AI

Anything Instrument

Team 20

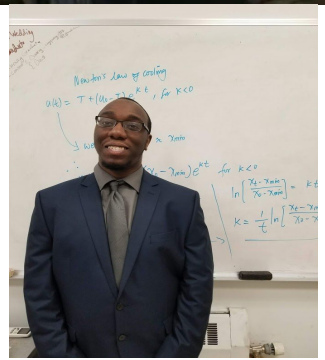
Matthew Avison, Carley Davis, Ivan Norman, Cory Vandergrift

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
Budget Management Lead - UI Subsystem

Team Responsibilities

Team Coordinator: Carley Davis

- Closest to campus - can obtain ordered parts from UMass. Responsible for accessing Marcus labs if needed, and building the power supply subsystem.

Hardware Lead: Matthew Avison

- Has access to E-Lab tools and oscilloscopes - can prototype and assemble hardware remotely. Responsible for project assembly and keyboard subsystem.

Altium Lead: Ivan Norman

- Responsible for managing custom PCB orders, and the MIDI synthesis subsystem.

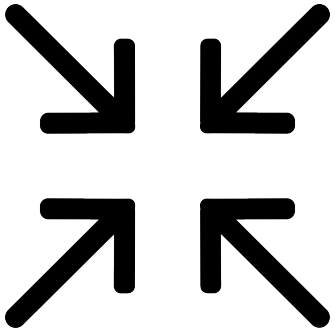
Budget Management Lead: Cory Vandergrift

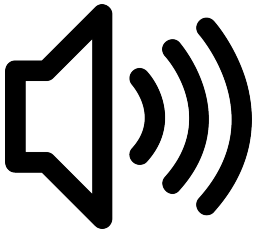
- Responsible for keeping track of hardware & software used, reporting any cost overruns, and for the LCD user interface subsystem.

Anything Instrument - Recap

The anything instrument is designed to be a ultra-portable musical device able to utilise everyday 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.





Fundamental Ideas

1. User connects probes to conductive objects to play as musical keys and tares the capacitance on the keys before playing

2. Instrument proceeds to detect key touches as a function of capacitance on the probe

3. User selects custom sound options via LCD interface

4. User listens to their musical talent via 8-ohm speaker or AUX device

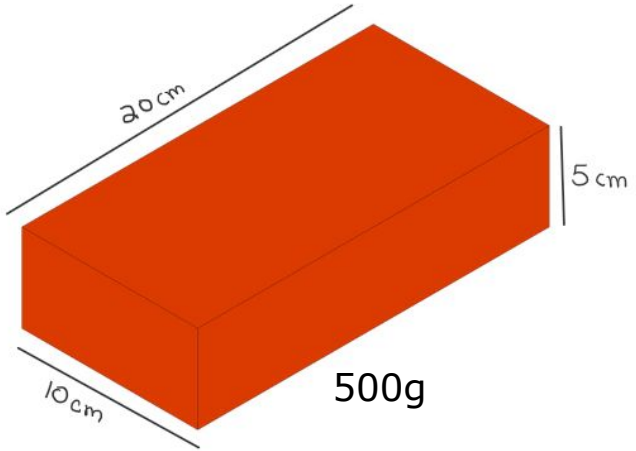
System Specifications

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 smaller than 20x10x5 cm

(2x)

(1x)



500g

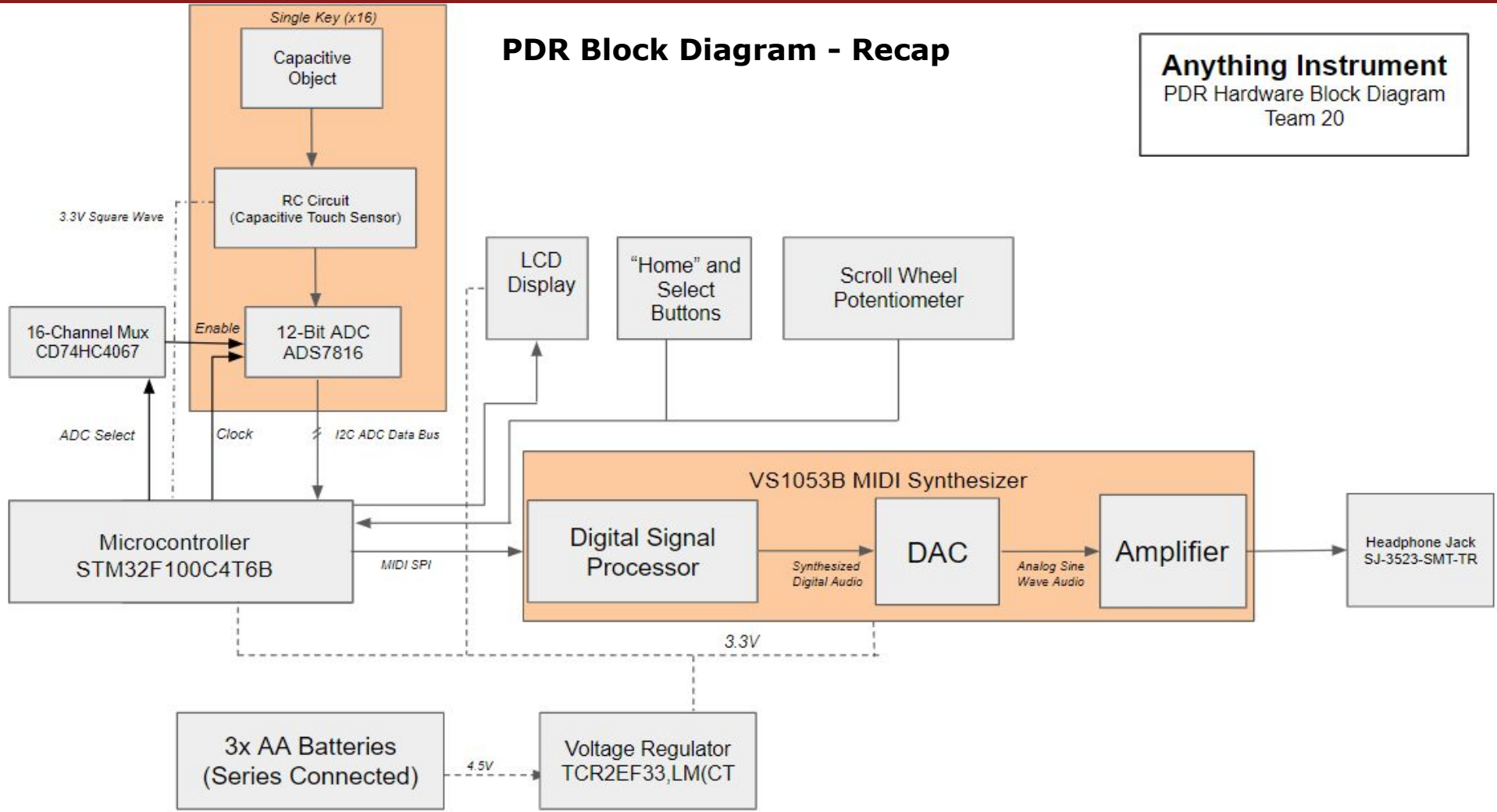
Proposed MDR Deliverables

1. Demonstrate a functional and reliable touch-sensing keyboard
   - Determine optimal RC component values, square wave frequency and sampling timing of the touch sensors that allow human touch to be detectable
   - Prove ability to detect touch on common capacitive objects (i.e soda can, apple, tin foil)

2. Demonstrate a working user interface
   - Implement a custom options menu template that can be interacted with using push buttons and an encoder scroll wheel

