Robinson Observatory

Scale Model Project

Sponsored by Florida Space Grant Consortium

Group A

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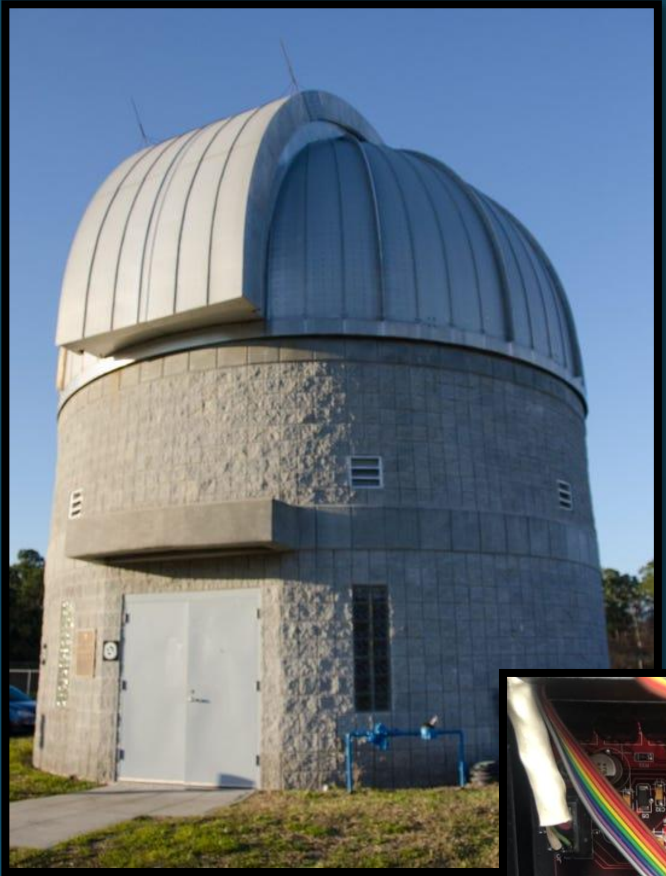
Presentation Outline

- Introduction
  - Goals & Objectives
  - Specifications
  - Features
  - Constraints
  - System Block Diagrams
- Parts Selection and Schematic Design
- PCB Design and Testing
- Software Development
- Administrative Content
  - Project Milestones
  - Work Distribution
  - Budget

Introduction

- UCF Robinson Observatory on Ara Drive was built in 1994 and has been a research and education facility run by the Department of Physics
- The current control system is built by BisqueTCS and is a highly proprietary piece of hardware that requires flying in a specialist any time there is an issue at a cost
- FSI asked a team of EE, CS and ME students to create an open-source scale model of the existing 20” Ritchey-Chrétien Telescope and its control box as the first phase of replacing the current system



Goals & Objectives

- To create a scale model for use as a testing platform without posing harm to the expensive existing hardware such as the custom Pittman motors
- The secondary intent of the project is to create and release open-source plans which would allow amateur astronomers to build their own scale model of the telescope system
- This involves designing a PCB to interface with astronomy software to translate commands to the right ascension and declination motors that drive the telescope

Specifications

Constraint	Maximum Value
Sensor response time	20ms
Cost	$800
Power consumption	80W
Pointing accuracy	+/- 1 degree
Electronics dimensions	20" x 20" x 10"
Weight	5lb

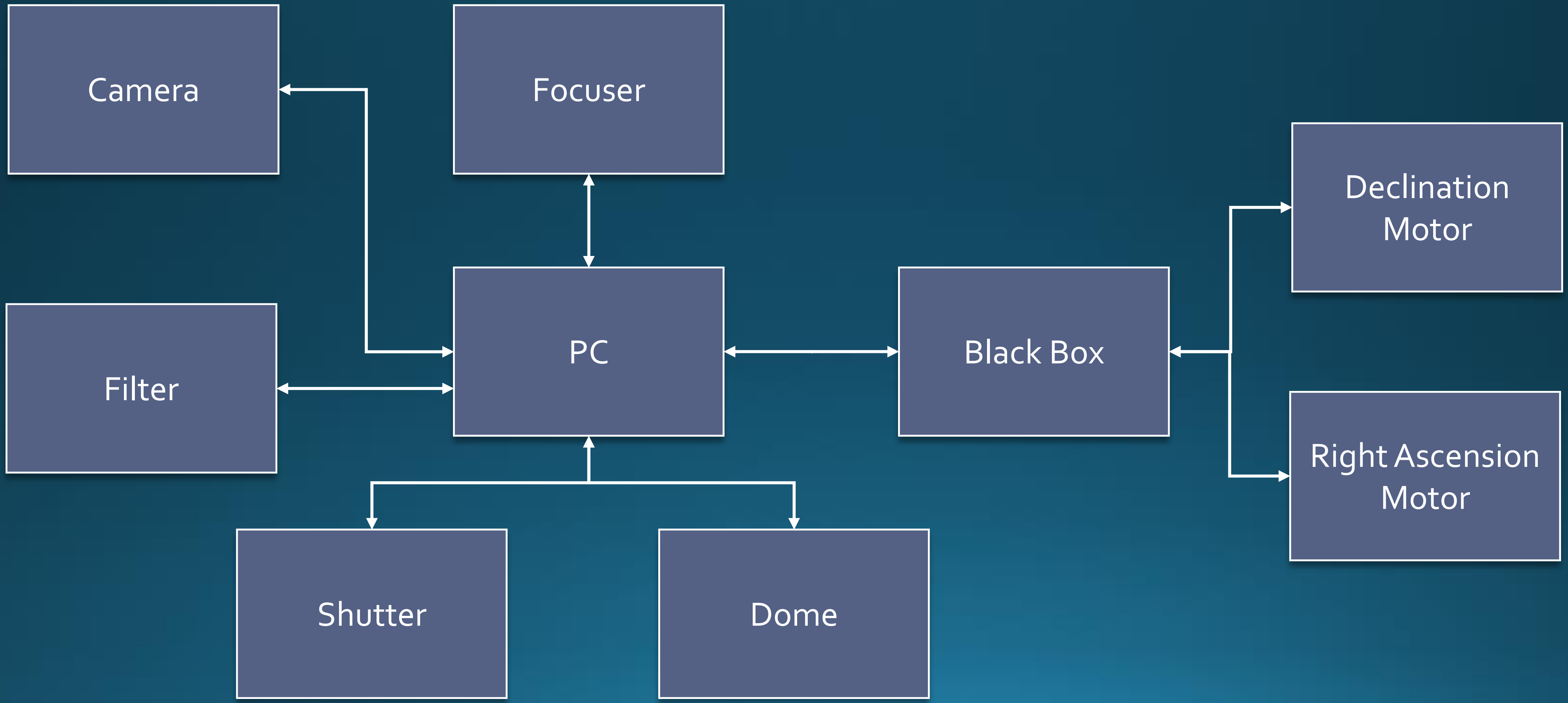
Required Features

- Shall interpret control signals from Stellarium software.
- Shall accept secondary input from user operated joystick to move motors manually at variable slew rates
- Shall support homing capability for the telescope.
- Shall support pointing limits (no horizontal azimuths that will damage the telescope)
- Shall support sidereal tracking in which the declination motor does not move and right ascension motor tracks at sidereal rate

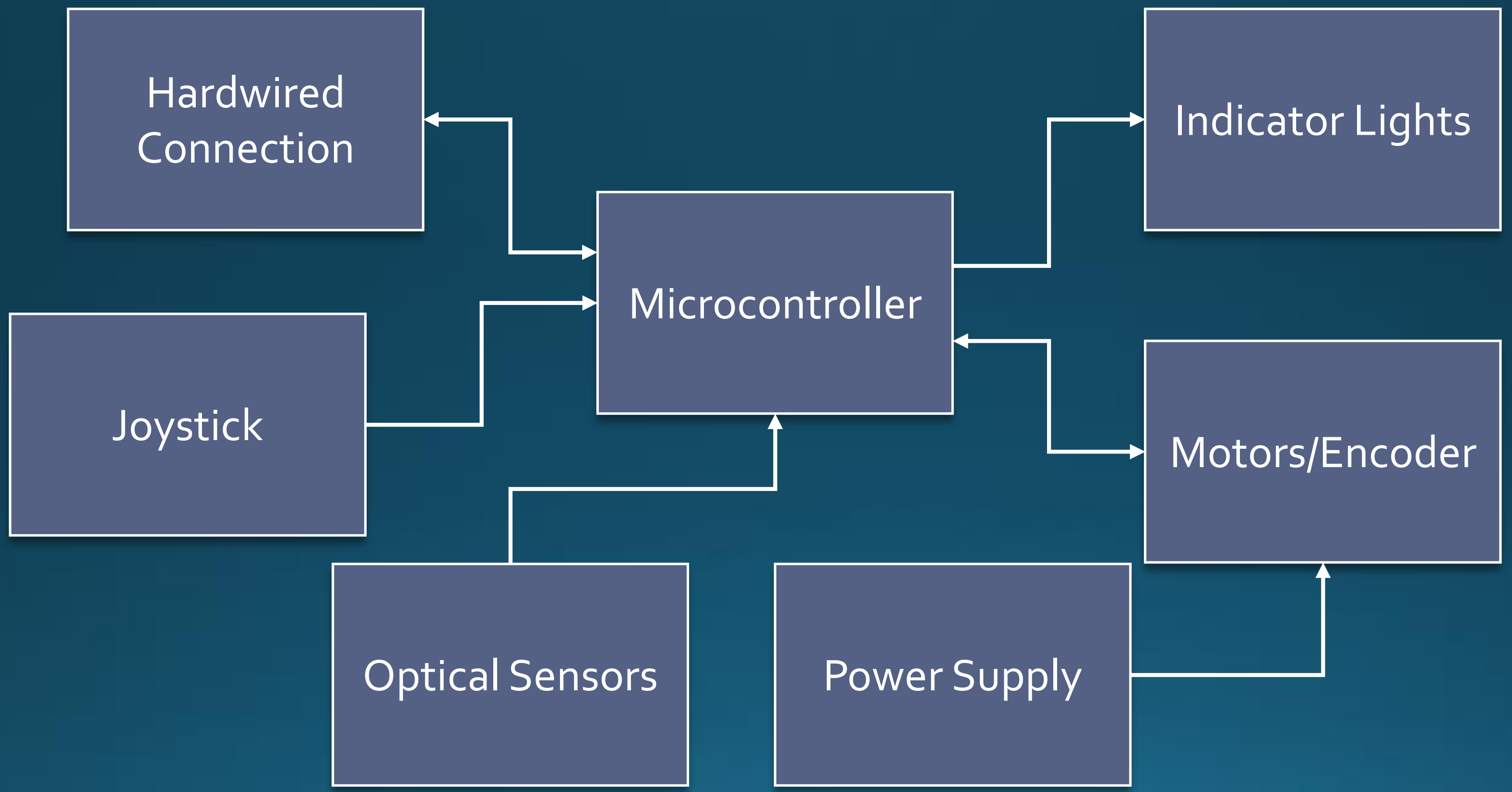
Realistic and Design Constraints

- Economic and Time Constraints
  - Shared $1,000 grant
  - Interdisciplinary team milestones
- Environmental, Social and Political Constraints
  - Geared towards amateur astronomer
- Manufacturability and Sustainability Constraints
  - Open-source, COTS equipment

