LOW EARTH ORBIT(LEO) SATELLITE TRACKING SYSTEM

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ABSTRACT

With the increase in satellite launched by different countries, awareness about satellites over own space has become vital. Special eavesdropping and remote sensing satellites are employed by adversaries in space to listencommunication and observe activities. Information on satellites available online cannot be validated/confirmed. Satellite tracking facility is required for prediction of overhead satellites for synchronization of activities/operational maneuvers. Satellite tracking can be done by radars but they require high maintenance, high power and are quite expensive. In this research we developed a solution to predict and track the orbital trajectory of satellite using optical telescope and dual axis azimuth-elevation mount.

CERTIFICATE FOR CORRECTNESS AND APPROVAL

Certified that work contained in the thesis – Low Earth Orbit Satellite tracking system carried out by SabihaSiddique, Fakiha Khan, Muizz Jamal and HamzaShafiq in supervision of Lt. Col. Syed AmerAhsanGilanifor partialfulfillment of Degree of Bachelor of Electrical (Telecomm) Engineering is correct and approved.

Approved by

____

Lt. Col. Syed AmerGilani

EEDEPARTMENT

MCS

DATED:

DECLARATION

Thework,oranyofitsportion,writteninthisthesishasnotbeensubmittedforprovision ofanyanotherawardorqualification,eitheratthisinstitutionorelsewhere.

DEDICATION

In the name of Allah All Mighty, the Most Gracious, the Most Benevolent Dedicated to our parents and our supervisor, who proved to be unwavering pillars of support and encouragement in helping us complete a work of the order of this magnitude.

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ACKNOWLEDGEMENTS

We would like to thank Allah All Mighty for bestowing upon us, His countless blessings. Whatever we have achieved, we owe it to Him, in totality. We are also highly obliged to our friends and families for their unflinching support which has helped us achieved all the milestones of ourlives.

We are extremely thankful to our project supervisor Lt. Col. AmerGillanifrom MCS who in addition to providing us with valuable technical help and guidance also provided us moral support and encouraged us throughout the development of the project.

We are also grateful to all faculty and staff of MCS who supported and guided us during our course work. Their support, knowledge insight, advice, training and guidance facilitated us in completing this difficult task.

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INTRODUCTION

1. INTRODUCTION

1.1 Overview

This project uses a laptop to feed information of the satellite to be tracked. This information is further sent to the controller which directs the motors along with the feedback from the sensors to orient themselves towards the satellite. The telescope is placed on a mount to which motors are connected and as the motors move the mount, telescope moves consequently so that the targeted satellite can be observed.

1.2 Problem Statement

Space situational awareness requires real time tracking of satellites done by using radars and optical telescopes. Radars are used for satellite tracking but can only be acquired by government institutions or large organizations with the permission of the government. They are high power, sophisticated and expensive. On the contrary, satellite tracking using optical methods uses telescopes for tracking which has many advantages which include

- Low Power
- User friendly
- Low maintenance
- Low cost
- Smaller in size

1.3 Approach

This project will use Two line element set, which can be found online,to aid in finding the trajectories of low earth orbiting satellites so that the motors can move the mount in that particular direction. The two line element set is an array of earth orbital parameters of each satellite. This data will be fed in SPGA-4 program in MATLAB which will send data to arduino. Arduino will compare the values with feedback values from the sensor. Sensors will be used to detect the angular motion of the mount such as elevation angle and azimuthal angle. This information will be used for directing the mount as required to face towards the satellite.

1.4 Scope

This project has a very vast scope in the field of tracking as it is very less expensive as compared to radars. It is easy to use and requires very less maintenance as compared to any other satellite tracking system.It can easily track communication satellites, earth observation satellites, military satellites and scientific experimental satellites.

1.5 Aim &Objectives

The basic aims of this project are:

- To track low Earth orbiting satellites with precision
- To design software and hardware for tracking satellites at low cost and easier operability
- To design low maintenance equipment for observing satellites paths

1.6 Contributions

This is a military project, designed and developed mainly for military purpose. The R&D Wing of MCS is the main contributor.

1.7 Organization

Thesis’s first part is the abstract which gives basic information related to the tracking system for Low Earth Orbiting satellites. After this is the introduction section which consists of statement of problem, approach going to be followed, scope of project and objectives of project. The literature review section present different resources that have been read online regarding the Low Earth orbiting satellites, Two line element set, earth Orbital parameters, inclinometers and accelerometers before initiation of project. The design and development part demonstrates the flow charts of different steps involved in satellite tracking as well as description of main modules. The future work gives further improvements and point out additional developments which can be made to enhance the scope ofproject.

CHAPTER:2
LITERATURE REVIEW

2. Literature Review

2.1 Background

A Low Earth Orbit (LEO) is an Earth orbit with an altitude between the Earth's surface and 2,000 kilometers (1,200 mi), with an orbital period between about 84 and 127 minutes. Following are the types of LEO satellites

- Communication Satellite (Iridium constellation)
- Earth Observation Satellite (Spot, Risat-1, Cartosat-2C)
- Military Satellites (Spirale B)
- Scientific Experiments (Terra, Cloudsat)

A two-line element set (TLE) is a data format encoding a list of orbital elements of an Earth-orbiting object for a given point in time, the epoch. Using suitable prediction formula, the state (position and velocity) at any point in the past or future can be estimated to some accuracy. The format uses two lines of 80-column ASCII text to store the data, having originated as punch card format with one line per card. TLEs can describe the trajectories only of Earth-orbiting objects. It has a list of different orbital parameters of satellite.

2.1.1 Keplerian orbital Parameters

Orbital elements parameters are required to identify a specific orbit. These elements are generally considered in classical celestial systems, where a Keplerian orbit is used.
In astronomy, a Keplerian orbit is the motion of one heavenly body relative to another heavenly body, as a parabola, ellipse or hyperbola; which forms an orbital plane in three-dimensional space.

2.1.2 Epoch Time

Epoch time determines how fast the satellite is moving with respect to Earth.

Orbital Inclination is the angle between the equator and the orbit when looking from the center of the Earth ranging from 0 to 180 degrees.

2.1.3 Right ascension of ascending node

The ascending node is the place where the satellite crosses the equator while going from the Southern Hemisphere to the Northern Hemisphere or vice versa. Now since the Earth rotates, you need to specify a fixed object in space. Right ascension of ascending node is an angle measured from the center of the earth between the Aries and ascending node.

2.1.4 Eccentricity

The eccentricity tells you how flat the orbit is. For a perfect circle, eccentricity is zero.

Since an orbit usually has an elliptical shape, the satellite will be closer to the Earth at one point than at another.

2.1.5 Perigee and Apogee

The point where the satellite is the closest to the Earth is called the perigee. The point where the satellite is the furthest from the Earth is called the apogee.

