOMING MESSAGE	STATUS	DATA
10010111 00001000 01111111	10010111 Message Type = Note Is being turned on	00001000, 01111111 Note = 8 Velocity = 127

- So the message above would tell us that note 8 is turning on with a velocity of 127
- Other status messages include Note Off, Control change and Aftertouch (hitting the key harder after it reaches the bottom).

Simultaneous Notes



Wave Addition: This is the method we use for playing multiple notes at once. We add the waves together and then create a normalized output.



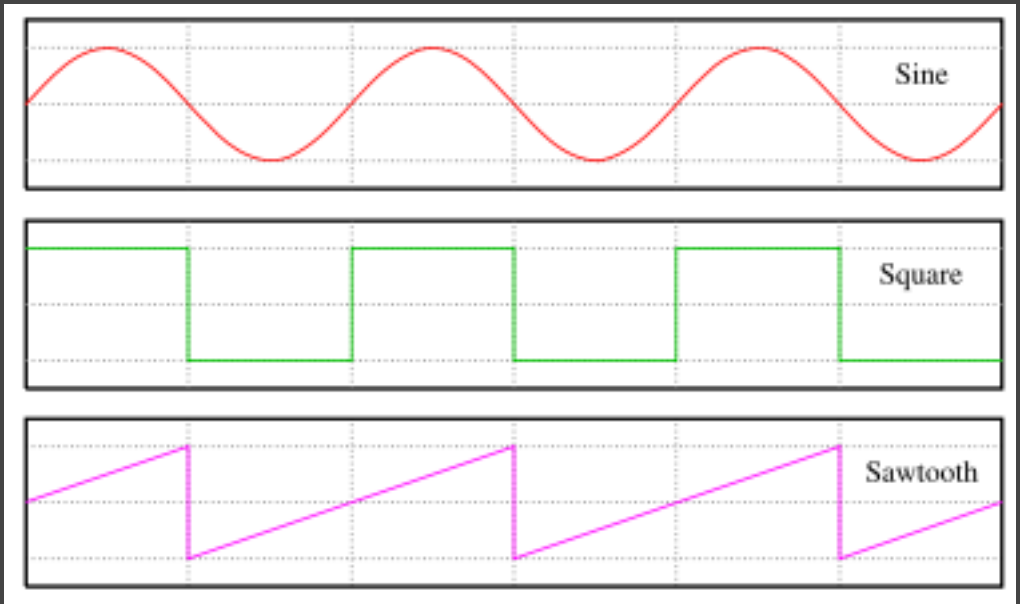
Wave Multiplication: This method would be used for effects like tremolo. Our current RAM limitations did not allow us to implement this in the end.

Images from http://www.jjgifford.com/expressions/geometry/wave_addition.html

Keyboard

61 keys, which range from a C1 (32.703 Hz) to a C7 (2.093 KHz). Acts as our MIDI Controller

