ArachnoBotics Research Inc.

The ArachnoBot™

Simon Fraser University
Faculty of Applied Science
School of Engineering Science
440/305 Capstone Project by:
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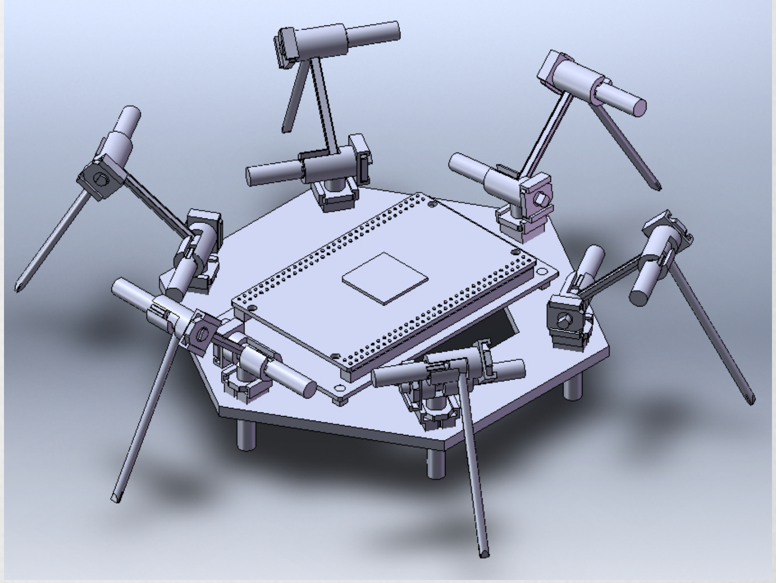
Pavel Bloch
Pranav Gupta
Stefan Strbac

Project Introduction

- The ArachnoBot
- Lightweight Robotic Hexapod
- Initial Prototype
- Based on European Space Agency Project
- Intended for Space Exploration



Presentation Overview

- Project Background
- System Overview
- Demonstration
- System Design
- Market Analysis
- Reflections
- Conclusion

Team Introduction

- Daniel Naaykens
  - Mechanical Design
- Pavel Bloch
  - Electronics Design
- Pranav Gupta
  - FPGA Design
- Stefan Strbac
  - FPGA and PCB Layout

Project Background

European Space Agency
Biomimetics
Mobile Robotics

European Space Agency

- Based on a project by the European Space Agency
  - Fleet of small and lightweight mobile robots
  - Explore planets
  - Maintain mechanical systems
  - Construct human outposts
- ArachnoBot furthered this idea for any exploration

Biomimetics

- Nature has evolved creative solutions to many problems
  - Even solutions for devices that have not been invented
- Powerful creative force in mimicking biology
  - Multi-legged walk cycles for walking, running, climbing
  - Flight, swimming, defense mechanisms

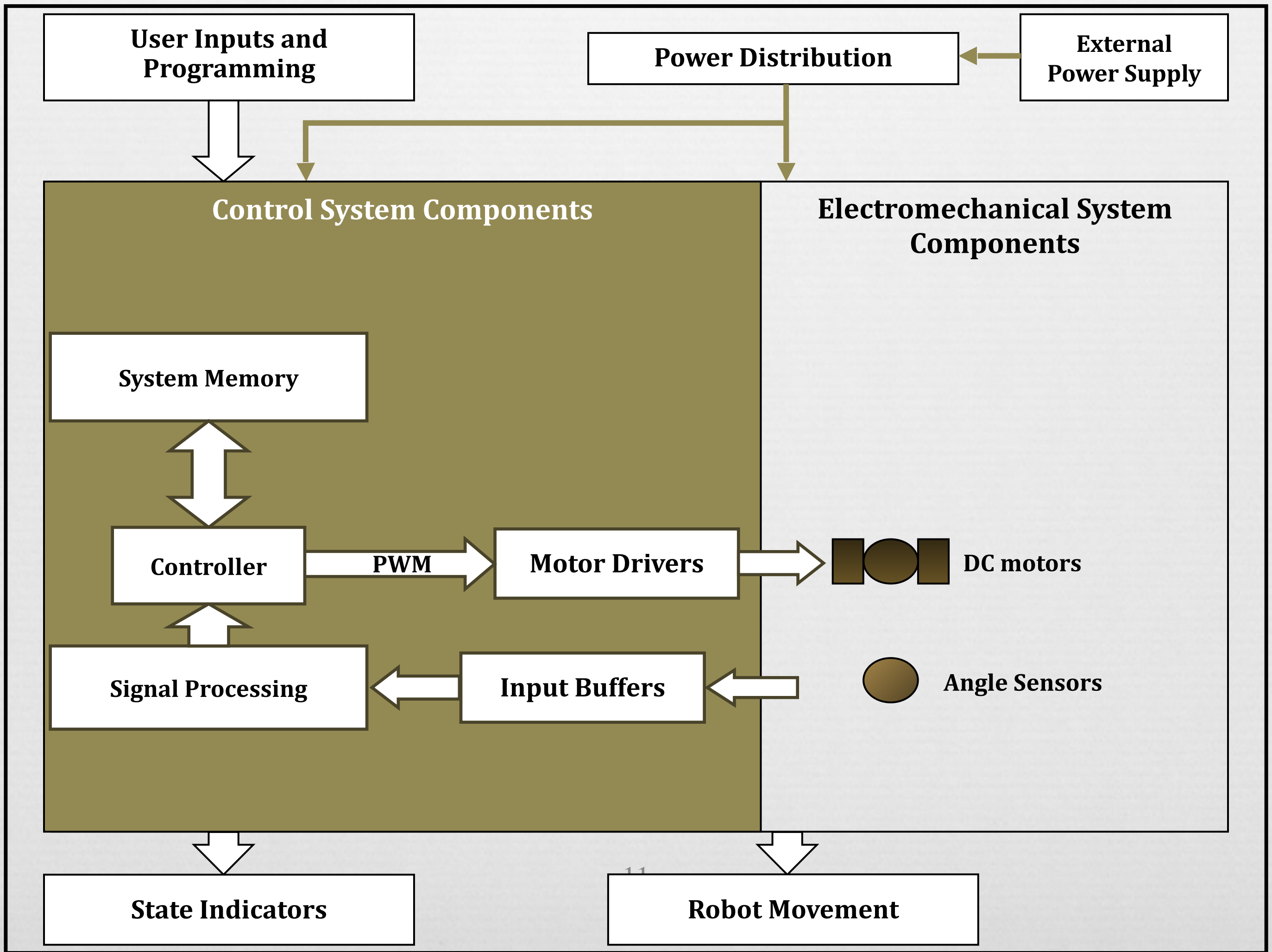
Mobile Robotics

- Study of robots capable of locomotion
- Locomotion can be powered bya number of ways
  - Wheels, Legs, Sliders, Flight, Swimming
- Sensors and actuators
- Central processing unit
- Electrical components

System Overview

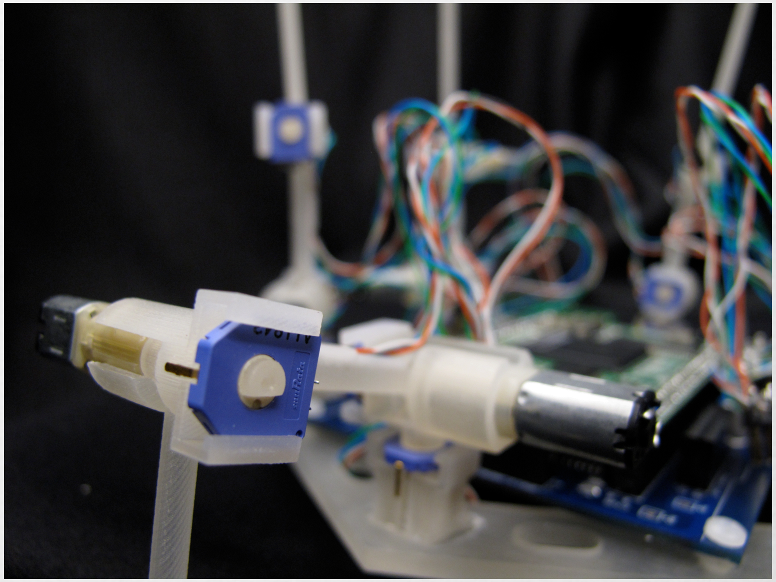
Electromechanical Components
Processing Components

