



C.O.R.E.

Controller for Organic Range of Exoskeleton



Group 14

Daniel Reveron
Brandon Johnson
Kelvin Feliciano
Gavin Bell

Electrical/Computer Engineering
Computer Engineering
Electrical Engineering
Electrical Engineering



Motivation

The team:

- Wanted Senior Design to be practical.
- Desired to improve quality of life for people in need.
 - Make them more independent.
- Oriented the project to suit each member's preferences.
- Sought originality in design to revolutionize current ideas.
 - Advance affordable technology.
 - Increase product accessibility.

Arthrogryposis Multiplex Congenita

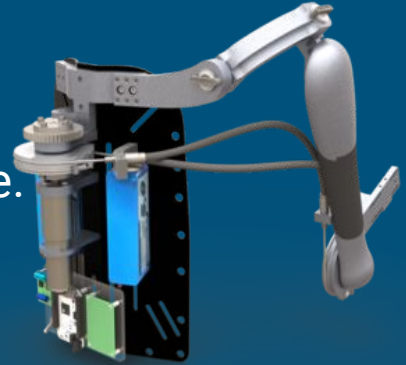
- Condition that occurs at birth.
- Characterized by contracture in the curvature of joints.
- These joints do not move fluently.
 - May degenerate to muscular dystrophy.
- Particular patient in wheelchair.
 - Patient needs assistance to eat.

Mom says it means my **bendy parts** are stuck.



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	2				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

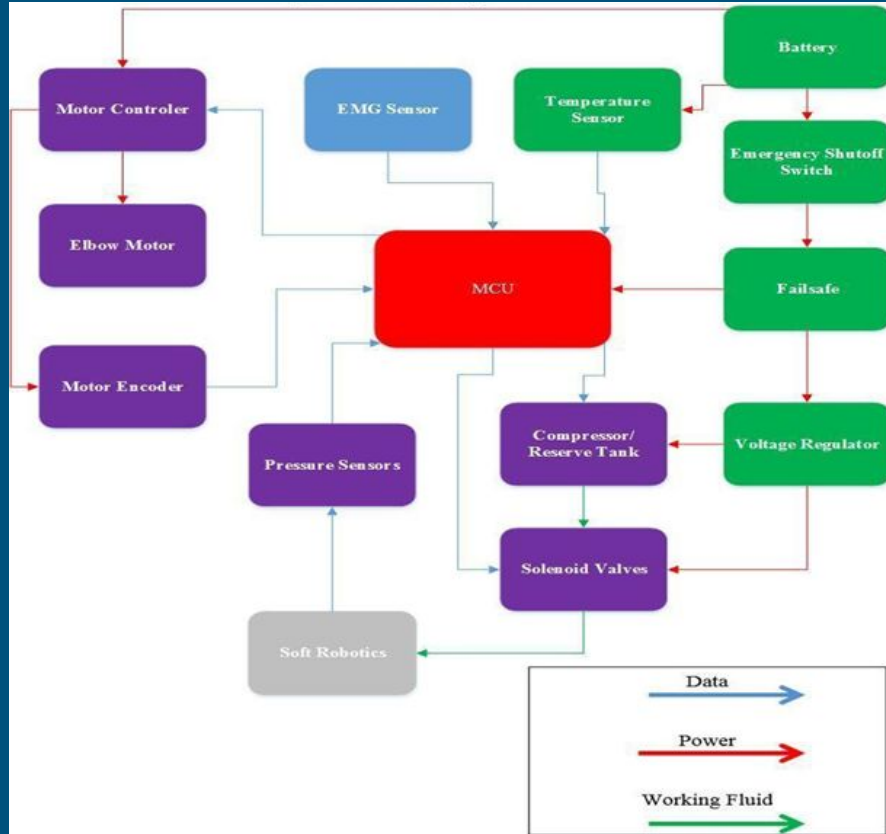
- **Electrical Requirements.**
 - Designed for Mech. Integration.
 - Intended for Safety and Comfort.

End-User Requirement	Engineering Requirement	Engineering Requirement Statement
EU.1	ENG.1.1	The system shall provide a fail-safe feature in case of emergency
EU.1	ENG.1.2	The system shall not exceed a temperature of 48 °C for components that are in direct touch with the user
EU.1	ENG.1.3	The power subsystem shall not compromise the user's safety in case of hazard
EU.2	ENG.2.1	The system shall be able to adjust its input signal detection criteria in a user-by-user basis
EU.2	ENG.2.2	The system shall have a response time no longer than 10 ms, as specified by mechanical engineering constraints
EU.3	ENG.3.1	The calibration of the electrical system for a daily basis use shall not exceed 2 minutes
EU.3	ENG.3.2	The system shall be able to shut down after exoskeleton reaches a position that makes arm easy to remove
EU.4	ENG.4.1	The system shall allow the powered system to be used for a period longer than 1 hour on maximum use for a single charge
EU.5	ENG.5.1	The system shall allow the user to reset the controls to their initial state in case a deadlock occurs

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

System Design Overview

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

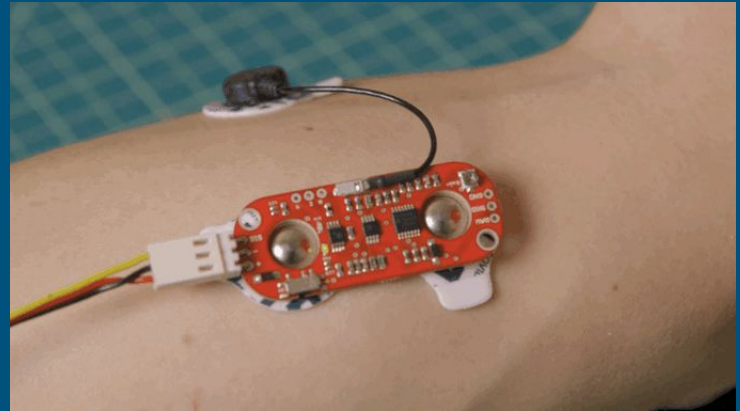


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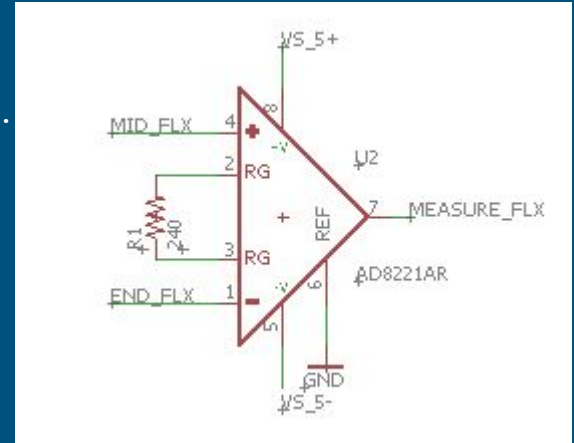
sEMG Sensors

- 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.



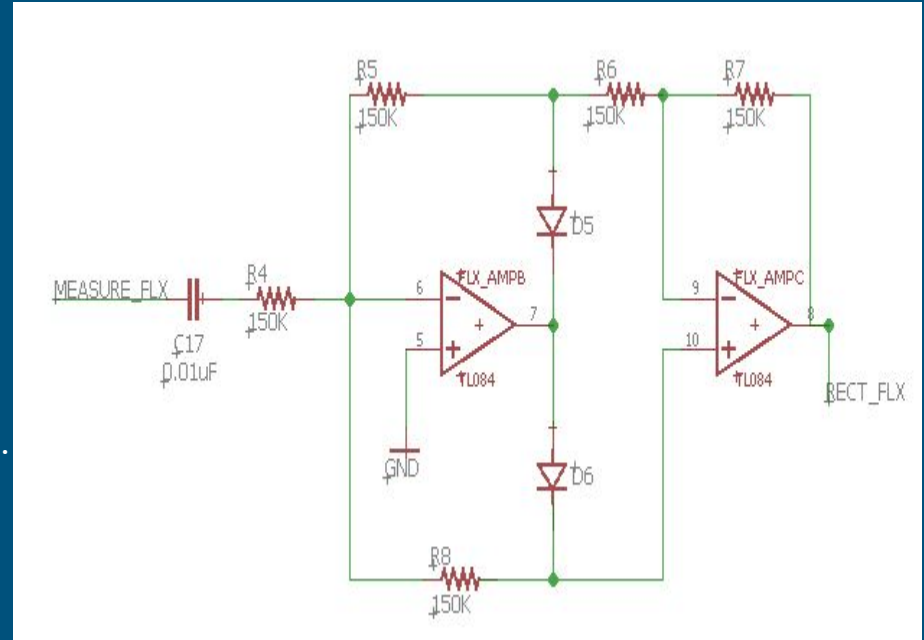
Integrated EMG Sensor Stage 1 - Diff Amp

- Bipolar electrodes located on the same muscle.
 - Mid located at muscle belly for higher Signal-to-Noise Ratio.
 - End located close to Mid electrode.
- Two signals have similar noise.
 - An instrumentation amplifier rejects common noise.
 - Signals are amplified to be passed down to the next stage.
- A reference electrode is placed on a bony area.
- Raw signal comes out of the instrumentation amp.



