Group #17

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Contents

Motivation

- 2 million individuals living with congenital/non-congenital amputations in the United States.
- Approximately 185,000 amputations occur in the United States each year. Main causes: vascular disease (54%); trauma (45%) cancer (less than 2%).
- The total number of veterans with major limb amputations as of June 1, 2015, is 1,645.
- Access to advanced arms limited: High cost barrier of bionics and powered prosthetics

Motivation

"Cost Barrier"

Simple myoelectric prosthetic arm:

- Partial loss of a hand - $18,703
- Up to the middle of the lower arm - $20,329;
- Up to the middle of the upper arm - $59,664
- Up to the shoulder - $61,655.

Advanced myoelectric prosthetic arm:

- ≥ $100,000

Health insurance covers around 50% of doctor's visits and cost of prosthetics.

Source: Department of Veterans Affairs study.

Project Initiative

To provide an affordable advanced powered prosthetic solution with multiple gesture/grip functionality.

- Limbitless Solutions (current) arm: 1 Motor, 1 Grip
- Better response time
- Improved Accessibility Features
- Increase of intuitive function

Gripping Methods

Open/Close Grip

One-Finger Pinch Grip

Point Grip

Thumbs Up

Requirements

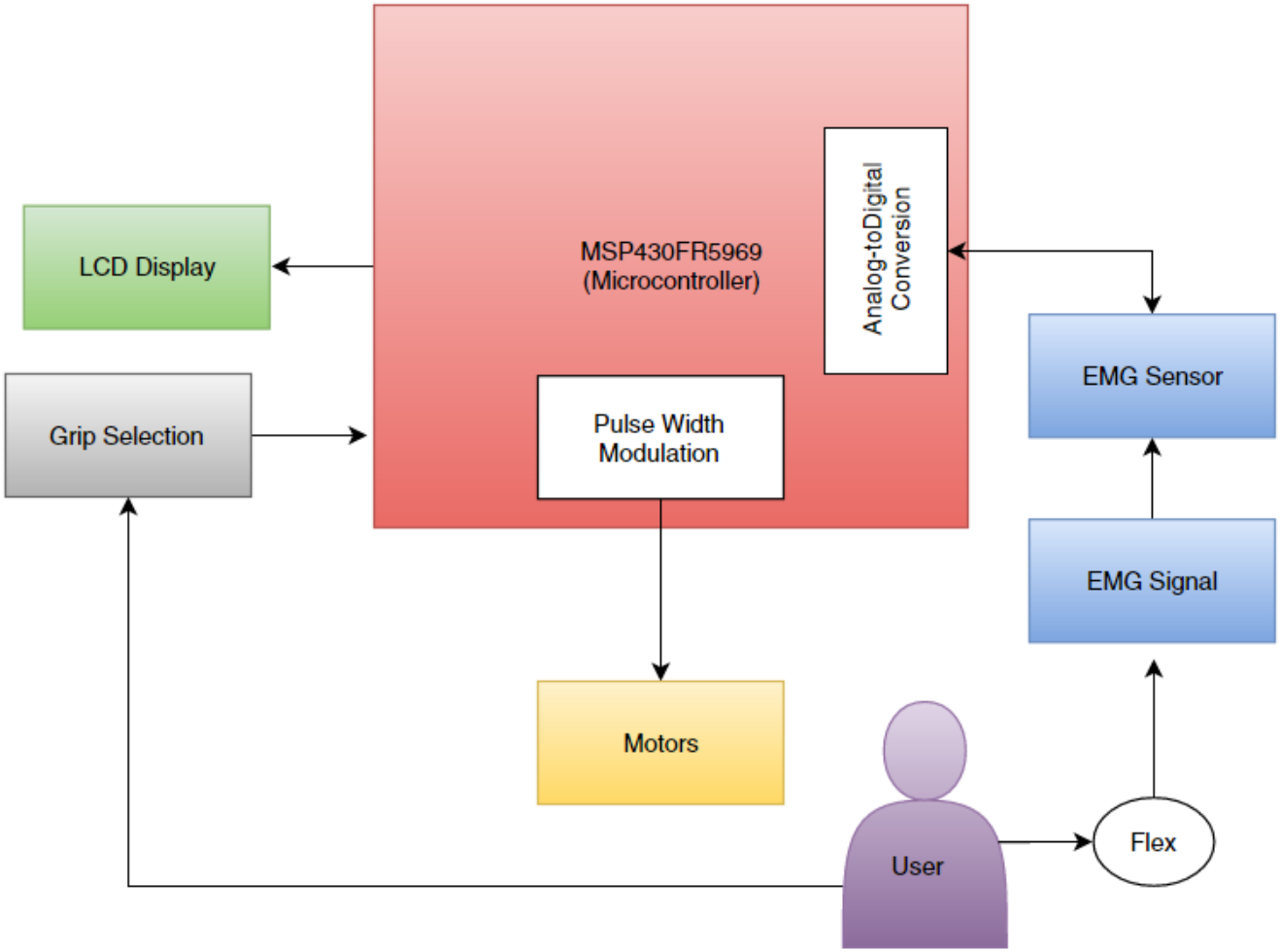
Requirements:

- To be usable for both transhumeral (above-elbow) and transradial (below-elbow) amputees.
- Calibration methods to customize voltage level.
- Light enough to be usable in everyday environment by adult men/women.
- Use non-tactile method to actuate the arm (EMG)

