Dynamic Seat Cushion

Electrical & Computer Engineering

Team 34

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in collaboration with Dr. Golecki, Jason Robinson, and Isaiah Rigo

04 December 2023

INTRODUCTION

Our team

Introduction to our Team

Angelica Fu
Electrical Engineering
Focus: Sensor array, PCB, Final Assembly

Anthony Cruz Macedo
Computer Engineering
Focus: Sensor Array, Microcontroller

Eric Cheng
Electrical Engineering
Focus: Pneumatic Controller, Gas Control

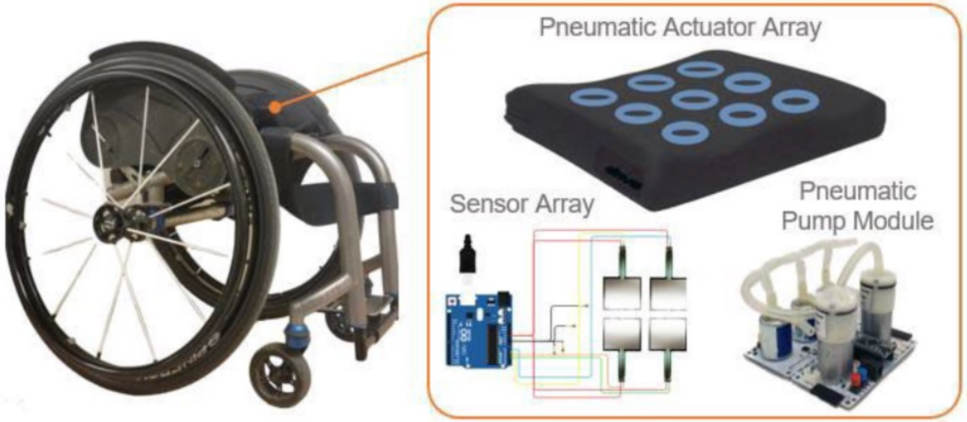
OBJECTIVE

What is the problem? What is our solution?

~3 million people develop pressure sores every year, with over 500,000 cases requiring extended hospitalization.

- Wheelchair users face higher risk
- Those with limited mobility and/or sensation struggle with manual readjustments and/or feeling when a readjustment is necessary

While conventional cushions provide some relief, the solution they offer is static, limited, and does not eliminate the risk of pressure sores due to its inability to adapt to the user.



Dynamic Seat Cushion

Our solution uses a combination of resistive sensors, a pneumatic controller, and thermoplastic polyurethane bladders to create a dynamic seat cushion that will relieve pressure for wheelchair users.

- Collaboration with Dr. Golecki's research group
- Electronics portion: sensor array, user interface, inflation, microcontroller