2.1.6 Mean Anomaly

The mean anomaly states where the satellite is present its orbital path. The mean anomaly ranges from 0 to 360 degrees. The mean anomaly is referenced to the perigee. It is zero if satellite is placed on perigee.

2.1.7 Mean Motion

While moving in a keplerianorbit, velocity ofsatellite changes.Velocity of satellite increases as satellite approaches closer to the Earth because the motion of satellite depends on how close or far it is from another heavenly body. Mean motion hence tells about the relative motion of satellite.

We will be using Arduino UNO to serve as an on-board controller; it will take data from

MATLAB and compare it with the data from different sensors and will control the movement of the motors accordingly. We studied different features of Arduino UNO and how to connect and get data from different sensors with the help of Arduino UNO. Also we learned MATLAB programming. We did research on the appropriate motor and motor drives and gears to be used for the movement of the mount.

2.2 Existing Literature

Advancements in technology have enforced us to look for better and faster means to communicate with each other. One of the best solutions for achieving most favorable communication has been through the use of satellites. Hundreds of satellites as well as debris are orbiting above our atmosphere at Low Earth Orbit (LEO) which is considered between 100 and 1,000 statute miles. LEO satellites are launched to determine physical properties of space, to study gravitational field and other celestial bodies. They have been used for communication and surveillance purposes for a long time. Satellites that are controlled from the ground must be tracked so that necessary maneuvers are carried out timely. Telescope tracking provides an effective and economical method to obtain information about satellites. The telescope's main optic is used for observations. It can be connected to a camera that is integrated in the mount with the lens. The telescope uses a mount that moves along azimuth and elevation angles to track the satellite. The rate at which the telescope moves depends on the orbit of the tracked object. For a typical LEO object that is directly overhead it takes approximately 9 minutes to travel from rise to set $\approx 180°/9$ min. This means that a LEO objects travels at about 1/3 of degree per second. After reading a number of research papers on optical satellite tracking, we learned various methods for determining the apparent position of a satellite.

CHAPTER:3
DESIGN ANDDEVELOPMENT

3. DESIGN ANDDEVELOPMENT

3.1 Preliminary Design

The details for the design are given as below.

Technical Specification

The project consists of the following blocks:

- Two Line element set
- SPGA-4 propagator
- TEME co-ordinate transformation
- ECEF co-ordinates transformation
- Topo-centric co-ordinates, azimuth and elevation range
- Arduino Mega
- Motors and Motor Drive
- Sensors
- Mount
- Location of user

3.1.1 TWO LINE ELEMENT SET

A two-line element set (TLE) is data list of orbital elements of Earth-orbiting satellites for describing trajectories of satellites orbiting around Earth.Two line element set represents satellite number, year of launch, time derivative of mean motion, eccentricity, argument of perigee, mean motion defined in a Newtonian-inertial space. The values of these parameters do not remain constant. As Earth inclination angle changes while orbiting around its axis and Sun so does the mean motion, eccentricity and angle between equator and orbit plane. These are defined in a Newtonian-inertial space. The position and velocity at any point in future can be predicted/ propagated.

3.1.2 SGP-4

Simplified perturbations models SGP-4 is used to calculate orbital state vectorsof satellites relative to the Earth-centered inertialcoordinate system (more specifically True Equator Mean Equinox). These models predict satellite ephemerides under the influence of perturbationscaused by the Earth's gravity, shape, drag, and other gravitational effects from heavenly bodies such as the sun and moon.

3.1.3 TEME COORDINATES

SGP-4 produces ephemerides in "True Equator Mean Equinox" coordinate system. The motion of the Earth ecliptic plane due to general precession causes the Equinox to move along the equator called as "ecliptic of the date". The Earth's rotation axis also processes secularly about North ecliptic pole causing equator to wobble about the ecliptic. This is modeled as "mean equator of date" measuring the nearly secular motion of Earth rotation axis. The intersection of these two planes on a given date defines the "mean equinox of date". By including the nutation effects of the luni-solar (moon and sun) perturbations on the equator, one gets "true equator of date". Details are provided in reference [7].

3.1.4 ECEF COORDINATES

A geocentric coordinate system fixed to the rotating Earth called the Earth Central Earth Fixed (ECEF) coordinate system is commonly called the Conventional Terrestrial System (CTS). Any Cartesian coordinate system can be changed to another Cartesian coordinate system through three successive rotations if their origins are equivalent and if they are both right-handed or left-handed coordinate systems.

3.1.5 TOPOCENTRIC COORDINATES

Topocentric coordinates conversion takes ECEF conversion outputs as input and transforms it into topocentric which are azimuth elevation angle and range. It provides tracking information for viewing satellites.The topocentric coordinate conversion involves extracting variable values from The True Equator Mean Equinox coordinates system and transforming into topocentric variables which are azimuthal angle, elevation angle and range.

The equinox is the line of intersection between the plane of the equator and the plane of the ecliptic. The equator is the plane perpendicular to the Celestial Ephemeris Pole passing through the center of Earth. The equator is either the “mean equator” or the “true equator” depending upon the equator and pole to which is it referenced.

3.1.6 Arduino UNO

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 06 can be used as PWM outputs), 06 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button.

In our project, we are using Arduino Uno to take values from sensors, to control motors and to get data from MATLAB. Basically MATLAB tells Arduino about the satellite Azimuthal, Elevation and Range value. By getting continuousfeedback values from sensors the Arduino will control the motors in such a way to give sensor value equal to Satellite’s Azimuthal and Elevation value.

Figure 1: ArduinoUNO

3.1.7 Accelerometer

Accelerometer measures accelerations in three axis. One knows how fast something is speeding up or slowing down. Acceleration is displayed either in units of meters per second squared (m/s^2), or G-force (g), which is about 9.8 m/s^2 to be more appropriate. Accelerometers are used to sense acceleration both static such as gravity and dynamic such as sudden starts and stops. One of the more widely used applications for accelerometer is tilt sensing. As they are affected by the acceleration of gravity, an accelerometer can tell how it's orientated with respect to the Earth's surface.

3.1.8 Gyroscope

Gyroscopes measure angular velocity, how fast something is spinning about an axis. If trying to monitor the orientation of an object in motion, an accelerometer may not give information to know exactly how it's orientated. Unlike accelerometers gyros are not affected by gravity, so they make a great complement to each other. Angular velocity is represented in units of rotations per minute (RPM), or degrees per second (◦/s). The three axes of rotation are either referenced as x, y and z, or roll, pitch and yaw.

3.1.8.1 MPU-6050

MPU-6050 also known as GY-521 has an embedded three axis MEMS gyroscope, a three axis MEMS accelerometer. It's used for motion detection. It will be connected to the Arduino(pin 2(I/O)) and will provide feedback values to compare with MATLAB values and get accurate azimuthal values of satellite.