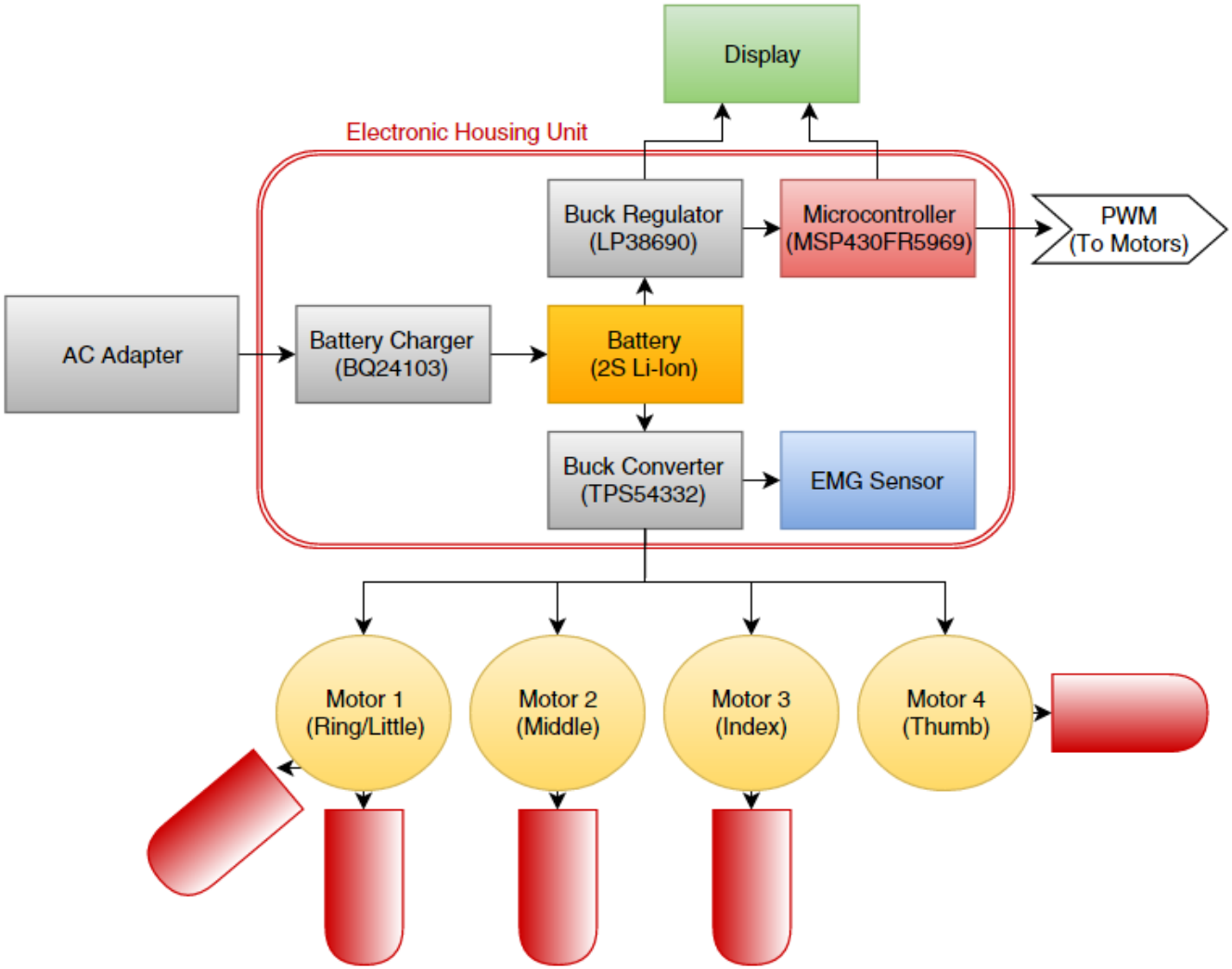
Specifications

Specification	Value
# of Grips	4
Signal Delay	0.5 second
Weight	Under 3 lbs.
Sustainable Load	1 lb.
Battery Life	8-10 Hrs. (Normal Use)
Battery Type	Rechargeable
Open/Close speed	3.33 ms/Degree

Simple Logic Diagram



Hardware Diagram



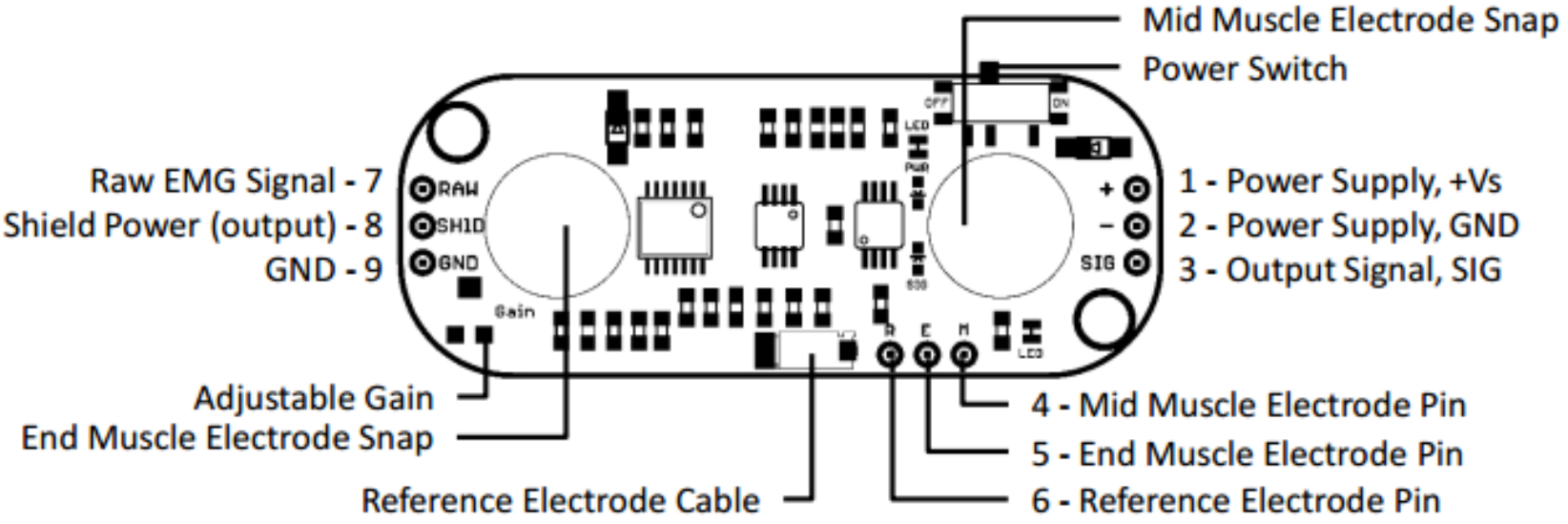
EMG Sensor

The Electromyography Sensor can be used to measure the electrical activity of muscles. EMG signal is in the order of up to 3,000 micro volts and can be easily manipulated which makes it one of the most popular sensors used as a control signal in prosthetic devices.

MyoWare EMG Sensor

The MyoWare EMG sensor is a muscle sensor offered by Advancer Technologies. This sensor performs by allowing the electrodes to be attached to the EMG board itself, with the ground breaking out into its own separate cable.