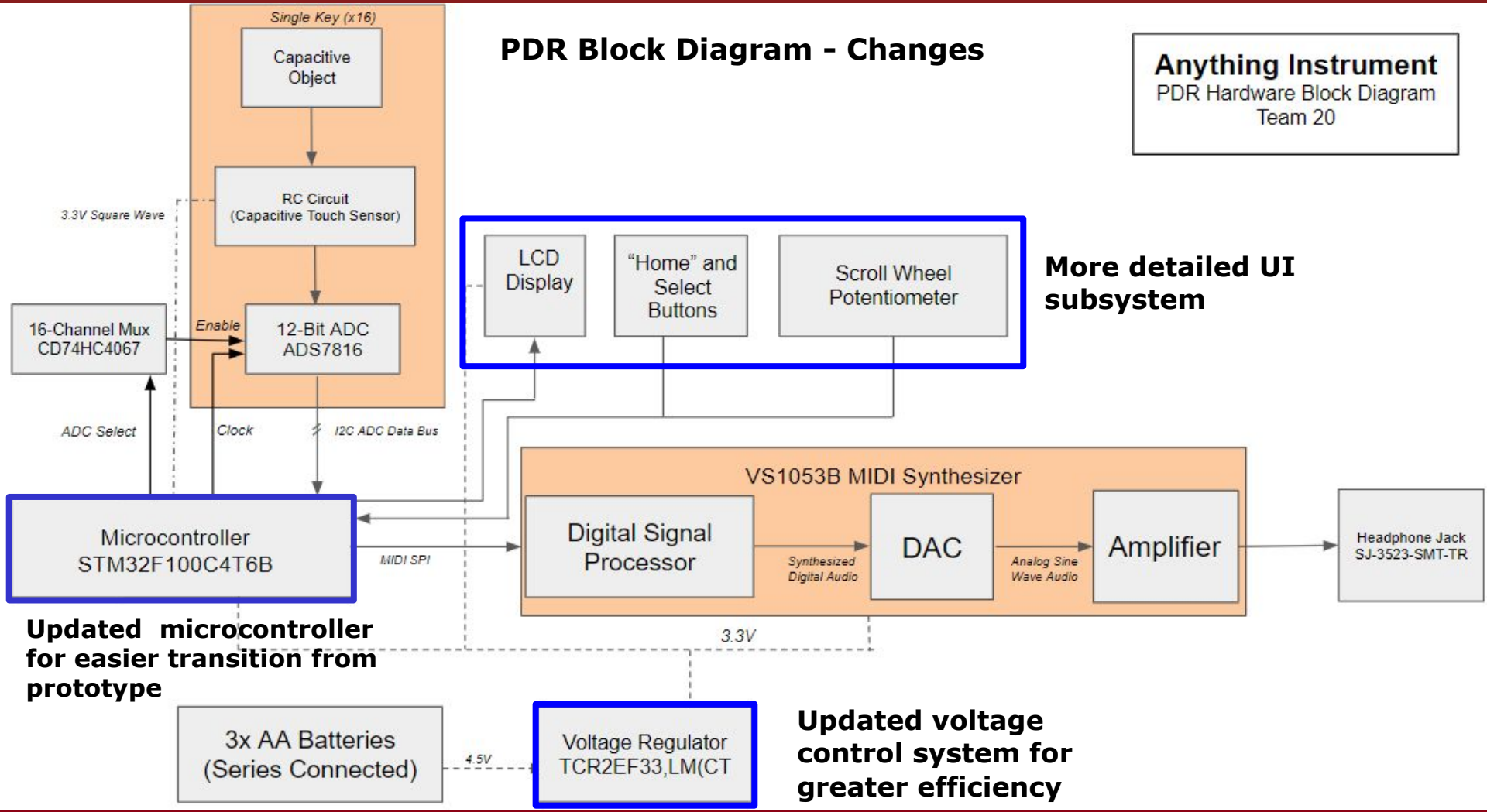
3. Demonstrate the ability to play audio from the MIDI synthesizer
   - Implement SPI interface between microcontroller and MIDI synthesizer
   - Be able to generate custom MIDI instructions, pass them to the synthesizer, and play back corresponding notes over the synthesizer's stereo output

PDR Block Diagram - Recap



PDR Block Diagram - Changes

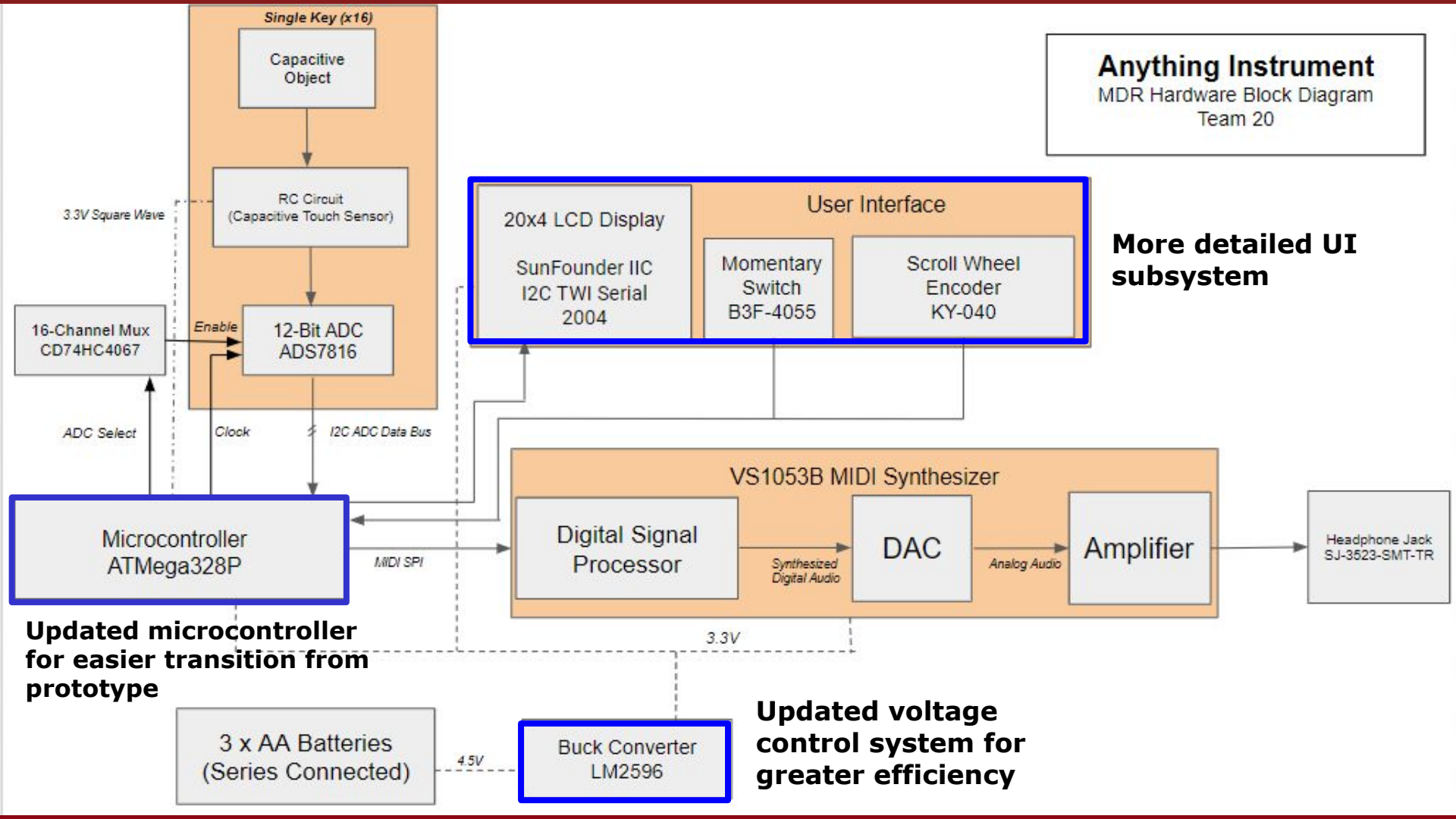
Anything Instrument
PDR Hardware Block Diagram
Team 20

