UMass Amherst

AI

Anything Instrument

Team 20

Matthew Avison, Carley Davis, Ivan Norman, Cory Vandergrift

The Team - Recap

Team 20

Matthew Avison - EE

Hardware Lead - Touch Sensing Keyboard

Carley Davis -EE

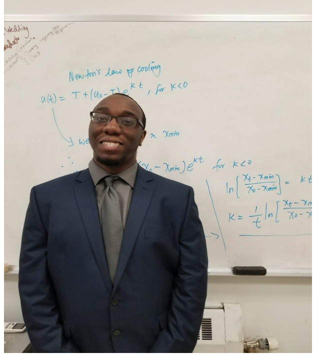
Team Coordinator - Power Supply Subsystem

Ivan Norman - EE

Altium Lead - MIDI Control Subsystem

Cory Vandergrift - EE

UI Lead - Team Budget and Logistics



Team Responsibilities

Team Coordinator: Carley Davis

- Responsible for building the power supply subsystem and accessing UMass labs if needed. Also responsible for scheduling meetings, keeping meeting minutes, documentation, building the team website, and soldering the final PCBs.

Hardware Lead: Matthew Avison

- Responsible for building the touch-sensing keyboard interface, integrated prototype assembly and final product assembly. Also designed the custom PCBs and contributed to programming the sound system.

Altium Lead: Ivan Norman

- Responsible for designing the MIDI synthesizer subsystem.

UI Lead: Cory Vandergrift

- Responsible for the LCD user interface subsystem, tracking and placing parts orders, and producing team reports.

The Anything Instrument - Recap

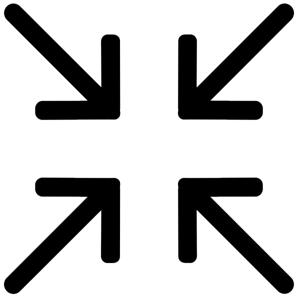
The Problem

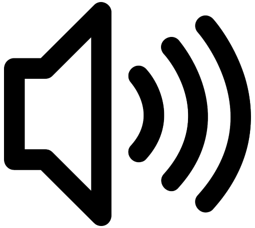
Musical instruments are shown to strengthen memory, reduce stress, inspire creativity, and bring happiness to those who play them. However, the cost, space requirement, and noise produced by most instruments can prevent many people from having the opportunity to play.

Introducing the Anything Instrument

The anything instrument is an ultra-portable musical device allowing one to use everyday conductive objects as playable keys.

This device will bring the many benefits of playing an instrument to more people in more places through its reduced **cost**, **size**, and **noise level**.





User Operation

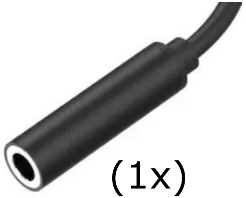
1. User will first **connect probes** to conductive objects to use as musical ‘keys’
2. User then pushes the tare button to **recalibrate** the Anything Instrument to the chosen objects
3. User will **select custom sound options** via the LCD interface
4. User proceeds to **touch** the **custom ‘keys’** and listens to the corresponding tones through an onboard speaker or 3.5mm AUX port

Original System Specifications

Anything Instrument will **meet or exceed** the following criteria

- Offer 8 playable connections
- Have an interchangeable battery
- Offer at least two different instrument modes
- Include a headphone jack
- Weigh 500 grams or less (not including connected objects)
- Have a main control body smaller than 20x10x5 cm

(2x)



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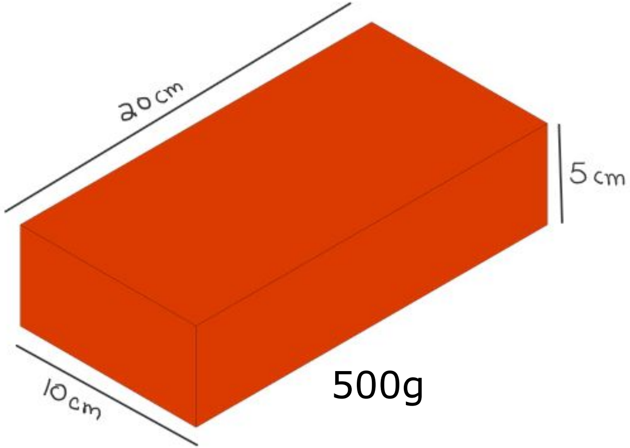


500g

Proposed CDR Deliverables

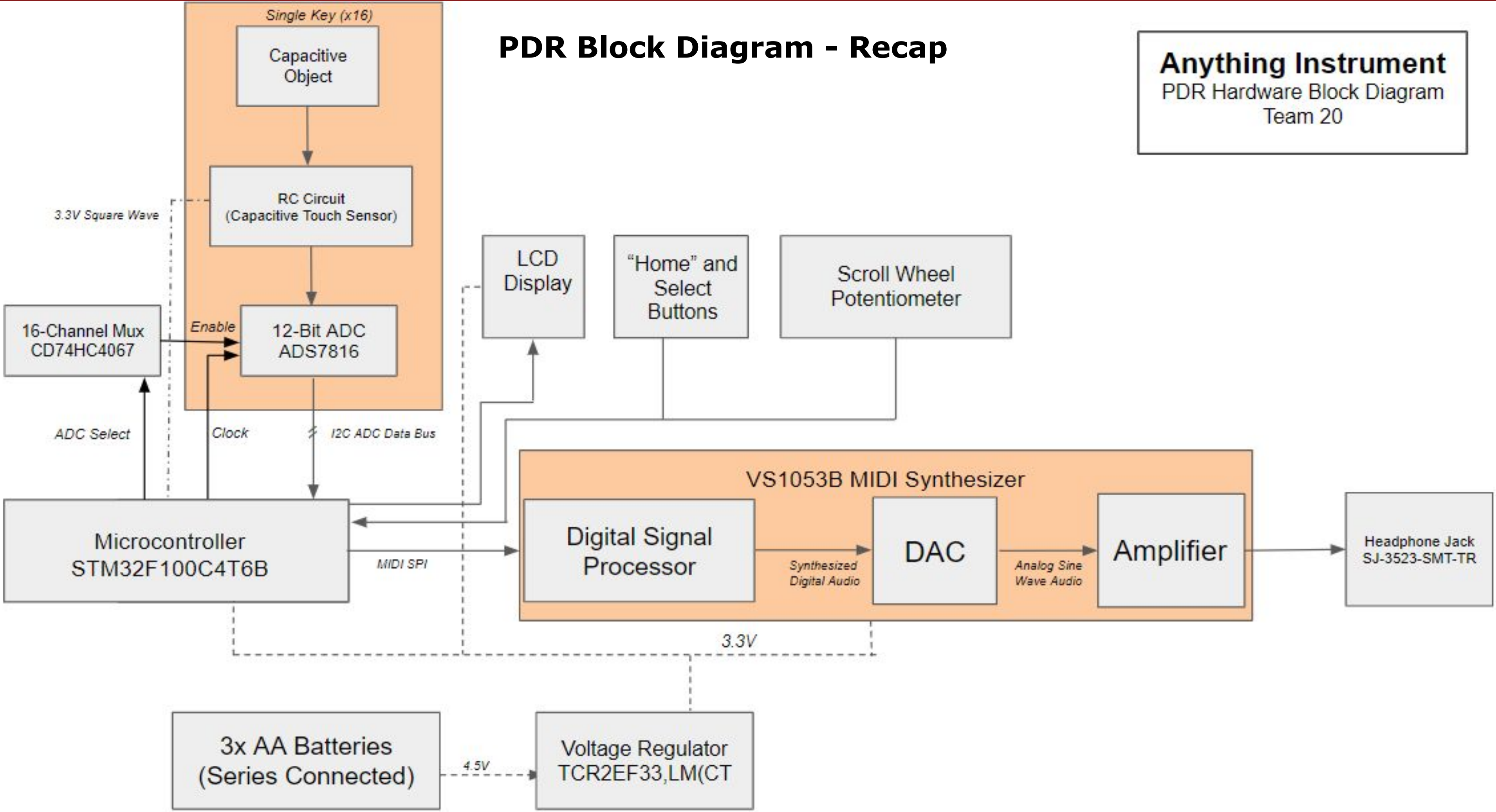
1. Demonstrate updated subsystems capable of being transferred onto PCB
   - Utilize through-hole version of individual components to demonstrate our final subsystem design on breadboard

2. Demonstrate a functional and complete prototype
   - All systems combined and functioning together to demonstrate the system’s complete functionality

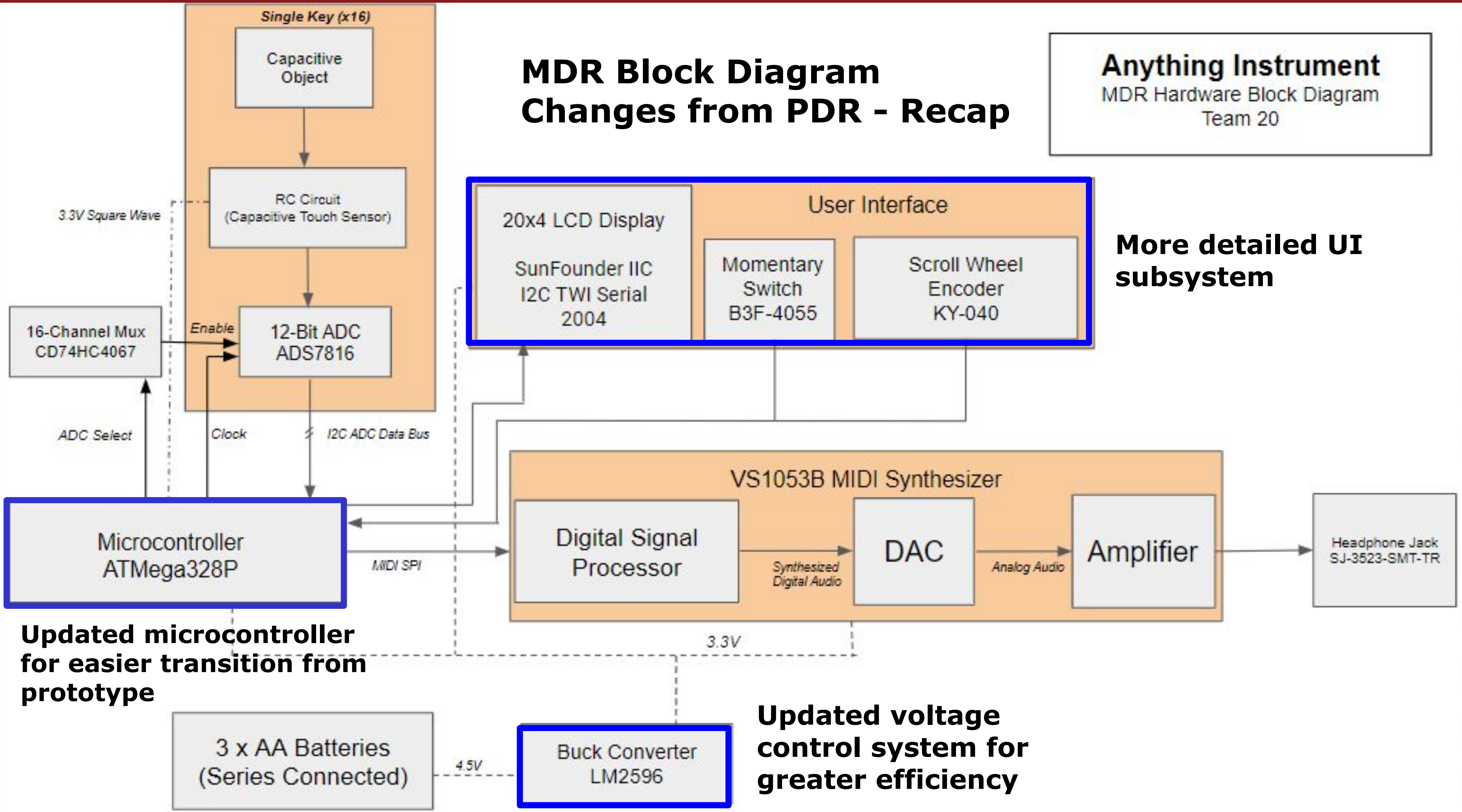
3. Complete Altium layout and PCB
   - Show a completed Altium layout design capable of hosting final project
   - Have printed PCB in hand

