AI

Anything Instrument

Team 20

Matthew Avison, Carley Davis, Ivan Norman, Cory Vandergrift

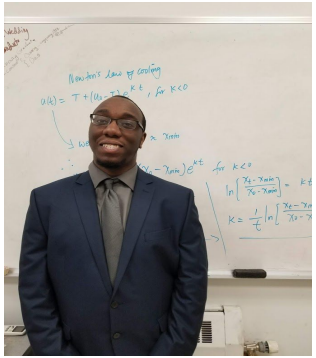
The Team - Recap

Team 20

Matthew Avison - EE
Hardware Lead - Keyboard Interface

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, assembled the integrated system for both prototype and final product. 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

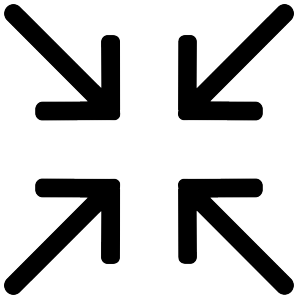
Musical instruments are shown to strengthen memory, reduce stress, inspire creativity, and bring happiness to those who play them. However, the cost, space requirement, and noise produced by most instruments can prevent many people from having the opportunity to play.

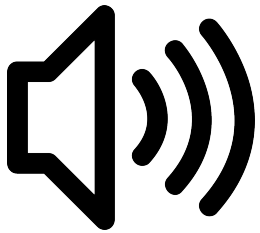



Introducing the Anything Instrument

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 Objectives

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

- Offer 8 playable connections
- Have an interchangeable battery
- Offer at least two different instrument modes
- Output audio via a headphone jack
- Weigh 500 grams or less (not including connected objects)

(2x)

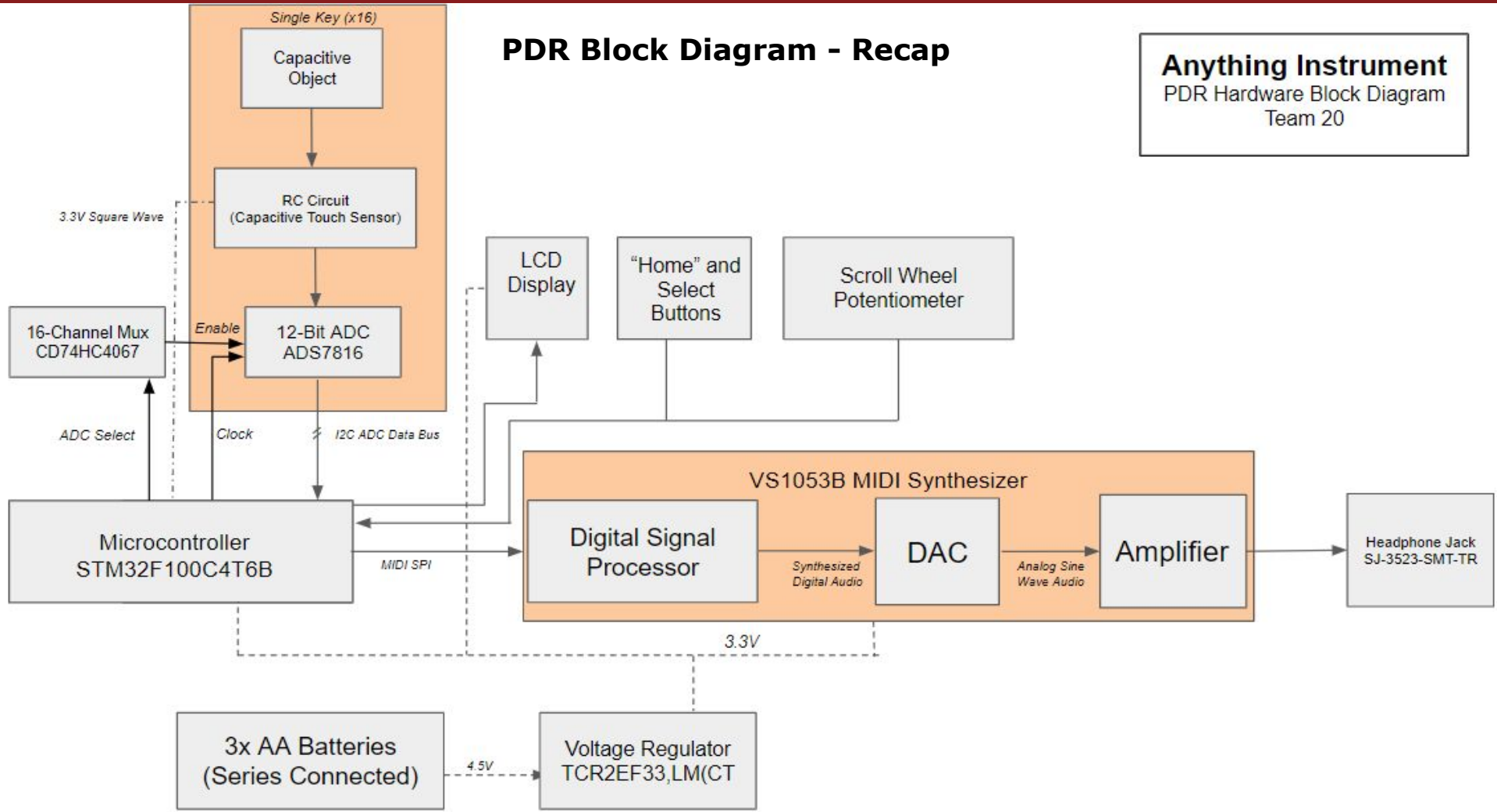
(1x)

