Programmable Elbow Orthosis

Team 10: David Cuevas – Nathan Glaser – Joe Loredo – Rafael Salas

Project Goals

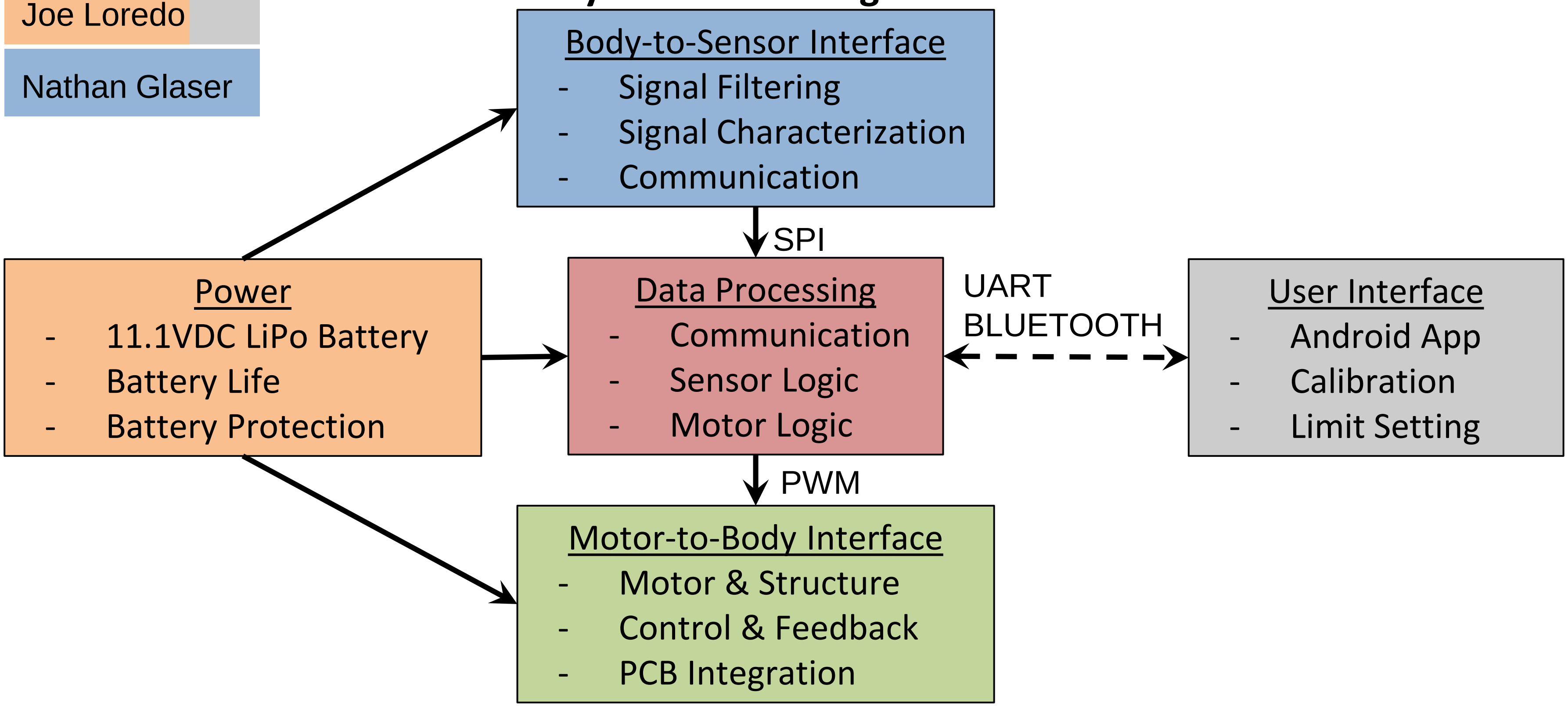
Our goal is to create a programmable elbow orthosis to

1. Provide structural support for the elbow
2. Resist and restrict harmful ranges of motion
3. Assist with intended elbow movements

Legend

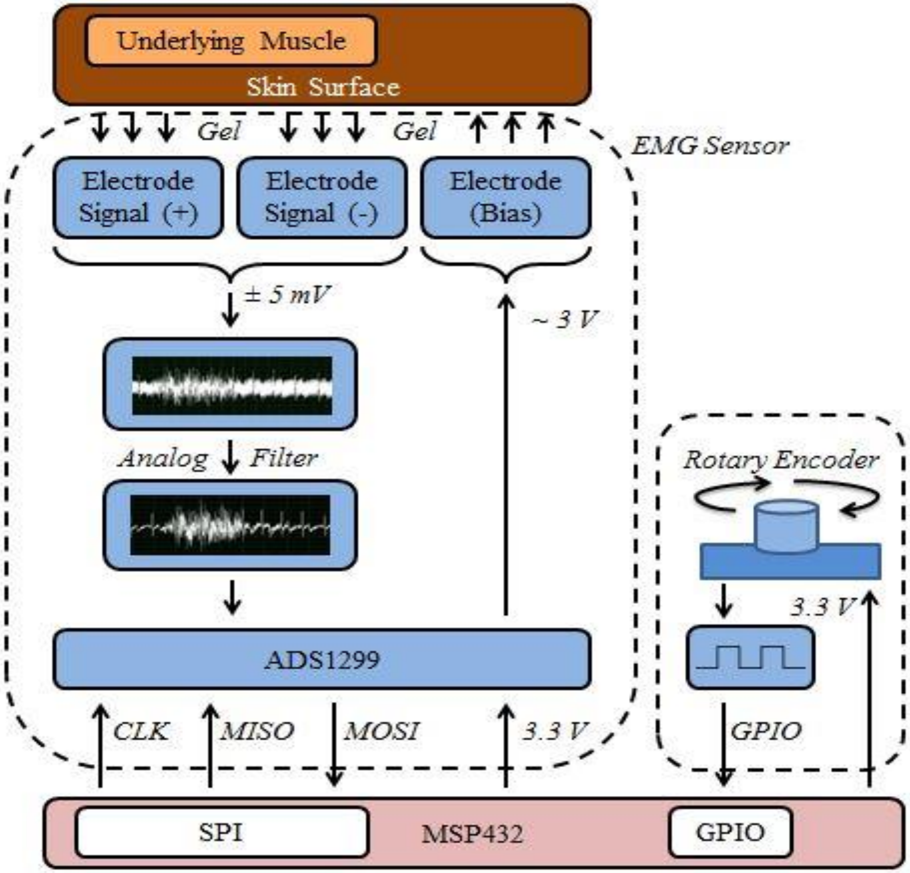
- Rafael Salas
- David Cuevas
- Joe Loredo
- Nathan Glaser