Design evolution

PDR Block Diagram - Recap



MDR Block Diagram
Changes from PDR - Recap



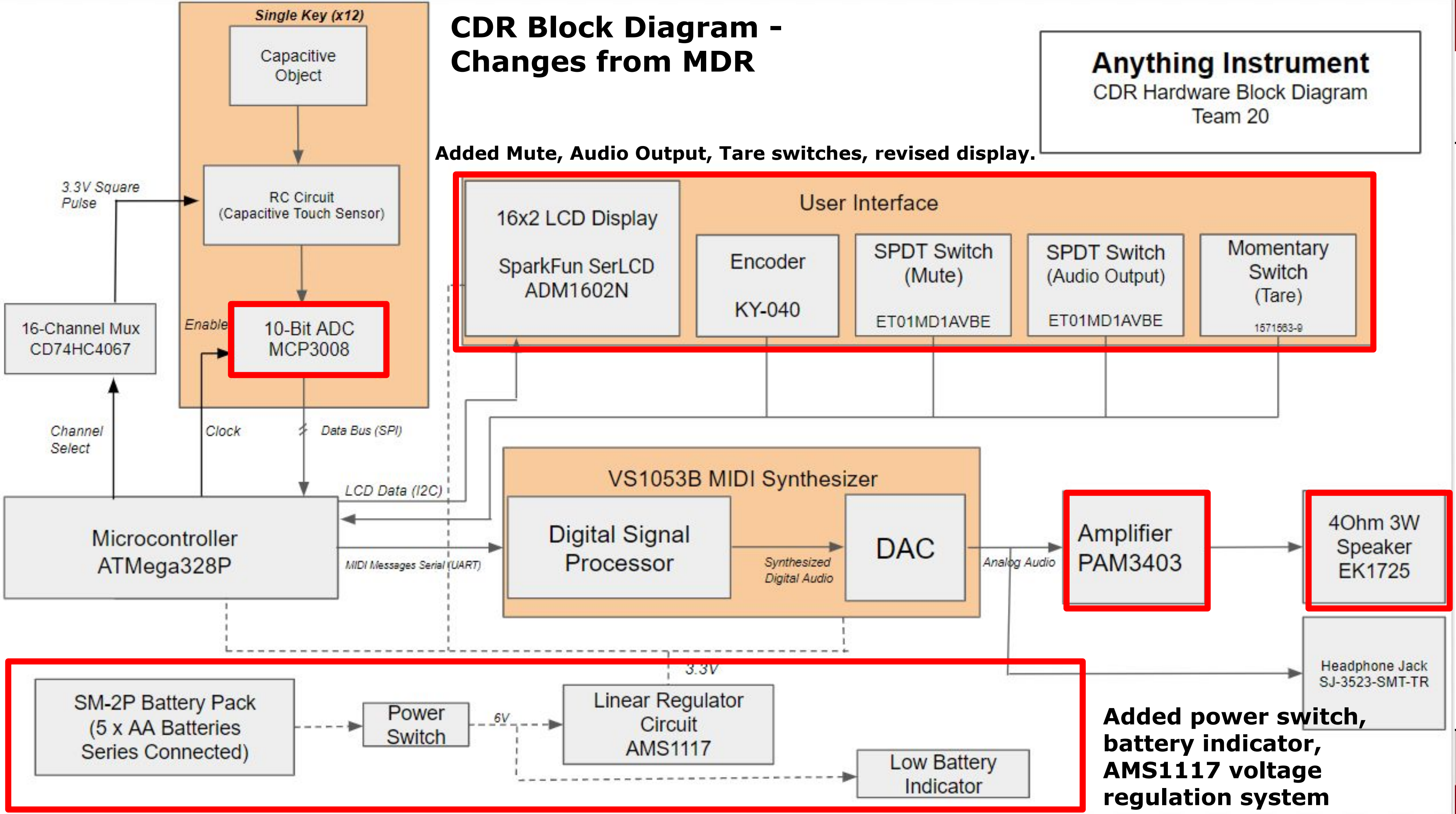
More detailed UI subsystem

Updated microcontroller for easier transition from prototype

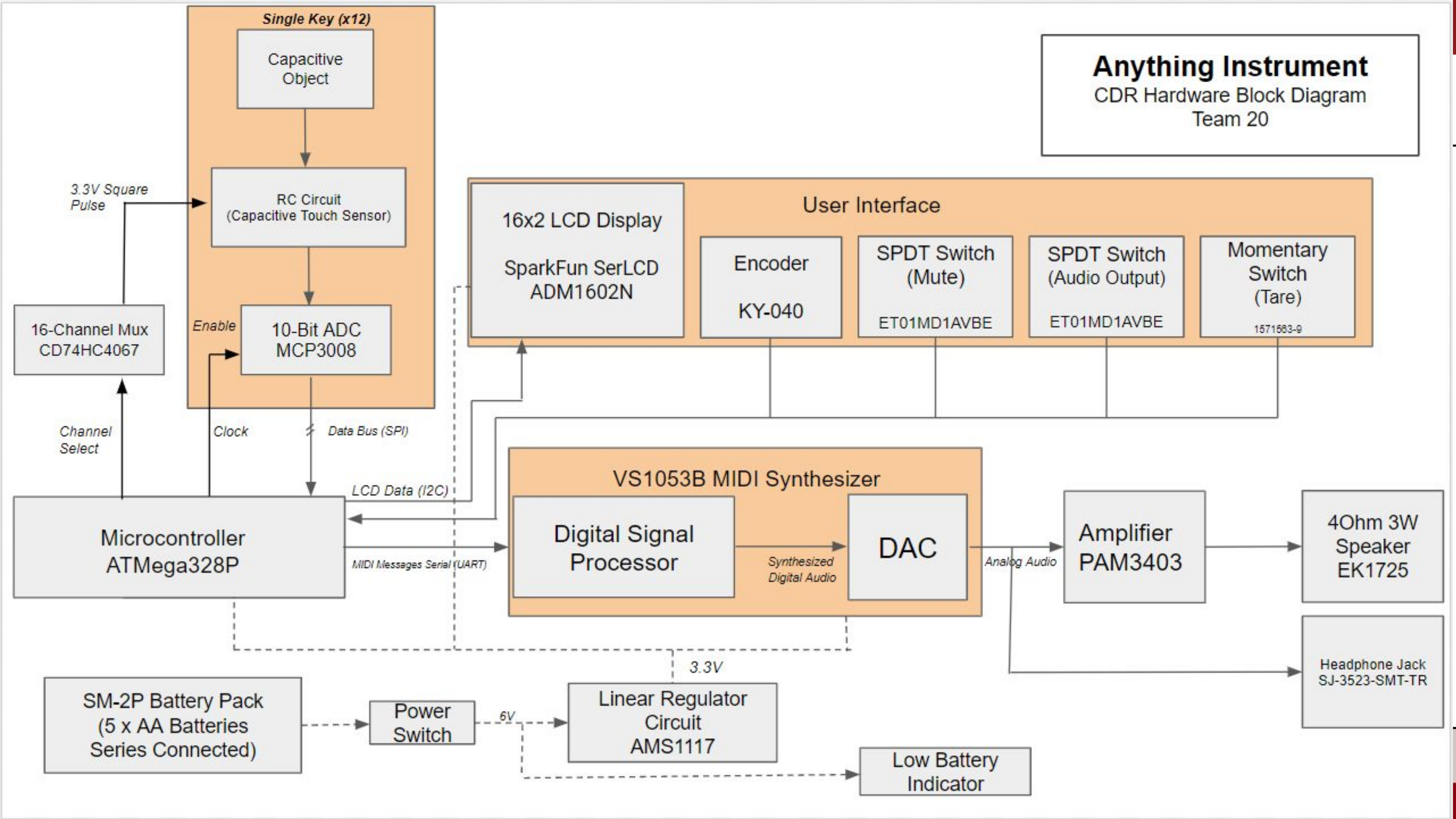
Updated voltage control system for greater efficiency

CDR Block Diagram - Changes from MDR

Added Mute, Audio Output, Tare switches, revised display.



Added power switch, battery indicator, AMS1117 voltage regulation system



Anything Instrument
CDR Hardware Block Diagram
Team 20
Single Key (x12)
Capacitive Object
RC Circuit (Capacitive Touch Sensor)
10-Bit ADC MCP3008
Enable
3.3V Square Pulse
16-Channel Mux CD74HC4067
Channel Select
Clock
Data Bus (SPI)
Microcontroller ATMega328P
LCD Data (I2C)
MIDI Messages Serial (UART)
User Interface
16x2 LCD Display
SparkFun SerLCD ADM1602N
Encoder
KY-040
SPDT Switch (Mute)
ET01MD1AVBE
SPDT Switch (Audio Output)
ET01MD1AVBE
Momentary Switch (Tare)
1571563-9
VS1053B MIDI Synthesizer
Digital Signal Processor
Synthesized Digital Audio
DAC
Analog Audio
Amplifier PAM3403
4Ohm 3W Speaker EK1725
Headphone Jack SJ-3523-SMT-TR
3.3V
SM-2P Battery Pack (5 x AA Batteries Series Connected)
Power Switch
6V
Linear Regulator Circuit AMS1117
Low Battery Indicator

Design Changes since MDR

Power Supply

- Addition of battery voltage monitoring circuit
- Addition of power switch
- Linear voltage regulator circuit in place of switching
- Higher voltage battery

User Interface

- Addition of mute, tare, and audio output switches
- Elimination of one of the two rotary encoders

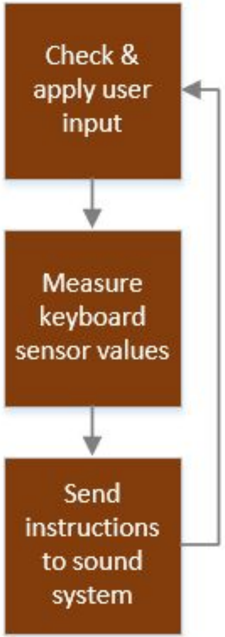
Keyboard Interface

- Switch to 10-bit ADCs from 12-bit ADCs

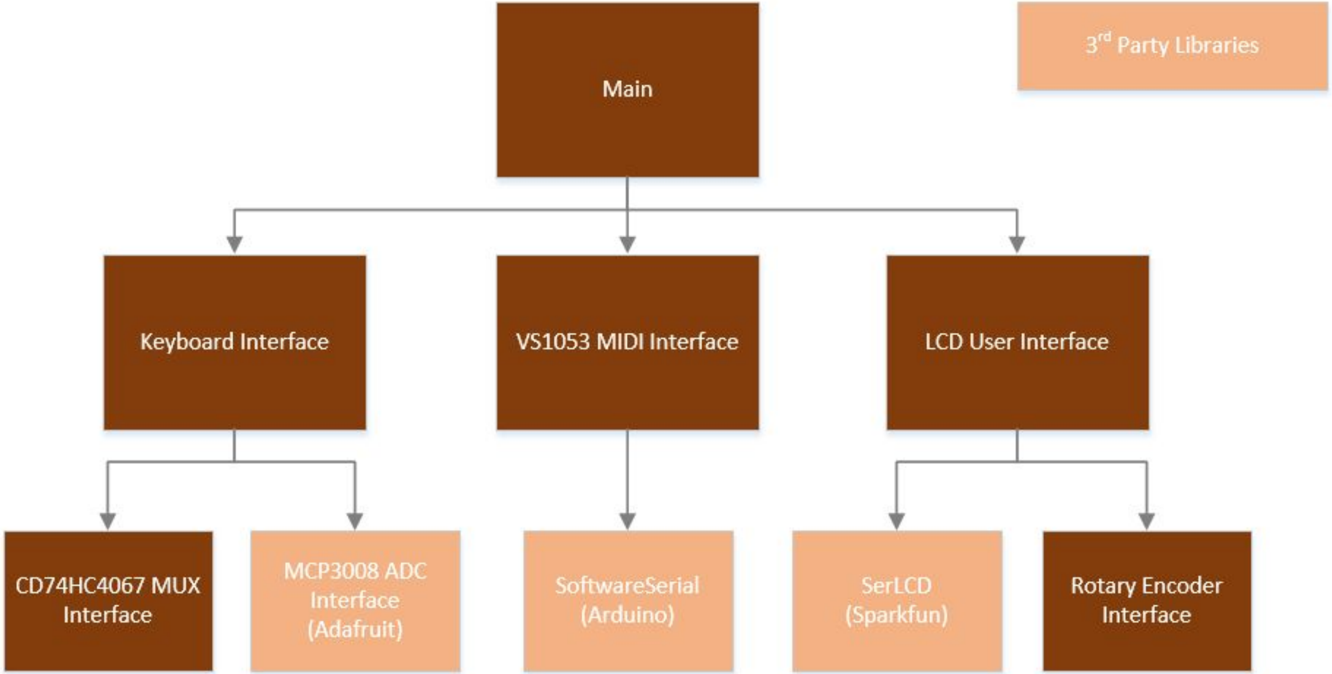
Sound System

- Addition of PAM8403 amplifier and 4Ω speaker

Anything Instrument - Software Visualization



High-level process



Software Library Hierarchy

Power Supply

Power Supply - System Specifications

- Needs to be able to power microcontroller, audio synthesizer, LCD display and amplifier - all run at 3.3V
- Needs to be easily turned on and off
- Needs to have option for batteries to be rechargeable and easily interchangeable
- Needs to be able to inform user that power is on and warn user when battery voltage is low
- Estimated battery life is approximately 5+ hours for our CDR prototype and 7+ hours for our FPR prototype, depending on usage and amplifier settings