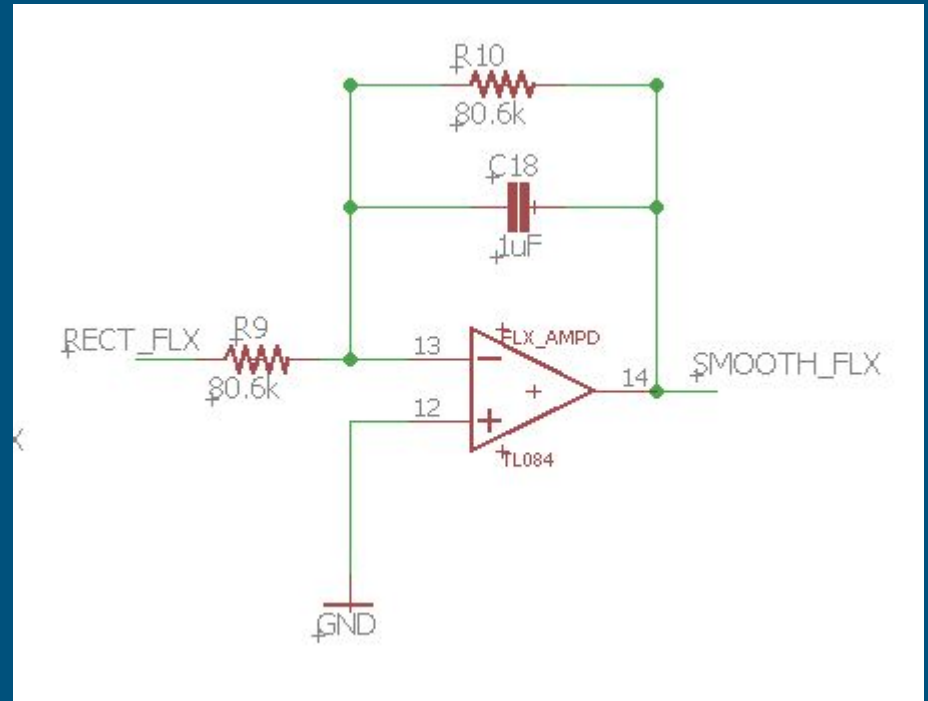
Integrated EMG Sensor Stage 2 - Rectifier

- Raw signal from stage 1.
 - Microcontroller can't read negative.
 - Signal must be rectified.
- Circuit focuses on magnitude.
 - Positive values are unchanged.
 - Negative values are inverted.
- A high-pass filter is used here.
 - Eliminates DC component from signal.
 - Typically associated with noise.



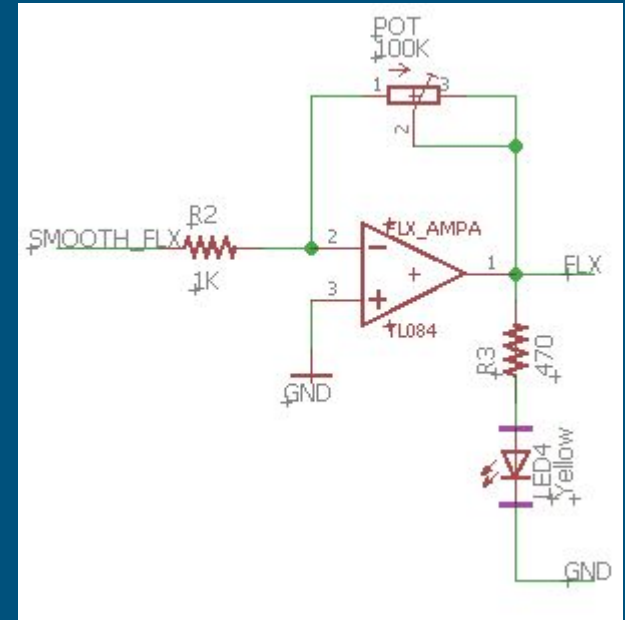
Integrated EMG Sensor Stage 3 - Smooth

- Signal changes rapidly.
 - May affect processing algorithm.
- Low-pass filter is used.
 - Eliminates high-frequency signals.
 - Smoothens out the output.



Integrated EMG Sensor Stage 4 - Gain

- Signal's Stage 3 output is very small.
 - Can range from μV to a few mV .
 - This is hard for the the microprocessor to analyze.
- Signal is made positive and amplified here.
 - Trimpot allows for variable gain depending on patient.
 - Ranges to 100K in case signal is in a few μV .
 - This could be the case for patient with AMC.
- LED is equipped just as a status light.
 - Tells testers that signals are being read.



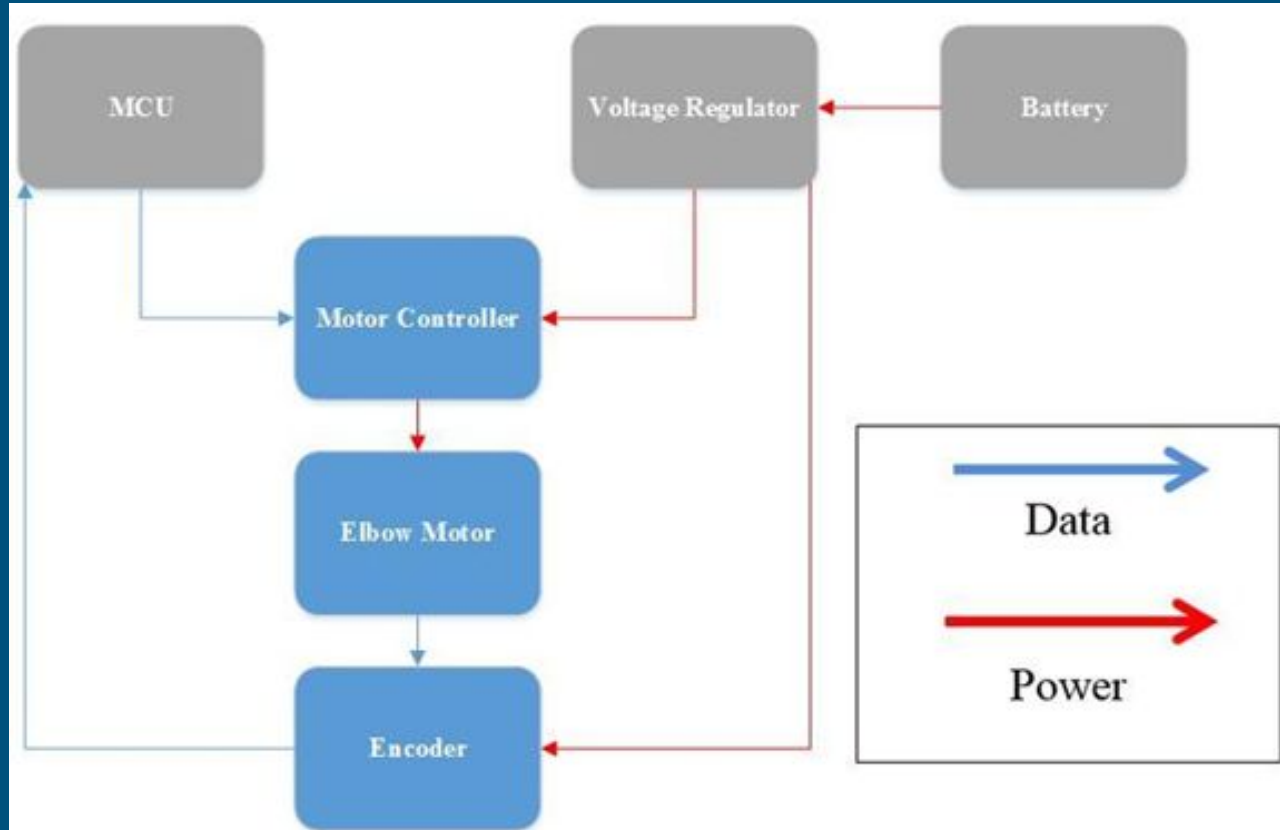
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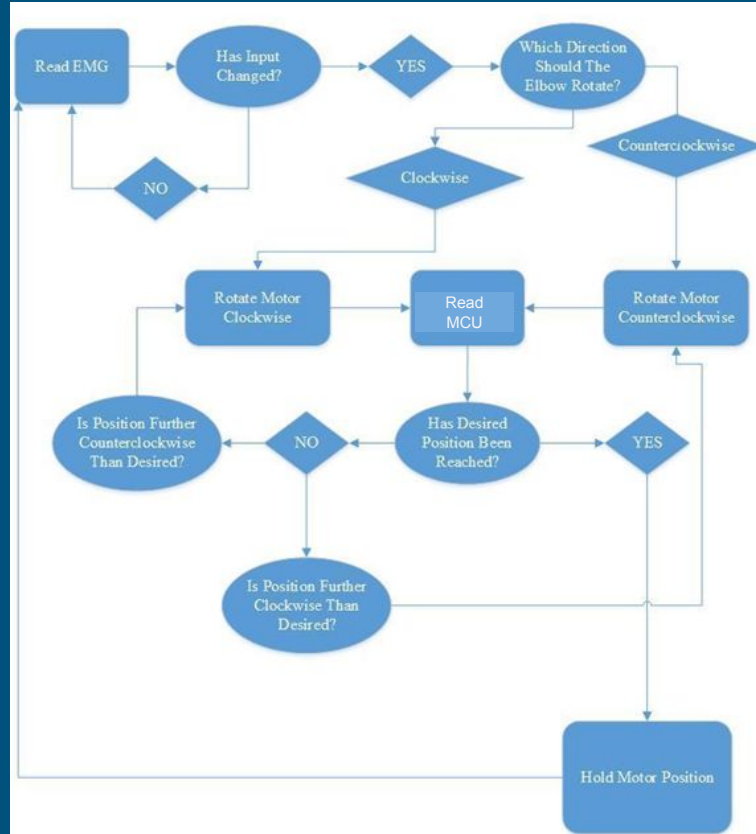
Elbow System