Figure 2 MPU-6050

3.1.9 Magnetometer

It is an instrument which is used to measure the magnetization or the force of a magnet. To find the location and vector of a magnetic force it uses earth's magnetic field. In our design Z axis will be fixed while rotation will be around X and Y axes.

3.1.9.1 HMC-5883L

HMC-5883L is a three axis compass module.It is also known as GY-271. It is a LOWFI magnetic sensing device with a digital interface. The compass module converts a magnetic field to a differential voltage output on three axes. This voltage shift is the raw digital output value which can be used to calculate headings or sense magnetic field coming from different directions. It will be controlled via arduino and will give elevation values for feedback to compare against MATLAB values to precisely position the telescope.

Figure 3 HMC-5883L

3.1.10 GPS

A device which has ability to receive information from GPS satellites and calculate the geographical position of device. The device displays the position on a map, and offer directions using software. We shall be using Google Maps to predict our location altitude and longitude values along with elevation value. These values will be hardcoded in our MATLAB program.

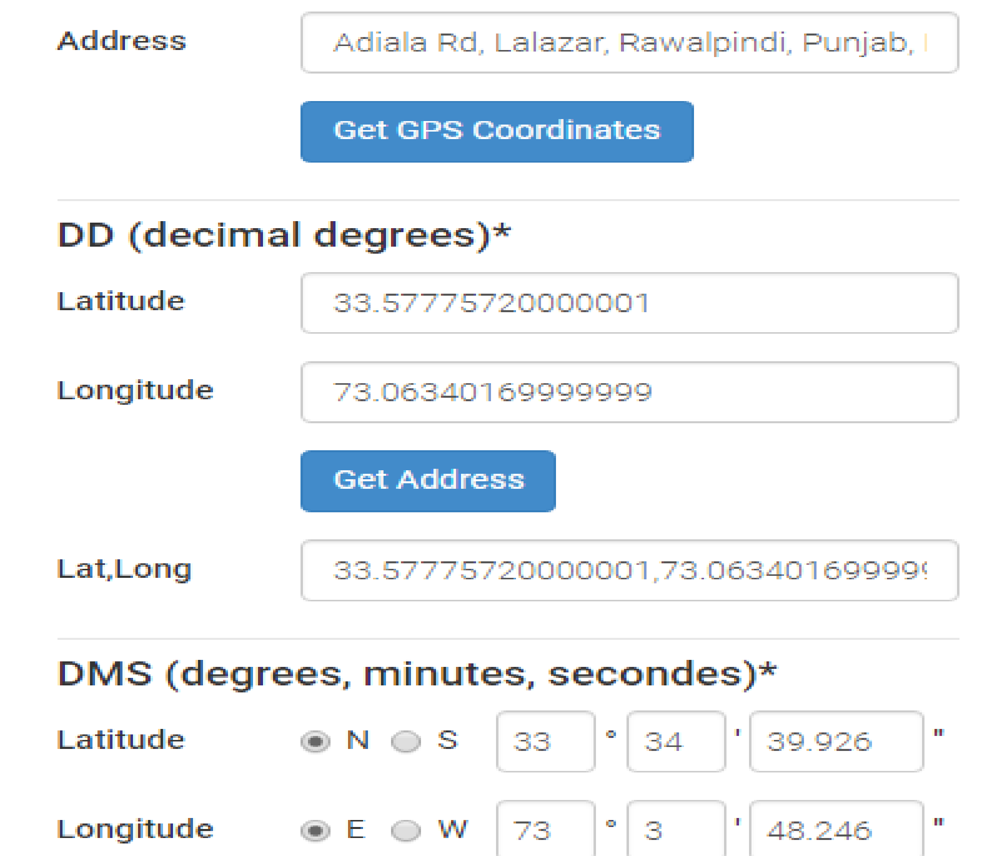


Figure 4 GPS Readings

3.1.11 Motors and Motor Drive

3.1.11.1 WormGear motor

We are using Worm gear motors to control the mount. One motor is fitted on the base of the mount to provide circular movement and one on the side of the mount to provide angular movement. The motors will be given values via arduino along with feedback from the sensors to achieve accurate positioning of the telescope.

3.1.11.2 Motor Drive

We are using L298N Dual H-Bridge Motor Controller as motor drive. The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

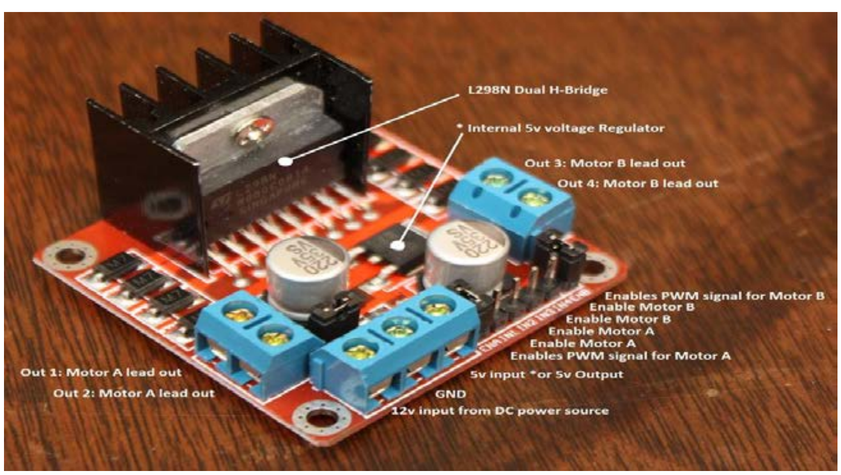


Figure 5 Motor Drive

3.1.12 Telescope

The telescope we'll use is Vision King's VS90900. It has following features:

Objective: 90mm

Focal length: 900 mm

Telescope Type:Refractor

Eyepiece: PL25mm PL32mm

Accessories:Tripod, Finder scope, Diagonal Prisms

Figure 6: Telescope

3.2 BlockDiagram

This block diagram shows the basic working of the satellite tracking system. TLE set will be generated via Internet and will be fed to the MATALB software to obtain normalized co-ordinates. These co-ordinates will be sent to the micro-controller which along with feedback fromsensors will move the motors to point towards the selected satellite visible via telescope.