Power Supply - Changes since MDR

- Previously used LM2596 adjustable buck converter breakout for voltage regulation

  Now using AMS1117 linear regulator circuit

- Added battery status indicator circuit
- Added power disconnect switch
- Added SM-2P battery connection

Power Supply - System Diagram & Hardware

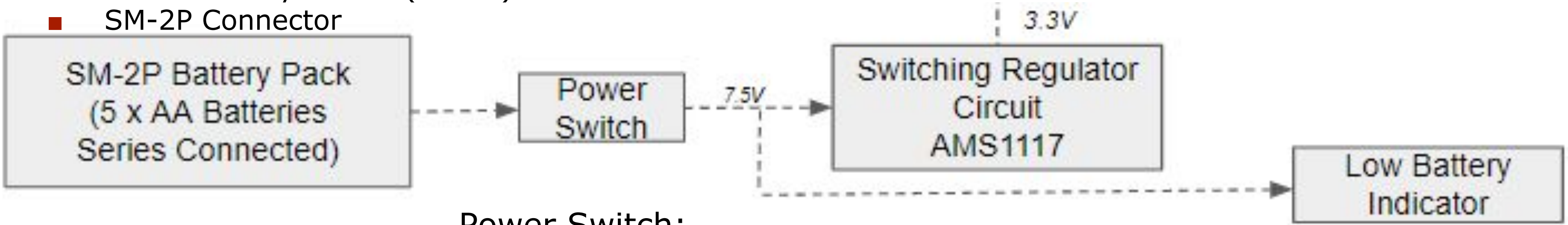
Hardware

<u>Battery Pack:</u>

- 5x AA Batteries (7.2V standard, 6V rechargeable)
- 5x AA Battery Holder (Series)
- SM-2P Connector

<u>Switching Regulator:</u>

- AMS1117 Breakout (custom AMS1117-ADJ circuit for FPR)



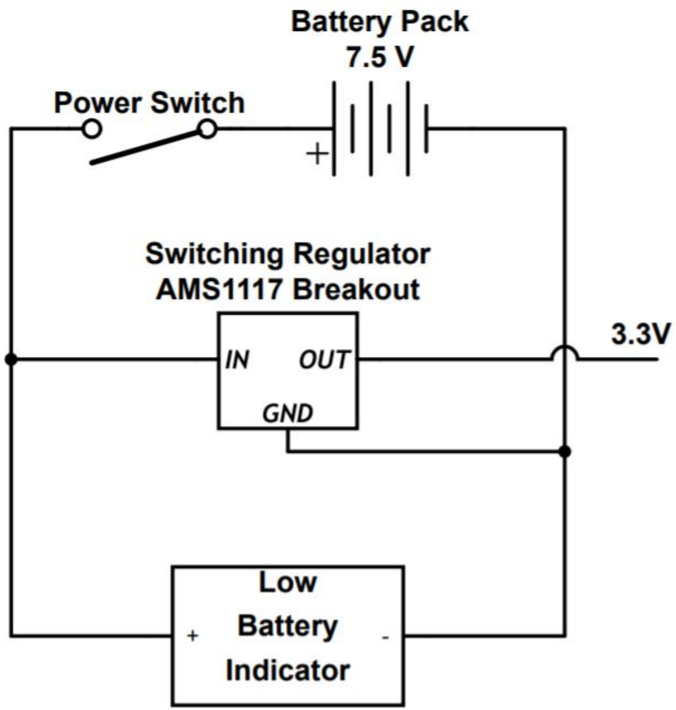
<u>Power Switch:</u>

- Eaton 1301-7W-SP-LW (KCD1-101 rocker switch for FPR)

<u>Low Battery Indicator:</u>

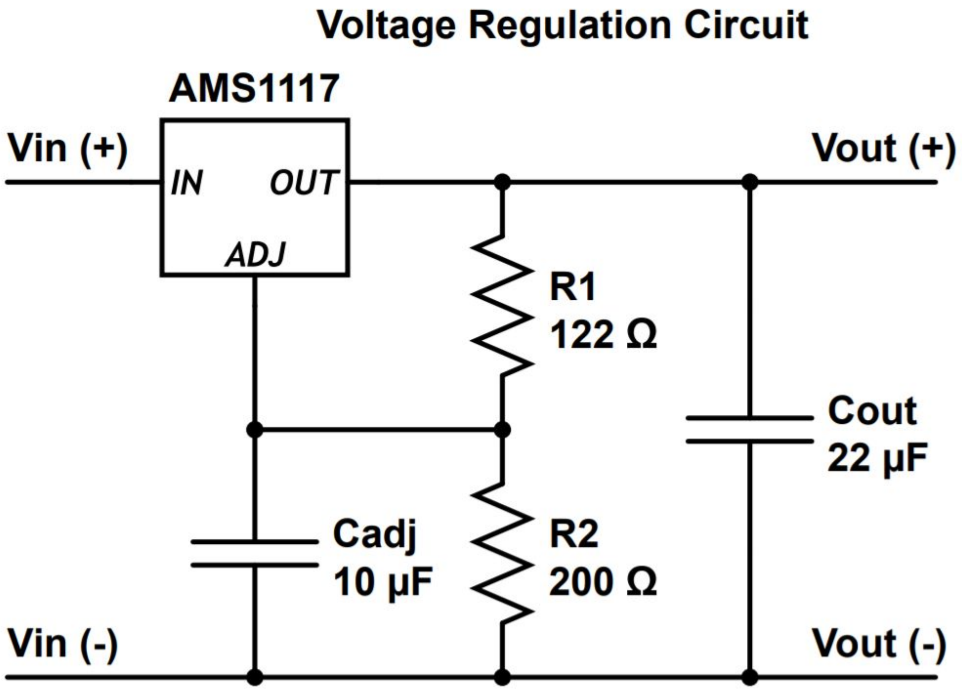
- 2x 2N3904 NPN Transistors
- Red LED (2.2V 20mA)
- Green LED (2.2V 20mA)
- Various Resistors

Power Supply - One Line Diagram

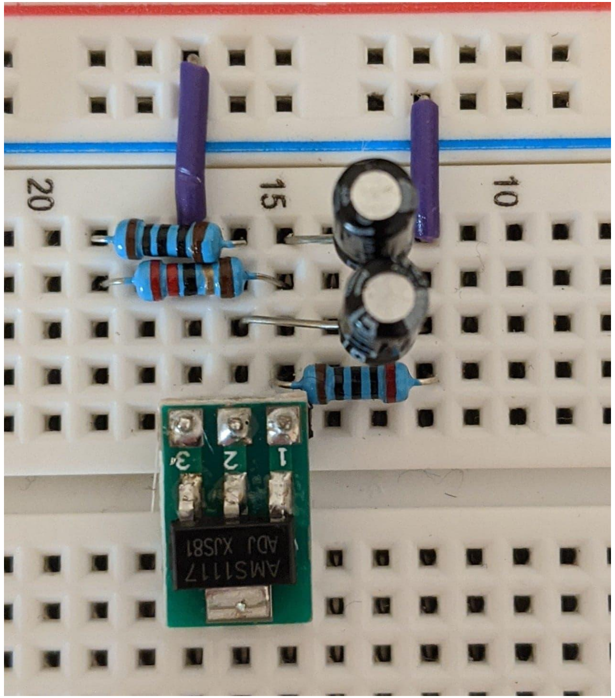


Power Supply - Voltage Regulator

- Used to regulate output voltage down to 3.3V
- Can be used with battery packs up to 10V
- Needs voltage to be above 4.75V
- Using breakout version for prototype, will be using this circuit for PCB

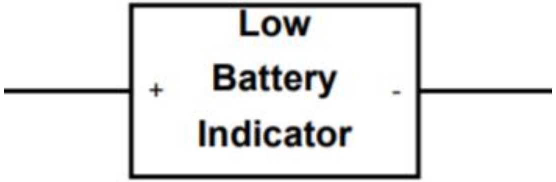


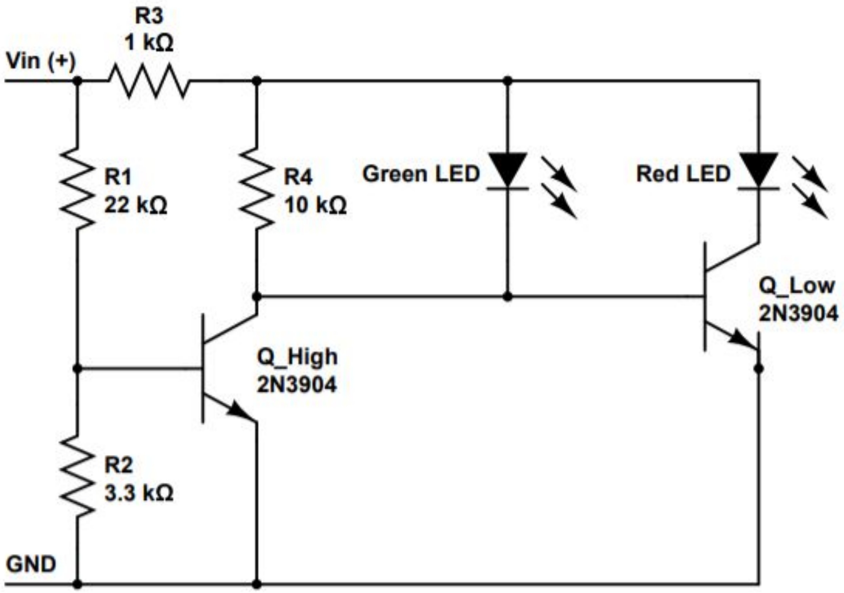
Power Supply - Prototype for PCB



Power Supply - Low Battery Indicator

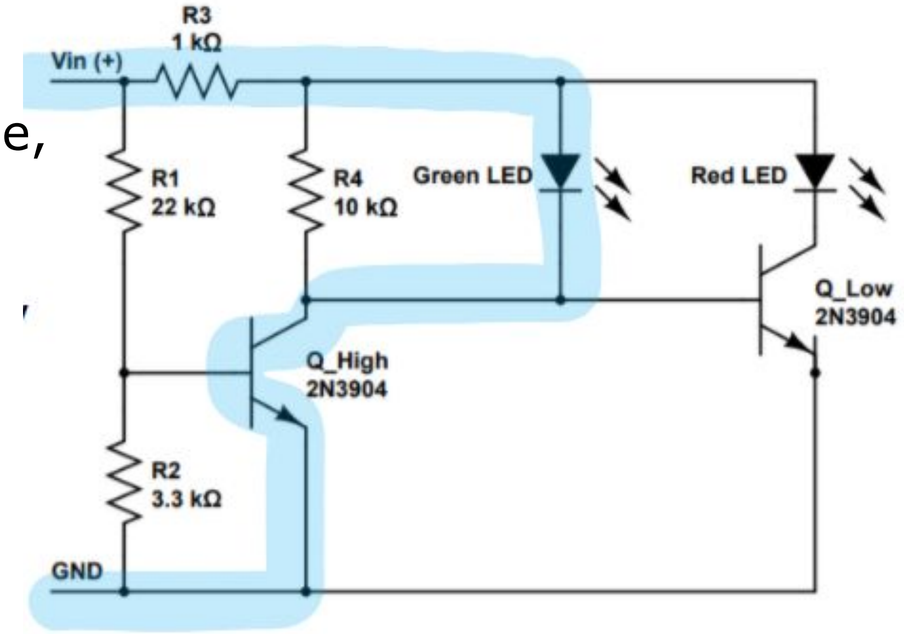
- Used to indicate when the battery needs to be recharged
- Green LED will light up when battery is fully charged, switch to red LED when battery nearing 5V