Overall System Diagram

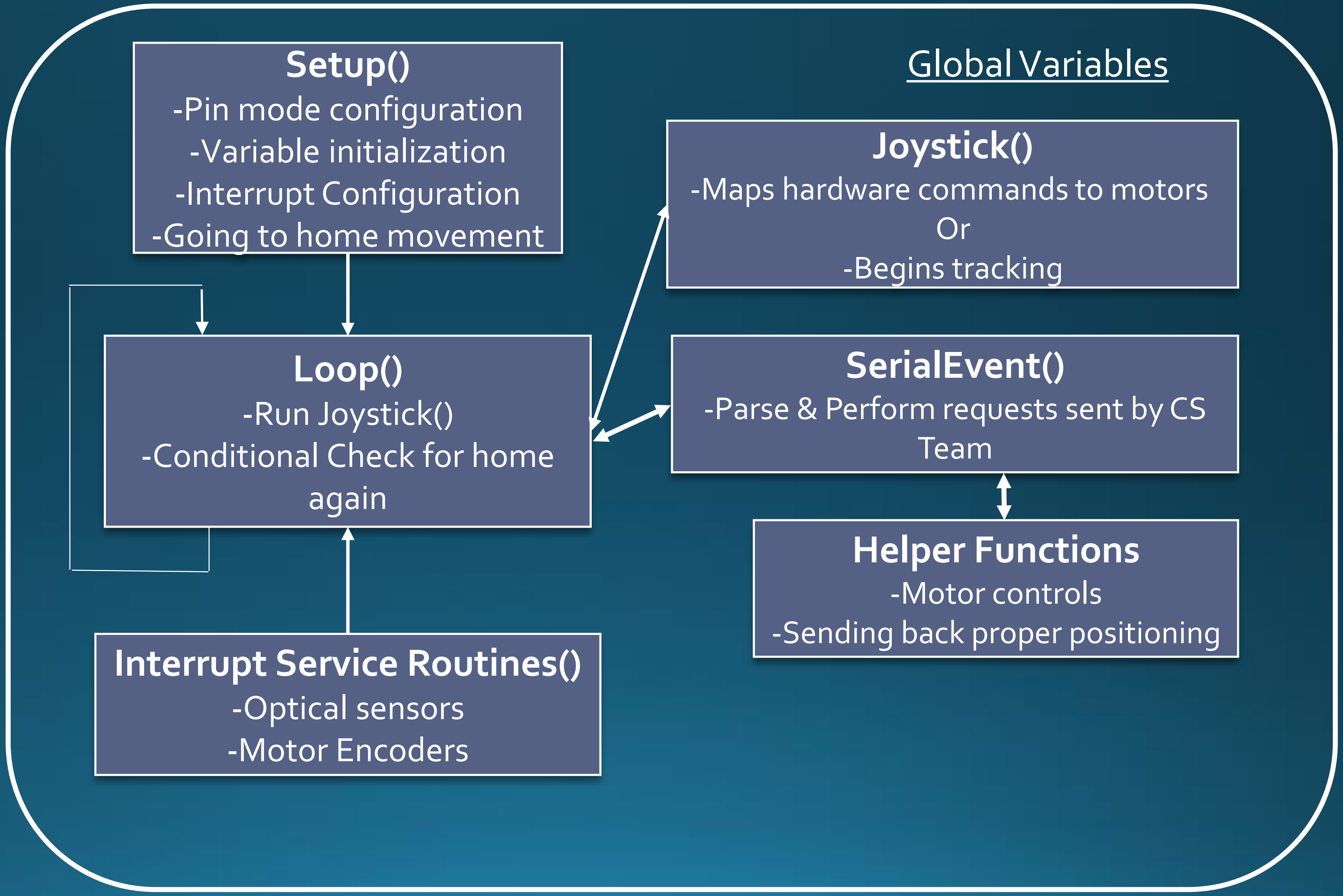


Control Diagram



Software Block Diagram

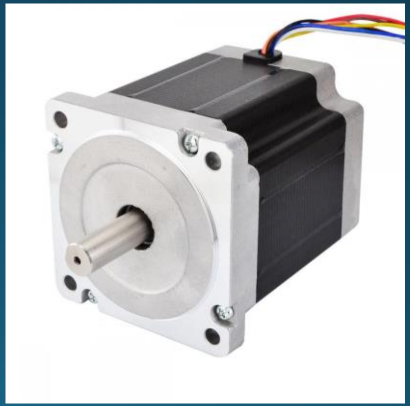
- Basic API for future endeavors with our own wrapper functions
- Serial events and corresponding helper functions for mathematics
- ISRs designed to be as light weight as possible



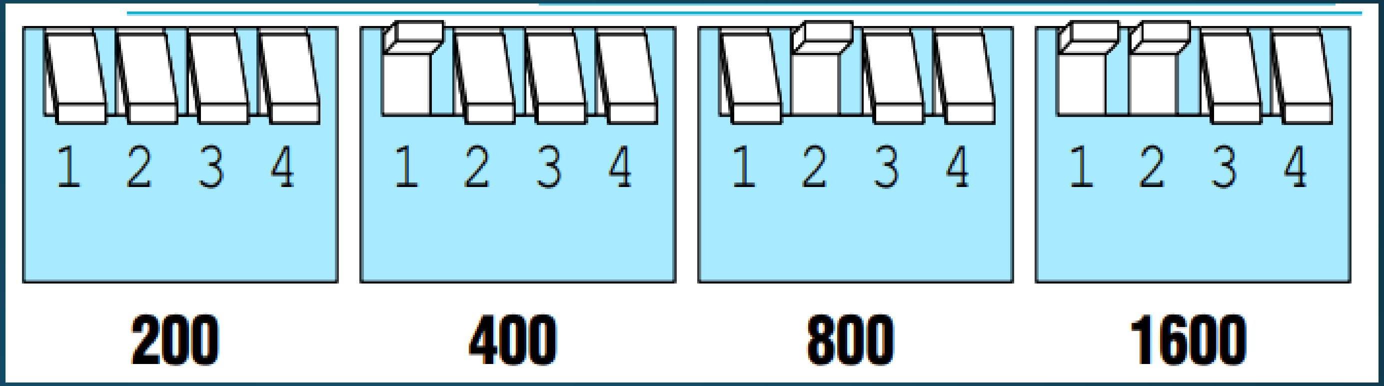
Part Selection and Design

Right Ascension & Declination Motors

	Stepper	Servo
Torque	High at low speeds	High even at high speeds
Accuracy	High with encoder feedback	High
Speed	More suitable for low speeds	More suitable for high speeds
Cost	Low	Moderate
Lifespan	High	Moderate

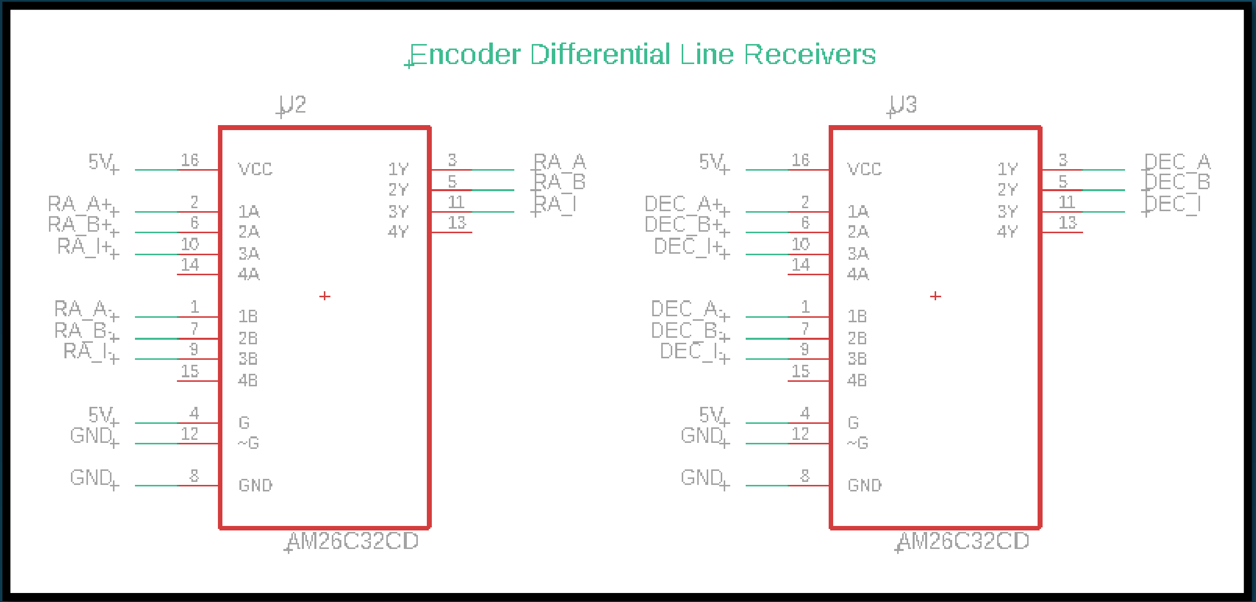


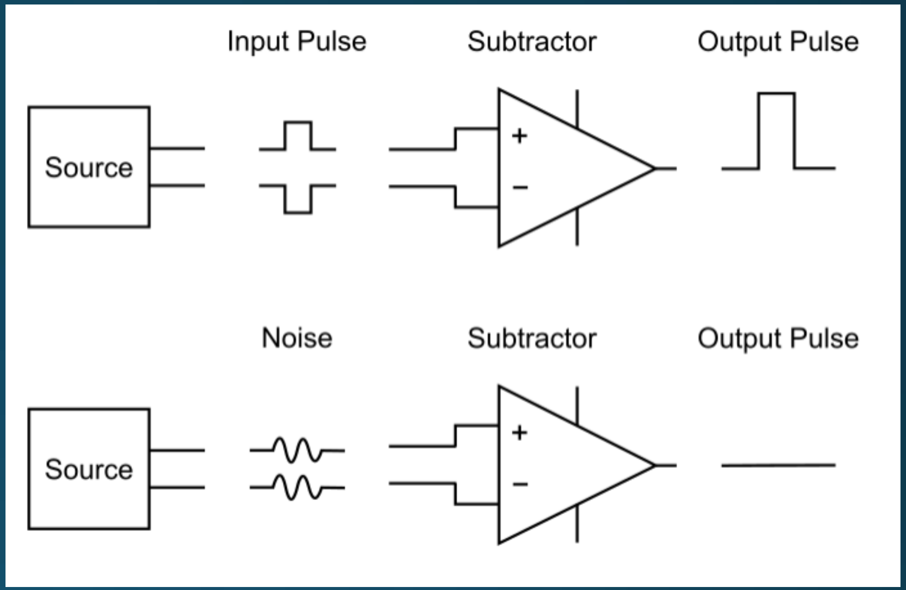
NEMA-17 STM17R-3NE

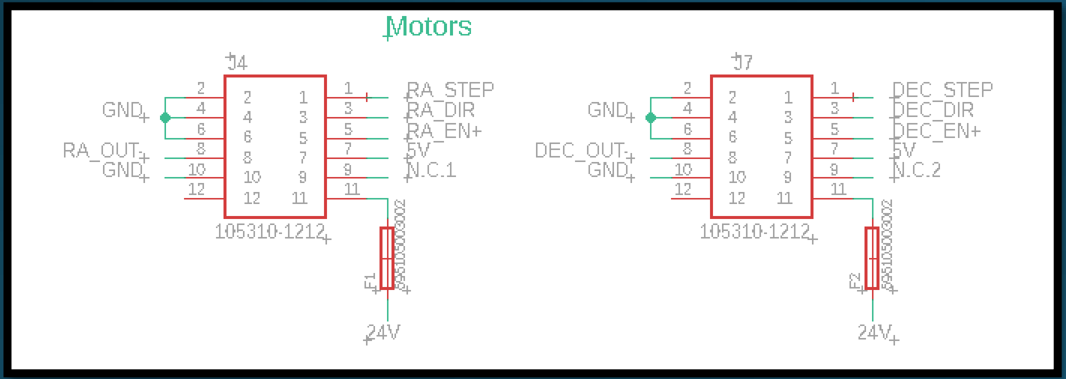


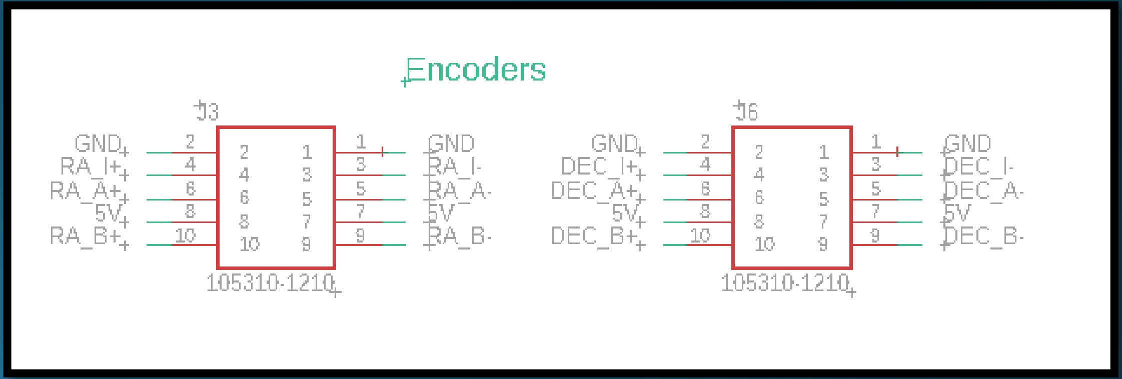
$$RPS * Step\ Count = Pulse\ Frequency$$

