# C.O.R.E.

Controller for Organic Range of Exoskeleton

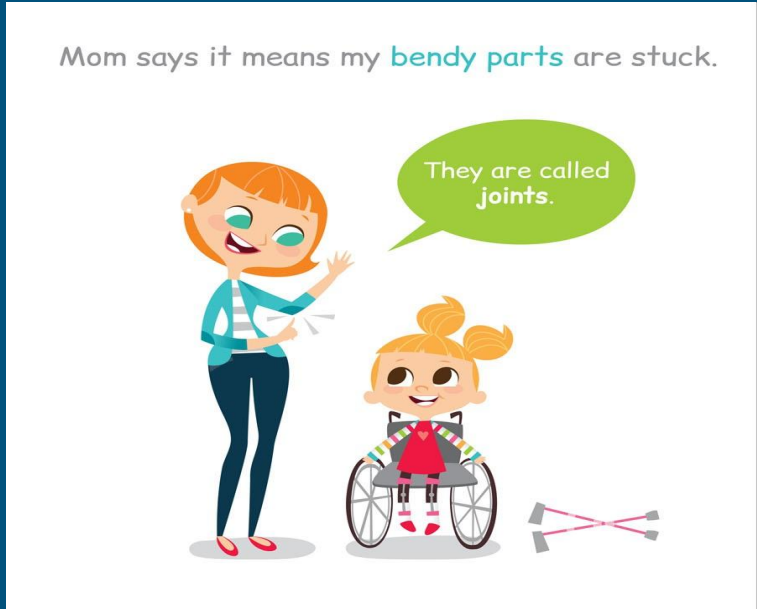
## Group 14


| | |
|---|---|
| Daniel Reveron | Electrical/Computer Engineering |
| Brandon Johnson | Computer Engineering |
| Kelvin Feliciano | Electrical Engineering |
| Gavin Bell | Electrical Engineering |


limbitless SOLUTIONS

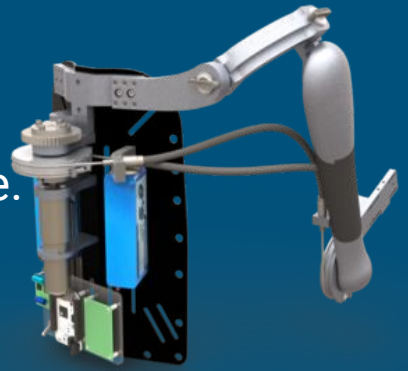
# Arthrogryposis Multiplex Congenita

- Condition that occurs at birth.
- Characterized by contracture in the curvature of joints.
- These joints do not move fluently.
  - May degenerate to muscular dystrophy.
- Particular patient in wheelchair.
  - Patient needs assistance to eat.



# Introduction

- Hybrid design that combines pneumatics with cable drive.
  - First of its kind.
  - Pneumatic actuation glove.
  - Bowden cable elbow.
- Assistive system that will provide functionality.
  - Patient will not need assistance to eat when working.
- Possibility for optimization.
  - Originally built for wheelchair scenario.
  - Reuse of components for optimization.
- **Team in charge of electrical framework.**
  - Some mechanical components for integration.



# Roles

| | |
|---|---|
| Daniel Reveron | Systems Lead |
| Brandon Johnson | Software Lead |
| Kelvin Feliciano | Hardware Lead |
| Gavin Bell | Electro-Mechanical Interface Lead |

| | EMGs | PCB | Microcontroller | Pneumatics/ Motors | Power | Software | Administrative | Integration/Test Rig |
|---|---|---|---|---|---|---|---|---|
| Daniel | 1 | 1 | | | | 2 | 1 | |
| Brandon | 2 | | 1 | | | 1 | 2 | |
| Kelvin | | 1 | | 2 | 1 | | | 2 |
| Gavin | | | 2 | 1 | 2 | | | 1 |

# Agenda

- ➢ System Overview
- EMG / Input
- Actuation / Output
- Software
- Hardware
- Integration and Testing
- Administration / Risk / Schedule

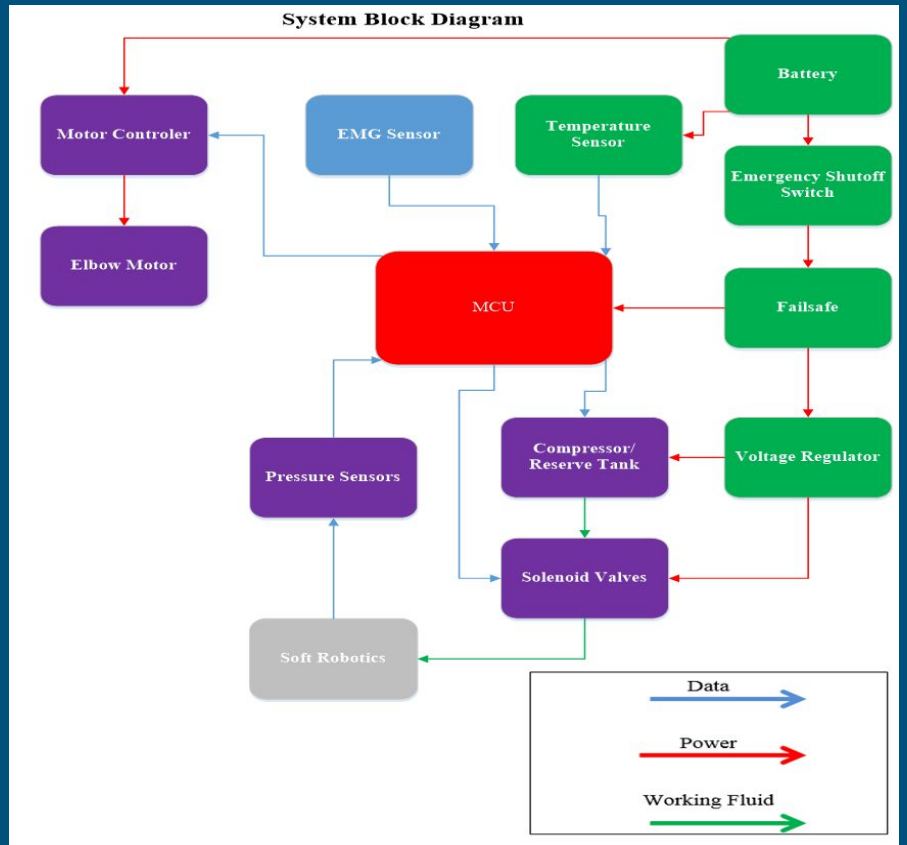
# Requirements

| Req. # | End-User Requirement Statement |
|---|---|
| EU.1 | The system shall not jeopardize user's safety |
| EU.2 | The system shall provide a fast response time to simulate human motion |
| EU.3 | The system shall be easy to install and remove |
| EU.4 | The system shall be durable to adapt to human lifestyle |
| EU.5 | The system shall be stable |

| ENG # | Engineering Requirement |
|---|---|
| ENG.1.1 | The system shall not exceed a temperature of 48 °C for components that are in direct touch with the user |
| ENG.1.2 | The pneumatic hand system shall maintain a reserve tank pressure between 25 and 40 psi at equilibrium |
| ENG.2.1 | The system shall be able to adjust its input signal detection criteria in a user-by-user basis |
| ENG.2.2 | The pneumatic hand sub-system shall maintain a pressure between 10 and 15 psi in hand actuator section while in the closed state |
| ENG.2.3 | The pneumatic hand sub-system shall maintain a pressure of between 0 and 1 psi in hand actuator section while in the open state |
| ENG.3.1 | The calibration of the electrical system for a daily basis use shall not exceed 5 minutes |
| ENG.4.1 | The system shall allow the user to reset the controls to their initial state in case a deadlock occurs |
| ENG.4.2 | The elbow motor shall be able to rotate clockwise and counterclockwise in 45 degree increments to an accuracy of +/- 5 degrees |

# System Design Overview

- Top-down design.
- Color-coded.
  - Blocks.
  - Arrows.
- All members involved in the system.




