# Battery-Free Handheld Game

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**Advisor/Client:** Henry Duwe

# Problem Statement

- Batteries can only hold a limited amount of energy
- Batteries need to be recharged and disposed of
- Batteries can take up significant space in a device
- Our device is a proof of concept to further knowledge and show capabilities of a battery-free system

# Functional Requirements

- Only use energy generated from user interaction
- Energy harvesting incorporated into gameplay
- Device supports some multiplayer  functionality
- The device shall show a low power screen when it is running out of battery, telling the user to energy harvest.
- The game shall run through at least one room challenge state after energy harvesting.

# Non-functional Requirements

- The game should be reasonably intuitive to pick up and play
- The game should go through at least one state change after energy harvesting
- The energy harvesting techniques should not physically strain the user

# Constraints

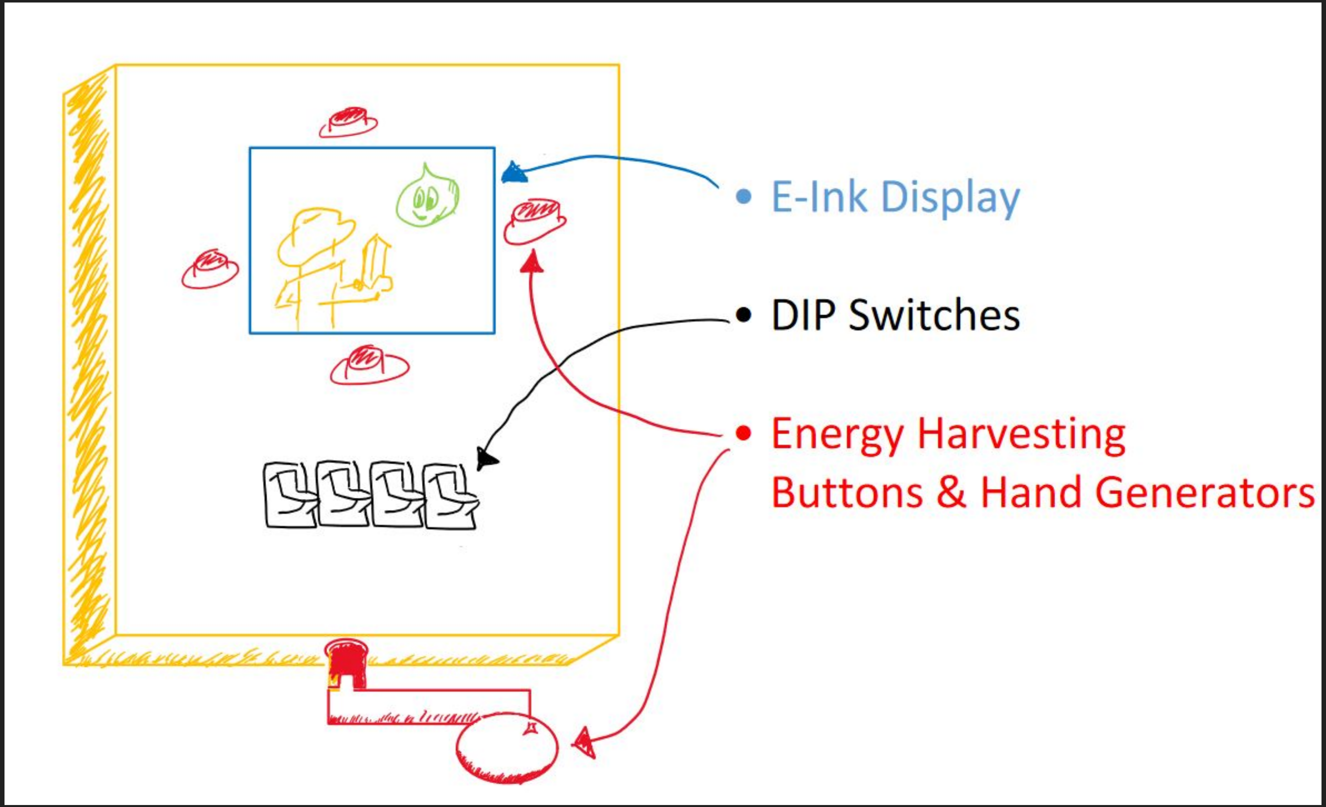
- The user must individually produce enough power to match or exceed the power demands of the game.
- The device must be produced at a reasonable cost of under $100.
- The device must be successfully designed and built within 26 weeks.
- The operating environment must be acceptable to the integrated hardware.
- The device must be unique from any other battery-free gaming devices available.