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**

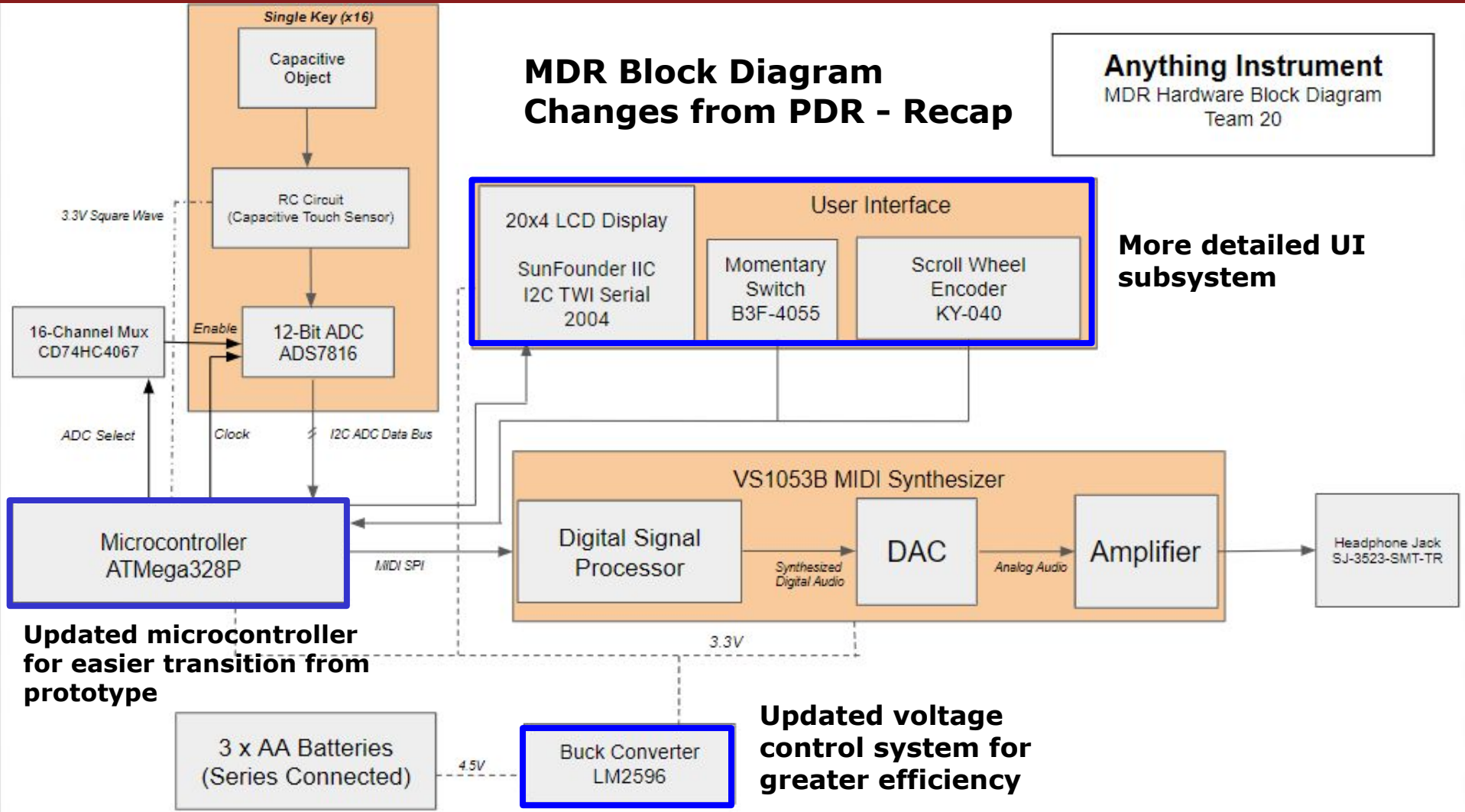
Design evolution

PDR Block Diagram - Recap



MDR Block Diagram Changes from PDR - Recap

Anything Instrument
MDR Hardware Block Diagram
Team 20



More detailed UI subsystem

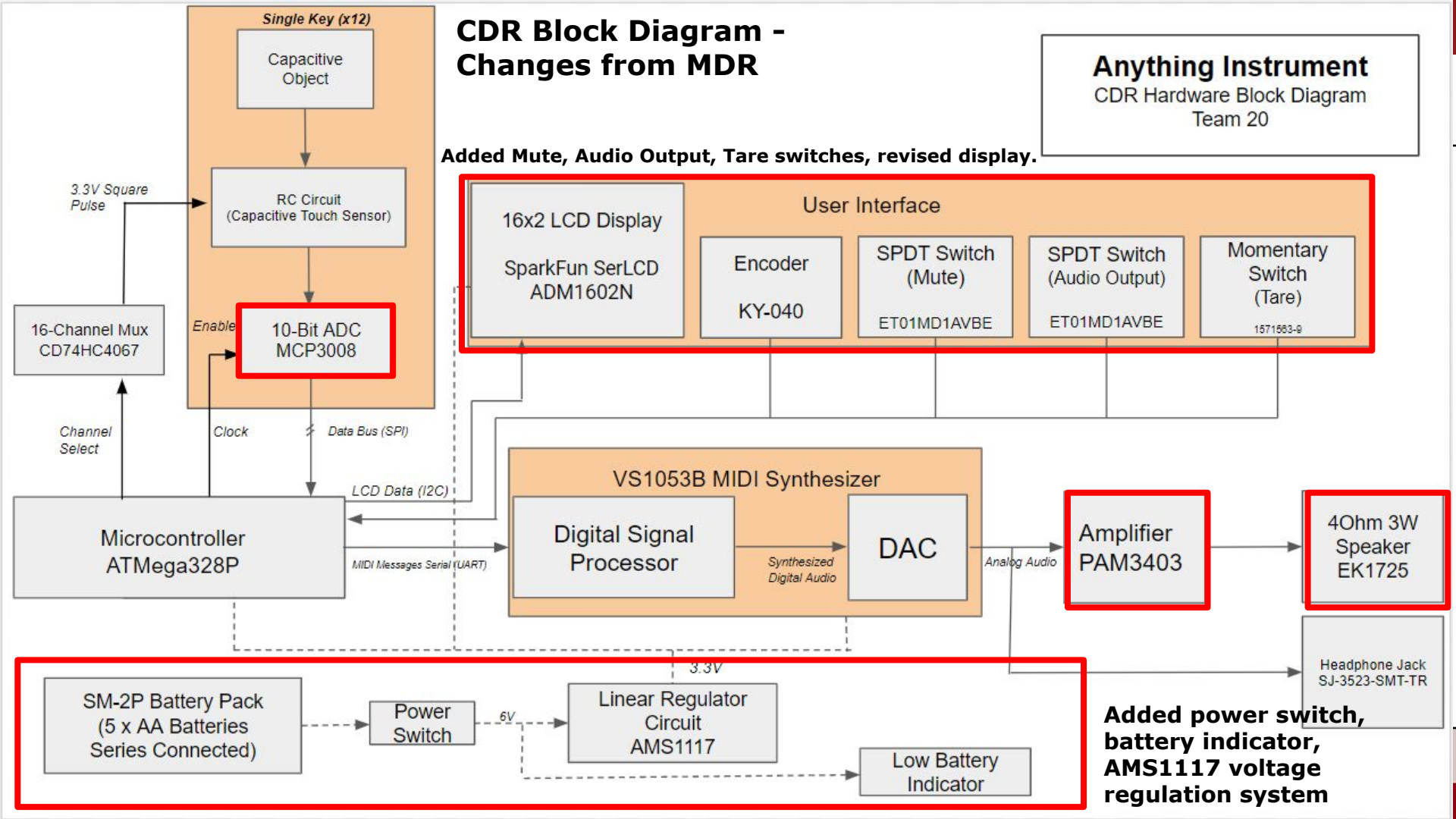
Updated microcontroller for easier transition from prototype

Updated voltage control system for greater efficiency

CDR Block Diagram - Changes from MDR

Anything Instrument
CDR Hardware Block Diagram
Team 20

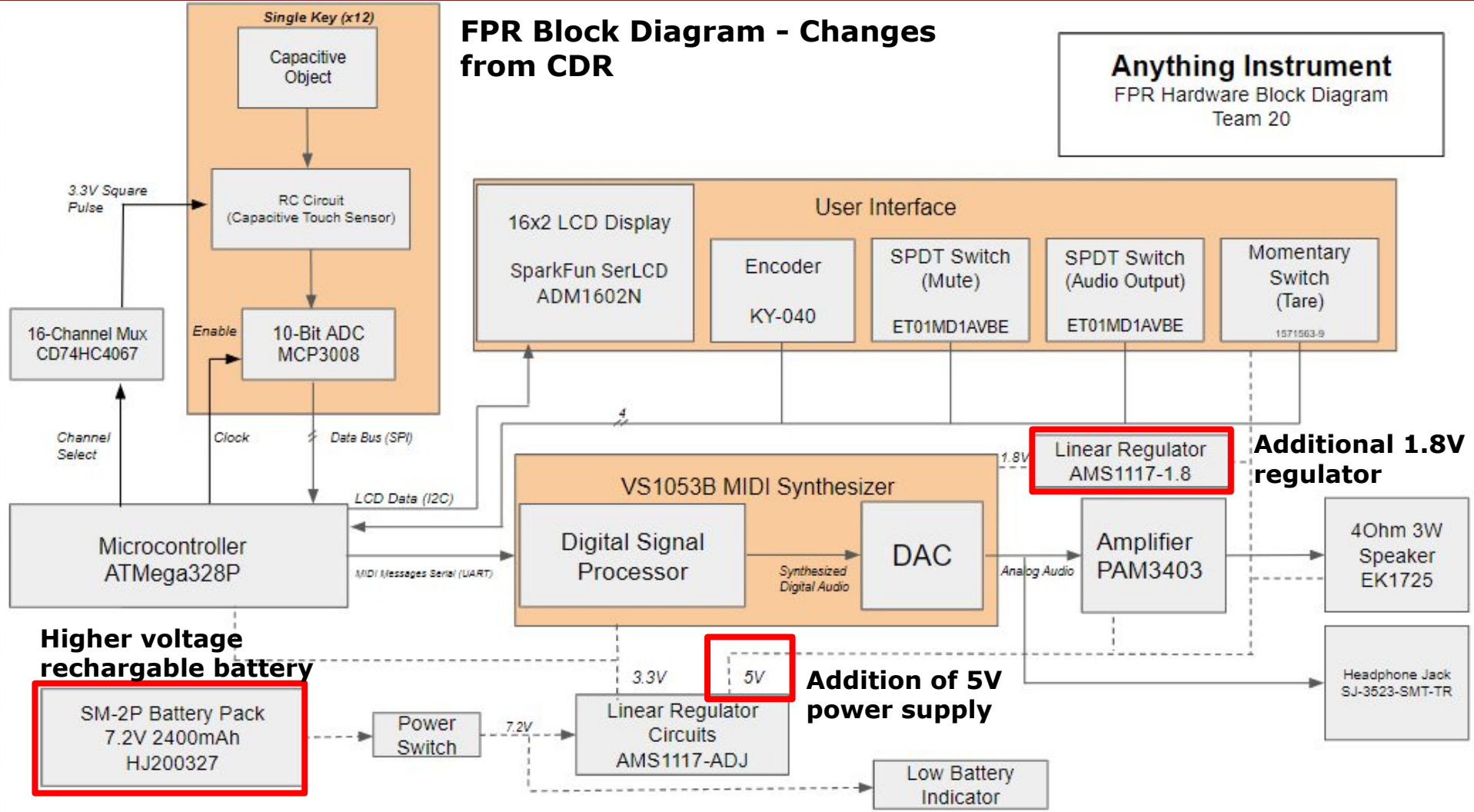
Added Mute, Audio Output, Tare switches, revised display.