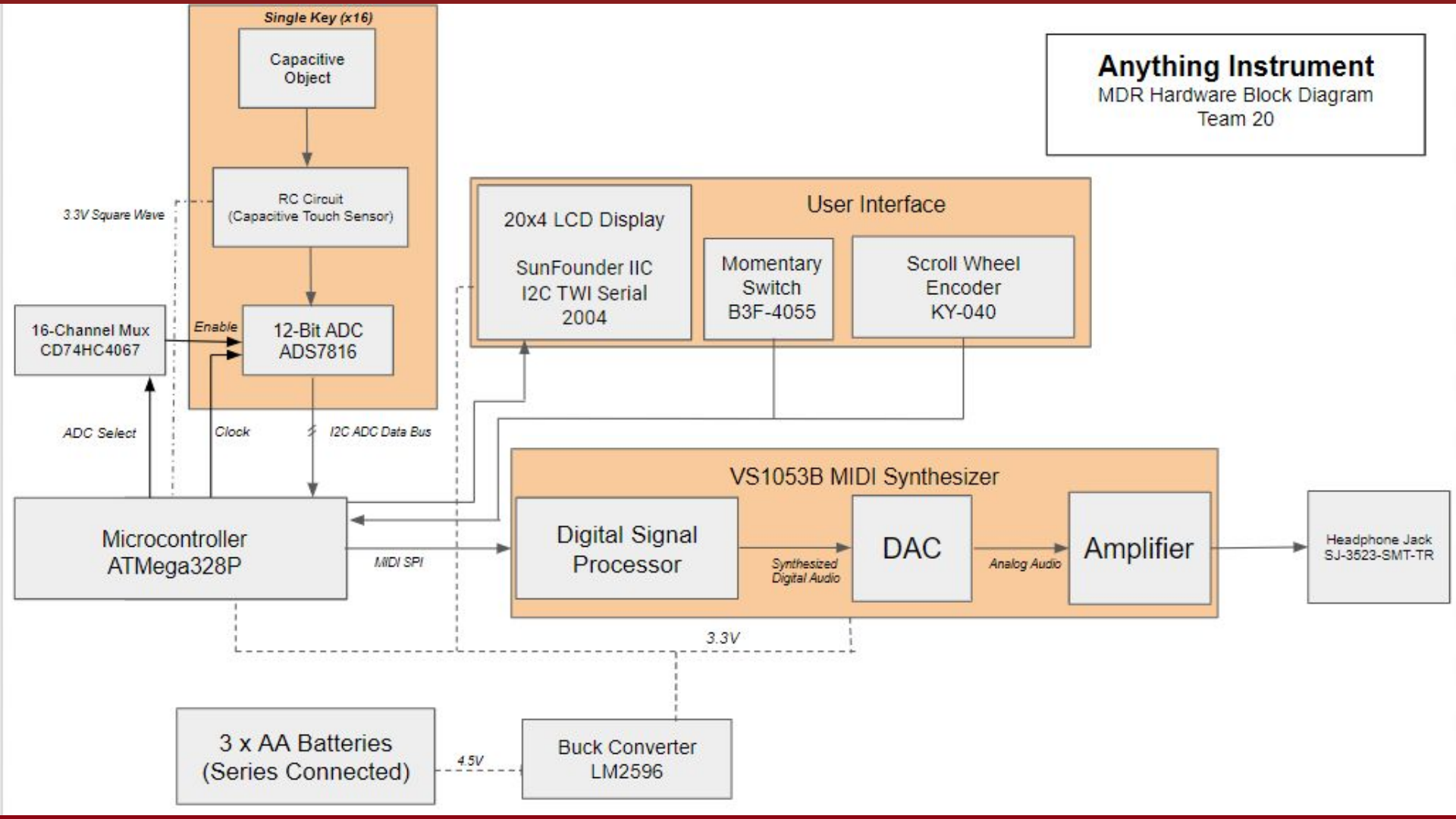


More detailed UI subsystem

Updated microcontroller for easier transition from prototype

Updated voltage control system for greater efficiency


Anything Instrument
MDR Hardware Block Diagram
Team 20
Single Key (x16)
Capacitive Object
RC Circuit (Capacitive Touch Sensor)
3.3V Square Wave
16-Channel Mux CD74HC4067
Enable
12-Bit ADC ADS7816
ADC Select
Clock
I2C ADC Data Bus
User Interface
20x4 LCD Display
SunFounder IIC I2C TWI Serial 2004
Momentary Switch B3F-4055
Scroll Wheel Encoder KY-040
More detailed UI subsystem
VS1053B MIDI Synthesizer
Digital Signal Processor
Synthesized Digital Audio
DAC
Analog Audio
Amplifier
Headphone Jack SJ-3523-SMT-TR
Microcontroller ATMega328P
MIDI SPI
Updated microcontroller for easier transition from prototype
3.3V
3 x AA Batteries (Series Connected)
4.5V
Buck Converter LM2596
Updated voltage control system for greater efficiency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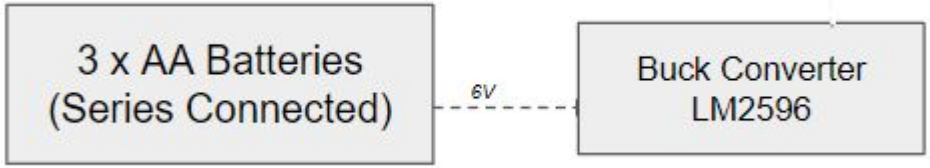
Microcontroller ATMega328P
MIDI SPI
3.3V
3 x AA Batteries (Series Connected)
4.5V
Buck Converter LM2596

Power Supply - System Diagram & Specifications

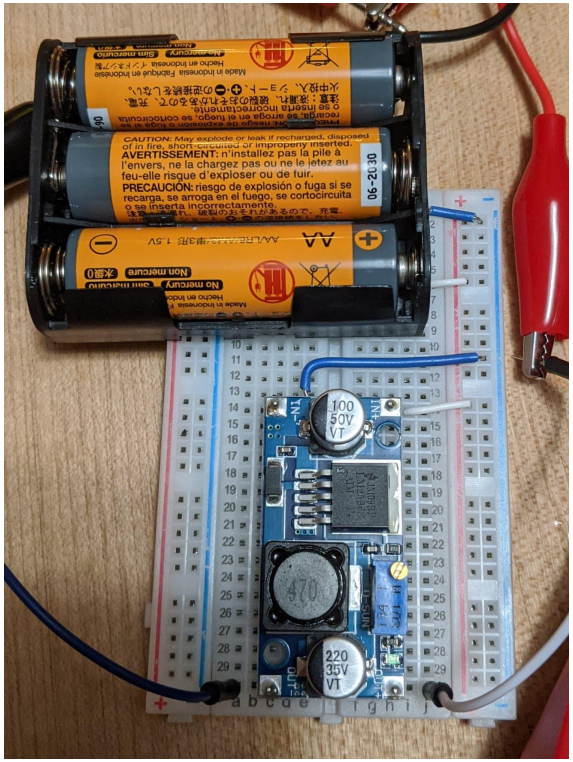
- Needs to be able to power microcontroller, audio synthesizer, LCD display and amplifier* - all run at 3.3V
- Estimated battery life is approximately 5+ hours, depending on usage and amplifier settings

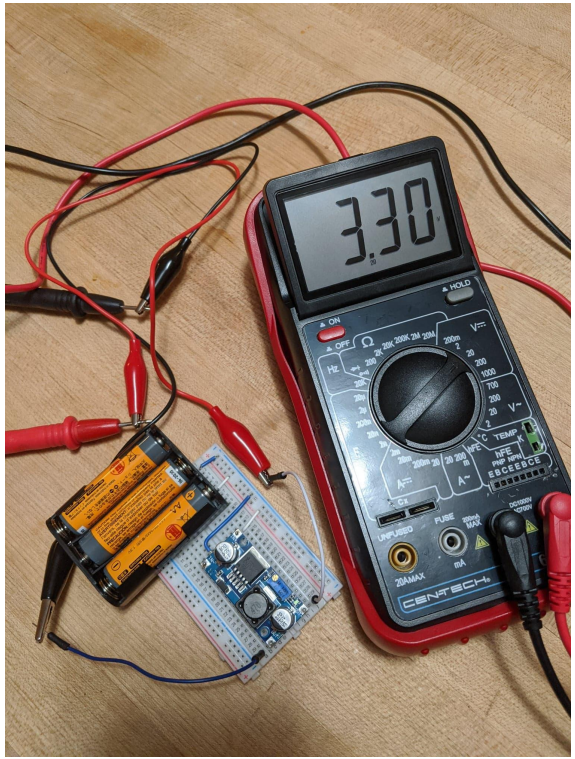
Hardware: -BH3AAPC Battery Holder
-LM2596 Adjustable Buck Converter