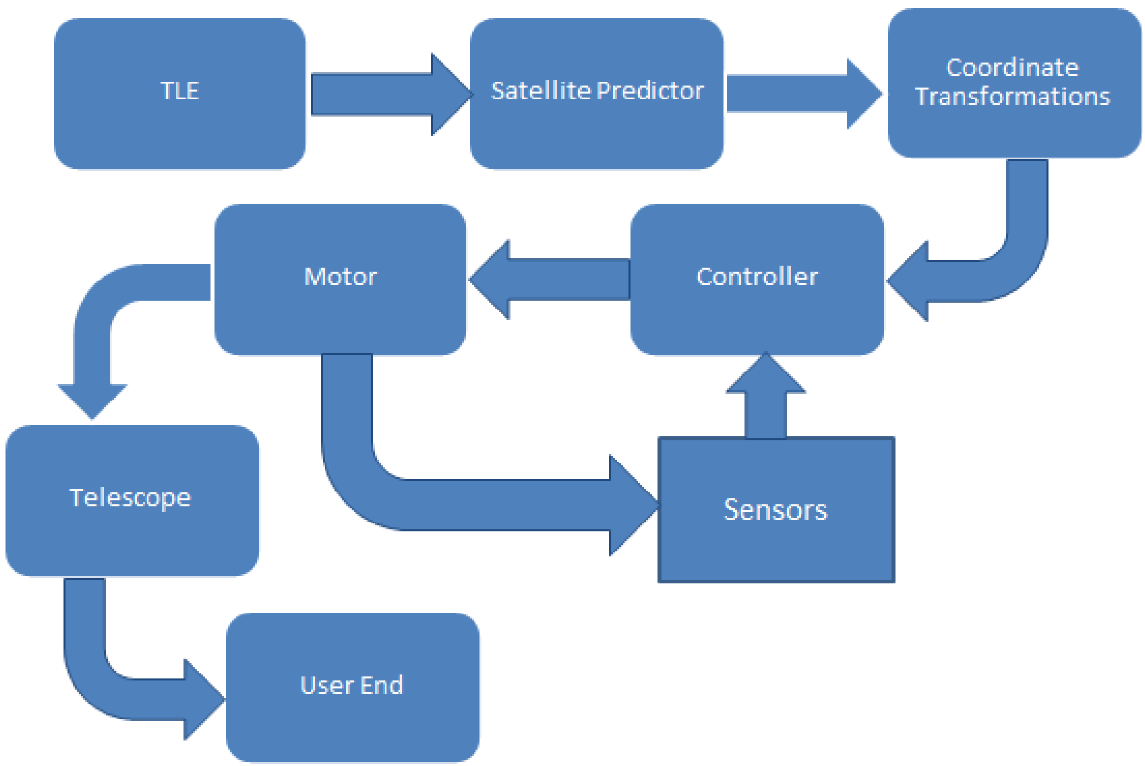


Figure 7 Block Diagram

3.3 Detail Plan

First of all, the latest Two Line Element (TLE) set,of the satellite being tracked, is taken from NORAD website. This TLE file is fed as an input to SPG4 Propagator (in MATLAB). Then, we update the Earth Orientation Parameters, taken from Earth Orientation Center SYRTE's website. Also, GPS location of the user is fed. Now, MATLAB code will convert TEME coordinate to ECEF and will give Topocentric coordinates i.e. Range, Azimuth and Elevation angles of the Satellite whose TLE set was provided. All this information will be sent serially to the controller i.e. Arduino UNO

Arduino will also be connected with two sensors i.e. MPU-6050 and HMC5883L. These sensors will give the current Elevation and azimuthal positions of our Telescope respectively. Two motors will also be controlled via Arduino, one for azimuth and other for elevation using L298 motor drive.

According to the angles calculated through MATLAB, Arduino will keep on moving the motors until and unless the current values of sensors become equal to the Satellite's position angles (obtained serially via MATLAB).

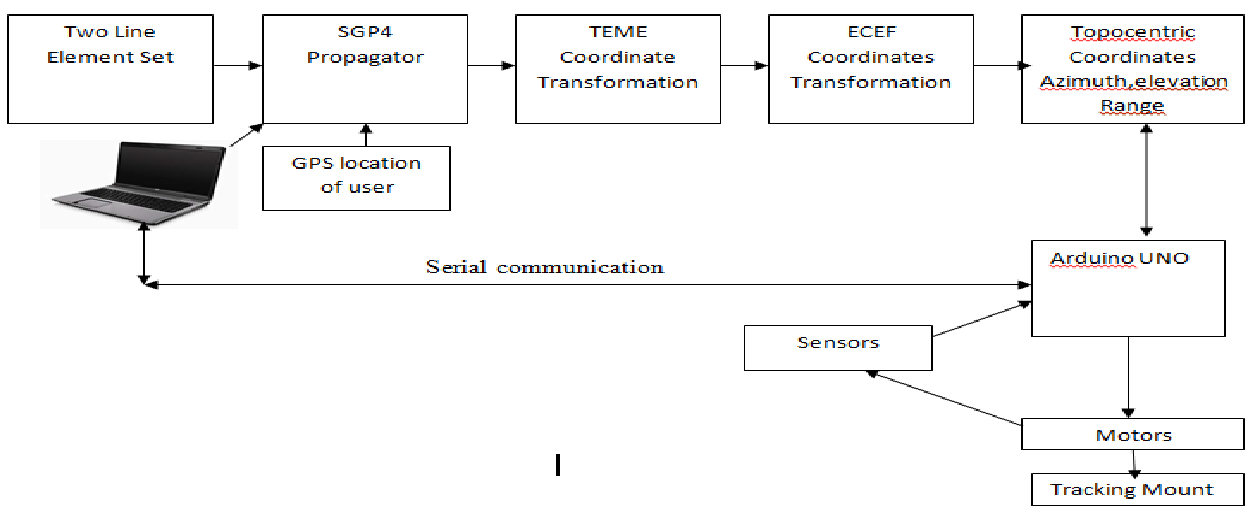


Figure 8 Detailed Plan

CHAPTER 4
MATHEMATICAL MODELING

4. Mathematical Modeling

4.1 SATELLITE LOOK ANGLE DETERMINATION (definitions)

Look angles:

The co-ordinates to which an ES (Earth station) must point to communicate with the satellite these are Azimuth (AZ) and Elevation angle (EL).

- Azimuth is the angle measured from north to east to the projection of satellite path unto horizontal plane.
- Elevation is the angle measured from horizontal plane to the orbital plane

4.2 SATELLITE LOOK ANGLE DETERMINATION(TOPOCENTRIC COORDINATE SYSTEM)

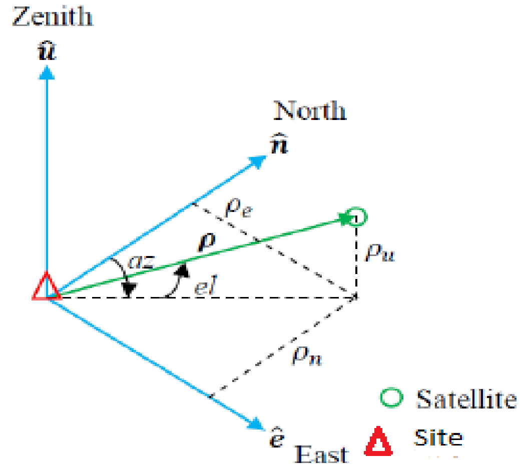


Figure 9Topocentric Co-ordinates

$$r = Rs + \rho \quad 4.1$$

Where, **r** is ECI co-ordinates of satellite, **Rs**is the ECI co-ordinates of site and **ρ** is the range of vector from site to satellite.