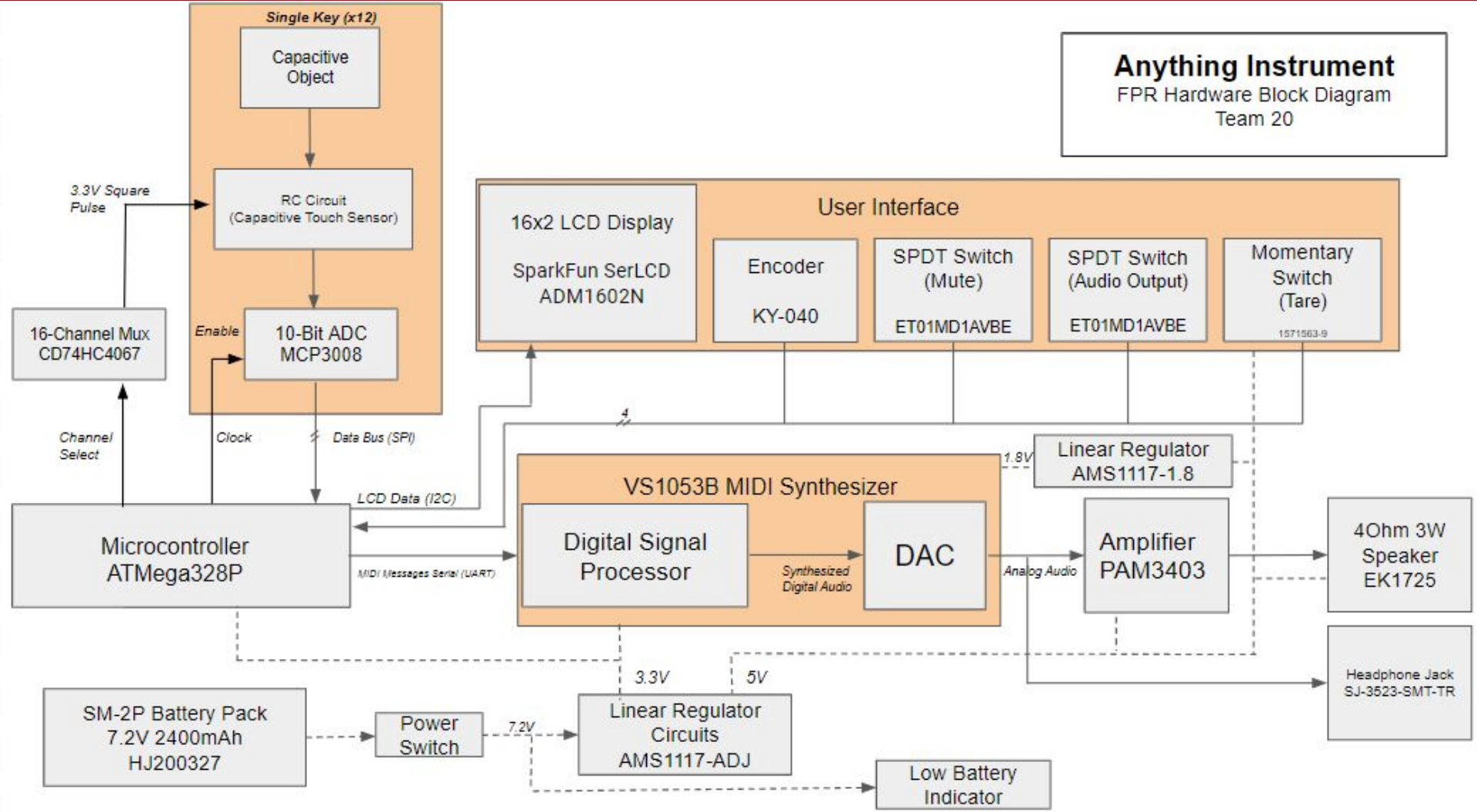


Added power switch, battery indicator, AMS1117 voltage regulation system

FPR Block Diagram - Changes from CDR

Anything Instrument
FPR Hardware Block Diagram
Team 20




Anything Instrument
FPR Hardware Block Diagram
Team 20
Single Key (x12)
Capacitive Object
3.3V Square Pulse
RC Circuit (Capacitive Touch Sensor)
16-Channel Mux CD74HC4067
Enable
10-Bit ADC MCP3008
Channel Select
Clock
Data Bus (SPI)
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
4
LCD Data (I2C)
Microcontroller ATMega328P
MIDI Messages Serial (UART)
VS1053B MIDI Synthesizer
Digital Signal Processor
Synthesized Digital Audio
DAC
1.8V
Linear Regulator AMS1117-1.8
Analog Audio
Amplifier PAM3403
4Ohm 3W Speaker EK1725
Headphone Jack SJ-3523-SMT-TR
3.3V
5V
SM-2P Battery Pack 7.2V 2400mAh HJ200327
Power Switch
7.2V
Linear Regulator Circuits AMS1117-ADJ
Low Battery Indicator

Changes since CDR

Migration to PCB

- Microcontroller, sound system, voltage regulation system, battery status system, keyboard touch sensors, and UI controls are now integrated on redesigned PCB

Rechargeable Battery

- HK200327 7.2V 2400mAh Ni-MH battery pack via SM-2P connecton is now used for easy battery swap out and ability to recharge

Power Supply

- Addition of 5.5V and 1.8V supply lines

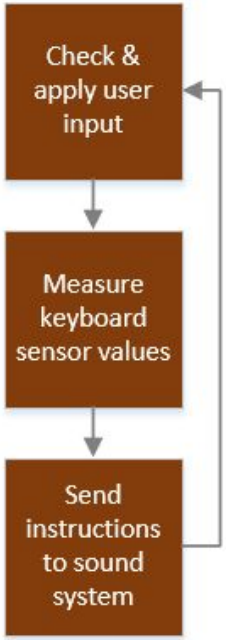
Optimized Code

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

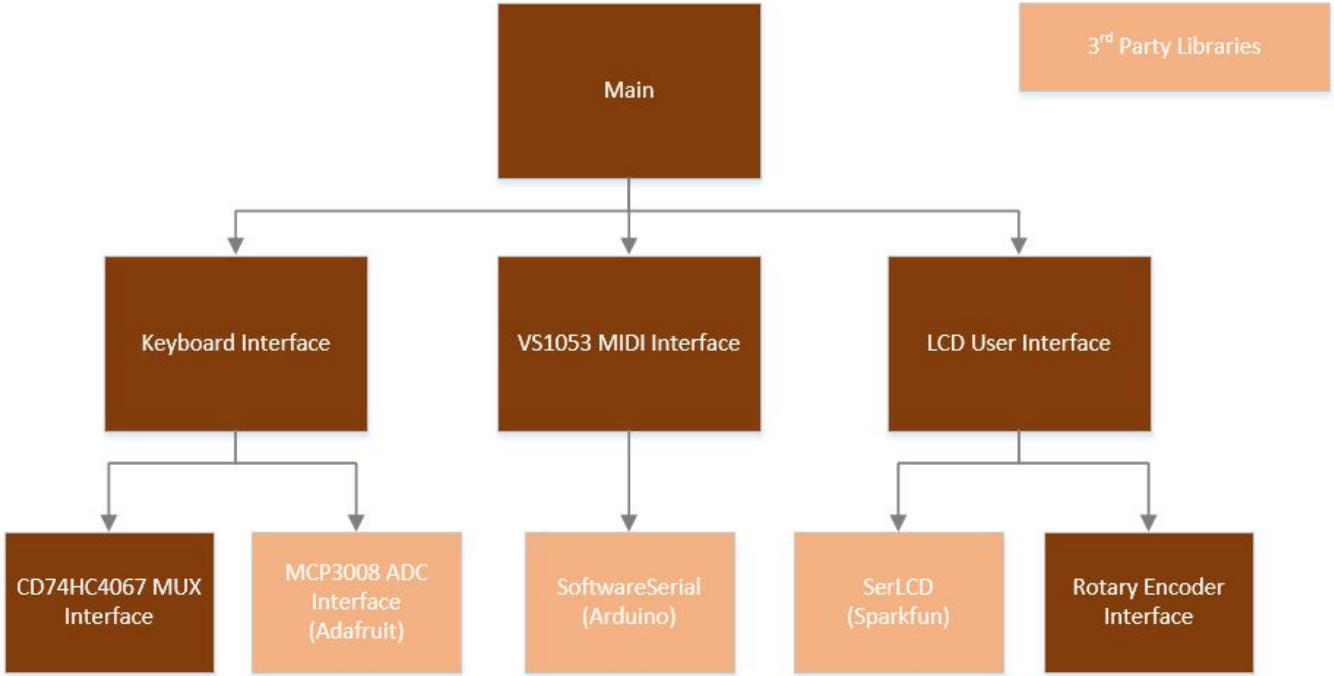
Plastic Case

- A clean & aesthetic 3D printed case has been designed to house the final system

Anything Instrument - Software Visualization



High-level process



Software Library Hierarchy

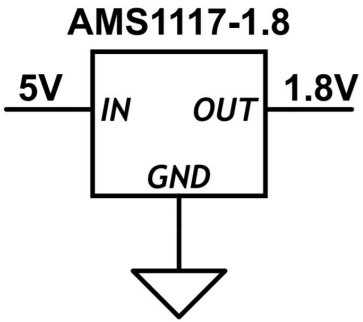
Power Supply

Power Supply - System Specifications

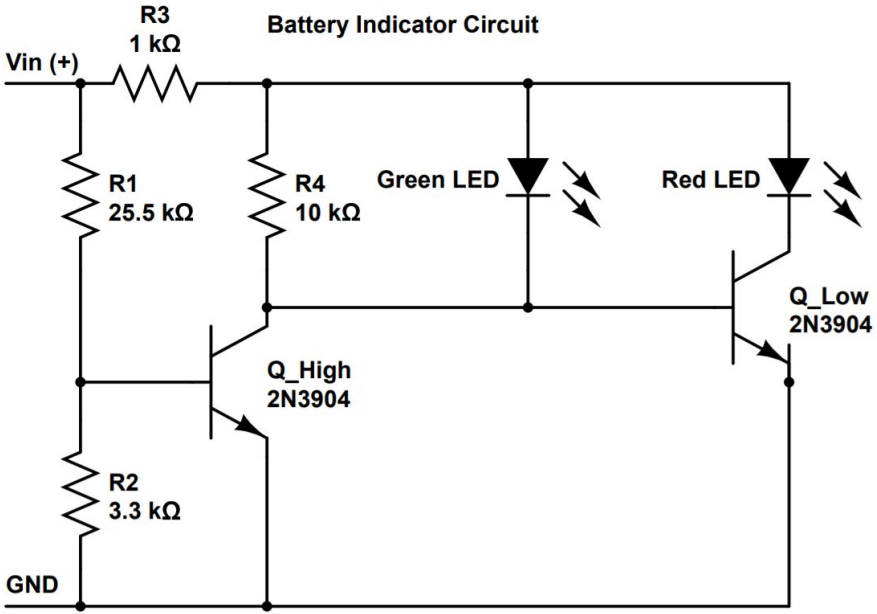
- Needs to be able to power microcontroller, audio synthesizer at 3.3V
- Needs to be able to power LCD display, amplifier and speaker at 5V
- Needs to have 1.8V line for VS1053B CVDD
- Needs to be easily turned on and off
- Needs to have rechargeable and easily interchangeable batteries
- Needs to be able to inform user that power is on and warn user when battery voltage is low

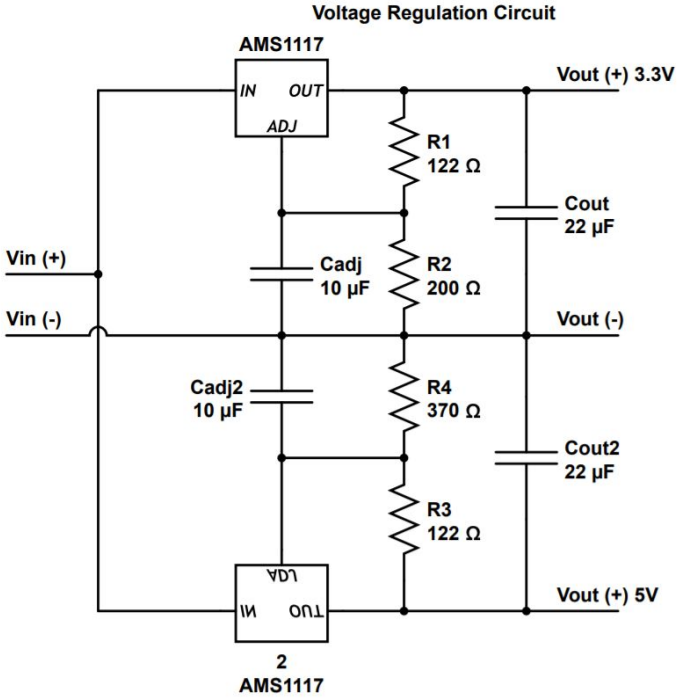
Power Supply - Changes since CDR

- Addition of 5V power supply system to power LCD display and speaker and 1.8V power step-down for VS1043B CVDD
- New 7.2V rechargable battery - HJ 200327
- Minor changes to battery indicator circuit to account for new battery