Functional Diagram



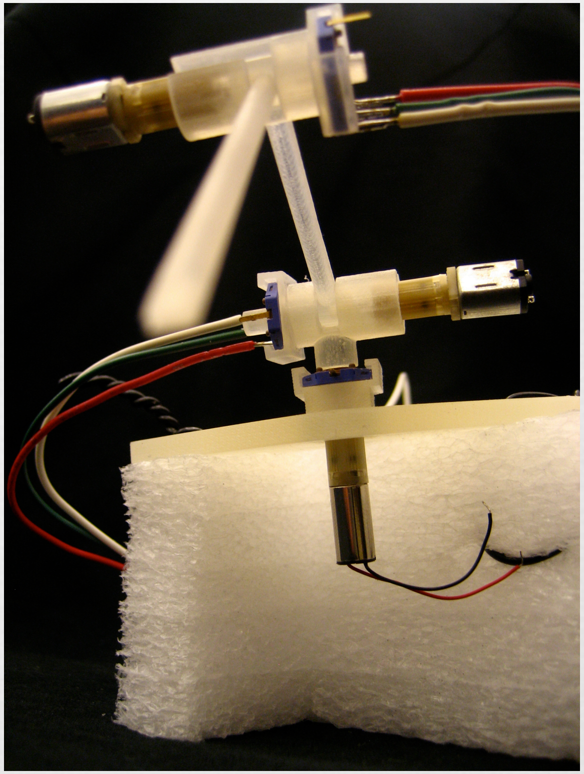
Sensors

- Used to determine each joint's position
- Small rotary potentiometers
- Design considerations included friction, size, and accuracy



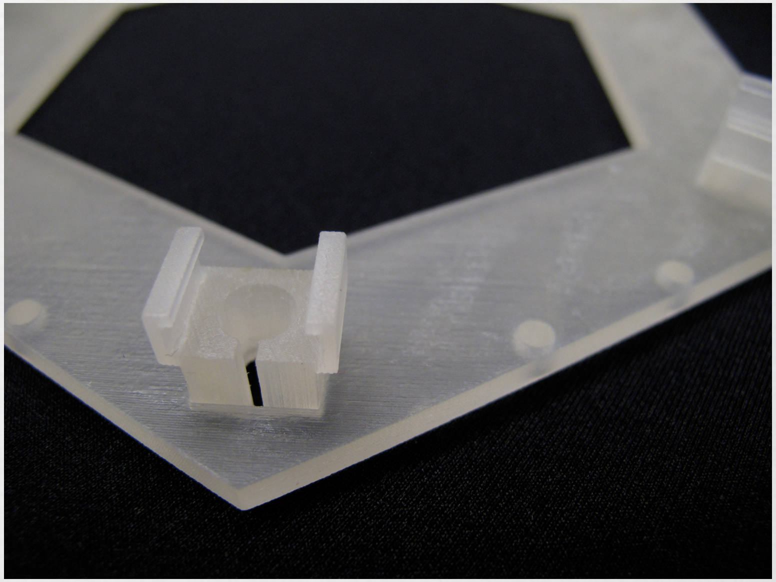
Actuators

- Used to move each joint
- Geared DC motors
- Design considerations included friction, torque, and speed



Mechanical Body

- Made of Rapid Prototyping material
- Replaceable
- Easily constructible
- Take wire routing into account
- Lightweight yet strong



Processing Components

- FPGA Development Board
- MicroBlaze architecture
  - Multi-core processing environment
  - Allows parallelization of tasks
- Each leg has its own MicroBlaze in conjunction with the master controller

Demonstration

Computer Interfaced Trajectory Traversal
Horizontal Walking
Untethered Movement

System Design

Electronic Components
PCB Design
Mechanical Components
Central Processing

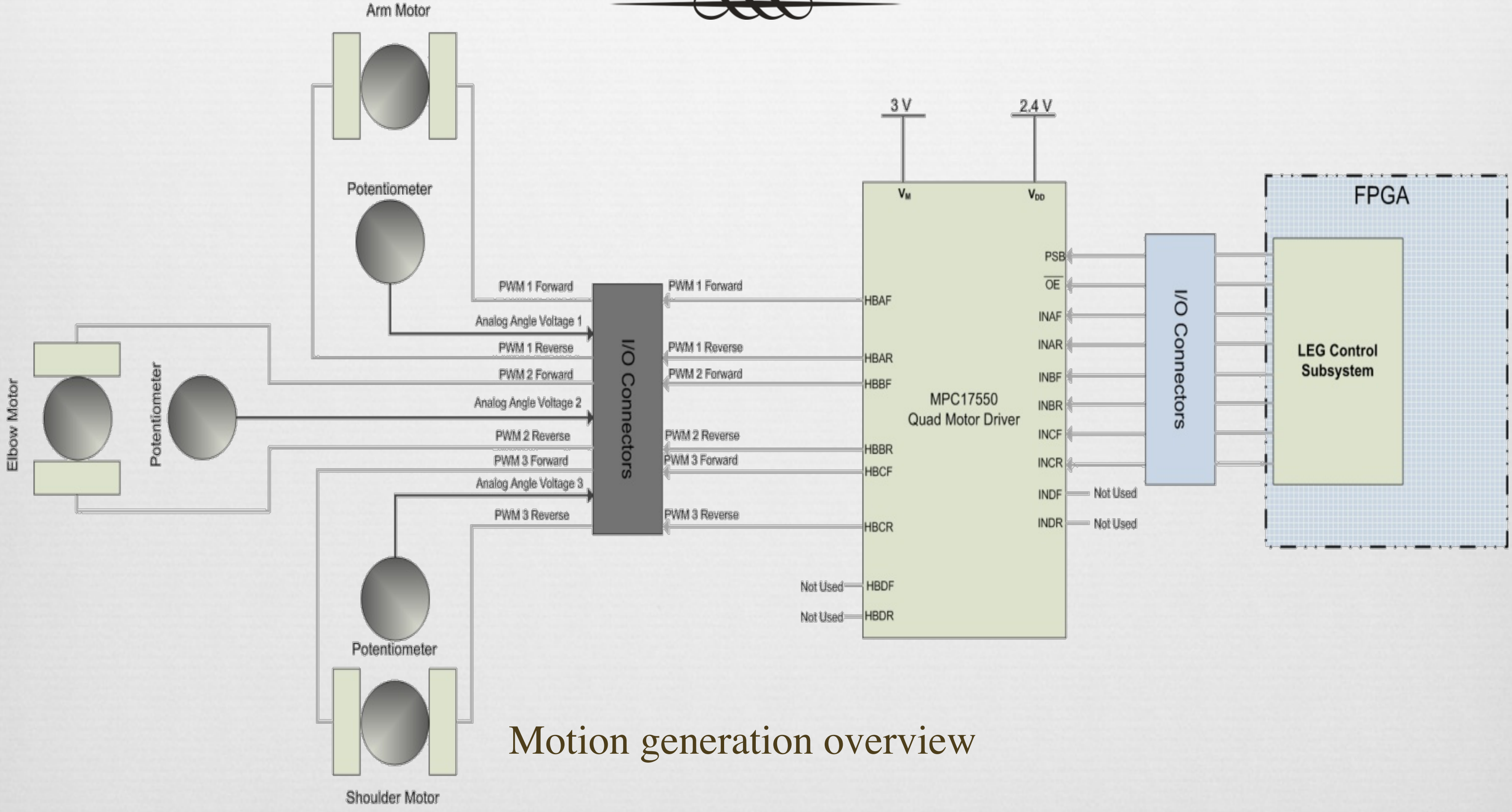
General Design

- Aesthetically pleasing
- Total weight
- Total dimensions: 16cm x 16cm x 12cm

Electronic Components

- Single common 5V power supply
- Main switching voltage regulator 3.3V (up to 6A)
- Supports use of external power supply for motors
- Cable length > 1m

Electronic Components



Motion generation overview

Electronic Components

Motor Control:

- FPGA PWM generator core
- 6 Quad H-Bridge Motor Driver (1 per leg)

Feedback Loop:

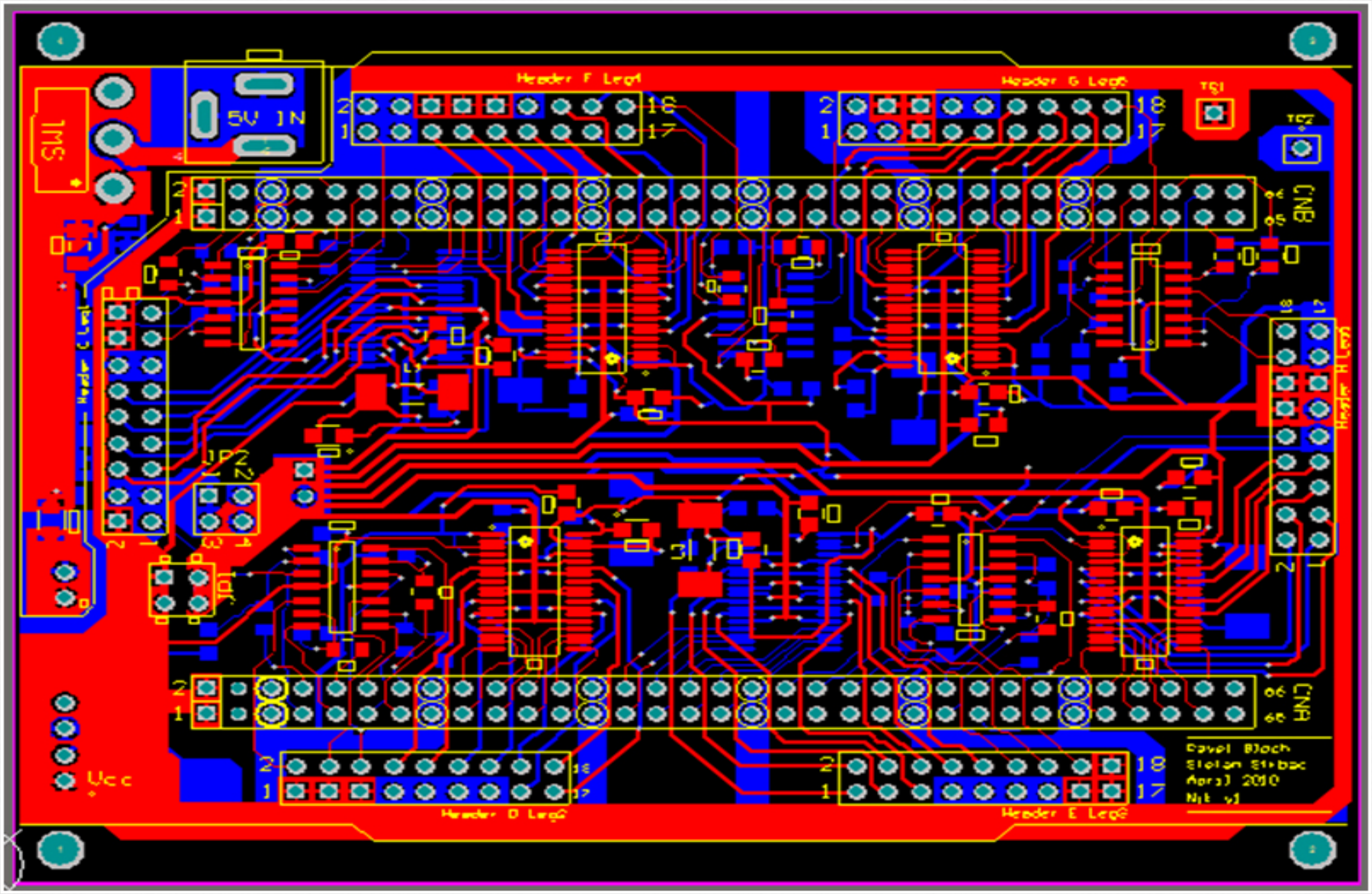
- Xilinx XPS-Delta-Sigma-ADC Core
- 5 Quad IC Comparators (20 comparators for 18 joints)
- 18 RC filters

PCB Design

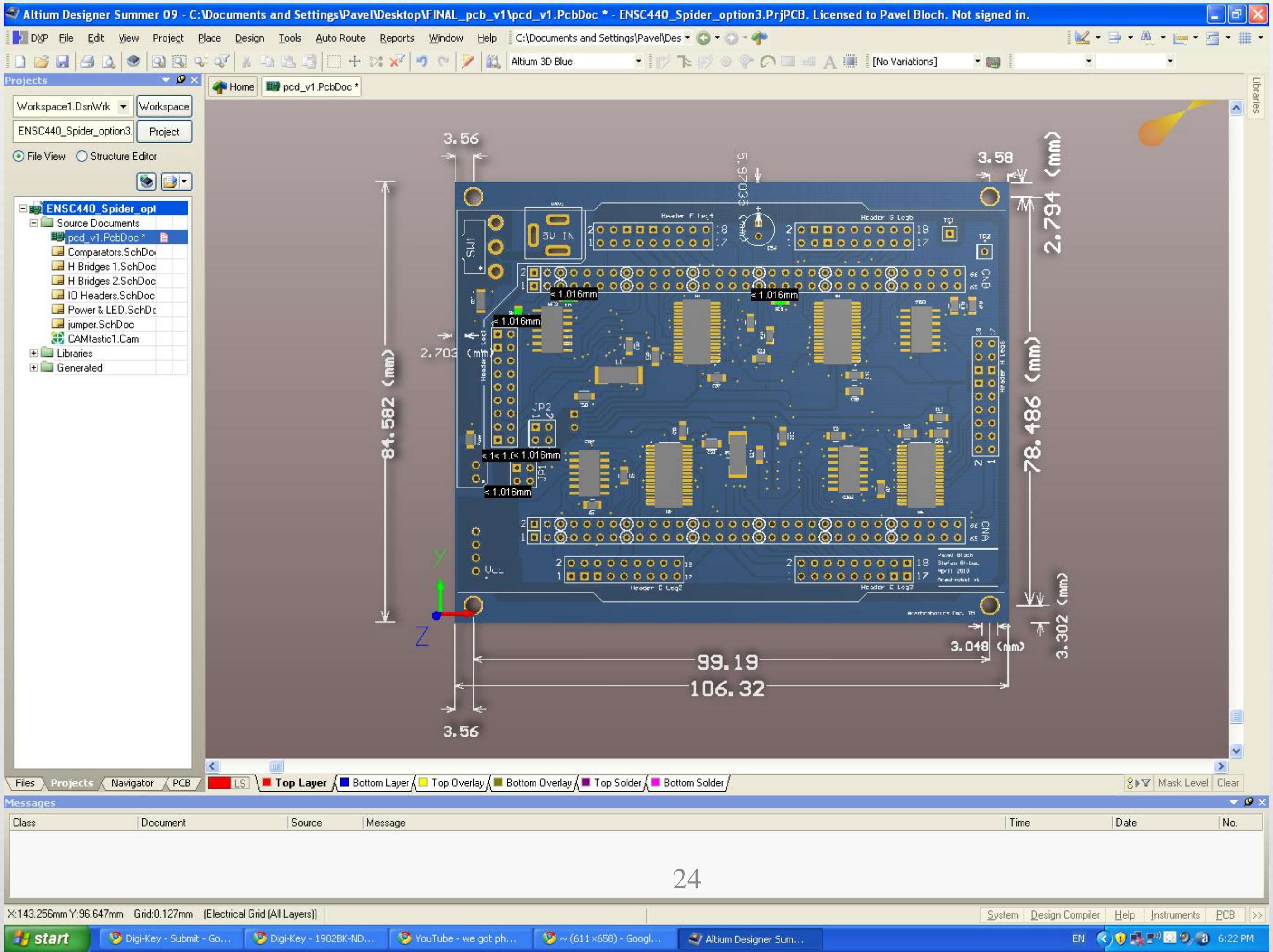
PCB Features:

- 5V in /3.3V out (6A) voltage regulator
- PCB design & layout with Altium Designer Suite
- PCB manufacturing at Enigma Interconnect