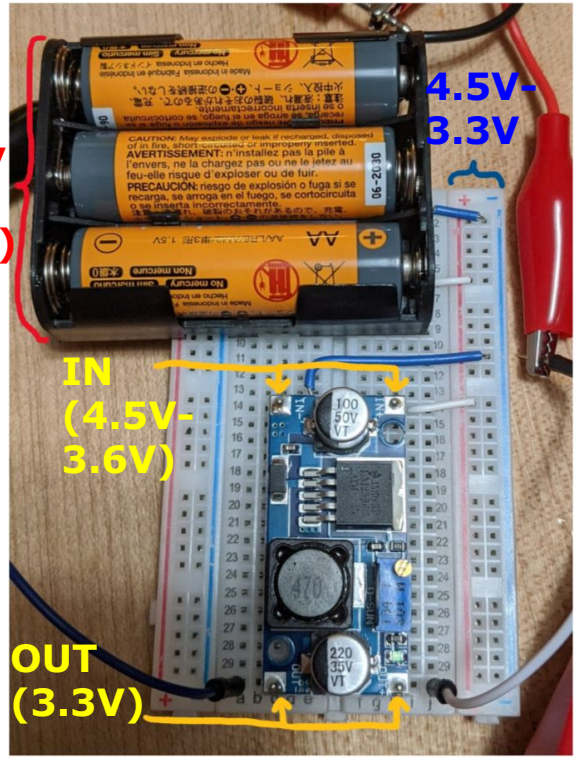
*Amplifier part of VS1053 breakout board for MDR

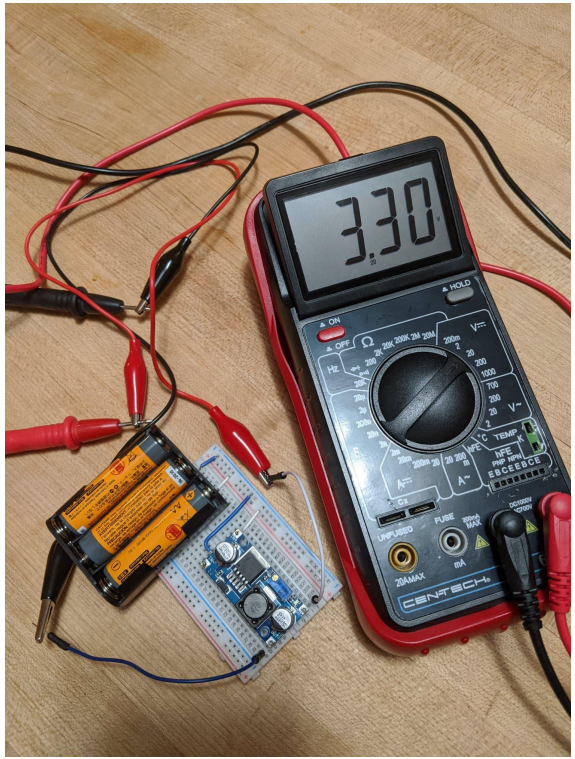
Power Supply - Prototype





Power Supply - Prototype





Live demo at end

Battery Life - Calculations

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
LTM2596 Adj. Buck Conv.	24

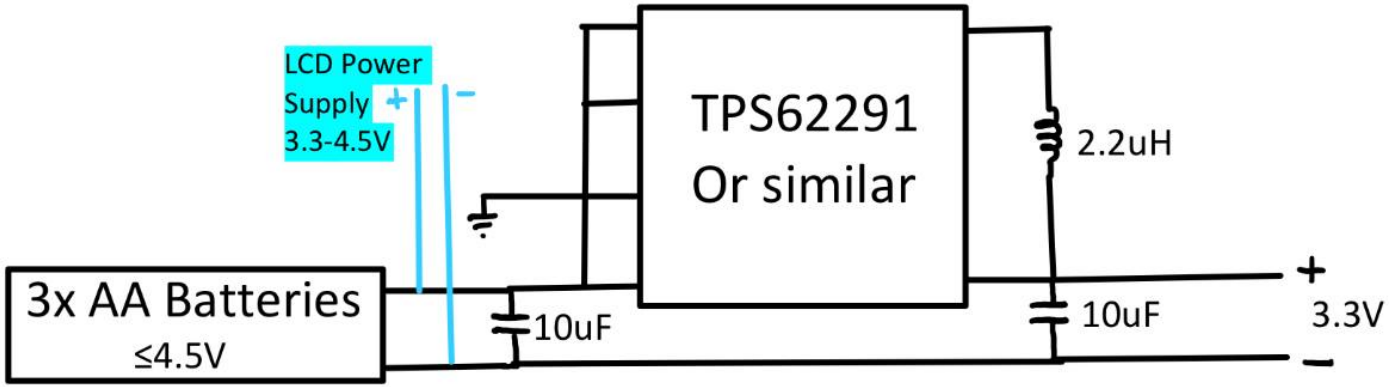
Total Operating Current (mA)	315
Total Operating Time (hours)	5.11

- Battery life of prototype estimated to be approximately 5 hours with all subsystems running at maximum capacity.
- Battery capacity adjusted by 0.7x the total battery capacity due to voltage drop during discharge. Minimum input operating voltage from batteries is 3.6V.

Power Supply - Possible CDR Updates

- Fixed voltage switching regulator circuit
- Additional amplifier connection for independent amplifier
- Low battery warning light

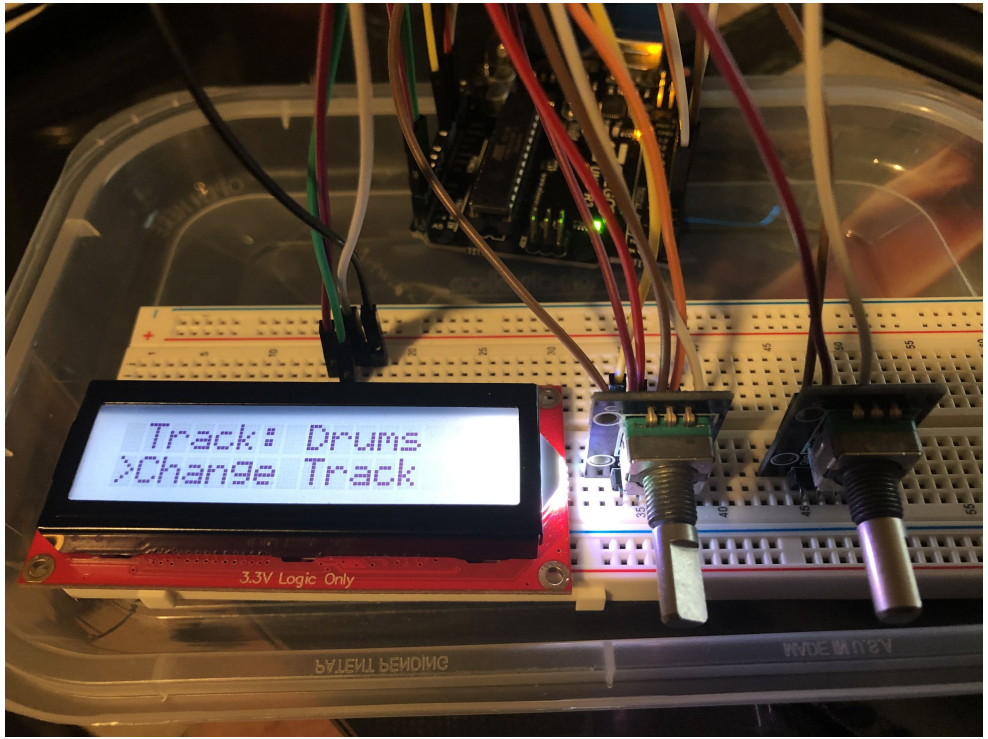
Potential fixed voltage regulator circuit