Sensor Layout

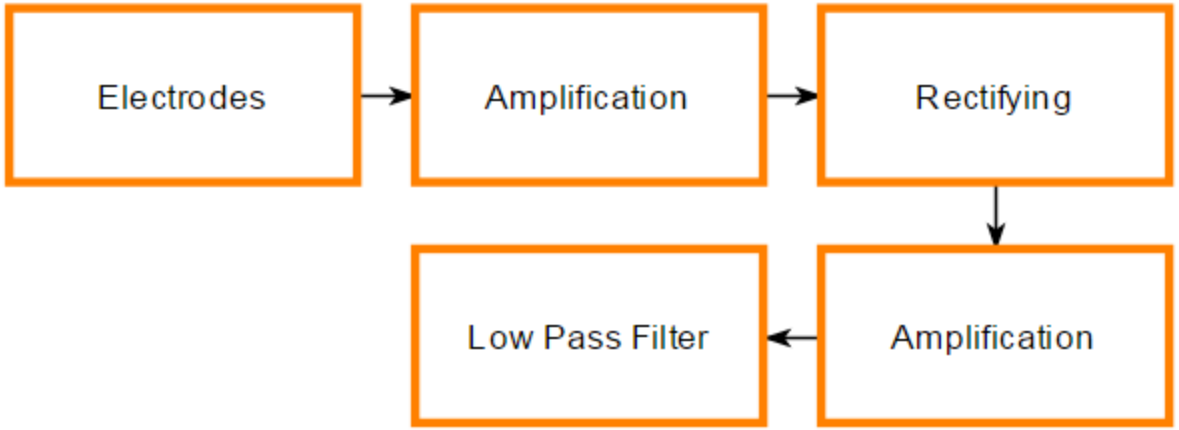


Electrical Specifications

Parameter	Min	TYP	Max
Supply Voltage	+2.9V	+3.3V or +5V	+5.7V
Adjustable Gain Potentiometer	0.01 Ω	50 kΩ	100 kΩ
Output Signal Voltage EMG Envelope Raw EMG (centered about +Vs/2)	 0V 0V	 -- --	 +Vs +Vs
Input Impedance	--	110 GΩ	--
Supply Current	--	9 mA	14 mA
Common Mode Rejection Ratio (CMRR)	--	110	--
Input Bias	--	1 pA	--

EMG Signal Processing

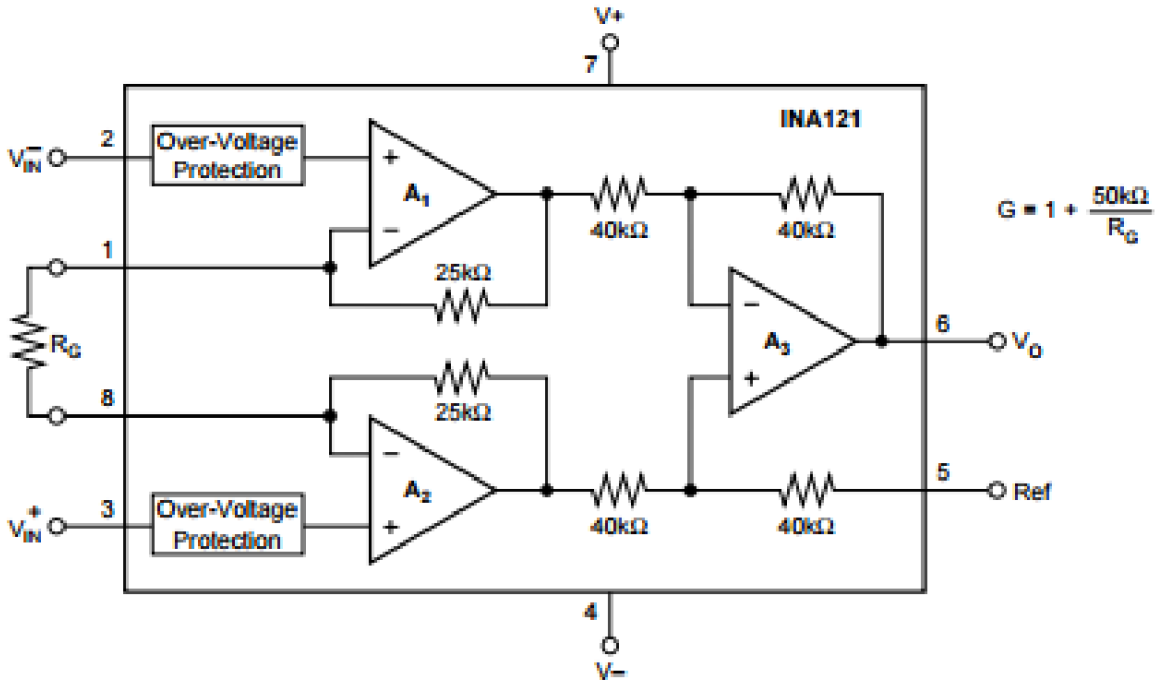
Stages:



Electrodes used with MyoWare sensor are standard disposable pre-gelled electrodes that are attached to the built-in electrode muscle snaps . They are easy to use and allow better contact with skin surface.

1st Stage Amplification

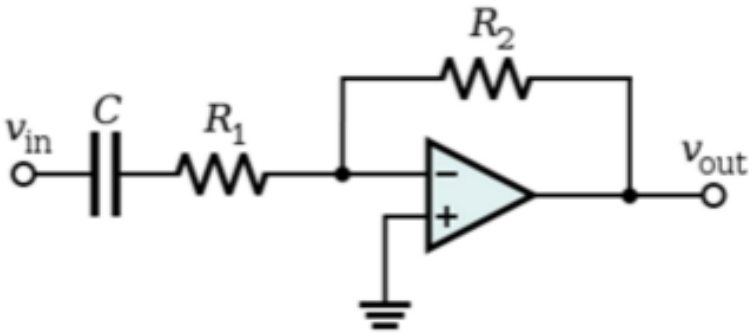
1st Amplification stage requires amplifier with high input impedance and very low output impedance. Instrumentation amplifier has to be used due to its excellent rejection of high frequency common-mode signals, low input bias current and, high speed. Performance remains excellent with power supplies ranging from ±2.25V to ±18V.



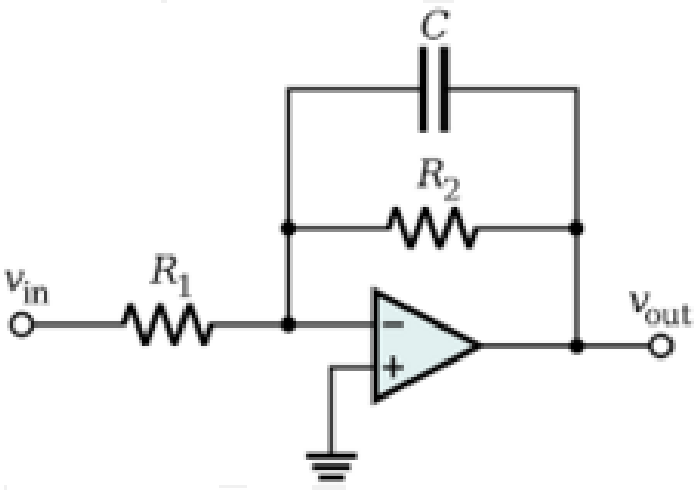
EMG Filtering

EMG filtering circuitry has high-pass and low-pass filters. The noises and the EMG signals are simultaneously amplified and this is not favorable so filtering has to be used after each amplification stage.