PCB Design



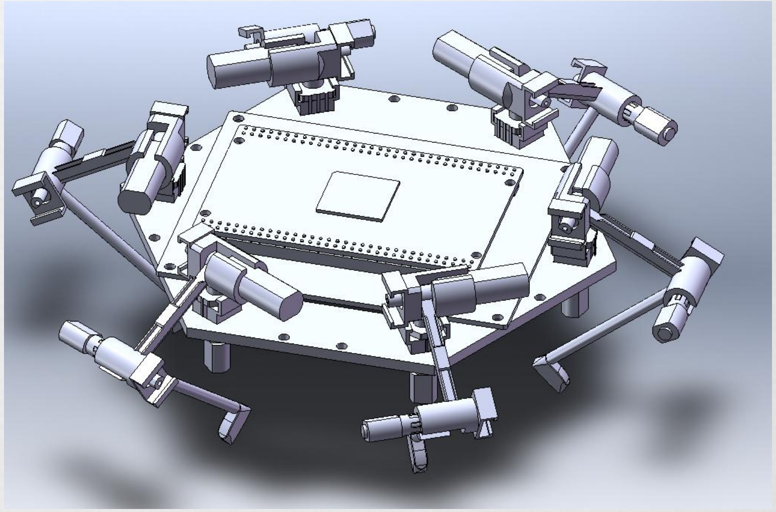
PCB Design



Altium Designer Summer 09 - C:\Documents and Settings\Pavel\Desktop\FINAL_pcb_v1\pcd_v1.PcbDoc * - ENSC440_Spider_option3.PrjPCB. Licensed to Pavel Bloch. Not signed in.
3.56
3.58
2.794 (mm)
84.582 (mm)
78.486 (mm)
3.302 (mm)
3.048 (mm)
99.19
106.32
3.56
Top Layer
Bottom Layer
Top Overlay
Bottom Overlay
Top Solder
Bottom Solder

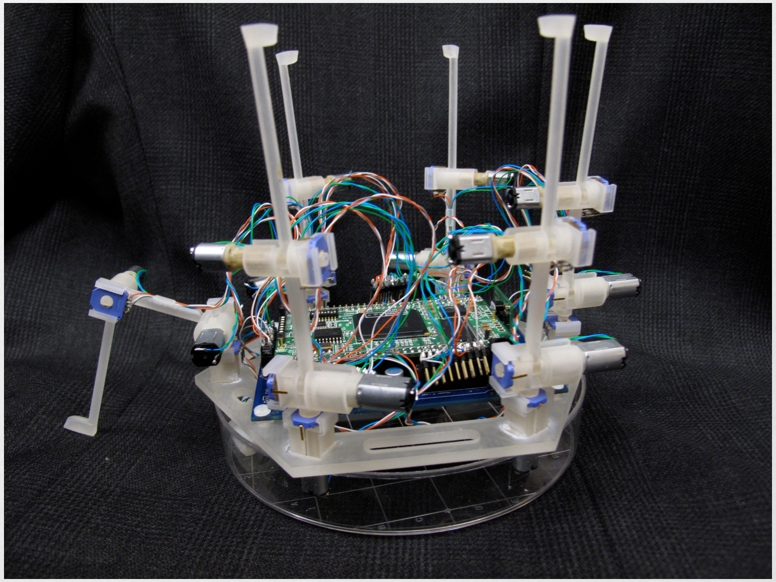
Mechanical Design

- Parts designed in SolidWorks
- Printed using SFU's Rapid Prototyping Machine
- Several Revisions



Final Mechanical Design

- 1 cm larger than proposed
- Includes a small notch for wire routing on the thigh
- Large areas removed from frame in order to reduce weight



Central Processing

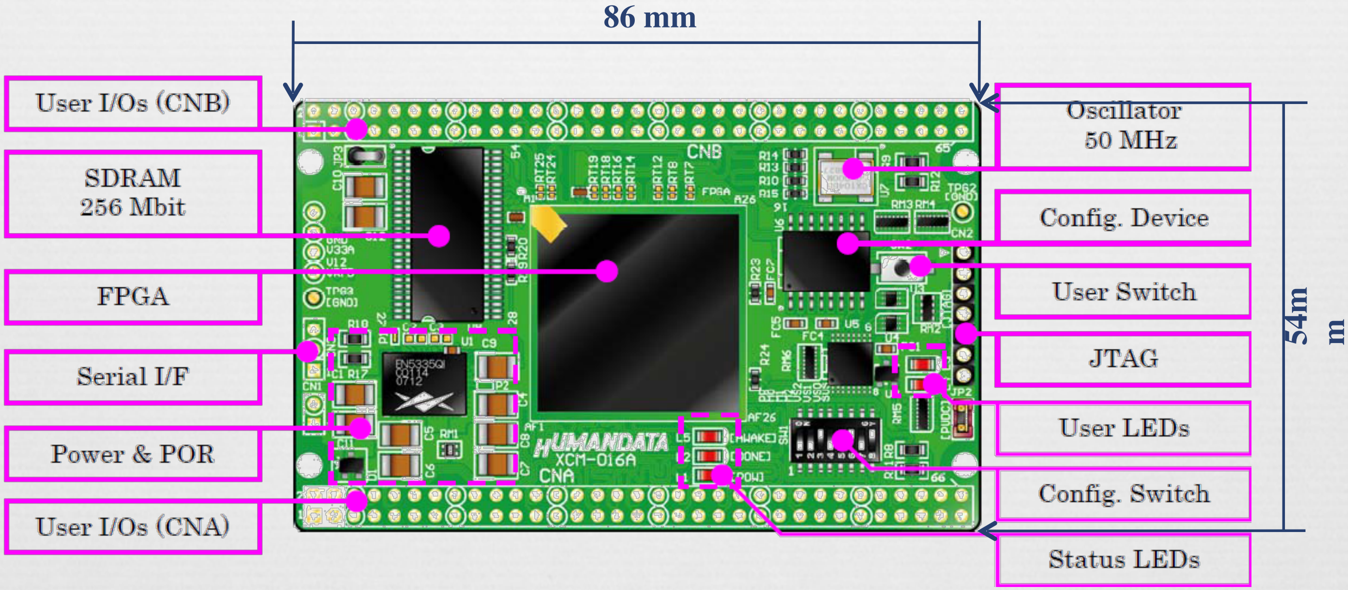
- FPGA – Field Programmable Gate Array
  - Integrated circuit configurable by the user after manufacturing
  - Configured using a Hardware Description Language (HDL)
- FPGA comes prepackaged on module with breakaway pins

Central Processing

Advantages of FPGA module versus microcontrollers:

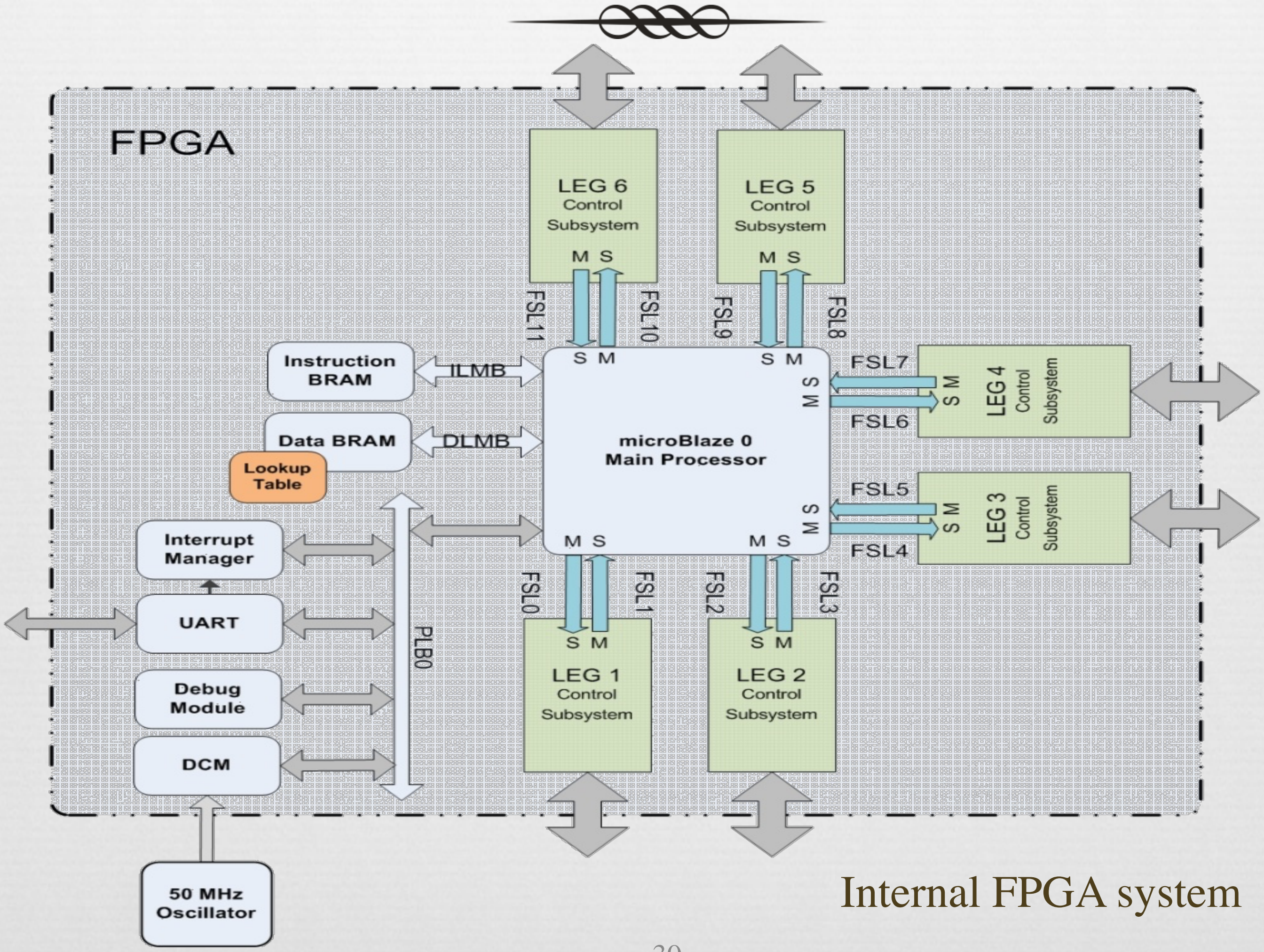
- 1 FPGA versus 7 microcontrollers (complicated interface)
- Lower power consumption
- More design flexibility
- Adding complexity does not affect size/weight
- Simpler PCB design
- Do not need external ADCs and MUX outputs