Power Supply - Changes since CDR



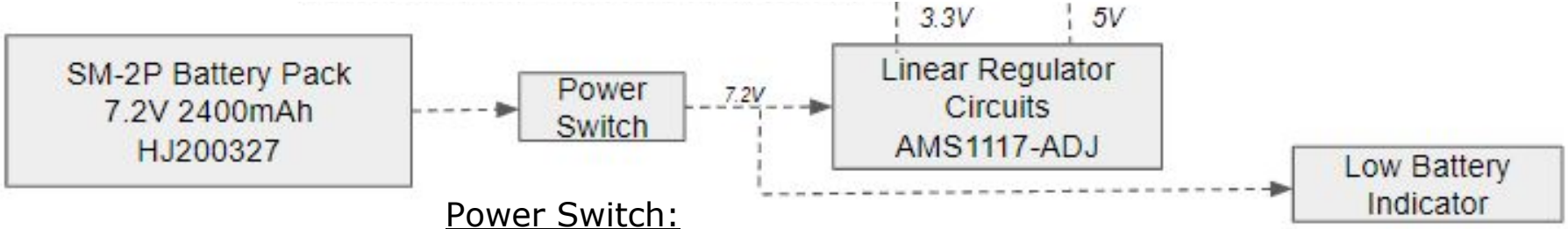


Power Supply - System Diagram & Hardware

Hardware

Battery Pack:
- SM-2P Battery Pack - 7.2V, 2400mAh HJ200327
- SM-2P Connector

Linear Regulators:
- (2x) AMS1117-ADJ
- Various resistors
- 10uF and 22uF Capacitors

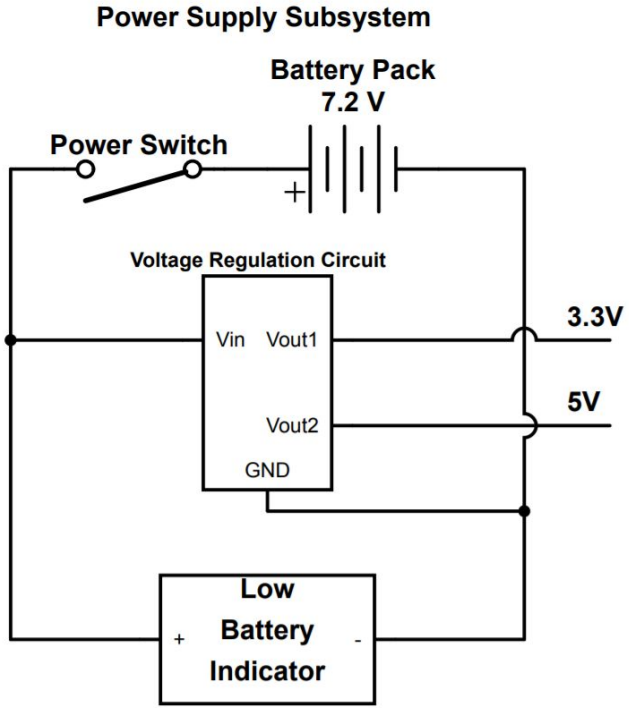


Power Switch:
- KCD1-101 Rocker Switch

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

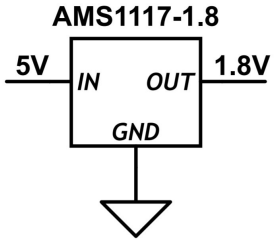
*Additional AMS1117-1.8 regulator used for VS1053B CVDD

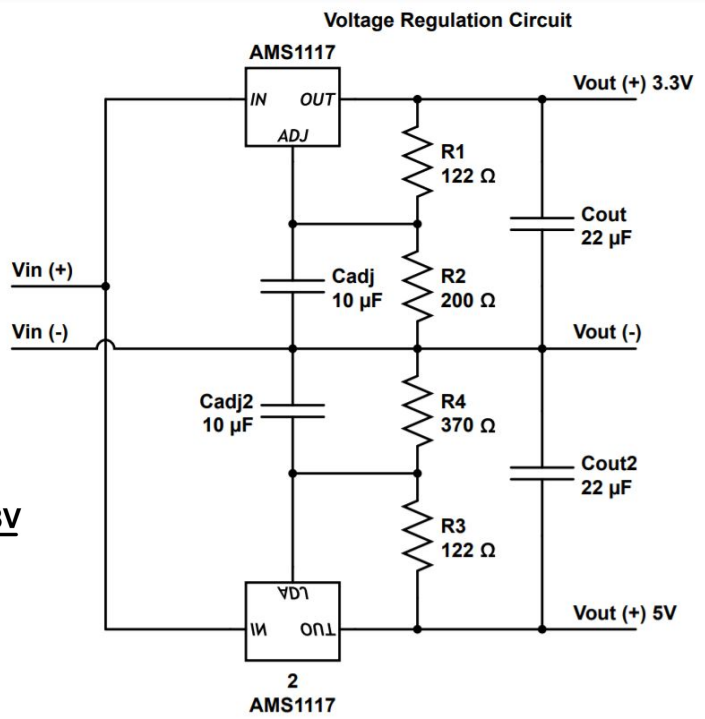
Power Supply - One Line Diagram



Power Supply - Voltage Regulaton

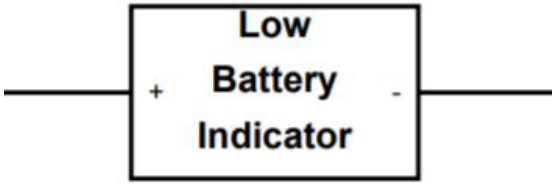
- Used to regulate output voltage down to 3.3V and 5V
- Additional regulator used off of 5V line to create 1.8V supply for VS1053 CVDD
- Can be used with battery packs 7.2V-10V
- Needs voltage to be above 6.2V

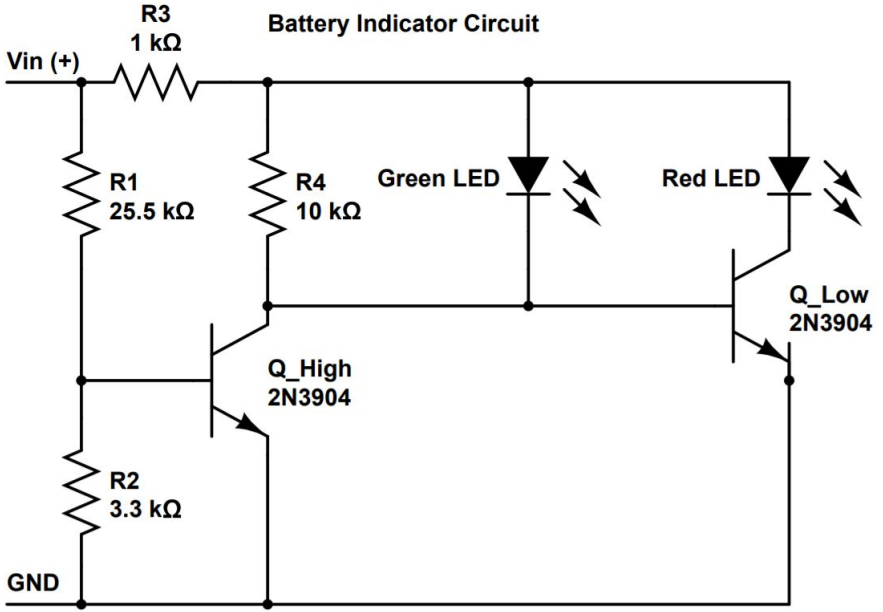




Power Supply - Low Battery Indicator Recap

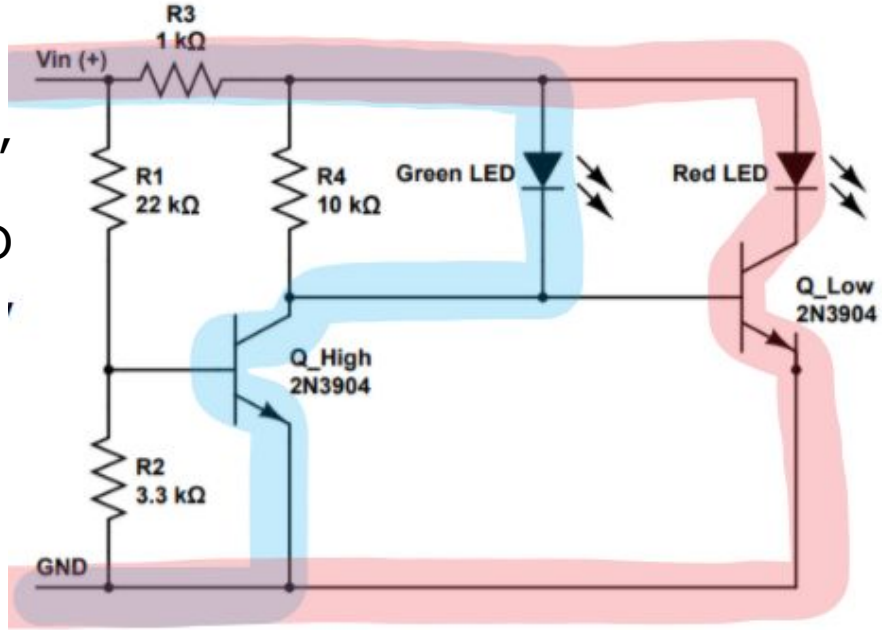
- Used to indicate when the battery needs to be recharged
- Green LED will light up when battery is fully charged, switch to red LED when battery nearing 6.2V