4.3 GEOMETRY FOR ELEVATION CALCULATION

The range ρ from the site to the satellite is defined in Topocentric coordinate system as:

$$\boldsymbol{\rho} = \rho_u\, \hat{u} + \rho_e\, \hat{e} + \rho_y\, \hat{y} \qquad 4.2$$

Range can be obtained by:

$$\rho = \sqrt{\rho u^2 + \rho e^2 + \rho y^2} \qquad 4.3$$

The azimuth (*az*) and elevation (*el*) angles are expressed by:

$$az = \tan^{-1}(\rho_e / \rho_y) \qquad 4.4$$

$$el = \tan^{-1}(\rho_u / \sqrt{\rho e^2 + \rho y^2}) \qquad 4.5$$

4.4 TOPOCENTRIC COORDINATE SYSTEM

The east, north, and zenith unit vectors in Topocentric coordinate system is given by:

$$\hat{e} = \begin{pmatrix} -\sin\Lambda \\ \cos\Lambda \\ 0 \end{pmatrix},\ \hat{y} = \begin{pmatrix} -sin\phi\cos\Lambda \\ -sin\phi\sin\Lambda \\ cos\phi \end{pmatrix},\ \hat{u} = \begin{pmatrix} cos\phi\cos\Lambda \\ cos\phi\sin\Lambda \\ sin\phi \end{pmatrix} \quad 4.6$$

Whereϕ andΛ are geographical latitude and longitude of site respectively.

$$\mathbf{R} = (\hat{\mathbf{u}}\hat{\mathbf{e}}\hat{\mathbf{y}})^{\mathbf{T}} \qquad 4.7$$

4.5 SATELLITE COORDINATES

The satellite's Topocentric coordinates in terms of site latitude and longitude may be obtained through following transformation

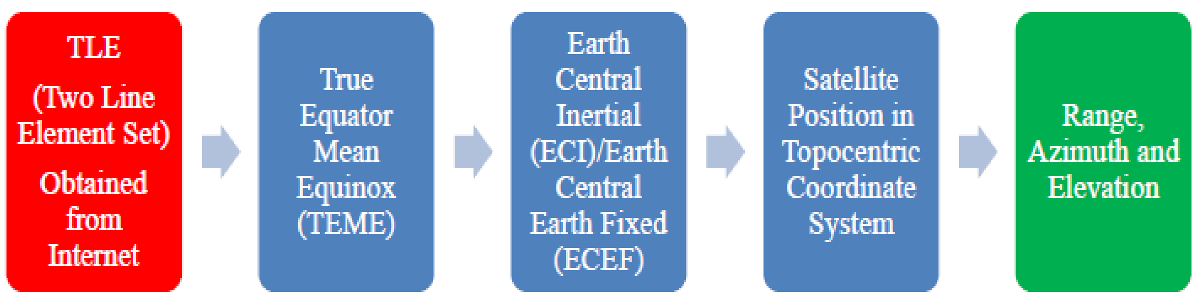
$$\rho=\begin{pmatrix} \rho e \\ \rho y \\ \rho u \end{pmatrix}= \mathbf{R}(R_z(\Theta)r- R_s) \qquad 4.8$$

where, $R_z(\Theta)$ stand for the rotation about Z-axis

Θ= Greenwich Mean Sidereal Time (GMST)

GMST stands for Greenwich hour angle which signifies the angle between the mean vernal equinox of date and the Greenwich meridian. It is a measure of Earth's rotation and expressed in angular units as well as time. For example 360 degrees correspond to 24 hours.

4.6 SATELLITE RANGE, AZIMUTH AND ELEVATION CALCULATION FOR SATELLITES



4.7 TLE SET DESCRIPTION

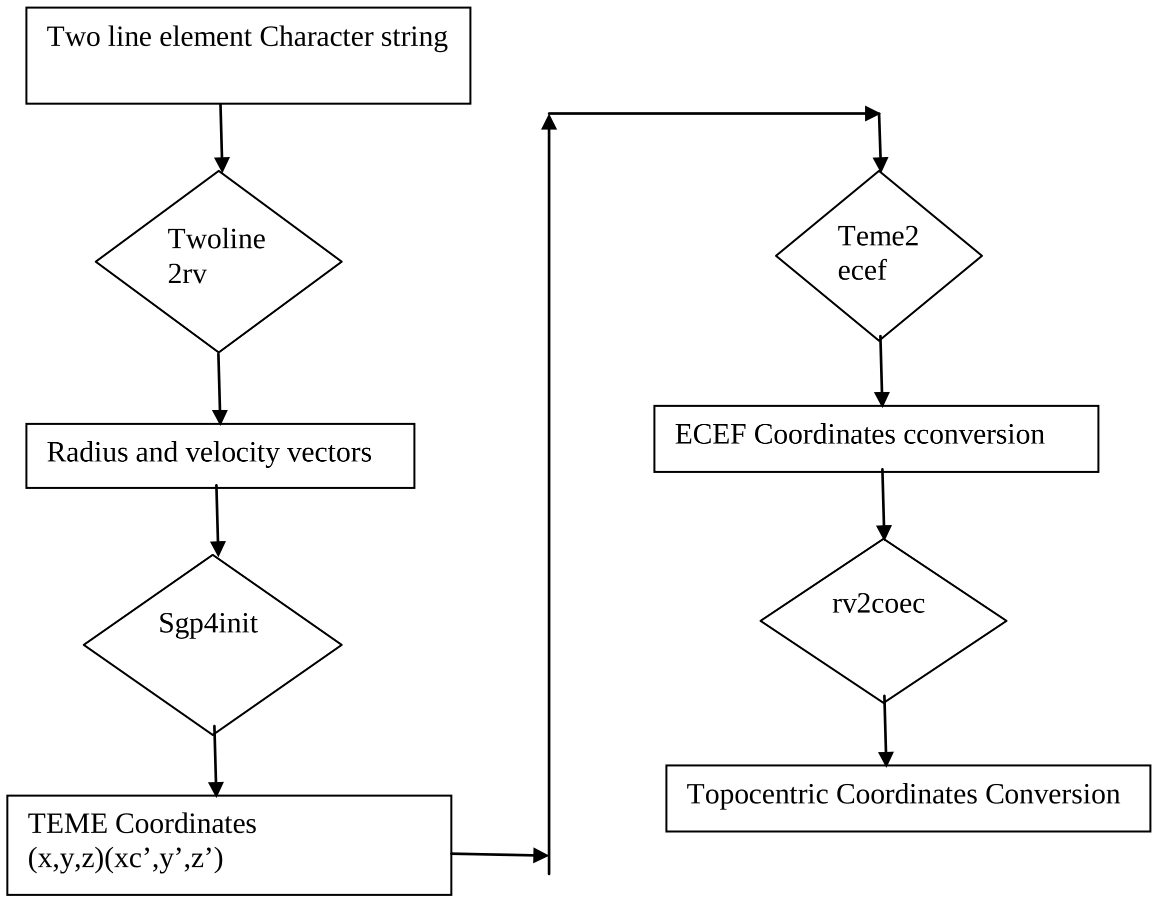
1 37779U 11042A 18086.53379241 .00000125 00000-0 00000-0 0 9996