Daniel

Kelvin

Brandon

Gavin

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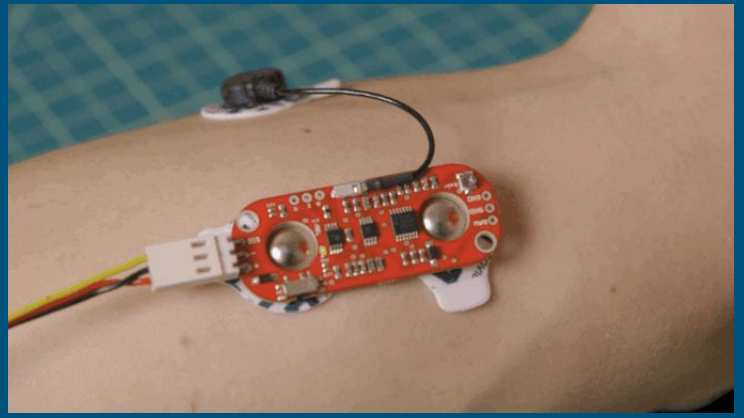
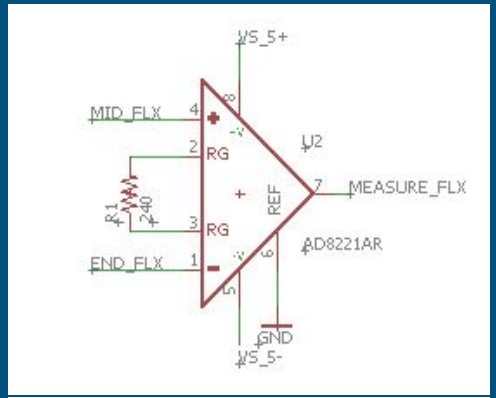
# sEMG Sensors



- Stands for surface ElectroMyoGraphy.
- Reads the potential produced by muscle.
  - Signals are produced by the brain and travel from nervous system to muscle fibers.
  - Muscle fibers receive signal and contract in an excitation state.
- A signal will be detected by a muscle contraction.
  - Signal will be read by microcontroller and analyzed.
  - When the muscle signal is significant enough, an actuation will occur.
  - Each muscle will have an EMG sensor dedicated to a different actuation.
    - Elbow - Flexion.
    - Elbow - Extension.
    - Hand - Open & Close.
- Sensors will be integrated into the PCB.

# Integrated EMG Sensor Stages 1, 2, 3, 4

1

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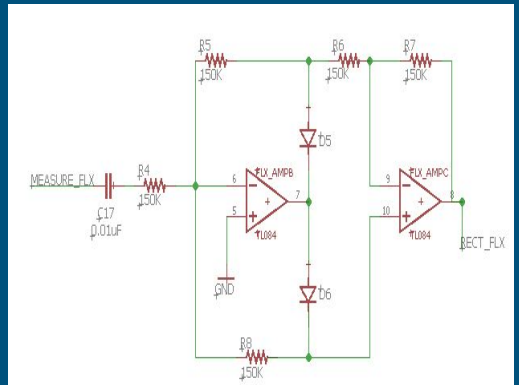


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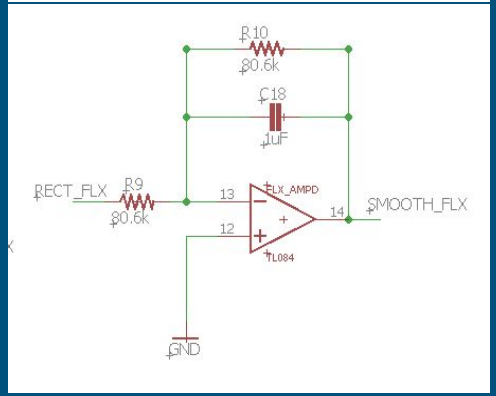


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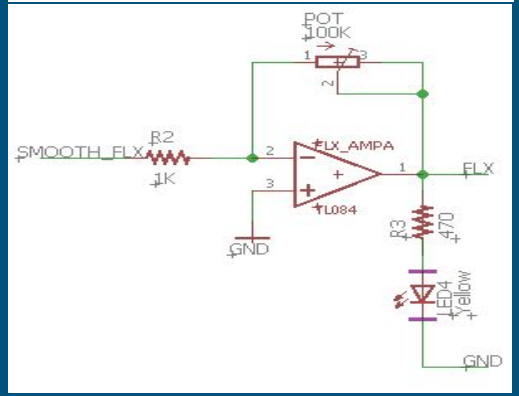

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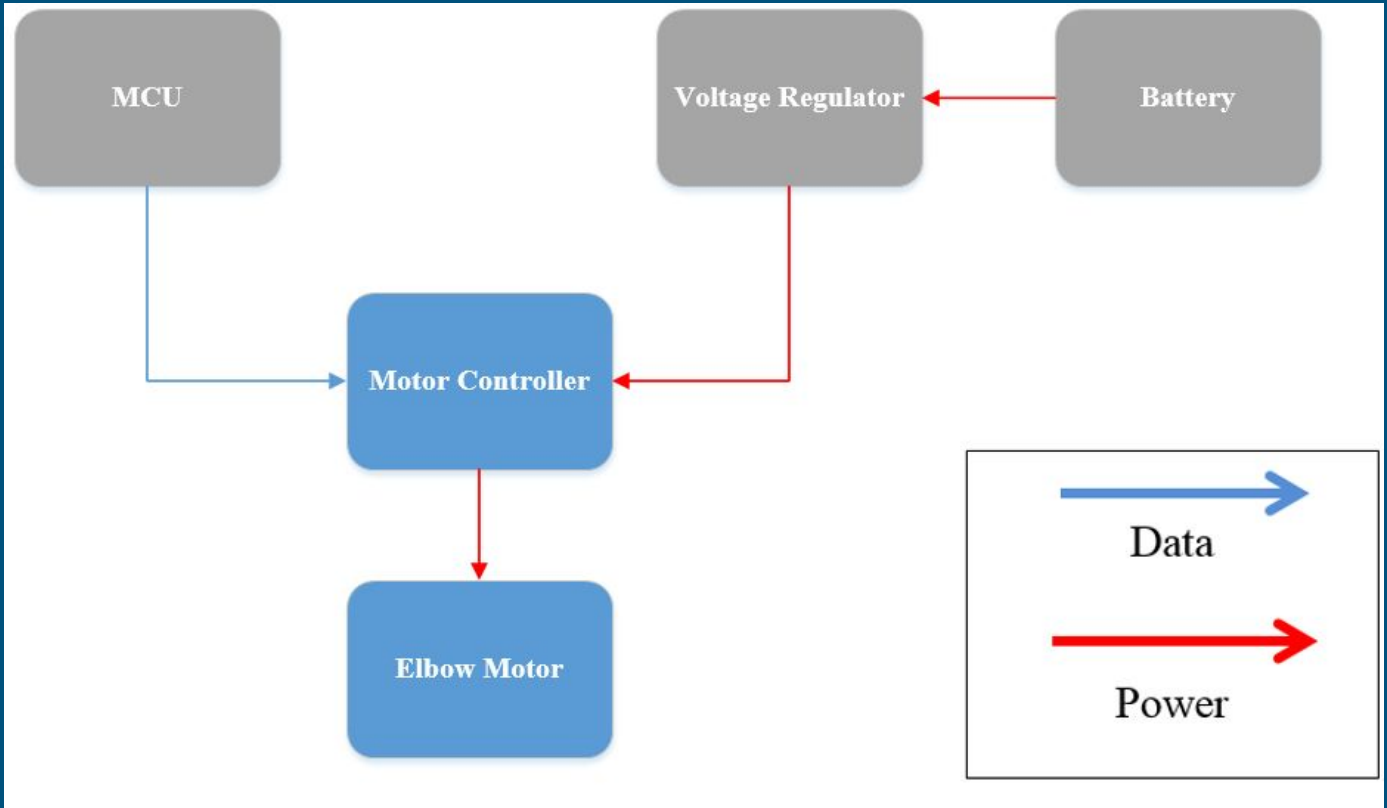
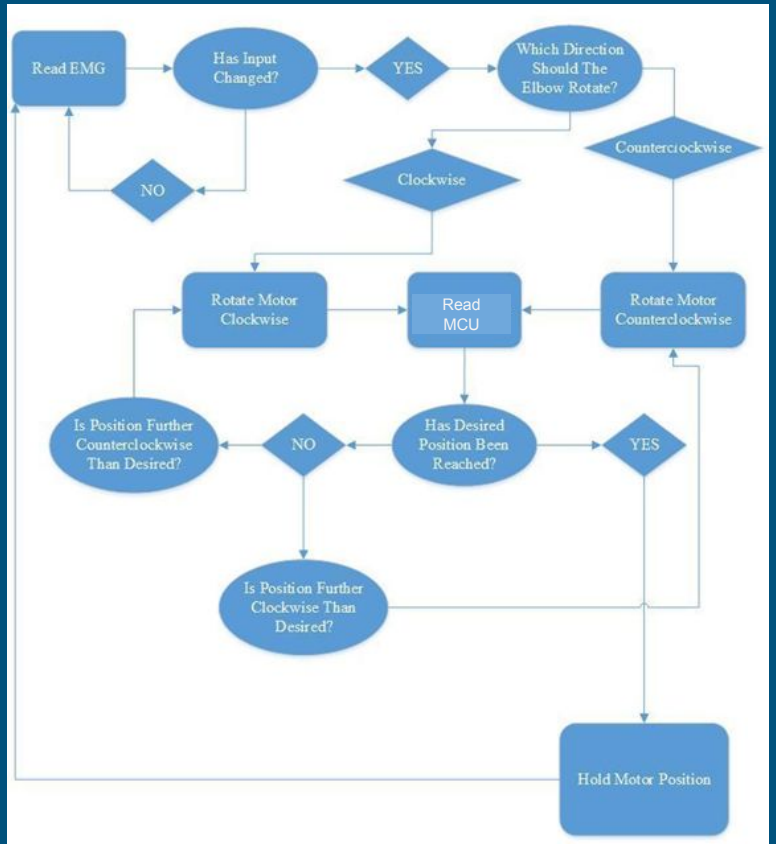
# Elbow System