Power Supply - Low Battery Indicator

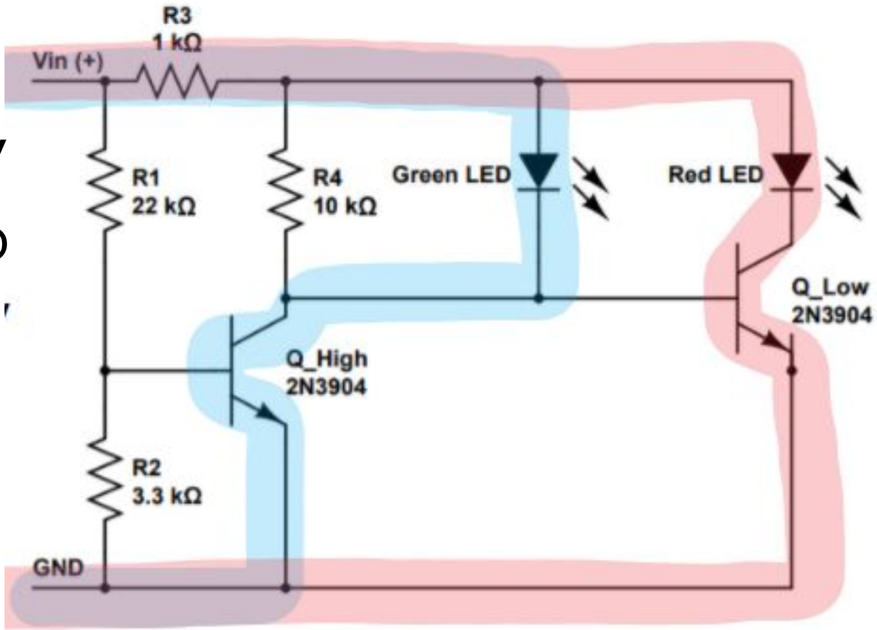
- If battery Voltage is >4.8 volts, Q_High will be above cutoff voltage, allowing current to flow through path 1



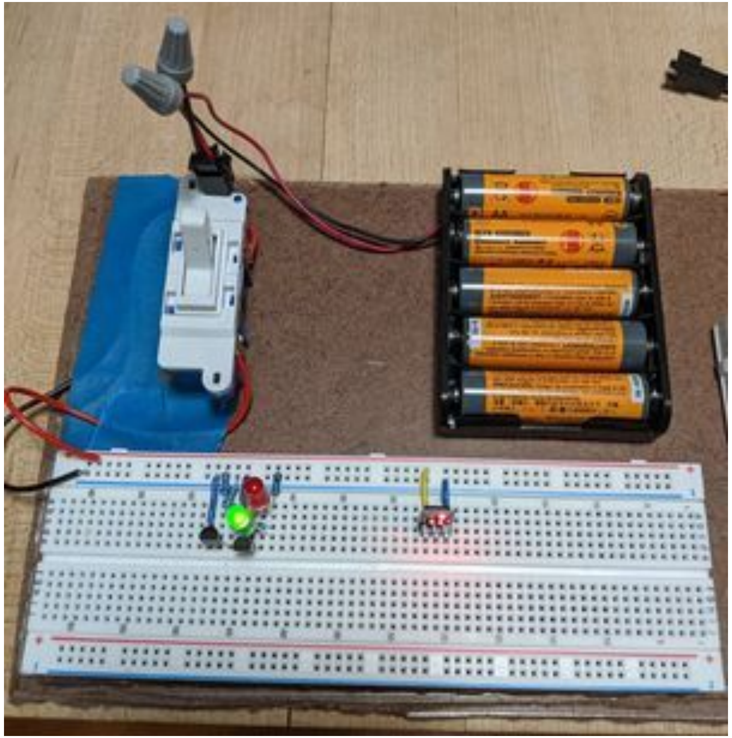
Power Supply - Low Battery Indicator

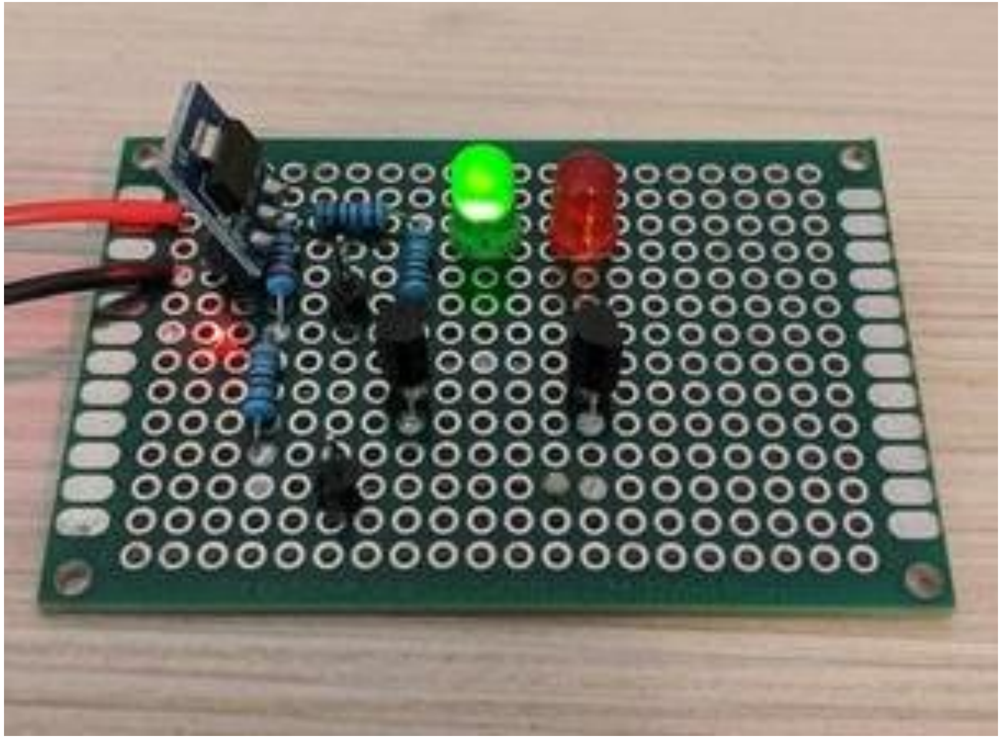
- If the battery voltage is >4.8 volts, Q_High will be above cutoff voltage, allowing current to flow through path 1 and illuminate the green LED

- If the battery voltage is <5 volts, Q_High will be below its cutoff voltage, causing the current to flow through the Q_Low path and illuminate the red LED

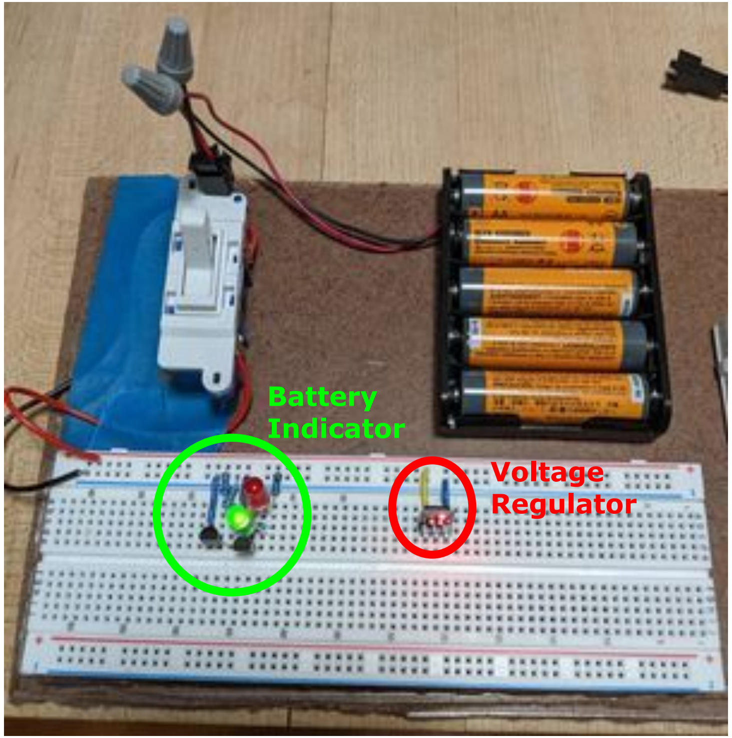


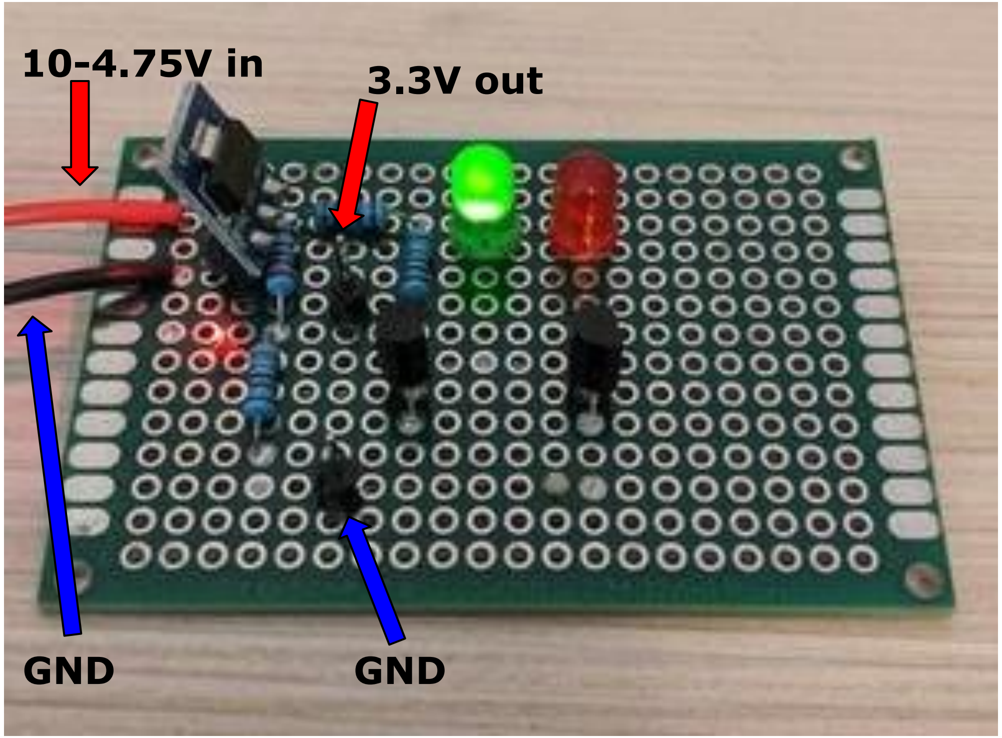
Power Supply - Prototype





Power Supply - Prototype





Battery Life - Calculations for CDR Prototype

NiMH Battery Capacity (mAh)	2300
Adjusted Battery Capacity (mAh)	1610

Equipment	Consumption (mA)
Arduino Uno (mA)	50
VS1053B - Dev Board	75
Sparkfun Display	164
Capacitive Touch System	2
Power Supply Subsystem	12.5

Total Operating Current (mA)	303.5
Total Operating Time (hours)	5.30

- Battery life of CDR prototype estimated to be 5 hours with all subsystems running at maximum capacity.
- Battery capacity adjusted by 0.7x the total capacity due to voltage drop during discharge. Minimum input operating voltage from batteries is 4.8V.

Total Operating Current/Adjusted Battery Capacity

Battery Life - Calculations for FPR Prototype

NiMH Battery Capacity (mAh)	2200
Adjusted Battery Capacity (mAh)	1540

Equipment	Consumption (mA)
ATMega328P	1.5
VS1053B	11
PAM8403 Amplifier (max)	16
Sparkfun Display	164
Capacitive Touch System	2
Power Supply Subsystem	12.5

Total Operating Current (mA)	207
Total Operating Time (hours)	7.44

Total Operating Current/Adjusted Battery Capacity

- Battery life of FPR prototype estimated to be 7+ hours with all subsystems running at maximum capacity.
- Extension from CDR due to no longer using breakout boards.
- Battery being used for FPR has a 2200mAh capacity as opposed to typical rechargeable AA batteries with 2300mAh.