Motors & Encoders





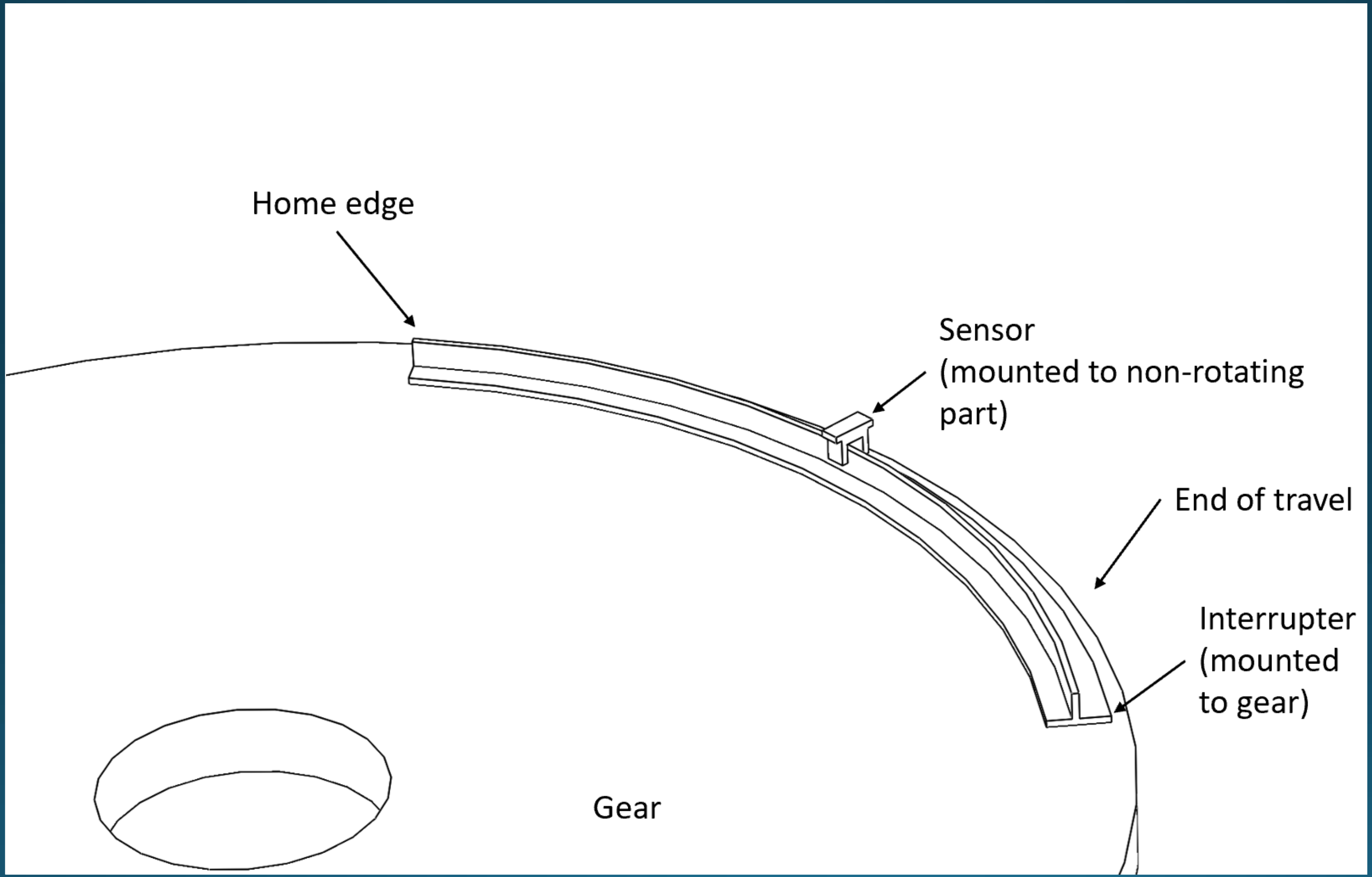




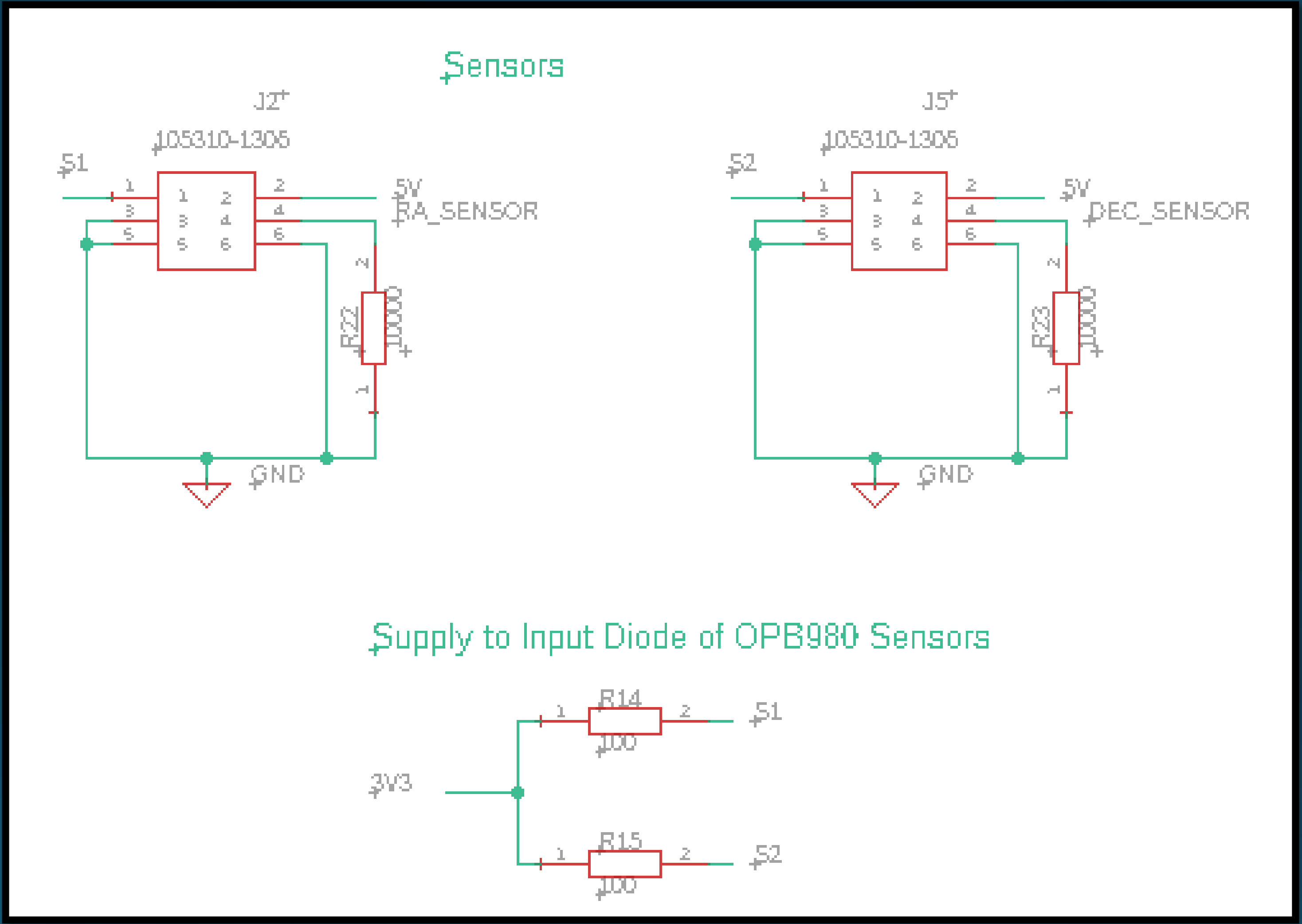
Sensors

	Optical	Hall Effect	Magnetoresistive
Supply Voltage	4.5 – 16V	5 V	3 – 5 V
Supply Current	12 mA	6.5 mA	16 mA
High-level Output	V_{DD} – 2.1 V	V_{DD} – 0.5 V	N/A
Interface	Digital I/O	I^2C	SSC / IIF
Manufacturer	TT Electronics	ams	Infineon
Part Number	OPB980T51Z	AS5601	TLI5012B
Cost	$5.04	$3.49 + Magnet	$7.23 + Magnet