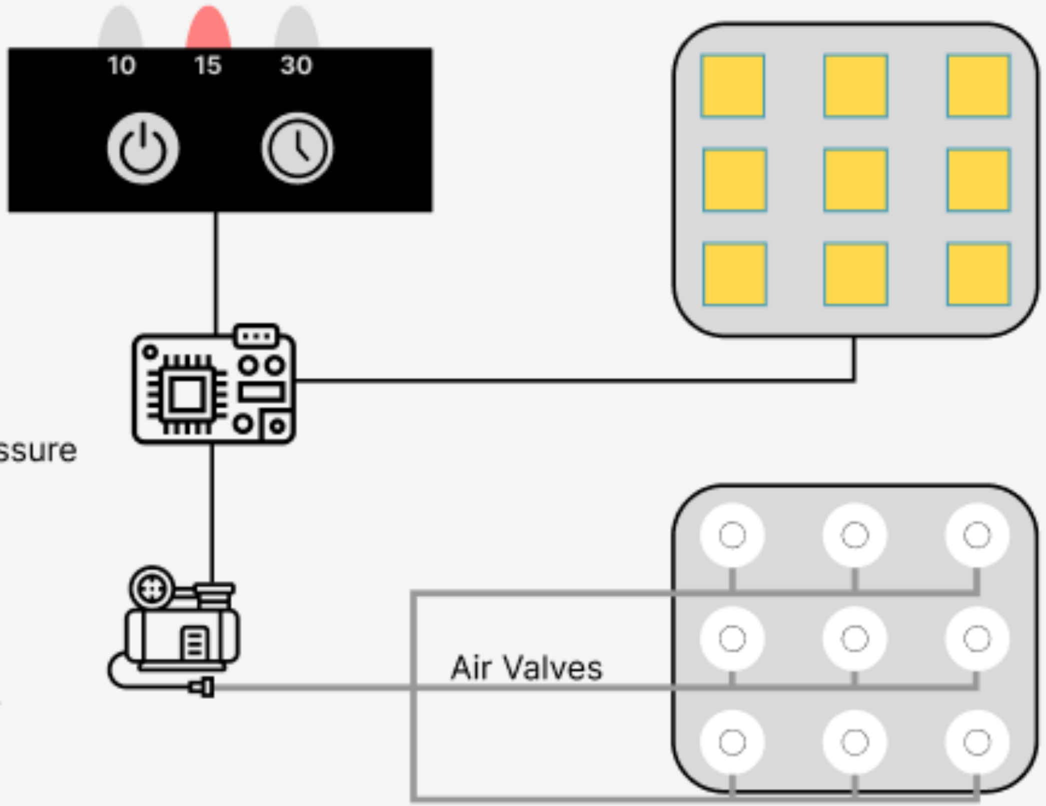
DESIGN

Design overview and functional blocks

1. LEDs/Buttons User Interface
- **(1)** power on/off
- **(2)** toggle time threshold

2. PCB/Microcontroller
- takes user input controls
- stores user preferences
- processes sensor array pressures
- measures time duration for high-pressure signals from FSR Array
- sends controls to air pump

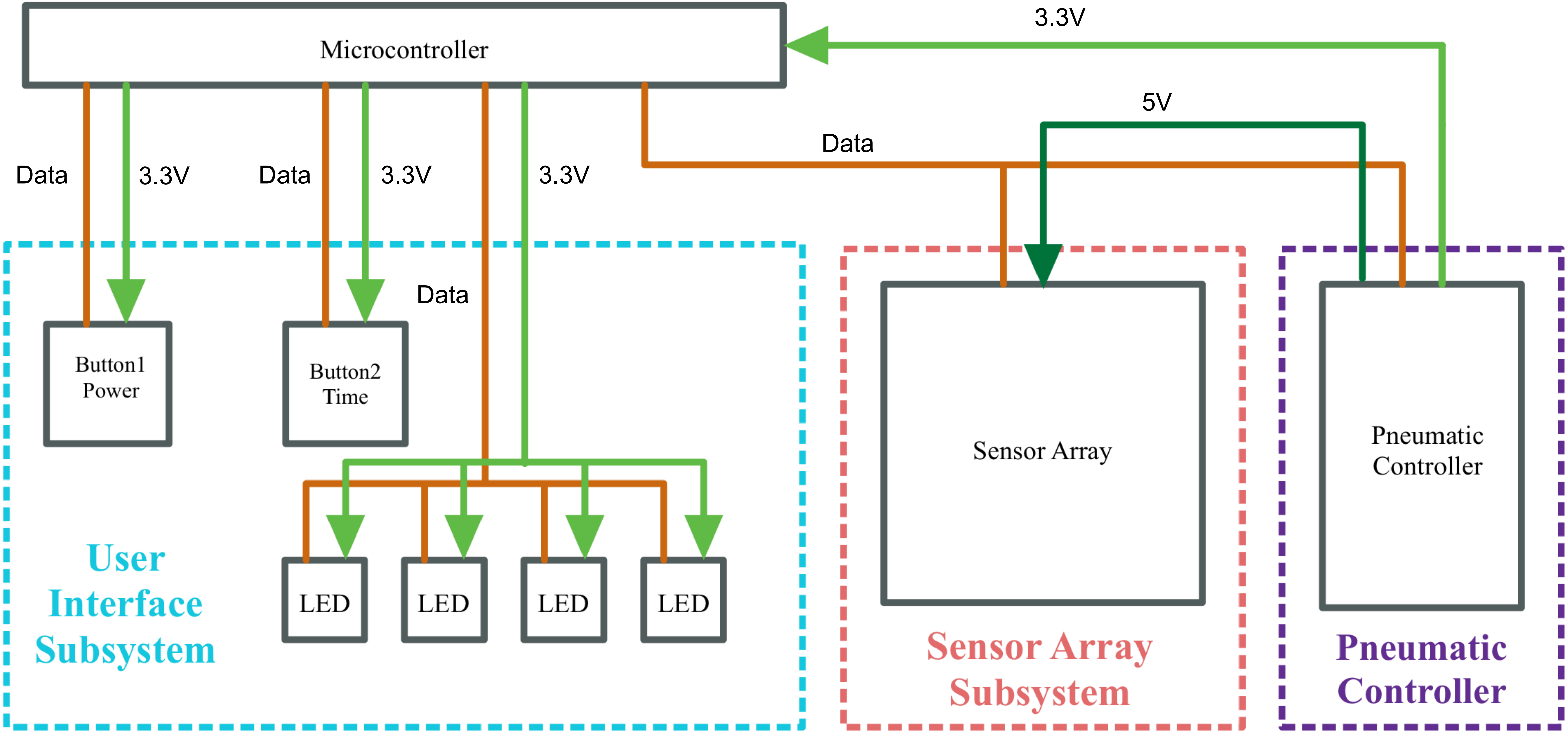
4. Air Pump
- inflates/deflates areas of the cushion bladder as instructed by the Microcontroller