HPF

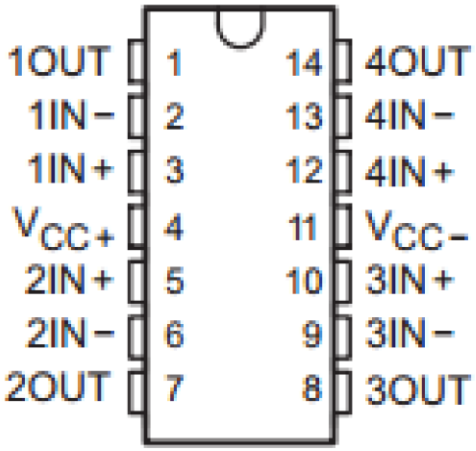


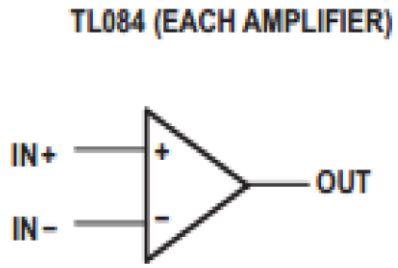
LPF



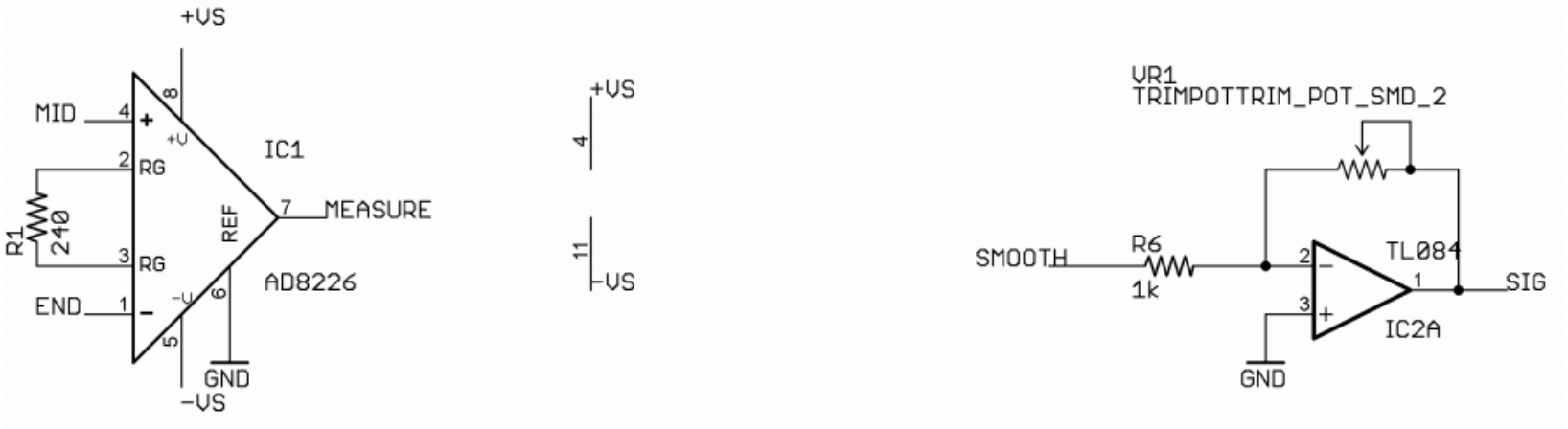
2nd Stage Amplification

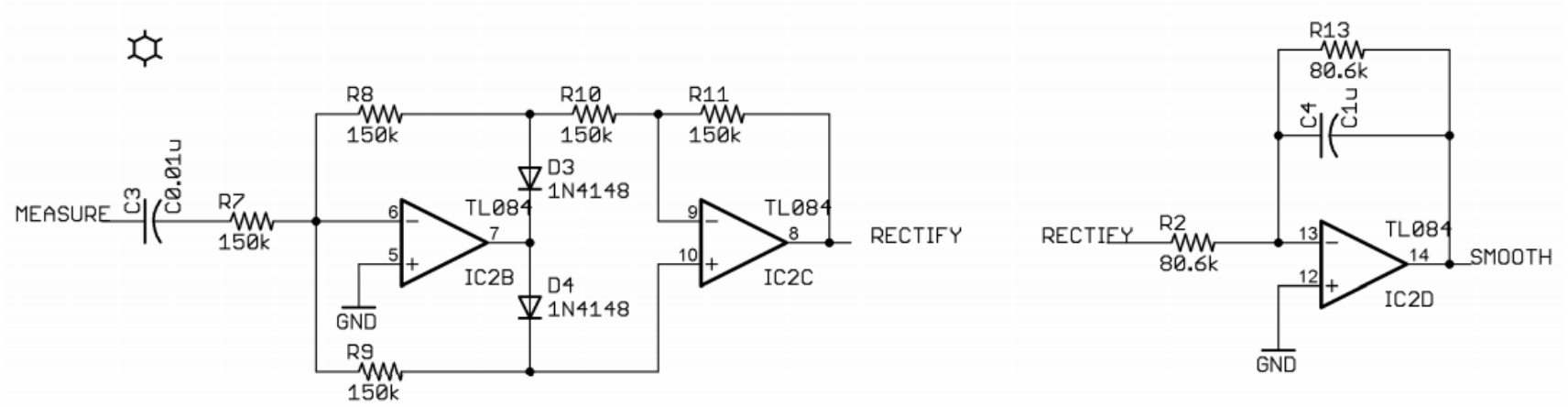
2nd Amplification can be achieved with the help of a non-inverting amplifier. TL084 with four built-in operational amplifiers was used to prototype this stage. It features high input impedance, low-input bias and offset currents, low power consumption, and output short-circuit protection.





Schematic Layout





Analog-to-Digital Converter

- Using on-board SAR analog-to-digital converter to convert EMG signal for usage of threshold value.
- Analog Supply Voltage 0 to 3.6V
- 12-bit ADC (2^12 = 4096 steps)
- 0.88 mV Resolution

Motor Considerations

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1. Type:

- Continuous DC, Stepper, Servo
- Servo includes control feedback for position

2. Size:

- Tradeoffs between strength of servo and physical size.