Optical Switch

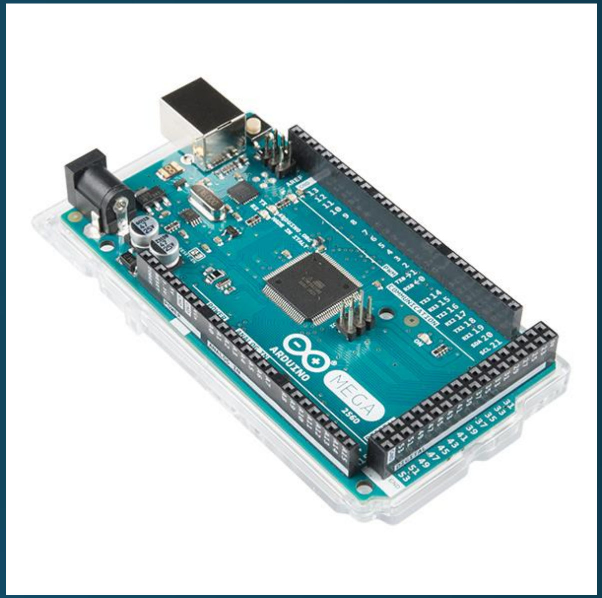


Optical Sensors



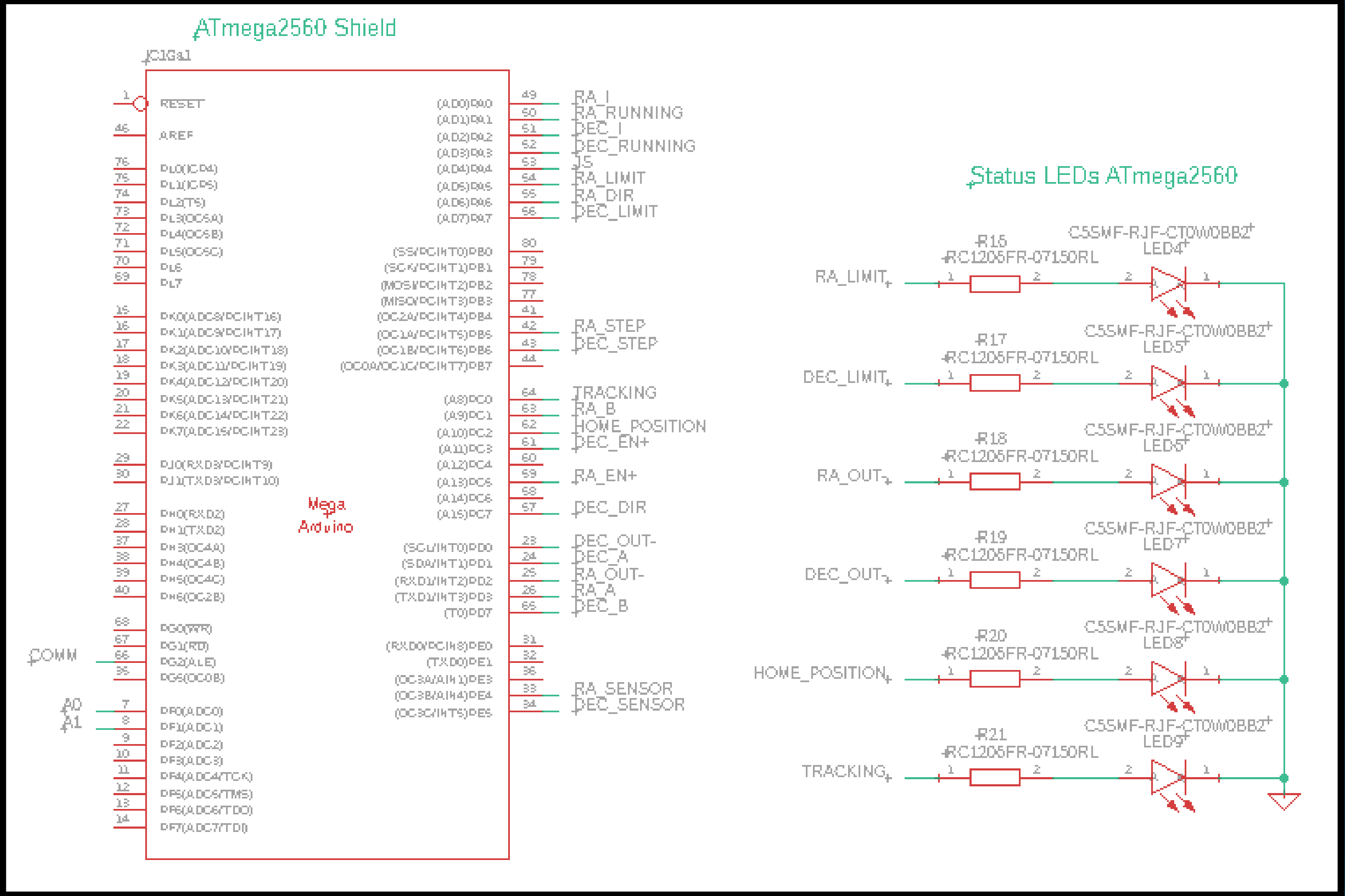
Microcontroller

	PWM pins	I/O pins	Total pins	Primary Programming Language	Clock speed	Price
MSP430G2	~	24	24	C/C++	16MHz	$17- 23.75
Raspberry PI 3	~	40	40	Python	900MHz	$35.68
ATmega328	6	14	20	C/C++	16MHz	$22
ATmega2560	14	54	70	C/C++	16MHz	$38.50

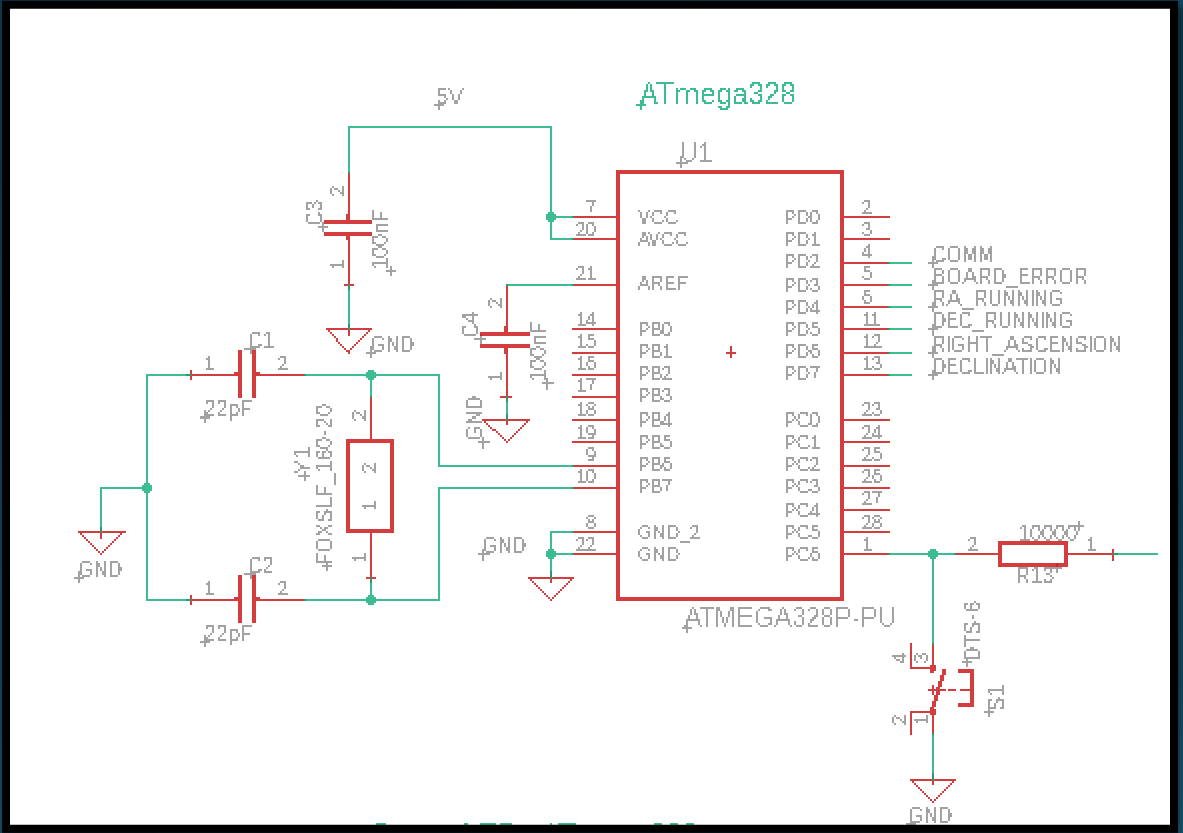


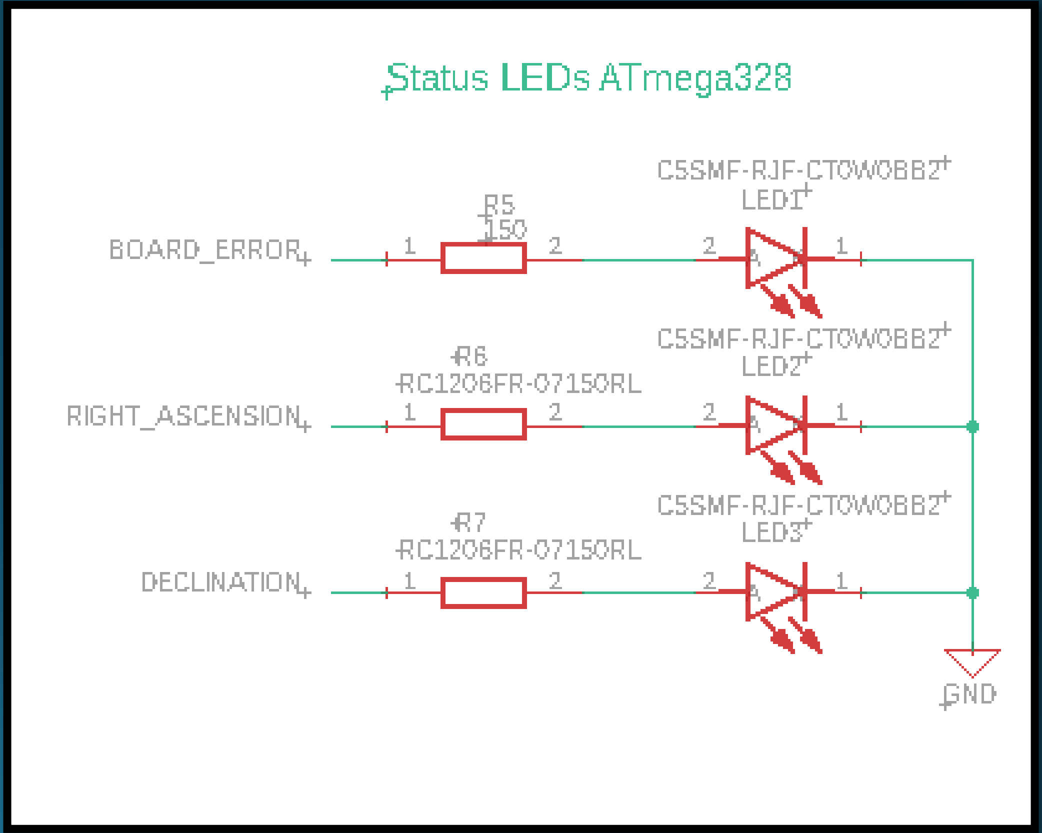
- ATmega2560 has large number of pins
- PWM pins very easy to use for development
- Client's desire for Arduino-compatible MCUs

ATmega2560 and Status LEDs



On-Board Microcontroller (ATmega328)





Joystick

- Analog outputs tell the program the speed and direction in which to move the right ascension and declination motors
- Digital output is used to take control of the telescope operation from the tracking software
- Need to make sure there are tolerances programmed to avoid unwanted telescope motion

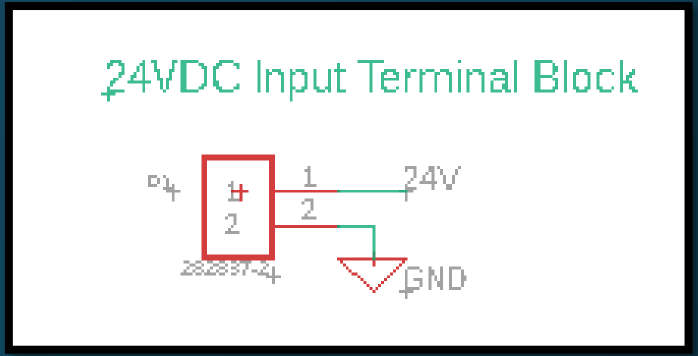
Feature	Mini Analog Joystick	2-Axis Joystick	Thumb Joystick with Select Button
Potentiometer resistance	10k Ω	10k Ω	10k Ω
Select button	No	No	Yes
Analog outputs	2	2	2
Digital outputs	0	0	1
Maximum operating voltage	5V	10V	5V
Breakout board included	No	Yes	Yes
Size	2.7 x 2.1 x 2.1	1.64 x 1.2 x 1.1	1.25 x 1.5 x 1.5
Price	$19.95	$6.95	$5.95

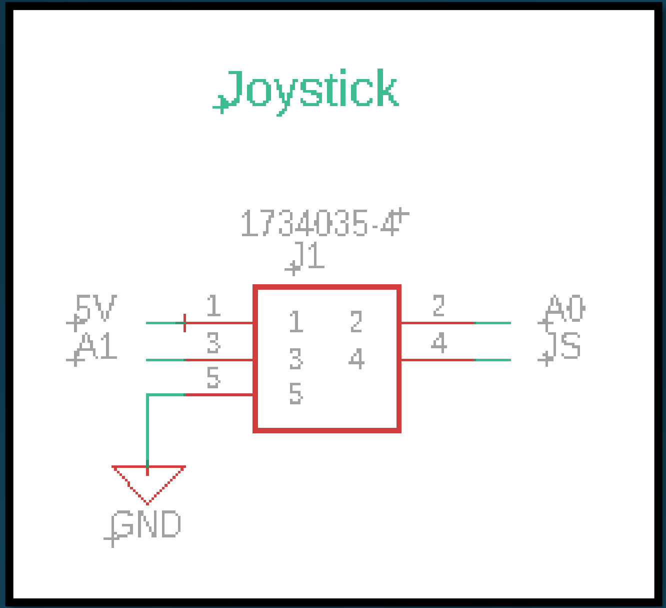
Power Supply

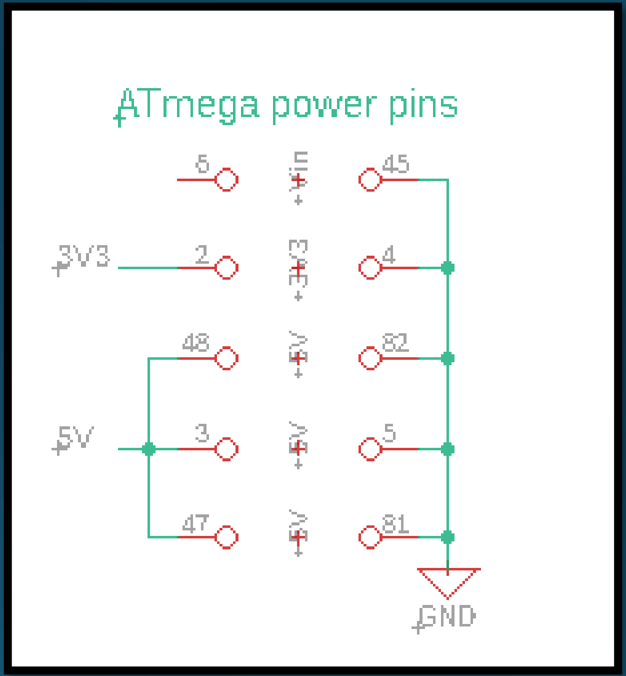
- 150W, 6.3A
- Universal input voltage
- Regulated output voltage
- Designed for use with DC-powered stepper/servo/integrated motors

