Light Bucket

Final Report

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Introduction

Project Light Bucket allows any person to use a phone application to pick a celestial body and have their selection be sent to an onboard system that will calculate the appropriate altitude and azimuth for an alt-az mount .These calculated coordinates will then be used to automatically configure a table top telescope to point to the right coordinates in the sky.

Project Overview

Light Bucket is, at it's core, a click-and-view telescope. Using a mobile application developed for android devices, the user can select a series of celestial objects to point the telescope at. The telescope will automatically rotate the scope and the base of the telescope toward the celestial body for easy viewing,

A standard table top telescope will be outfitted with two stepper motors to help position it towards a selected of celestial body that is viewable from the user's location. The Light Bucket android application will allow the user to interface with the telescope.

There are three main factors to this solution: user location, time of day, and julian day from julian day 2000. These factors play a pivotal roles into determining the location of our celestial body. They will also be responsible for maintaining the view of the object.

We will use a wireless Bluetooth communication to transmit the user data for positioning. The data that is obtained from the user will be used in a series of equations to determine the altitude and azimuth degree values that are needed when position the alt-az telescope.

Technology Overview

Stepper Motors

Stepper motors are motors that move in discrete steps. They have multiple coils that are organized in groups called "phases". By energizing each phase in sequence, the motor will rotate, one step at a time. With a computer controlled stepping you can achieve very precise positioning and/or speed control.

Bluetooth Communication

Bluetooth communication is wireless technology that allows data to be transferred between multiple devices over a short amount of distance.Devices connected over bluetooth can alternate between slave and master roles. Transmission of data is made using short-wavelength radio waves ranging from 2.4 to 2.485 GHZ

Typical modern day applications of bluetooth: bluetooth headphones, wireless controllers like the ones on NIntendo WII and Playstation 3.replacement of RS-232 in GPS receivers, test equipment,bar code scanner.

Android Applications

Android mobile applications are written in Extensible Markup Language (XML) and Java. The layout, also called Activities, is defined by the XML. Application Program Interfaces (API) are also defined in the XML. We will be using the Android's GPS and the Google Maps API to obtain the user's latitude and longitude. The Java files are responsible for much of the event handling when the user interacts with the application.

Microcontroller

A microcontroller is a single integrated circuit that contains a central processing unit (CPU).RAM,ROM, and programmable input and output pins. The are typically designed for doing one specific task and having this task be defined in its ROM.

Microcontrollers are most notably used as embedded systems in larger machinery and can typically be found in the following systems: phones , engine control systems, toys and power tools.

3D Modeling

In 3D computer graphics, 3D modeling (or three-dimensional modeling) is the process of developing a mathematical representation of any three-dimensional surface of an object (either inanimate or living) via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. The model can also be physically created using 3D printing devices.

The graphics software used for this project was Autodesk 123D.

Project Objectives

1. To be able to select any celestial body on the Android app
2. To be able to transmit the user's gps coordinates from the android app to the microcontroller via bluetooth.
3. To be able to transmit which celestial body was selected on the android app to the microcontroller via bluetooth
4. To have the microcontroller determine how much it needs to drive the stepper motors to have the telescope facing in the correct direction.
5. To have all components of the project work in the following order : 1) Have the user's gps location sent to the microcontroller, 2) Allow the user to select which celestial body they want to view on the android app and have that information sent to the microcontroller , 3) Have the microcontroller determine the necessary calculations needed to know how much the telescope must be moved, 4) have the microcontroller send the correct signalling to the stepper motor controller to make the telescope move to determined position it needs to be in.

Achieved

The following numbers in the format "#" refer to the above numbers in project objectives

1. Project Objective "2" was completed. We were able to receive the needed information from the developed android application that was needed to calculate altitude and azimuth degrees.
2. Project Object "4" was completed. The TM4C123GH6PM was able to use the received data given by the bluetooth module and be able to convert it into the required altitude and azimuth degrees needed to move the telescope
3. Project Objective "5" was completed. The users GPS location was sent successfully to the microcontroller. The microcontroller was able to utilize the sent data and then was able to control the signaling needed on the stepper motor drivers to move the two attached stepper motors.