# Market Survey

- Battery-Free Game Boy
  - Northwestern University and the Delft University of Technology (TU Delft) September 2020
  - Battery-Free
  - Uses solar panels and kinetic button harvesters

- What Makes Ours Unique
  - Soley uses human input to generate power
  - Incorporates energy harvesting into gameplay interaction

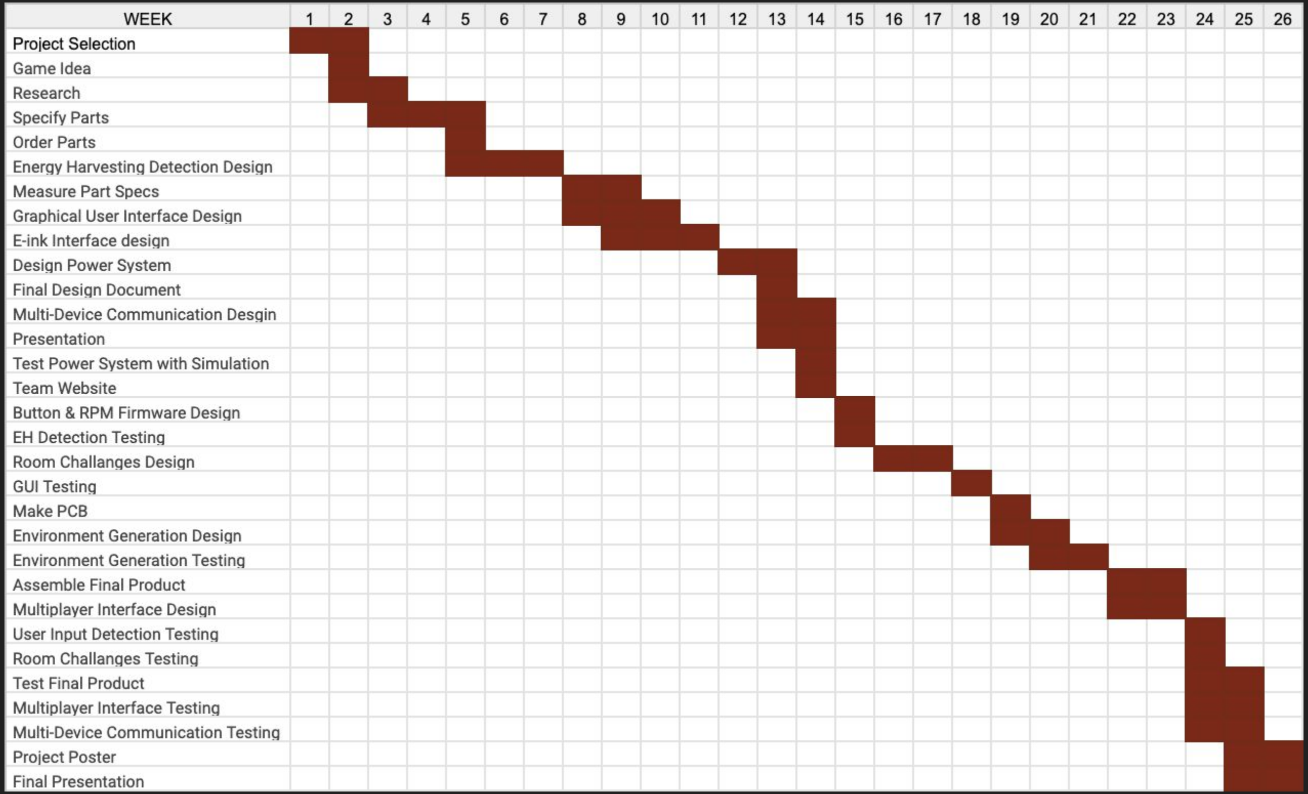