User Interface

User Interface - System Specifications

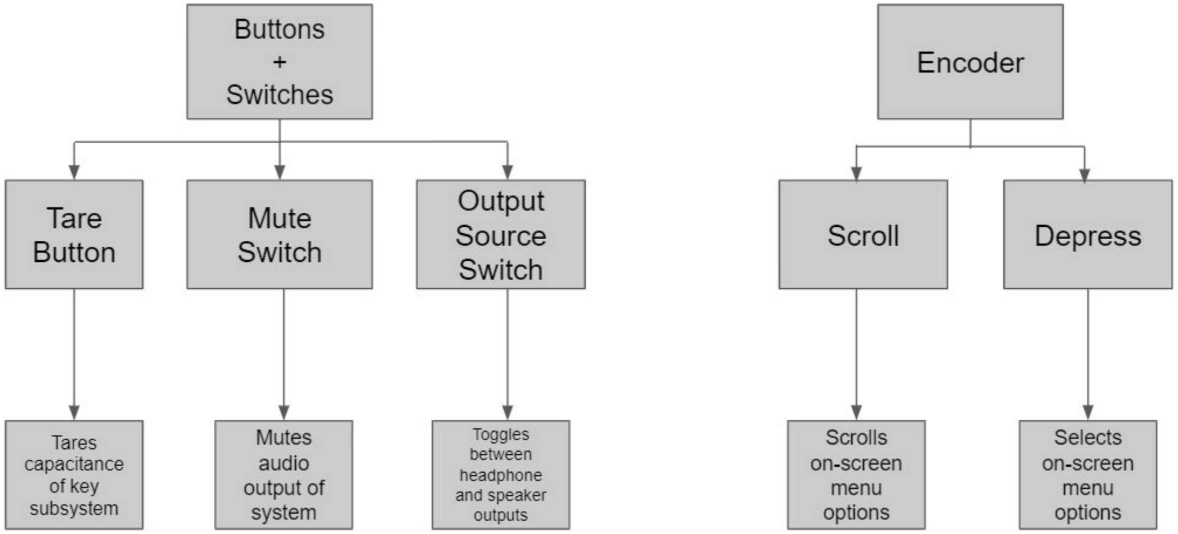
- Must be simple, intuitive, and easy to use
- Focus on most important information
- Room for menu expansion to fit needs of project

User Interface - Changes since MDR

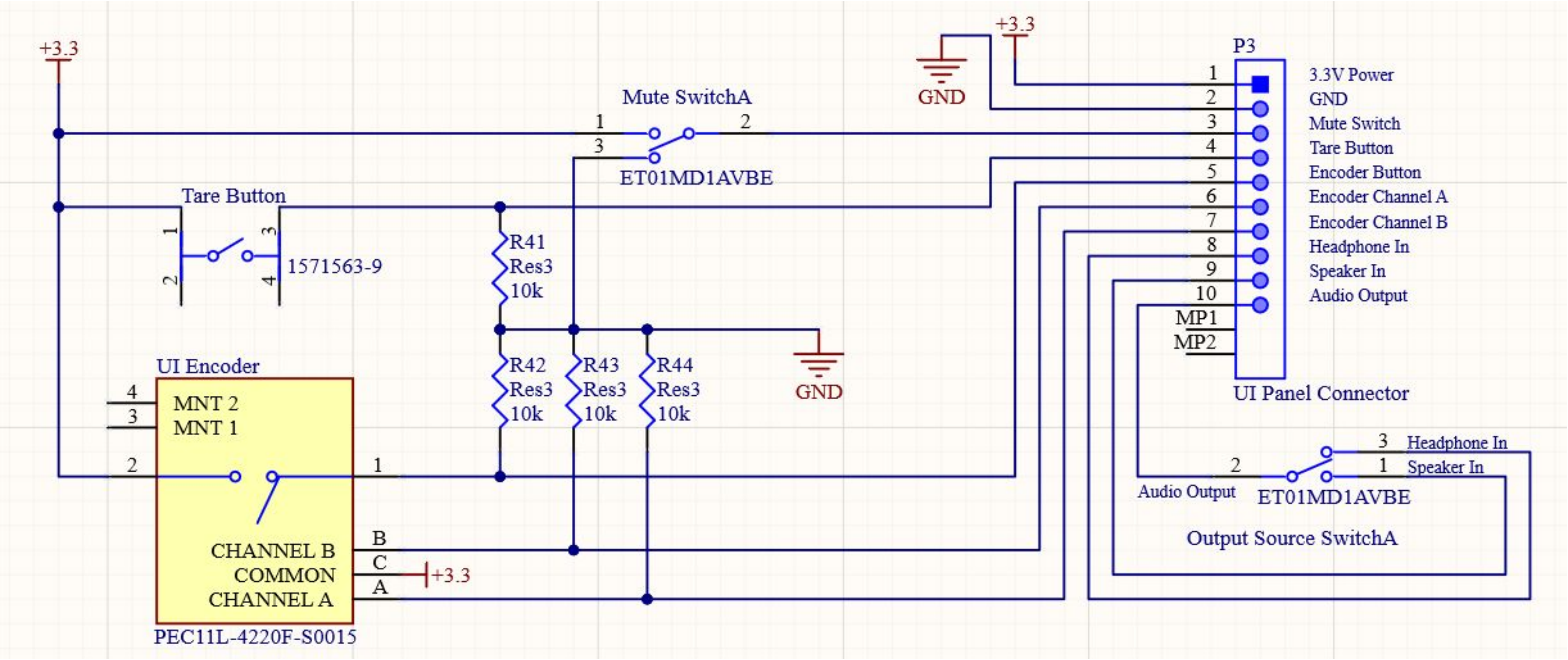
- I2C protocol finalized
- Reduced two encoder design to single encoder
- Added tare, output source, mute switches

User Interface - System Description

- 16x2 LCD display, one rotary encoder, two SPDT switches and one momentary switch
- UI encoder is twisted to scroll the menu and depressed to make menu selections
- Output source switch used to switch the audio output between the headphone jack and speaker
- Mute switch is used to disable the output of the device
- Tare button is used to tare the capacitance of the key input subsystem.



User Interface Panel - Circuit Diagram

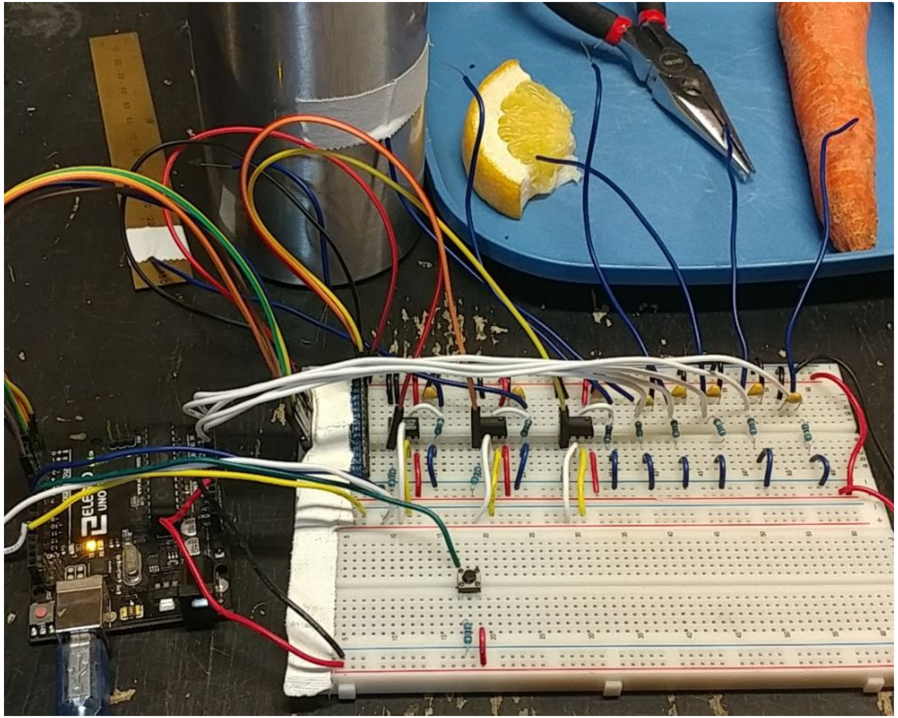


Keyboard Interface

Keyboard Interface - Specifications

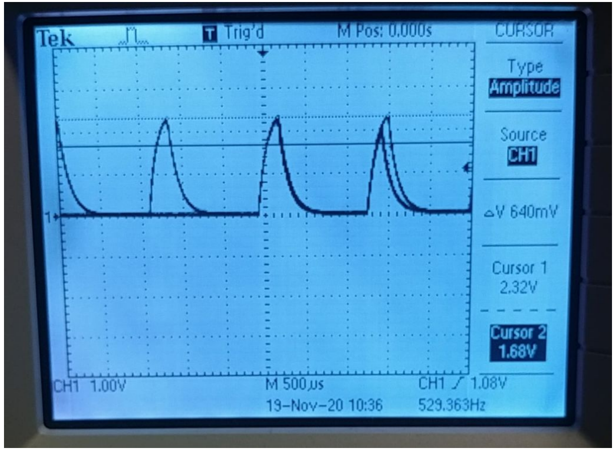
- 12 Individual keys sensitive to human touch
- Sensor response time under 1ms
- Each key able to be recalibrated to a unique capacitance

  (i.e. from an apple, soda can, screwdriver, etc.)

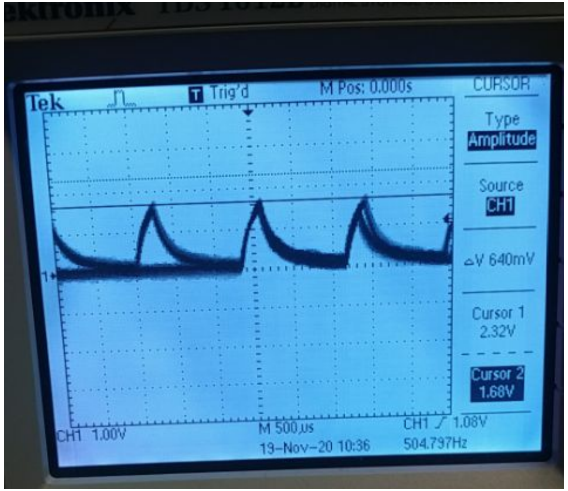


Keyboard Interface - Touch Sensor Recap

- Touch sensor measures the voltage across its capacitor at Time = Tau.
- Adding capacitance on that node drops the voltage at the same point during the cycle
- A voltage drop below a tolerance margin (5%) of the original value yields a “touch”

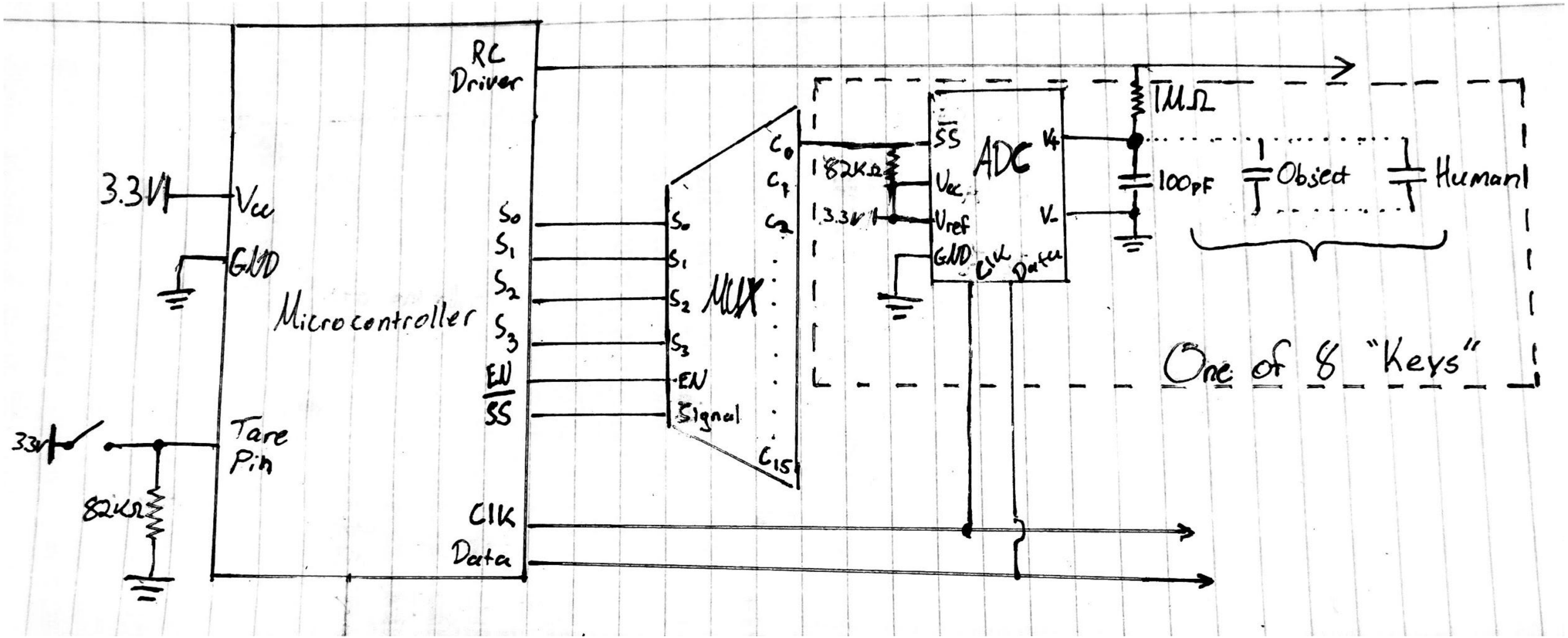


(Default RC charge cycle)



