

Power Distribution System for a CubeSat

*Project report to be submitted in partial fulfillment of the
requirements for the degree*

of

Bachelor of Technology in Electrical and Electronics Engineering

by

Mary Angel Gomez
TRV19EE036

Mayoogha SL
TRV19EE037

Naveen AB
TRV19EE038

Navya S
TRV19EE039



ELECTRICAL AND ELECTRONICS ENGINEERING
GOVERNMENT ENGINEERING COLLEGE, BARTON HILL

JANUARY 2, 2023

DECLARATION

Project Title Power Distribution System for a CubeSat
Authors Mary Angel Gomez, Mayoogha SL, Naveen AB, and Navya S
Student IDs TRV19EE036, TRV19EE037, TRV19EE038, and TRV19EE039

We, the undersigned, hereby declare that the mini project report titled *Power Distribution System for a CubeSat*, submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under the supervision of Prof. Rajesh M, Department of Electrical and Electronics Engineering, Government Engineering College, Barton Hill. This submission represents our ideas in our own words and ideas and words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or sources in submission. We understand that any violation of the above will be a case for disciplinary action by the institute and/or the University can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other university

Place: TVM

Date: January 2, 2023

Mary Angel Gomez TRV19EE036
Mayoogha SL TRV19EE037
Naveen AB TRV19EE038
Navya S TRV19EE039

Department of Electrical and Electronics
Engineering
Government Engineering College,
Barton Hill



Department of Electrical and Electronics Engineering
Government Engineering College, Barton Hill
Thiruvananthapuram - 695035

CERTIFICATE

This is to certify that the report titled **Power Distribution System for a CubeSat** submitted by **Mary Angel Gomez, Mayoogha SL, Naveen AB, Navya S** of the **Department of Electrical and Electronics Engineering** to the APJ Abdul Kalam University in partial fulfillment of the requirements for the award of the Degree of *Bachelor of Technology in Electrical and Electronics Engineering* is a bonafide record of the project work carried out by them under my guidance and supervision. This report in any form has been submitted to any other university or institute for any purpose.

Prof. Rajesh M Assistant Professor	Er. Karthika B Assistant Professor-Adhoc	Er. Thara Mohan Assistant Professor-Adhoc
EEE, Government Engineering College, Barton Hill	EEE, Government Engineering College, Barton Hill	EEE, Government Engineering College, Barton Hill

Place: TVM

Date: January 2, 2023

ACKNOWLEDGEMENTS

First and foremost, we thank God Almighty for all the blessings on the successful completion of this project. We show our sincere gratitude to all those who contributed in this project work, they can never be forgotten. We would love to express our sincere gratitude to Dr. N. Vijayakumar, Principal, Government Engineering College, Barton Hill for giving us the opportunity to do the project work. We owe a great deal of gratitude towards Dr. Elizabeth Cherian, Head of the Department of Electrical and Electronics Engineering, Government Engineering College, Barton Hill, for her whole hearted support for this project. We express our sincere thanks and deep sense of gratitude to our project internal supervisor Prof. Rajesh M, Department of Electrical and Electronics Engineering, for her encouragement and support throughout our preparations. At last but not the least, we also thank all our friends and well-wishers who stood beside us and encouraged for the success of our project.

Mary Angel Gomez, Mayoogha SL, Naveen AB and Navya S

Government Engineering College, Barton Hill

Date: January 2, 2023

ABSTRACT

FM transmitter is a small device that can transmit Frequency Modulated signal over short range. This document consists of most simple and economical technique for building a FM transmitter using basic electronic components like resistor, capacitor, inductor etc. The FM transmitter receives human voice signals through microphone. It further amplifies it, modulate it over carrier and finally transmit it. Assuming favorable conditions, output of transmitter can be received by anyone who tunes it in frequency of our transmitter. Here, we have described the circuit diagram, its working, components required, uses of various components in our circuit, its practical applicability. This design is capable of transmitting signal for distance of 200 m, tuned at FM range (88 MHz- 108 MHz). One could clearly hear sound produced at microphone of transmitter.

Contents

1	Introduction	1
2	Literature Review	2
3	Aim	3
4	The Electrical Power System	4
4.0.1	Comps	4
4.0.2	Comps	5
5	Methodology	7
5.1	Identifying Power Requirements	7
5.2	Literature Review	7
5.3	Architecture Design and Topology selection	7
5.4	Forming Specifications	8
5.5	Design and simulation	8
5.6	Procurement of components	8
5.7	Fabrication and Testing	8
6	Component Selection and Design	9
6.1	Solar Panels	9
6.2	MPPT Circuit	9
6.3	Battery	11
6.4	Battery Charger	11
6.5	BUBO	12
6.6	BUBO	13

