Design and Development of MSAT Nano satellite

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A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering

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Declaration

We, Maliha Hassan, Md. Arafat Dewan and Syed Md. Saiful Islam Asik the students of Computer Science and Engineering, East West University hereby, declaring that the task presented in this thesis is the outcome of our own IOT based investigation under the supervision of Dr. Mohammad Salah Uddin, Assistant Professor, Department of Computer Science and Engineering, East West University, Dhaka. We also declare that no part of this thesis has been submitted elsewhere for the award of any degree or diploma.

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Letter of Acceptance

This thesis report entitled "Design and Development of MSAT 1U Nanosatellite" submitted by Maliha Hassan (ID : 2015-1-60-043), Md. Arafat Dewan (ID : 2014-2-60-030) and Syed Md. Saiful Islam Asik (ID : 2014-3-60-023) to the Department of Computer Science and Engineering, East West University is accepted by the department in partial fulfillment of requirements for the Award of the Degree of Bachelor of Science and Engineering on December, 2019.

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Abstract

The introduction of cost effective small satellites have increased the engagement of researchers in making nanosatellites. In the past, it was impossible for a developing country to design and develop their own satellite and get the facilities from that satellite. Time has changed. Developing countries are also joining in this sector. In the era of space engineering, it is crucial to work in this field to get the space data for various purposes. For this reason, it is necessary to know how to design and develop a nanosatellite and also the characteristics of the subsystems of a nanosatellite. This thesis describes the design and development process of certain subsystems of a 1U Cubesat. Here, we have discussed about the design and development of 1U Cubesat, Electrical power subsystem, Attitude determination and control subsystem, Communication subsystem, Deployment of solar array and antenna, Structural subsystem and ground station set up. We have followed the standard design processes for designing the subsystems and ground station.

Acknowledgements

With the help of many people throughout the whole student life, we have reached the point of achieving an educational goal in our life. To complete our thesis, we have taken several help from several people who provide us their valuable time, opinion and experience. It is impossible to express our deepest gratitude in words to those people. Therefore, we are acknowledging those people who have contributed in this thesis. This work was submitted into Department of Computer Science and Engineering at East West University, Dhaka, Bangladesh.

At first, we would like to express our heartiest gratitude to the almighty Allah for His blessings upon us. Then, we would like to give special thanks to our supervisor, “Dr. Mohammad Salah Uddin”, who gave us the opportunity to work in this field “Design and Development of MSAT Nanosatellite”, and without whom it was impossible to complete the thesis work. His visionaries, encouragements, thoughtful valuable suggestions and unforgettable support was simply appreciating.

People who helped us a lot directly and indirectly to reach our goal, we are thankful to them. We also want to give special thanks to our family members, parents and friends for supporting us.

Maliha Hassan
December, 2019

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December, 2019

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CHAPTER 1

Introduction

1.1 Introduction

This is the age of telecommunication technology which controls people's personal communication needs for business, family and it also covers the overall communication needs including defence of a country. Therefore, the need of creating a strong, undisturbed and secured multi thread communication protocol became a need since electronic telecommunication has started ruling our lives.

An undisturbed communication protocol is highly dependent on undisturbed line of site and also less interference of various kinds. Having said that, this signal is interfered and disrupted sometimes easily by the environmental magnetic fields created by various transmission equipment, household equipment, multimedia and entertainment system. Strong interference also comes from high voltage electrical grid and other heavy duty electrical equipment. In such conditions, creating an undisturbed communication network is a tremendous challenge.

To have undisturbed communication line of site all over the world, this technology is proven to be so accurate and dependable that now we have got telecommunication, entertainment, business, weather forecasting, defence technology and even transport system completely depending on this satellite technology. Though satellite technology has become extremely essential for every single aspect of our lives that depends on communication, it is an extremely expensive process from launching system to designing a complicated communication satellite.

Besides communication and defence there is an extensive requirement in the field of research and development. When it comes to research and development, the percentage of the failure is usually high. High percentage of failure is inevitable. In that case, the cost of research and development becomes even more expensive. This situation persist a technology that is almost equivalent to the current satellite communication system but it is smaller and cheaper.

Small satellite has become an extremely fascinating topic around the world. People who can only dream about space nowadays can participate to make small satellite for the same purpose in which large satellites are working. Affordable technologies such as nano satellites are overwhelming people and different organizations like Nasa, private space agencies such as SPACEX are giving the chance to the people to launch satellites in space. Though Bangladesh launched their first Nano satellite Brac Onnesha and first commercial satellite Bangabandhu-1 but still research about space is not remarkable in Bangladesh. As most of the countries around the world are showing their interest in this science and technology sector, so it is crucial to cope up with new technologies and encourage students to work in this sector.

1.2 Artificial Large Satellites and Small Satellites

Sputnik 1 was the first artificial satellite around the world launched by Soviet Union on 4th October, 1957. After that, 40 countries launched 8900 artificial satellites in space. Among these satellites, around 5000 satellites remain in orbit and 1900 satellites were active according to estimation in 2018.

63% active satellites are in LEO (Low - Earth Orbit), 6% of the active satellites are in MEO (Medium - Earth Orbit) and elliptic orbit has 2% active satellites and the rest of the 29% are in GEO (Geostationary - Earth Orbit). There are different types of satellites exist to serve different purposes. These types include Earth observation satellites, navigation satellites, space telescopes, communication satellites and weather satellites. Spacecraft and space station in outer space are also called as artificial satellites.

When scientists were realized the importance of loss reduction in this sector, they started to develop a cost effective small satellite. Large satellites are 1000 kg to above, Medium satellites are 500 to 1000 kg, Mini satellite has a mass of 100 to 500 kg, Micro satellites are 10 to 100 kg, Nano satellite has a mass of 1 to 10 kg, Pico satellites are 0.1 to 1 kg and Femto satellites are 0.1 kg. From 1 to 50 kg range, there were less than 15 satellites annually launched in 2000 to 2005. In 2006, 34 small satellites launched, less than 30 satellites launched during the time period 2007 to 2011. There were more than 500 small satellites launched from 2015 to 2019.

1.3 Background

There is a lot of research took place in this field. The development of Nano satellites opens the door of research and development for all who are interested. The researchers of the paper [1] discussed the future missions of Nano satellite technology in outer space. They planned to observe solar spectral irradiance measurement, total solar irradiance, short-wave radiation measurement, long-wave radiation and stratospheric ozone measurement. They showed interest to observe the relationship between sun and earth.

Design and development of data transfer telecommunication system for a nano satellite which will be placed in LEO has some challenging problems. Earth station stays in communication with LEO satellites only if it is in visibility region.