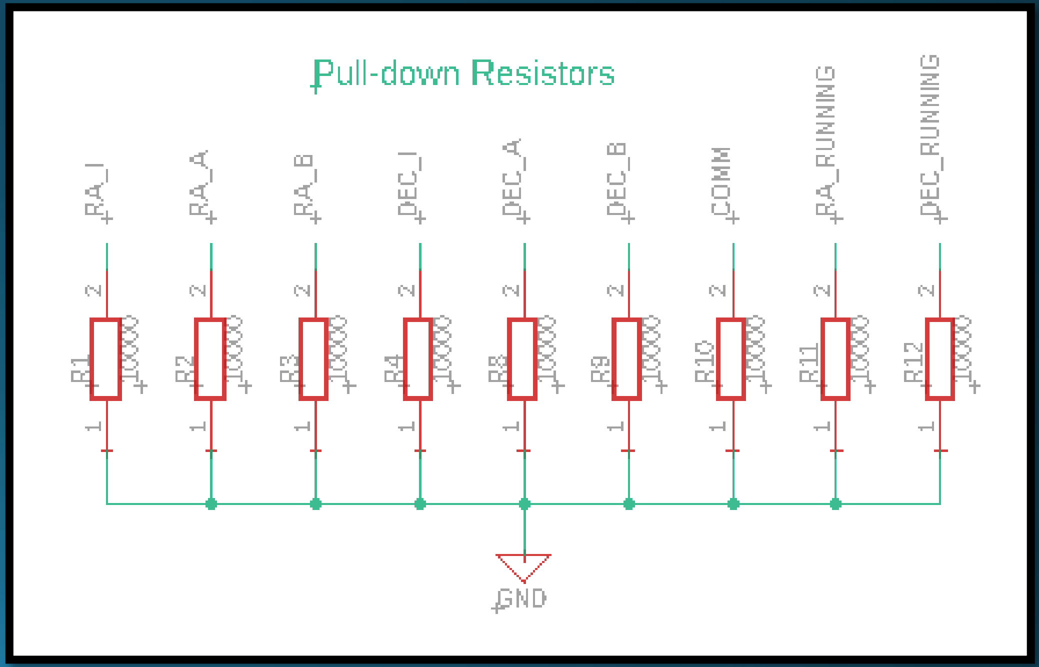
	PS150A24	PS50A24	PS320A48	Other
Recommended	YES	YES	YES	NO
Current Rating	6.3A	2.1A	6.7A	Variable
Voltage Output	24VDC	24VDC	48VDC	Variable
Watt Rating	150W	50W	320W	Variable
Cost	$172.00	N/A	$262.00	Variable