System Block Diagram



Subsystem – Team Matrix

Subsystem	Primary Contact	Responsibilities
Body-to-Sensor Interface	Nathan Glaser	– Develop and test wearable sensors which will transmit elbow angle and muscle activity – Filter noise from raw sensor signal – Ensure setup is not invasive and is not restrictive
Data Processing	Rafael Salas	– Convert sensor data into controller variables – Manipulate data to satisfy user specifications – Reconvert result into motor signal
Motor-to-Body Interface	David Cuevas	– Actuate motor and articulate elbow based on microcontroller signal – Ensure movement is assistive and natural
Power	Joe Loredo	– Provide portable and sustained power to each subsystem
User Interface	Joe Loredo	– Connect user-friendly interface which will calibrate EMG sensors and specify custom angle limits (without customizing microcontroller source code for every user)



Subsystem 1: Body-to-Sensor Interface

Nathan Glaser

OBJECTIVES:

- **Quantify Intention and Current State**
- **Communicate with Main Controller**
- **Filter Signal**
- **Compact Packaging**

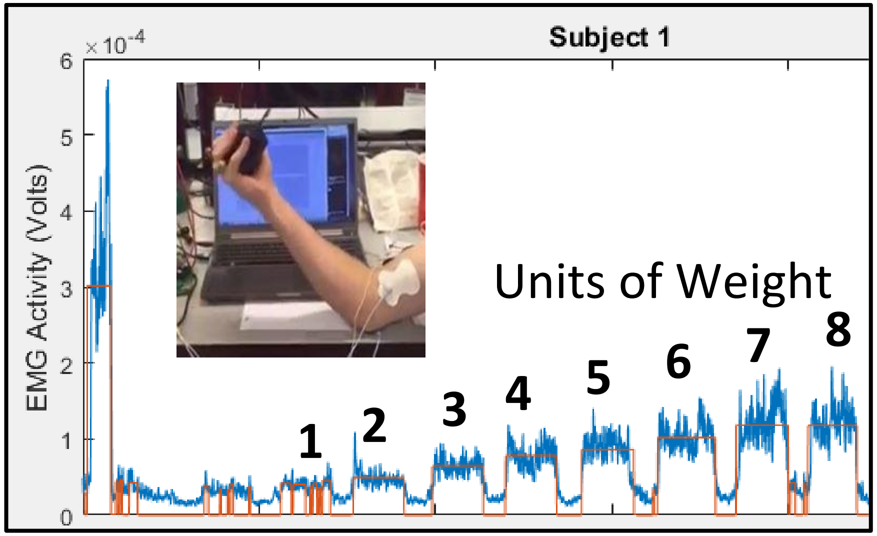
COMPLETE:

- **Characterize EMG Signal**
  - Independent* Muscles
  - Linear ($R^2 > 0.95$)
- **Rotary Encoder**
- **SPI Communication**
- **Signal Processing**
  - FIR High Pass FIlter
    - Filter Coefficients (Matlab)
    - Convolution (C Code)
  - Moving Average Function
- **ADS1299 PCB Schematic**

INCOMPLETE:

- **Implement Code on MSP432**
  - Muscle Group Comparator
  - Linear Calibration Routine
  - Real-Time FIR Filter (Trailing Window)
- **Solder and Test ADS1299 PCB**
- **Integrate Peripheral Sensors**
  - Force Sensitive Resistor