# Conceptual Sketch



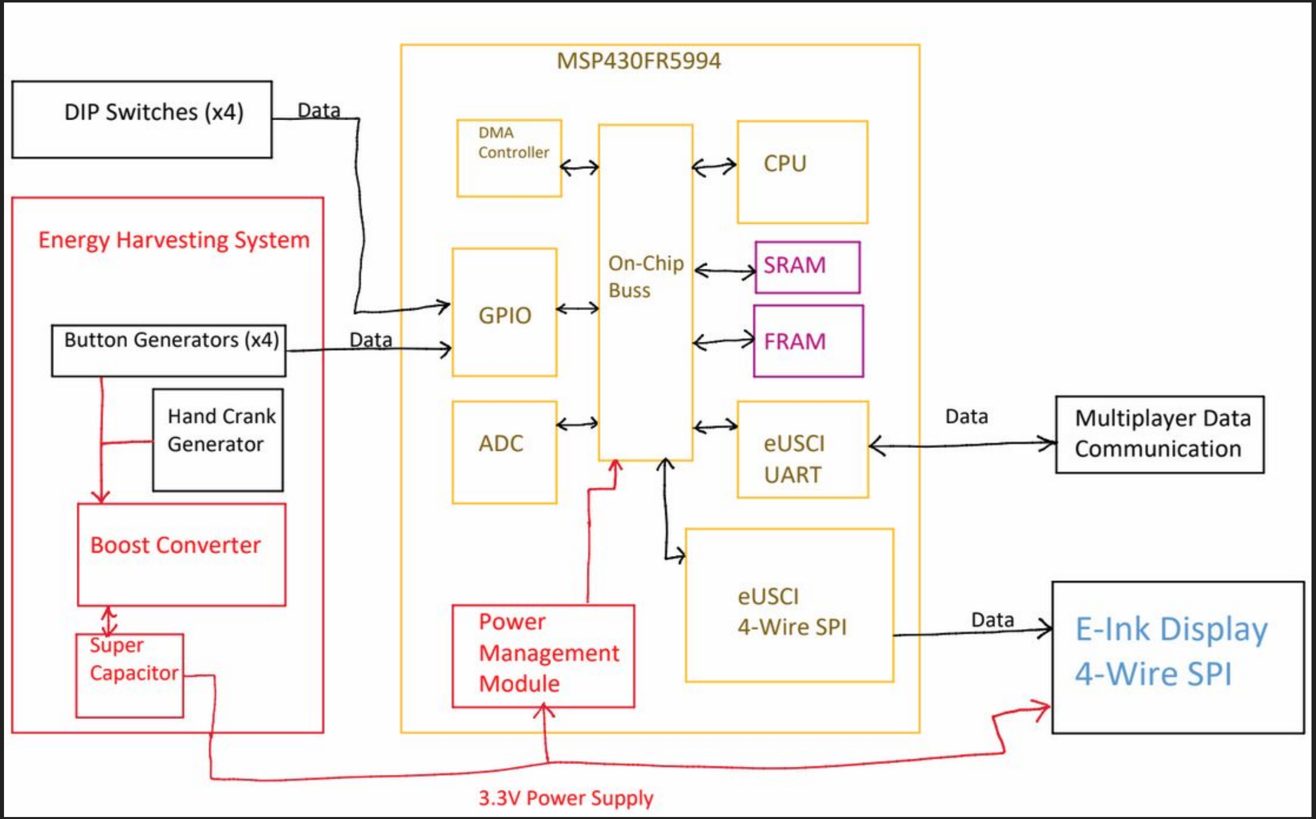
# Resource/Cost Estimate

| | | | |
|---|---|---|---|
| 200x200, 1.54" E-ink Display | $20.50 | 1 | $20.50 |
| Kinetic Button Harvester | $11.15 | 4 | $44.60 |
| Mini Motor Generator | $9.99 | 1 | $9.99 |
| BQ25504 Boost Converter | $4.70 | 1 | $4.70 |
| TPS610995DRV Boost Converter | $1.84 | 1 | $1.84 |
| MSP430 Dev Board | $20.39 | 1 | $20.39 |
| TOTAL | | | $82.68 |