Central Processing



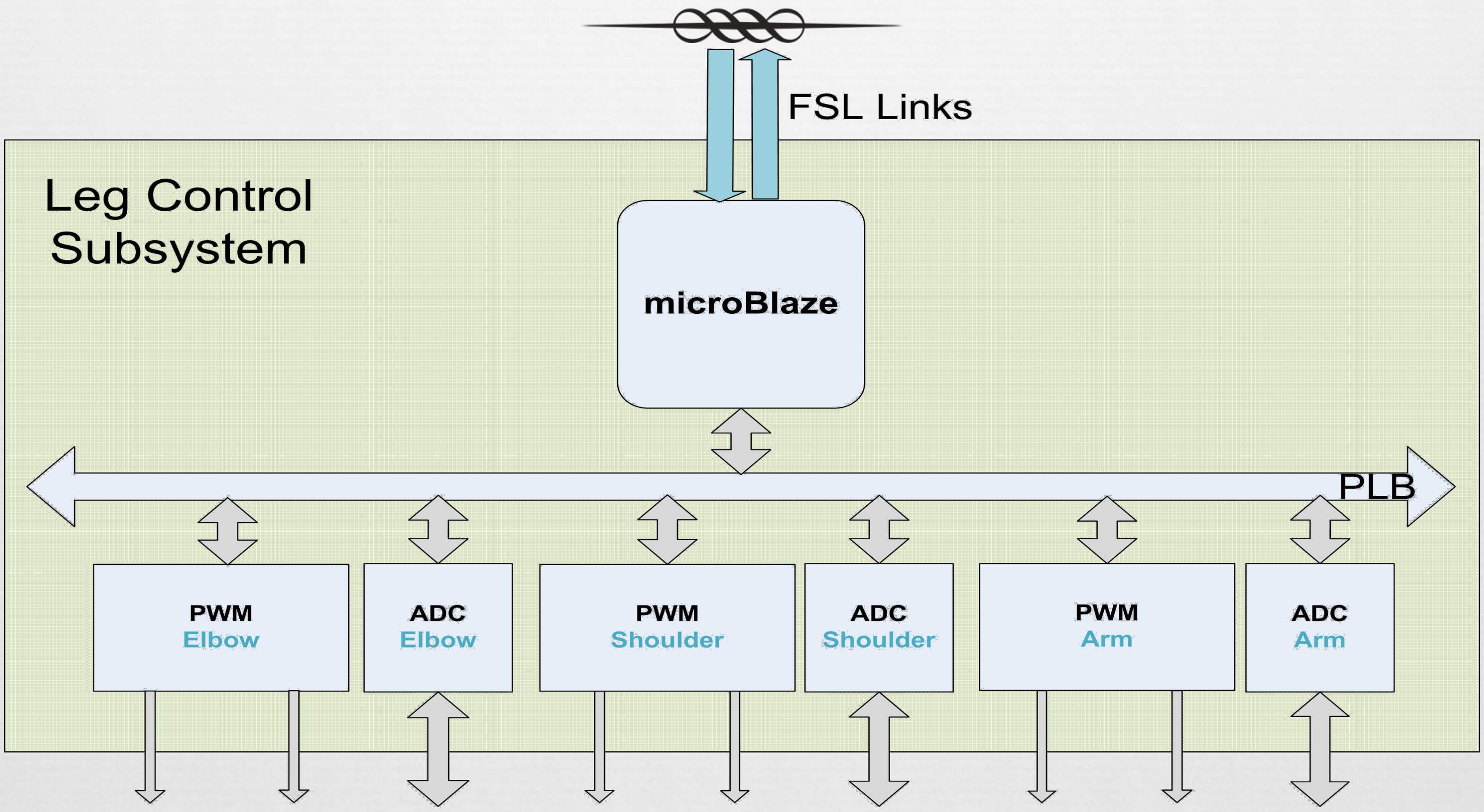
XCM-016 HUMANDATA Xilinx Spartan 3A FPGA Module