Subsystem 1:
Body-to-Sensor Interface
Linearity Test

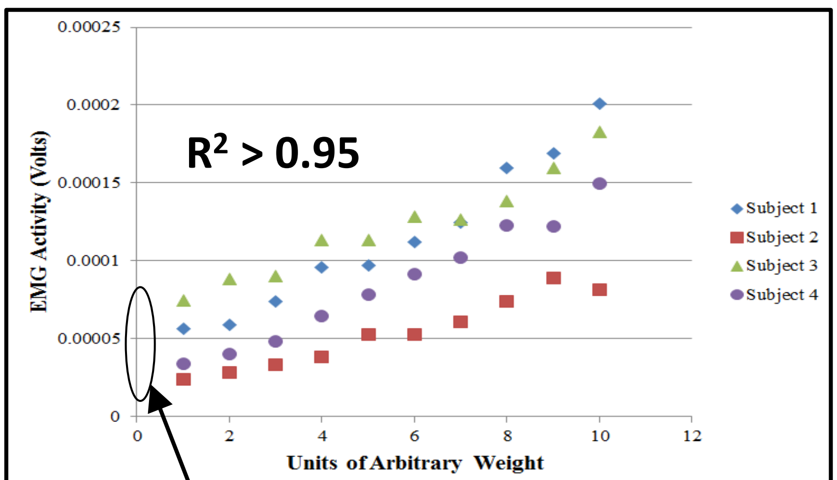


x 4 Subjects

<u>2 Calibration Signals</u>

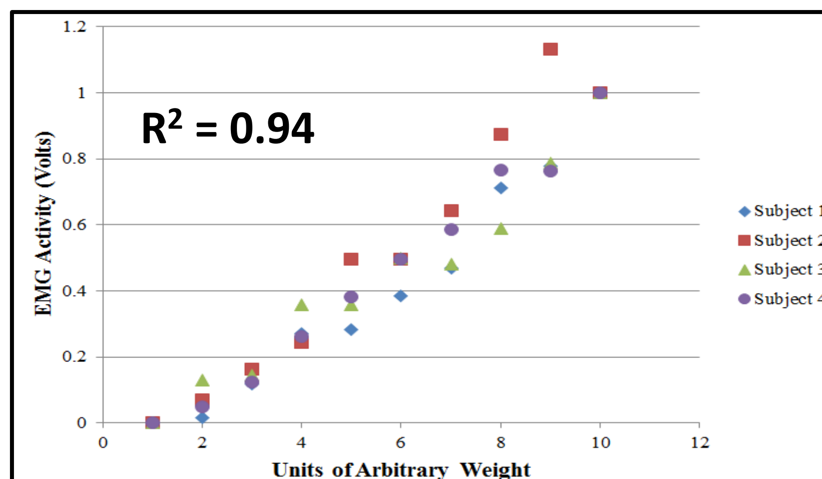
x_{min} = Resting EMG Signal

x_{max} = Max EMG Signal



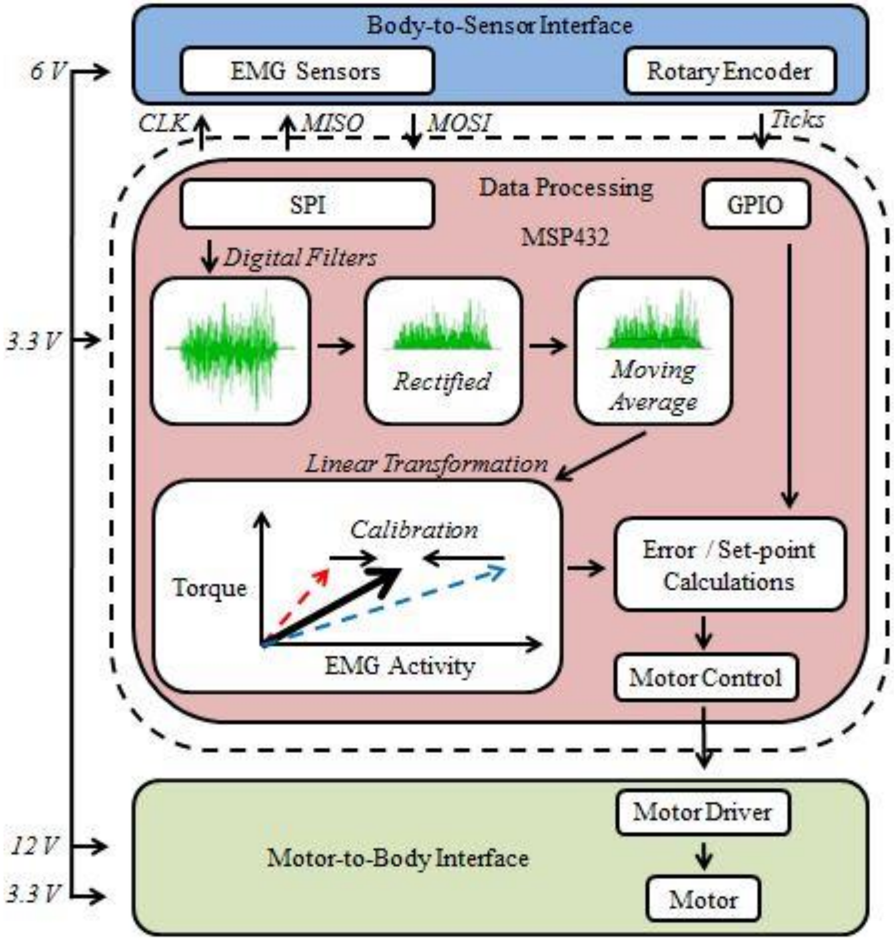
$$y = (x - x_{min}) / (x_{max} - x_{min})$$

Calibration Routine



Non-Zero Y-Intercept Significant:

→ Account for Resting EMG Signal



Subsystem 2:
Data Processing
Rafael Salas

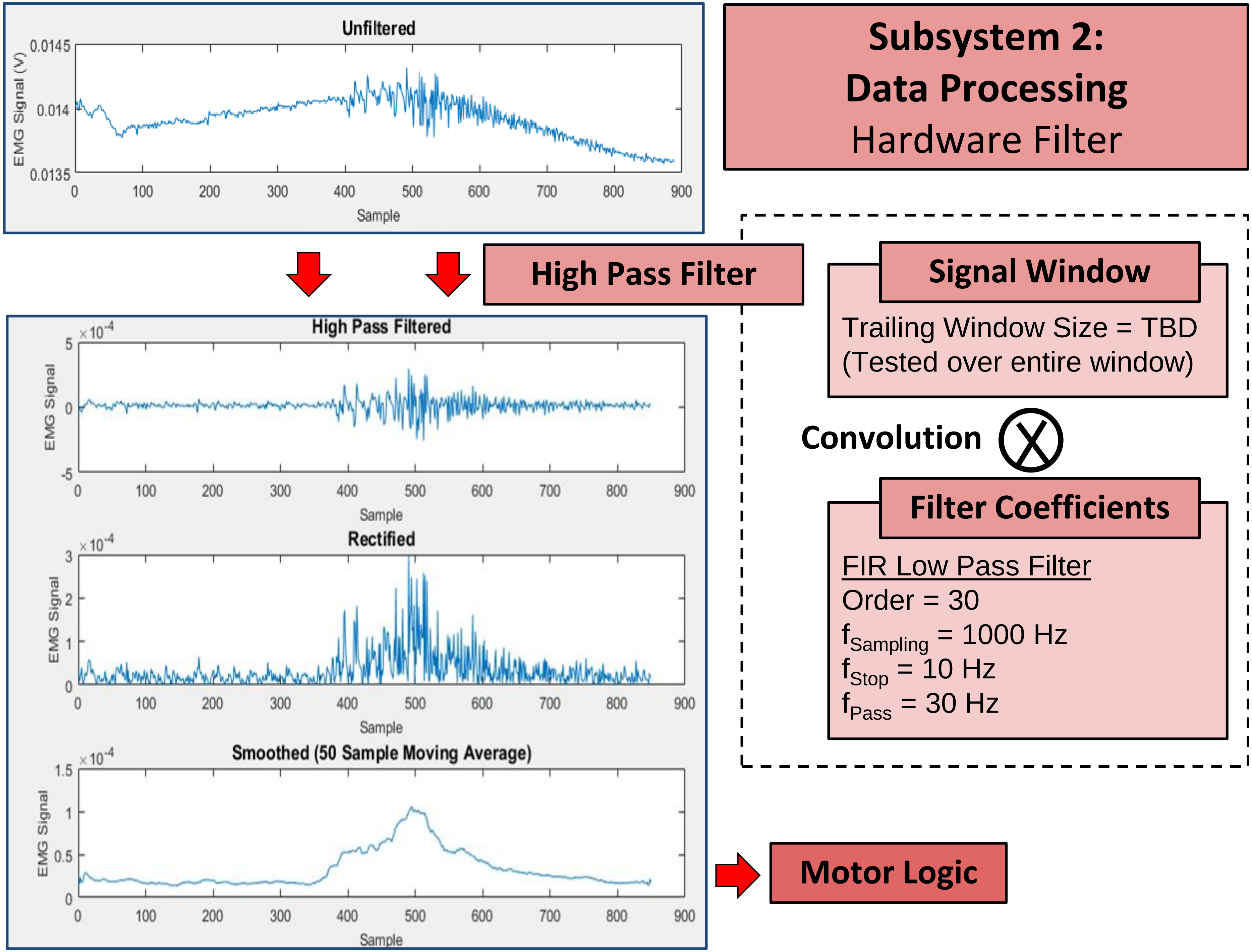
Objectives

Filtering Input Sensor Data:

- ❑ Perform running averages from filtered sensor data.