3. Force-Sensing Resistor Array
- reads the seat's surface pressures
- sends readings to PCB for processing, which are relayed to Microcontroller for actuation as needed

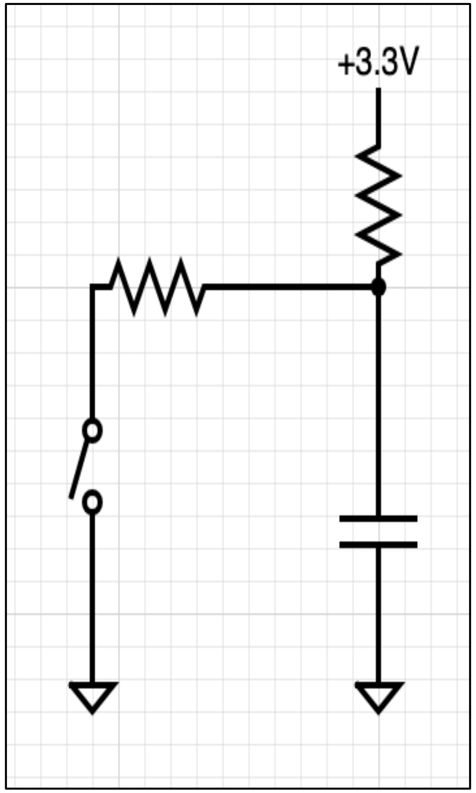
5. Inflatable Cushion Bladder
- connects to Air Pump
- mechanically inflates/deflates in areas as determined by the Microcontroller and regulated by the Air Pump