In the design period of telecommunication system addressed some constraints. PISAT nano satellites used to design wireless communication [2].

Another nanosatellite FITSAT - 1 was deployed from ISS on 5 October, 2012. It was active till 4 July, 2013. The goal of this research was to demonstrate a transmitter module of 5.84 GHz, 115.2 kbps, 2 W RF output, FSK. Their system took JPEG images pixel of 640*480. Which was received 2 to 6 seconds [3].

1.4 Research Objective

Though Bangladesh has recently entered into the space but even now Bangladesh has not explored enough in this sector. It is high time to explore the space and satellites sector to improve our experience.
The objective of this study is to design and development of a 1U Cubesat nanosatellite and entering a mission and vision of making a launchable nanosatellite. Another objectives are :

- Space observation
- Attitude detection
- Monitoring location of satellite
- Communication
- Attitude control
- Temperature detection
- Understanding the mechanism to make 1U Cubesat

1.5 Conclusion

Making satellites are cheap now. The motto to make such a small and cheap satellites is to involve students in outer space research and obviously cost cutting. Though Bangladesh has taken her first step in exploring outer space, it is necessary to work more in this sector by developing Nano satellites. In this research, we are concentrated on the design and development of Nano satellites and establishing communication between ground station and Nano satellites.

CHAPTER 2

Related Works

2.1 Introduction

From the beginning of satellites, scientists are working every day for the betterment of satellites to explore more in the outer space to know the unknown. Numerous researches have done in the field of small satellites and still many researches are running for the sake of the betterment of the small satellites. It is no longer a dream to have a small satellite in the sky. Researches in the various sectors of small satellites and the design and development of small satellites are opening new dimensions of research.

2.2 Related Works

2.2.1 Design and development of KNACKSAT: First fully in-house developed satellite in Thailand

This paper tried to make a conceptual design and overall development of a Cubesat satellite. Functions that used in the satellite included transmitting continuous wave of housekeeping data, downlink data, uplink data and take images. It has seven sub systems [4].

2.2.2 System design and development of VELOX-I nanosatellite

This study discussed the design of the nano satellite VELOX-I, related issues and solutions that were used while developing the satellite. They tried to demonstrate GPS, camera and inter-satellite payloads for communication purpose. They also discussed about piggyback pico satellite VELOX-PIII and deployment strategies [5].

2.2.3 Increasingly Safe, High-Energy Propulsion System for Nano-Satellites

In this paper researchers researched about propulsion system of a nano satellite. They discussed about hybrid chemical propulsion system and defines requirements for chemical propellant. They also specified propellant pairs depending on a compact metal hybrid [6].

2.2.4 Nano-innovation in Space Exploration

This article discussed about introduction of nanosatellites and they found that nano satellites feed the need successfully in space research sector. It has many advantages. It can contribute to the research purpose. So, it can be used for various research purposes [7].

2.2.5 Development of 6U CubeSat's Deployable Solar Panel with Burn Wire Triggering Holding and Release Mechanism

This research is about deployable solar panel based on nichrome burn wire triggering and release strategies which was developed for 6U Cubesat. It provides reliable cutting of nichrome wire, high capability of loading, multiplane constraints and tightening process of wire. Researchers made a demonstration model by printed circuit board model. The safety of solar panel verified by sine and random vibration testing [8].

2.2.6 Nano-satellite communication subsystem design and implementation

This paper tried to make communication subsystem for a nanosatellite. They were used commercial off-the-shelf components to do this task. They controlled various transmission channels through logic gates. They have tested the prototype and found a responsive performance [9].

2.2.7 Design and analysis of antennas for a nano-satellite

The researchers of this research paper did some practical tests and simulations for monopole and dipole antennas. They designed the antennas for 2U Cubesat. They made the antenna by measuring tape and found the same result of using monopole and dipole antennas. They also describes simulations in CAD software [10].

2.2.8 Conclusion

All the research related to nano satellite and the development of nano satellite inspired us to make such a nano satellite. We have acquired the information which we need to follow to make a standard nano satellite. These papers will guide us to go ahead to our mission and vision.

CHAPTER 3

Cubesats and Subsystems

3.1 Introduction

Cubesat has introduced to accelerate the design of nano satellites and to maintain a worldwide standard for designing nano satellites. There are several approaches to make cubesats. Cubesats are defined by Cubesat Design Specification. Sometimes it can be slightly vary in height. The range of payload for cubesats in between 0.2U to 8U.

3.2 Types of cubesats

Cubesats can be 1U, 1.5U, 2U, 3U, 6U and 12U in size. Each U has a mass not more than 1.33 kg. It provides the researchers to do multiple mounting. This mounting configuration process gives a researcher highest flexibility to design a cubesat. Figure 3.1 is showing the types of cubesats here.

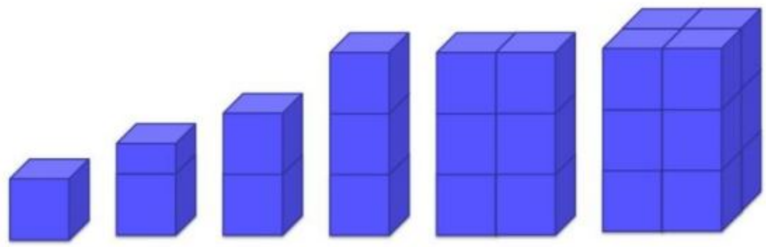

Figure 3.1: Different types of cubesats

Cubesat is scalable in design. It supports multiple PCB. The design of cubesats are modular. Side panels are detachable.

- The dimension of 1U is 10 cm * 10 cm * 10 cm.
- The dimension of 2U is 10 cm * 10 cm * 22.70 cm.
- The dimension of 6U is 20 cm * 10 cm * 34.05 cm.
- The dimension of 12U is 20 cm * 20 cm * 34.05 cm.

3.3 Design Specification for 1U Cubesat

In this research work, we have chosen 1U Cubesat for design and development purposes. As cubesats are scalable, we can easily scale it to another dimension. For this reason, we have designed 1U Cubesat. To make this cubesat there are some specific standards for nano satellites that we needed to maintain in every aspect of our design and development process of 1U Cubesat.

Nasa deploy cubesats from Poly-Picosatellite Orbital Deployer called as P-POD. There is a predefined structure for this deployer. There are other private organizations deploying cubesats. They also follow the same standards. So it is crucial to ensure that the 1U Cubesat is maintaining the standards. Generally researchers use commercial-off-the-shelf (COTS) product for structural design. But we did not use COTS for our structural design purpose.