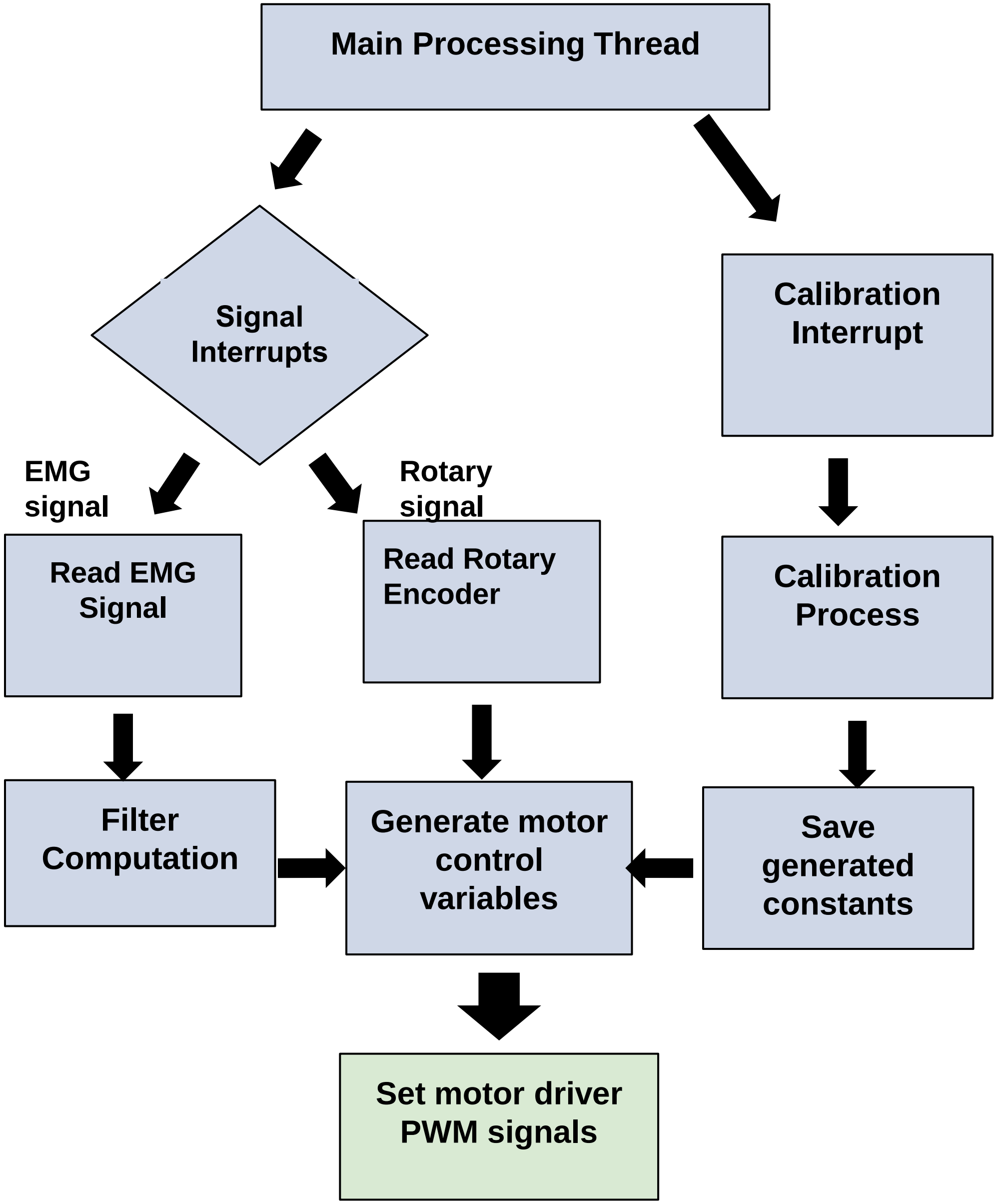
Produce Motor Variables from Data:

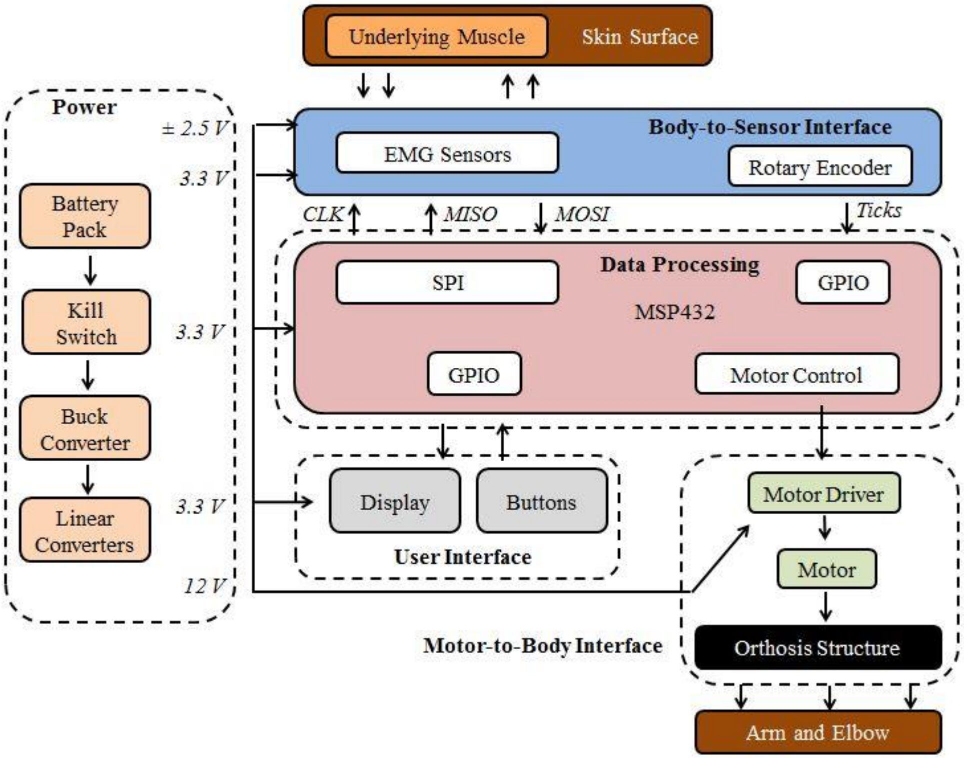
- ❑ Use filtered data to produce variables to actuate motor.