Power Supply - Low Battery Indicator Recap

- If the battery voltage is >6 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 <6 volts, Q_High will be below its cutoff voltage, causing the current to flow through the Q_Low path and illuminate the red LED



Battery Life - Calculations for FPR Prototype

NiMH Battery Capacity (mAh)	2400
Adjusted Battery Capacity (mAh)	1680

Equipment	Consumption (mA)
ATMega328P	1.5
VS1053B	11
PAM8403 Amplifier (max)	16
Sparkfun Display	164
Capacitive Touch System	2
Speaker (if used, at max)	200
Power Supply Subsystem	12.5

Total Operating Current (mA)	407
Total Operating Time (hours)	4.13

⇐ Total Operating Current/Adjusted Battery Capacity

- Battery life of FPR prototype estimated to be 4+ hours with all subsystems running at maximum capacity.
- Battery being used for FPR has a 2400mAh capacity

User Interface

User Interface - Original System Specifications

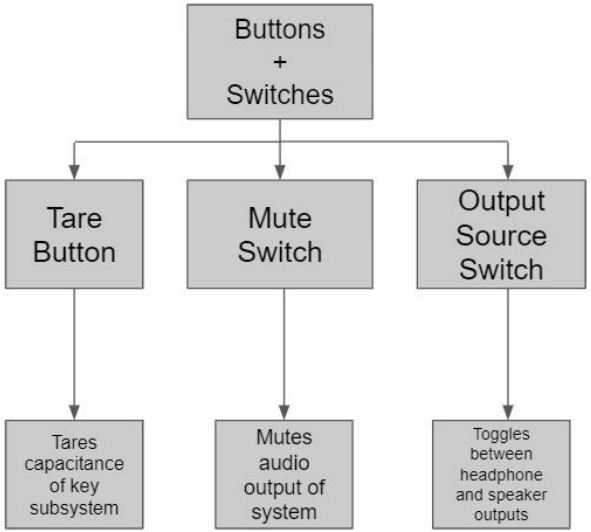
- Must be simple, intuitive, and easy to use
- Focus on most important information
- Room for menu expansion to fit needs of project

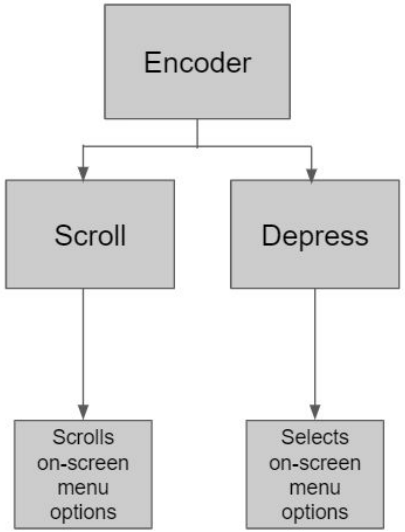
Changes Since MDR/CDR

- Removed second encoder, added additional physical inputs
  - Quicker access to often used functionality
- Refined Code
  - Encoder tracking
  - Synthesis with other subsystems
- Populated UI PCB

User Interface - Input 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.



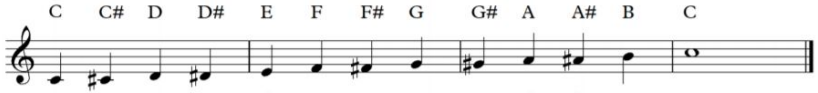


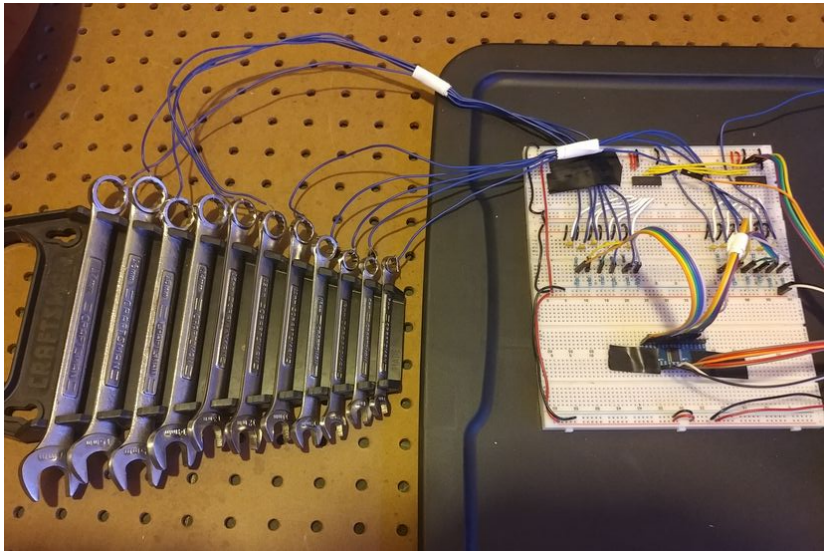
Keyboard Interface

Keyboard Interface - Specifications

- 12 Available keys sensitive to human touch - Able to play full chromatic scale
- Sensor response time under 1ms
- Able to recalibrate/”tare” each key to a unique default capacitance

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

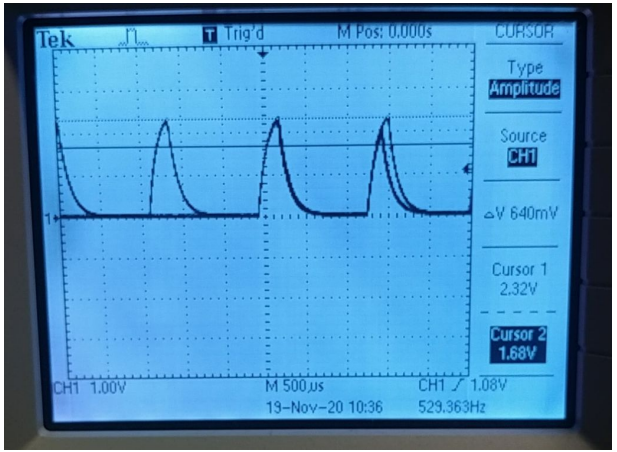




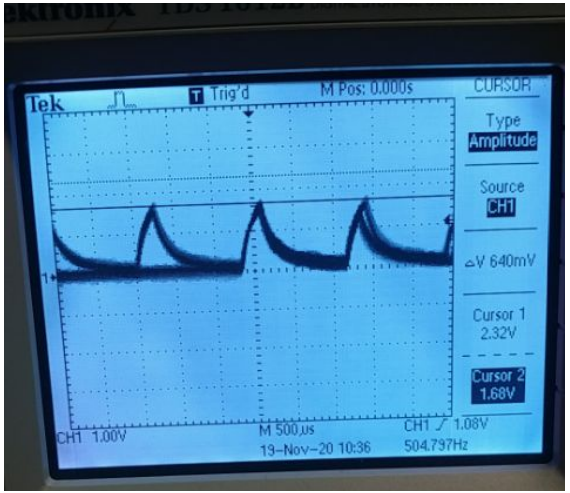
Keyboard prototype demonstration

Keyboard Interface - Touch Sensor Principles

- Touch sensor measures the voltage across its capacitor at Time = Tau
- Adding capacitance to that node drops the "tau voltage" at the same point during charge cycle
- A voltage drop below a tolerance margin (5%) of the default value yields a "touch" response

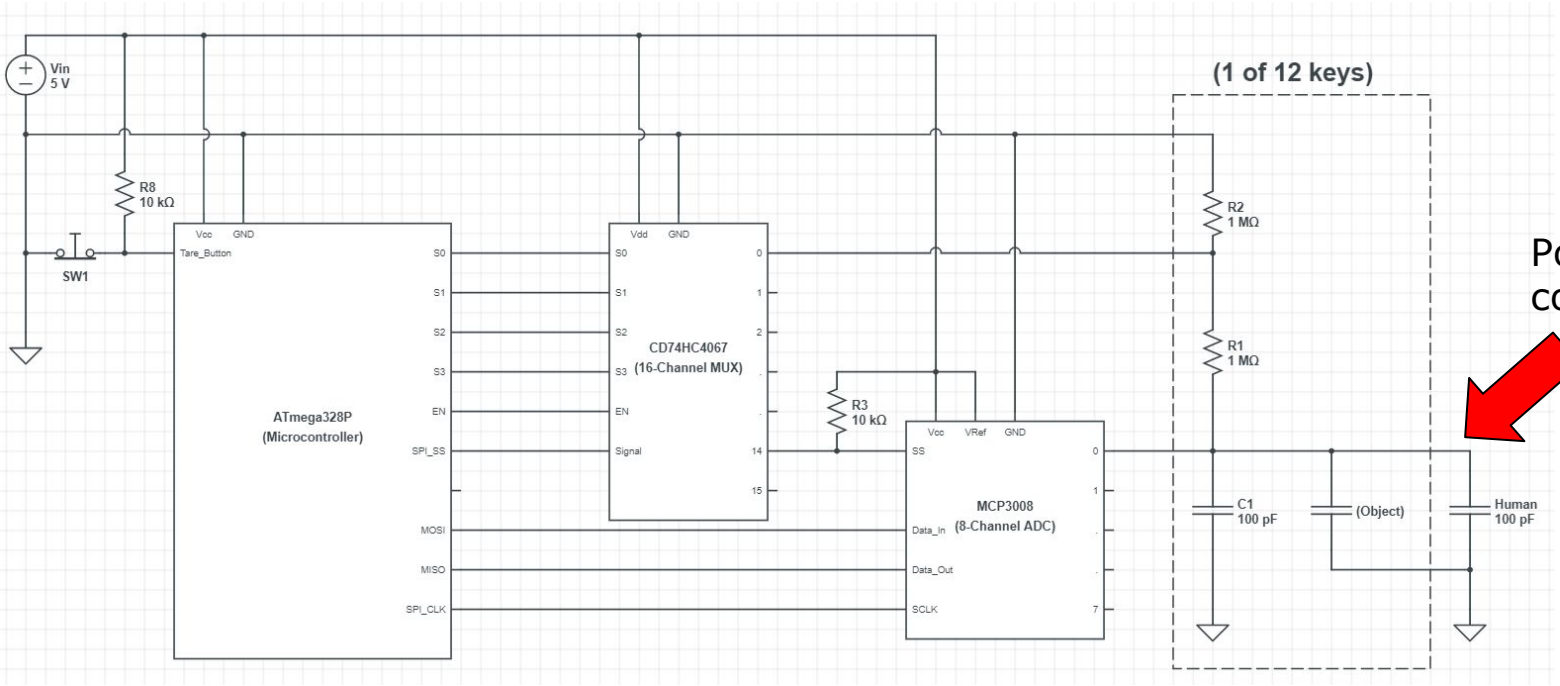


(Default RC charge cycle)