User Interface - System Specifications

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

User Interface - Prototype



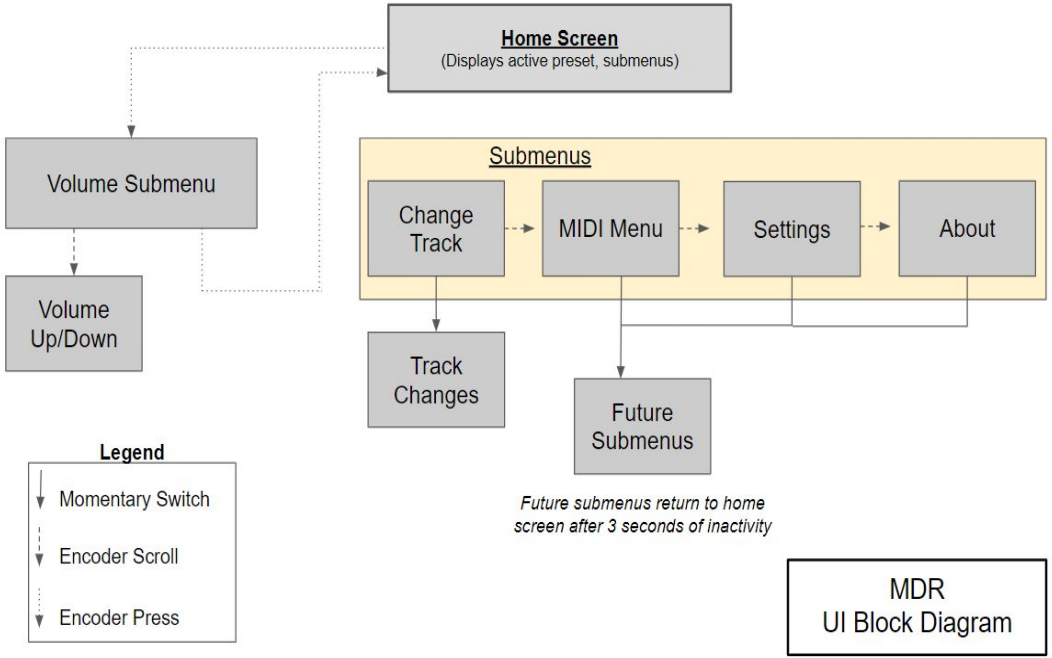
Components

- Arduino Uno (Elegoo) R3
- Sparkfun 16x2 LCD
- 2x Rotary Encoder

Software

- Coded in Arduino IDE
- Language: C
- LCD controlled via I2C

User Interface: Prototype One-Line



Design Philosophy

- Expandable subsystem tree that is easily modified through function based programming
- Easy to reach volume and MIDI track manipulation
- Only 2 input devices required, saving space and weight in final design

Video Demonstration

Live demonstration to be presented at end

User Interface - Possible CDR Updates

System Components

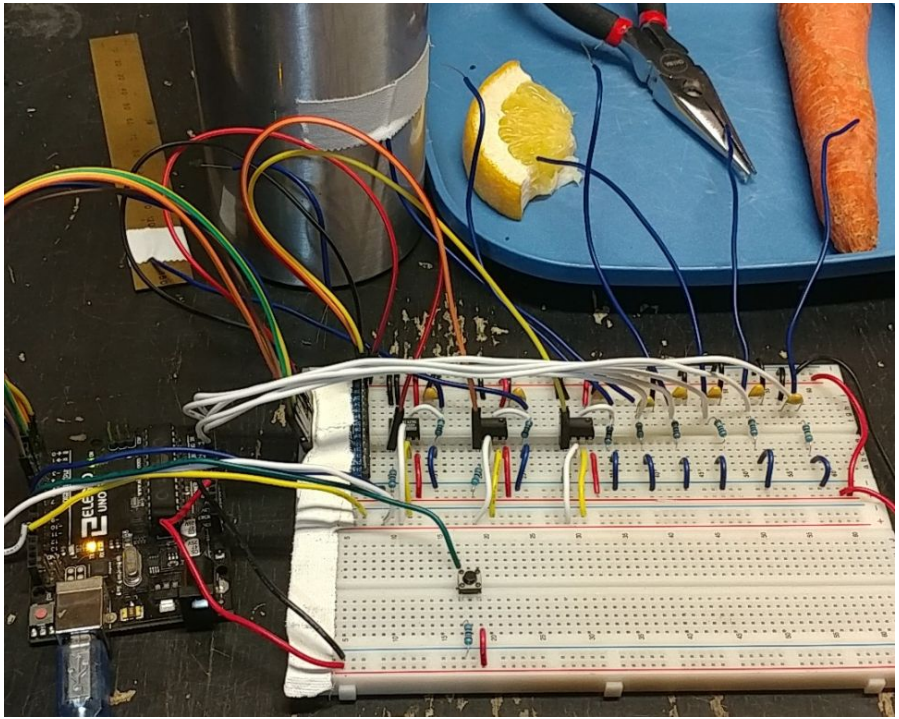
- Needs based on integration with other systems
- Display upgrade from 16x2 to 20x4
- Adding momentary switch
- Upgrade quality of Encoder

System Operation

- Battery level / life estimate
- Sleep mode - Display sleep and wake
- Selectable MIDI keys (note assignments)

Touch Sensing Keyboard - Specifications

- 8 Individual keys, able to play one full major scale
- Response time under 1ms
- Each key able to be calibrated to a different capacitance (i.e. from a soda can, apple, screwdriver, etc.)
- Consumes less than 2mW