Subsystem 2:
Data Processing
Hardware Filter
Unfiltered
EMG Signal (V)
Sample
High Pass Filter
High Pass Filtered
EMG Signal
Sample
Rectified
EMG Signal
Sample
Smoothed (50 Sample Moving Average)
EMG Signal
Sample
Signal Window
Trailing Window Size = TBD
(Tested over entire window)
Convolution
Filter Coefficients
FIR Low Pass Filter
Order = 30
$f_{Sampling}$ = 1000 Hz
f_{Stop} = 10 Hz
f_{Pass} = 30 Hz
Motor Logic

Data Processing Flow Chart

Rafael Salas

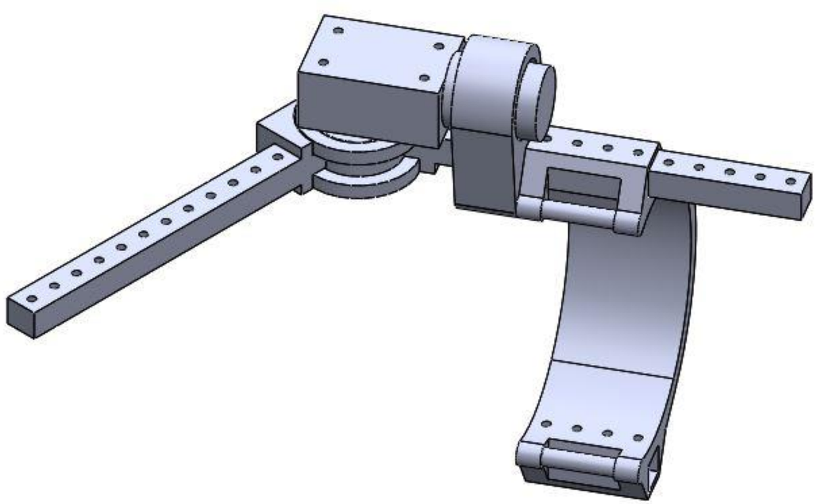


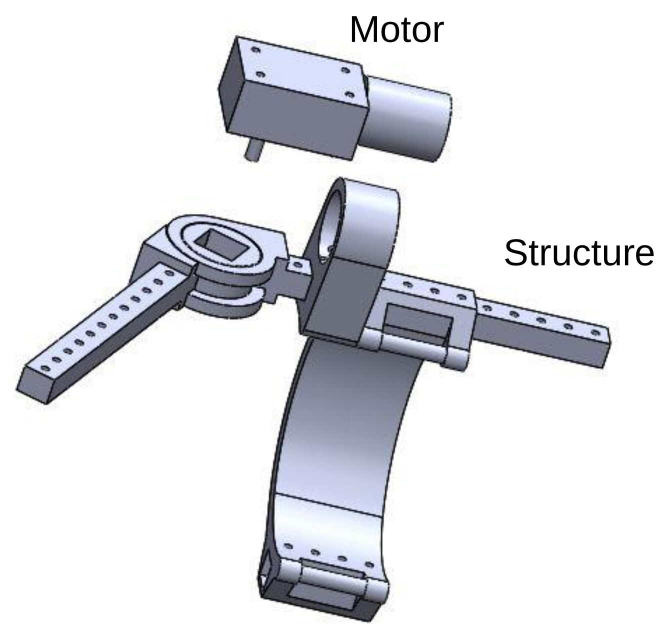


Subsystem 3:
Motor-to-Body Interface
David Cuevas

- ❑ DC motors were the winners based on their High Torque and low Current draw when compared to Stepper Motors
- ❑ The Structure will be driven directly by the 9RPM DC motors. This will ensure proper torque distribution and decrease loss of torque by 3d printed gears