Uncomplete

The following numbers in the format "#" refer to the above numbers in project objectives

1. Project Objective "1" was incomplete. Due to mishaps that stalled production of the android app and bluetooth communication between the TM4C123GH6PM, only the moon is able to be selected for viewing.
2. Project Objective "3" was incomplete. Since the user android application only allowed for the moon to be selected, there was no need in implementing a checker for which object was selected for viewing

Overall Project Completion

The Light Bucket project succeeded in positioning the telescope to the approximately calculated altitude and azimuth coordinates.

The android application to bluetooth module worked accordingly ; all the required data was transmitted. As well as the TM4C123H6PM was able to use this transmitted data to calculate the altitude and azimuth need for the alt-az telescope.

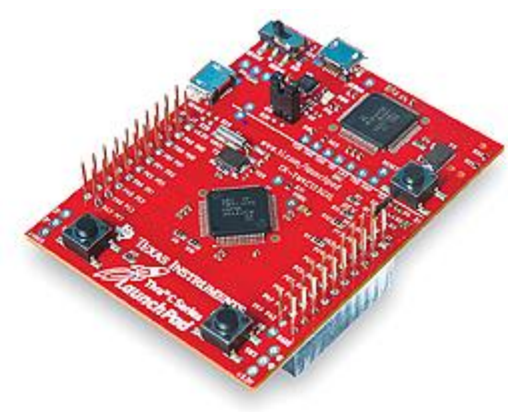
Overall, even though the project ended up not allowing for more than the moon to be selected, a proof of concept was achieved.

Hardware Design

Celestron Table Top Telescope

- Price: $69.95
- Model : Celestron Cosmos FirstScope Telescope
- Product Dimensions: 25.4 x 20.3 x 25.4 cm7
- Aperture: 76mm aperture Newtonian reflector
- Weight: 4.40 lbs
- Type of telescope mount : Altazimuth mount

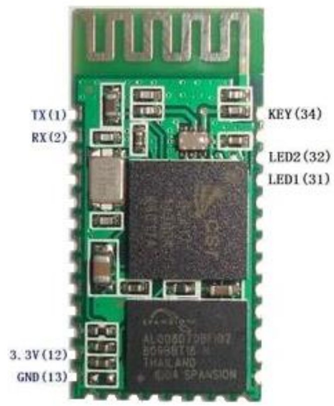
TM4C123GH6PM Microcontroller



- Price :$39.95
- Processor :32-bit ARM® Cortex™-M4 80MHz processor core
- Flash Ram: 256 kb
- SRAM: 32 kb
- 43 GPIO pins
- 12 ADC channels
- 8 UART channels
- 12 bit ADC Resolution
- Max Speed: 80 MHZ
- Input Voltage: 3.3v

Purpose: The TM4C123GH6PM will control the stepper motors to move the telescope to the required position and will receive data retrieved from an attached HC-05 Bluetooth module to determine how much to step the stepper motors.