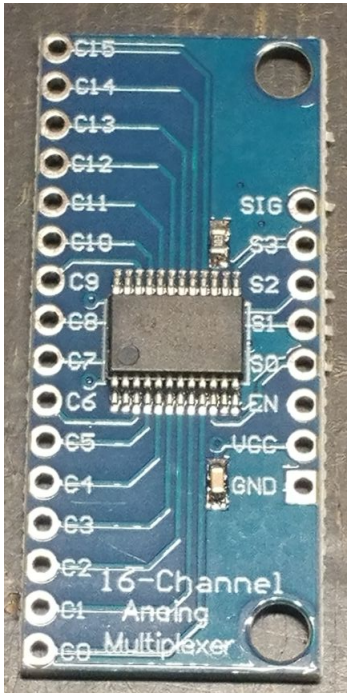
Touch Sensing Keyboard - Hardware

Multiplexer (x1): CD74HC4067

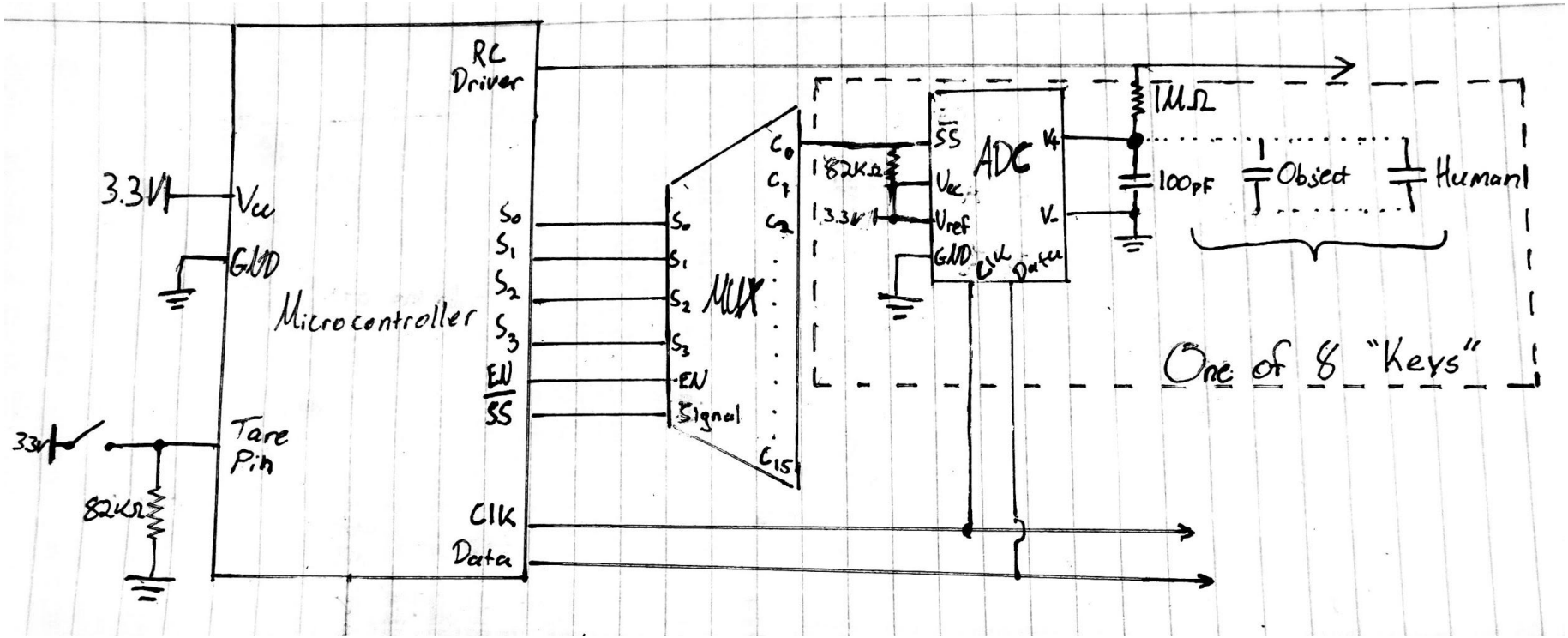
- 16 Channels

Analog to Digital Converter (x8): ADS7816

- 12-Bit resolution
- 200kHz Max sampling rate
- SPI Interface

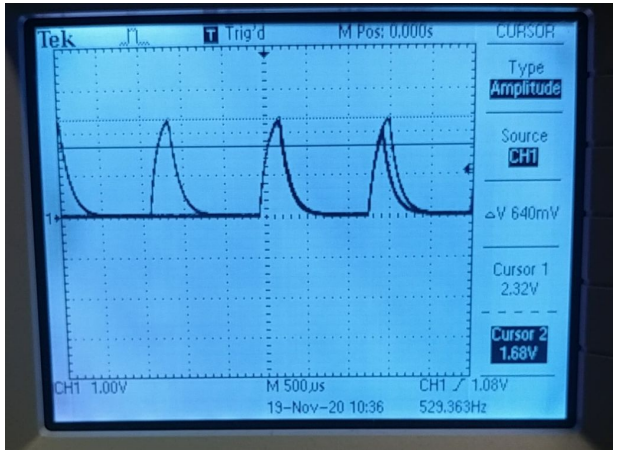


Touch Sensing Keyboard - Circuit Diagram

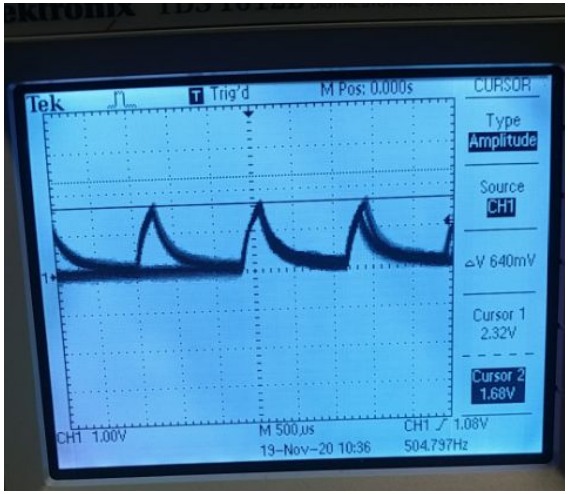


Touch Sensing Keyboard - RC Waveforms

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

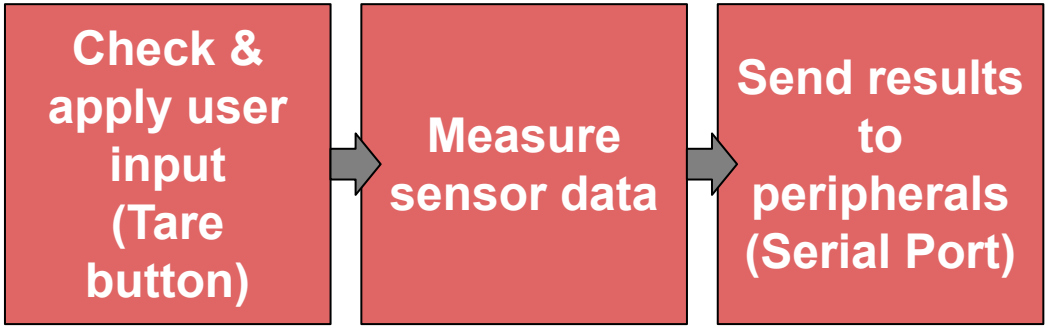


(Default RC charge cycle)



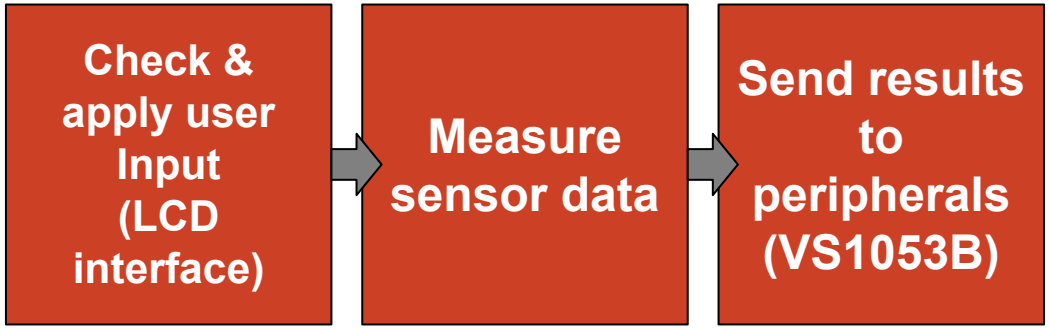
(Charge cycle upon touching probe)