Line 1	
Column	**Description**
01	Line Number of Element Data
03-07	Satellite Number
08	Classification (U=Unclassified)
10-11	International Designator (Last two digits of launch year)
12-14	International Designator (Launch number of the year)
15-17	International Designator (Piece of the launch)
19-20	Epoch Year (Last two digits of year)
21-32	Epoch (Day of the year and fractional portion of the day)
34-43	First Time Derivative of the Mean Motion
45-52	Second Time Derivative of Mean Motion (decimal point assumed)
54-61	BSTAR drag term (decimal point assumed)
63	Ephemeris type
65-68	Element number
69	Checksum (Modulo 10) (Letters, blanks, periods, plus signs = 0; minus signs = 1)

2 37779 0.0457 103.7318 0004592 263.7181 47.5423 1.00269626 2435

Line 2	
Column	**Description**
01	Line Number of Element Data
03-07	Satellite Number
09-16	Inclination [Degrees]
18-25	Right Ascension of the Ascending Node [Degrees]
27-33	Eccentricity (decimal point assumed)
35-42	Argument of Perigee [Degrees]
44-51	Mean Anomaly [Degrees]
53-63	Mean Motion [Revs per day]
64-68	Revolution number at epoch [Revs]
69	Checksum (Modulo 10)

4.8 Flow Chart



A **two-line element** set (**TLE**) is data layoutthat contains a list of orbital elementsof an Earth-orbiting object for a given point in time, the epoch. Using suitable prediction formula, the position and velocity at any point in future can be predicted. It contains information such as Line number, satellite number, Epoch Year. The elements in the two-line element sets are mean elements calculated to fit a set of observations using a specific model—the **SGP4** model. Accuracy of the two-line element sets is dependent upon a number of factors. These range from the particular sensors used and amount of data collected to the type of orbit and condition of the space environment. The primary source for the **SGP4/SDP4** orbital models is found in Space track Report Number 3: Models for Propagation of **NORAD** Element Sets.The**SGP4** propagation outputs information in true equator mean equinox frame.

We need to transform a vector from the **True Equator Mean Equinox** frame (TEME) to an earth fixed frame and this information is than transformed to topocentric coordinates because we need the output in terms of azimuth and elevation angles and range.

CHAPTER: 5
ANALYSIS AND EVALUATION

5. Analysis and Evaluation

5.1 Hardware Prototype

We used wooden mount to test our motors and sensors

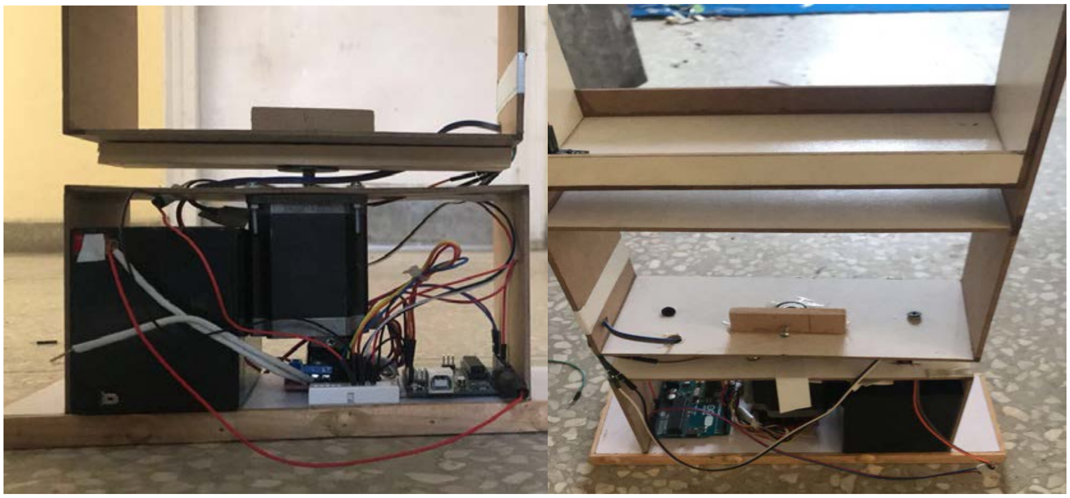


Figure 10 Testing Mount

5.2 Mount Design

For final design, we made an aluminium mount. It was designed using Google Sketchup 3D software.