Joystick, Power Supply and Resistor Connections

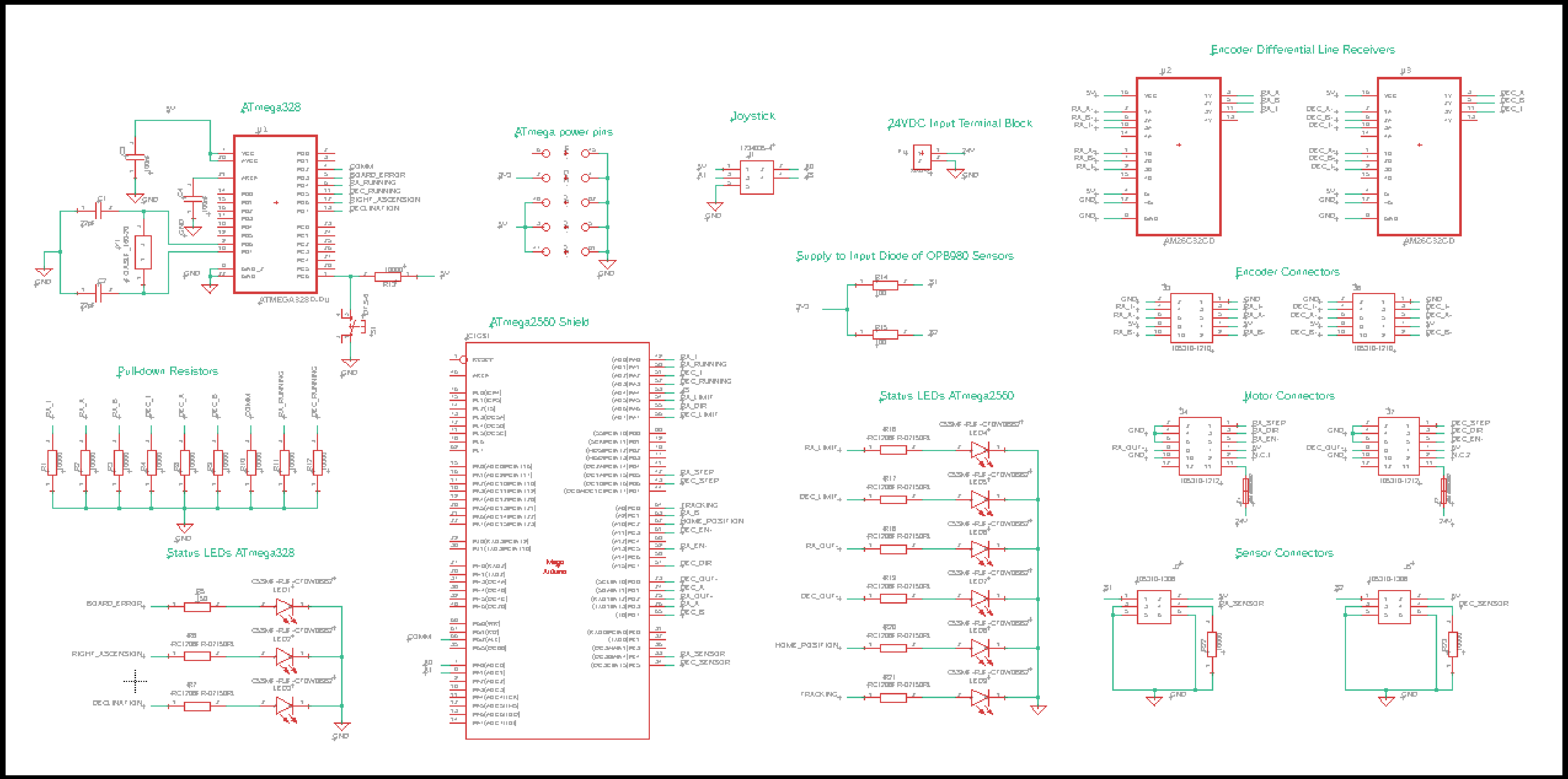




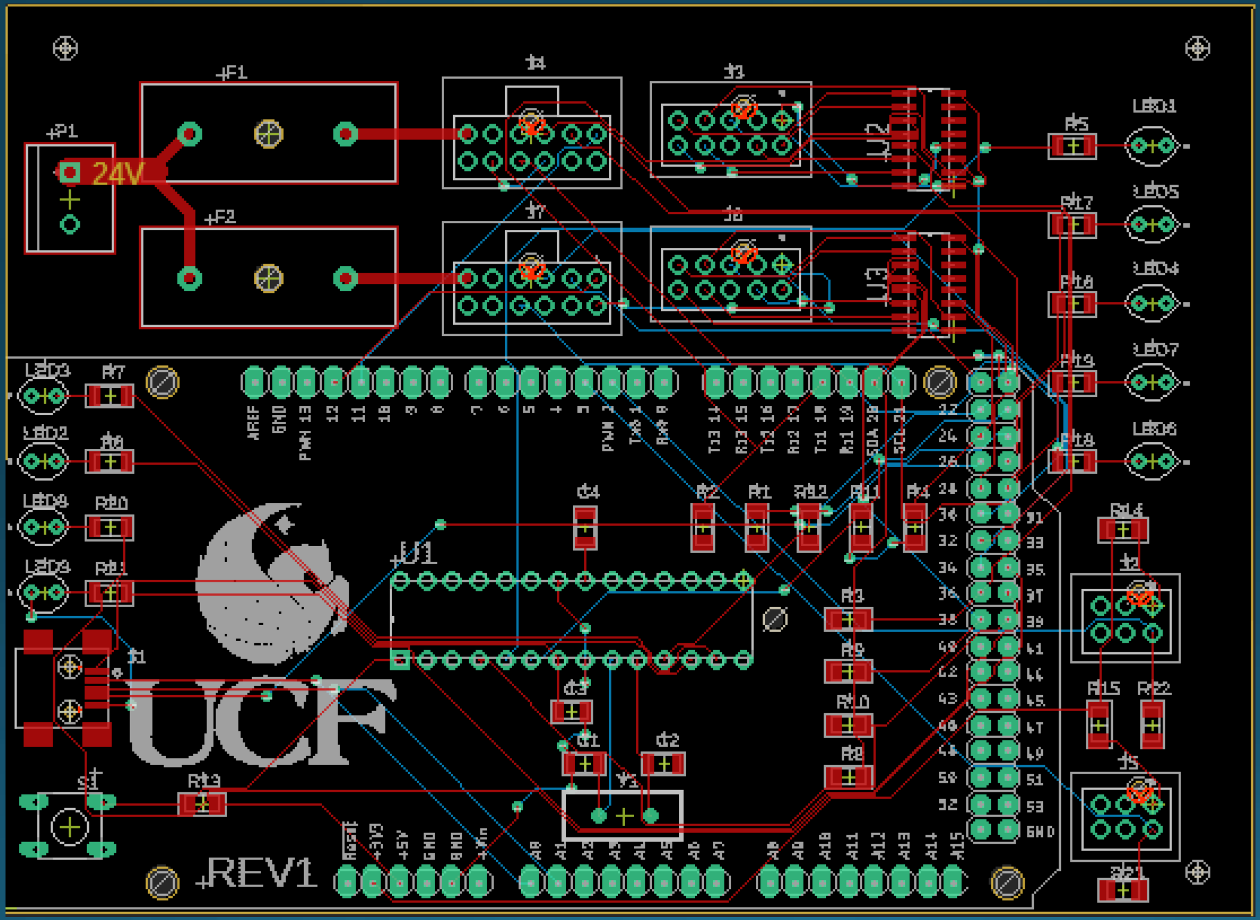




Overall PCB Schematic

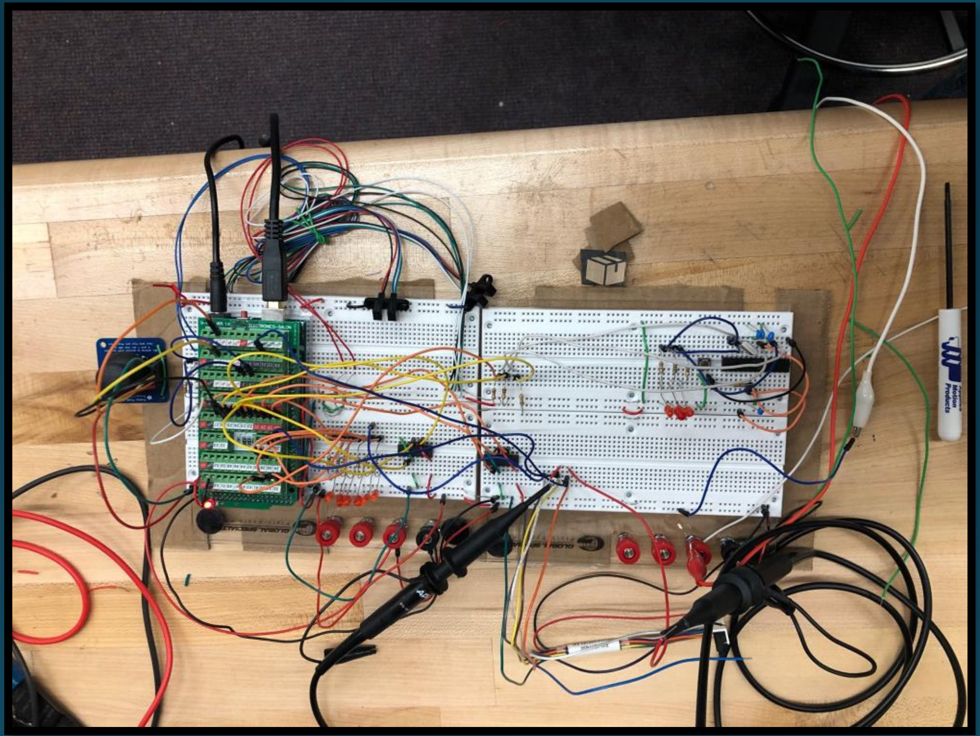


Overall PCB Layout – Rev 1

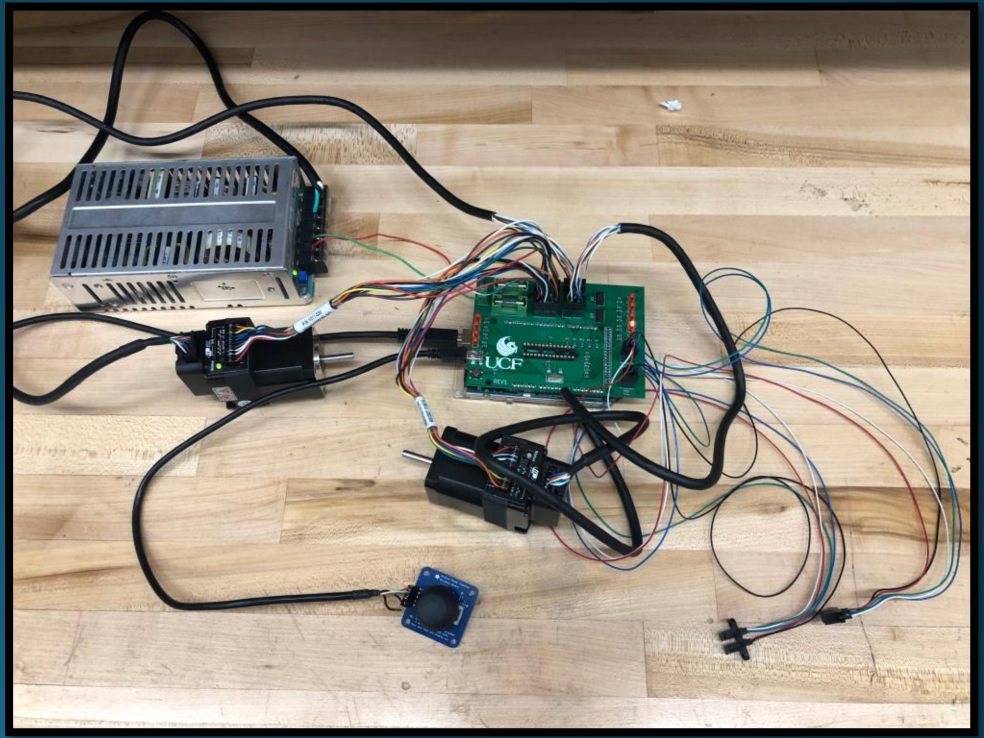


Testing

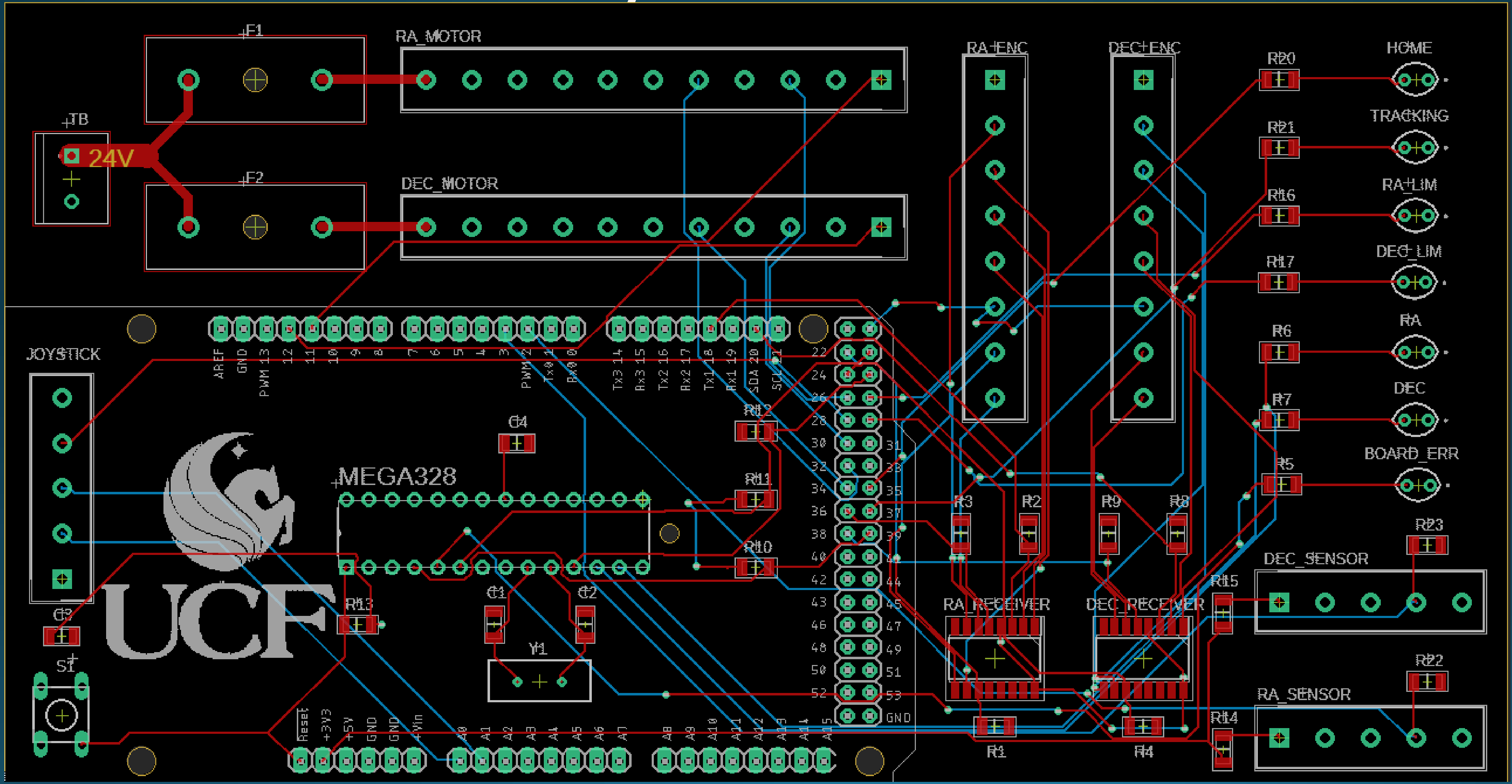
- Breadboard



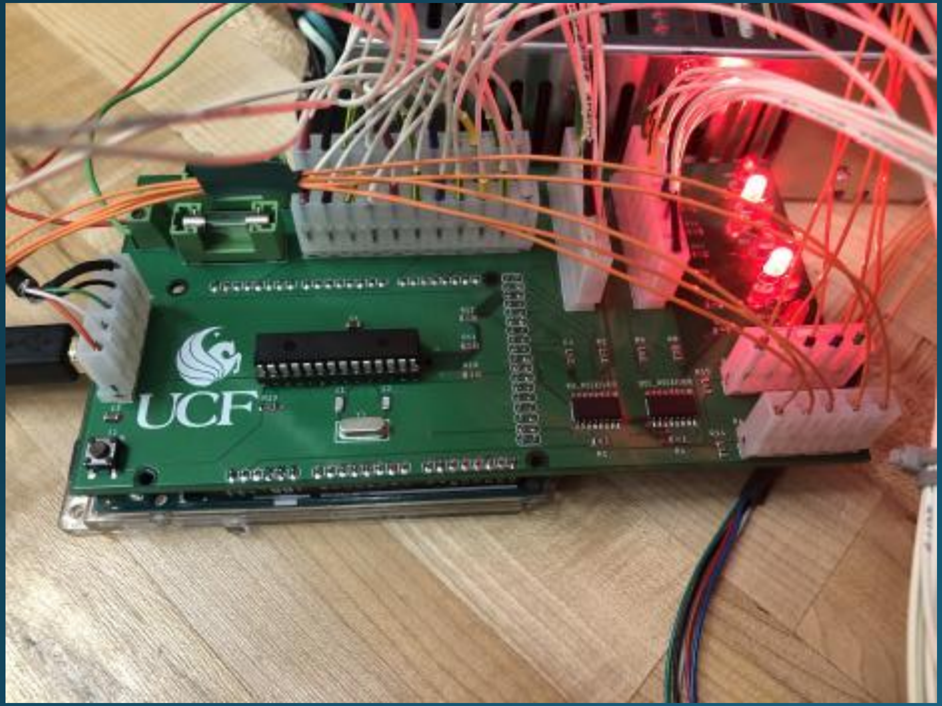
- PCB

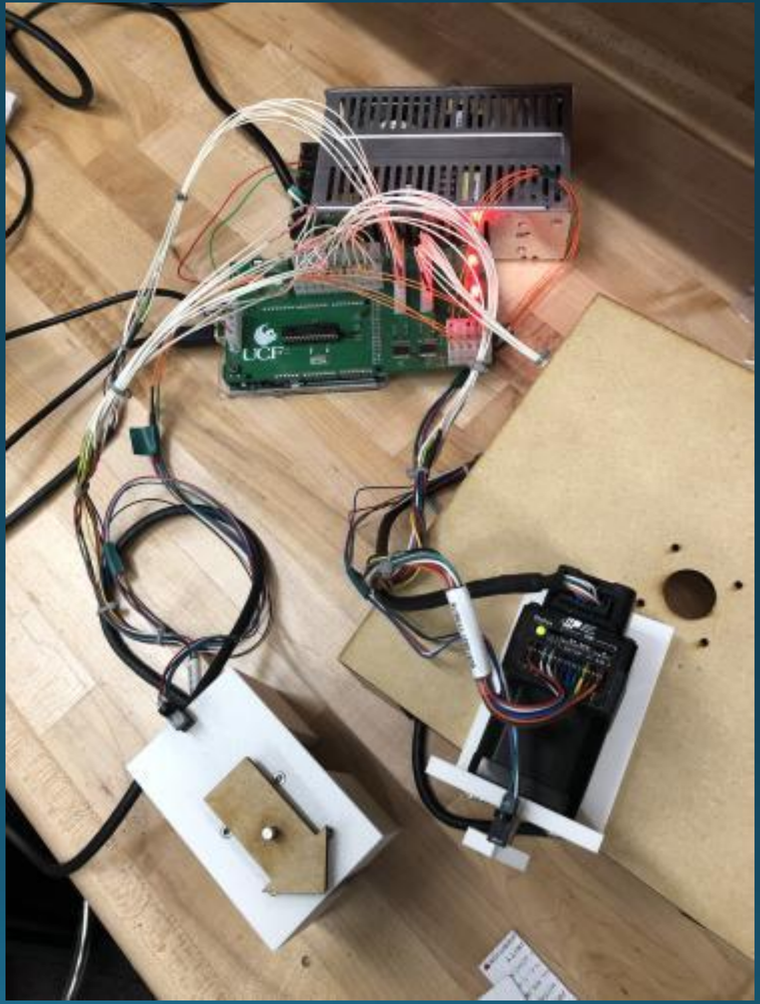