The length and width of 1U Cubesat nanosatellite is 10 cm * 10 cm. But the range for height varies from 11.35 cm to 34.05 cm. Weight is not more than 1.33 kg. All materials are not permitted for making the structure of Cubesat. Aluminium alloys of series 6061, 7075, 5005, 5052 are permitted for structural design. Anodization is required for preventing the Cubesat from cold welding. Stainless steel is also allowable to build the structure. We used stainless steel in our nano satellite. Four rails are required to make 1U Cubesat which is shown in figure 3.2.

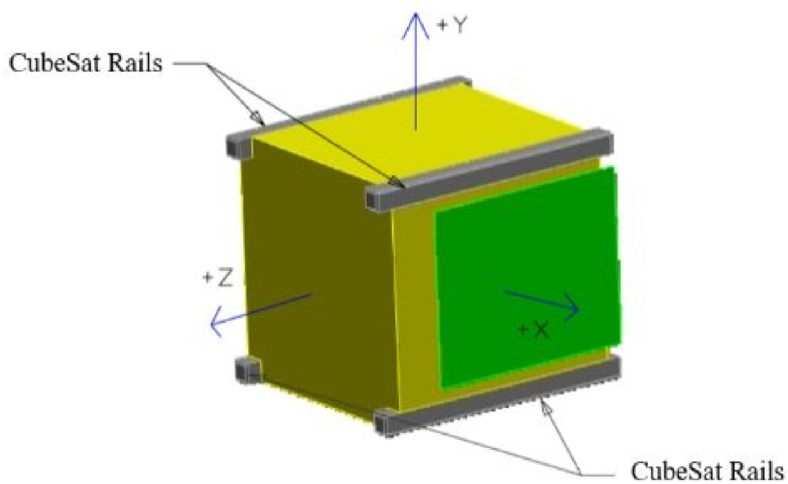

Figure 3.2: Cubesat Rails

The coordinate system of Cubesat needs to match with P-POD coordinate system. The length of support beam is 0.85 cm. X and Y coordinates are 10 cm shown in figure 3.3. Origin is situated at the geometric center of the Cubesat.

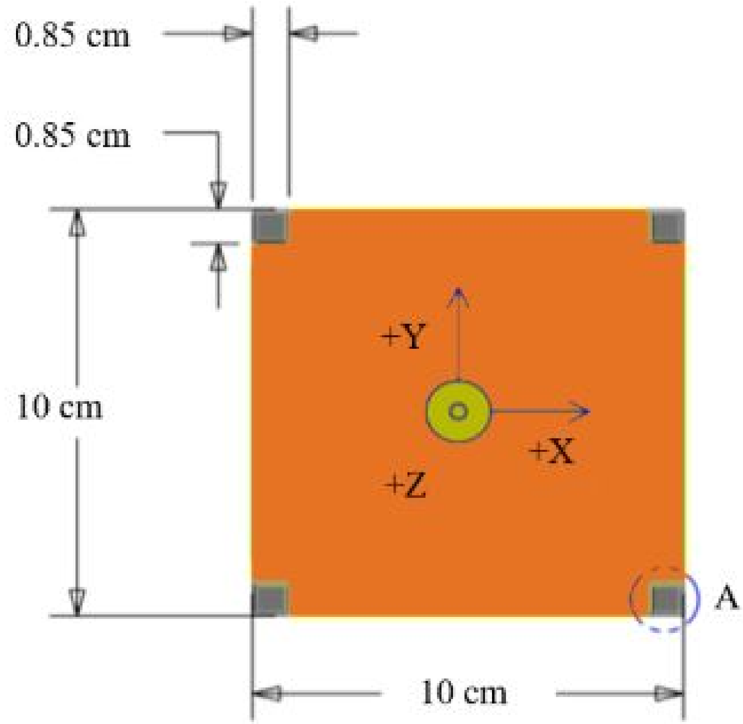

Figure 3.3: Coordinate of a side of 1U cubesat

The ‘A’ point of figure 3.3 specified in figure 3.4 with more details. The radius of the edges of rails are 1.0 mm.

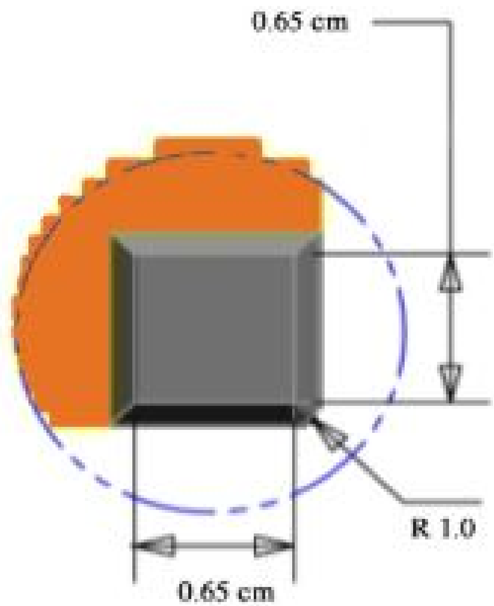

Figure 3.4: Zoomed output of A

The Z face will enter first into P-POD. In figure 3.5, it is shown that the rails should have a length of 11.35 cm on each side. Minimum width of rail is 0.85 cm. In the finishing point of rails on +/- Z face has a surface area 0.65 cm * 0.65 cm.

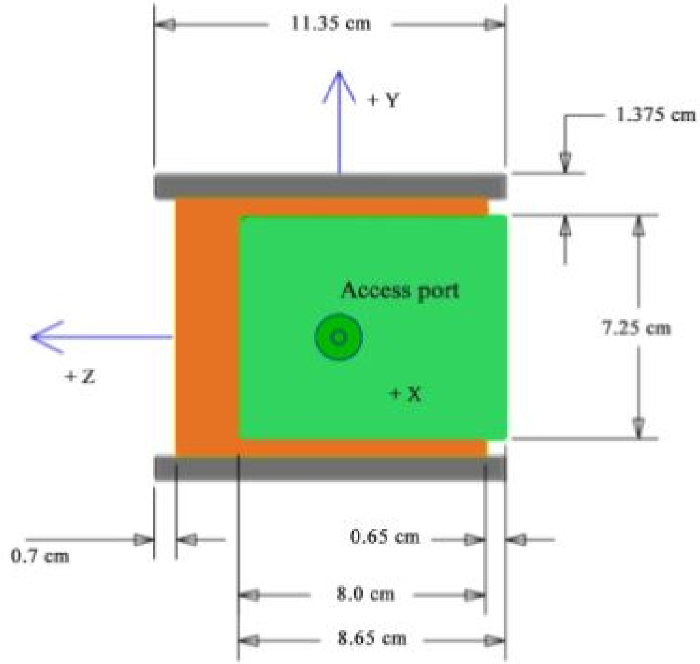

Figure 3.5: Measurement of rails and access port in mm

75% of the rail will be connected with P-POD rails. Any part of Cubesat will not exceed the limit. The 1U Cubesat has a mass of 1.33 kg.Our 1U Cubesat is shown in figure 3.6.