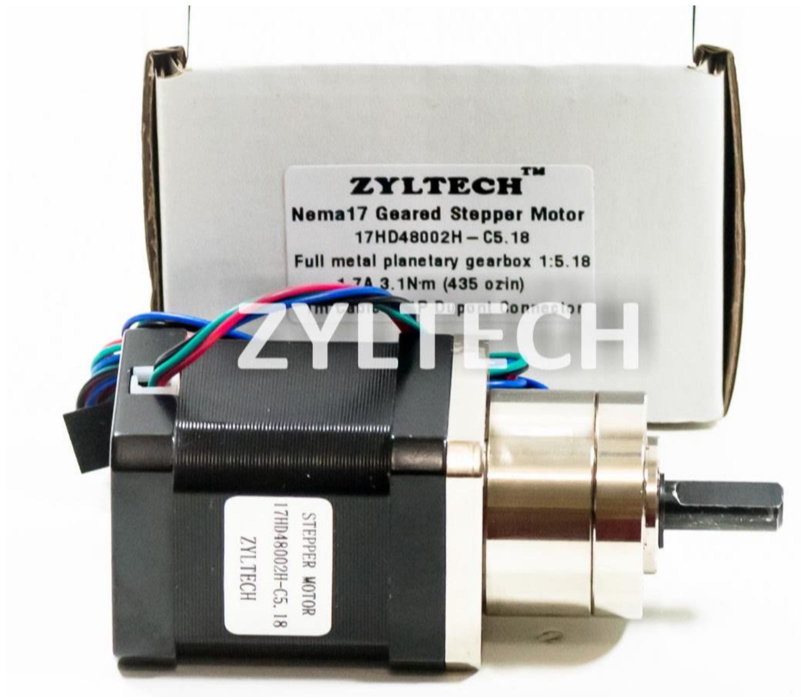
HC-05 Bluetooth Module



- Price :$3.35
- Input Voltage: 3.3v
- UART interface with programmable baud rate
- Data Bits: 8
- No Parity
- Stop Bit : 1
- Default Baud Rate: 38400
- Supported Baud Rates : 9600,19200,38400,57600,115200,230400,460800.

Purpose: This Bluetooth module will be connected to the TM4C123GH6PM microcontroller. Its purpose will be to be able to have data sent via Bluetooth from the android app to the microcontroller.

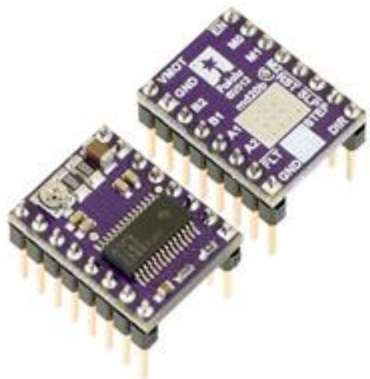
NEMA 17 Stepper Motors



- Price: $26.00
- Gear ratio: 1:5.18
- Step Angle: 1.8
- Step Accuracy: 5%
- Rated Voltage: 3.1 V
- Weight: 518 g

Purpose: To be used to move the telescope to a set location. One stepper motor will be used to control the altitude and one stepper motor will be used to control the right azimuth of the telescope. Stepper motors were selected instead of dc motors because the angle in which the telescope points will be more precise and more easily controlled than if the motors were DC motors

DRV8825 Stepper Motor Driver



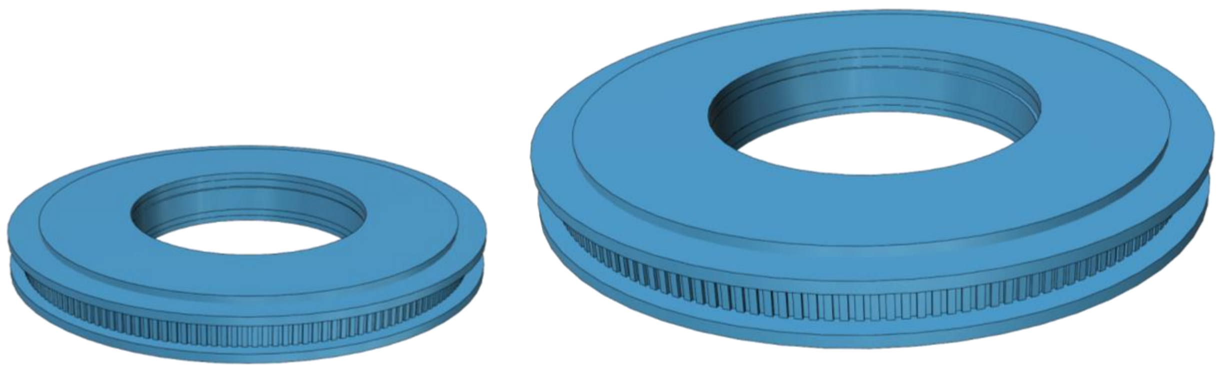
- Price: $8.95
- Manufacture : Polulu
- Operating Voltage : 8.2v
- Maximum Operating Voltage : 45v
- Maximum Current Phase : 2.2A
- Minimum Logic Voltage : 2.5v
- Maximum Logic Voltage : 5.25v
- Step Resolution :   1/2 , 1/4, 1/8, 1/16, 1/32

Purpose : To drive an individual stepper motor The step amount of each motor will be determined by the level logic present on the STEP pin and the Step resolution will be set by pins MO , M1, M2.