Waveform Variations

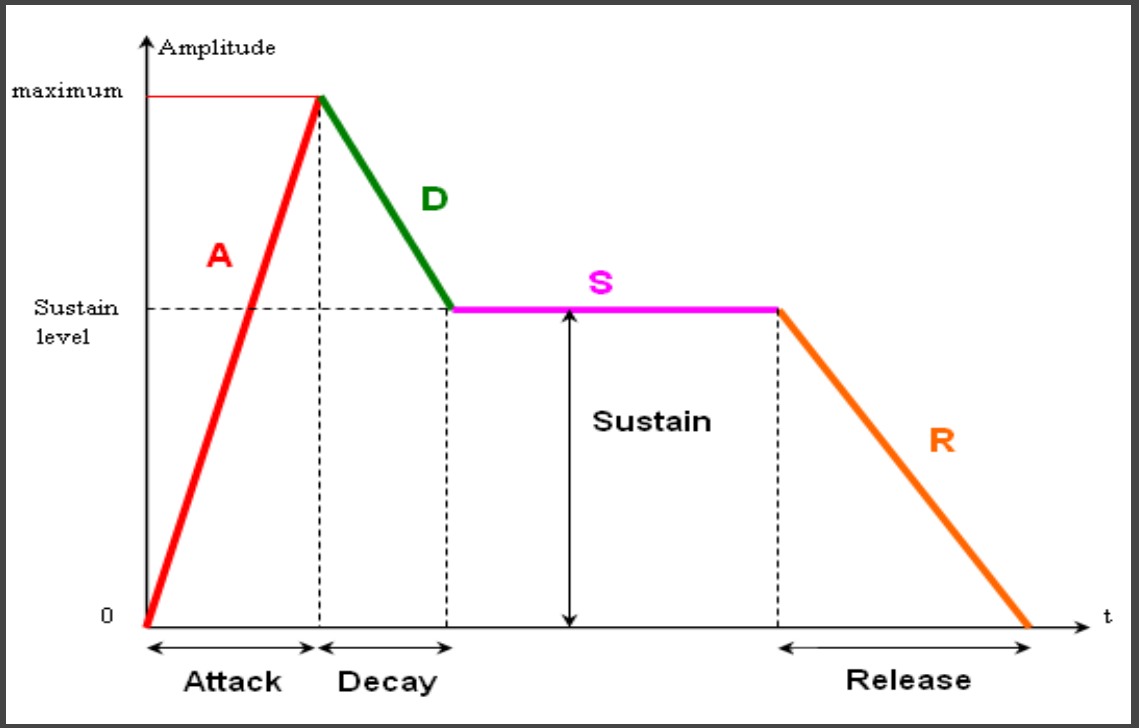


- Capable of producing 3 types of waveforms.
- Sine wave produced with wavetable lookup
- Square and Sawtooth can be produced algorithmically

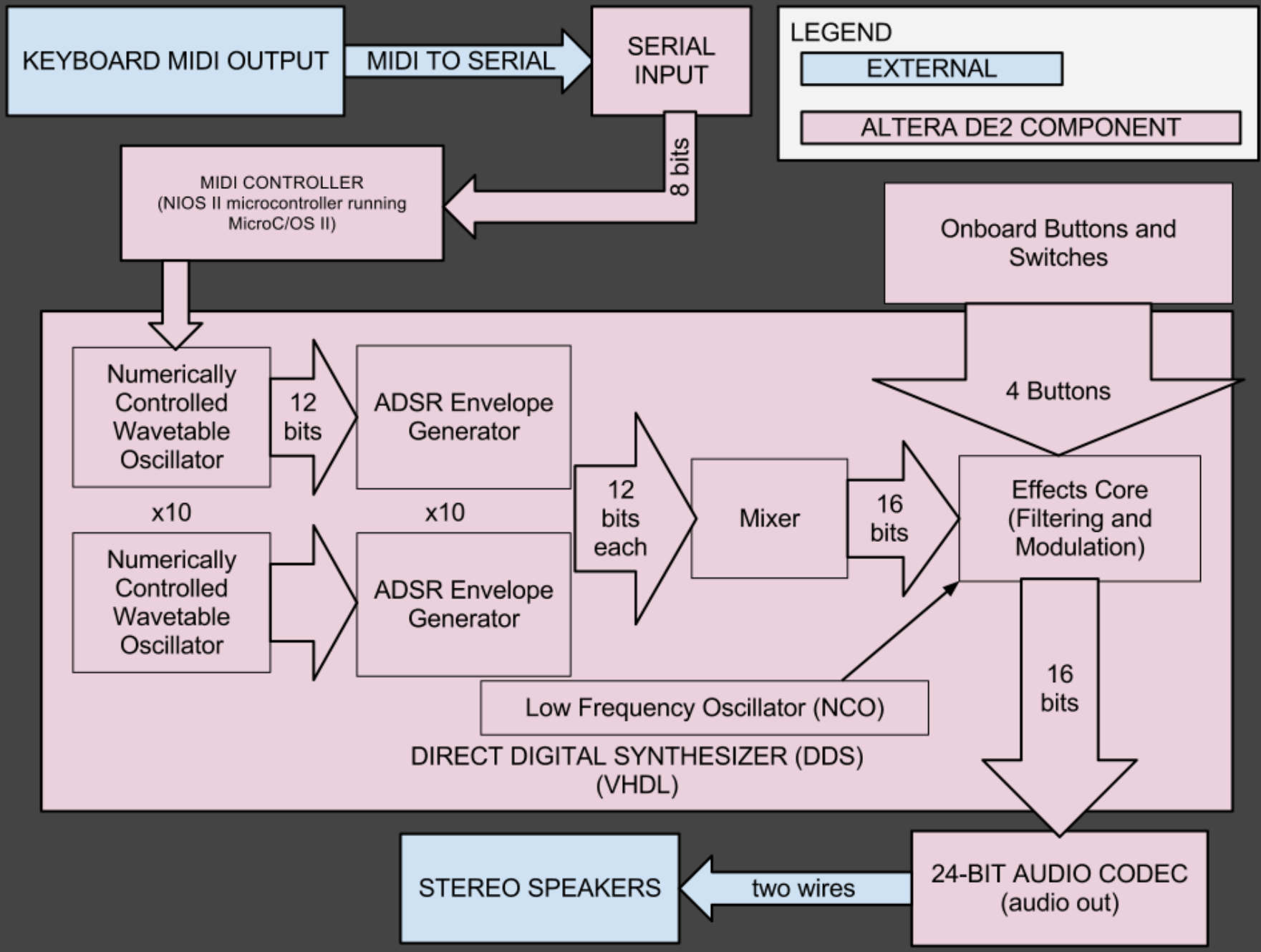
http://www.tronaudio.com/assets/Uploads/Images/waveforms.png