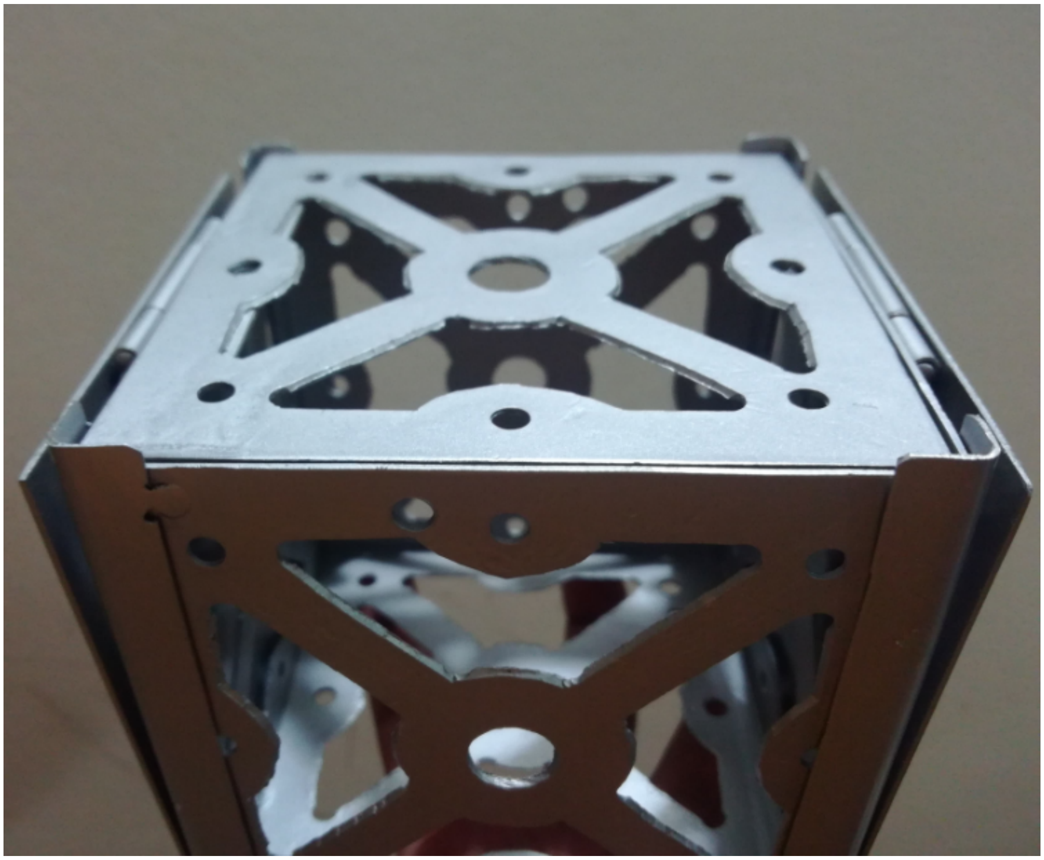

Figure 3.6: 1U Cubesat

3.4 Subsystems of nano satellite

Several subsystems are there to ensure the performance of nano satellite. Every satellite has a lifetime of performance. Nano satellite has also lifetime. For that particular period of time these satellites will be functional or active. After that, satellites will be non-functional and dead. It is highly crucial to make such sub systems of nano satellites which can help the artificial nano satellites to remain functional throughout the lifetime. Multiple subsystems are there to ensure the functionality of nano satellites. They are :

- Structural Subsystem
- Electrical Power Subsystem
- Payload or Camera Subsystem
- Command and Data Handling Subsystem
- Attitude Determination and Control Subsystem
- Communication Subsystem
- Deployment Control Subsystem

3.5 Conclusion

We need to make these subsystems in our nano satellite. We are focusing to make 1U Cubesat with most of the vital subsystems of nano satellites in our project.

CHAPTER 4

Electrical Power Subsystem

4.1 Introduction

Electrical power system (EPS) includes electrical power generation, storage facility and the distribution of power where it is needed to distribute. It is a compulsory and major subsystem of any satellite. As it is running the other components and subsystems of a nano satellite, it is the heart of the nano satellite which comprises one third portion of the whole satellite. Conventionally the only power generation source in outer space is deployasion of solar array. Storing that current redistributing the power had been the only means of powering a satellite. We had no other choice like every other satellite manufacturer but use a similar system. Rechargeable batteries are basically used for storage purpose.

4.2 Power Generation

Solar panels are irreplaceable for generating solar power from the sun. All satellites use solar panels for this purpose. Nanosatellites are equipped and feed the demand of the power from various components in space by solar panels and batteries. This is why we used solar panels and batteries. We used 5v and 30mA solar panels for power generation. But solar panels have certain limitations. It is not possible to feed the whole power requirements by solar panels. Because solar panels reduces efficacy in various applications of deep-space. It does not generate power in eclipse time. It covers a lot of area and increases mass. Figure 4.1 shows the solar panel used in this research.

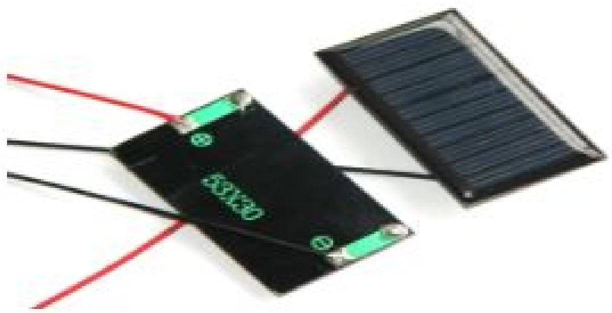

Figure 4.1: Solar panel (model - SOL00005)

Solar cells are made of semiconductors that generate current from the sunlight while it is exposed to the light. Solar arrays are used in nanosatellites to acquire more power from the sun. The surface area of solar panels differs as a cosine of angle between sun and solar panels. Nowadays multi junction solar cells are using in this field. In our research, we have used solar panels and arrays.

4.3 Power Storage

When the sun is not available at night, solar panels do not generate power at all. For this reason, single - use primary batteries and secondary rechargeable batteries are used to store power. But primary batteries are only used for short duration mission. Because it is not rechargeable. Some of the primary batteries are silver-zinc, lithium carbon monofluoride (LiCFx), lithium thionyl chloride (LiSOCl2) and lithium sulphur dioxide (LiSO2). There are certain secondary batteries used in nano satellites such as nickel-cadmium (NiCd), lithium-ion (Liion), nickel-hydrogen (NiH2) and lithium polymer (LiPo). Portable electronic devices use lithium based batteries. We have also used this portable rechargeable secondary batteries to serve our purpose. Because these batteries has low mass, high energy and obviously rechargeability feature.