# Elbow System Overview



# Elbow System Decision Tree

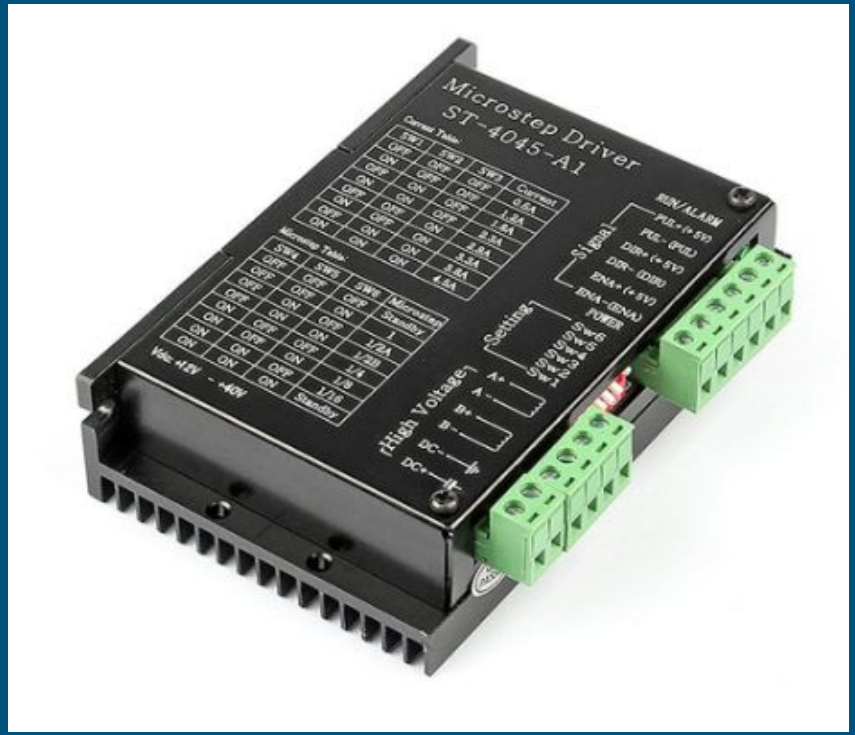


# Stepper Motor

- Nema 23 Motor
- 47:1 Gearbox
- Holding Torque: 29ft*lb
- Voltage: 24V-48V
- No load Current: 0.66A
- Current at 25ft*lbs Load: 1A
- Price Tag $65.23
- Manufactured By OMC Stepper Online

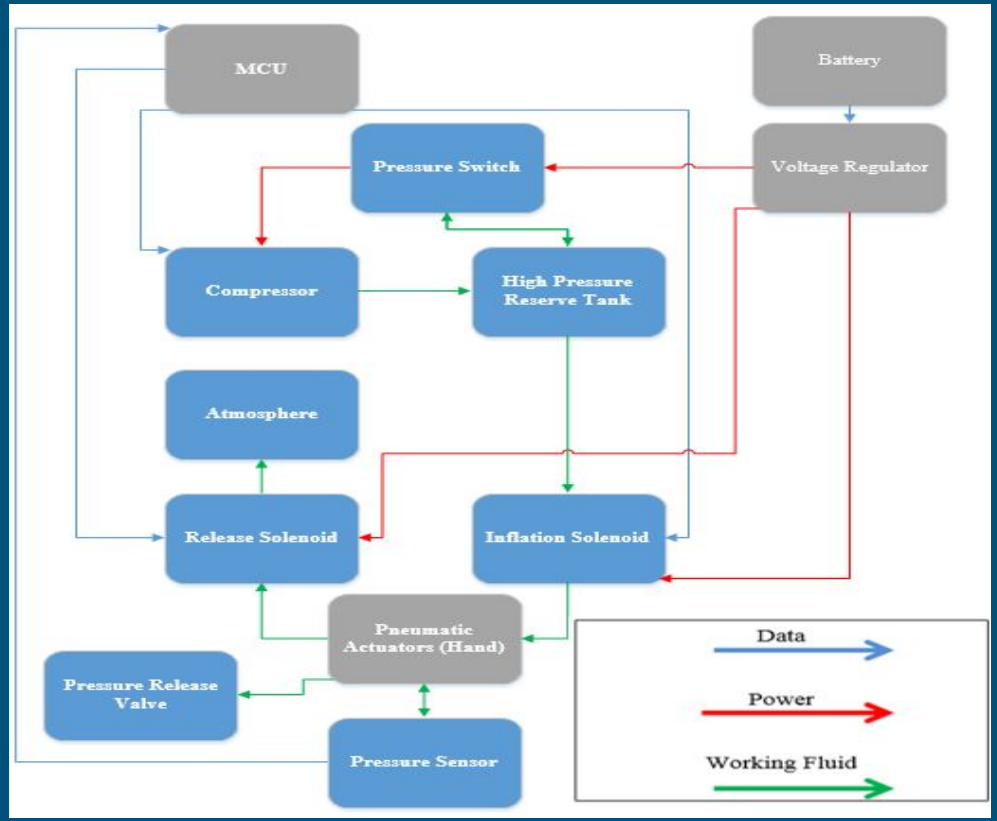
# Stepper Motor Driver

- SainSmart TB6600
- DC power input type: 12V-40V
- Output current: 0.6A-4.5A
- Adjustable overcurrent protection.
- Adjustable stepping.
- Price Tag $26.99
- Manufactured By SainSmart

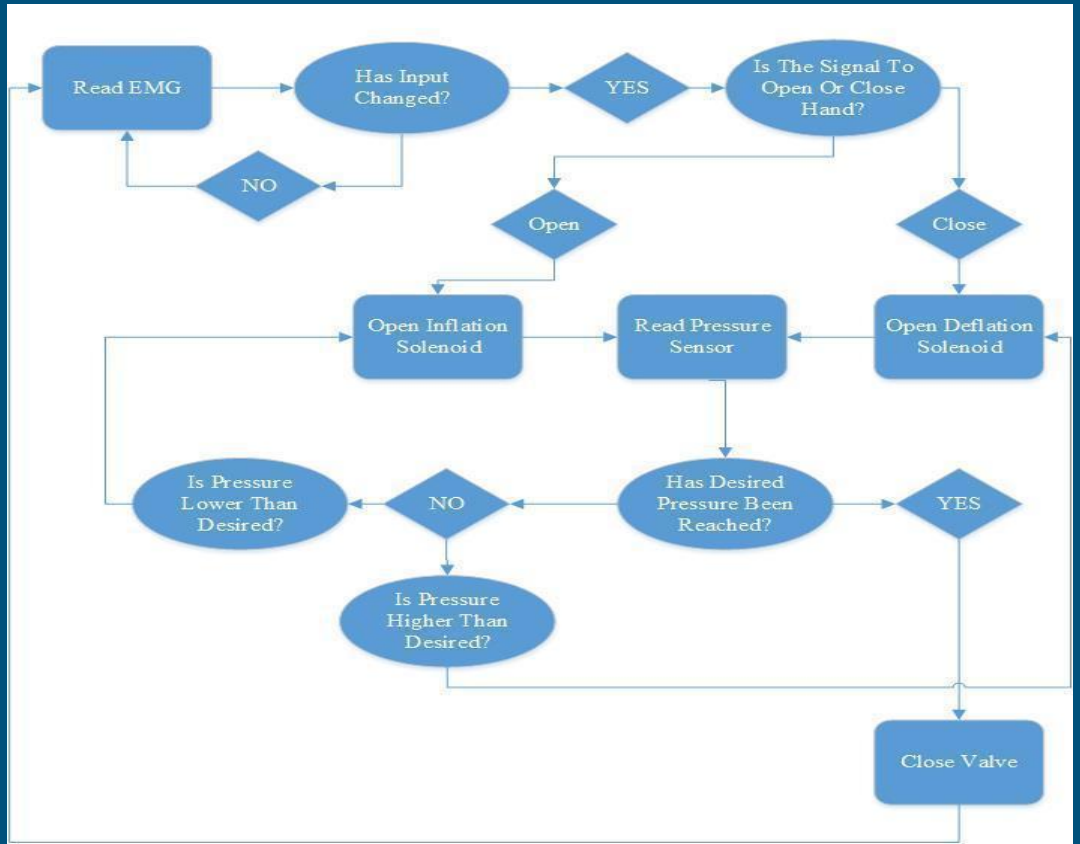


# Pneumatic Hand System

# Pneumatic System Overview



# Pneumatic System Decision Tree



# Pneumatic Pump

- Max Pressure: 58 psi
- Vacuum Pressure: -12 psi
- Voltage: 12V
- Power Consumption: 26W
- Price Tag $30.00
- Manufactured By Made in China Distributor

# Solenoid Valves

- US Solid Solenoid Valve
- Max Operating Pressure: 145 psi
- Voltage: 12V
- Power Rating: 4.8W
- Price Tag $11.77 per unit
- Manufactured By U.S. Solid