3D Gear Design

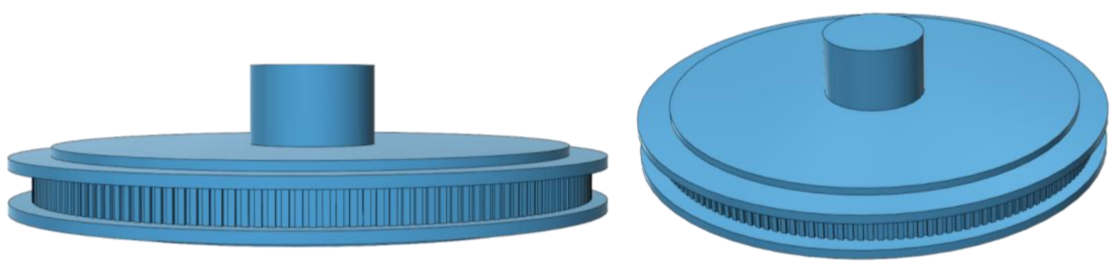
Gear 1

This Gear was designed to fit around a protruding piece on the side of the Celestron telescope. Friction holds this pulley in place and rotates the telescope when it is moved. This pulley was designed to work with a MXL belt.



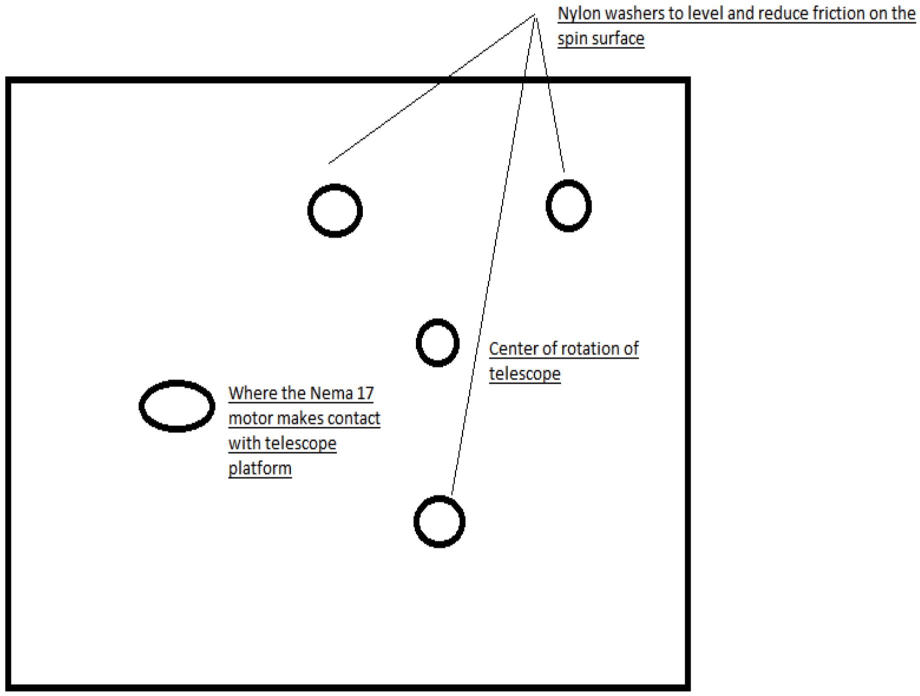
Gear 2

This pulley was designed to be driven by a nema 17 stepper motor.



Structural Design

Top View of Light Bucket Stand



Power Supply

Hardware	Voltage Requirements
TM4C123GH6PM Microcontroller	5 v
NEMA 17 Stepper Motor	3.1 v
HC-05 Bluetooth Module	3.3 v
DRV8833 Dual H-Bridge Motor Driver	8.2 v - 54 v

Power Source Connections

1. TM4C123GH6PM will receive voltage from 5v usb port
2. Voltage to the Bluetooth module HC-05 will come from 3.3v voltage pin on the TM4C123GH6PM microcontroller.
3. Voltage to each stepper motor driver will come from 12V Tenergy 2000mAh NiMh Battery Pack

Note: All stepper motor driver voltage and current where provided by in lab variable output current and voltage power supply boxes during production of project. Actual use of Tenergy battery was only stated and selected as an appropriate battery pack for the drivers based on specifications but never tested due to battery pack not arriving in time.