ADSR Envelope Generator

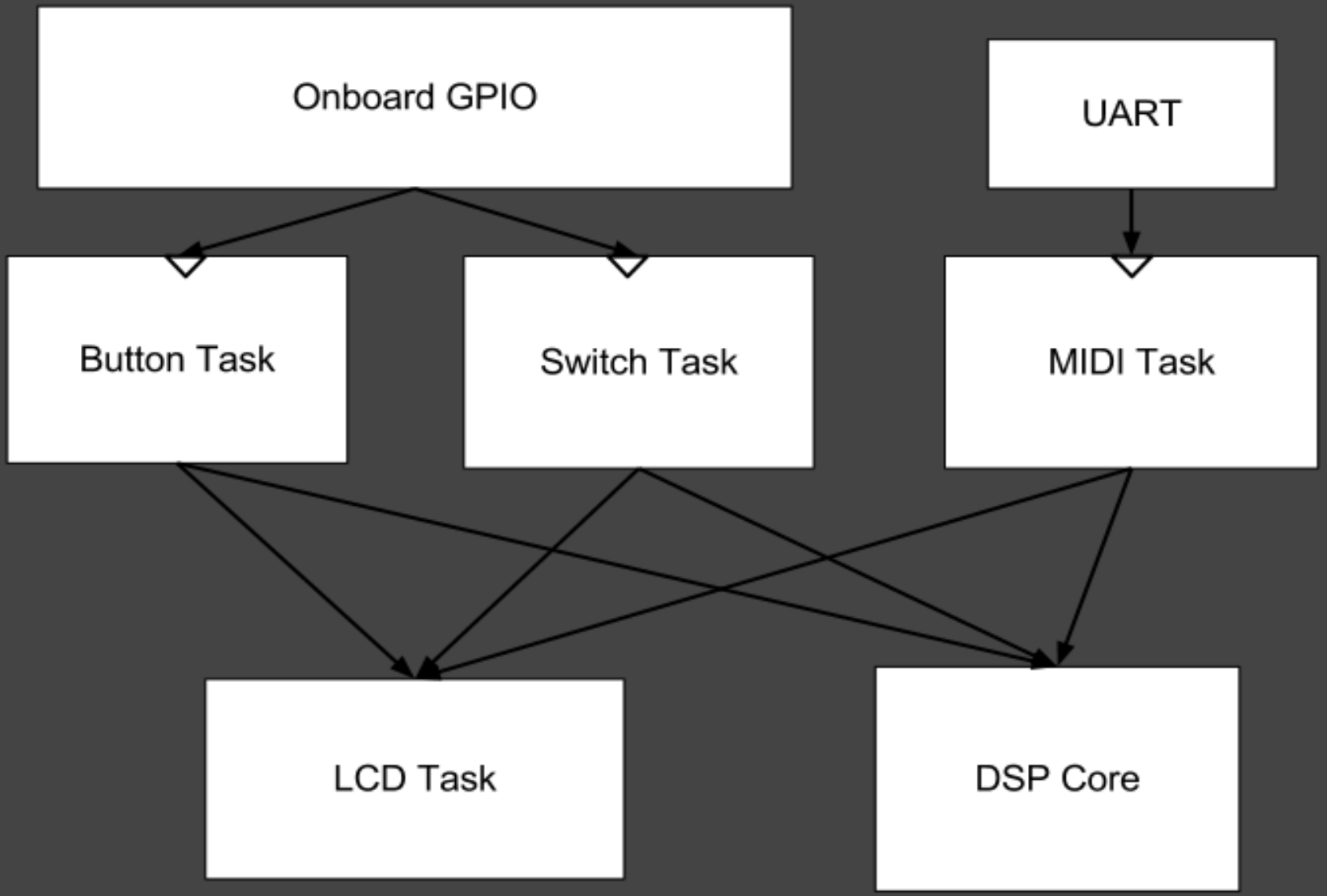
- In our design we implemented a modified (A)ttack (D)ecay (S)ustain (R)elease envelope generator.
- Our ADSR is actually a ASR, because we took out the decay stage to reduce memory usage.