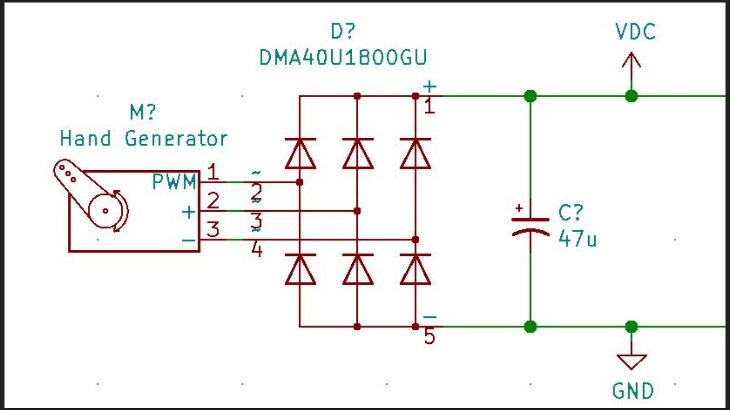
# Project Milestones & Schedule

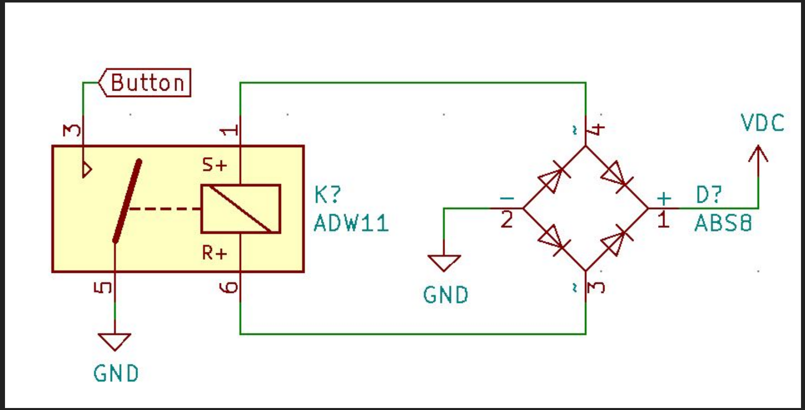


# Functional Diagram



# Energy Harvesting - Production



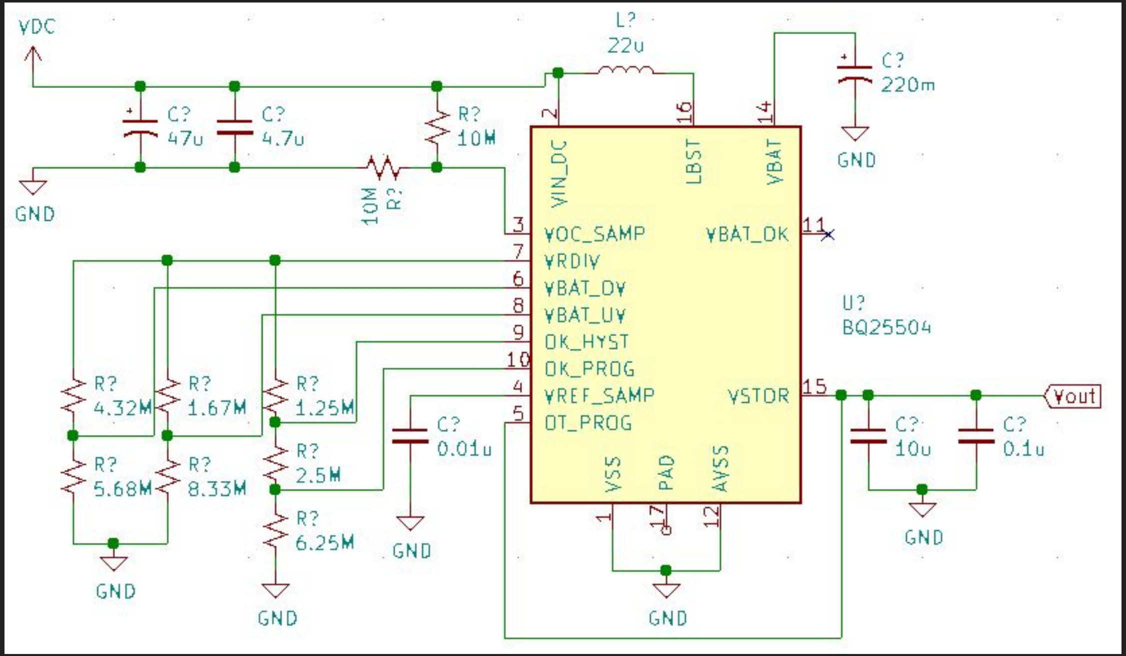

## Mini Motor Generator

- Full-wave 3-phase rectification
- Smoothing capacitor

## Kinetic Button Harvester

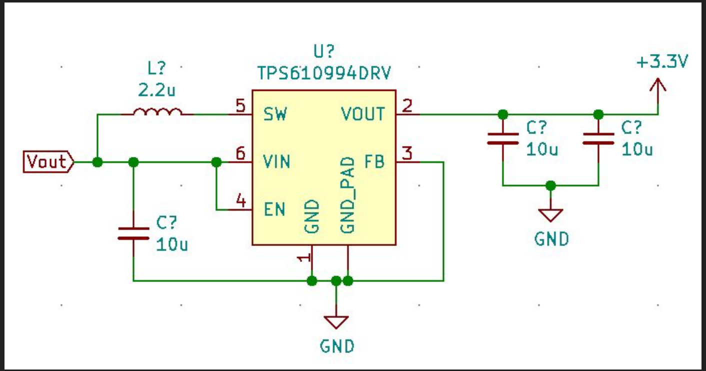
- Full-wave rectification
- Smoothing capacitor

# Energy Harvesting - Storage/Supply




## BQ25504 - Energy Harvester Controller

- Safely charges/discharges supercapacitor
- Bucks/Boosts input ranging from 0.13V - 5V
- Maximum of 3.3V on supercapacitor