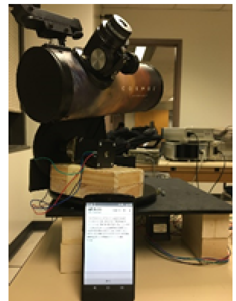
12V Tenergy 2000mAh NiMH Battery Pack

Components	10x AA NimH 2000mAh Cells
Connector	Bare Lead
Weight	10oz

Dimensions	50mm(width); 29mm (Height); 72mm (Length)

Bill of Materials

Light Bucket



Assembly Name :	
Assembly Number :	
Assembly Revision :	2
Approval Date :	
Part Count :	16
Total Cost :	$263.45

Part #	Part Name	Description	Qty	Units	Picture	Unit Cost	Cost
21024	Celestron Cosmos FirstScope Telescope	76 mm reflector optical tube Altazimuth mount	1	1		$ 69.95	$ 69.95
TM4C123GH6PM	TI Tiva Microcontroller		1	1		$ 39.95	$ 39.95
17HD48002H	Zyltech Nema17 Stepper Motor w/ planetary gearbox	Stepper Motor	2	2		$ 25.25	$ 50.50
HC-05	Bluetooth Module	Input Voltage: 3.3v UART interface with programmable baud rate	1	1		$ 3.35	$ 3.35
DRV8825	Dual H-Bridge Motor Driver	45 V maximum supply voltage. Adjustable current control	2	2		$ 2.94	$ 5.88
0	Custom 3D printed pulleys		2	2		$ 7.50	$ 15.00
	Seaboard High Density Polyethylene Sheet	1/4 inch Thick	1	1		$ 16.95	$ 16.95
	Wood Blocks		4	4		$ 5.00	$ 20.00
	MXL Timing Belt	Belt Pitch 2.032mm Width 6mm	1	1		$ 21.88	$ 21.88
	Tenergy Battery Pack	12V 2000mAh	1	1		$ 19.99	$ 19.99
							$ -
	Total		**16**				**$263.45**

Theory

The following are terms and equations that were used when calculating the altitude and azimuth degrees needed for the alt-az telescope.

Right Ascension: The angular distance measured eastward along the celestial equator from the vernal equinox to the hour circle of the point in question.

Declination: The angular distance of a point North or south of the celestial equator.

Latitude: The angular distance of a place north or south of the earth's equator.

Longitude : Thee angular distance of a place east or west of the meridian at Greenwich, England.

Day number(Julian Date): The Julian date is used to find the number of days since the fundamental epoch J2000. Calculations are as follows:

Julian date = ((UniversalTimeHour + (universalTimeInMinutes/60))/(24) + CurrentDayToBeginningOfYearInCurrentMonth + CurrentDayMonth + CurrentDaySinceJan2000(Jan1))

Local Sidereal time: The sidereal time is the right ascension of the points crossing the meridian. This is used as well as the time for all observers with the same geographical longitude. Equation is as follows:

*LST acronym for local sideral time

LST = (100.46 + 0.98567*JulianDate-Longitude + 15*(universalTimeInDecimalForm))

If the LST is greater value than 360, we subtract LST = LST - 360

Hour angle: The hour angle is one of the coordinates used in the equatorial coordinate system to give a direction of a point in the celestial sphere, in our case the moon. Value must be positive. If value is not positive, then we add 360, in the 0 to 360 range.

Hour Angle = Local Sidereal Time - Right Ascension

Pacific standard time to universal time: We live in southern california, so the time zone for us would be the pacific standard time. We need to convert this to universal time.

Universal Time: Universal time is a time standard for earth's rotation. Calculations are as follows:

UTC = pacificStandardTime + 7

If current time is not daylight savings, then equation changes as follows:

UTC = pacificStandardTime + 8

Altitude: The height of an object or point in relation to sea level or ground level.