Central Processing



Internal FPGA system

Central Processing



Leg control subsystem

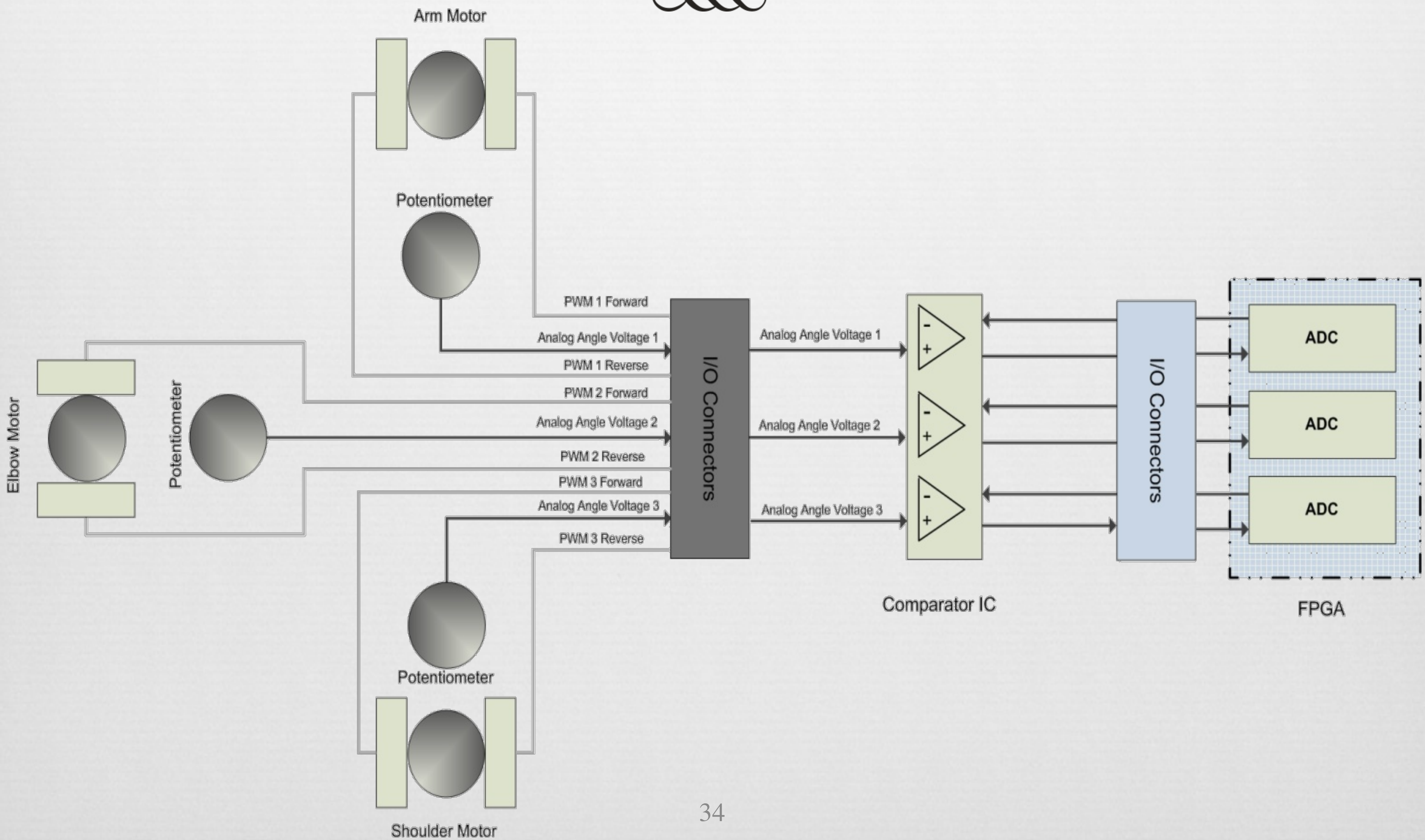
Software

- ADC reads in angle
  - Formula converts it into degrees
- Determines and adjusts motor positions
  - Uses PID control to increase torque to the motor under high load
- PWM control to the motor drivers.

PCB Interface

- Interfaces all components
- Critical in it’s operation, includes backups such as overload protection and fuses
- Provides power to all components through a 5V – 3.3V DC-DC Converter

Control Algorithm



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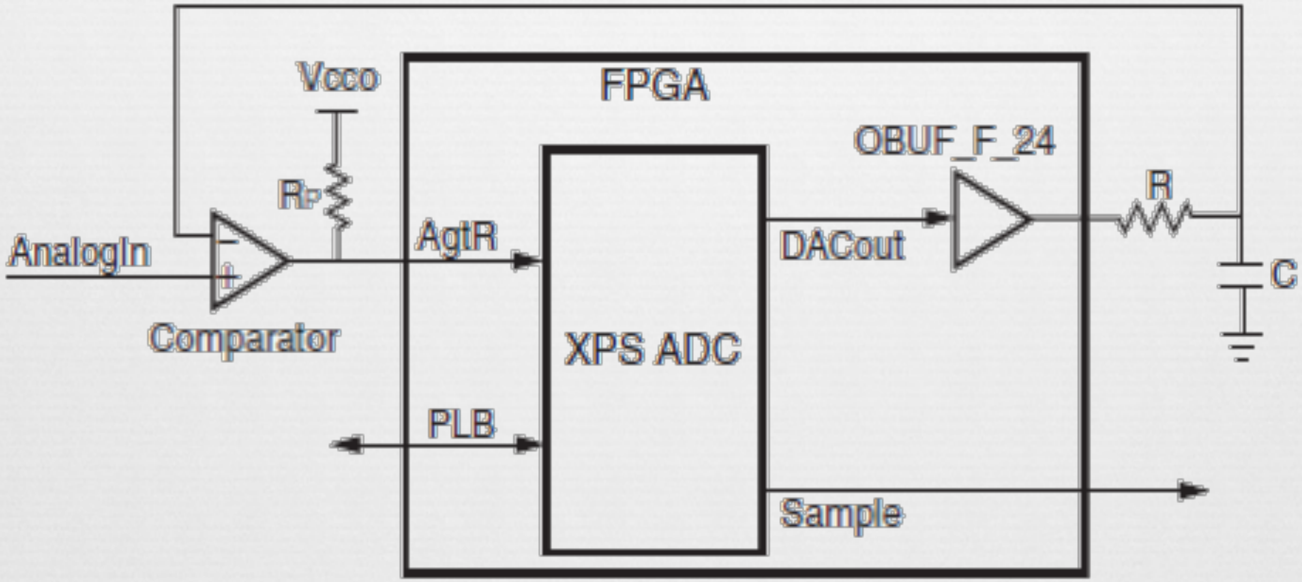


Xilinx XPS-Delta-Sigma ADC

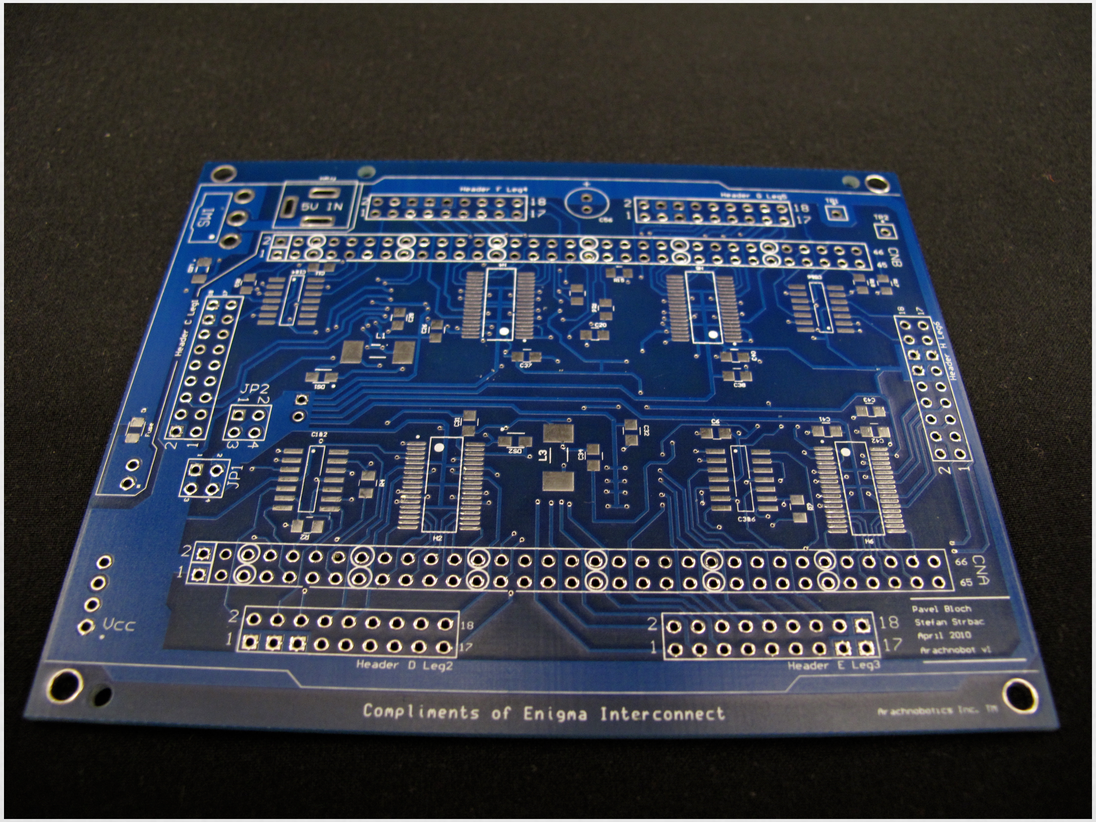
Control Algorithm

- FPGA monitors the current angle of each joint
- Then determines the necessary direction of travel to reach a desired angle
- Once the desired angle has been reached, the FPGA keeps the joint at that position through proportional feedback control
- Future work will include PID control of the motors