# Pressure Sensor

- Honeywell - PX3AN1BH100PSAAX
- Pressure Range: 0-100Psi
- Output Voltage: 0.5-4.5V
- Supply Voltage: 5V
- Price Tag w/cable $74.56
- Manufactured By Honeywell

# Pressure Switch

- Gems PS61-10-4MNZ-B-SP
- Pressure Adjustment Range: 10-60Psi
- Maximum Current: 0.8A
- Price Tag $28.74
- Manufactured By Gems

# Agenda

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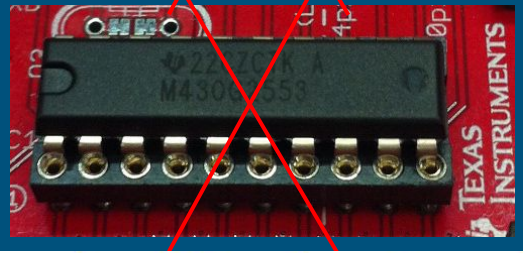
# Microcontroller

## ATMEGA2560

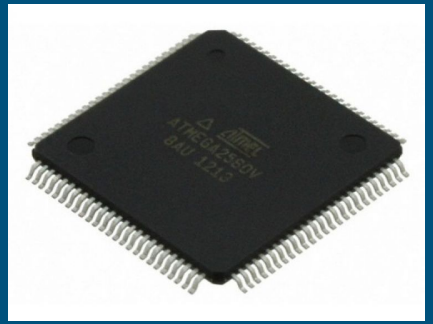
- Price: $10.91
- 256KB flash
- 8KB SRAM
- 16MHz
- 86 I/O pins
- UART
- Analog To Digital Converter

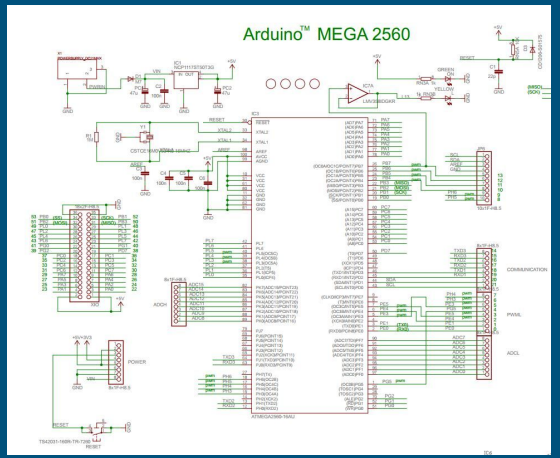



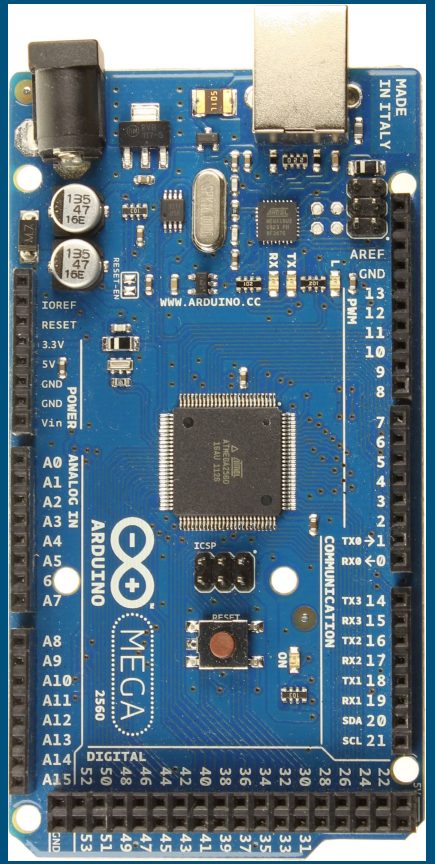

| Criteria | Importance Weight | ATMEL | | TI | |
|---|---|---|---|---|---|
| | | Rating | Weighted Rating | Rating | Weighted Rating |
| Ease of Use | 20% | 5 | 1.00 | 2 | 0.40 |
| Low Cost | 20% | 3 | 0.60 | 5 | 1.00 |
| # of I/O pins | 25% | 5 | 1.25 | 3 | 0.75 |
| Processing Speed | 15% | 4 | 0.60 | 4 | 0.60 |
| Availability of External Components | 5% | 5 | 0.25 | 3 | 0.15 |
| Power Needs | 5% | 4 | 0.20 | 5 | 0.25 |
| Large Community | 10% | 5 | 0.50 | 1 | 0.10 |
| Total | 100% | 4.4 | | 3.25 | |

# Microcontroller cont...

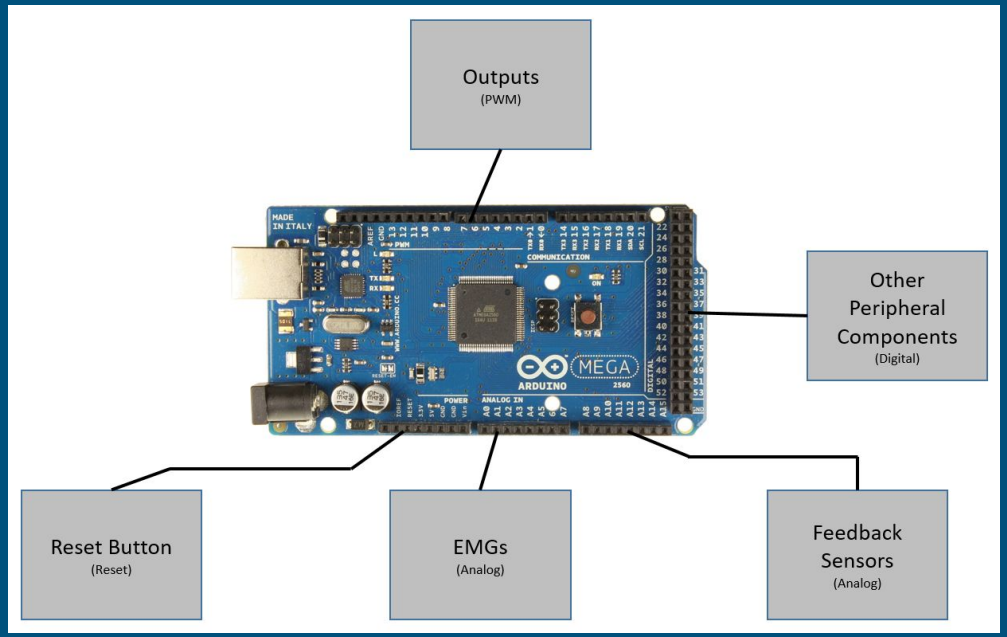
- Arduino MEGA 2560 for prototyping
- Required components built-in
- Easy to reprogram
- Simple to connect to breadboard
- Good for pin mapping