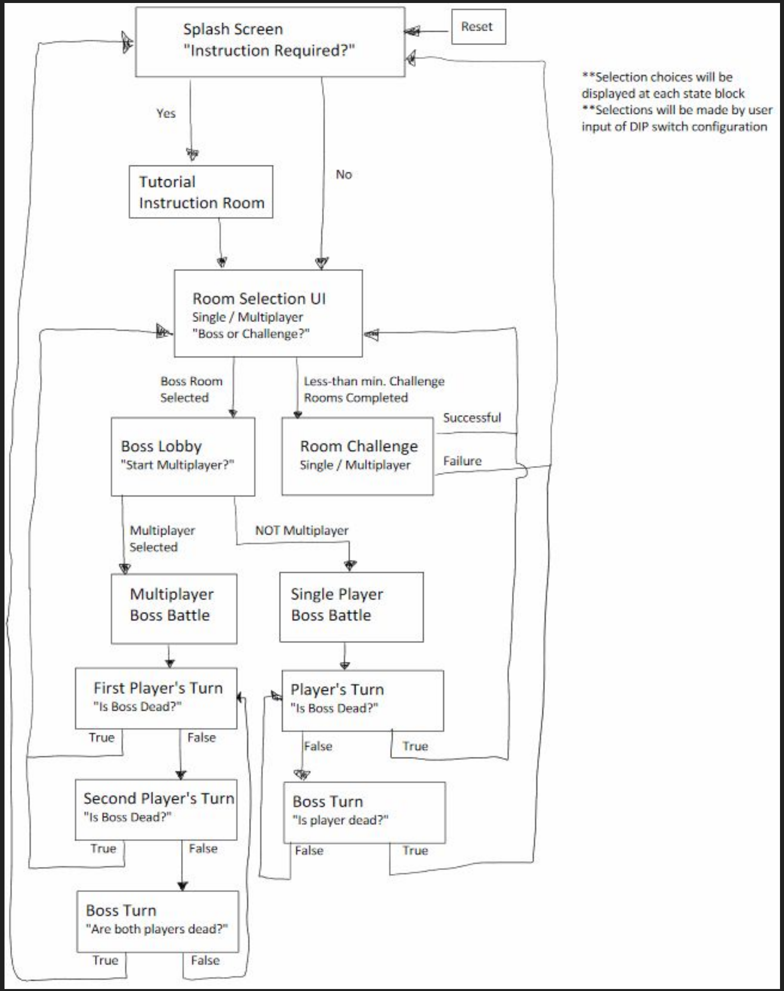



## TPS610994 - Boost Converter

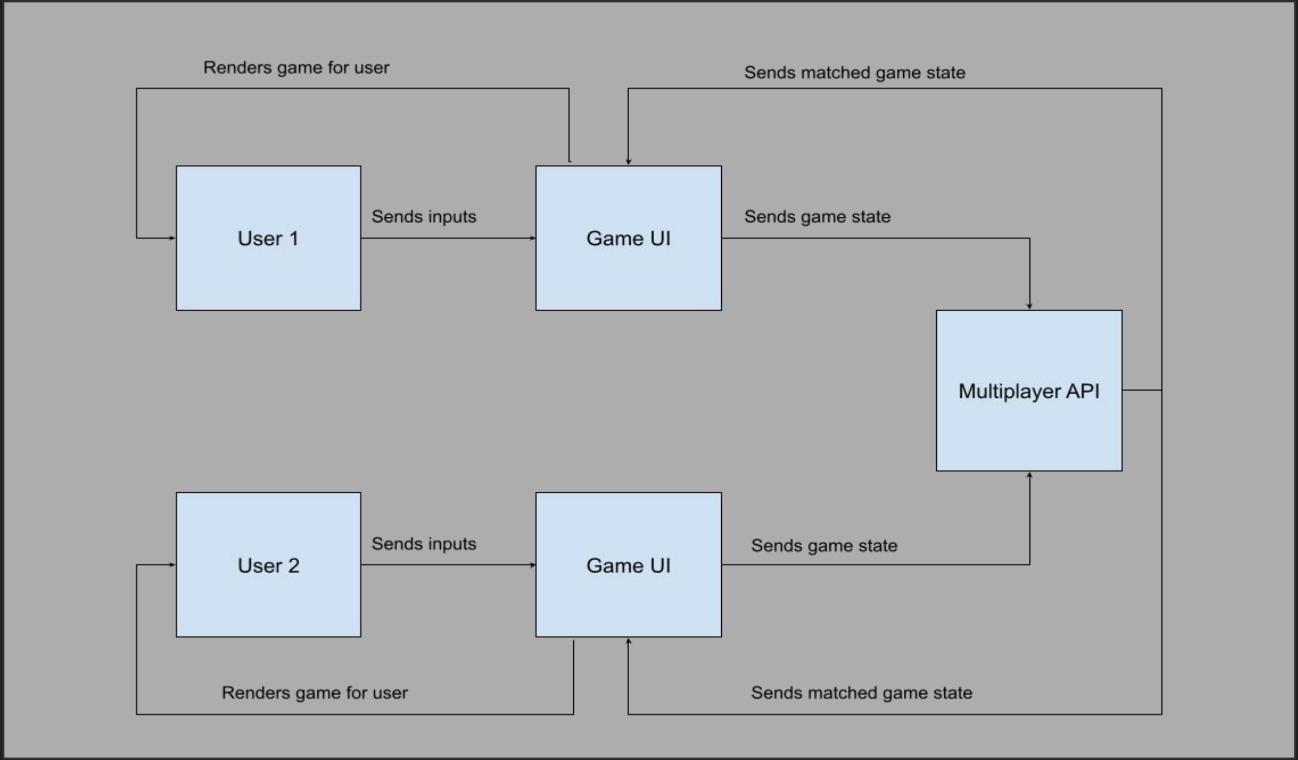
- Ultra-Low quiescent current
- Boosts full range of supercapacitor
- Boost to constant 3.3V

# High Level Software Design:

- Dungeon crawler gameplay
- Splash Screen with choice of instruction
- Room selection gives choice of three room challenges
- Choice of multiplayer or singleplayer boss fights
- Endless Loop



# Multiplayer Software Design



# Potential Risks & Mitigation

| Risk | Mitigation |
| --- | --- |
| Energy Harvesting Circuit is insufficient/exceeds the power requirements of the whole device. | • Include/remove more generation devices in the circuitry.<br>• Introduce a gear ratio for the hand generator. |
| Energy harvesting devices exceed 5V output. | • Introduce a zener diode to sink damaging voltages.<br>• Include a regulator before the energy harvester controller. |
| Software memory requirements exceed the MCU onboard memory available. | • Utilize SD card memory storage<br>• Reduce the software complexity |

# Hardware/Software Technology Platforms

- Software
  - Code Composer Studio
  - CLion
- Hardware
  - KiCAD

# Energy Harvesting Testing

## Crank Generator

- Tests to confirm that the crank generator can deliver power to the system without damaging it.
- Verify voltage values do not exceed limits at output node
- Confirm capacitor can be charged by circuit
- Note: all tests were done with rectification circuit