http://abletonempire.com/wp-content/uploads/2011/08/adsr_envelope01.gif


KEYBOARD MIDI OUTPUT
MIDI TO SERIAL
SERIAL INPUT
LEGEND
EXTERNAL
ALTERA DE2 COMPONENT
8 bits
MIDI CONTROLLER
(NIOS II microcontroller running MicroC/OS II)
Onboard Buttons and Switches
4 Buttons
Numerically Controlled Wavetable Oscillator
12 bits
ADSR Envelope Generator
x10
x10
Numerically Controlled Wavetable Oscillator
ADSR Envelope Generator
12 bits each
Mixer
16 bits
Effects Core (Filtering and Modulation)
Low Frequency Oscillator (NCO)
16 bits
DIRECT DIGITAL SYNTHESIZER (DDS)
(VHDL)
STEREO SPEAKERS
two wires
24-BIT AUDIO CODEC
(audio out)

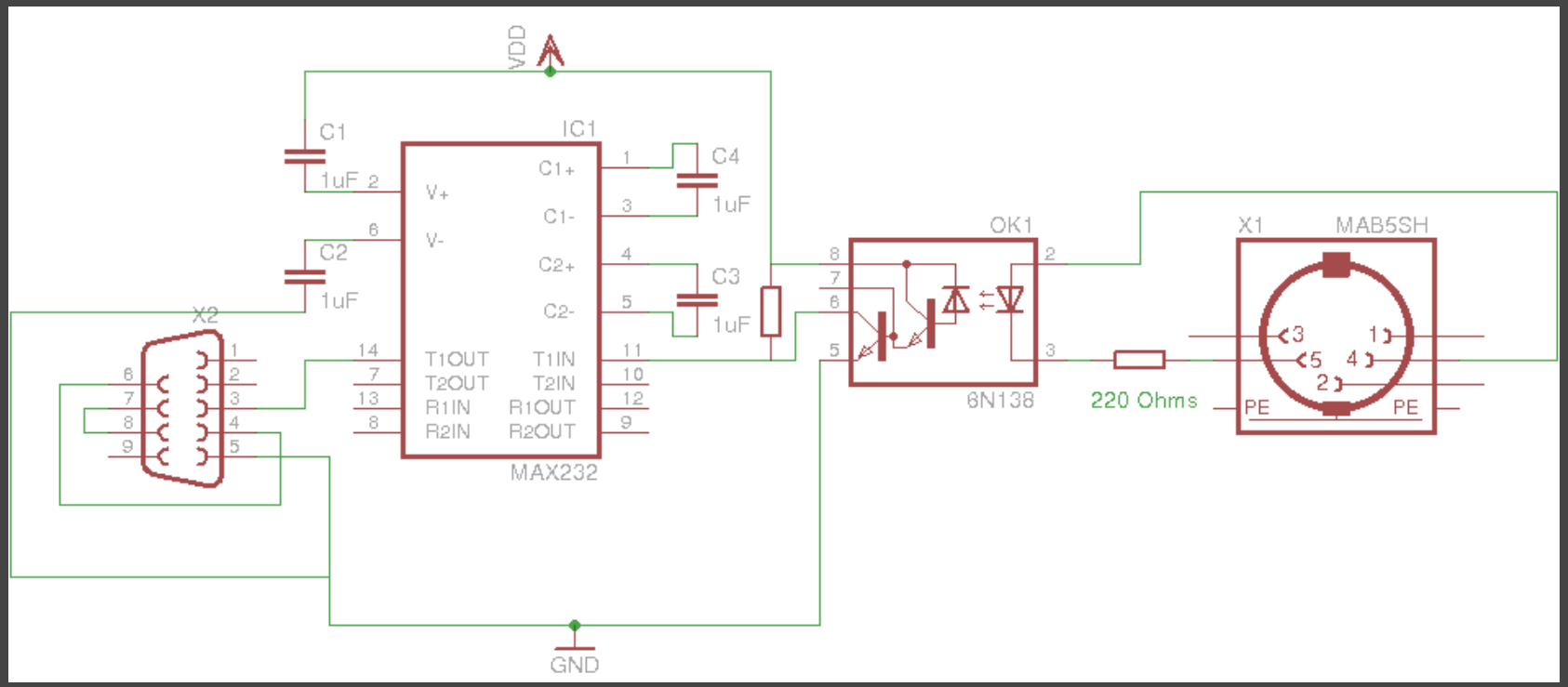
Software Architecture



Software Architecture

- Needed Real-Time Responsiveness
  - Use Hardware Interrupts for all Inputs
  - Use Separate Task For Each Function
- Needed Simple and Efficient Output
  - Output Devices are Memory Mapped
- Needed to Avoid Resource Contention