Elbow System Overview



Elbow System Decision Tree



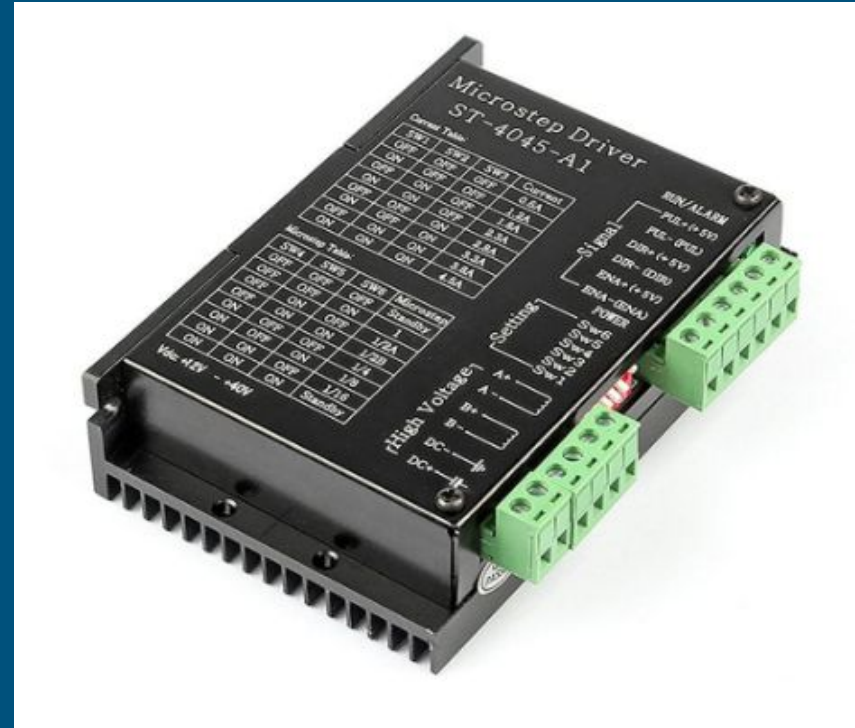
Stepper Motor

- Nema 23 Motor
- 47:1 Gearbox
- Holding Torque: 29ft*lb
- Voltage: 24V-48V
- No load Current: 0.66A
- 25ft*lb Load Current: 1A



Stepper Motor Driver

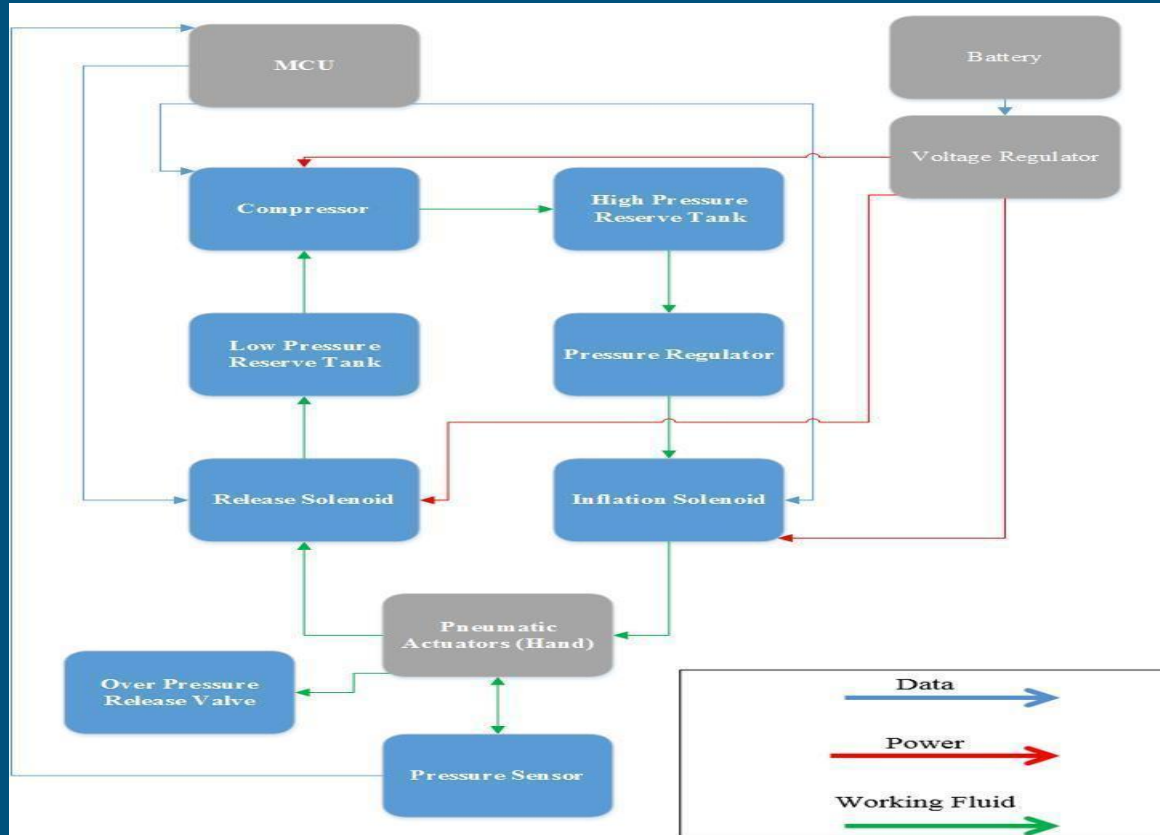
- SainSmart TB6600
- DC power input type: 12V-40V
- Output current: 0.6A-4.5A
- Adjustable overcurrent protection.
- Adjustable stepping.