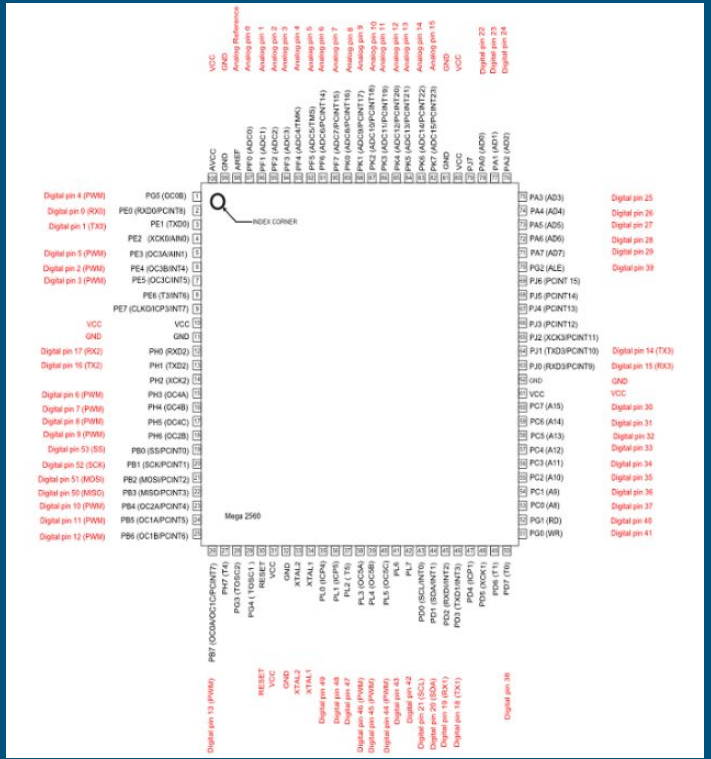




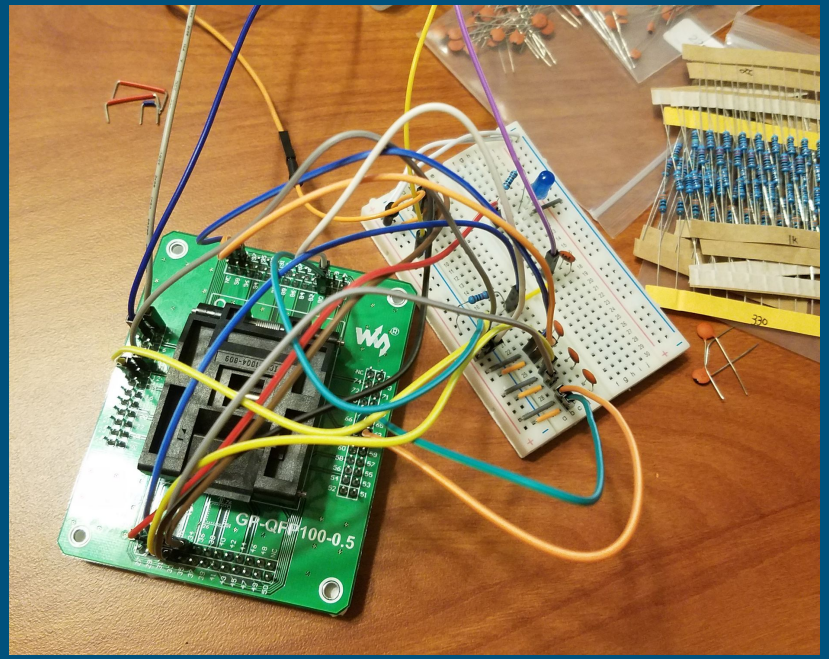
# Microcontroller Pin Mapping



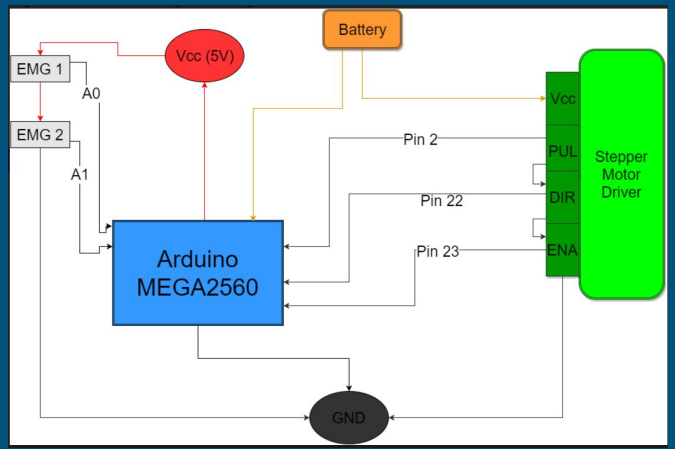
# Microcontroller Standalone

- Fully programmable.
- Burn bootloader in adapter.
- Pins on PCB for programming.



# Microcontroller Controls

- All controls will be routed through the microcontroller
- Input through EMGS
- Output through Motors and Solenoids



# Software Environment

- Written in C/C++
- Arduino IDE

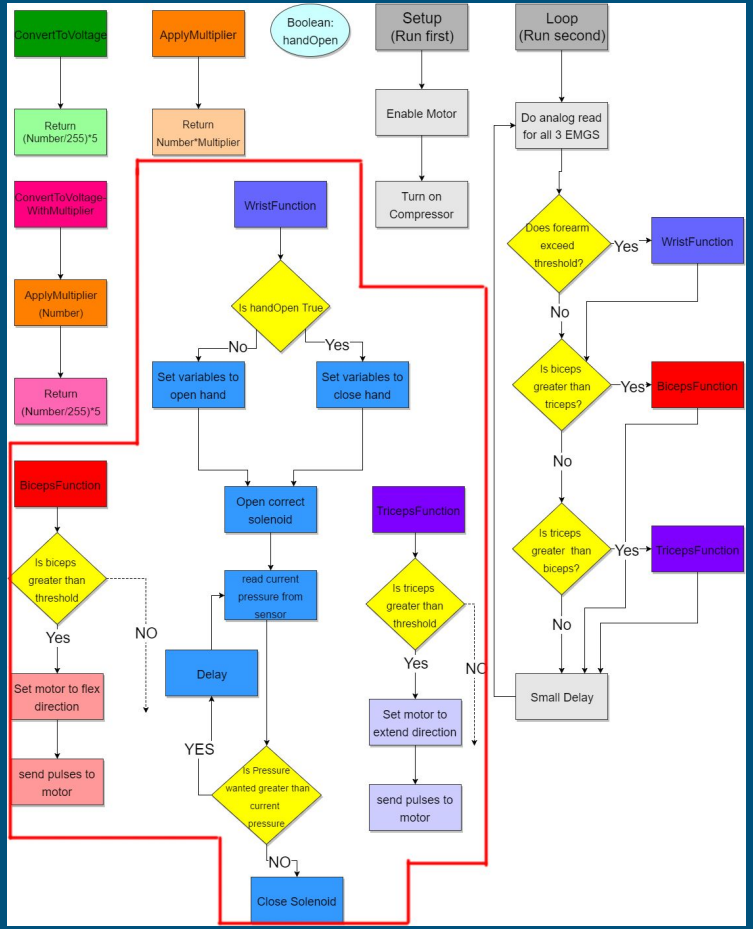
C/C++

- Must burn bootloader to chip
- Program with USB Module

ARDUINO™

# Software Control

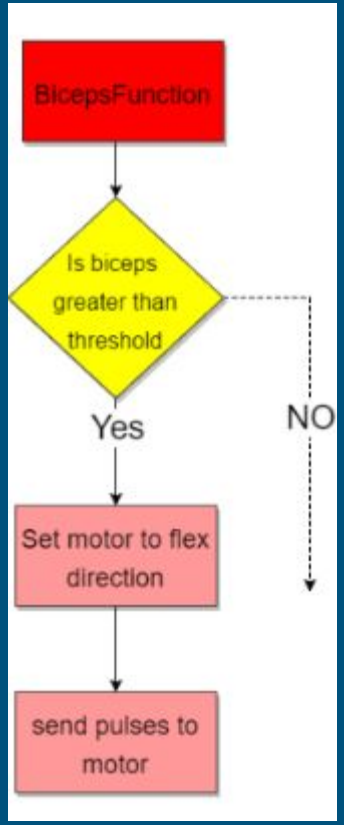
- Code listens for muscle movement by EMG Input
- If threshold surpassed generate output
- Wrist = Hand Control
- Biceps & Triceps = Elbow Control

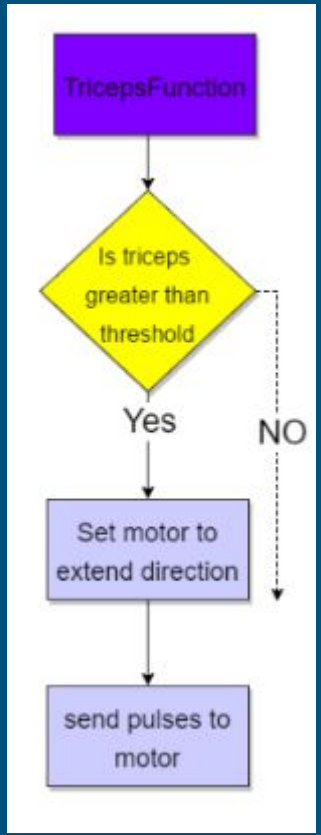


# Software Control cont...

Elbow Control

- Check if reading is over threshold
- Set direction of the motor
- Send pulses to motor

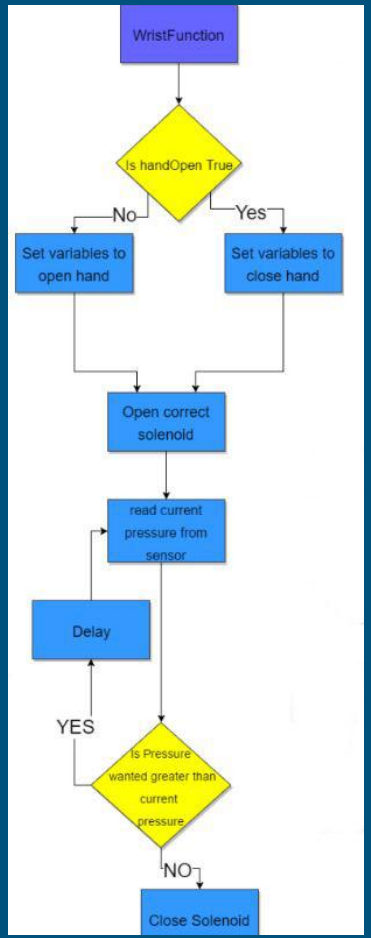


# Software Control cont...

Hand Control

- Determine if hand is to be opened or closed
- Open correct solenoid
- Wait until pressure is at appropriate level
- Close solenoid