4.4 Power Management and Distribution

Power management is the most sensitive part for the entire design. Any failure or disruption in the power management system will directly hamper satellite's main functionality. Disruption in power distribution may also cut down the life cycle of the satellite. Power management and distribution plays the most significant role to maintain uninterrupted and quality service of the satellites system. Power distribution unit receives the power from the solar array and recharge the battery system for maximum endurance which ensures prolonged usage of the stored power. Distribution system also manages to keep the other facilities of the satellite system such as telemetry and attitude control, temperature system, main transponder and on-board computing. Figure 4.2 shows the power distribution model of our nanosatellite.

4.5 Power Distribution Model

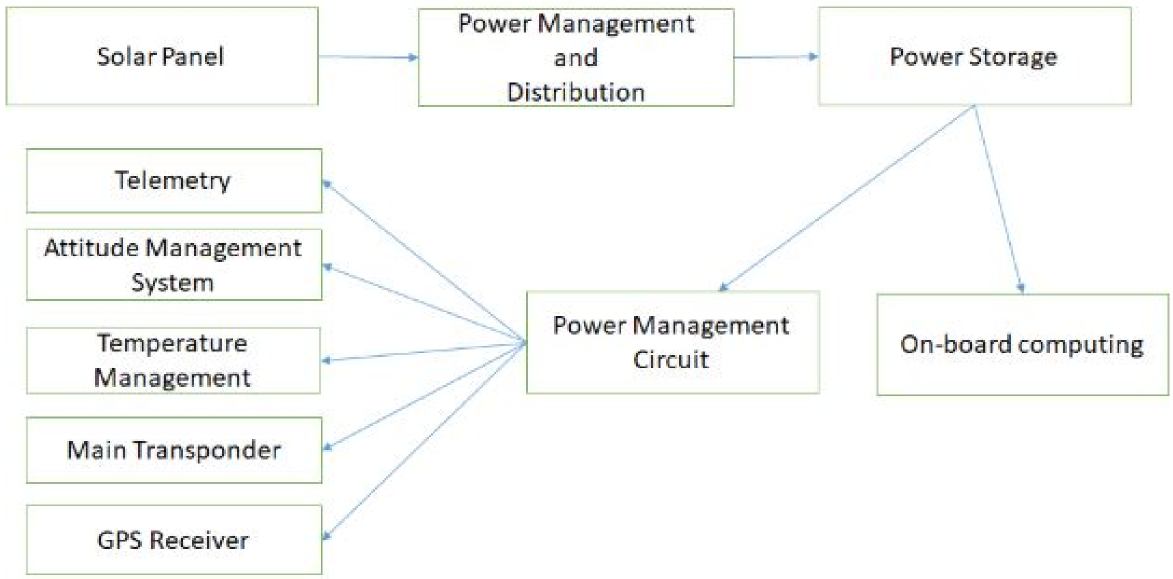

Figure 4.2: Power Distribution Model

4.6 Conclusion

In this chapter we have discussed about the whole power management subsystem of a nanosatellite. We followed all the procedures and able to power up our nanosatellite and made it functional.

CHAPTER 5

Attitude Determination and Control Subsystem

5.1 Introduction

Attitude determination and control subsystem is the fundamental subsystem of a satellite. This subsystem determines the positioning coordinates of a satellite and also controls the movement of the satellite. After the launching of a satellite it is a must to get continuous data about the positioning coordinates of a satellite. If we have no information about the positioning coordinate, we will not be able to track the satellite and the whole project will be converted to a wastage.

5.2 Attitude Determination

Attitude determination (ADCS) gives continuous information about relative pointing of a nanosatellite and also manage the three dimensions orientation of a spacecraft. ADCS is the first phase of attitude determination and control subsystem. Without the prior knowledge of attitude determination, attitude control cannot be functional. It is not possible to find out attitude directly by single measurement. It must be estimated from a set of measurements from several sensors. There are two approaches to calculate the attitude.

- Statically
- Use statistical Kalman filter

In statical approach, determine the attitude by currently available measurements. On the other hand, Kalman filter combines previous value of attitude with new sensor value to get an optimal result of the current attitude. We have used statical approach to determine the attitude.

5.3 Hardware for attitude detection

In order to know the exact position of a nanosatellite, several sensors are needed. These sensors will help us by providing the location information. In this research, we used compass and GPS receiver to determine the position of nanosatellite.

5.3.1 Compass

Compass is a multi-chip module for magnetic sensing. It is used for magnetometry and low cost compassing. Here, we used three-axis compass to serve our purpose. It has 1 to 2 compass heading accuracy. It has certain modes of operation. Mode registers are controlling the power management portion. For continuous measurements, continuous-measurement mode goes in active state and the device starts to read continuously at a user defined selectable rate. It stores the data in data output register. Another mode is idle mode. It is used to conserve current measurements while output register is updated. Figure 5.1 is the compass that we used in this research work.

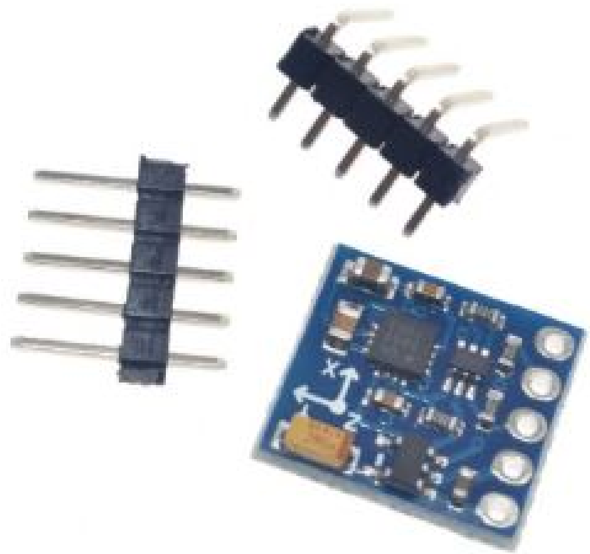

Figure 5.1: Compass

Feature:

- 3-Axis ASIC in a 3.0x3.0x0.9mm LCC surface mount package and magnetoresis-tive sensors.
- It has self testing feature.
- Low power consumption of 100 A package and magnetoresis-tive sensors.
- Range of magnetic field (+/-8 Oe).
- Maximum Output Rate of 160 Hz.