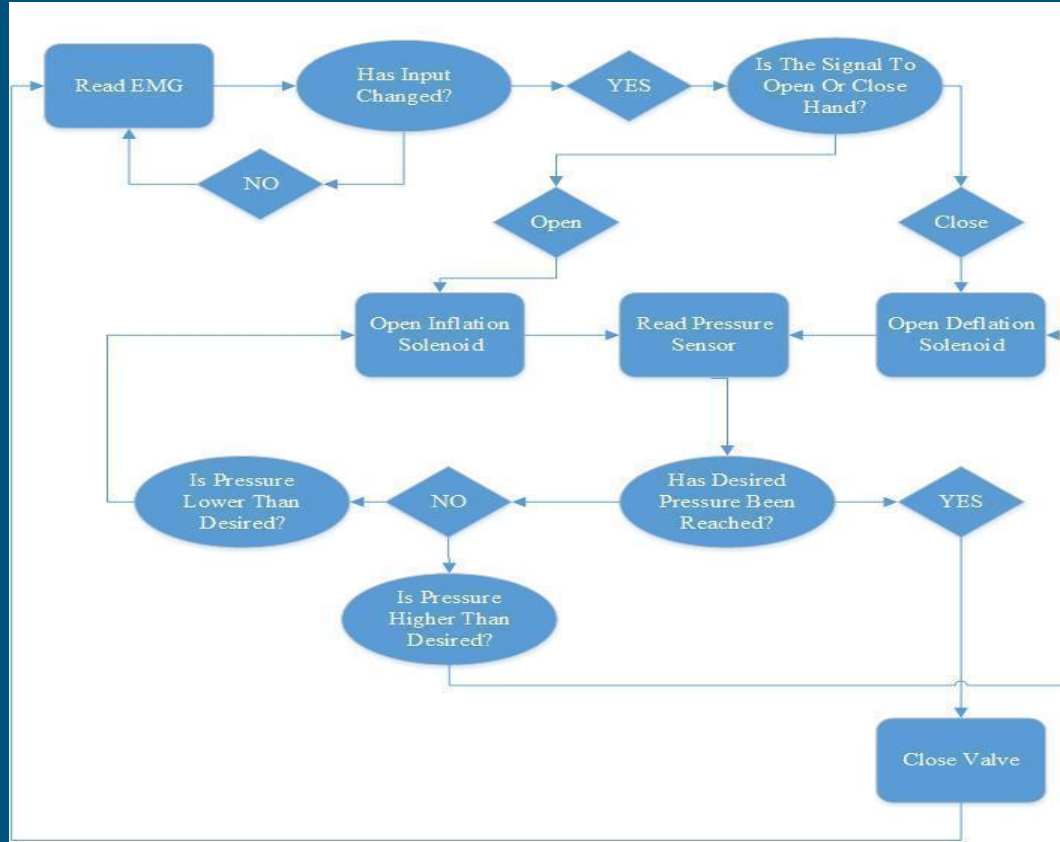
Pneumatic Hand System



Pneumatic System Overview



Pneumatic System Decision Tree



Pneumatic Pump

- Max Pressure: 58 psi
- Vacuum Pressure: -12 psi
- Voltage: 12V
- Power Consumption: 26W



Solenoid Valves

- US Solid Solenoid Valve
- Max Operating Pressure: 145 psi
- Voltage: 12V
- Power Rating: 4.8W



Pressure Sensor

- Honeywell -
PX3AN1BH100PSAAX
- Pressure Range: 0-100Psi
- Output Voltage: 0.5-4.5V
- Supply Voltage: 5V



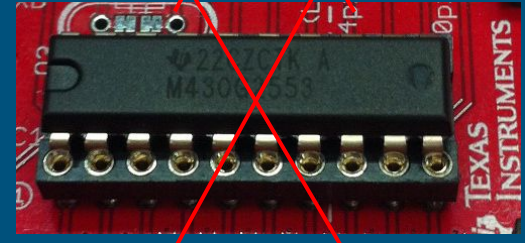
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Microcontroller

ATMEGA2560

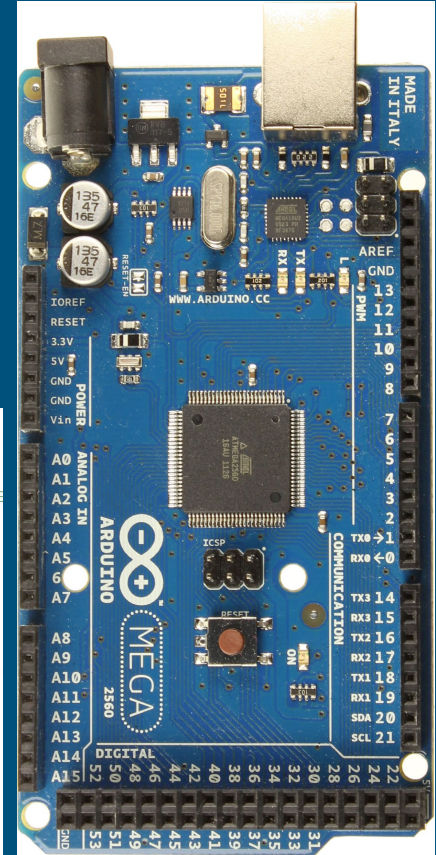
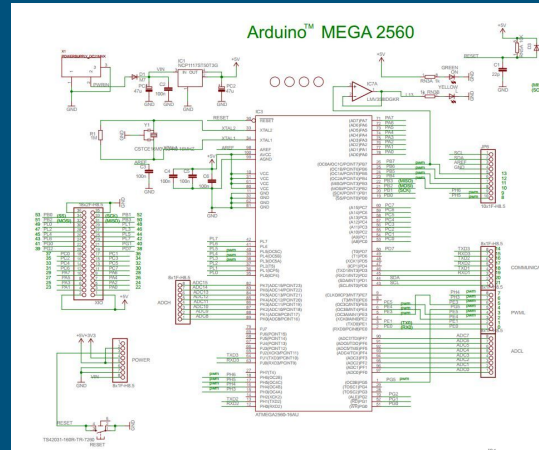
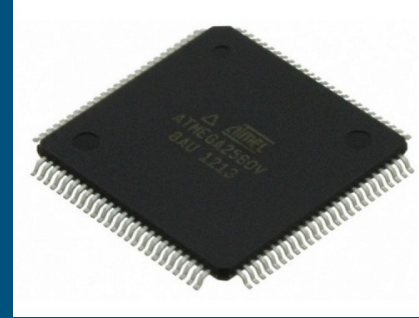
- 256KB flash
- 8KB SRAM
- 16MHz
- 86 I/O pins
- UART
- Analog To Digital Converter



Criteria	Importance Weight	ATMEGA		MSP430	
		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

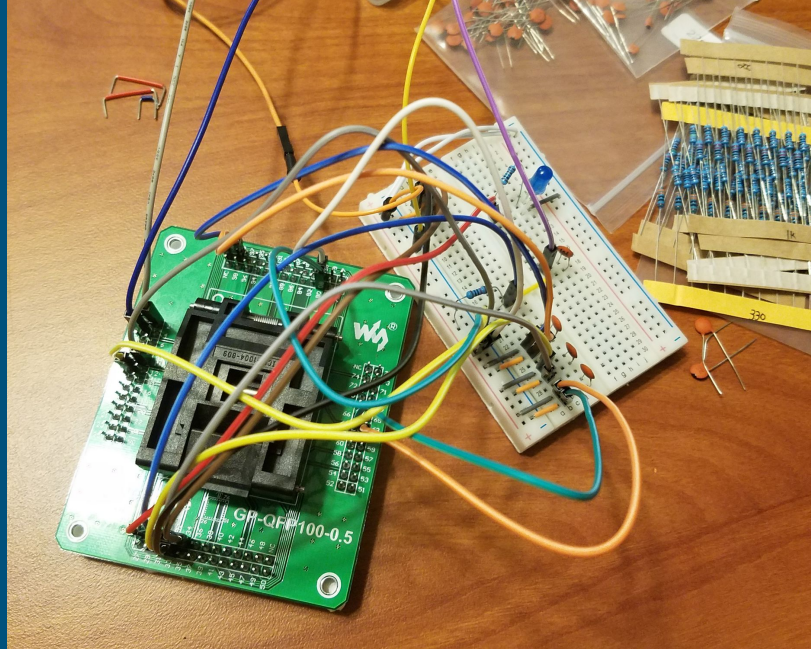
Microcontroller cont...