# Agenda

- System Overview
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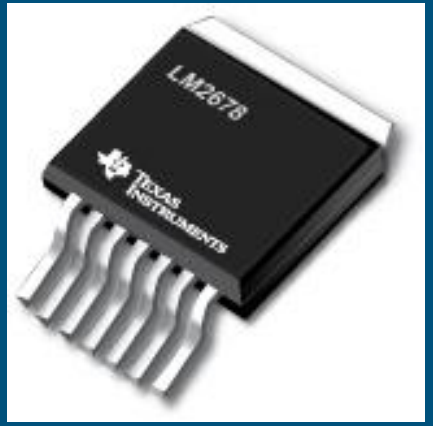
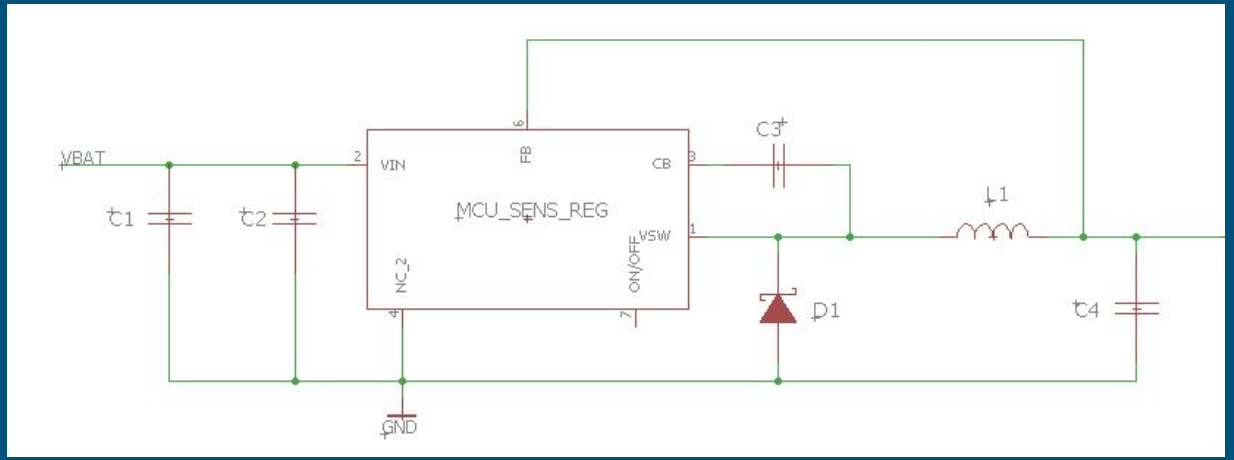
# Power

- LiFePO4 Battery
- 25.6V 6.6Ah (168Wh, 16A rate)
- Overcharge (> 31.2V)
- Over Discharge (< 16.0V)
- Over Drain (> 16 Amp)
- Short circuits

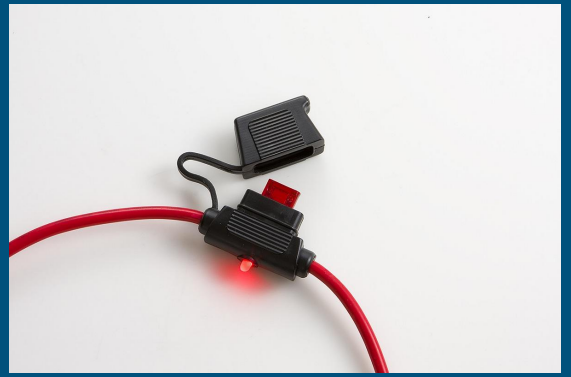
# Voltage Regulator

- LM2678 Simple Switcher with Integrated Switch
- Buck Converter
- Vin range 8V - 40V
- Vout range 1.23V - 37V
- Iout Max 5.0 Amp
- Efficiency up to 92%
- Enable pins



# Failsafes

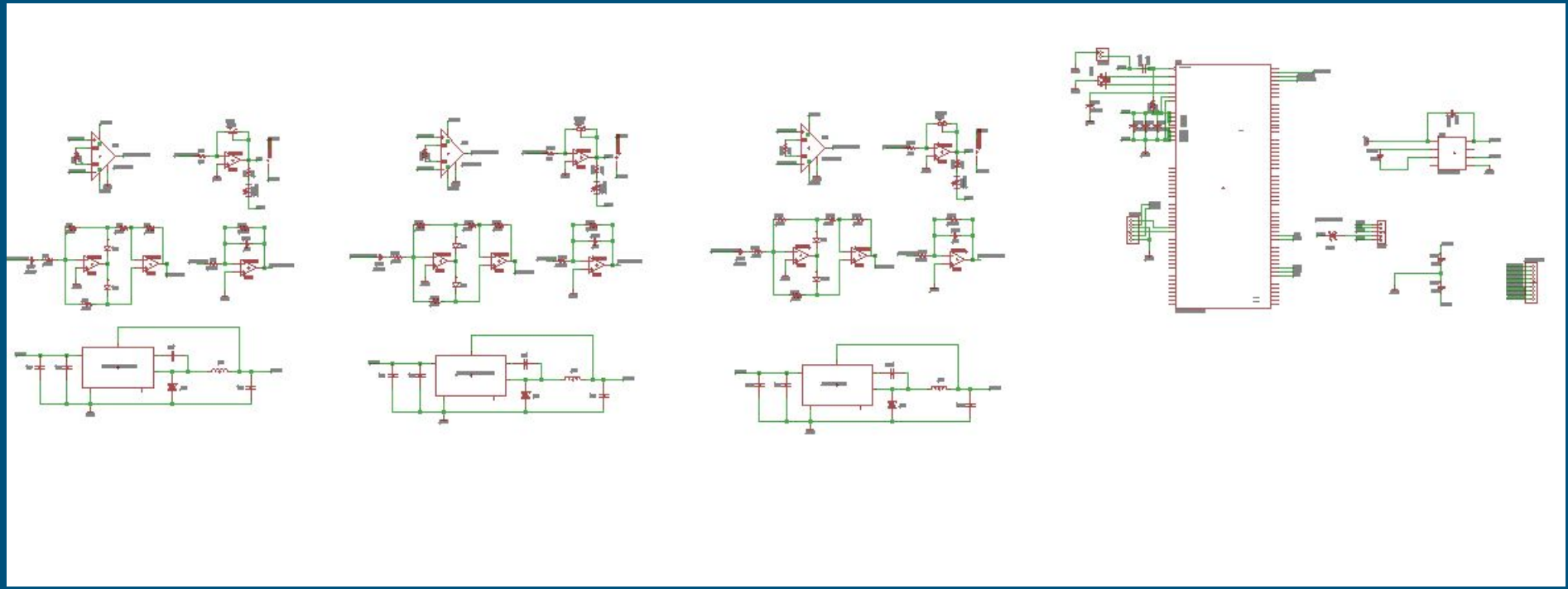


- Reset button used for resetting system.
  - In case of system instability.
- Team to discuss ergonomic implications.
  - Mechanical team to choose switches under C.O.R.E. constraint.

# PCB

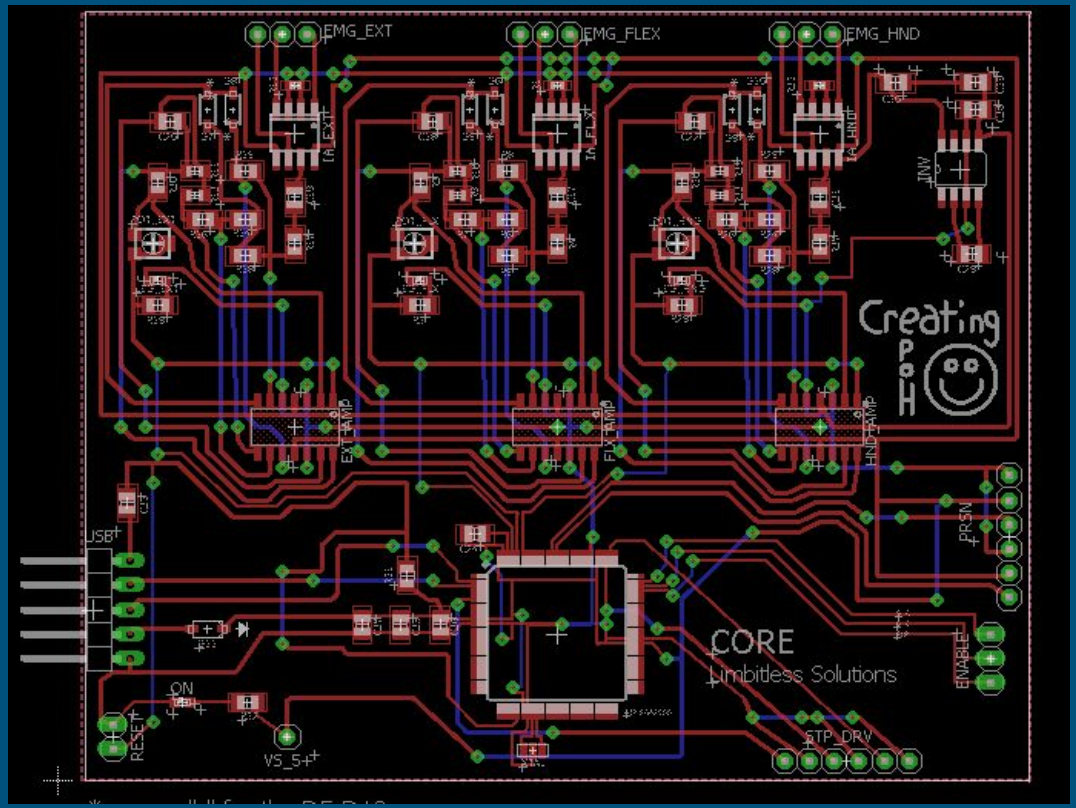
- 2 PCBs.
  - Numerous, large components.
  - Regulators in PCB 1.
  - MCU with Actuators and Sensors in PCB 2.
- Will use connectors for cleaner connections.
  - EMGs.
  - Sensors.
  - Stepper Motor Driver.