Overall PCB Layout – Rev 2

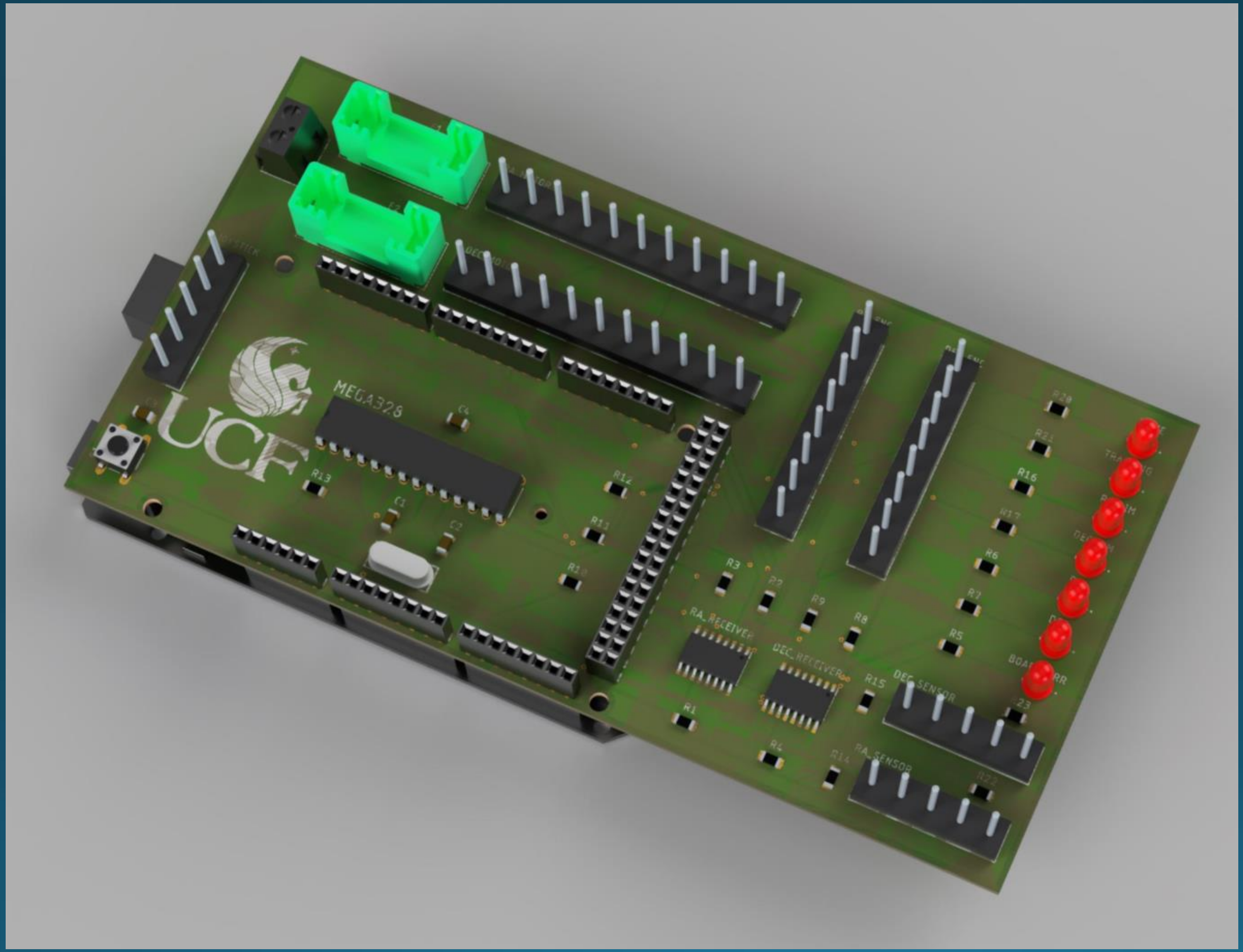


PCB – Rev 2

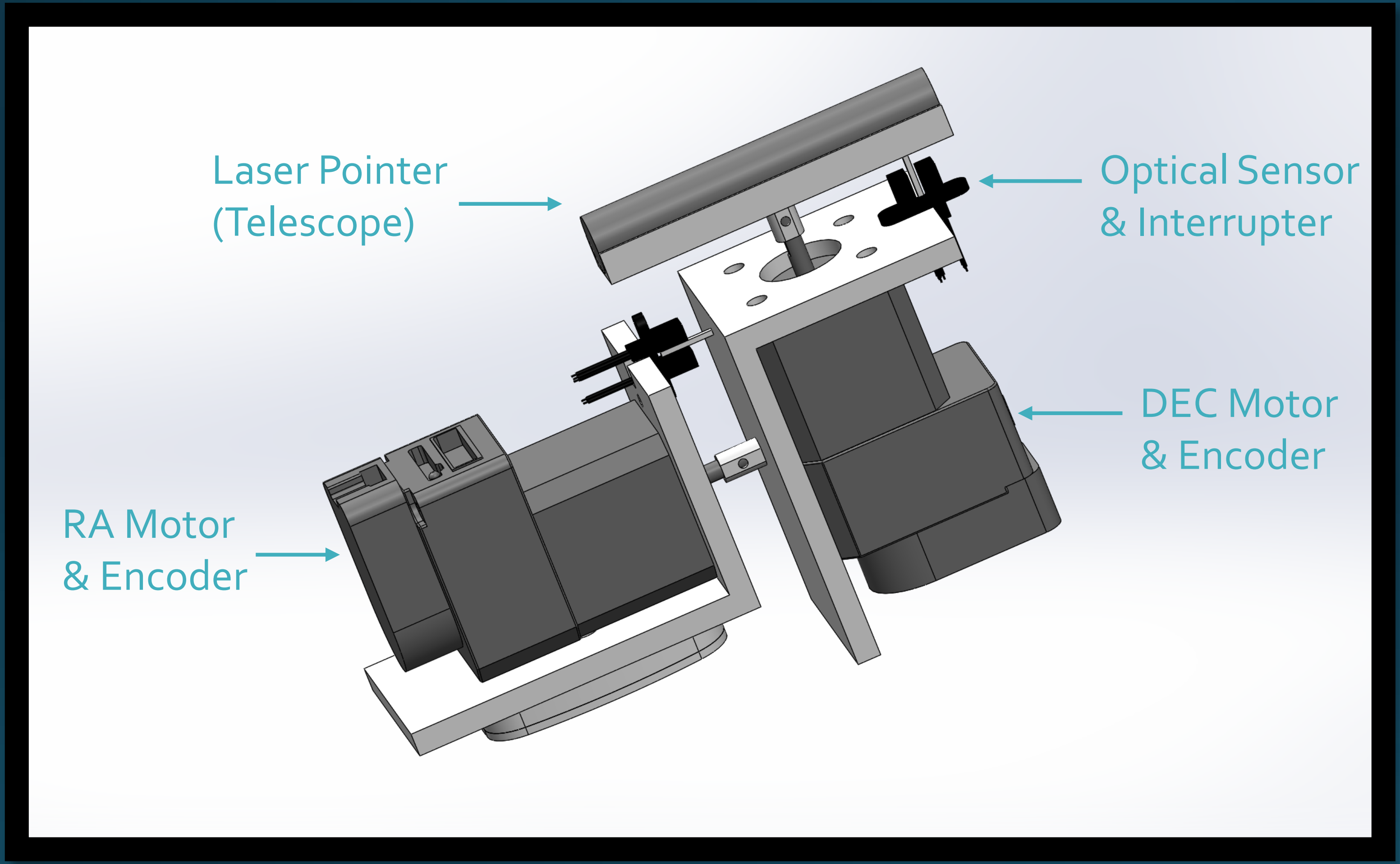




3D PCB model

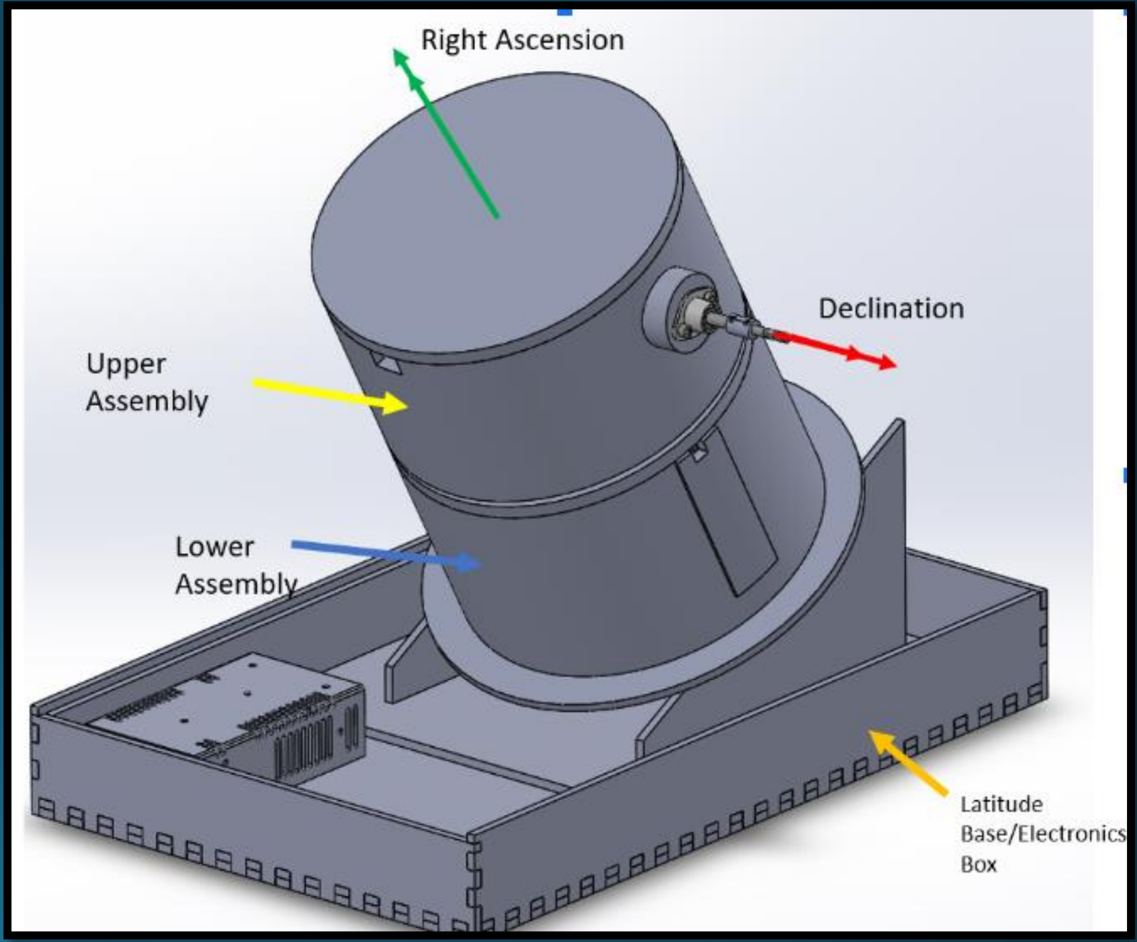


Temporary Mount



Intradisciplinary Integration - ME

- Gear Ratio
  - 38000:1 for RA
  - 100:1 for DEC
- 38,000:1 gear ratio makes 6°/second slew rate impossible.
- Also requires higher PWM frequency than Arduino is capable of.