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



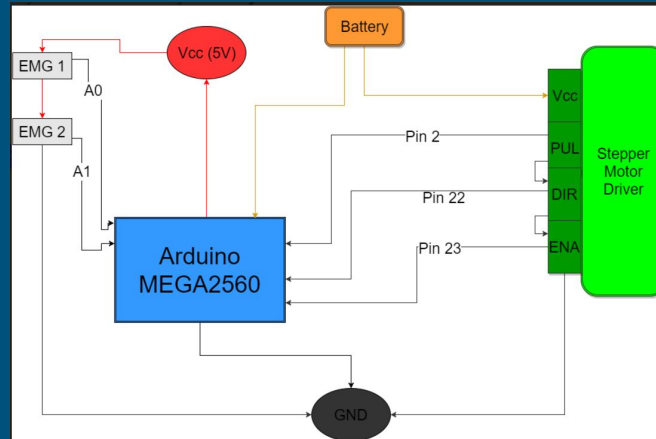
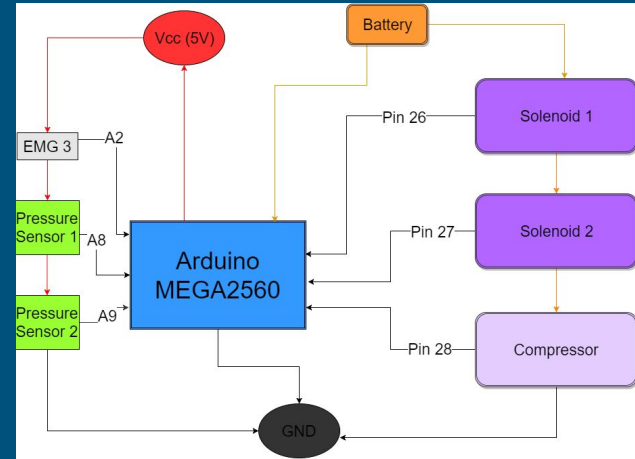
Microcontroller Standalone

- Completed and Tested ATmega circuit.
- 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

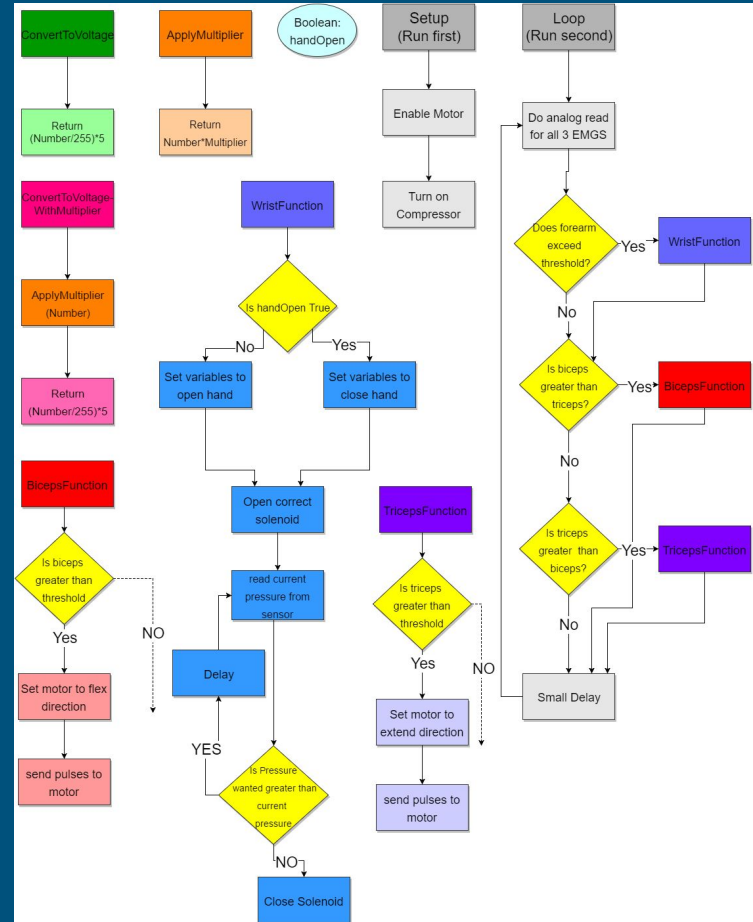
- Must burn bootloader to chip
- Program with USB Module

C/C++



Software Control

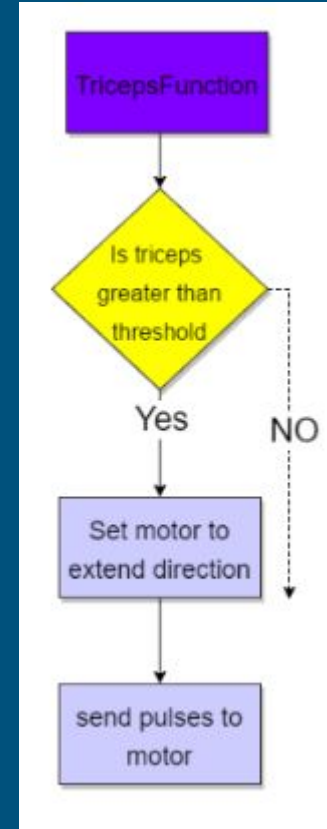
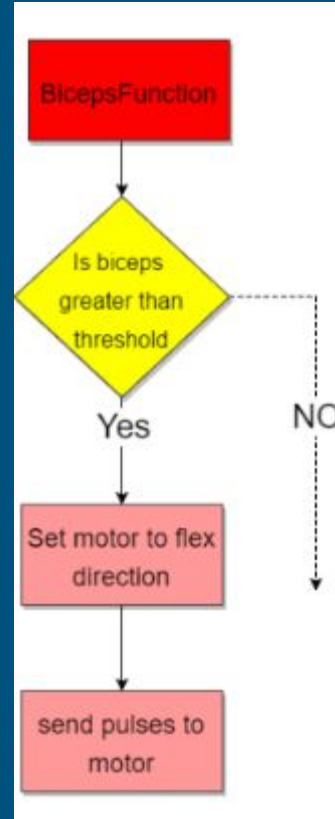
- Code listens for muscle movement by EMG Input
- If threshold surpassed generate output
- Forearm = Hand Control
- Biceps & Triceps = Elbow Control



Software Control cont...

Elbow Control

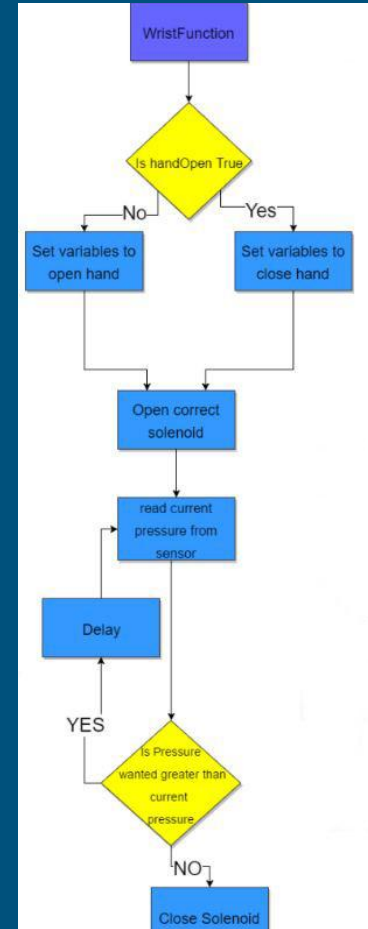
- Check if reading is over threshold
- Set direction of the motor
- Send pulses to motor



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



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Power

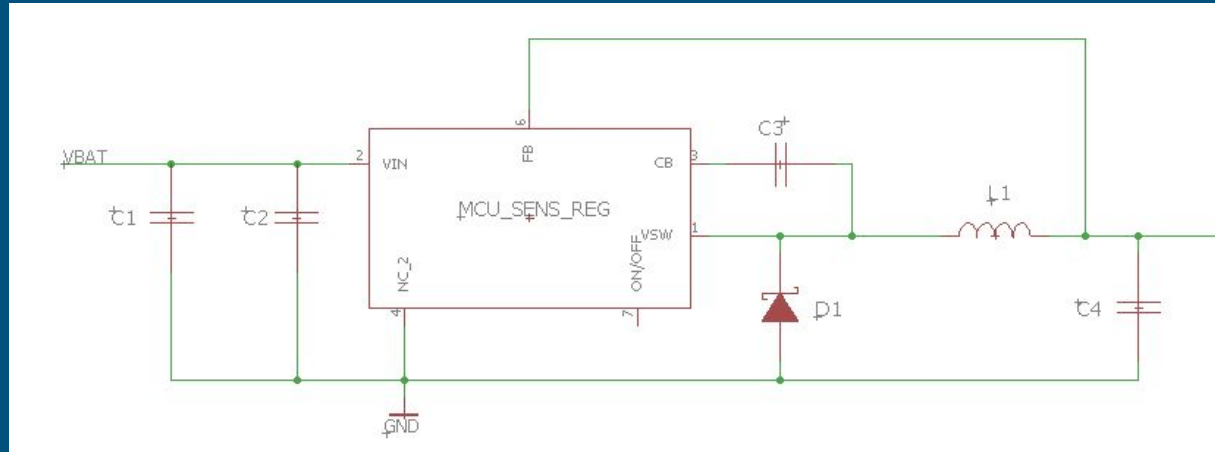
- LiFePO4 Battery
- 25.6V 6.6Ah (168Wh, 16A rate)
- Overcharge (> 31.2V)
- Over Discharge (< 16.0V)
- Over Drain (> 16 Amp)
- Short circuits