# PCB Schematic Overall



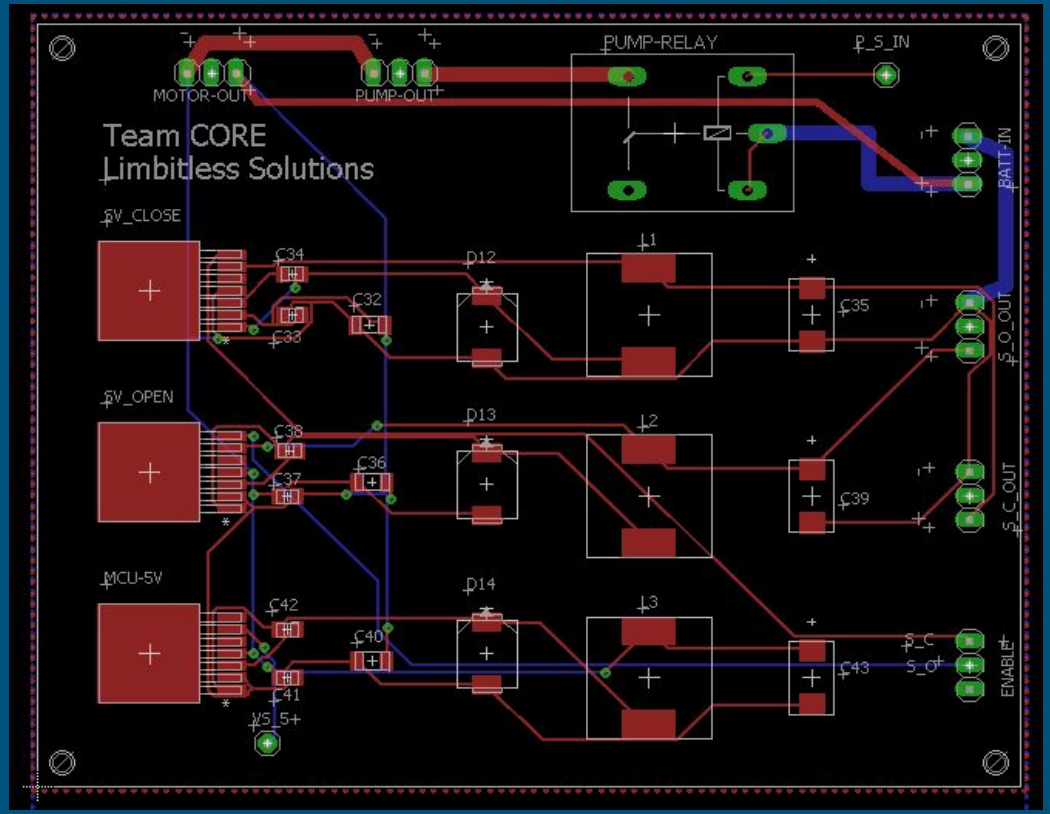
# PCB 1 - The Brain

- Deals with control system
  - Carries signals from EMG
  - Connects with pressure sensor
  - Controls stepper motor driver
  - Contains MCU and USB ports
- Interfaces with Heart PCB
  - 5V to power components
  - Enable signals for regulators



# PCB 2 - The Heart

- Deals with the power system.
  - Distributes power to components.
  - Regulates voltage.
    - 12V for Solenoid Valves.
    - 5V for MCU.
- Interfaces with Brain PCB.
  - Enable pins for Solenoid Valves.
  - MCU receives constant power.
- Contains extra connections.
  - Pressure switch and relay.



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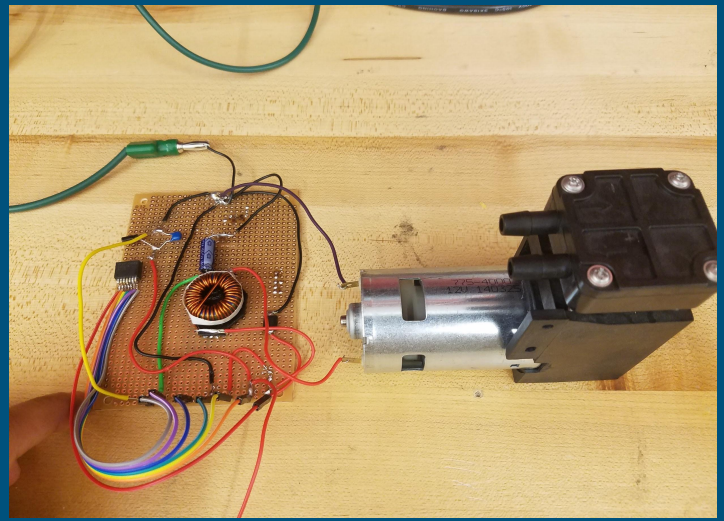
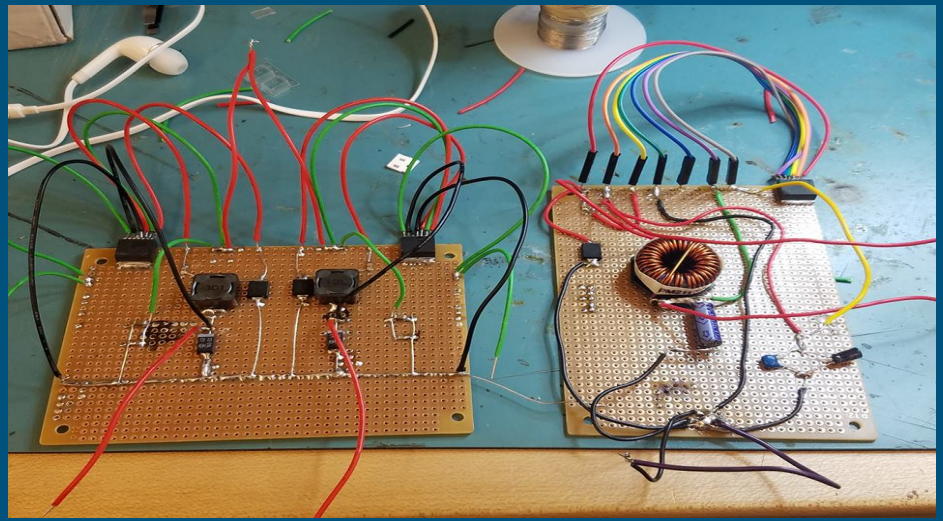
# Input Testing

- Muscle groups will be chosen for EMG placement.
  - Ensure that muscles are far apart enough to avoid cross-talk.
- SNR can be adjusted via a potentiometer located on each EMG on PCB.
  - The higher the potentiometer value, the more amplified the signal.
  - ...But the more susceptible the signal is to noise.
- LEDs are also placed on PCB for calibration purposes.
  - Significant signals make the LED light up and provide an analog output to the MCU.
- Threshold value can be adjusted via software.
  - Lower voltage threshold can be used for subjects that have weaker muscle signals.