Calculating Altitude from Declination , Latitude and Hour Angle :

sin(altitude) = sin(declination)*sin(latitude)+cos(declination)*cos(latitude)*cos(hour angle)

ALT = asin(altitude)
* ALT being the final value of altitude

Azimuth: Geographical coordinates of the point on Earth, from which the object is seen directly in zenith.

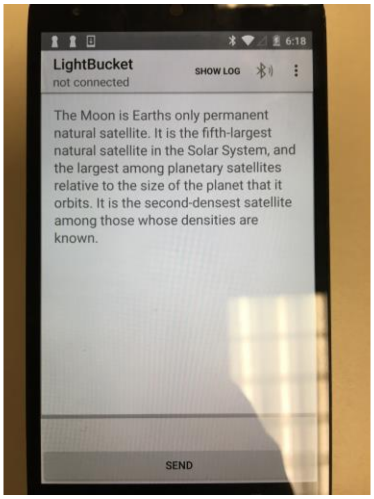
Calculating Azimuth from Declination , Altitude and Latitude:

```
            sin(Declination) - sin(altitude)*sin(latitude)
cos(az0)   =   --------------------------------
                cos(altitude)*cos(latitude)
```

az1 = acos(az0)

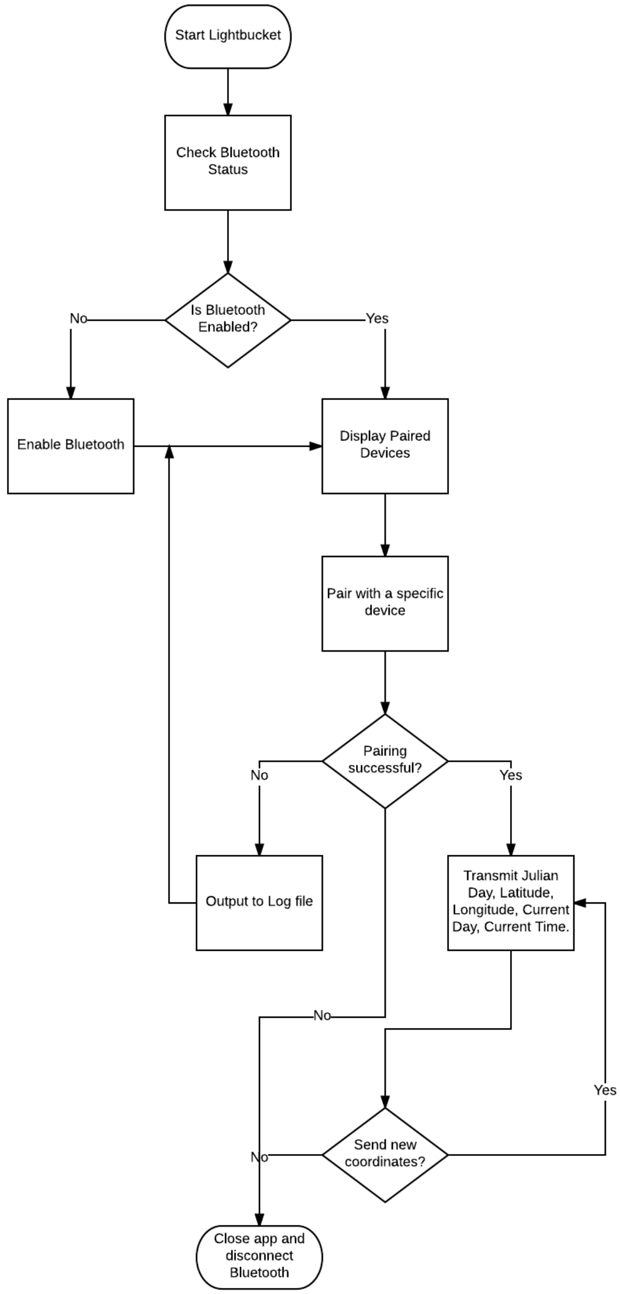
If sin(hour angle) is negative, then Azimuth = az1, otherwise
Azimuth = 360 - az1