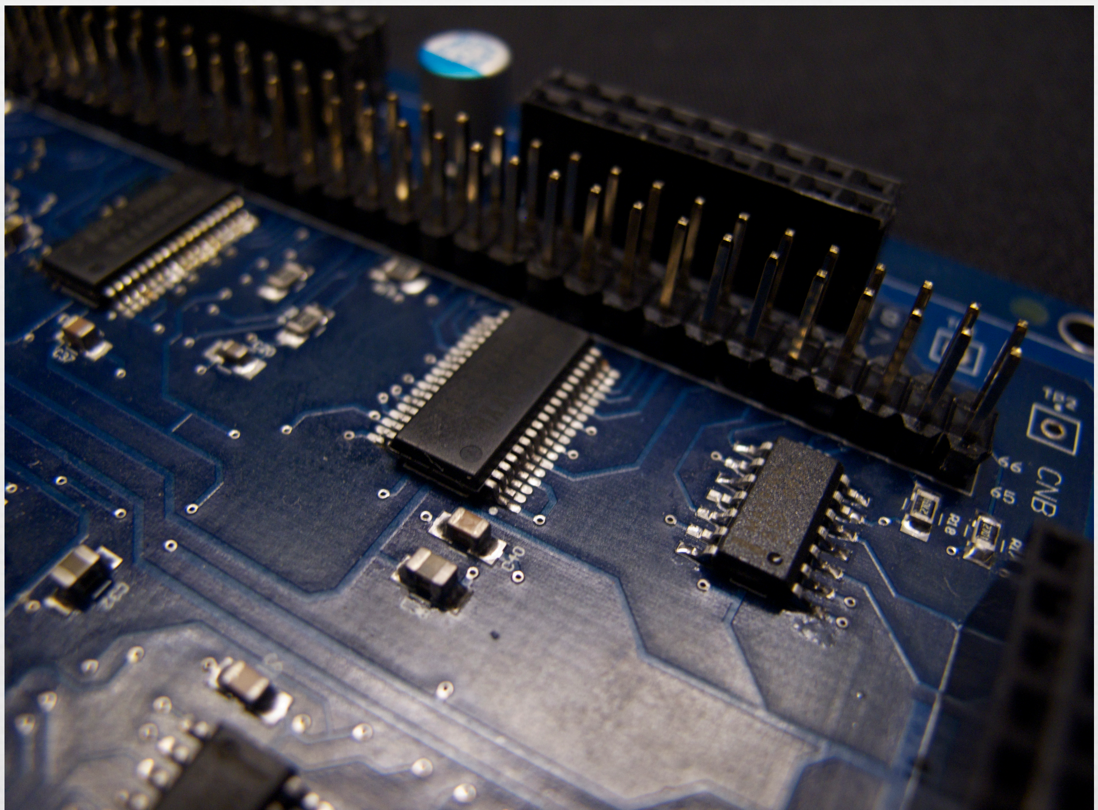
Trajectory Generation

- Generated a simple walk cycle to move the ArachnoBot™ 1 cm forward
- Each leg rises 1 cm, and then lowers to the ground
- Ground position determined through Visual Nastran, which performs inverse kinematics
  - Inverse Kinematics determines joint angles for a given trajectory