# Prototype Testing

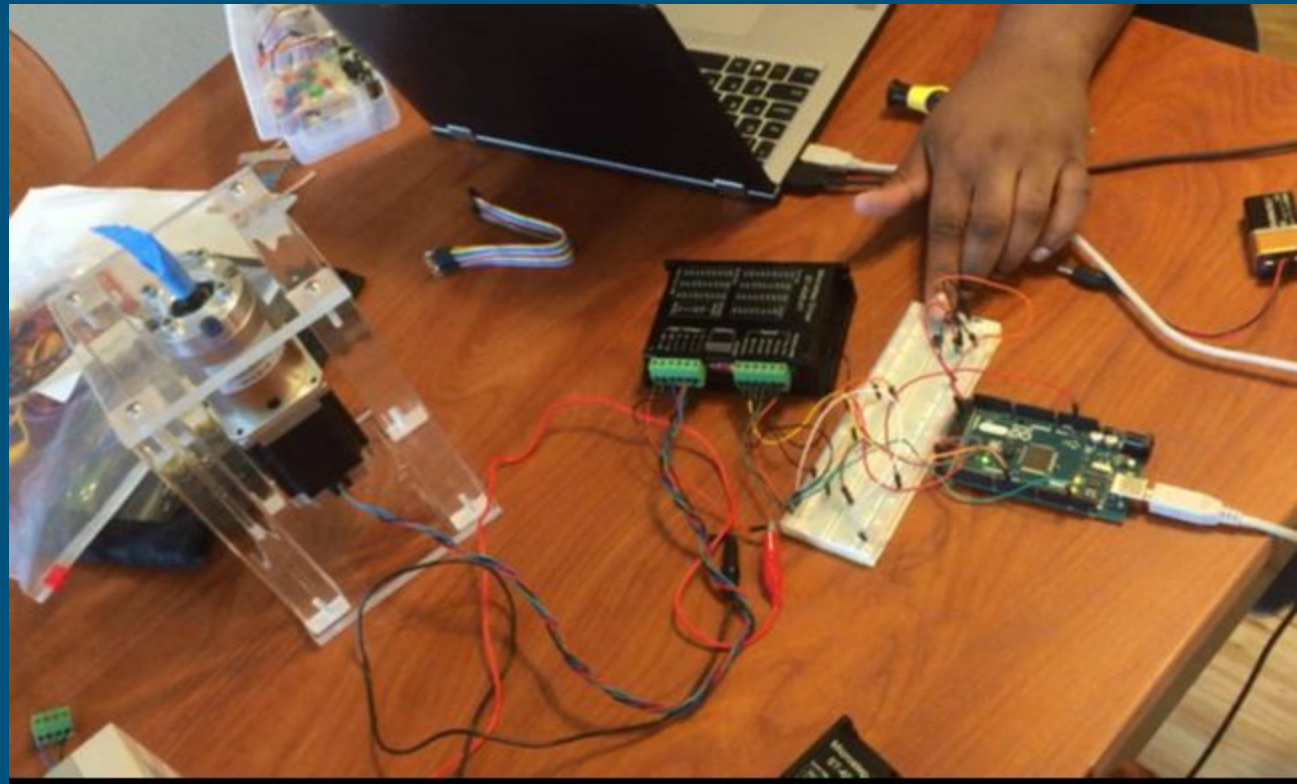
- Solenoid Valves Circuit.
- Air Pump Circuit.
- Microcontroller Circuit (not shown on pictures).





# Test Rig Elbow Motor

- Speed
- Direction
- Holding Torque

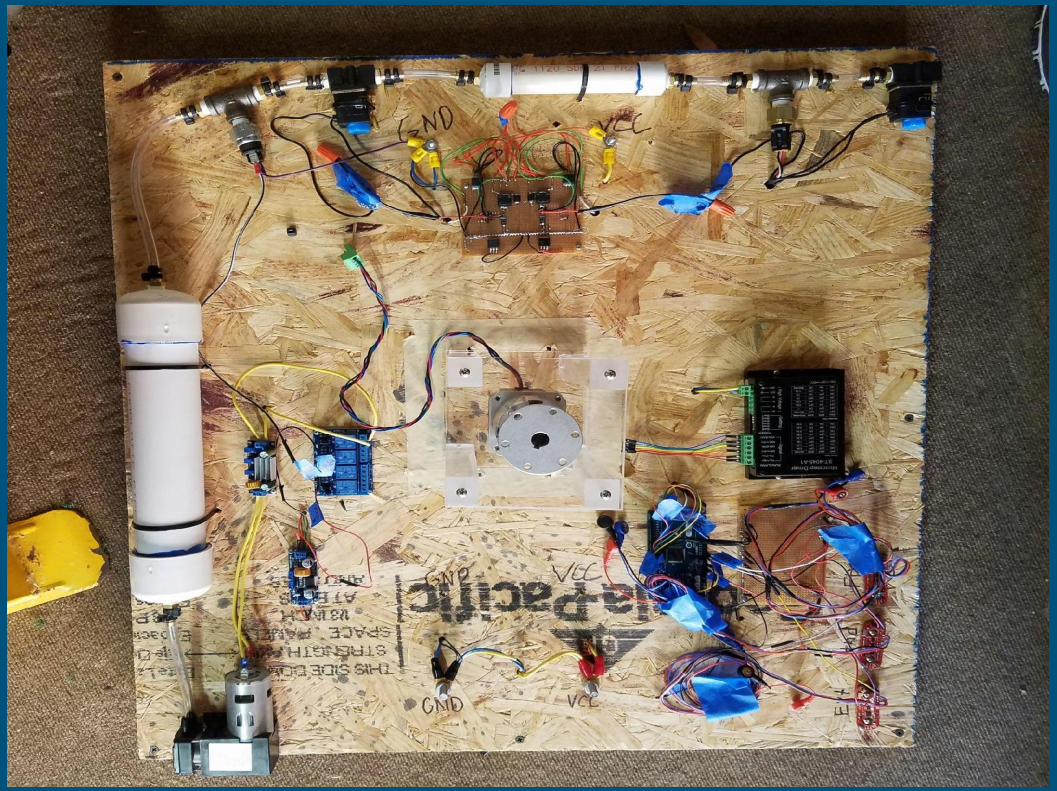


# Test Rig Pneumatic Hand

- Pressure Readings
- Solenoid Actuation
- Air Pump Activation

# Midterm Prototype

- Fully Operational.
- Elbow System.
- Pneumatic System.
- PCBs missing in this model.



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# Budget

- Electronic parts chosen.
  - Regulates actuators and MCU.
- Electro-mechanical parts chosen.
  - Provides mechanical actuation of the exoskeleton.

| Item Label | Quantity | Part Number | Unit Price | Total Price |
|---|---|---|---|---|
| Boost Capacitor (Reg) | 3 | GRM216R71H103KA01D | $0.02 | $0.05 |
| Input Cap (S.V. + Chip) | 3 | GRM31CR71H225KA88L | $0.12 | $0.36 |
| Input_L Cap (S.V. + Chip) | 3 | C0805C104K5RACTU | $0.03 | $0.08 |
| Output Cap (S.V. + Chip) | 3 | 593D226X9025D2TE3 | $0.61 | $1.82 |
| Schottky Diode (S.V.) | 2 | PMEG6010CEH,115 | $0.18 | $0.37 |
| Inductor (S.V) | 2 | SRR1260-101M | $0.87 | $1.74 |
| 12V Buck Converter | 3 | LM2678SX-12/NOPB | $5.39 | $16.17 |
| 5V Buck Converter | 1 | LM2678SX-5/NOPB | $5.39 | $5.39 |
| Schottky Diode (Chip) | 1 | 1N5819HW-7-F | $0.22 | $0.22 |
| Inductor (Chip) | 1 | NPI31W470MTRF | $0.50 | $0.50 |
| ATmega2560 16AU | 1 | ATMEGA2560-16AU | $16.55 | $16.55 |
| 16 MHz Ceramic Resonator | 1 | CSTCE16M0V53-R0 | $0.40 | $0.40 |
| USB Module | 1 | PF-681A | $6.99 | $6.99 |
| TQFP100 Adapter | 1 | XYG-Adapter | $78.99 | $78.99 |
| SMT Assorted C & R | 1 | BCBI7957 | $15.99 | $15.99 |

# Budget - Cont.

- Does not reflect full cost of project.
  - Test materials were purchased.
  - Surplus materials purchased as well.
  - Reflects how much expenses would be be

| Item Label | Quantity | Part Number | Unit Price | Total Price |
|---|---|---|---|---|
| PCB | 2 | N/A | $20.00 | $40.00 |
| Red LED | 1 | SML-LX0603SRW-TR | $0.32 | $0.32 |
| Green LED | 3 | LG L29K-F2J1-24-Z | $0.25 | $0.75 |
| Trimmer Potentiometer | 3 | TC33X-2-104E | $0.27 | $0.81 |
| Stepper Motor | 1 | 23HS30-2804S-PG47 | $65.23 | $65.23 |
| Stepper Driver | 1 | TB6600 | $26.99 | $26.99 |
| Pump | 1 | DH712-4003-3800 | $30.00 | $30.00 |
| Relay Board | 1 | 4450182 | $6.99 | $6.99 |
| Solenoid Valve | 2 | USS2-00005 | $11.77 | $23.54 |
| Pressure Sensor | 1 | PX3AN1BH100PSAAX | $30.87 | $30.87 |
| Press. Sensor Connector | 1 | 3685301 | $43.69 | $43.69 |
| Pressure Switch | 1 | PS61-10-4MNZ-B-SP | $28.78 | $28.78 |
| | | System Total: | | $414.80 |

# Difficulties

- Integration with mechanical team.
- Availability of parts and foot prints.
- Air pump struggles when interfacing with system.
- Code creation in parallel with hardware creation.
- Difficulty to obtain and analyze EMG signals.

# Conclusion

- Project achieved most of the goals that were originally set.
  - Controls were created for an exoskeleton system given requirements from last semester.
  - Team managed to show proof of concept despite other teams did not deliver on time.
  - Project is modular and easily upgradeable.
    - Made up of smaller subcomponents that can be diagnosed separately.
- Prototype has areas that can be improved by future projects.
  - Full mechanical integration to existing system for an actual exoskeleton.
  - Integration of pump into PCB without using external regulator and relay.
    - For purposes of saving space and patenting.
  - Implementation of a closed-loop system at the elbow.
  - Addition of a battery to power the system for a long period of time.
  - Parallelism of the MCU to actuate elbow and hand at the same time.

# Questions

Any Questions?