(Charge cycle upon touching probe)

Keyboard Interface - Simplified Diagram



(Full schematic in later slides)

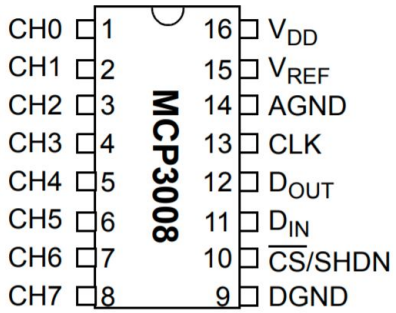
Keyboard Interface - Hardware Details

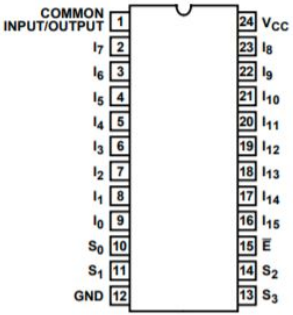
Multiplexer (x1): CD74HC4067

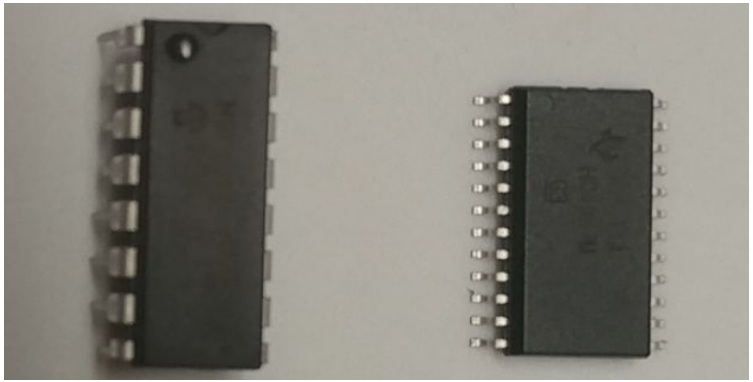
- 16 Channels

Analog to Digital Converter (x2): MCP3008

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



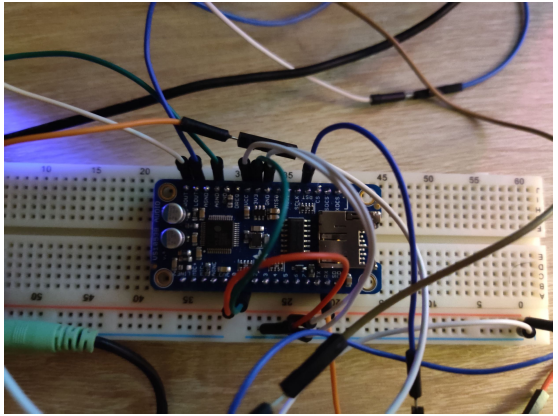




Sound System

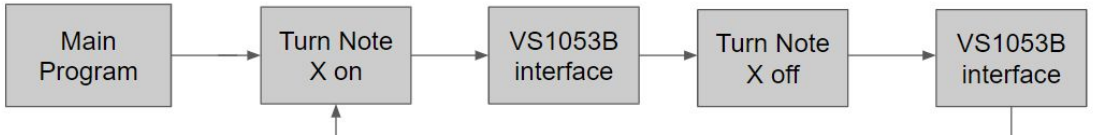
Sound System - Specifications

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

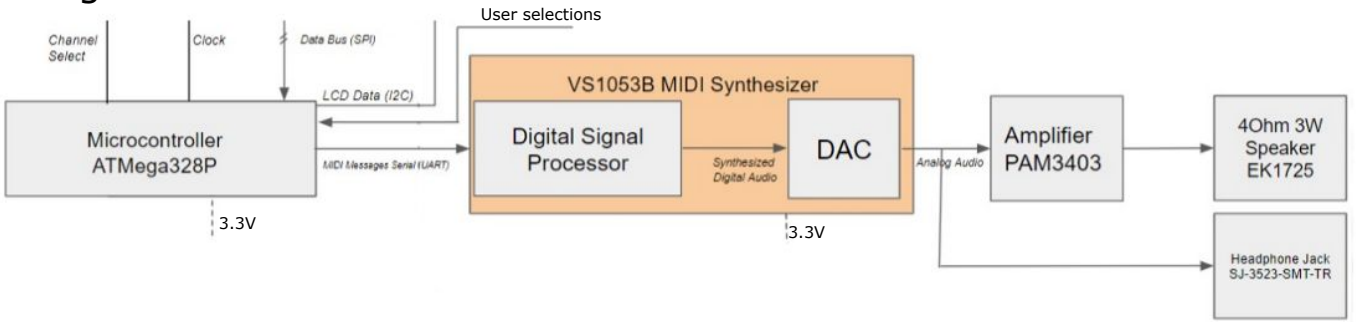


Sound System - System & Hardware Diagram

Software Diagram



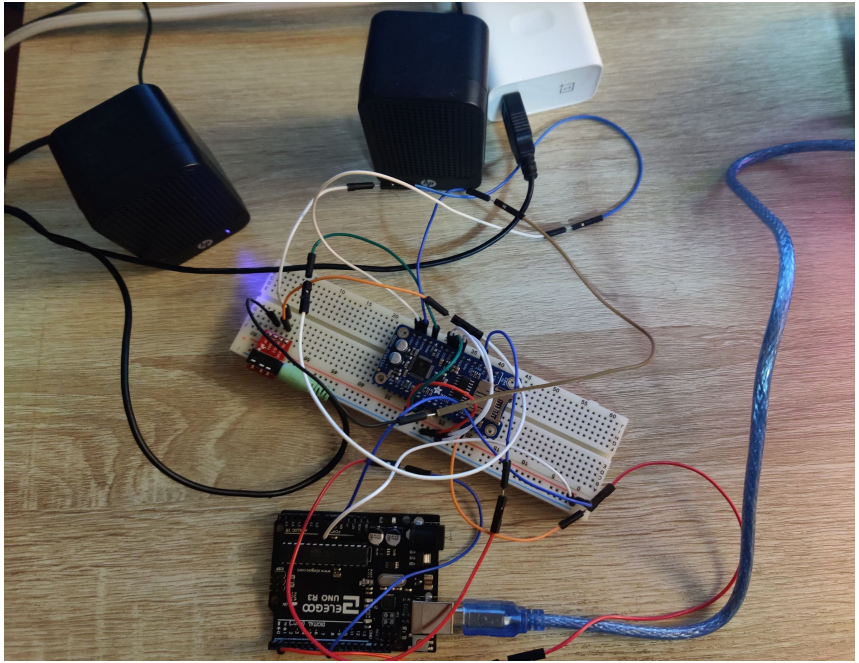
Hardware Diagram



Sound System - Hardware

Components

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

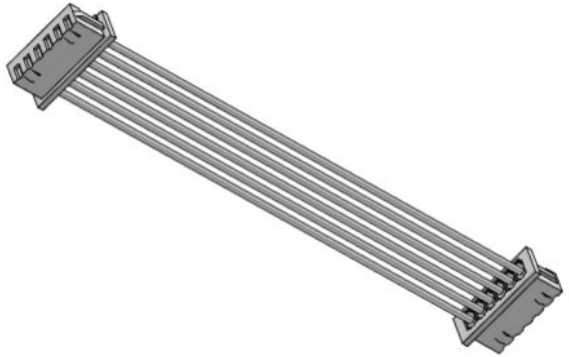


Printed Circuit Boards

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



Example Molex Connector between Motherboard and UI Panel

Components on the **UI Panel PCB**

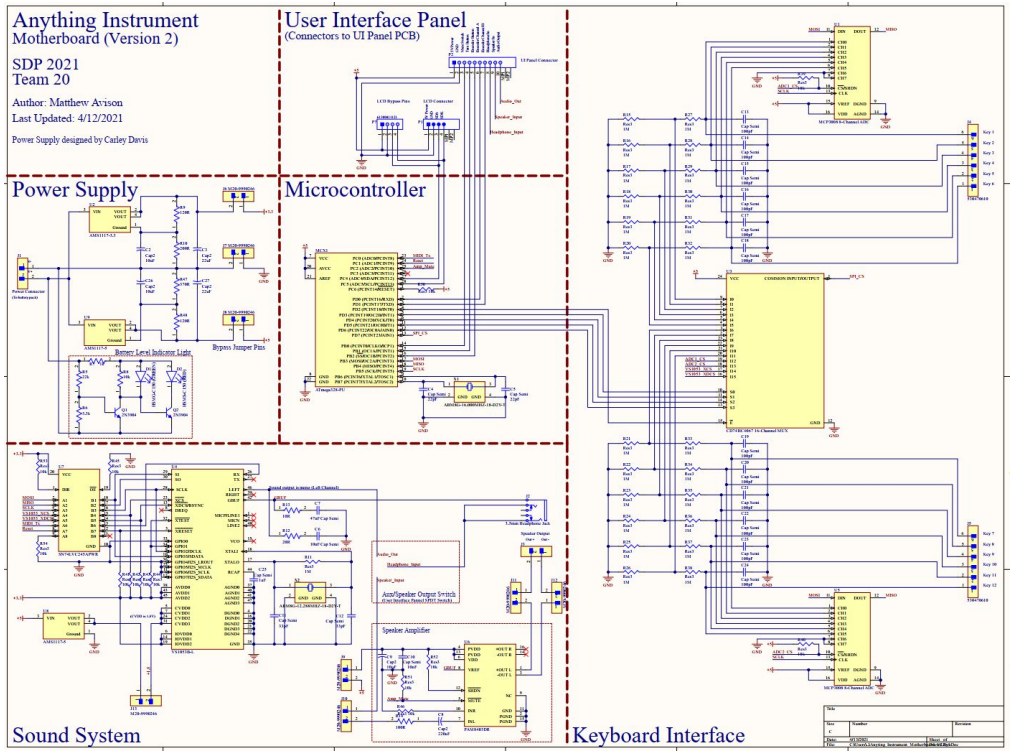
- Rotary Encoder
- SPDT Switches
- Tactile Button