## Energy Harvesting Buttons

- Tests to confirm that power can be collected from these buttons and also detect a GPIO signal from them.
- Verify GPIO pins receive correct “high” value when buttons are pressed
- Confirm capacitor can be reasonably charged from button pressing
- Note: all tests were done with rectification circuit

# Hardware Testing

## Signal Detecting Circuit

- Measures the voltage at the output of all power generating components
- Uses the microprocessor’s ADC converter to read the voltage output of the crank generator

## E-Ink Display

- Determine the amount of energy needed for to load an image onto the display
- Determine the maximum frame rate we can achieve with a fully charged supercapacitor
- Measure the power usage when updating a different percentage of the display pixels

# Software Testing

## Communication & Interfacing

- Display Communication
  - Ensure interface correctly communicates display information for the GUI
- User Input Detection
  - Ensure user inputs are correctly deciphered
- Multiplayer Communication
  - Ensure correct game state communication between devices.
- Power loss
  - Ensure state save captures required information for restoration.
  - Ensure the correct state is restored.

## Gameplay Testing

- Room Generation
  - Ensure each room and button prompts render correctly with all of their components and check components positions.
- Environment Generation
  - Test and confirm each input combination for the room selection UI.
  - Test for paths from the start room to the end.
- Room Challenges
  - Test success/failure state for each room and check if players are updated.

# Interface Testing

## Power Production/Usage

- Power to Capacitor
  - Confirm energy harvesters increase voltage on supercapacitor
- Power to System
  - Confirm 3.3V to system over full range of supercapacitor

## User Interaction

- E-Ink SPI
  - Confirm microcontroller can update E-ink
- E-ink Powering
  - Validate that energy harvesting system can produce enough energy to update E-ink
- Multiplayer Functionality
  - Validate multiplayer communication between microcontrollers

# Test Results

| Results | | |
|---|---|---|
| Max DC voltage on capacitor after long time turning with drill | | |
| 6.7 | | |
| Average Power(mW) | | |
| 10.624815 | | |
| Can Easily introduce a gear ratio and get much higher power output since it is dependent upon rpm | | |
| Time to produce enough energy to update E-ink once (based off of datasheet) | | |
| Average Power (Hand Crank) | Energy to update E-ink once (mJ) | Seconds |
| 10.624815 | 52.8 | 4.969498292 |

Crank Generator

| Results | | |
|---|---|---|
| Max DC voltage on capacitor after long time pressing | | |
| 4.8V | | |
| Average Power(mW) | | |
| 1.056121567 | | |
| No Clear increase or decrease of power output when capacitance increases | | |
| Time to produce enough energy to update E-ink once (based off of datasheet) | | |
| Average Power (Hand C | Energy to update E-ink once (mJ) | Seconds |
| 1.056121567 | 52.8 | 49.99424467 |

Energy Harvesting Button

Note: We will increase power production using a gear ratio which further proves the feasibility of this design.

# Project Status

- This semester we have performed research and feasibility designs into creating a batteryless handheld game.

- So far we have:
    - Developed the idea of our game
    - Selected and purchased several of our components
    - Completed some unit tests
    - Created several diagrams and schematics for use in the next semester with the initial prototype.

- We have taken steps to prepare ourselves for actual implementation and design of our project so we can get to work immediately in the Fall.