Touch Sensing Keyboard - Software Flow

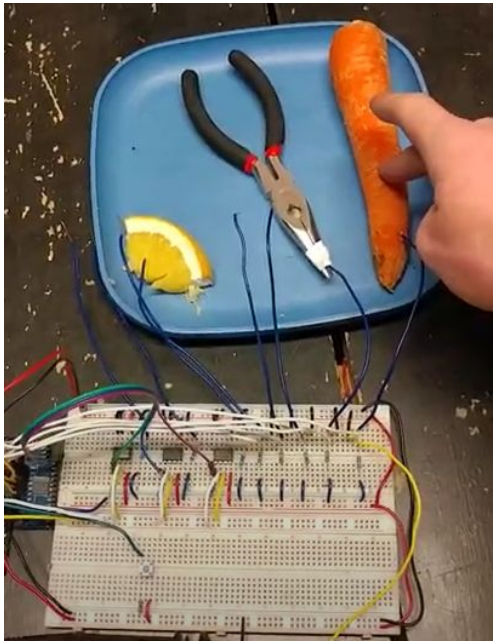


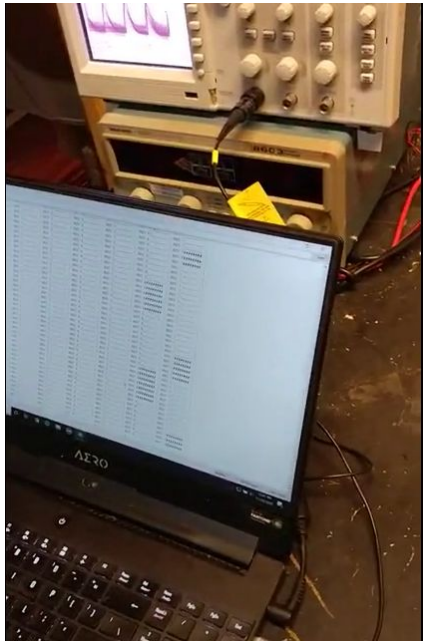
MDR Prototype keyboard process

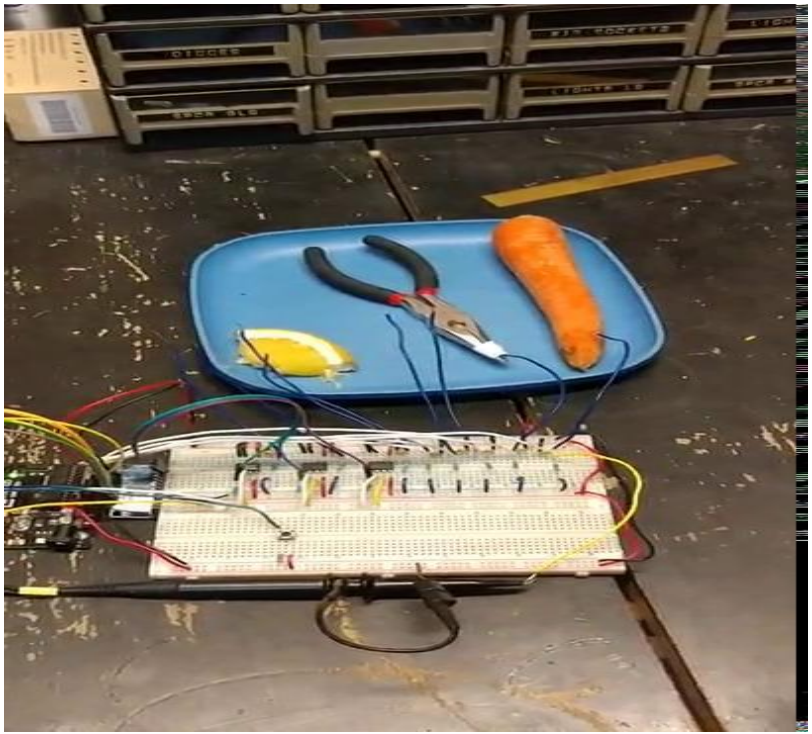
Final CPR Keyboard process



Video Demonstration



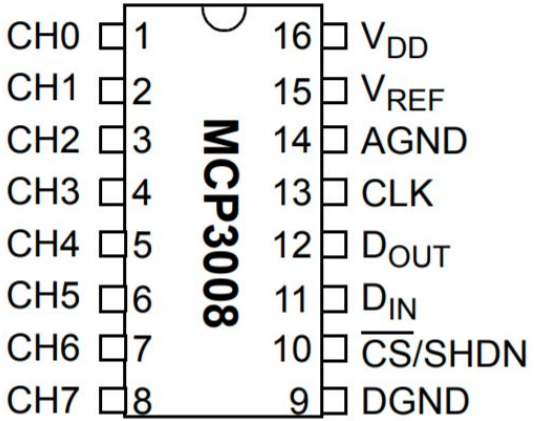




Capacitive Touch System - Possible CDR Updates

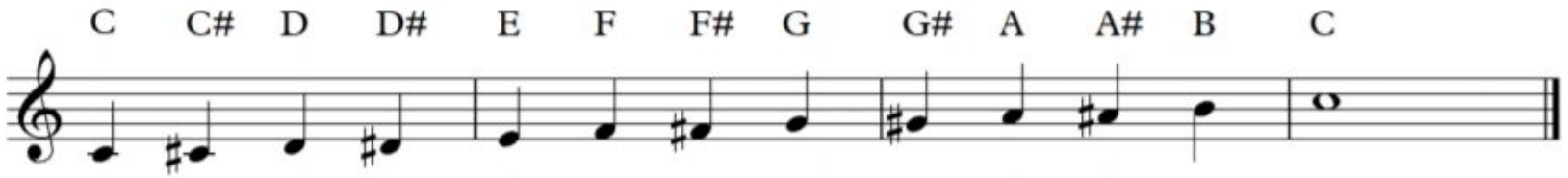
Make the switch to Microchip's MCP3008 ADCs

- 10-bit resolution
- 8 Input channels per chip



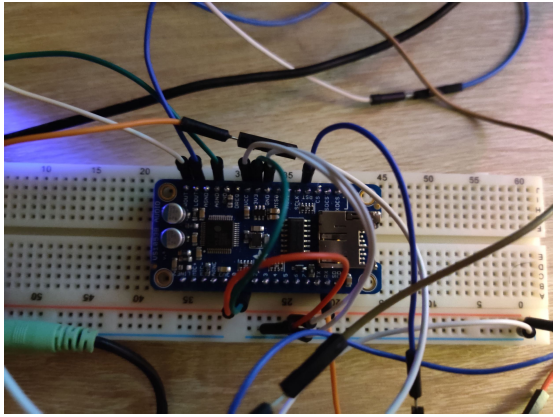
Increase number of playable keys from 8 to 12

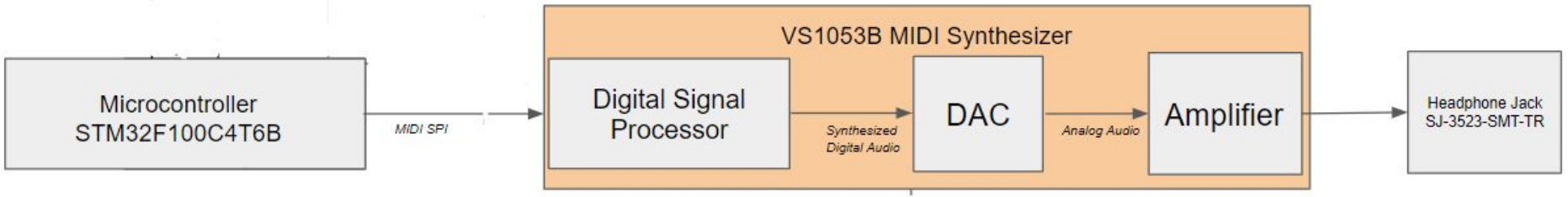
- Able to play a full chromatic scale



MIDI Synthesizer - Specifications

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

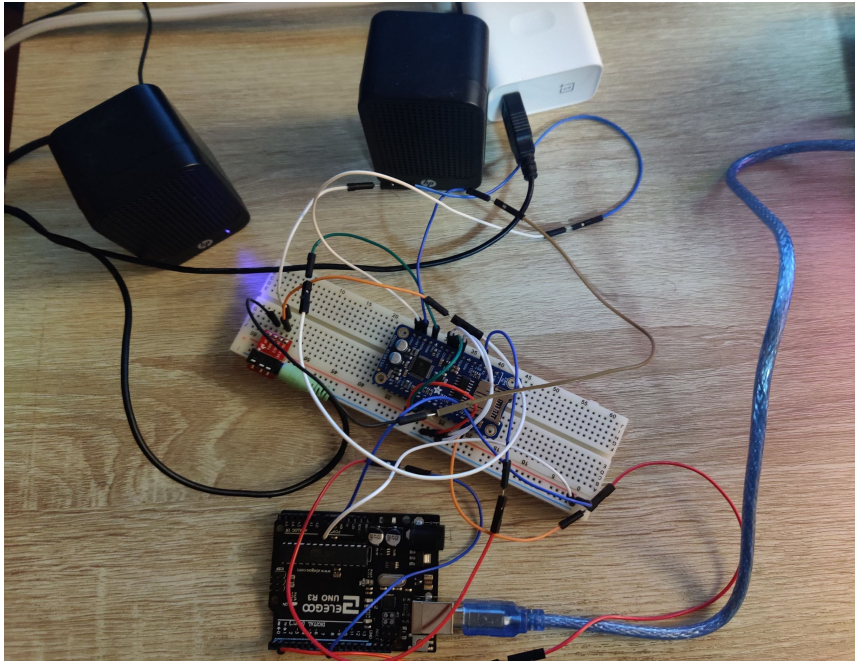




MIDI Synthesizer - Prototype

Components

- Arduino Uno R3
- Adafruit VS1053b
- Unbranded speakers



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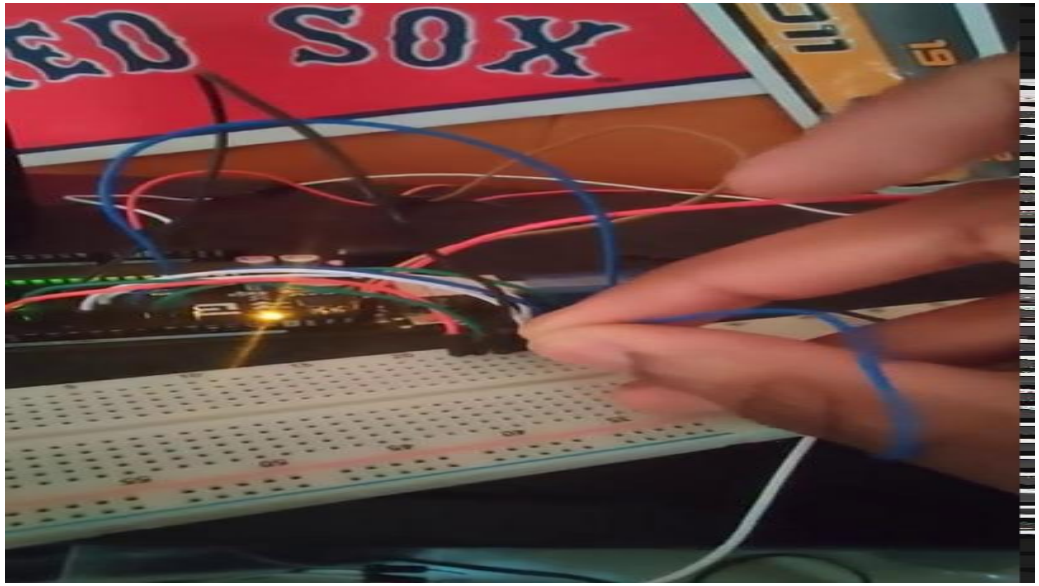