Voltage Regulator

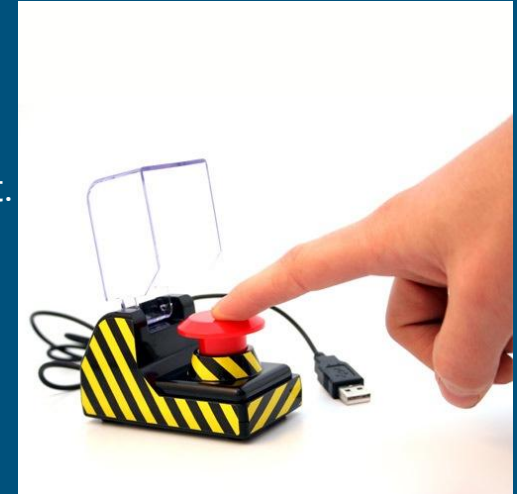
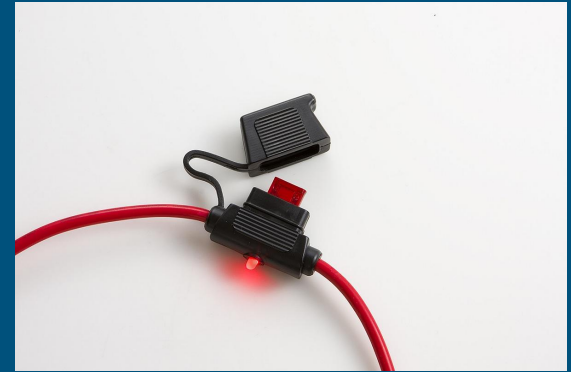


- LM2678 Simple Switcher
- Buck Converter
- V_{in} range 8V - 40V
- V_{out} range 1.23V - 37V
- I_{out} Max 5.0 Amp
- Efficiency up to 92%
- Enable pins



Failsafes

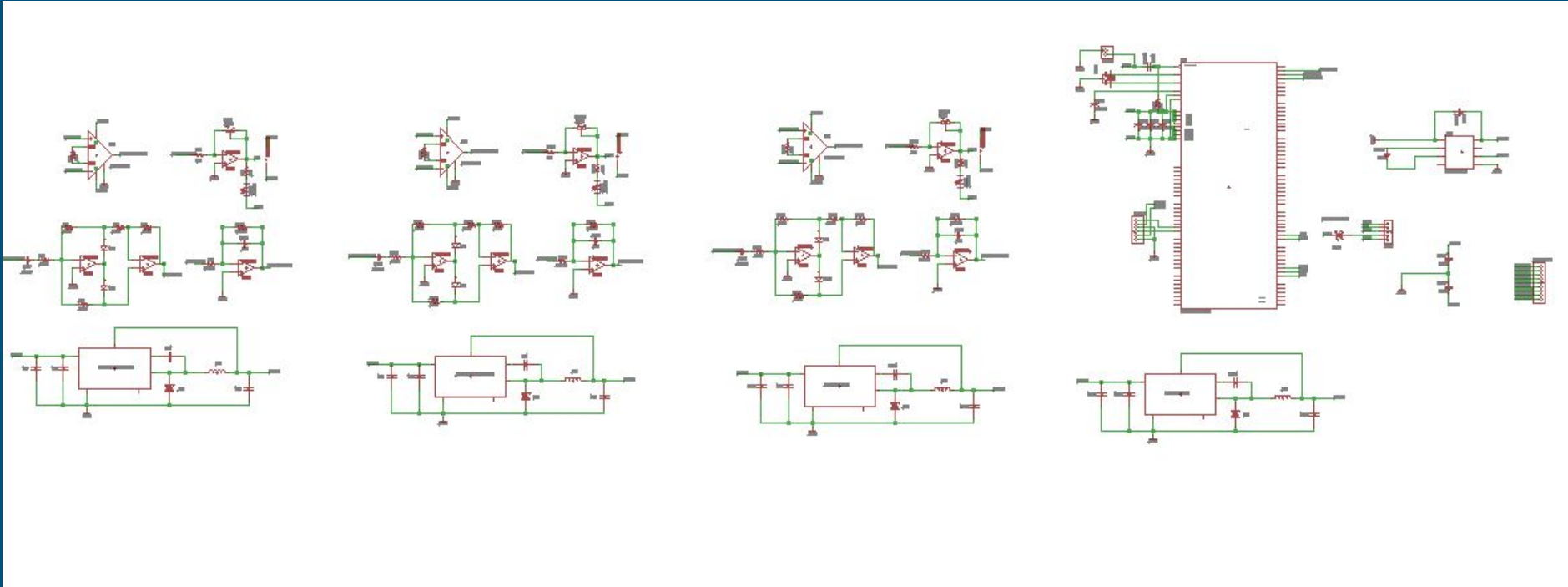
- In-line fuse close to the battery.
- Emergency system shut off switch.
 - Located by patient's arm for easy access.
- Reset button used for resetting system.
 - In case of system instability.
- Team to discuss ergonomic implications.
 - Mechanical team to choose switches under C.O.R.E. constraint.



PCB

- Stacking of 2 PCBs.
 - Numerous, large components.
 - Regulators in PCB 1.
 - MCU with Actuators and Sensors in PCB 2.
- Will use plugs for cleaner connections.
 - EMGs.
 - Sensors.
 - Power.

PCB Schematic Overall

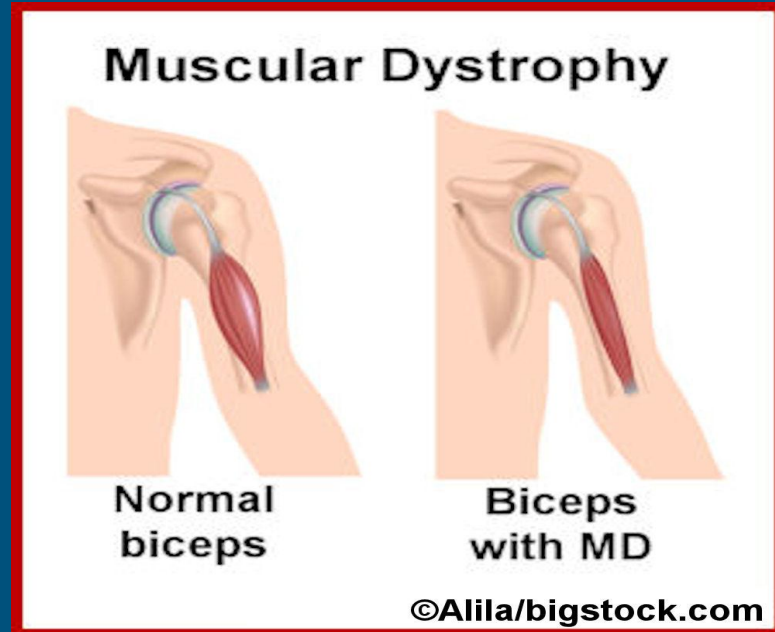


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Input Testing

- Patients with AMC have less muscle fiber.
 - Muscular dystrophy is a consequence of AMC.
 - This produces low SNR for muscles.
- Proper muscles must be chosen.
 - 3 separated muscles groups are required.
 - Preferred but not needed to be placed on arm.
 - Different muscles must be tested on patient to determine which muscle produces best SNR.
- A threshold value will be found after input testing is complete.
 - This value will be sought out by microcontroller to trigger a response.