Elbow Orthosis Structure

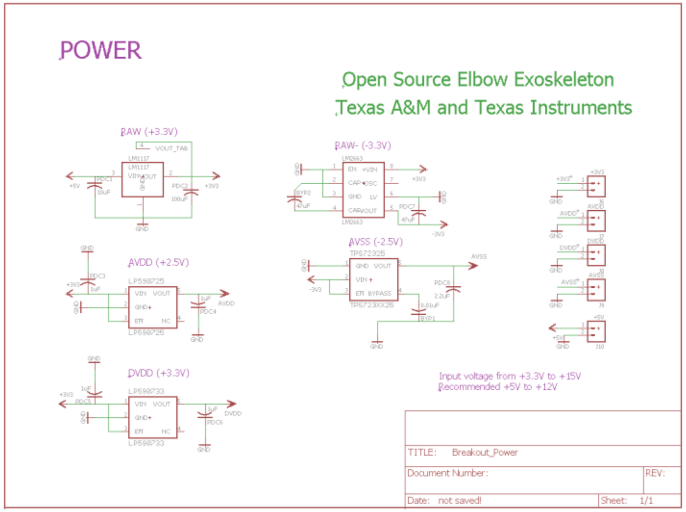


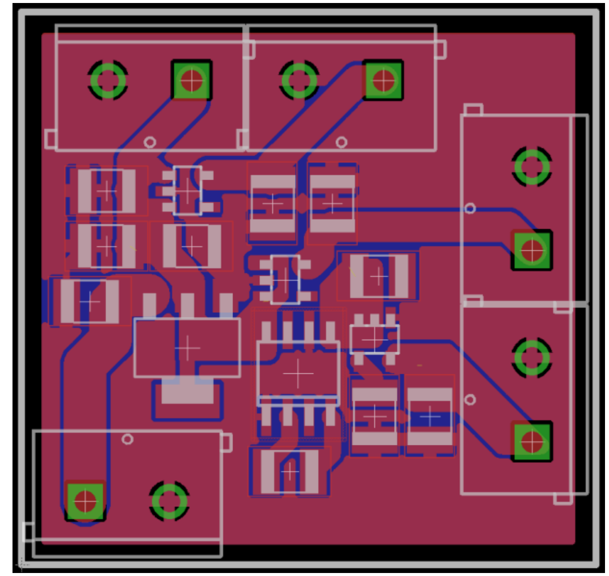


Motor-to-Body PCBs

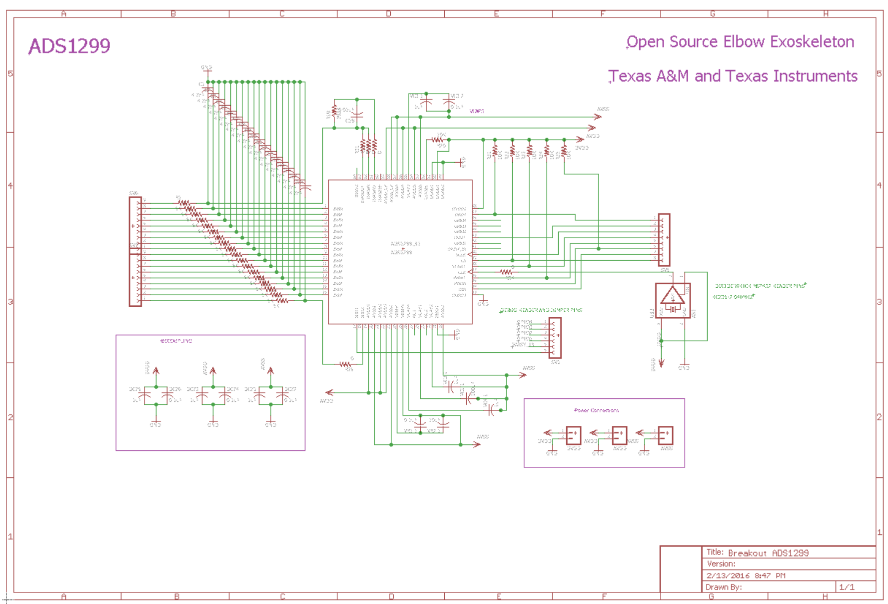
David Cuevas

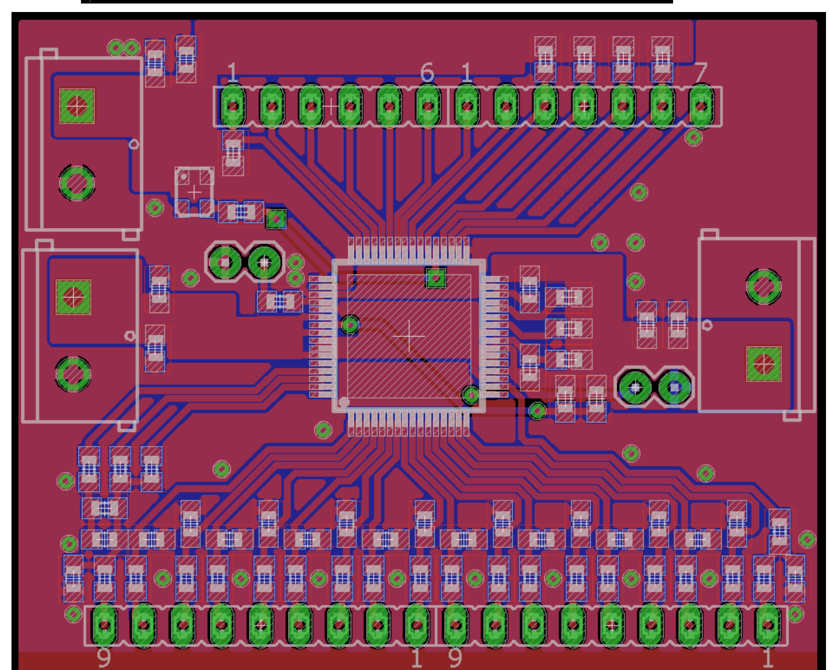
Power Breakout Board





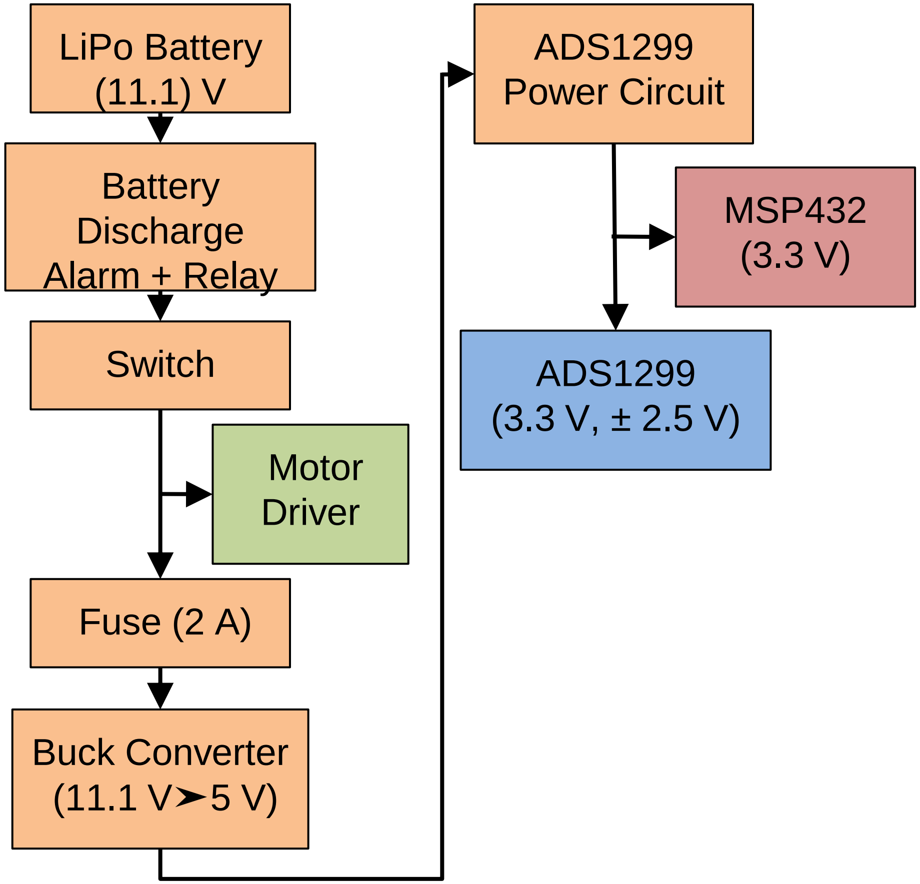
ADS1299 Breakout Board





Subsystem 4: Power

Joe Loredo



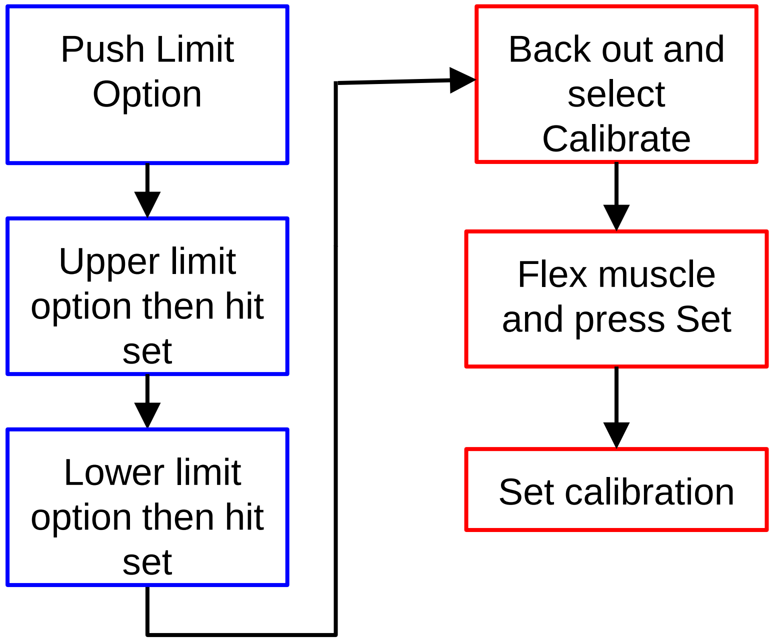
Objectives

Provide adequate power for all subsystems

- ❑ 5 linear voltage regulators used to achieve the voltages for the ADS1299 (3.3 and ±2.5 V) and MSP432 (3.3 V)
- ❑ A buck converter produces the 5 V required by the circuit from a power source of 11.1 V
- ❑ Discharge alarm in conjunction with a relay switch disconnects the battery if the battery level of any lipo cell gets too low

Power BreadBoard Test

Specification	Input (V)	Ideal Output (V)	Actual Output (V)	Current Output (mA)
DROK Buck Converter	11.1	5	5.01	31
LM1117IMP-3.3/NOPB	5	3.3	3.26	31
LP5907MFX-2.5/NOPB	3.3	2.5	2.48	31
LP5907MFX-3.3/NOPB	3.3	3.3	3.27	31
LM2663M/NOPB	3.3	-3.3	-3.27	31
TPS72325DBVT	-3.3	-2.5	-2.51	31



Subsystem 5:
User Interface
Joe Loredo

Objectives

Allow the user to set limits and calibrate the orthosis

- ❑ Communicate with MSP432 using Bluetooth module and Android app