3. Grip Strength

- Amount of Torque
- Tradeoff between torque and current draw

4. Current Draw

- Maximum stall current equal to or under 0.5A

Servo Selection

TowerPro MG930

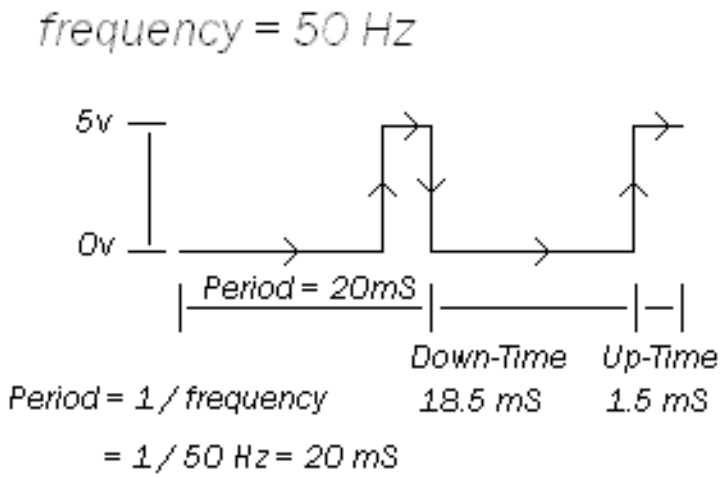
Modulation	Digital
Torque:	4.8V: 50.0 oz-in (3.60 kg-cm) 6.0V: 62.5 oz-in (4.50 kg-cm)
Speed:	4.8V: 0.14 sec/60° 6.0V: 0.11 sec/60°
Weight:	0.92 oz (26.0 g)
Dimensions:	Length: 1.43 in (36.2 mm) Width: 0.60 in (15.2 mm) Height: 1.13 in (28.7 mm)
Rotation:	Dual Bearings
Gear Type:	Metal

Airtronics 947616

Modulation	Digital
Torque:	4.8V: 55.0 oz-in (4.0 kg-cm) 6.0V: 68.5 oz-in (4.80 kg-cm)
Speed:	4.8V: 0.15 sec/60° 6.0V: 0.12 sec/60°
Weight:	0.8 oz (23.0 g)
Dimensions:	Length: 1.06 in (26.7 mm) Width: 0.47 in (11.9 mm) Height: 1.18 in (30.0 mm)
Rotation:	Dual Bearings
Gear Type:	Metal

Pulse Width Modulation (PWM)

- 50 Hz servo motor, period of 20ms
- 0.5ms to 1.5ms pulse width turns the servo from 0 to 180 degrees.
- Duty Cycle = [(1/180)*degrees + 0.5ms]/20ms



Display

1. 1.3 inch screen of 96 x 96 pixels
2. Ultra low power consumption
3. Display is controlled serially using SPI
4. Two capacitive touch sliders (three-element sliders)

Vendor	Texas Instruments
Price	$20 USD

Display

1. Calibration

The calibration menu will be used to recalibrate and adjust the thresholds.

2. Gesture Menu

The gesture menu will consist of a list of the gestures named. The current gesture selected will be highlighted.

Microcontroller Considerations

1. Amount of timers:

The timers are most importantly used to perform pulse width modulation(PWM). PWM is used to control the angle of the servo motors.

2. Serial Peripheral Interface(SPI):

SPI is an interface bus commonly used to send data between microcontrollers and small peripherals. SPI is needed to control the display serially

Microcontroller Considerations

3. Type/Amount of Memory

Adding gestures/display requires more code than initial Limbitless arm.

Ferroelectric Random Access Memory(FRAM) - retains data without a power source, has the speed of SRAM, and the security of flash.

4. Power/Cost

To stay within spec inexpensive low power MCU is needed

Microcontroller Considerations

5. Analog-to-Digital Conversion

Most microcontrollers support ADC. ADC is used to convert user input to digital means the MCU can understand.

6. Amount of Pins

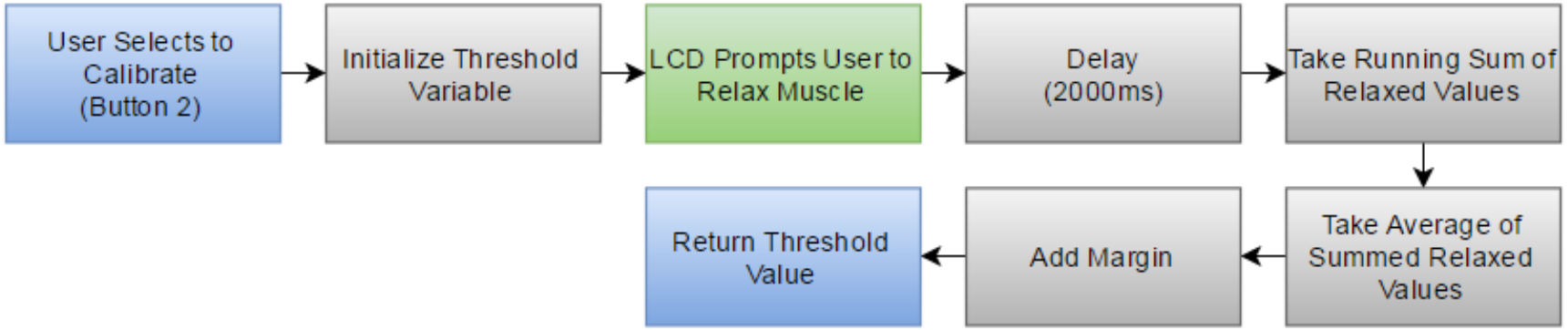
Enough pins are needed to implement the project. Through the beginning phases of research number of pins was not known.