Components **externally connected** to the Motherboard

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

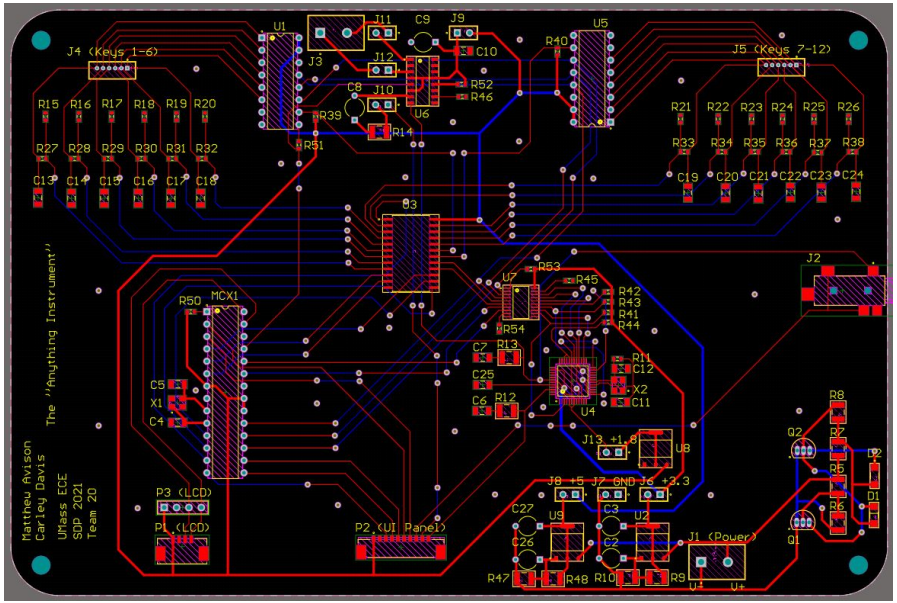
Motherboard - Full Schematic

Power input from battery pack

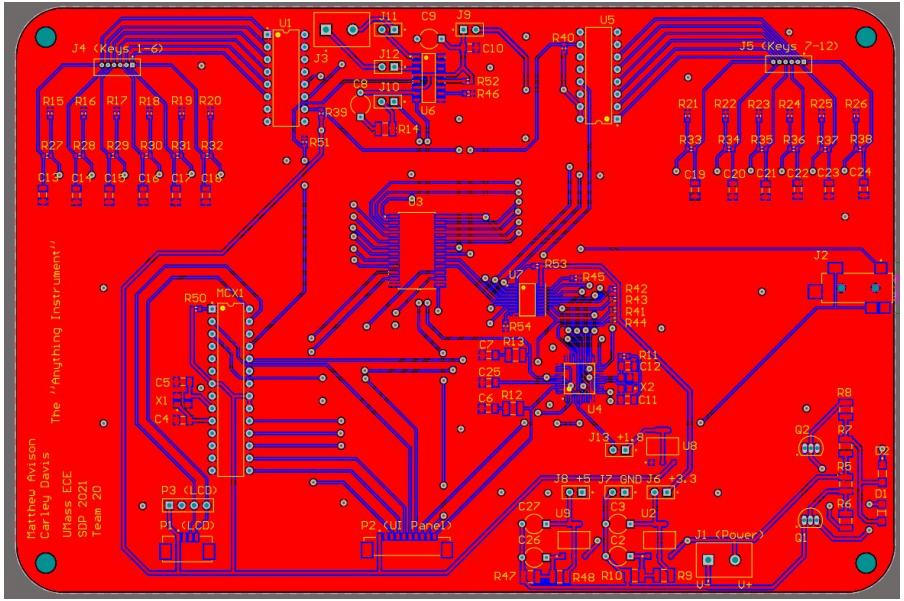


Points of connection for keyboard probes

Motherboard - PCB Design

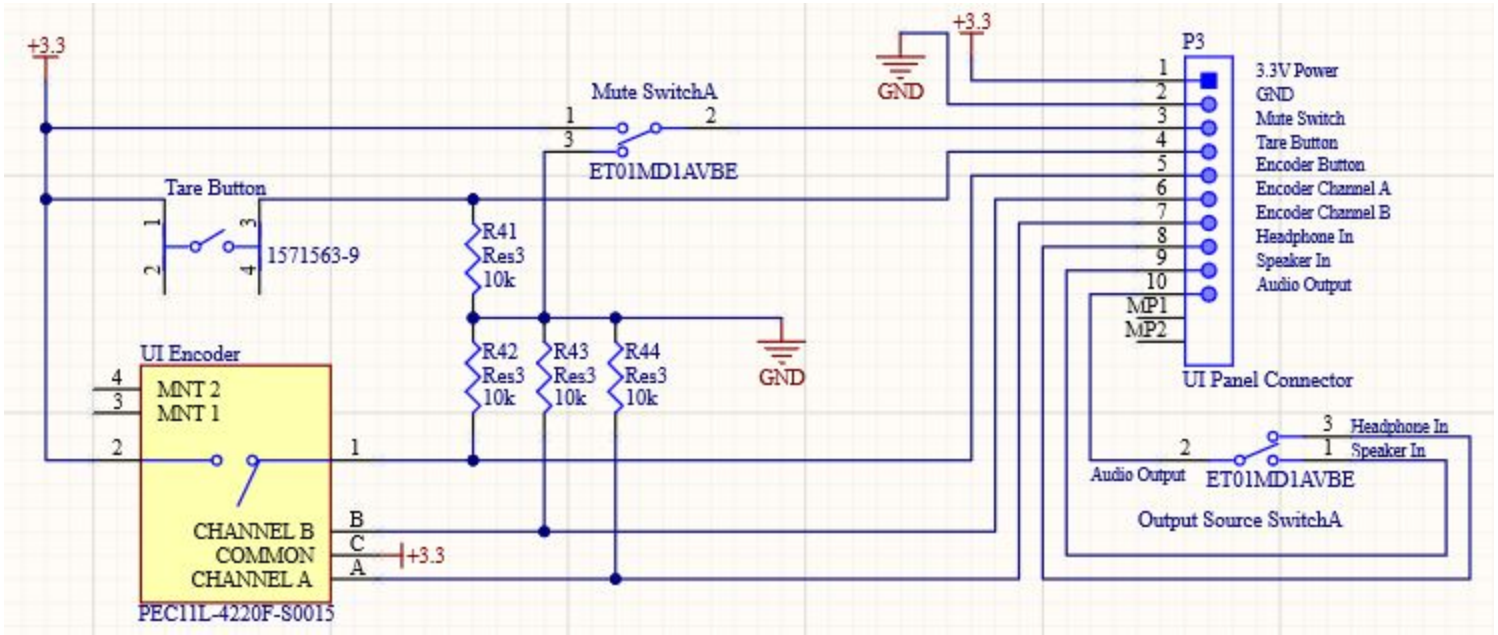


Ground planes hidden

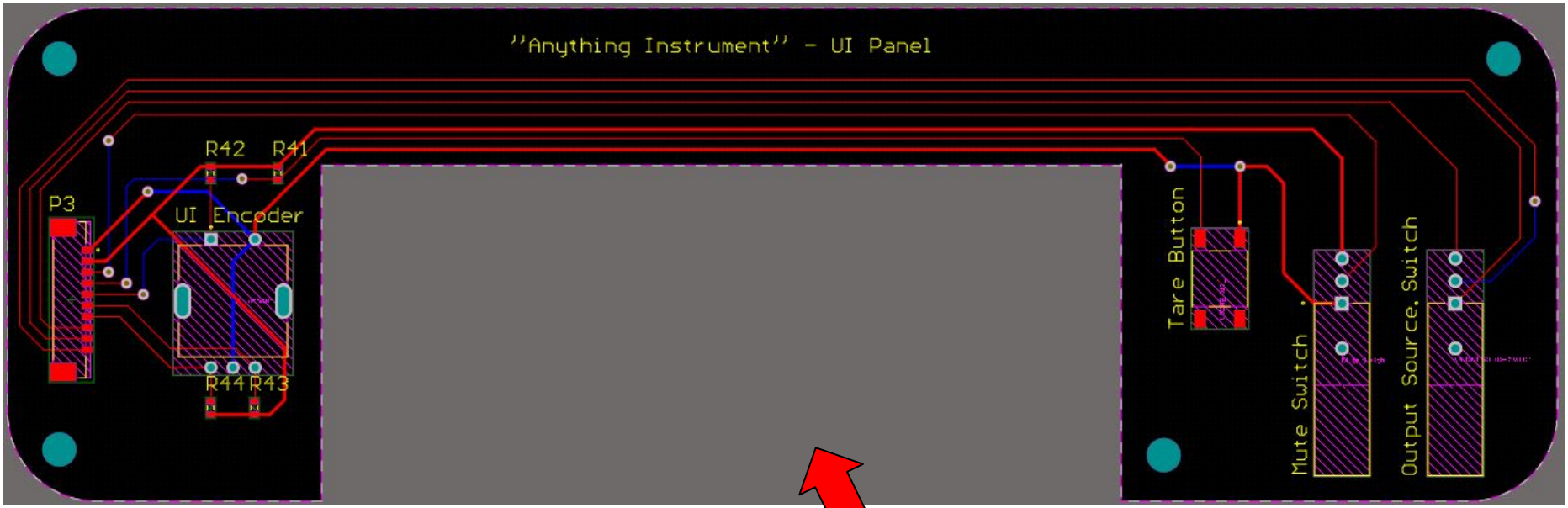


Ground planes visible

UI Panel - Full Schematic

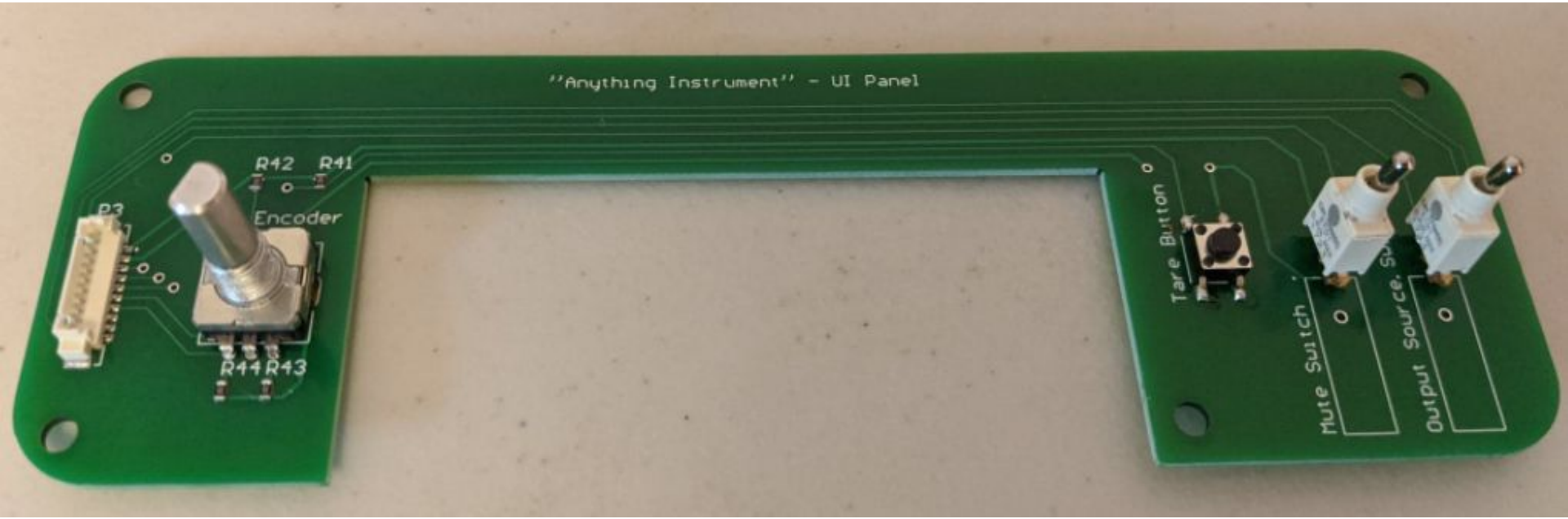


UI Panel - PCB Design



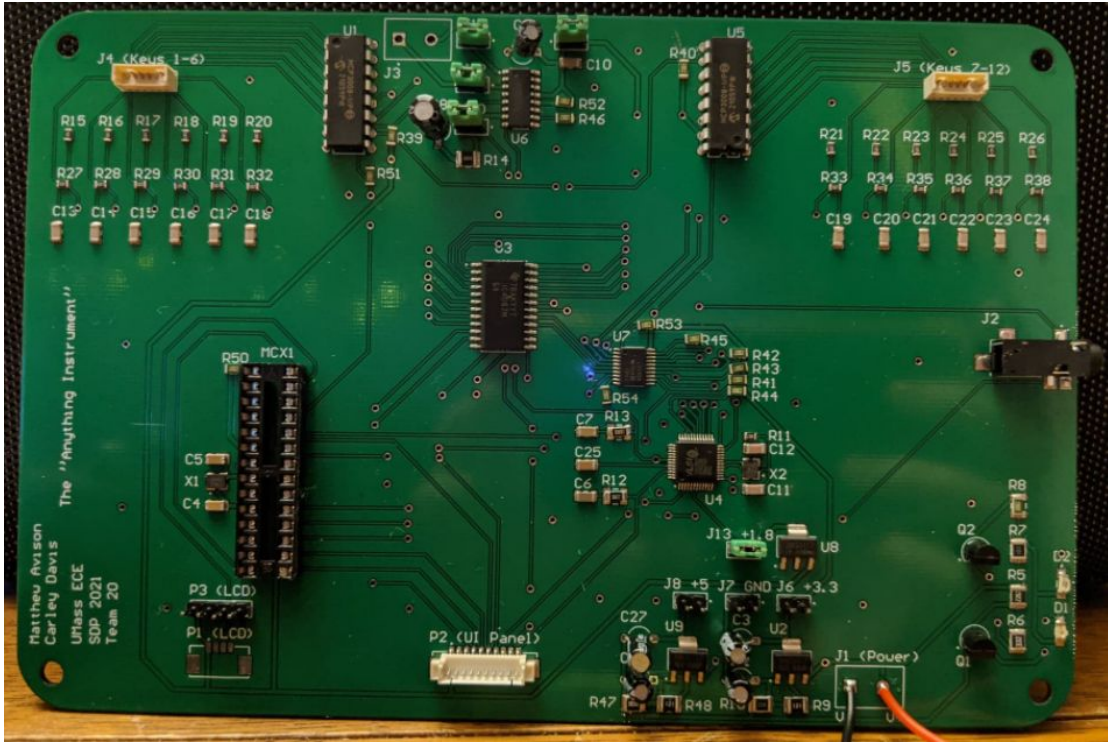
Cutout for Sparkfun 16x2 LCD

Populated PCBs - UI Panel



Questions?

Populated PCBs - Motherboard



Budget & Logistics

Budget

- The final cost of our project is $495.93
- We also have received $146.09 worth of parts from M5

Cost Breakdown as of CDR

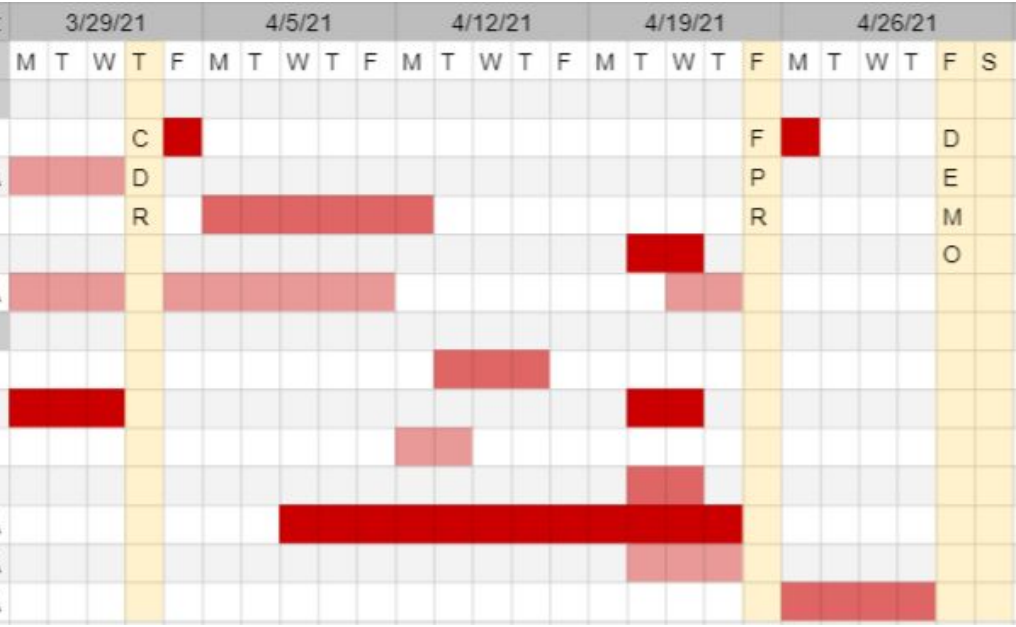
Part Number	Function	Cost (each)	Qty.	Total Cost (USD)
			Fall 2020	
VS1053B	Audio Synthesizer	$12.50	2	$25.00
ADS7816P	12-Bit ADC -For each input	$2.54	4	$10.16
CD74HC4067	Multiplexer	$0.29	2	$0.58
STM32F100C4T6B	Microcontroller	$3.13	2	$6.26
SJ-3523-SMT-TR	Headphone Jack	$0.52	2	$1.04