Intradisciplinary Integration - CS

Software Development

Problem Recap

- How to utilize a set of hardware (motors, optical sensors, joystick) to view celestial bodies
  - Physical setup of telescope
  - Locating the body as desired
  - Preventing damage to telescope
  - A tracking implementation
  - Designing in a way to be simple to code and understand

Mount Selection

German Equatorial Mount

Advantages-

- Standard Tracking
  - Only one motor required
  - Less complicated algorithm
- Integration with observatory
- Easier programming

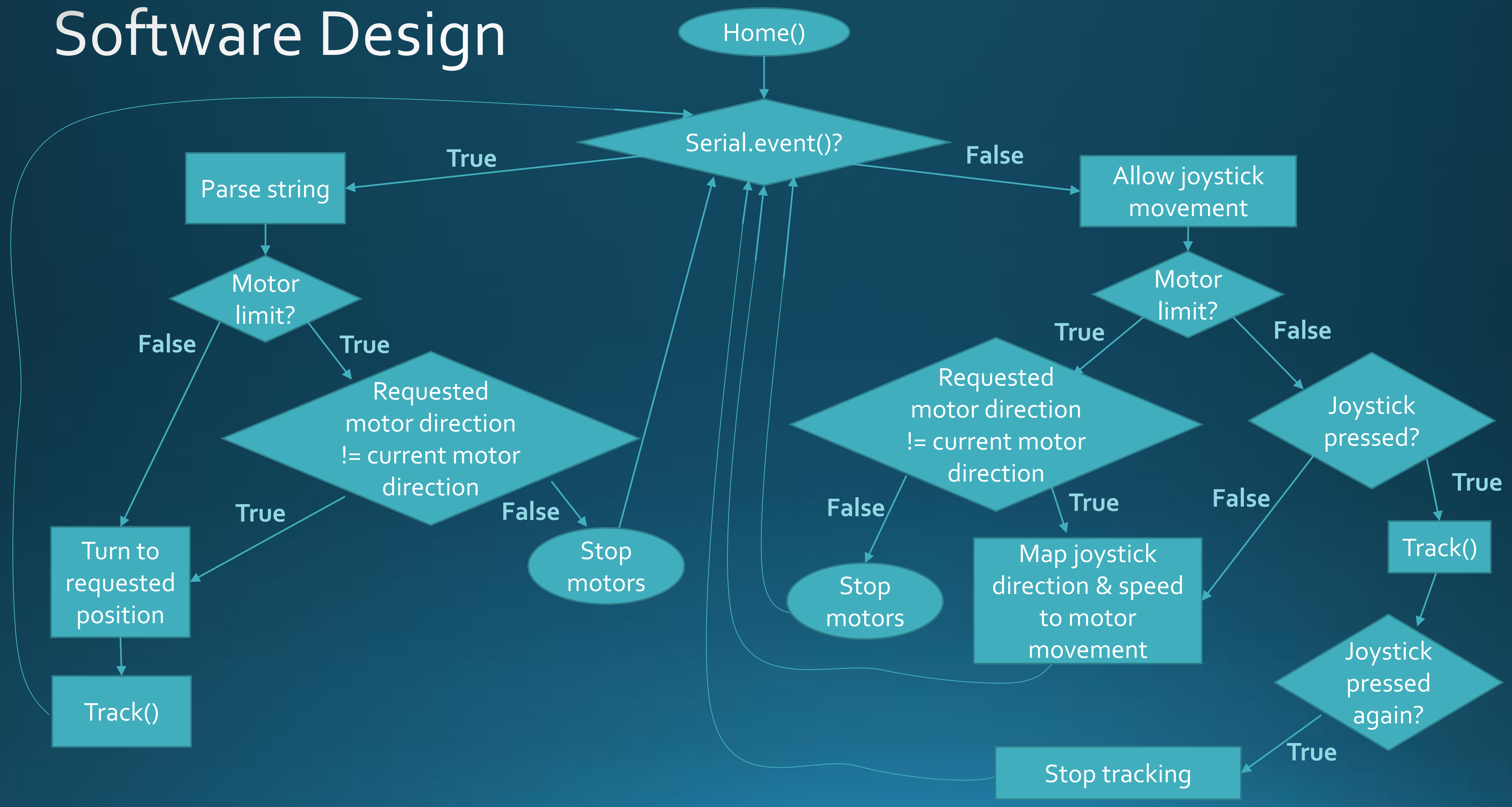
Drawbacks-

- Mount needs to be angled to north pole

Hardware to Software Translation

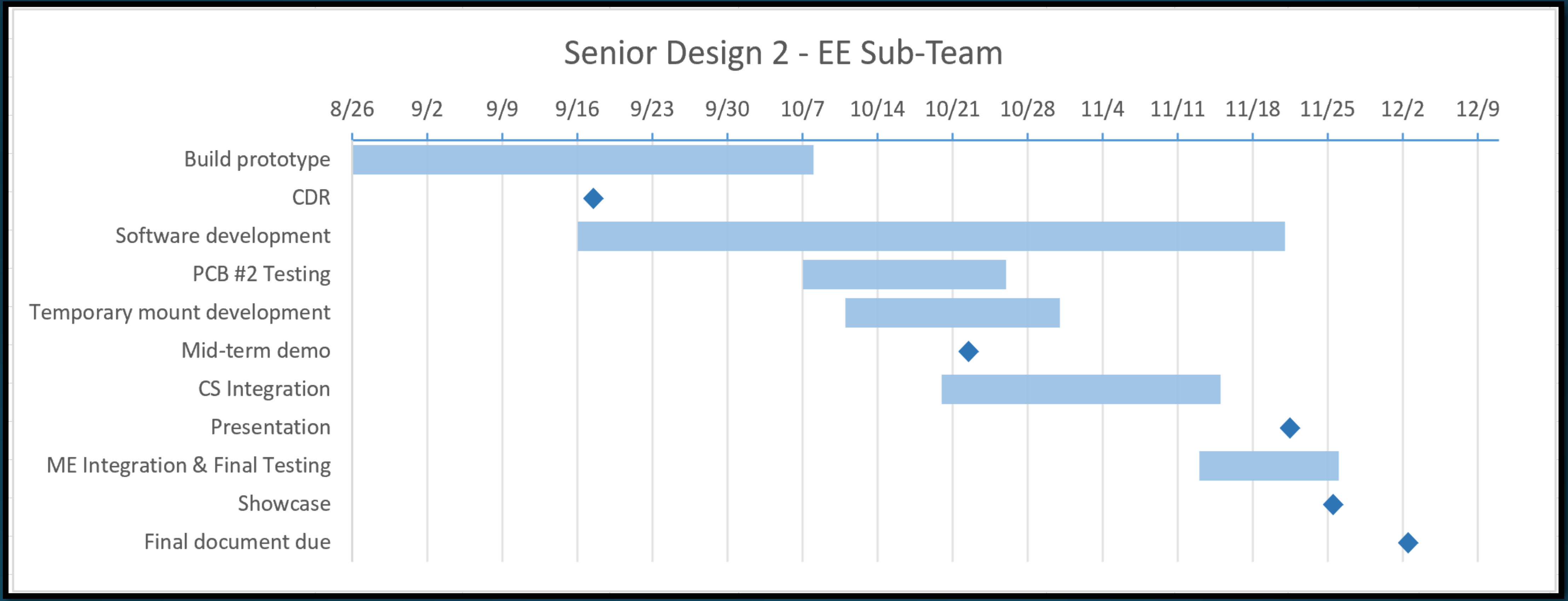
- German Equatorial Mount maps the sky as a latitude and longitude coordinate system
- Encoders on the stepper motors are directly translated to degrees in the sky

Software Design



Administrative Content

Project Milestone Chart



Budget

Description	Quantity	Unit Price	Extended Price
Integrated Motors with Encoders	2	$204.00	$408.00
Arduino Mega 2560	1	$38.50	$38.50
Power Supply	1	$172.00	$172.00
Optical Sensors	2	$5.04	$10.08
Joystick	1	$5.95	$5.95
PCB manufacturing	1	$16.41	$16.41
PCB & misc. components	N/A	$105.21	$105.21
Total			**$756.15**

Work Distribution

Subsystem Name	Primary	Secondary
PCB Development	Anthony Eubanks	Melinda Ramos
Status LEDs and Sensor	Brian Glass	Anthony Eubanks
Motors	Brian Glass	Anthony Eubanks
ATMega2560	Thomas Vilan	Melinda Ramos
Software Development	Thomas Vilan	Anthony Eubanks
Joystick	Melinda Ramos	Brian Glass
ATMega328	Anthony Eubanks	Thomas Vilan

Questions?

DEMO

Stellarium commands

- ***:GD#*** (command for requesting declination motor position)
- ***:GR#*** (command for requesting right ascension motor position)
- ***M-RA motor degrees-DEC motor degrees*** (string created by CS team to integrate with EE team. Example: ***M-114.04-106.09***)

Stellarium - Live demo

1. Set Stellarium time to midnight
2. Slew to 12225 (Yanfernandez)
   - RA position: ~ ***7h 32m 9.2s***
   - DEC position: ~ ***16° 5m 15.2s***
3. Slew to Cappella
4. Joystick

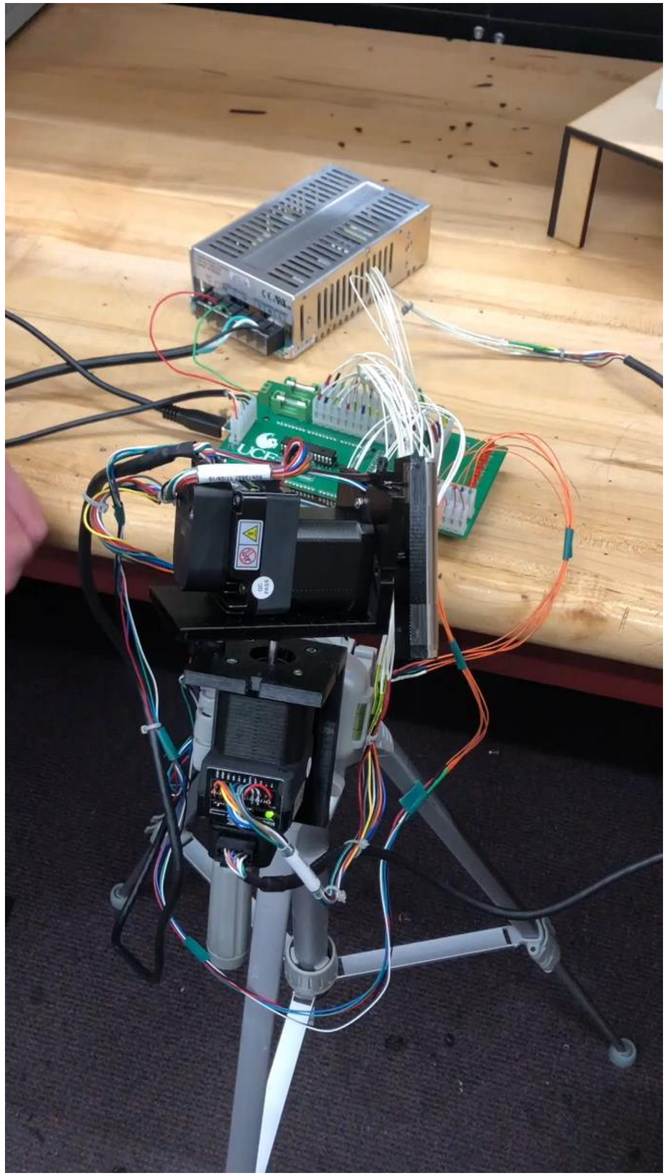
Pointing accuracy demonstration

- Command is sent to RA motor to slew to 225 degrees
- After confirming it reached the position, a new command is sent for 20 degrees
- Using a 1:1 gear ratio for testing
    1) ***M-225.0-225.0***
    2) ***M-20.0-20.0***

YouTube Link

Video demonstration

- During boot-up sequence, motors go to home position (where both sensors are triggered)
- Once reached home, allow movement
- Joystick will only let movement occur in opposite direction of motion from which sensor was hit
- Clicking the joystick button triggers tracking
- A second press takes it out of tracking



YouTube Link