(Charge cycle upon touching probe)

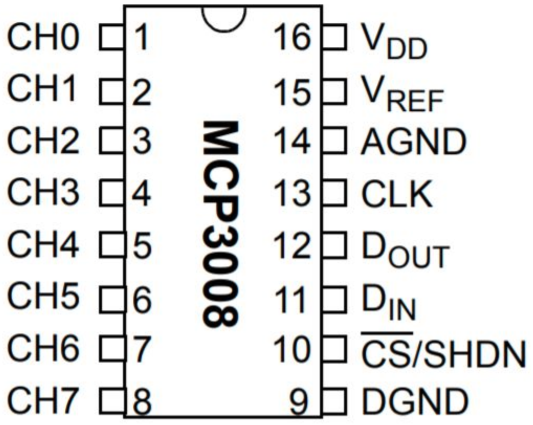
Keyboard Interface - Circuit Diagram



Keyboard Interface - Changes since MDR

Made the switch to Microchip's MCP3008 ADCs

- 10-bit resolution
- 8 Input channels per chip



Increased number of playable keys from 8 to 12

- User able to play a full chromatic scale

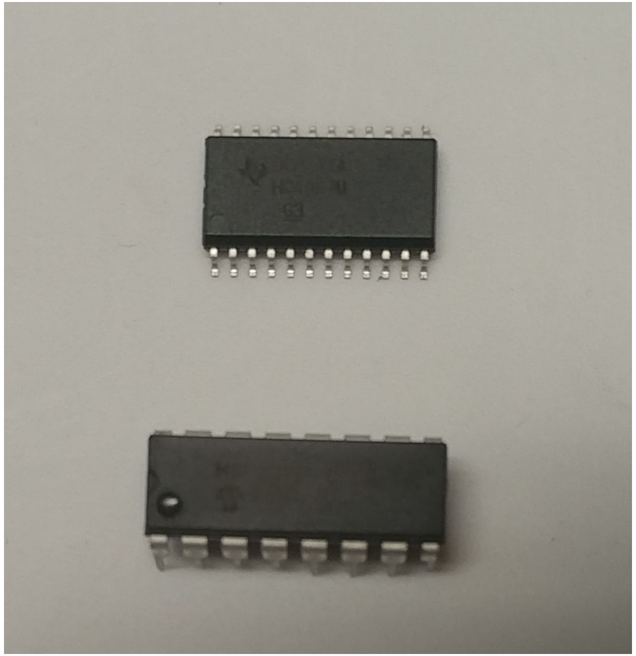
Keyboard Interface - Final Hardware

Multiplexer (x1): CD74HC4067

- 16 Channels

Analog to Digital Converter (x2): MCP3008

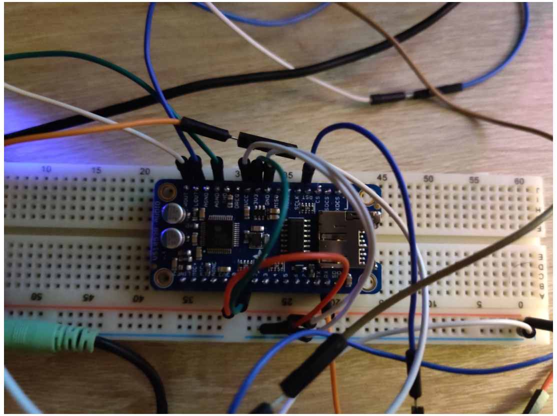
- 8 channels per chip
- 10-Bit resolution
- 200kHz Max sampling rate
- Interfaced via SPI



Sound System

Sound System - Specifications

- Receive MIDI messages via SPI
- Play MIDI messages through a headphone jack

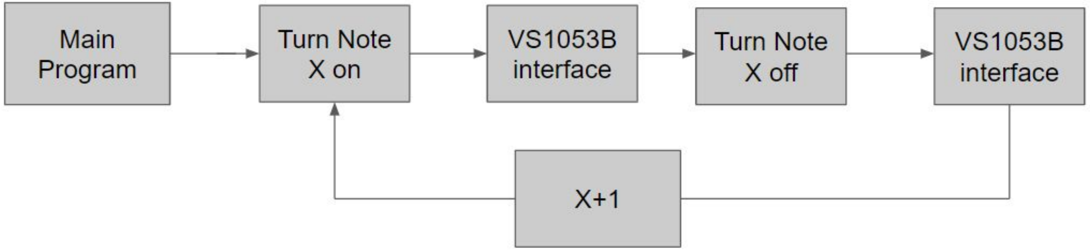


Sound System - Changes since MDR

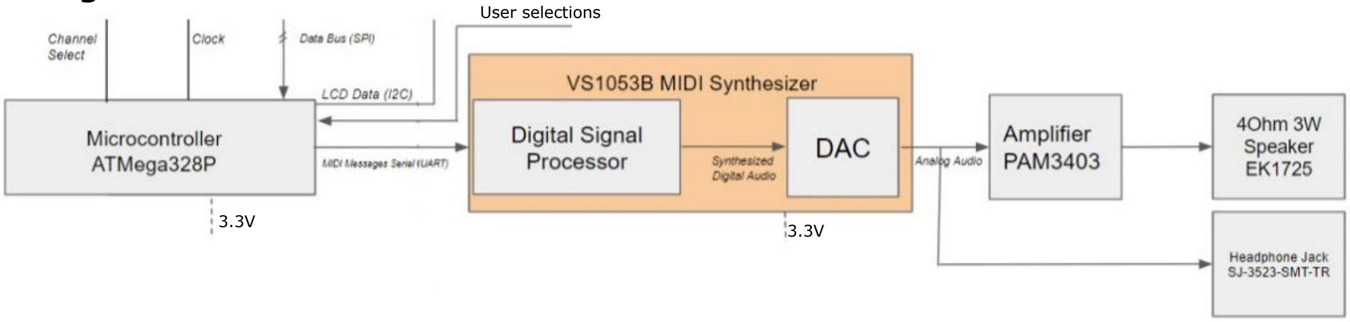
- Implemented menu features
  - Track switching
  - Volume adjustment
- Implement and use capacitive touch circuit output instead of wire contacts

Sound System - System & Hardware Diagram

Software Diagram



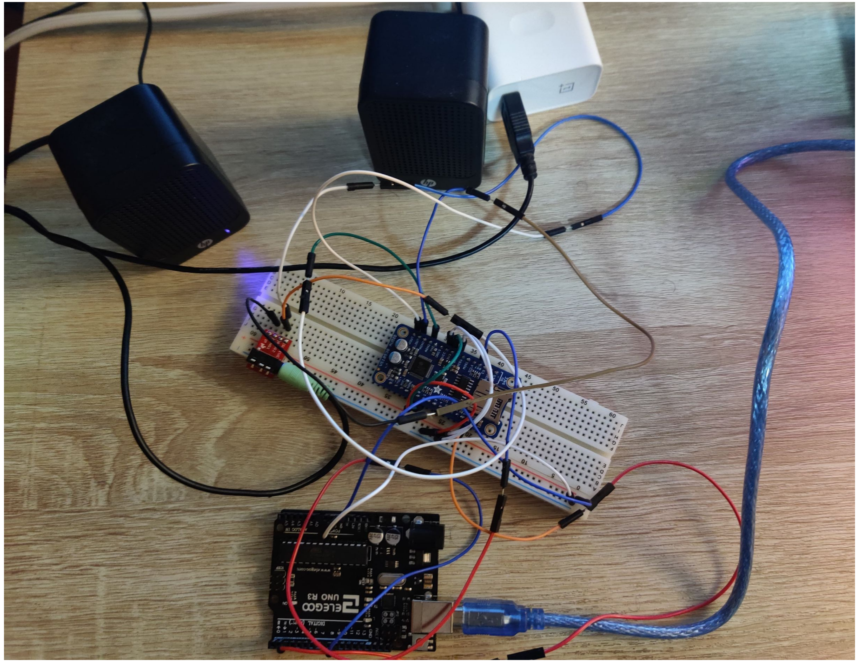
Hardware Diagram



Sound System - Hardware

Components

- VS1053 as MIDI decoder
- PAM8403 amplifier
- 3.5mm headphone jack
- 4Ω Speaker



Complete Prototype

Proposed CDR Deliverables

1. Demonstrate updated subsystems capable of being transferred onto PCB
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2. Demonstrate a functional and complete prototype
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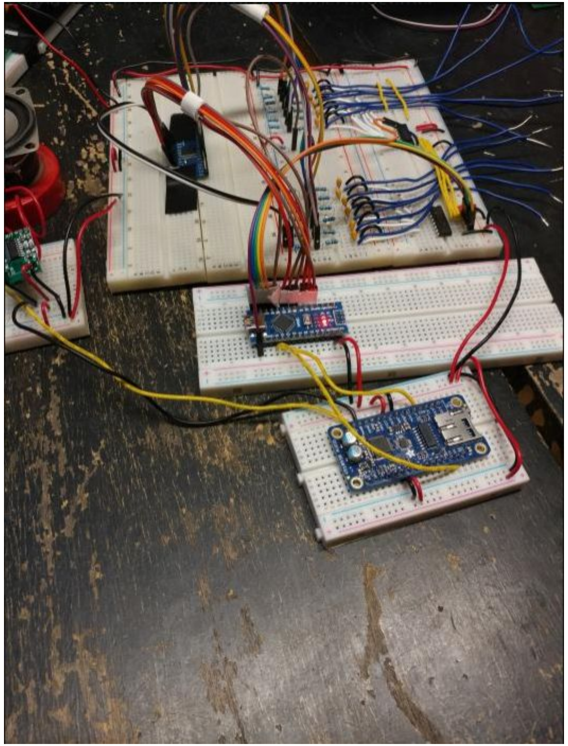
3. Complete Altium layout and PCB
   - Show a completed Altium layout design capable of hosting final project
   - Have printed PCB in hand - Currently at UMass in campus mail

Complete Prototype



Live demo at end

Printed Circuit Boards

Printed Circuit Board Hardware

Components on the main **Motherboard PCB**

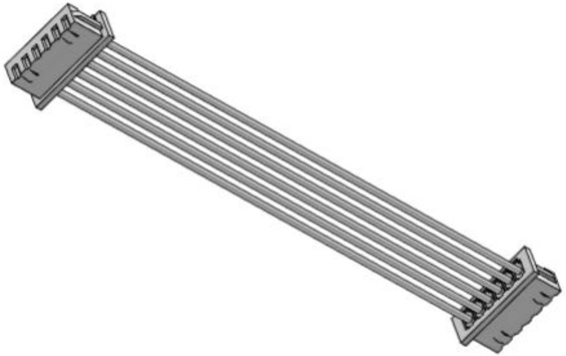
- ATmega328P Microcontroller
- VS1053 MIDI Decoder
- Audio Amplifier
- Keyboard touch-sensors
- Power Supply and Voltage Regulator