User Interface



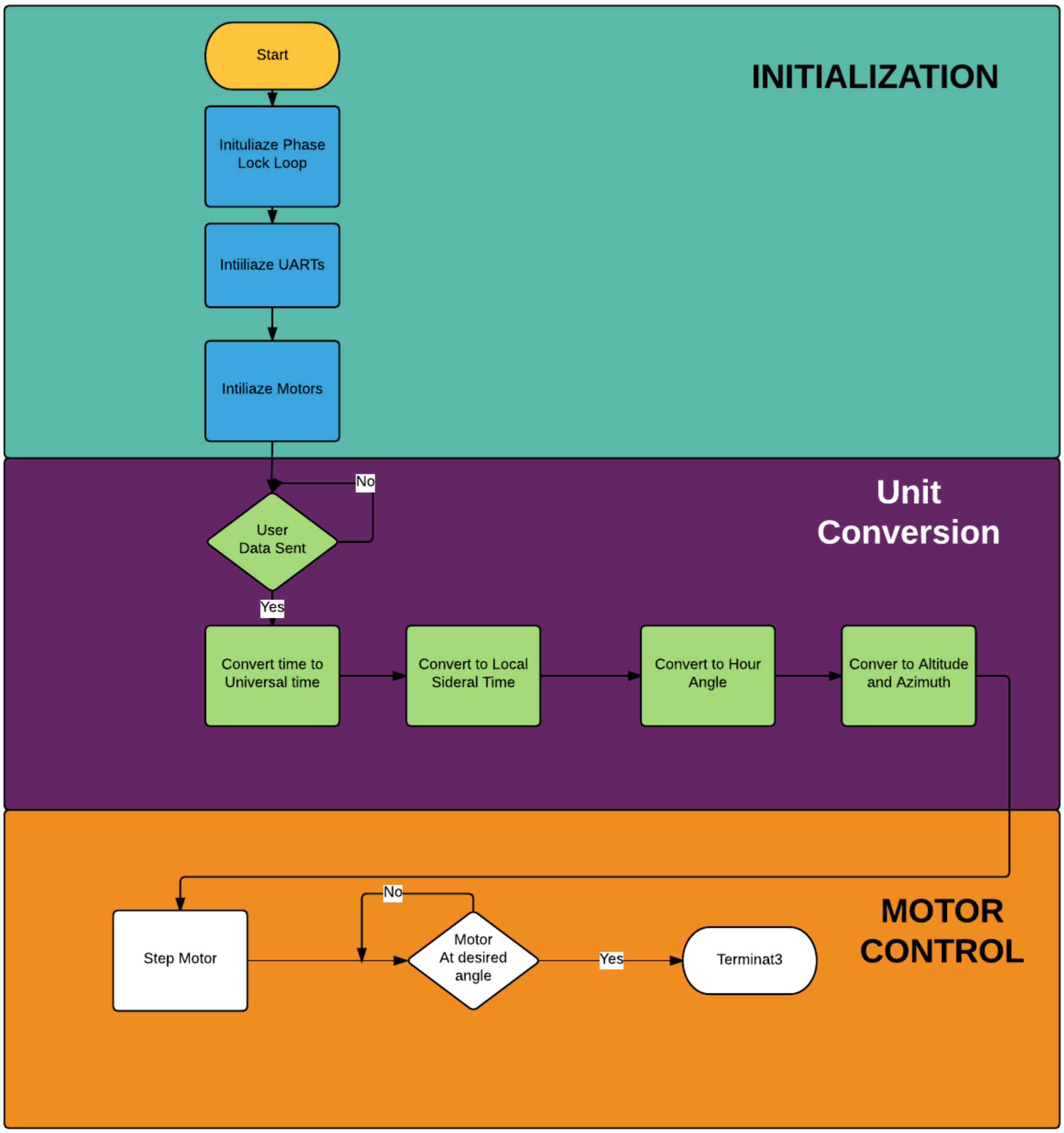
The user interface for LightBucket is an Android application that can connect to the telescope's on-board Bluetooth module and transmit data to the telescope. The data string consists of the julian day, latitude, longitude, current date, and current time. The on-board microcontroller would then take that received data and compute the Alt-Az coordinates. This would then result in pivoting the telescope toward the moon ready for easy-viewing.

User Interface Software Flow



Software

Software Flow



Block Diagram