5.3.2 GPS Receiver

Nowadays nanosatellites are using Global Positioning System receivers to achieve orbit control, orbit transfers, attitude and deorbiting for end-of-life. GPS receivers are often used for terrestrial purposes. But it is quite challenging to use in space. Because it also uses embedded software. Beside that there is some technical and regulatory limitations while using GPS receiver. According to International Traffic in Arms Regulations (ITAR), output of the navigation will not exceed the ITAR limit of 1,000 knots and 60,000 feet. Despite the issues it has been shown a positive response for in-orbit task. GPS module has ceramic patch antenna, on-board memory chip and it is cost-effect. Voltage range for GPS module is 3.3 to 5 V. Figure 5.2 is the compass that we used in this research work.

Figure 5.2: GPS receiver

Feature:

- Attitude determination
- Spacecraft formation of flying
- Orbit determination
- Onboard time synchronization
- Payload information geocoding

The National Marine Electronics Association (NMEA) has some specification. GPS receiver follows the specification for communication purpose. The programs which generate real time position data understand and can read NMEA formatted data. GPS receiver computes the data to find PVT that is position, velocity and time data. We used TinyGPS++ library to parse the NMEA data.

5.4 Attitude Control

The subsystem which controls the orientation of a nanosatellite with respect to inertial frame of reference or any other object in outer space is called as attitude control subsystem. Attitude of a spacecraft needs to be stabilized so that spacecraft antenna can be able to point earth for communication properly. It is also needed for collecting data, intelligent thermal control and also for guidance. For controlling the spacecraft attitude, sensors are required to measure spacecraft orientation. Actuator is used for reorient the spacecraft to a targeted attitude. Algorithms are written to command the actuator to reorient the spacecraft. This algorithm considers current attitude and goal attitude. We have implemented attitude control algorithm partially to control the attitude.

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5.4.2 Flow chart for Attitude Cont

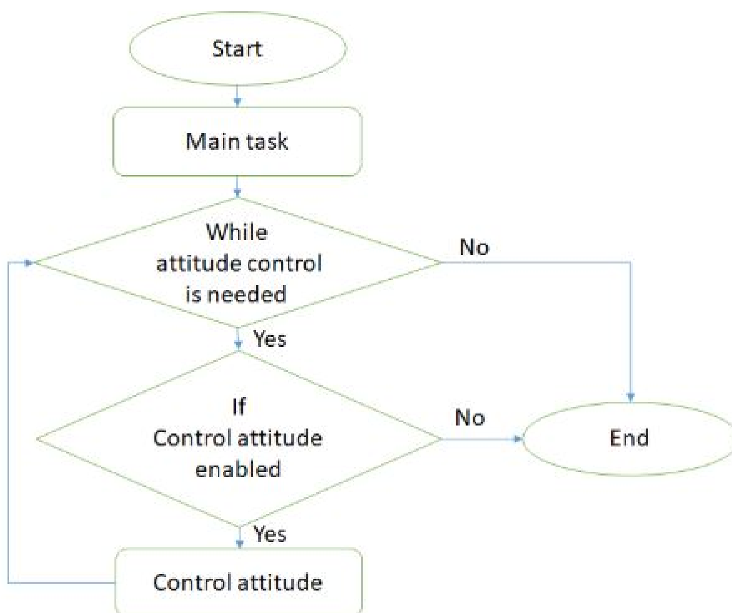

Figure 5.3: Flow chart for attitude control

5.5 Conclusion

In this chapter, we discussed about attitude determination and attitude control subsystem, components that we needed, limitations. We also illustrated the way we applied to make the subsystem. Then we have shown the flowchart for controlling the attitude of the spacecraft.

CHAPTER 6

Communication Subsystem

6.1 Introduction

The communication subsystem is an obvious and fundamental part of a spacecraft. Communication module provides the only essential communication link between the earth and the orbital platform. It has two different models in most cases. Satellites are fully dependent on communication and command module which helps the ground station to operate and initiate all necessary commands. Side by side the major mission of any satellite is to transmit data and telemetry to Earth. To transmit and receive data, we can use transceiver. But in satellite researchers usually use transponder which follows the same technology as transceiver. The communication between satellites are often called InterSatellite Link (ISL). The communication between satellite and Earth depends on the radio spectrum which is 30 MHz to 40 GHz.

6.2 Radio Bands

There are certain communication bands that a satellite can use to establish communication and transmit data to Earth. These communication bands are :

- Very High Frequency (VHF), range from 30 to 300 MHz

- Ultra High Frequency (UHF), range from 300 MHz to 3 GHz
- L band, range from 1 to 2 GHz
- S band, range from 2 to 4 GHz
- C band, range from 4 to 8 GHz
- X band, range from 8 to 12 GHz
- Ku band, range from 12 to 18 GHz
- K band, range from 18 to 27 GHz
- Ka band, range from 27 to 40 GHz
- Laser communication, range from 100 to 800 THz

6.3 Bands and antenna used for nanosatellite communication

UHF and VHF frequencies are used for nanosatellite or Cubesat communication. Nanosatellites are not operated above LEO. This situation has become an advantage as it allows them to take patch antenna or whip in communication system. A communication link is established while using patch antenna. It helps to control pointing accurately. There is no need to deploy patch antenna. Patch antenna are used from UHF to S-band. Another antenna used in nanosatellites that is Monopole antenna. Because it is easy to deploy from a Cubesat. Researchers use Monopole antenna for VHF and UHF band communication. Dipole antenna also do the same. If the frequency is higher, aperture of antenna will reduce and no change in gain. But atmosphere can easily absorb higher frequency.

6.4 Segments of Communication Subsystem

The term communication is indicated that there are at least two users who are communicating with each other. Similarly, nanosatellite communication subsystem has two subsystems.

- Space segment subsystem
- Earth segment subsystem

6.5 Space Segment Communication Subsystem

The communication system which exists at spacecraft in space is called space segment subsystem. Space segment communication subsystem is capable of communicating with ground station and with other satellites. It is a full communication setup which can transmit and receive both while needed. It can also capable of making network with other satellites.

6.5.1 Space Segment Hardware Equipment

The spacecraft consists of transponder and antenna for communication purpose. Transponder can transmit and receive data while communicating with ground station or any other satellites. Antenna transmits data and receives radio signals by identifying electromagnetic wave from other wave. Antenna is designed for 1U nanosatellite and to operate in VHF bands.

6.5.2 Designing Monopole Antenna by Measuring Tape

Monopole antennas operate in VHF bands. VHF bands have a range of 30 MHz to 300 MHz.This antenna is made by steel tape which we found from measuring tapes. The width of the antennas are 18 mm and thickness 0.2 mm. Length of antennas are 570 mm. It is perpendicularly mounted over a conductive surface.