Dynamic Seat Cushion Functionality Overview

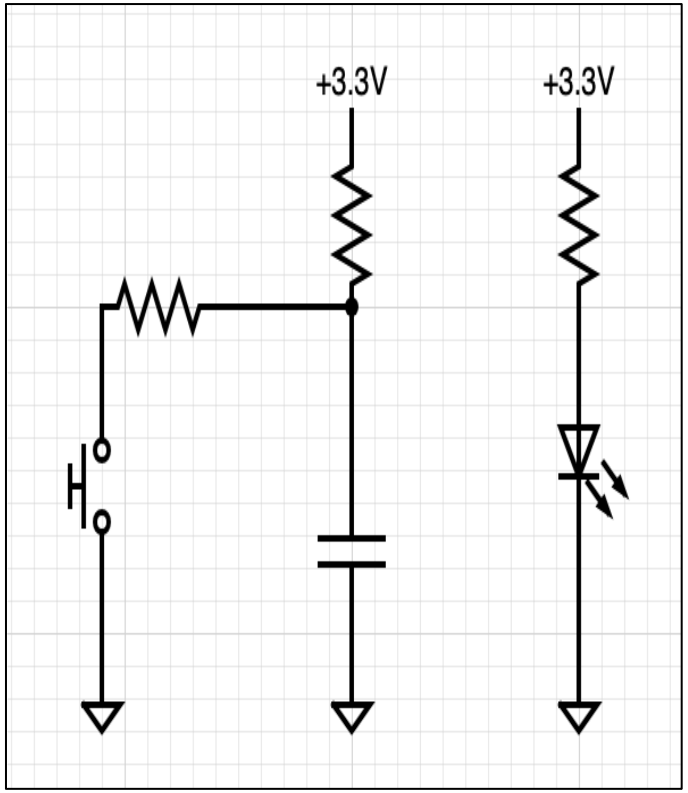


Block Diagram

User Interface Subsystem



Power Switch



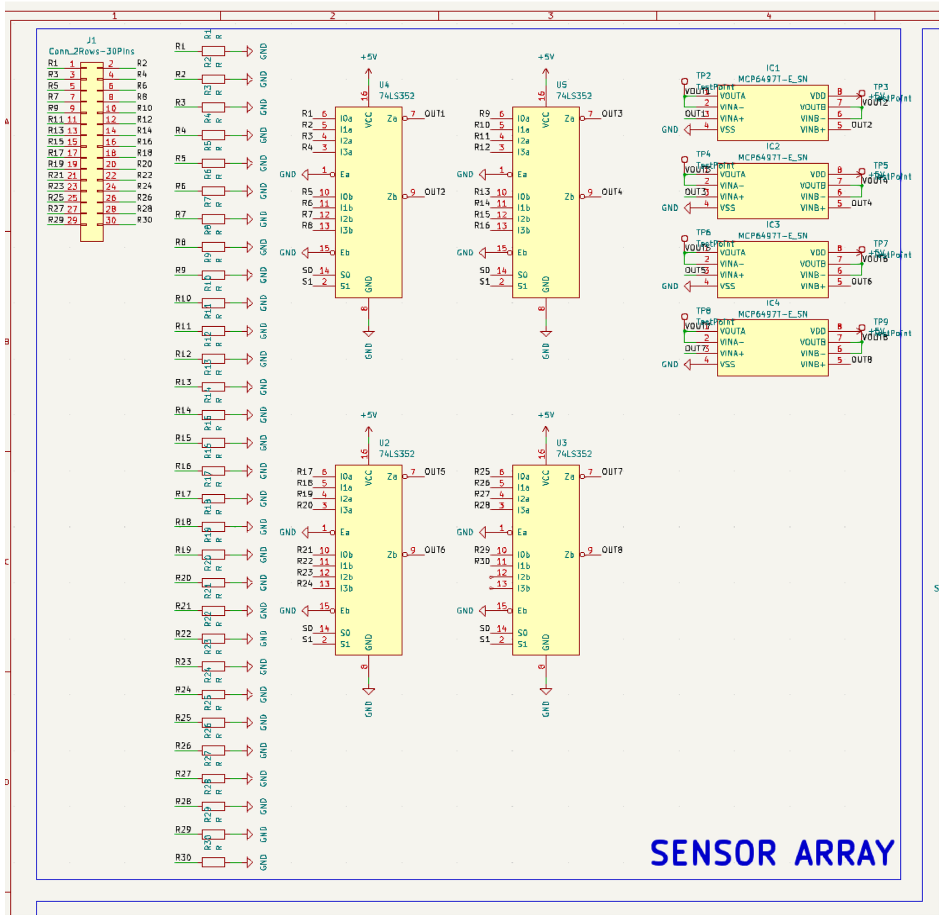
Time/LED Toggle Button

UI Functionality

1. Power the device on/off
   - Physical power switch opens/closes microcontroller's line to supply voltage

2. Toggle through time threshold options
   - GPIO pin detects rising edge to toggle between time threshold options and corresponding display LEDs