- ❑ Android app is used to calibrate and set orthosis limits
- ❑ Utilizes the Motor-Body radial encoder for limits and the Body-Sensor electrodes for calibration

Ongoing Progress/Problems

Body-to-Sensor Interface:

- ❑ Real-Time FIR Filtering (Trailing Window?)
- ❑ Multiple Sensor Integration
- ❑ Juggling (Filter, UART, SPI, PWM, and ADC)

Data Processing:

- ❑ Managing interrupt flags
- ❑ Rotary Encoder calibration
- ❑ Calibration work flow

Motor-to-Body Interface:

- ❑ Rotary encoder feedback loop
- ❑ Motor Control Precision

Power & User Interface:

- ❑ Finish bluetooth connectivity with MSP432
- ❑ Work with Data Processing to accomplish calibration and limit setting
- ❑ Solder power board and test all components for appropriate voltage/current output
- ❑ Construct and test discharge relay circuit

Conclusion

Our team has made substantial progress towards our initial objective.

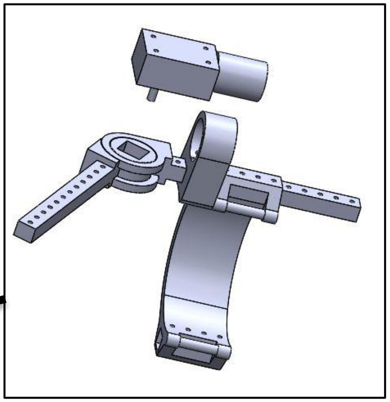
Each subsystem works in isolation…now we need to integrate them.

Power

Data Processing

Our **powered**, **portable**, **programmable** elbow orthosis:

- Provides structural support for the elbow
- Resists and restricts harmful ranges of motion
- Assists with intended elbow movement



Motor-to-Body

Body-to-Sensor