MSP430FR5969

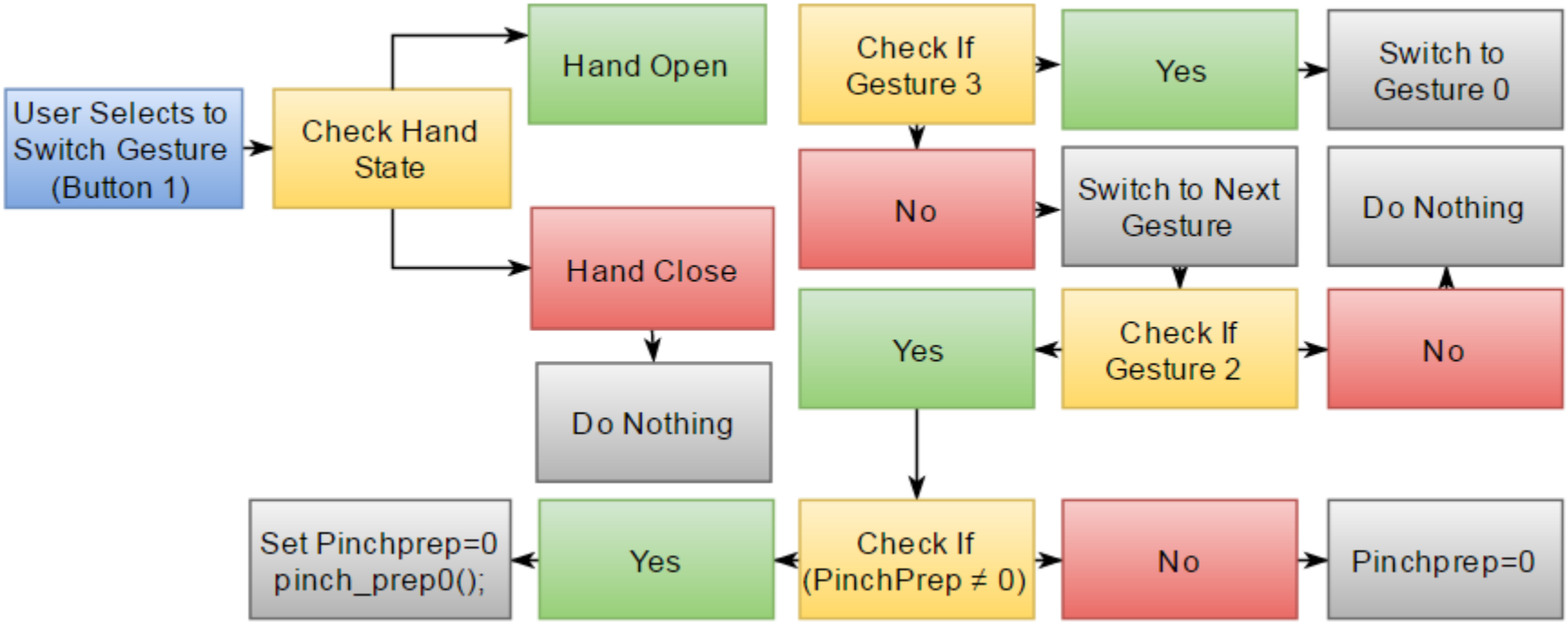
Features
64KB FRAM
2KB SRAM
SPI 3x
UART
I2C
40 Input/Output