Sensor Array Subsystem



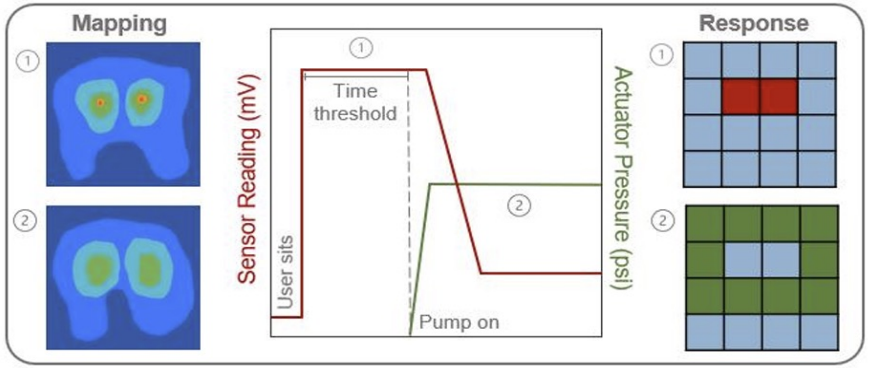
6x5 Force Sensing Resistor Array

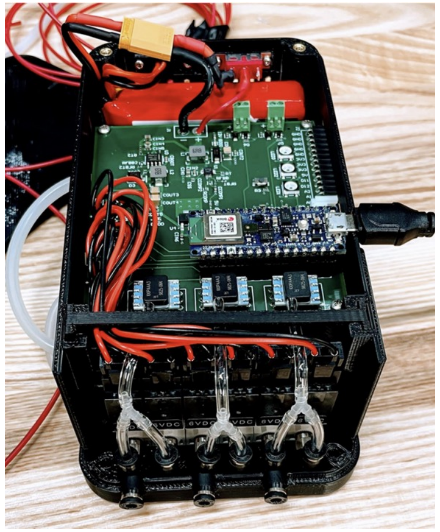
→ Supply 5V
→ Read voltage at each FSR
→ Compute and store averages over each inflatable region
→ Compare values to time and pressure threshold criteria
→ Actuate in corresponding regions as necessary

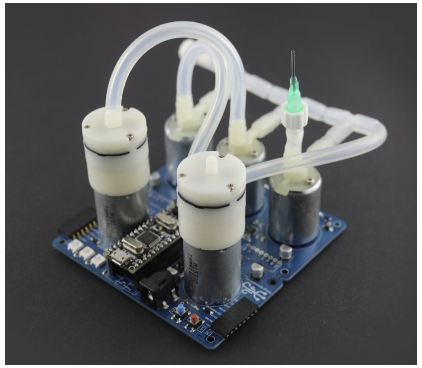
Microcontroller Implementation Details

1. Scan eight outputs four times with ADC peripheral, calculate reading at each sensor
2. Stores and compare previous readings
3. If time and pressure thresholds are both met, signal pneumatic controller to actuate region