This antenna will use for downlink data to the ground station. Figure 6.1 shows antenna made by measuring tape.

Figure 6.1: Making Monopole antenna by measuring tape

Feature:

- Directional radiation pattern
- Extremely high gain

6.5.3 Transponder for satellite

A long range transponder has been used to transmit and receive data. It uses the same technology as transceiver. It enables long range transmission with low power consumption. The miniaturised transponder has become one of the advanced technology around the world.

Feature:

- Low power consumption
- Less weight
- Small in size
- Long range
- Increased power transmission

We have used LoRa as transponder in our satellite project. To establish LoRa based direct connectivity to satellite gateways, LoRaWAN protocol has introduced. For this reason, we have chosen to use LoRa to complete the communication circuit.

6.6 Earth segment subsystem (Ground Station)

Earth segment communication subsystem refers to the ground station or earth station. Satellites are communicating with ground station and transmit data to the ground station. The data or communication is transmitted from a satellite to the

Earth station is known as downlink and when communication is going Earth station to satellite that is known as uplink.
The moment a spacecraft receives an uplink signal at the same time Earth station also receives a downlink signal. A two way communication will establish between satellite and ground station. This ground station consists of communication equipment and software. Ground station sends command to the satellite for further action. Telemetry subsystem involves communicating with the station.

6.6.1 Hyperlink Antenna

Hyperlink offers a wide area of wireless communication. It is omnidirectional so that we can catch signal easily. That means it will give 360 degree coverage. Radio frequency is a rate of oscillation which has a range of 3 KHz to 300 GHz. It gives 24 dBi omnidirectional operation. This antenna will simplify the system and reduce tracking error. Directional antenna needs the system pointing the antenna to the direction of satellite. For this purpose, we need to use rotator. But rotators are so heavy and set up process is difficult. On the other hand, omnidirectional antenna does not use rotator and it consumes less energy. Figure 6.2 is a hyperlink antenna.

Figure 6.2: Omnidirectional Hyperlink Antenna

frequency by hyperlink antenna is given below.

- 900 MHz
- 1.2 GHz
- 1.9 GHz
- 2.4 GHz
- 2.6 GHz
- 3.5 GHz

- 4.9 GHz
- 5.1 GHz
- 5.3 GHz
- 5.4 GHz
- 5.8 GHz
- Multi band
- Very Broad-Band
- Custom

Multi-path, signal strength and reflection is crucial for wireless communication. Wireless radio has different type of hardware and software to operate with multi-path while necessary.

6.6.2 Transponder for ground station

Transponder which will transmit and receive data for ground station to the satellite. It will provide two way communication and it is the ground station equipment. Figure 6.3 used to show serial monitor output.

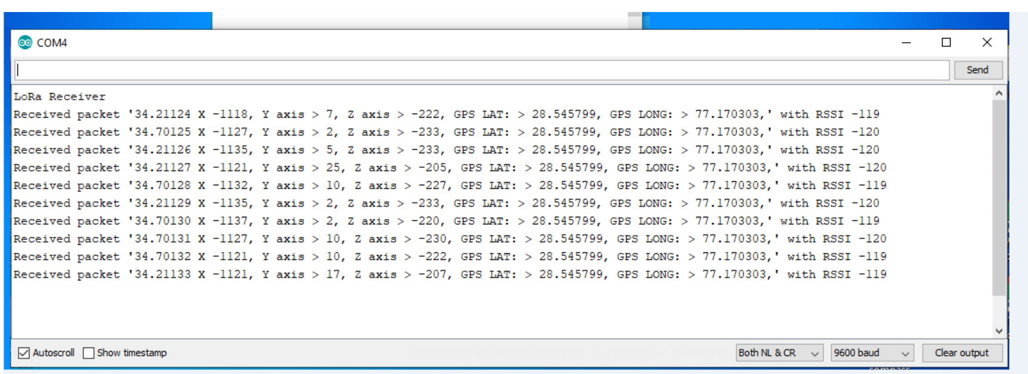

Figure 6.3: Satellite data in serial monitor of ground station

6.6.3 Software

We have designed our own ground station software for reporting the collected data from satellite. The software communicates with the ground station transponder through communication port. It collects the raw data from the transponder and then shows data in a segmented format to be displayed more appropriately. Figure 6.4 shows the ground station software.

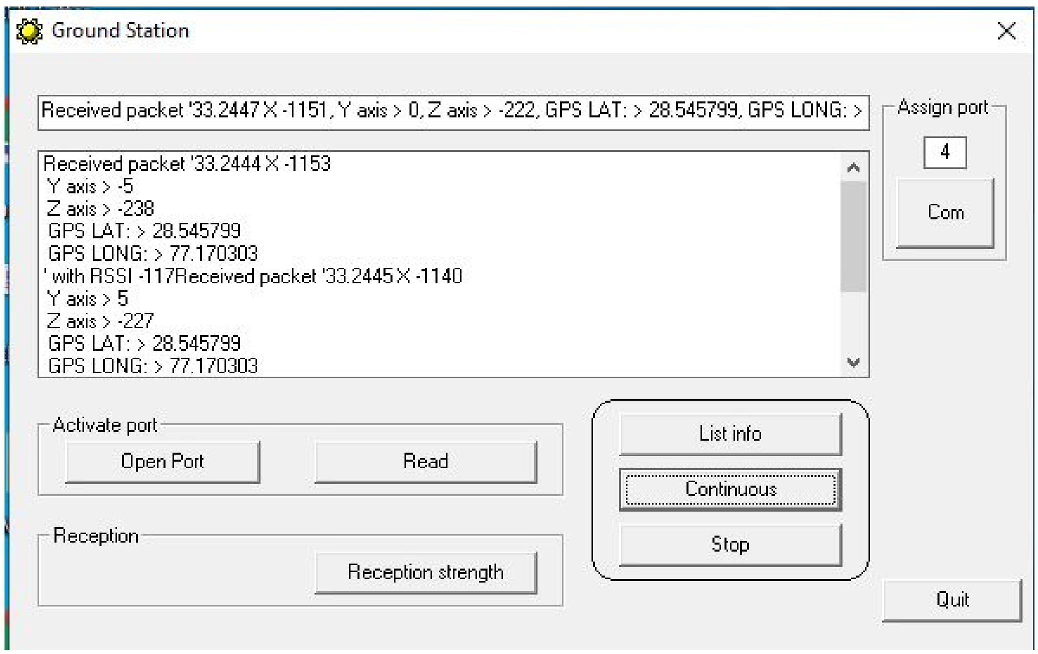

Figure 6.4: Ground Station Software

6.7 Conclusion

In this chapter we have learned the overall communication subsystem that exists between the nanosatellite and ground station. We have also shown how we established a communication mechanism between these.