Input Testing - Equipment

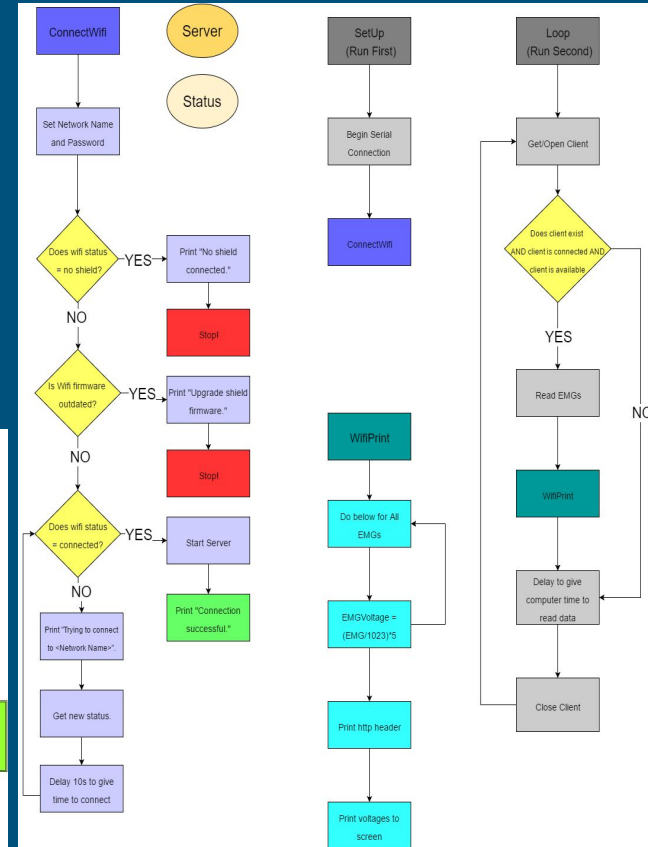
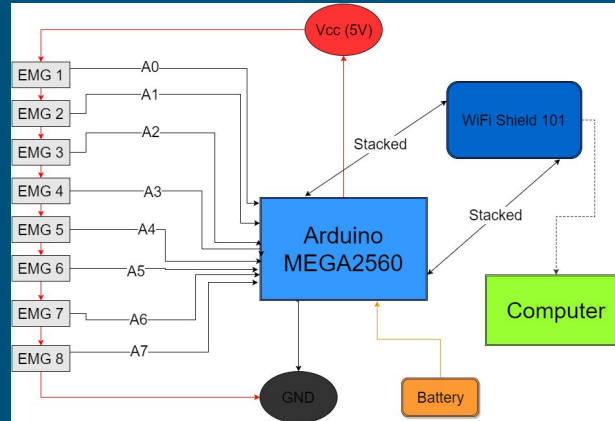
- MyoWare sEMG to be used here.
 - Easy set-up and measurement.
 - Multiple muscle groups measured simultaneously.
- Disposable electrodes to be applied.
 - Required to rub test patient's skin with alcohol.
 - This eliminates some impedance.
- Oscilloscope will read the signals.
 - Multiple channels to read all sEMGs.
 - Ability to analyze frequency response.
 - Helps determine sampling frequency.



Input Testing

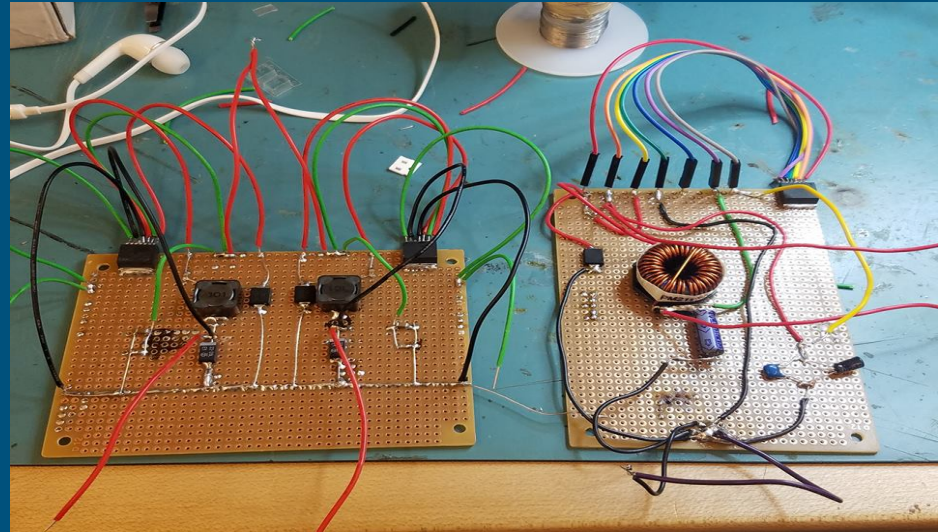
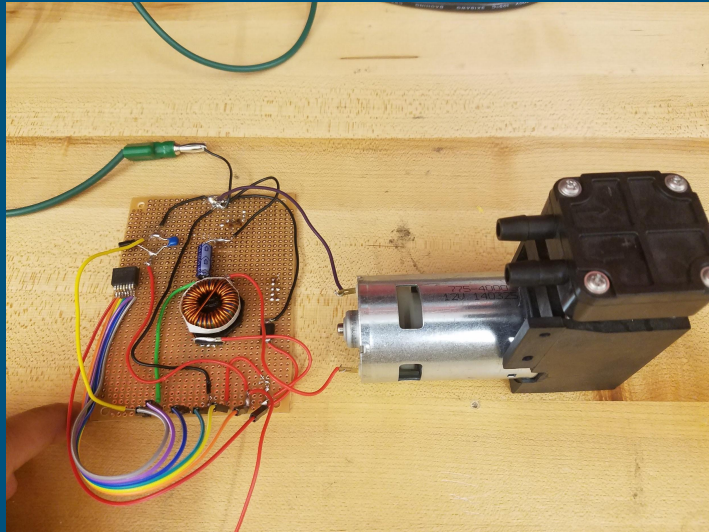
Software

- Wifi shield used for wireless connection
- Arduino as Server
- Read EMGs and send info to browser
- Open Browser on Computer



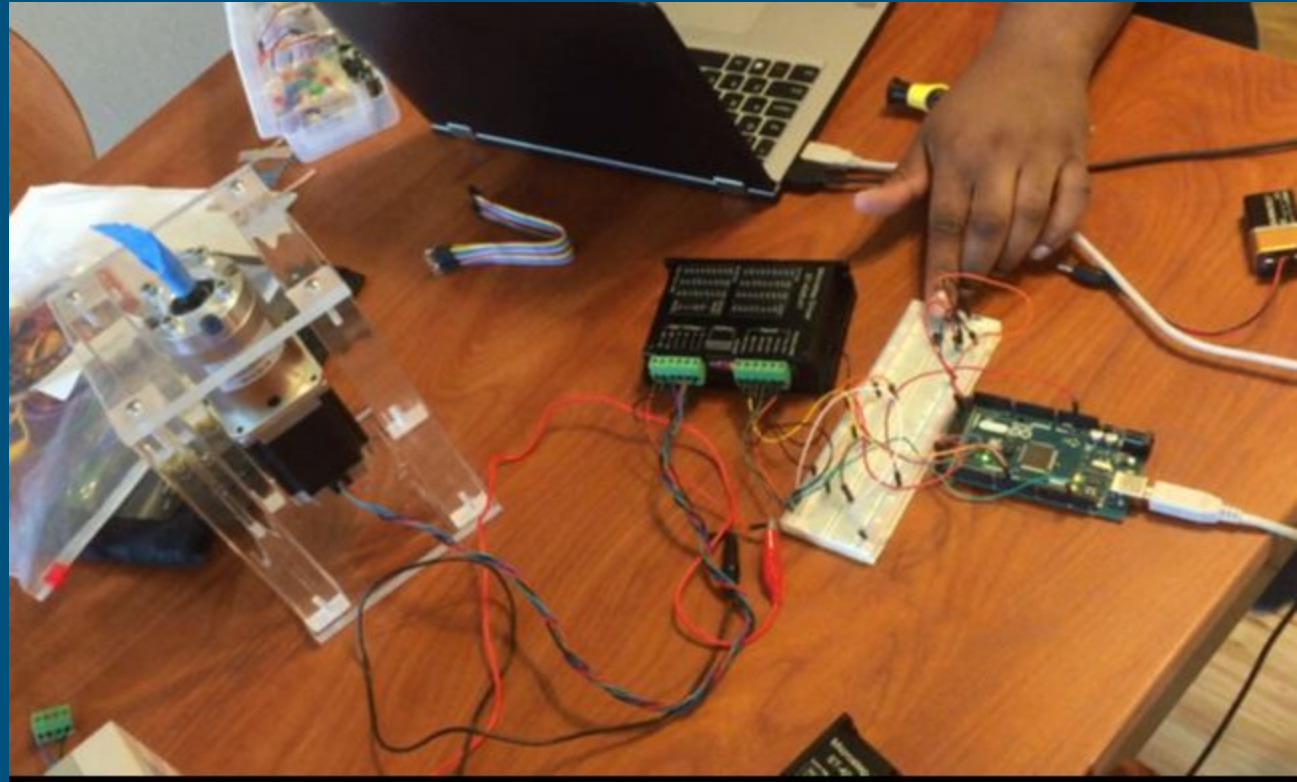
Prototype Testing

- Solenoid Valves Circuit.
- Air Pump Circuit.