Pneumatic Controller Subsystem





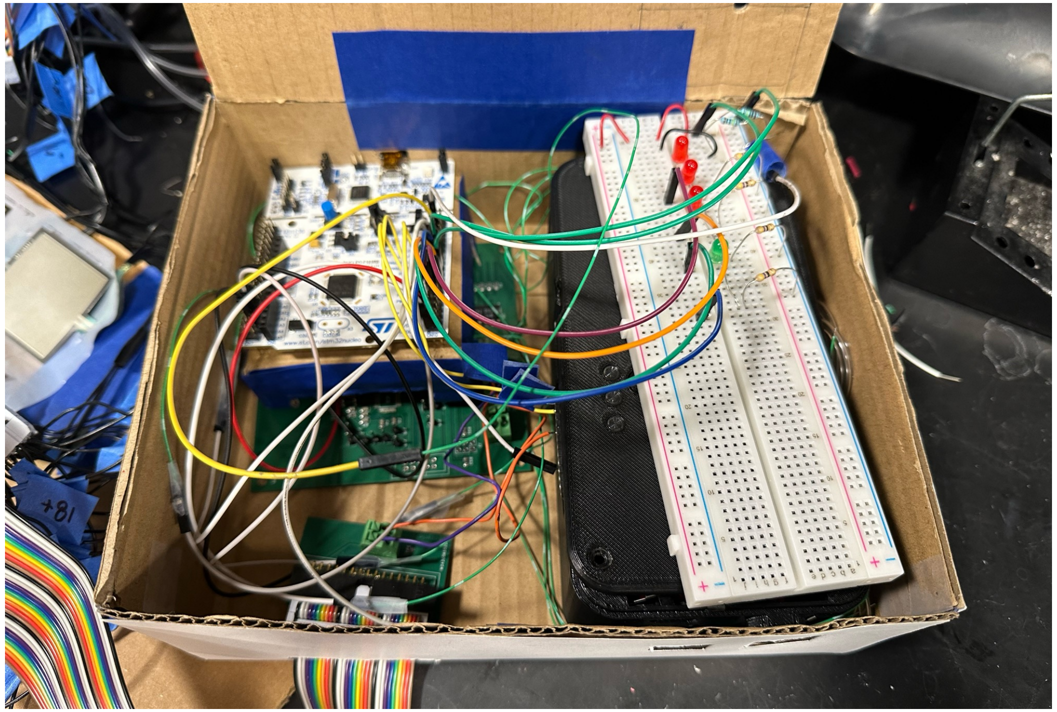


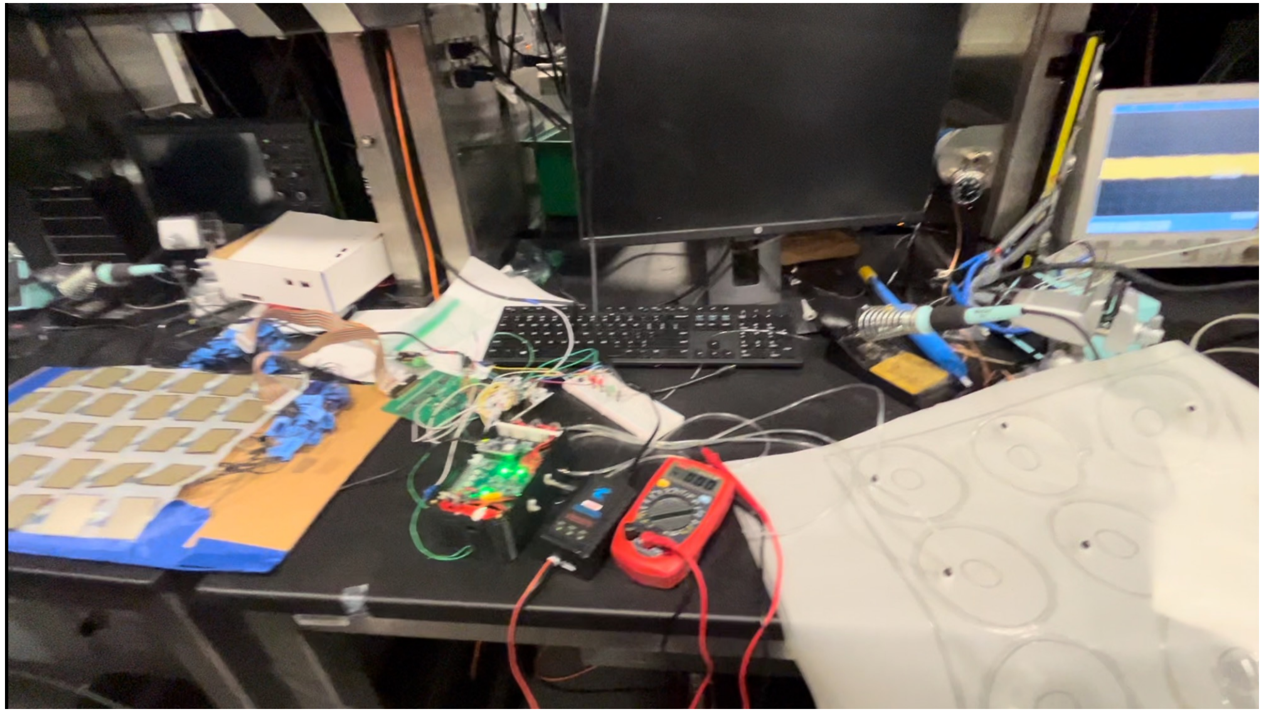
	Pneumatic Controller	Programmable Air
Power Delivery	10000mAh 3.3V / 5 V	Need BMS 3.3V / 5V
Pump Power	Two Pumps More internal gas leakage	One Pump
Versatility	3 Programmable Valves	2+1 Programmable Valves
Size	Bigger and Heavier	Compact
Communication and Time Threshold management	I2C + Digital	Digital
Pressure Control	Individual valve Pressure Readings	Central Pressure Readings