Components on the **UI Panel PCB**

- Rotary Encoder
- SPDT Switches
- Tactile Button

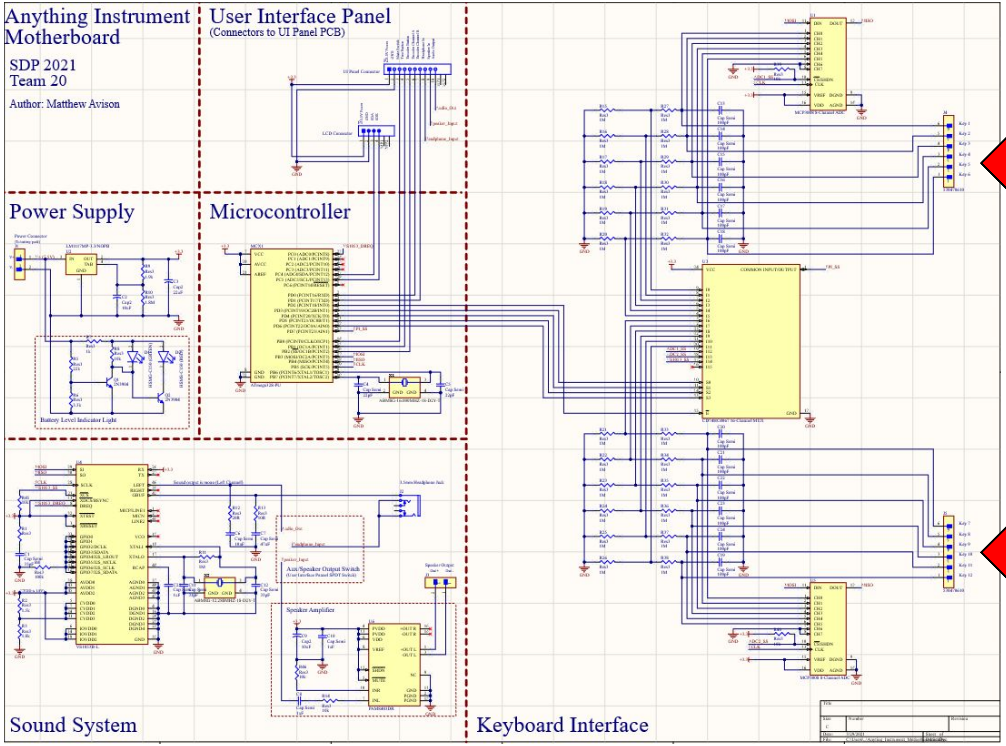
Components **externally connected** to the Motherboard

- Battery pack
- 16x2 LCD Display
- Probes for connecting to conductive objects



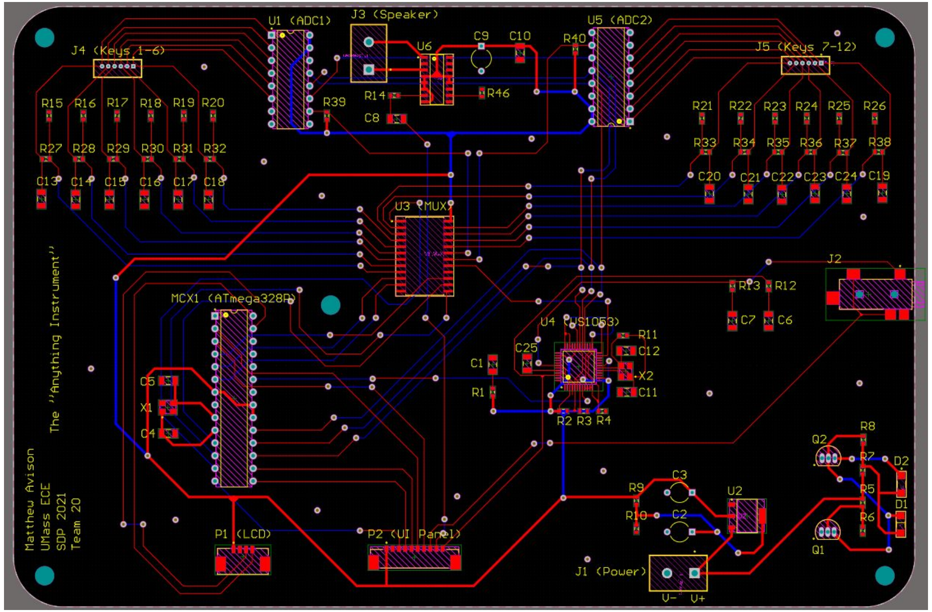
Molex Connector between Motherboard and UI Panel

Motherboard - Schematic

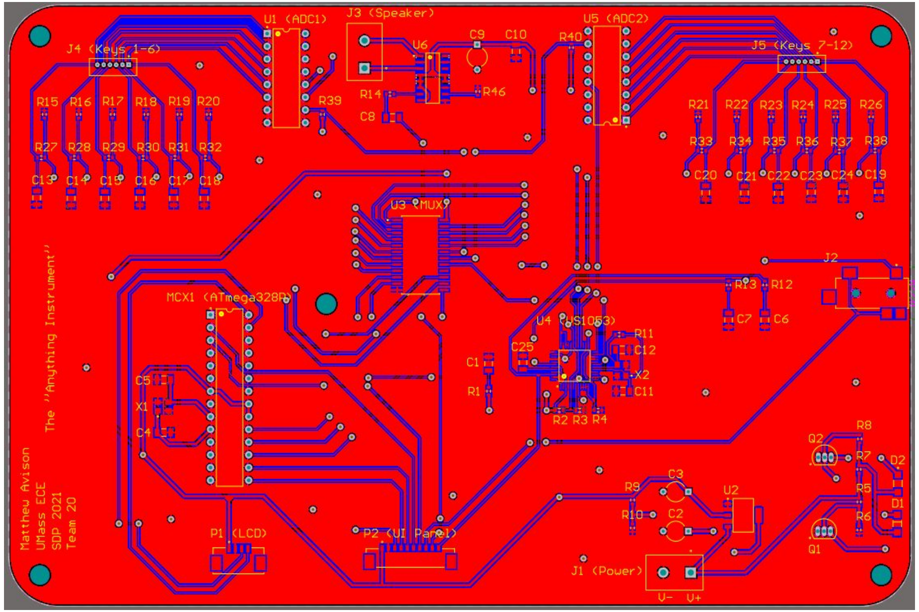


Points of connection for keyboard probes

Motherboard - PCB Design

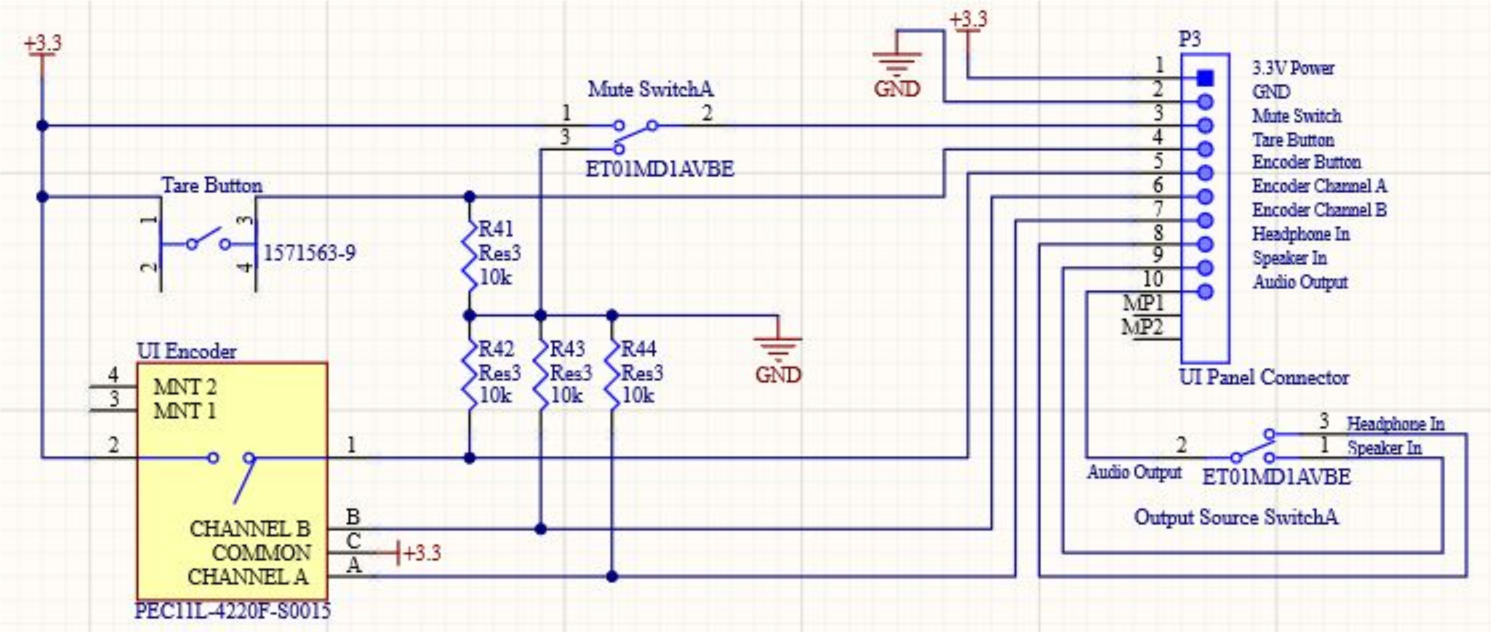


Ground planes hidden



Ground planes visible

UI Panel - Schematic



UI Panel - PCB Design

Cutout for Sparkfun LCD

Final Project Plans

FPR- Changes from CDR

Migration to PCB

- Microcontroller, sound system, voltage regulation system, battery status system, keyboard touch sensors, and UI controls will all be on PCBs

Rechargeable Battery

- Blomiky 6V 2200mAh Ni-MH battery pack will be used via SM-2P connectors for easy battery swap out and ability to recharge

Optimized Code

- Seamless UI transitions, more menu options and a smoother overall user experience

Plastic Case

- A clean & aesthetic 3D printed case will be designed to house the final system

FPR - PCB Population and Testing

Carley will be using the hot plate at M5, a home soldering station, and PCB stencil to populate the PCB.

Matt will test the PCBs, ensuring that the they function as expected and prepare them for final product assembly & troubleshooting

Ivan and Cory will assist remotely with any logistical and software faults that arise.

Proposed FPR Deliverables

1. Demonstrate the **complete product** on our custom PCBs
2. Demonstrate **system housing**
3. Demonstrate the system meeting **all specifications**
4. Live concert **demonstration**

Budget & Logistics

Budget

- We expected the parts for the final project to cost approximately $497 (board revisions/shipping/margin)
- Our cost to date has been <u>$417.83</u>
- We also have received $146.09 worth of parts from M5

Cost Breakdown To Date

Part Number	Function	Cost (each)	Qty.	Total Cost (USD)
				Fall 2020
VS1053B	Audio Synthesizer	$12.50	2	$25.00
ADS7816P	12-Bit ADC -For each input	$2.54	4	$10.16
CD74HC4067	Multiplexer	$0.29	2	$0.58
STM32F100C4T6B	Microcontroller	$3.13	2	$6.26
SJ-3523-SMT-TR	Headphone Jack	$0.52	2	$1.04
BH3AAPC	AA Battery Holder	$1.13	1	$1.13
LM2596	Buck Converter (2 EA)	$5.99	1	$5.99
STM32 Dev Board	Microcontroller	$29.15	4	$116.60
VS1053B Dev Board	Synthesizer	$24.95	2	$49.90
SunFounder IIC I2C TWI Serial 2004	LCD Display and Controller (2 EA)	$15.99	1	$15.99
KY-040	Encoder (8 EA)	$12.98	1	$12.98
				Spring 2021
VS1053B Dev Board	Synthesizer	$24.95	2	$60.89
PCB Order	Both Boards (10 EA) + Stencil	$112.95	1	$112.95
PCB Components	Digikey - per Spreadsheet	$90.60	1	$109.41
PCB Components	Mouser - per Spreadsheet	$12.06	1	$20.05
6V 2200mAh NiMH Battery	Rechargable Battery	$14.99	1	$14.99
			Total Cost:	$563.92
*Indicates items recieved entirely from M5			From M5:	$146.09
*Indicates items partially recieved from M5			Cost Against Budget:	$417.83