Test Rig Elbow Motor

- Speed
- Direction
- Holding Ability



Test Rig Pneumatic Hand

- Pressure Readings
- Solenoid Actuation
- Air Pump Activation



Integration with Mechanical Teams

- End goal integrate with the three mechanical teams
 1. Pneumatic Team
 2. Elbow Team
 3. Structural Team



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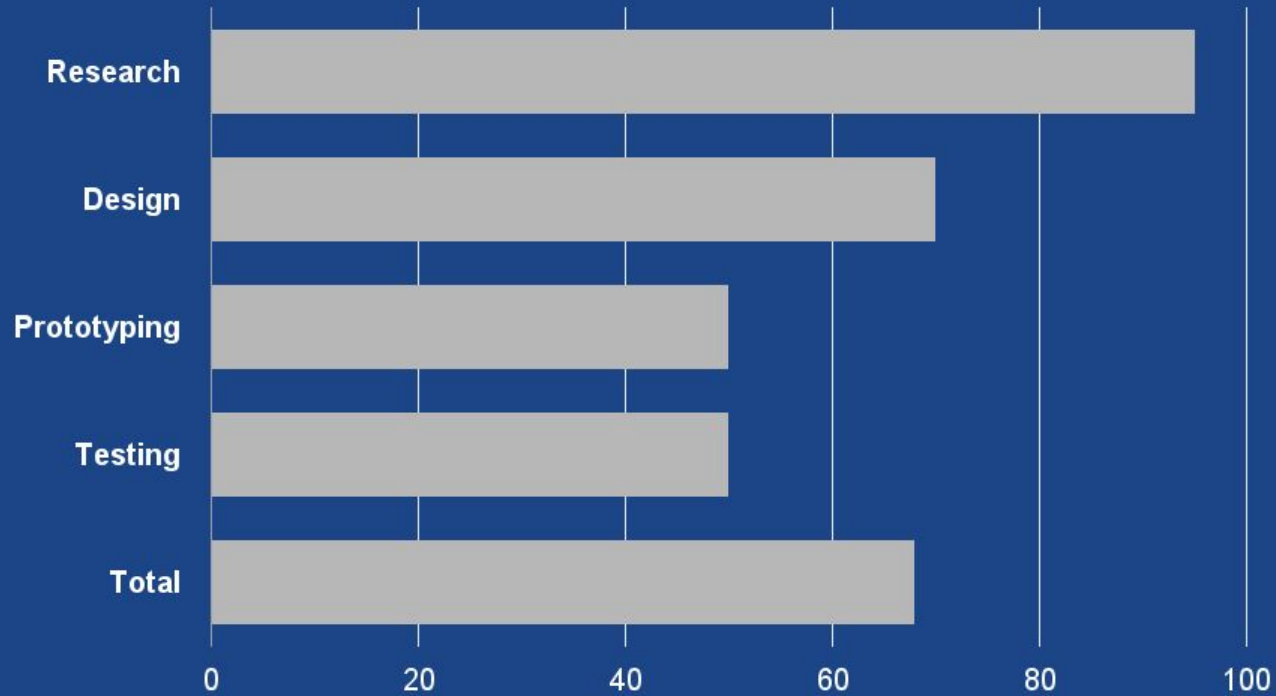
Milestones

- We are mostly on schedule with our high-level milestones
- Plan to move quickly from here forward
- Leave ample time to test

Description	Weeks	Soft Deadline
Senior Design I		
Project Introduction & Group Formation	Week 1	5/20/16
Determine Project Idea	Week 2	5/26/16
Initial Proposal	Week 3	6/3/2016
System Design Review with Mechanical Team	Week 3 - Week 5	6/17/2016
Research Input Sensors & Feedback Sensors	Week 4 - Week 5	6/17/2016
Research Power Requirements	Week 4 - Week 5	6/17/2016
Research Printed Circuit Board Design	Week 4 - Week 5	6/17/2016
Research Microcontroller	Week 4 - Week 5	6/17/2016
Begin Design Paper and Continue Research	Week 6 - Week 8	7/8/2016
Generate and Turn in Table of Contents	Week 7	7/1/2016
Design Models/Input Test and Continue Design Paper	Week 7 - Week 9	7/15/2016
Turn in Current Draft of Senior Design Documentation	Week 8	7/8/2016
Finalize Paper and Begin Ordering Parts	Week 9 - 11	7/29/2016
Submit Final Document	Week 12	8/2/2016
Input Testing on Patient to Calibrate Electronics	Week 12 - Break	8/12/2016
Small Break Before Fall Classes		

Senior Design II		
Regroup and Discuss Plans	Week 1	8/26/2016
Gather All Parts and Finalize Design	Week 2 - Week 3	9/9/2016
Prototype System	Week 4 - Week 8	10/14/2016
Test and Debug system. Begin Final Documents	Week 9 - Week 11	11/4/2016
Integrate with Mechanical Team and Test	Week 11 to 14	11/25/2016
Final Presentation/ Evaluation	Week 15	12/1/16

Progress



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)	4	GRM216R71H103KA01D	\$0.02	\$0.06
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
Input Cap (Pump)	1	GRM31CR71H475KA12L	\$0.15	\$0.15
Output Cap (Pump)	1	GRM32ER61C476ME15L	\$0.33	\$0.33
Schottky Diode (Pump)	1	B560C-13-F	\$0.35	\$0.35
Inductor (Pump)	1	PM2110-680K-RC	\$1.61	\$1.61
Schottky Diode (Chip)	1	1N5819HW-7-F	\$0.22	\$0.22
Inductor (Chip)	1	NPI31W470MTRF	\$0.50	\$0.50
12V Linear Reg. (Pump)	1	MIC29300-12WU	\$3.30	\$3.30
12V Linear Reg. (S.V.)	2	LM2940S-12/NOPB	\$2.06	\$4.12

Budget - Cont.

- Does not reflect full cost of project.
 - Test materials were purchased.
 - Surplus materials purchased as well.

Item Label	Quantity	Part Number	Unit Price	Total Price
ATmega2560 AU	1	ATMEGA2560-16AU	\$16.55	\$16.55
16 MHz Ceramic Resonator	1	a12092100ux0654	\$4.45	\$4.45
16MHz Crystal Oscillators	1	a14073000ux0215	\$7.43	\$7.43
Programming 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
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
Solenoid Valve	1	USS2-00005	\$11.77	\$11.77
Pressure Sensors	2	PX3AN1BH100PSAAX	\$30.87	\$61.74
Press. Sensor Connectors	2	3685301	\$43.69	\$87.38
Battery	1	LFPB-25.6V6.6A-D	\$210.00	\$210.00
Charger	1	CH-L2596SM	\$86.00	\$86.00
Grand Total:				\$746.07
Grand Total + 25% Contingency				\$932.59

Difficulties

Everyone

- Availability of parts and foot prints.
- Output Voltage from regulator was not as expected.
 - Linear Regulators need to be appended to outputs at the expense of efficiency.
- Air pump struggles when interfacing with regulator.
- Using ATmega separate from development board.
- Code creation in parallel with hardware creation.
- Difficulty to obtain and analyze EMG signals.

Conclusion

- Project is on track and in a good direction.
 - High and low level design defined and minor incidences encountered thus far.
 - Should have a working table model by the beginning of December.
 - Active heat sink might be added to system once it has been assembled.
- Main concern is integration with mechanical team.
 - A test rig will be set in place as a plan B.
 - Test rig will show how the arm's controls will operate on an integrated model.
 - If integration works, team could be looking at a full product delivered next year.
 - At this point, the product will have to go through further tests and regulations.

Questions

Any Questions?