Vendor	Texas Instruments
Price	$14.5 USD

Calibration Mode

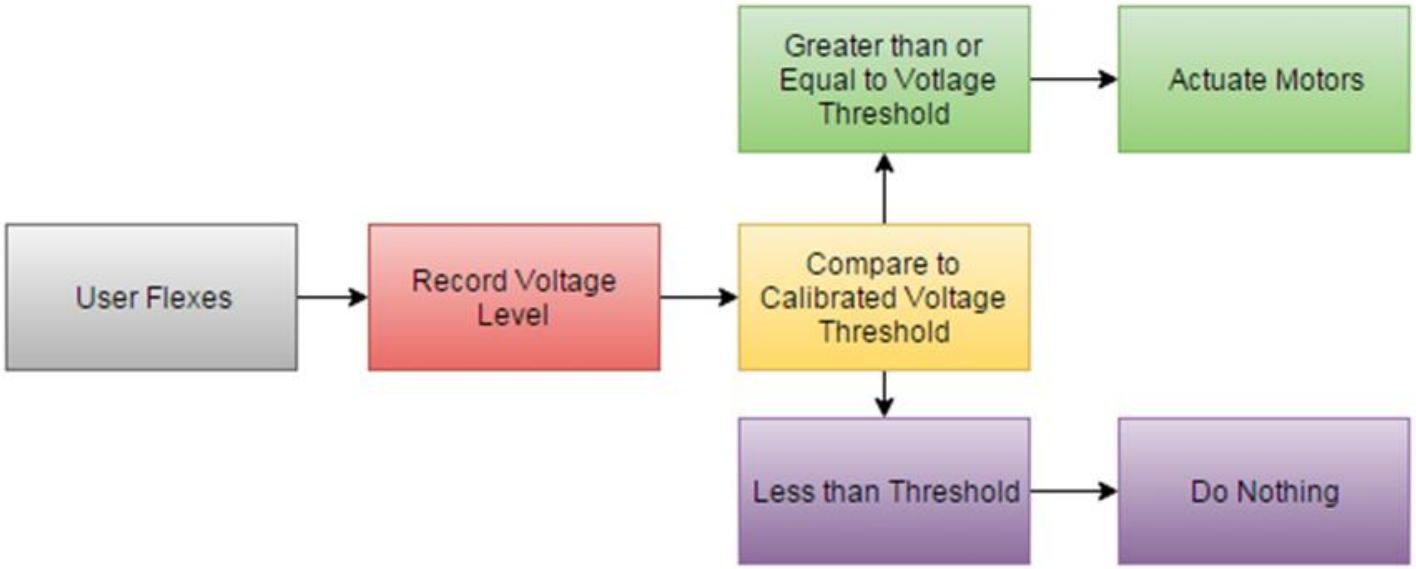


Switch Gesture Mode



Gesture Description	Number
Full Grip	0
Pinch	1
Pointer	2
Thumbs Up	3

Operating Mode



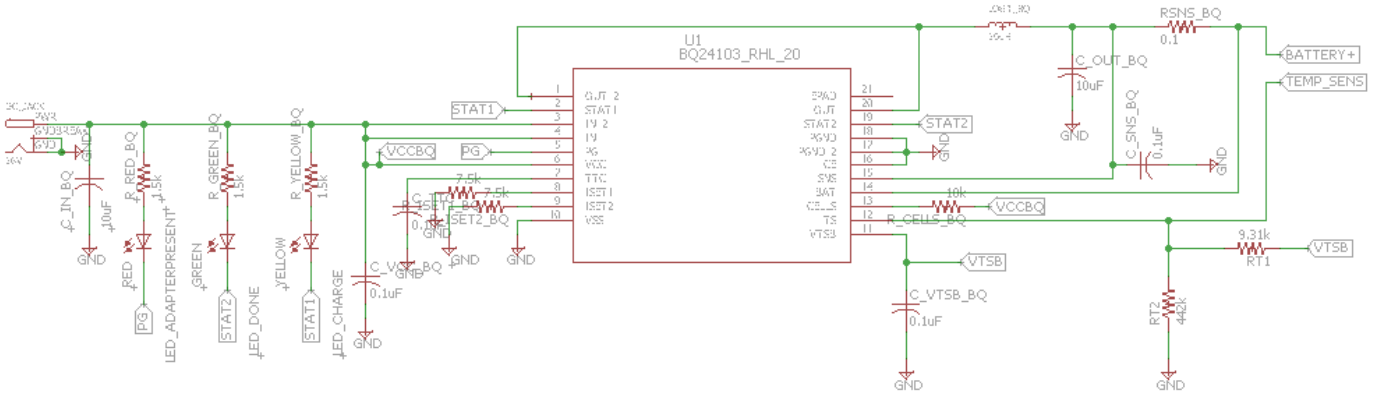
Power Supply Considerations

Battery: **2S1P Tenergy 18650 Li-Ion Battery**

- Rechargeable
- Small Form Factor
- Two cell with 7.4 nominal voltage (vs. Single-Cell 3.7)
- Allows for bucking as opposed to boosting to supply voltages
- Included PCB Overcharge and Over-discharge Protection

Charging: **bq24103 Li-Ion Charger**

- Allows for 2-Cell balanced charging
- Allows for 10-16V AC adapter charging
- Special application to dual charge with 5V USB
- Price: $4.50



Power Supply Considerations

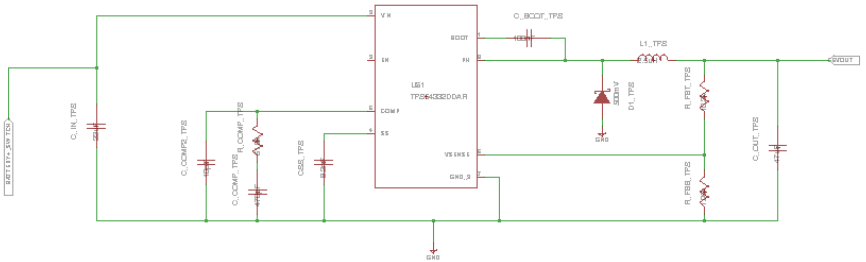
2. Supply Voltage / Current Requirements:

Part	Supply Voltage Requirement (V)	Current Draw - Maximum (A)
Motor #1	4.8-6V	0.5A
Motor #2	4.8-6V	0.5A
Motor #3	4.8-6V	0.5A
Motor #4	4.8-6V	0.5A
LCD Display	+3.3V	Varies with Application
EMG Sensor	+3.3V	15 mA
Microcontroller	1.8-3.6V	3 mA

Power Supply Considerations

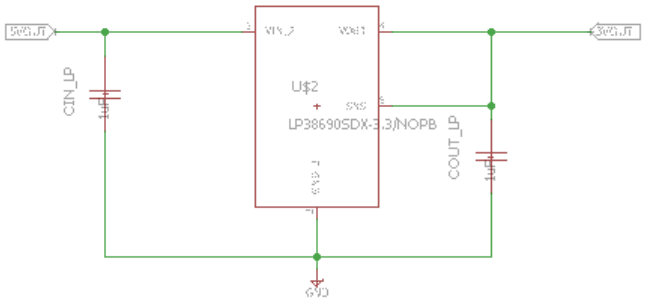
TPS54332 Buck Converter

- 3.5-28V Input Voltage Range
- Adjustable Output Voltage (Allows for 5V Rail)
- Available output current up to 3.5A
- Smallest footprint option for this application
- Price: $2.04