  - MIDI Task Finds Unused Hardware
- Needed to Implement Pre-Produced Performances
  - Modular Design Allows Us To Input Task and Write Directly to Audio Hardware

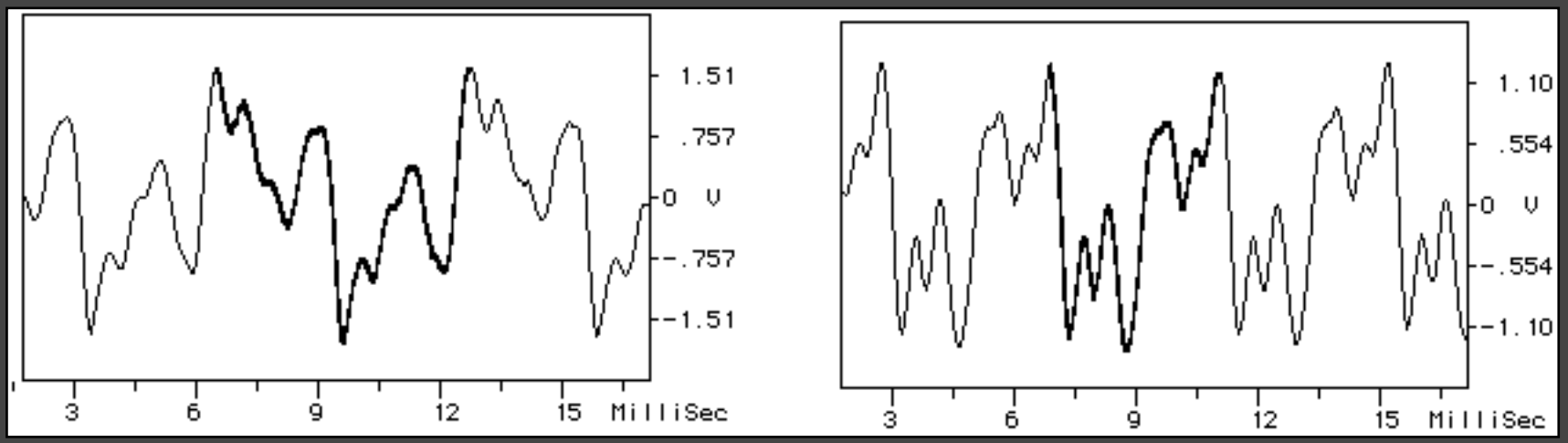
Physical Hardware



- MIDI physical connection uses current switching.
  - Current=1 - No Current=0
- Needed to convert to RS-232 +5V and -5V using MAX232
- MIDI Spec requires opto-isolator to prevent current loops

Issues Encountered

- Constrained by space on board
  - Insufficient RAM space to have all features implemented at once.
  - Had to cut some effects from final version.
- Difficult to get additional "instruments" to sound right.
  - We tried to create additional instruments by using a combination of harmonics in at various levels
  - As shown below, instruments are not a simple waveform (Clarinet at 156 Hz vs 233 Hz)



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Got Questions?