Live demonstration to be presented at end

MIDI Synthesizer - Possible CDR Updates

- Implement menu features
  - Track switching
  - Volume adjustment

- Implement and use capacitive touch circuit output instead of wire contacts

PCB Plan

The following components will be included on our custom PCB:

- Microcontroller
- MIDI Synthesizer
- Capacitive touch system control
- Fixed-voltage voltage regulator

The following components will be connected to our PCB via leads:

- Battery pack
- LCD Display
- Encoders
- Push button

There will also be leads coming from PCB to connect to playable objects

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

Budget

- We expected the parts to cost approximately $144.
- Our cost to date has been $98.93
- We also have received $146.09 worth of parts from M5

Cost Breakdown To Date

Part Number	Function	Cost (each)	Qty.	Total Cost (USD)
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

Total Estimated Cost:	**$245.63**
CTD:	$98.93
From M5:	$146.09

*Indicates items recieved entirely from M5

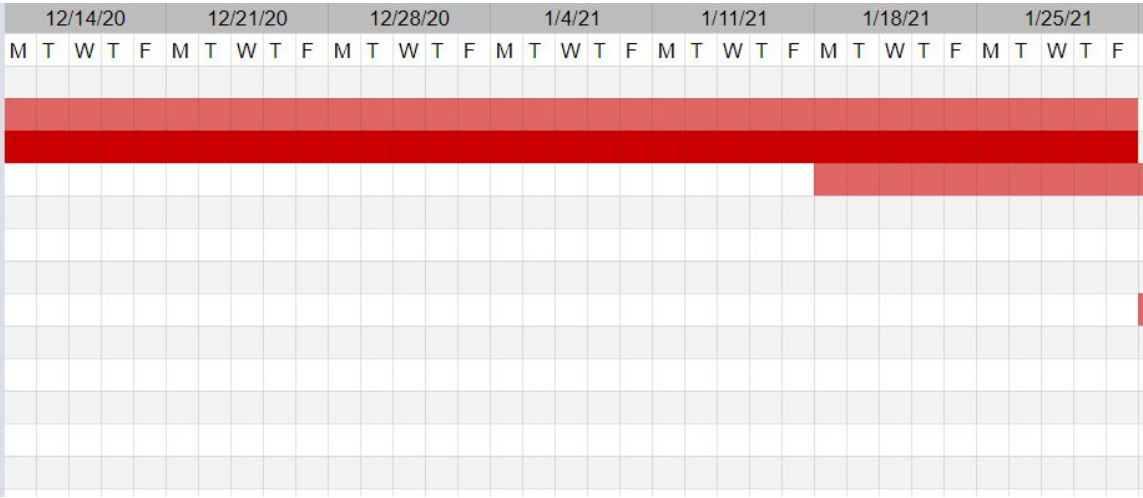
*Indicates items partially recieved from M5

Spring Budget

Part Number	Function	Cost (each)	Qty.	Total Cost (USD)
MCP1603T	3.3V Switching Regulator	$0.98	3	$2.94
ATMEGA1284-PU	Microcontroller (Through Hole)	$5.00	4	$20.00
ATMEGA1284-ARU	Microcontroller (Surface Mount)	$4.90	2	$9.80
LCD	SunFounder 2004 20x4 LCD Module (2 pack)	$19.99	1	$19.99
Encoder	KY-040 Rotary Encoder Module (5 pack)	$8.99	1	$8.99
Momentary Switch	B3F-4055 Momentary Switch	$0.44	4	$1.76
MCP3008-IP	Analog to Digital Conv. (Through Hole)	$2.19	3	$6.57
MCP3008T-I-SL	Analog to Digital Conv. (Surface Mount)	$2.19	3	$6.57
			Total Estimated Cost:	**$76.62**

Schedule

Task Name	Start Date	End Date	Week of: Team Member
Hardware			
Fixed Voltage Power Supply Prototyping	12/14/20	1/29/21	CD
Combining Subsystem Prototypes	12/14/21	1/29/21	CD. CV, IN, MA
PCB Design	1/18/21	2/12/21	CD, CV, IN, MA
Solder components to PCB	3/8/21	3/19/21	CD, MA
System Troubleshooting (Critical)	3/22/21	4/16/21	CD, CV, IN, MA
Logistics			
Order MDR Parts	2/1/21	2/5/21	CV
Obtain Parts	2/8/21	2/19/21	CD
Order PCB	2/15/21	2/19/21	
Obtain PCB	3/1/21	3/12/21	CD
Complete FPR Presentation Materials	3/22/21	4/16/20	CD, CV, IN, MA
Damage Control Meeting	4/5/21	4/16/20	CD, CV, IN, MA



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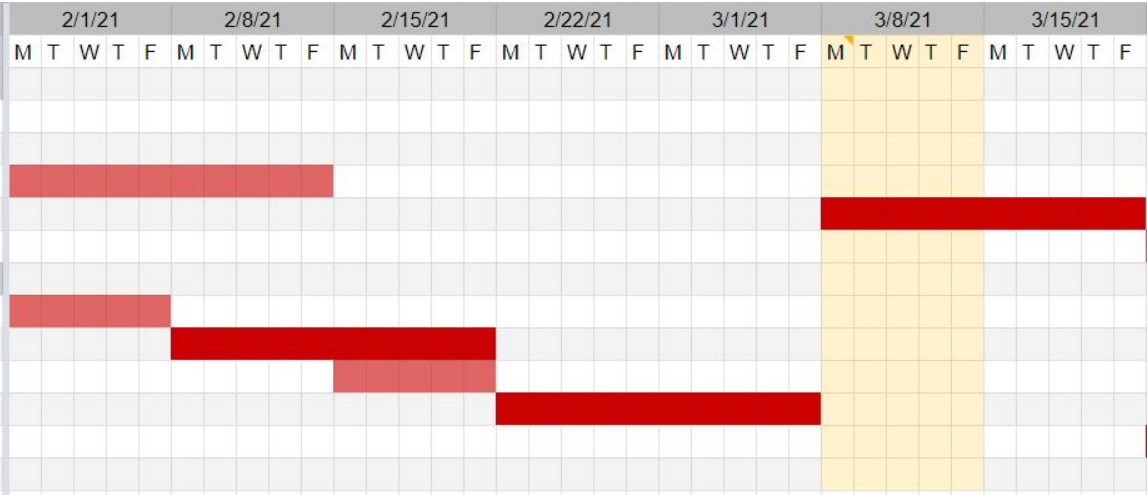
System Troubleshooting (Critical)	3/22/21	4/16/21	CD, CV, IN, MA
Logistics			
Order MDR Parts	2/1/21	2/5/21	CV
Obtain Parts	2/8/21	2/19/21	CD
Order PCB	2/15/21	2/19/21	
Obtain PCB	3/1/21	3/12/21	CD
Complete FPR Presentation Materials	3/22/21	4/16/20	CD, CV, IN, MA
Damage Control Meeting	4/5/21	4/16/20	CD, CV, IN, MA



Schedule

Task Name	Start Date	End Date	Week of: Team Member	3/22/21 M	T	W	T	F	3/29/21 M	T	W	T	F	4/5/21 M	T	W	T	F	4/12/21 M	T	W	T	F	4/19/21 M	T	W	T	F	M
Hardware																												
Fixed Voltage Power Supply Prototyping	12/14/20	1/29/21	CD																									
Combining Subsystem Prototypes	12/14/21	1/29/21	CD. CV, IN, MA																									
PCB Design	1/18/21	2/12/21	CD, CV, IN, MA																									
Solder components to PCB	3/8/21	3/19/21	CD, MA																									
System Troubleshooting (Critical)	3/22/21	4/16/21	CD, CV, IN, MA																									
Logistics																												
Order MDR Parts	2/1/21	2/5/21	CV																									
Obtain Parts	2/8/21	2/19/21	CD																									
Order PCB	2/15/21	2/19/21																										
Obtain PCB	3/1/21	3/12/21	CD																									
Complete FPR Presentation Materials	3/22/21	4/16/20	CD, CV, IN, MA																									
Damage Control Meeting	4/5/21	4/16/20	CD, CV, IN, MA																									

Questions?