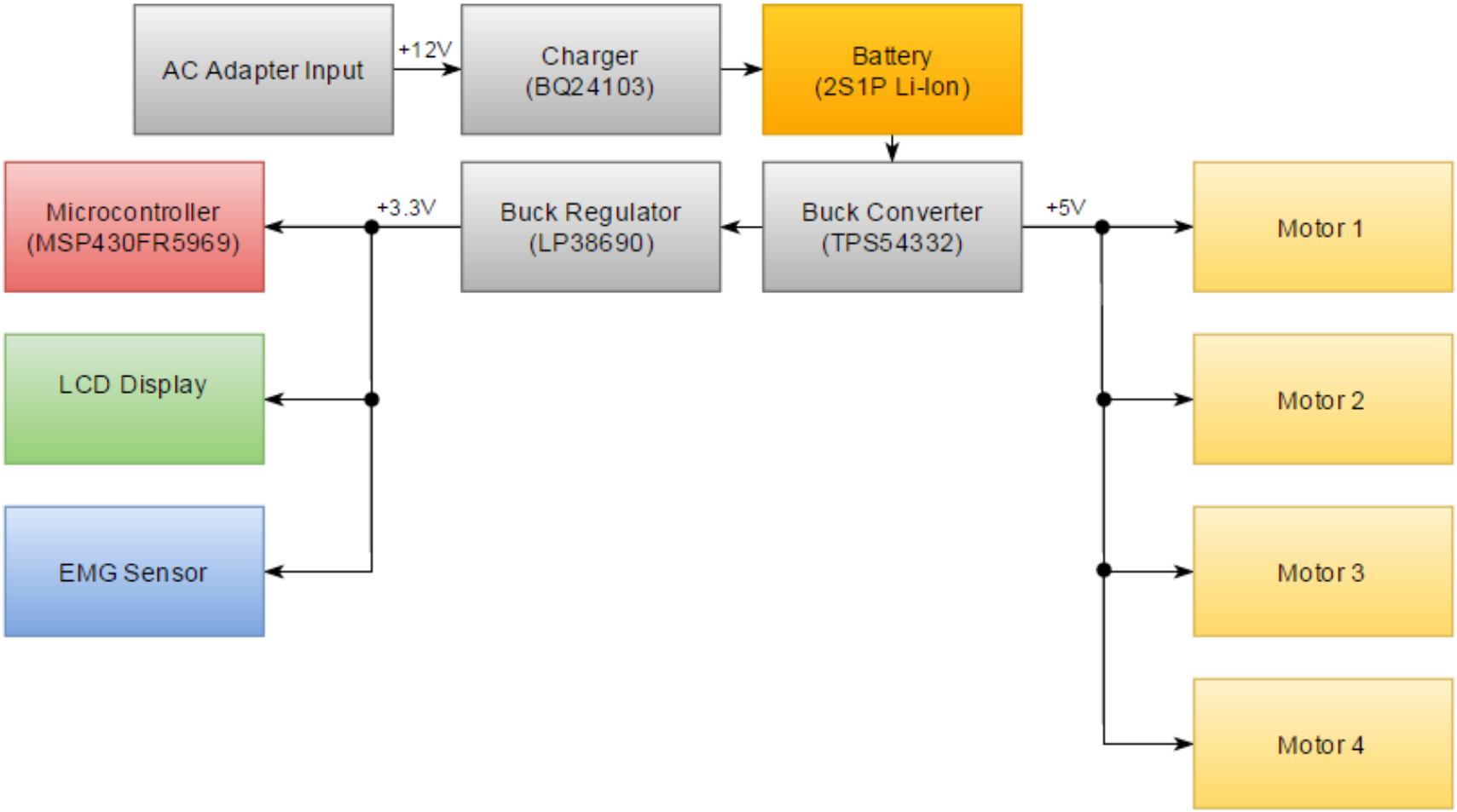


LP38690 LDO Linear Regulator

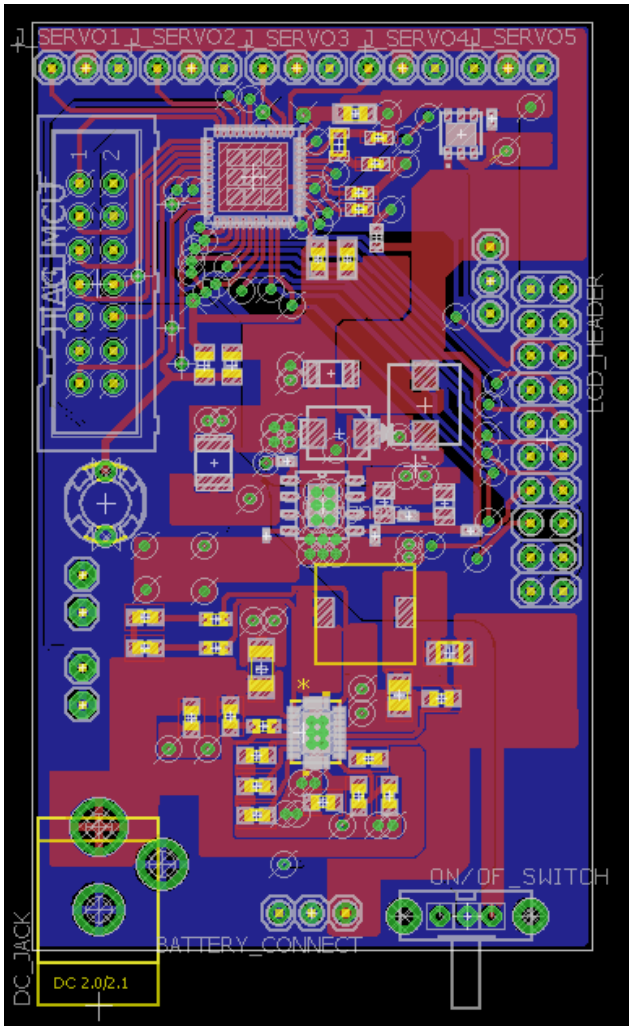
- 2.7-10V Input Voltage Range
- Small footprint (linear regulator)
- Price $0.63

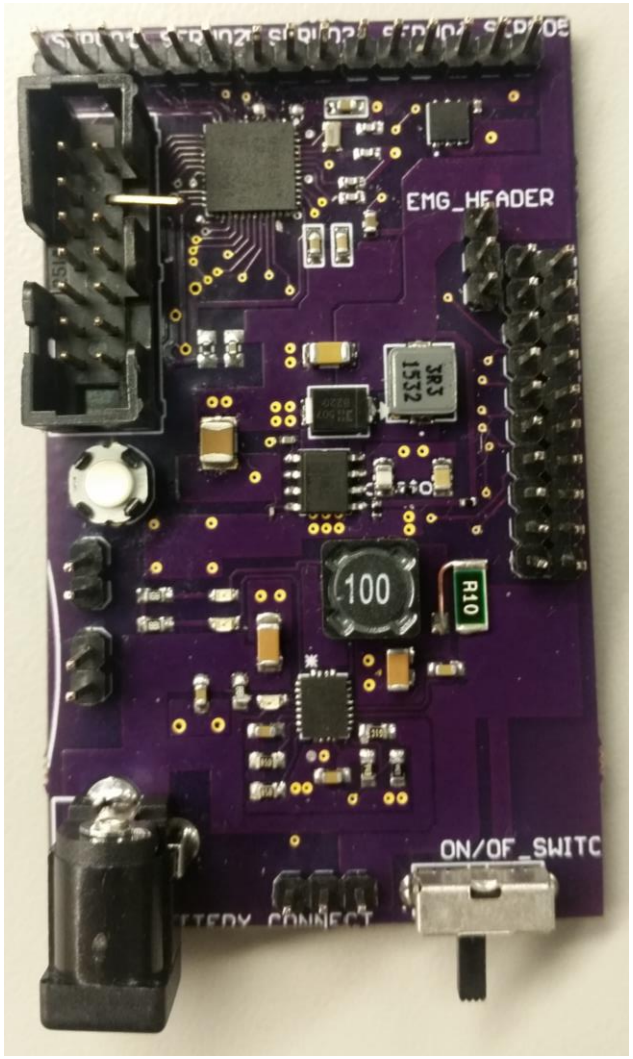


Power Supply Block Diagram



PCB Design





Administrative Content

Work Distribution

The project was divided into 4 major hardware component subsystems: Power, Sensor, MCU, and Servos. Even though, each group member was assigned a specific subsystem, collaboration is absolutely necessary for successful completion

Section	Christopher	Javier	Tatiana	Arian
Administrative / Technical Writing	S		P	
Power System Design	P		S	
EMG Implementation		S	P	
Servo Implementation	S	P		
Calibration/LCD (Programming)		S		P
PWM / Gestures (Programming)		P		S
PCB Design / Board Layout	P		S	S
Part Ordering / Budget Management	S		P	

P – Primary
S - Secondary

Estimated Cost

Component	Quantity	Price ($)
Microcontroller	1	36.50
Servos	4	250.00
Battery	1	50.00
Charging	1	12.50
EMG Sensor	1	35.00
EMG Prototype	1 (Box)	20.00
LCD Display	1	53.98
PCB Components	3	25.00
PCB Manufacturing	3	145.20
TOTAL	**17**	**728.02**

Difficulties:

Power:

- Battery Charging.
- Protection circuit if high capacity RC Li-Ion battery is used.

EMG sensor:

- Can be damaged by electrostatic discharge; ESD damage can range from subtle performance degradation to complete device failure.

Servos:

- May not have enough torque to overcome the load. As a result different motors will have to be considered.
- Size of Servos to fit in the arm.

Questions?