BUILD

Project build and functional test results

Visual





Requirement and Verification: Sensor Array Subsystem

Requirements	Verification
FSR array avoids saturation up to 2kg per FSR in normal use.	1. Using a voltmeter or oscilloscope, probe the Vout of the FSR voltage divider and ground. 2. Place a 2kg weight on FSR, nothing on other FSRs. 3. Record probe reading. 4. Place a 100g weight on top of the 2kg weight. 5. Record probe reading and verify a difference of at least 50mV 6. Repeat for every single FSR in the array.
Microcontroller instructions for bladder inflation operate within 100ms of each other.	1. Using the oscilloscope, probe the individual bits of bladder inflation opcode (3-bit) from the microcontroller and ground. 2. Reset the opcodes to 000 3. Place weight on FSR array to initiate opcode change to 111. 4. Record and verify the time from the initial bit change until the last bit change is under 100ms. 5. Reset the opcode to 000. 6. Record and verify the time from the initial bit change until the last bit change is under 100ms.

Requirement and Verification: UI Subsystem

Requirements	Verification
On/Off functionality through the user-controlled switch.	1. Using an oscilloscope, probe the output of the voltage regulator and ground. 2. Click the button. 3. Verify if the system is on by probing areas and checking for voltage.
User is able to cycle through the default time thresholds with Button 2 and the time is correct.	1. Turn the power on. 2. Click Button 2 and visually see if the time setting increases (LED light for next time is on from 10, 15, 30 one after the other and then back to 10). 3. Double-check each time setting is accurate to the time by using a timer: a. Place a heavy object on a sensor. b. Wait the duration of time with a timer. c. Check if the output of the microcontroller (inflate/deflate signal) is HIGH.

Requirement and Verification: Pneumatic Controller Subsystem

Requirements	Verification
The system must provide a stable supply of 3.3V (±0.1V) and 5V to the microcontroller, sensor array, and the User Interface Subsystem.	1. Connect the output of the voltage regulator to a load on a separate test breadboard which is also connected to the ground. 2. These are the loads that will be used for verification: 1kΩ, 2.5kΩ, 10kΩ resistors 3. Probe the output of the voltage regulator and ground using an oscilloscope. 4. Record voltage drop readings across the load.
Air pump draws less than 10mA of current when not in operation	1. Add weights to initiate air module pumps. 2. Reset opcode to 000 by removing all weights. 3. Use a multimeter to measure and verify current through the pump resistor is less than 10mA. 4. Record results

RESULTS

Our successes, failures, and why

Successes and Failures

Successes

Overall

- Works! (with development board)

Sensor

- Detects pressure reliably

Pneumatic Control

- Microcontroller based control
- Pressure based control

Failures

Overall

- Microcontroller on PCB

Sensor

- MUXs read inverted HIGH or LOW

Pneumatic Control

- Gas leakage (valve has gas leakage)

CONCLUSION

What we learned

What we learned

Design	Build	Overall
PCB designing + routing	Soldering	Process of making a project from start to finish
Choosing parts/components through assessing our requirements	Integrating different parts together	Technical writing and presenting
Meeting needs of research group while making it feasible	Debugging and using isolation	Collaborating with different groups

IEEE Code of Ethics

1. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others.
2. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations
3. To treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression

Safety Concerns and Precautions

1. Battery Failures
2. Circuit Failures
3. Air Pump failures

We hope to continue working with Dr. Golecki and her research group.

- Polish and redesign PCB to optimize functionality
- Professionally package the circuit parts for user experience
- Fully put project together with all the bladder from research group
- Collaborate with research group to write research paper.

Thank you

The Grainger College of Engineering

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