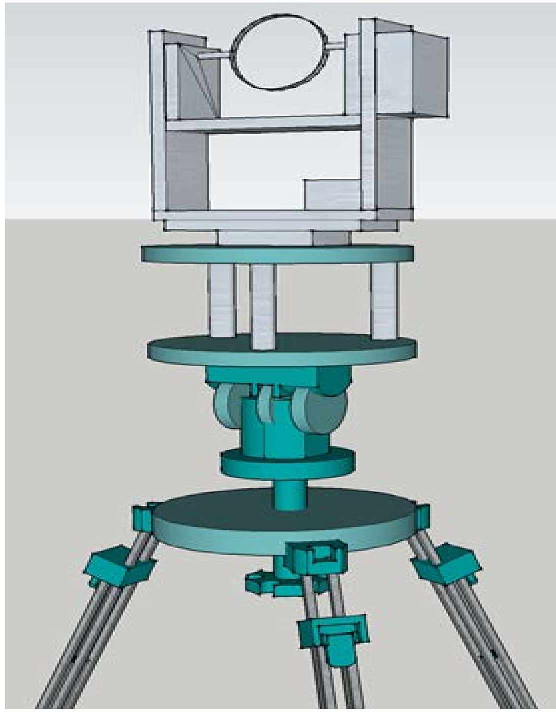


Figure 11Aluminium Mount

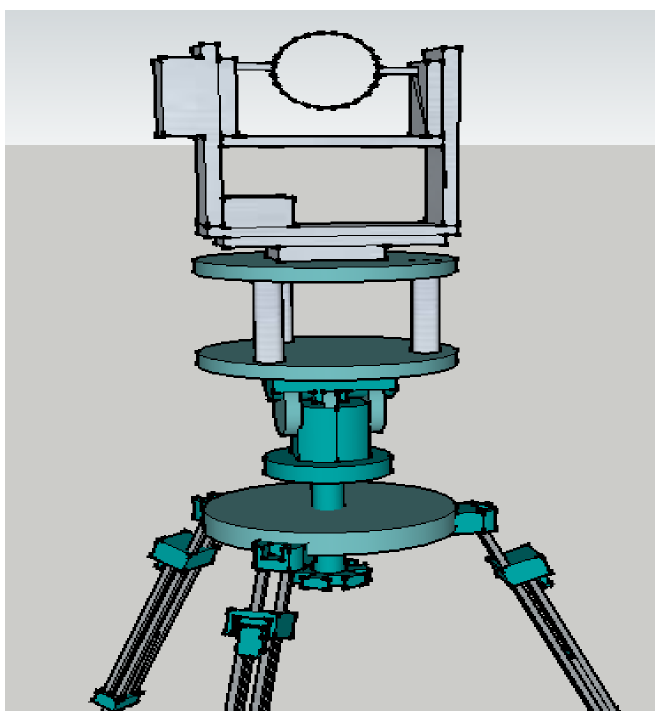


Figure 12 Front View of Mount

5.3 TLE Set

We downloaded the updated TLE of IRIDIUM-65 as shown below;

1 25288U 98021D   18177.26162617 .00000167 00000-0 52425-4 0 9996

2 25288 86.3966 67.5183 0002123 87.6714 272.4724 14.34218475 58635

5.4 Code Testing and Evaluation

To track a certain satellite, we enter the specific date and time at which we want track.

```
>> optrack
input elset filename: Iridium 65.txt
input start year2018
input start mon06
input start day27
input start hr00
input start min00
input start sec00
input stop year2018
input stop mon06
input stop day28
input stop hr00
input stop min00
input stop sec00
input time step in minutes 1
 25288
    1063.25831518   -2188.29810482   -5793.62311688   -3598.55741592  1.825594944  3.299783670 -6.433196151
    1064.25831518   -2074.56453142   -5584.46233946   -3977.25973294  1.964276833  3.669941949 -6.186099683
    1065.25831518   -1952.73926817   -5353.51979243   -4340.40921394  2.095231127  4.025608023 -5.914939372
    1066.25831518   -1823.30122871   -5101.70651627   -4686.59411612  2.217954440  4.365408329 -5.620799650
    1067.25831518   -1686.75853152   -4830.01401314   -5014.47038570  2.331976940  4.688035149 -5.304851665
    1068.25831518   -1543.64643872   -4539.51015683   -5322.76670372  2.436863931  4.992251219 -4.968348012
    1069.25831518   -1394.52520524   -4231.33483714   -5610.28920973  2.532217259  5.276893976 -4.612617256
    1070.25831518   -1239.97784865   -3906.69536165   -5875.92589142  2.617676551  5.540879400 -4.239058278
    1071.25831518   -1080.60784995   -3566.86163776   -6118.65063089  2.692920277  5.783205490 -3.849134483
fx
```

Figure 13OpTrack Output

Below is the Topocentric coordinates of LEO satellite;

Range (km)	Azimuth (deg)	Elevation (deg)	Year	Month	Day	Time (GMT)
2983.590982	134.01947	2.570023	2018	6	27	4: 7: 0.000002
2683.743491	128.06196	5.696938	2018	6	27	4: 7:59.999998
2416.086369	120.59514	8.875787	2018	6	27	4: 8:59.999995
2193.823919	111.26810	11.901992	2018	6	27	4: 9:59.999991
2033.061203	99.91531	14.383630	2018	6	27	4:10:59.999987
1949.920058	86.88403	15.780863	2018	6	27	4:11:59.999984
1954.813245	73.23365	15.672940	2018	6	27	4:12:59.999980
2047.222208	60.35930	14.089425	2018	6	27	4:14: 0.000017
2216.010028	49.25099	11.484867	2018	6	27	4:15: 0.000013
2444.926026	40.18629	8.392763	2018	6	27	4:16: 0.000010
2718.128784	32.96644	5.183179	2018	6	27	4:17: 0.000006
3022.781658	27.23494	2.042560	2018	6	27	4:18: 0.000003
2975.836587	197.12781	2.666393	2018	6	27	5:46: 0.000010
2593.957810	199.64896	6.744380	2018	6	27	5:47: 0.000006
2220.911248	203.07096	11.554778	2018	6	27	5:48: 0.000003
1863.817205	207.99633	17.439644	2018	6	27	5:48:59.999999
1535.610786	215.64843	24.852955	2018	6	27	5:49:59.999996
1260.683425	228.66367	34.001606	2018	6	27	5:50:59.999992
1081.722727	251.90957	42.958445	2018	6	27	5:51:59.999988

Figure 14Topocentric Coordinates

Motors will keep on moving and changing its direction in until the sensors' readings becomes equal to the satellite's readings at that specific time. In this way, telescope will move as the satellite will move.