BH3AAPC	AA Battery 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

FPR - Final Cost Breakdown

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
PCB Order 2	Motherboard (5) + Stencil	$35.65	1	$35.65
Final PCB Compnent Order	Various	$42.45	1	$42.45
			Total Cost:	**$642.02**
*Indicates items recieved entirely from M5			**From M5:**	$146.09
*Indicates items partially recieved from M5			**Final Cost:**	$495.93

Current Schedule

Task Name	Start Date	End Date	Team Member
Hardware and Code			
Website Updates	4/2/21	4/2/21	CD
Combining Subsystem Prototypes	3/8/21	3/31/21	CD, CV, IN, MA
PCB Redesign	4/5/21	4/12/21	MA
Solder components to PCB	4/20/21	4/21/21	CD, MA
System Troubleshooting (Critical)	3/15/21	4/22/21	CD, CV, IN, MA
Logistics			
Order FPR Parts	4/13/21	4/15/21	CV
Obtain Parts	4/20/21	4/21/21	CD
Order PCB	4/12/21	4/13/21	CV
Obtain PCB	4/20/21	4/21/21	CD
Complete FPR Presentation Materials	4/7/21	4/22/21	CD, CV, IN, MA
Damage Control Meeting	4/20/21	4/16/20	CD, CV, IN, MA
Complete Demo Presentation Materials	4/26/21	4/29/21	CD, CV, IN, MA



Final Prototype

Final Prototype

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**

Live Demo