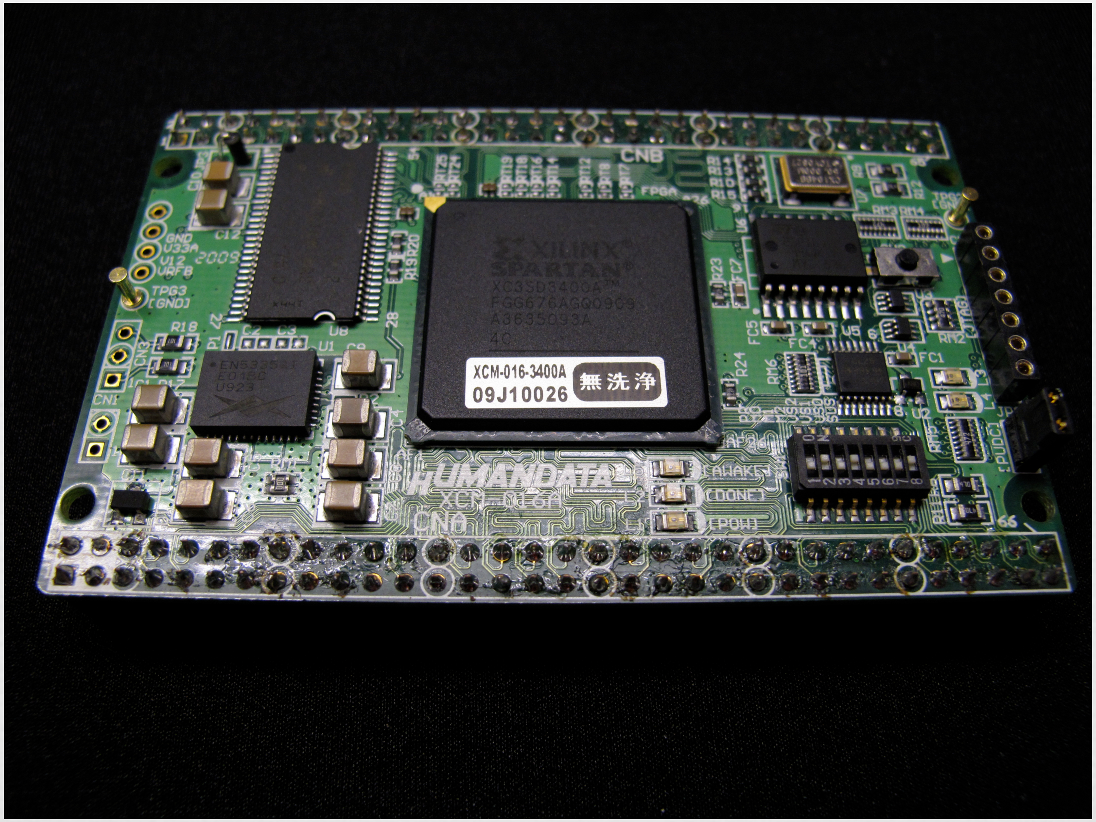
Construction Process



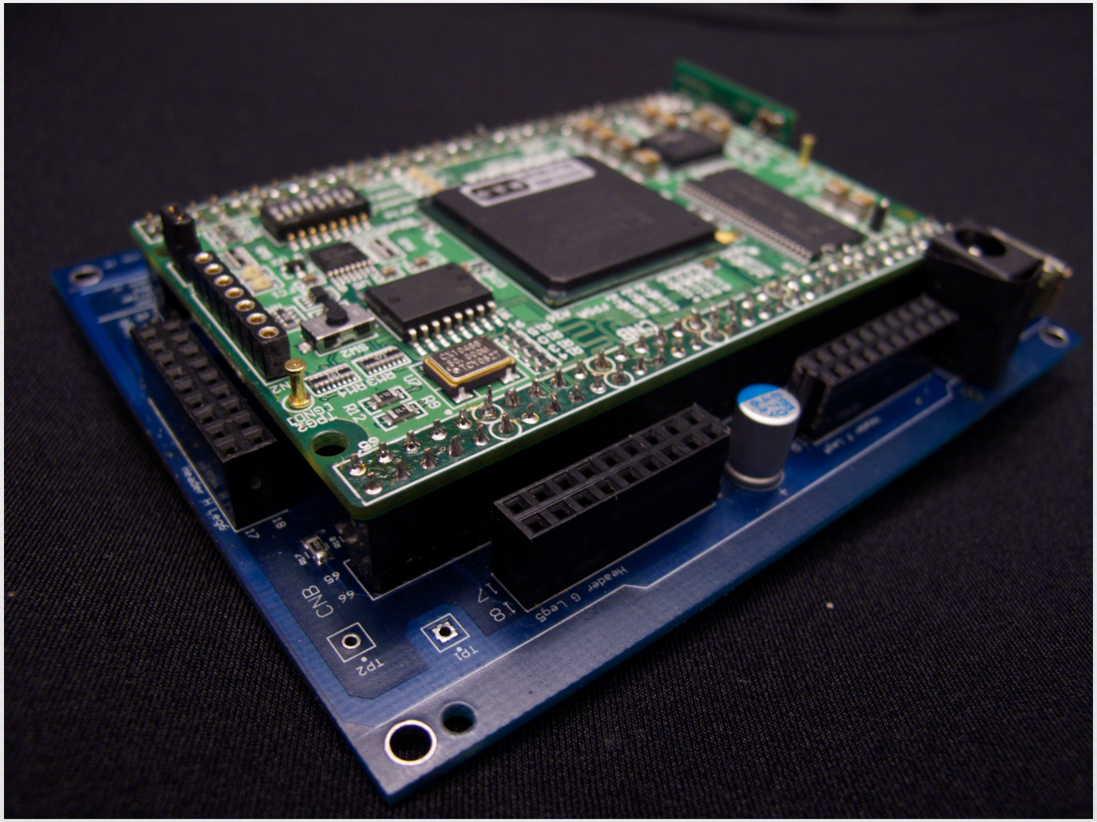
Construction Process



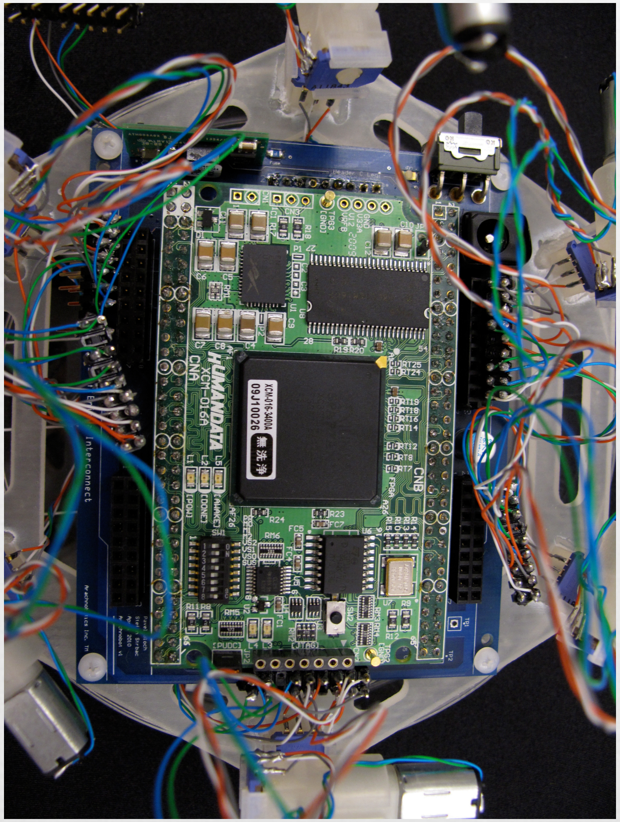
Construction Process



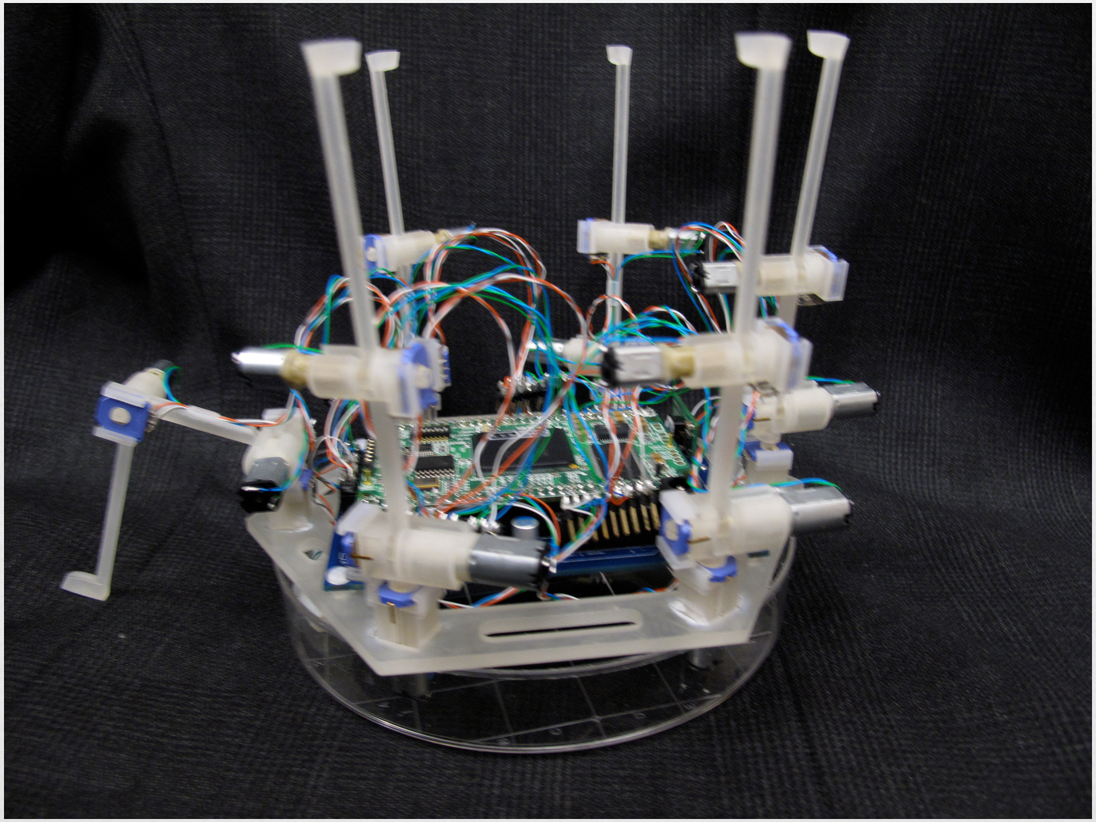
Construction Process



Construction Process



Final Result



Reliability

- Reproducibility
  - Prototype material for frame and legs
- Redundancy
  - Quad Motor Drivers have spare port
  - Separate power rails and separable power supplies for motors
- Reparability
  - Every component can be detached
  - Modular design

Market Analysis

Market Segment
Possible Competitors
ArachnoBot™ Advantages
Product Cost

Market Segment

- Arachnobot ™ version 1 is a prototype for a robotic spider intended for space exploration and research.

Version 3 of the design is intended for the following markets:

- Space Research & Exploration
  - European Space Agency (ESA)
  - Canadian Space Agency (CSA)
  - National Aeronautics and Space Administration (NASA)

- Other uses may include land exploration, and university research.

Similar Products

Several similar robotic platforms exist for our prototype:

- HiBot Roller Walker
  - 4-Leg platform allowing walking, and skating using servos
  - http://www.hibot.co.jp/html/webapps/top.php?lang=en
- Lynxmotion CH3-R Combo Kit
  - Features 3DOF Leg design, and servo motor controllers
  - http://www.lynxmotion.com/Category.aspx?CategoryID=3

ArachnoBot™ Advantages

- Allows additional functionality to design
  - Eg, Bluetooth for wireless trajectory control
  - Artificial Intelligence
- Allows tweaking of motor control
- Design is highly modular
  - Can switch components

Product Costs

	Arachnobot Unit		Arachnobot Mass Prod		Lynxmotion CH3-R
	Cost	Retail Price	Cost	Retail Price	Retail Price
Exoskeleton	$500		$50		
FPGA module	450		100		
PCB	400		50		
Motors	306		100		
Total Product	$1656		$300		
Labour	$2000*		$200**		
Total Cost	$3,656	$5000	$500	$1000	$1200

2 jr. engineers * 40hrs/week *$25/hr=$2000

**Assume mass assembly requires 4 hrs/unit

Reflections

Budget
Timeline
Lessons Learned
Future Work
Acknowledgements

Budget

Part	Proposed	Actual
FPGA Development Board	$200.00	$450.00
Xilinx JTAG Cable	$0	$350
Printed Circuit Board Manufacturing	$1000.00	Donated ($1200)
Rapid Prototyping	$100.00	Donated ($1500)
Sensors	$200.00	$150
Motors	$250	$600
Circuit Elements	$400.00	$500
Contingency	$150.00	$0
Final	$2,300.00	$4750
Difference:		$2450

Timeline


ON AND DELIVERABLES
Estimated
Realized
Mechanical Construction
Proto-board Construction
Mechanical Testing
Software Testing
TION AND COMPLETION

Lessons Learned

Team Dynamics:

- Scheduling conflicts need to be resolved early
- Well defined roles and responsibilities are important
- Efficient teamwork is critical
- Communication is crucial

Lessons Learned

Project Development:

- Order parts early, purchase in bulk, and buy extra
- Budget for a larger contingency, especially for debugging
- Rapid Prototyping errors happen
- Create test plan, run tests that are likely to create errors first
- Test entire system integration first, even if subsystems are not in their final versions

Future Work

- Wireless control walking, battery power
- Vertical climbing
- Use PCB as base frame to reduce weight
- Thinner and lighter exoskeleton
- Anything else? ****

Acknowledgements

- Dr. Carlo Menon
- Dr. Lesley Shannon
- Cristian Panaitiu
- Lucky One and Fred Heep
- John Parsons (Enigma Interconnect)
- Yasong Li, Ausama Ahmed, and Juan Pablo Diaz Tellez
- Andrew Rawicz and Steve Whitmore
- Pranil Reddy
- ESSEF

Conclusion

Conclusion

- Proof of concept accomplished!
- In retrospect, FPGA was the right choice for processor
- Most functional specs met or nearly met

ArachnoBotics Research Inc.