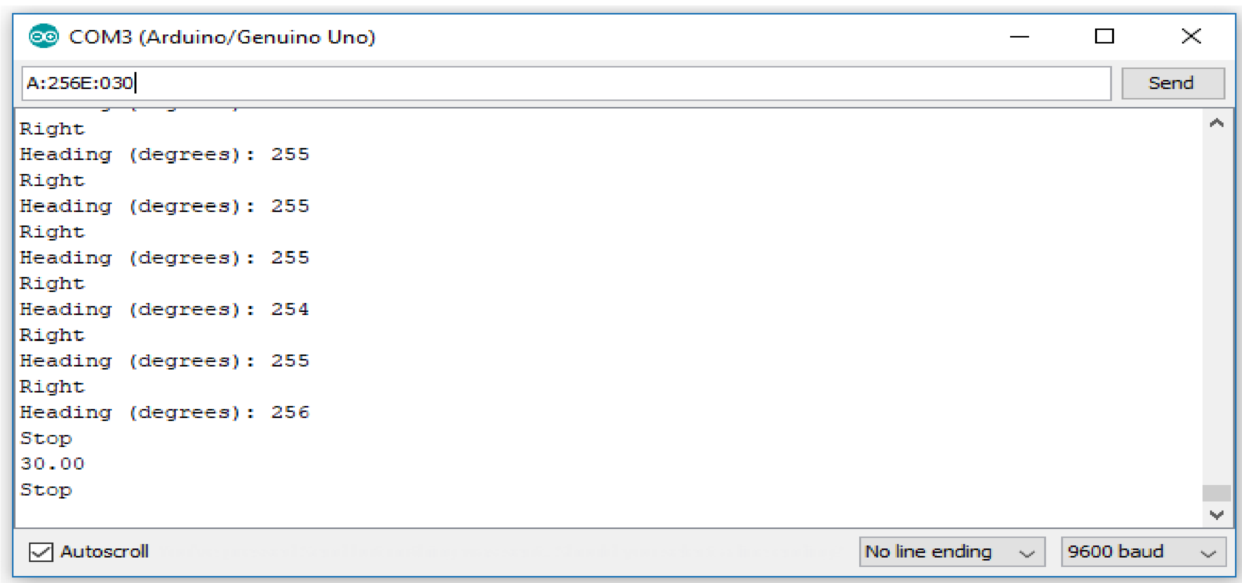


Figure 15 Sensors' Readings

5.5 Final Design

Figure 16 Design 1

Figure 17 Design

CHAPTER: 6
CONCLUSION

6.1 Overview

To conclude, we designed a system for tracking various LEO satellites. The main result we achieved is that our program is able to track desired targets with adjustment of telescope orientation according to calculated angles i.e. azimuth and elevation and to display images of these target satellites. In addition, tracking program lets the user know when a target will be observable from the observation point according to the prediction algorithm called satellite prediction software Simplified perturbations model SPG-4 was used to calculate earth orbital parameters.

6.2 Achievements

We aimed at tracking LEO satellite with precision and design a software and hardware that is cost effective and easy to operate. We achieved our task to make the software and hardware easy to maintain and less expensive. There were some limitations in the project because of the pollution in our atmosphere; satellite was not viewed much clearly

CHAPTER:7
FUTURE RESEARCH

7.1 Future Research

In future, the sensor inaccuracy can be reduced because of which the satellite was incapable of being tracked for a long duration. Time delay can also be reduced. Multiple tracking sites could not be observed until a single site was viewed. A multiple satellite tracking system could be developed.

CHAPTER 8:
APPENDIXES

Appendix A:Synopsis

LOW EARTH ORBIT SATELLITE TRACKING SYSTEM

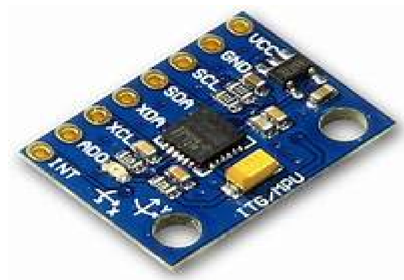
Extended Title: Design and development of optical tracking system for Low Earth Orbit (LEO) satellites.
Brief Description of the Project /Thesis with Salient Specs: This project aims at design and development of hardware and software for optical tracking system for LEO satellites. For an observer on surface of Earth LEO satellites appear in the sky for 5-10 min with continuous change in location. Optical tracking of such moving objects would require ground based observer to have appropriate optical telescope, motorized platform, control electronics and satellite prediction software. The project would enable tracking of all communication, Earth Observation (EO), military and scientific experimental satellites with publicly available orbital parameters.
Scope of Work: Design and development of software and hardware for optical tracking system for LEO satellites.
Academic Objectives: Skills in design/development of electronic circuits/systems, mechanical systems, control theory, electrical machines/motors, MATLAB programming languages, satellite orbital mechanics and optical aids/telescopes.
Application/End Goal Objectives To develop hardware and software for optical LEO satellite tracking system.
Previous Work Done on Subject: (1) Bayesian Estimation of Satellite Orbital Parameters Based on Mixture of Orthogonal Expansion by Lt Col DrAmerGilani. (2) Space Situational Awareness Software Toolkit (programmed in Java) by Students Aqsa, Anum and Asad (Supervised by Lt Col DrAmerGilani)
Material Resources Required: (1) Optical Telescope. (2) DC motors (Azimuth/Elevation). (3) Laptop PC. (4) Controller board (Arduino). (5) Sensors (magnetometer, gyroscopes and GPS). (6) Motor drive electronics. (7) MATLAB programming languages.
No of Students: NC SabihaSiddique NC Fakiha Khan

PC Muizz Jamal NC HamzaShafiq
Special Skills Required: Knowledge of subject relevant to the project in C/MATLAB, mathematics, electronic/mechanical designs and simulation software.
Supervisor: Lt Col DrAmerGilani, R&D Wing MCS.

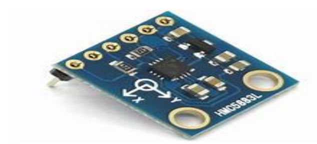
Appendix B:Equipment Used

ArduinoUNO

MPU-6050



HMC-5883L

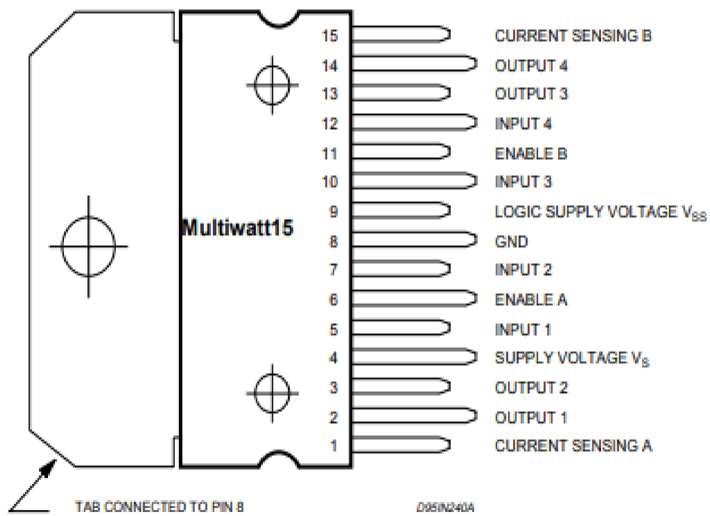


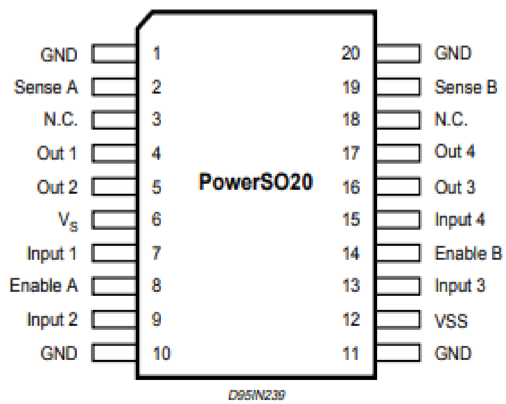
Motor Drive L298

Worm Gear motor

Telescope VS90900

Appendix C: Datasheet of L298





CHAPTER:9

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