CHAPTER 7

Deployment of Solar Panel and Antenna

7.1 Introduction

Solar panel is the driving force of the satellites to keep alive the satellites. It is an essential part of any kind of large, medium and small satellites. To get the power from satellite, satellite deployment is the fundamental approach. One can also use solar panel in the faces of nanosatellites. But to acquire more power from sunlight it is necessary to have a deployable solar array. There is another reason to use deployable solar array. If one uses solar panel in the faces of satellite and any of the solar panel is damaged for some reason in the space, it is difficult to fix it or change it. As a result, it will affect the whole power management system. So, it is necessary to deploy solar array in space.For communication purposes, we use different types of antennas for different reasons. Antenna deployment is necessary for the transponder to receive weak signal and also strengthen the transmission.

7.2 Procedure applied for deployment of Solar Panel and Antenna

Remote switching from ground station will trigger simultaneous deployment of two solar panels and two monopole antennas. Until the solar panels have been deployed, the central power management system will keep the transponders and the onboard computer system up and running. After the solar panels are deployed the power management system will start functioning by simultaneously charging the batteries and supply the required current to all the onboard system. Our deployment procedure of the solar panels have been designed using minimum current so that any delay from launching the cubesat from the launch platform shall not put the system in lack of battery power. Because until the solar panels are deployed, all the onboard systems will be fully activated using the onboard battery. We are using nichrome burn wire mechanism to deploy the solar panels and antenna.

Deployment of monopole antennas will only ensure full transmission and reception capability of the transponder. Therefore, proper deployment of monopole antennas at the same time of deployment of solar cells are necessary.

7.3 Conclusion

In this chapter we have discussed about the deployment procedure of solar panels and antennas.

CHAPTER 8

Structural Subsystem

8.1 Introduction

Nanosatellites are well suited for a space mission because of their size. The basic structure of all nano satellites are identical. It has several subsystems to manage different types of task. The structure associated with these subsystems is called structural subsystem. It is the skeleton of a nanosatellite.

8.2 Structure

Structure consists of structural design, multifunctional structure, integration and integration issues in nanosatellite. We have made 1U Cubesat which has 10 cm in length, 10 cm in height and 10 cm in volume. The frame is made of 6 faces. Among them, two side faces are used to deploy solar arrays. There is access port with the frame. Frame is made of stainless steel. Then we have electrical power subsystem (EPS). Electrical power subsystem consists of rechargeable batteries and the power distribution circuit. After that communication subsystem arrives in the nanosatellite. Nanosatellite establishes the communication with ground station and with other satellite from this subsystem. Then we have attitude determination and control subsystem. This subsystem determines the attitude and control the movement of satellite in a desired way. For controlling purpose, we have used motors. We have uplink and downlink antennas for communication with ground station. There is an another subsystem called thermal determination subsystem in our model nanosatellite. It detects the internal thermal condition of the nanosatellite.

8.3 Conclusion

In this chapter we have tried to discuss about the structural subsystem of the nanosatellite. It includes the main critical subsystems of the nanosatellite.

CHAPTER 9

Thermal Detection Subsystem

9.1 Introduction

Every element has a range of acceptable temperature in which it can survive and can be functional. Components have threshold temperature for both the positive and negative temperature. To control the temperature of the satellite in space, it is necessary to know the temperature of the satellite. It will help to ensure thermal requirements of the spacecraft.

9.2 Thermal Detection

Thermal detection gives continuous information about the temperature of the nanosatellite. Without the prior knowledge of thermal detection, thermal control cannot be functional. We have implemented internal thermal detection in our nanosatellite.

9.3 Hardware for Thermal detection

In order to know the exact temperature of a nanosatellite, sensor is needed. These sensors will help us by providing the temperature information. In this research, we used temperature sensor to determine the temperature of nanosatellite.

9.3.1 Temperature Sensor

Feature:

- Calibrated in Centigrade
- Operation range from 4 to 30 volts.
- Low impedance
- Rated for -55°C to 150°C

9.4 Conclusion

This section discussed how we detect the internal temperature of nanosatellite. We have shown the features of the temperature sensor.

CHAPTER 10

Conclusion

10.1 Introduction

The objective of this thesis was to design, development and understand the subsystems of a 1U Cubesat nanosatellite. We have tried to fulfill our objective by measuring location, GEO position, attitude control, establish communication between satellite and ground station, power management subsystem, deployment of antenna and solar panel. There are several subsystems in a nanosatellite. We have tried to develop the main subsystems.

10.2 Limitations

We have tried to design and develop the main subsystems of a nanosatellite. We could not complete all possible subsystems in our cubesat. Then again we must admit that the possibilities of including various facilities on a cubesat are unlimited.

10.3 Future Work

Our future plan is to launch the 2nd nanosatellite of Bangladesh in space. We are targeting to reach our goal by a step by step process which will lead us to achieve our goal. We took it as our mission and vision to step ahead toward space and space engineering. We are targeting to launch our 2nd Cubesat into the orbit. But this time the complete design and most of the subsystems will be designed by us.

10.3.1 Subsystem Development

We are determined to design the rest of the subsystems of the nanosatellite. We will complete the development of subsystems in the near future to accelerate our aim.

10.3.2 Future Ground Station

We have tried to make our ground station along with required equipment. If we can accomplish our mission and vision then maybe we need to set up ground station as per the rules of multinational project.

10.3.3 Launching procedure

There is no gravitational force in space. So, the satellite does not require additional frames in outer space. But additional frames are necessary while launching the satellite. Because during the whole launching procedure satellite vibrates violently. This vibration can create tremendous problems if it is not designed properly. For this reason, the design should be compatible with launching vehicle.

The launching process is the process of placing a satellite in a desired orbit. There are four phases in launching satellites.

- Launch vehicle consists of fuel and rockets to lift the satellite from ground.
- Launch vehicle has smaller rockets that will ignite to send satellite in space. These rockets contain their own fuel tanks.

- Launch vehicle will be connected with satellite by fairing. This metal shield will protect the satellite.
- When launching vehicle will reach to outer atmosphere, satellite will separate from the upper portion of the launching vehicle. The nanosatellite will reach to the transfer orbit. This orbit helps the satellite to go to higher in the space.

After reaching the desired orbit, antennas and solar panels will be deployed.There are several private organizations who are helping students to launch their own satellites. We will communicate with them and show our strong interest to launch a nanosatellite.

10.4 Conclusion

The objective of our study was to develop the subsystems of a nanosatellite. We have developed certain subsystems of a nanosatellite. This experience will help us to design the rest of the subsystems so that we can be able to make a complete launchable nanosatellite.

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