Value of borrowed hardware to be returned to M5

FPR Budget Plan

Part Number	Function	Cost (each)	Qty.	Total Cost (USD)
				Fall 2020
VS1053B	Audio Synthesizer	$12.50	2	$25.00
ADS7816P	12-Bit ADC -For each input	$2.54	4	$10.16
CD74HC4067	Multiplexer	$0.29	2	$0.58
STM32F100C4T6B	Microcontroller	$3.13	2	$6.26
SJ-3523-SMT-TR	Headphone Jack	$0.52	2	$1.04
BH3AAPC	AA Battery Holder	$1.13	1	$1.13
LM2596	Buck Converter (2 EA)	$5.99	1	$5.99
STM32 Dev Board	Microcontroller	$29.15	4	$116.60
VS1053B Dev Board	Synthesizer	$24.95	2	$49.90
SunFounder IIC I2C TWI Serial 2004	LCD Display and Controller (2 EA)	$15.99	1	$15.99
KY-040	Encoder (8 EA)	$12.98	1	$12.98
				Spring 2021
VS1053B Dev Board	Synthesizer	$24.95	2	$60.89
PCB Order	Both Boards (10 EA) + Stencil	$112.95	1	$112.95
PCB Components	Digikey - per Spreadsheet	$90.60	1	$109.41
PCB Components	Mouser - per Spreadsheet	$12.06	1	$20.05
6V 2200mAh NiMH Battery	Rechargable Battery	$14.99	1	$14.99
Anticipated PCB Order	Motherboard (10 EA)	~$80	1	$80
			Total Cost:	$563.92
			From M5:	$146.09
*Indicates items recieved entirely from M5			Cost Against Budget:	$417.83
*Indicates items partially recieved from M5			Est. Final Cost Against Budget:	$497.83

Anticipated board revision and reorder ~$80

Current Schedule

			Week of:	3/29/21					4/5/21					4/12/21					4/19/21					4/26/21					
Task Name	Start Date	End Date	Team Member	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	S
Hardware																													
Website Building	3/1/21	3/19/21	CD				C																					D	
Combining Subsystem Prototypes	3/8/21	3/31/21	CD, CV, IN, MA				D													F	P	R						E	
PCB Design	2/22/21	3/12/21	MA				R																					M	
Solder components to PCB	4/2/21	4/5/21	CD, MA																	W	E	E	K					O	
System Troubleshooting (Critical)	3/15/21	4/16/21	CD, CV, IN, MA																										
Logistics																													
Order FPR Parts	3/22/21	3/26/21	CV																										
Obtain Parts	3/29/21	4/2/21	CD																										
Order PCB	3/15/21	3/19/21	CV																										
Obtain PCB	3/26/21	3/31/21	CD																										
Complete FPR Presentation Materials	4/5/21	4/16/21	CD, CV, IN, MA																										
Damage Control Meeting	4/5/21	4/16/20	CD, CV, IN, MA																										

Upcoming Team Member Responsibilities

Carley

- Assembling PCBs
- Testing PCB components
- Scheduling FPR
- Updating team website
- Assisting with SDP report

Ivan

- Drafting SDP report with Cory
- Assisting with code/software where applicable

Matt

- Testing & troubleshooting final system hardware
- PCB redesign
- Designing 3D printed housing
- Assembling final product

Cory

- Drafting SDP report with Ivan
- Assisting with code/software where applicable
- Ordering components, maintaining budget

Team Website

Anything Instrument

UMass SDP21 Team 20

Matthew Avison - Carley Davis - Ivan Norman - Cory Vandergrift

Home | The Team | The Design | Presentations

About the Anything Instrument

The Problem

Instruments are shown to strengthen memory, reduce stress, inspire creativity, and bring happiness to those who play them. However, the cost, space requirement, and noise produced by most instruments can prevent many people from being able to enjoy them.

The Solution

The Anything Instrument is a solution to all of these problems by allowing anything conductive to become part of a playable instrument. The user is able to attach leads to whatever objects they desire to play, select a sound mode (i.e. piano, drums, etc.), plug in an audio output, and play.

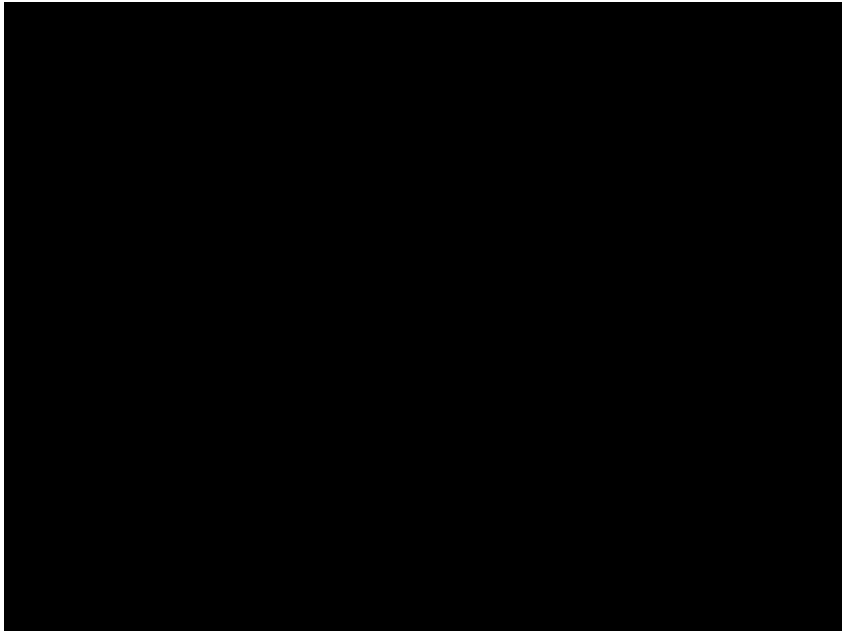
http://www.ecs.umass.edu/sdp/sdp21/team20

Questions?

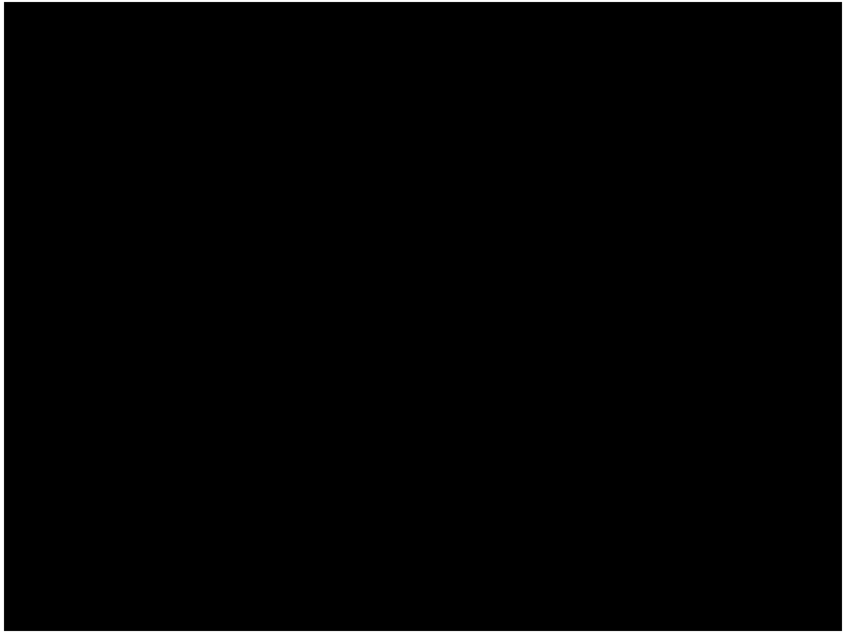
Demo Videos

Power supply - Prototype Demo

Demonstration of voltage regulation



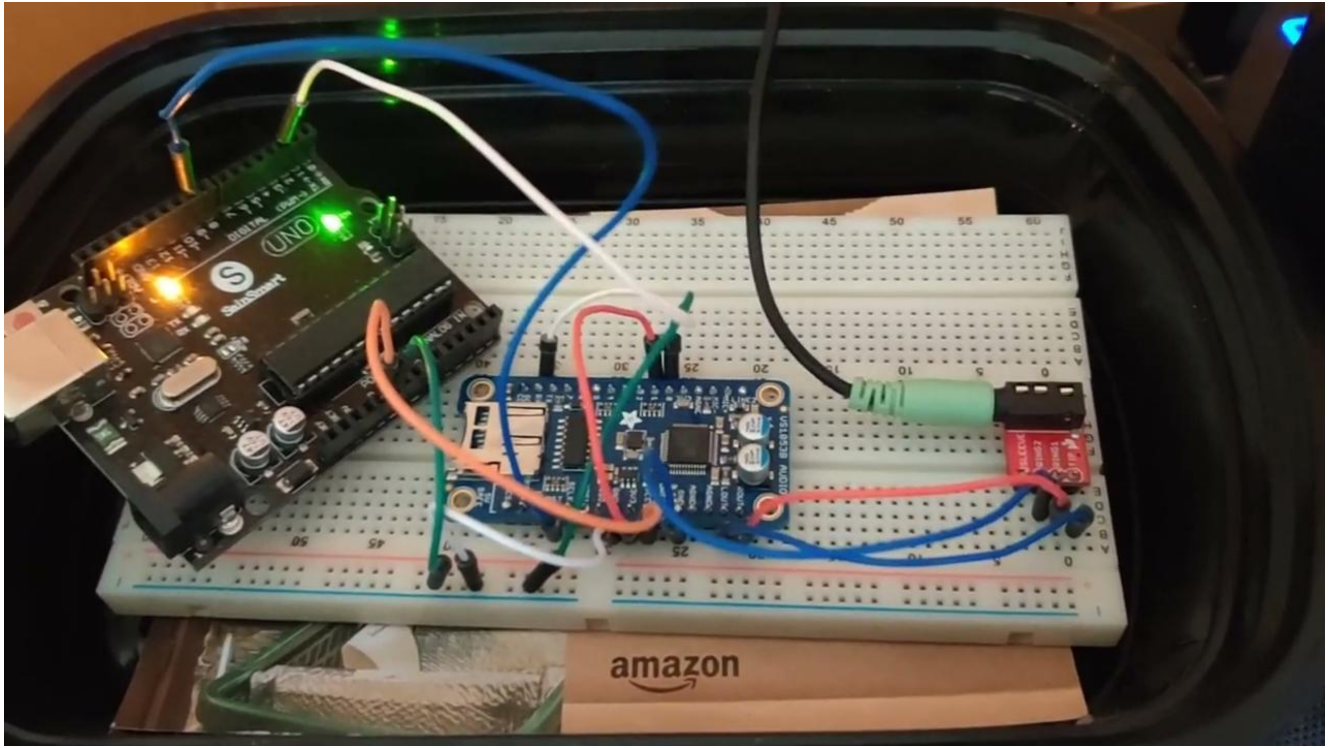
Demonstration of low battery indicator circuit



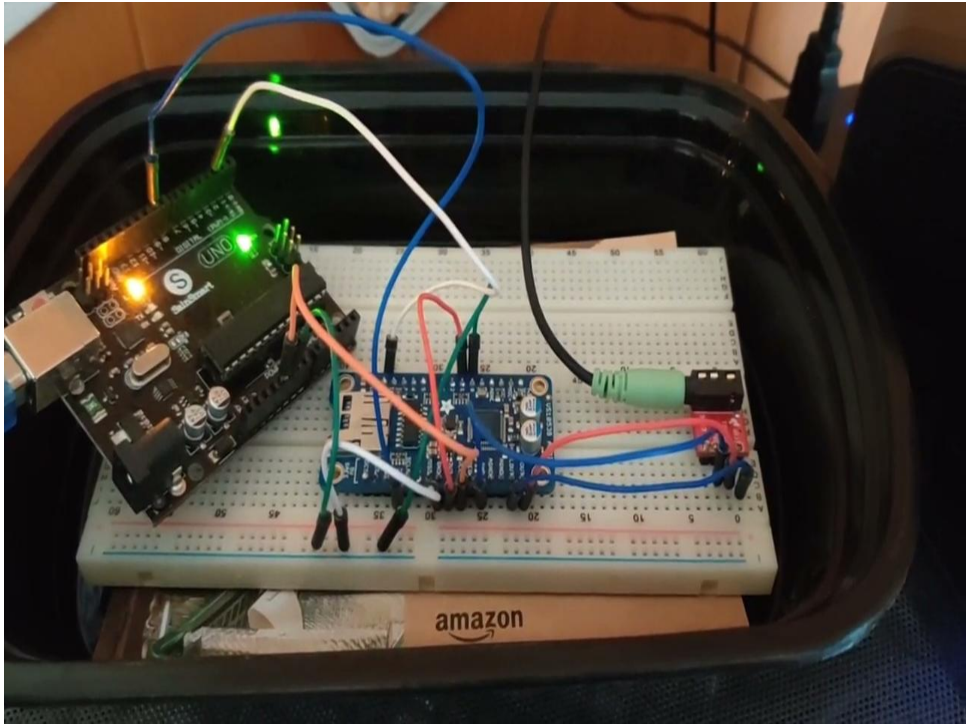
User Interface - CDR Demo

UMassAmherst

Sound System - Playing Notes



Sound System - Volume Change



Sound System - Track Change