# Task Responsibilities and Contributions

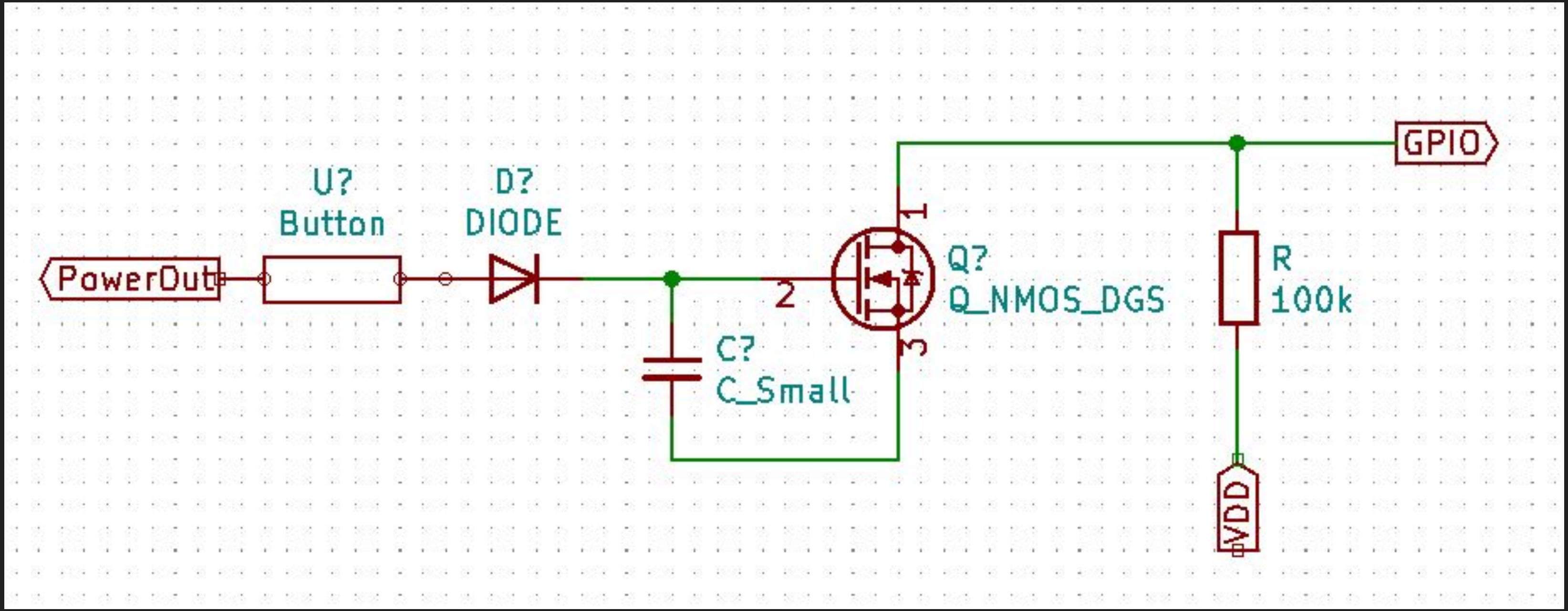
- John Brose
  - Chief Engineer- Power Systems
  - Meeting Facilitator
- Jake Larimore
  - Chief Engineer- Integration
- Franklin Bates
  - Chief Engineer- Microcontroller
  - Meeting Scribe
- Daniel Lamar
  - Test Engineer
  - Report Manager
- Shivam Vashi
  - Chief Engineer- Software

# Future Plans

- Begin large scale integration
- Complete testing on integrated components i.e. energy harvesting system
- Begin software testing i.e. GUI, room generation, multiplayer functionality
- Design PCB, casing, and the layout of the device components
- Debug prototype and finalize the project design.

# Any Questions?

# Energy Harvesting - Buttons



# Energy Harvesting Testing

1. Energy Harvesting Button & Rectification
   a. Set up an energy harvesting button into a full-wave diode rectifier.
   b. Connect the output of the rectifier to a capacitor (C).
   c. Start at zero volts on the capacitor and push the button as fast as possible for x amount of time.
   d. Measure the final voltage (V) on the capacitor after time has stopped.
   e. Obtain the energy produced using E=0.5CV2 and the resulting average power using P=Etime.
   f. Perform steps a through e for multiple trials using various capacitance values and amount of time to obtain a set of power produced.
   g. Average the set of power produced from each trial to obtain a final average power for the energy harvesting button.

1. Crank Generator & Rectification
   a. Setup crank generator in a circuit with full-wave 3-phase rectification
   b. Connect capacitor to output of rectifier
   c. Have a user crank generator at different RPM rates including smallest, average, and maximum RPM.
   d. With an initial state of zero volts on the capacitor, crank generator at different speeds for x amount of time.
   e. Measure the final voltage (V) on the capacitor when the time limit is reached.
   f. Obtain the energy produced using E=0.5CV2and the resulting average power using P=Etime.
   g. Repeat steps a through f using different speeds as well as different users to obtain a set of power outputs.
   h. Average the set of power produced from each trial to obtain a final average power for the crank generator.