7	Working	15
7.1	Pre-amplification stage	15
7.2	Modulator & Oscillator stage	16
8	Workplan	17
9	Applications	18
	Bibliography	20

List of Figures

6.1	MPPT circuit with SPV1040	10
6.2	Battery Charger circuit with BQ25302	12
6.3	LTC3426 as boost IC and TPS62203 as buck IC	13
7.1	FM transmitter circuit block diagram	15

Chapter 1

Introduction

A CubeSat is a class of miniaturized satellite based around a form factor consisting of 10 cm cubes. CubeSats have a mass of no more than 2 kg per unit, and often use commercial off-the-shelf (COTS) components for their electronics and structure. CubeSats are put into orbit by deployers on the International Space Station, or launched as secondary payloads on a launch vehicle. As of August 2021, more than 1,600 CubeSats have been launched.

For more than a decade, CubeSats, or small satellites, have paved the way to low-Earth orbit for commercial companies, educational institutions, and non-profit organizations. These small satellites offer opportunities to conduct scientific investigations and technology demonstrations in space in such a way that is cost-effective, timely and relatively easy to accomplish. It give students an experience in developing flight hardware and conducting space missions.

CubeSat missions benefit Earth in varying ways. From Earth imaging satellites that help meteorologists to predict storm strengths and direction, to satellites that focus on technology demonstrations to help define what materials and processes yield the most useful resources and function best in a microgravity environment, the variety of science enabled by CubeSats results in diverse benefits and opportunities for discovery.

Chapter 2

Literature Review

Information transmission is very vital to human life just as the early men used sticks to produce sound which indicates the location of each other as they wander about also down to the middle era when town crises come into play for the same information propagation to be transmitted from one point to another with the aid of radio communication which necessitates the application of radio transmitter and receiver.

Frequency modulation (FM) is a technique for wireless transmission of information where the frequency of a high frequency carrier is changed in proportion to message signal which contains the information. FM was invented and developed by Edwin Armstrong in the 1920's and 30's. Frequency modulation was demonstrated to the Federal Communications Commission (FCC) for the first time in 1940, and the first commercial FM radio station began broadcasting in 1945.

A radio transmitter is device whose major function is to send information (intelligence) from one point to another in most cases the information to be transmitted are voice music and code signals. However the transmission of radio signal is done with the aid of electrical resonance this is when the frequency of the receiver is equal to the incoming one from the transmitter resonance is observed which is the totality of radio communication, frequency modulation (FM) transmitter is less distorted than other wave bands like amplitude modulation and short wave band. The frequency on the tuning dial ranges from 88MHZ to 108MHZ.

Chapter 3

Aim

To design and implement a fully autonomous power generation, storage and distribution system for a CubeSat

Chapter 4

The Electrical Power System

The Electrical Power System (EPS) is an electronic circuit board that is designed to supply, manage and store energy in an efficient way. The EPS must be able to harvest energy from the solar panels and store it in the battery, as well as delivering power to the satellite, using switch controlled converters to supply a regulated voltage. Redundant circuitry must be present to ensure continuous and reliable operation of the satellite in case of the failure of EPS components.

The output of the solar panels is first run through the power path control. While in sunlight operation, the power path will select the voltage from the panels based on its higher voltage. The output of the Power Path control is sent to DC-DC converters to provide 5V and 3.3V regulated DC supply for the Cubesat modules. During the eclipse, the power path will select the battery to power the circuit components.

The software is implemented in order to manage the overall energy of the satellite, regulate the converters to extract maximum power from solar panels, perform power diagnostics, engage redundant circuitry and to communicate with the On Board Computer. The software also employs four operating modes: Initialization mode, Safe mode, Normal mode and Low Power Mode.

4.0.1 Components of EPS

The EPS of a cubeSat can be designed with many different architectures, but some components are common to all designs, such as:

- Solar panels to harvest the energy from the Sun
- Battery charger to manage the charging profile of the battery
- Voltage regulators to feed the regulated power bus of the satellite
- Remove Before Flight (RBF) switches and deployment switches, to cut the power while the satellite is not deployed

Other components of the EPS are:

- Battery and associated charging circuit
- Solar panels on 6 faces of the satellite
- MPPT converters which help optimise power collection from the sun
- Buck and boost converters which help provide required voltage busses for components of different voltages
- STM32 used as the MCU which controls the tasks that the EPS performs and monitors the status of the components
- Over Current Protection Circuit which helps protect important components from high current flow
- Current and Voltage sensors to keep track of their consumption.
- Temperature sensors to measure battery temperature, based on which battery heater is used
- Battery heater circuit

4.0.2 Tasks of EPS

Tasks of the EPS are:

- Collect housekeeping for various components associated with it, like the various current & voltage sensors and the battery's state of charge.
- Handle housekeeping requests and other commands from the OBC (ON/OFF requests of any subsystem by OBC).

- Implement MPPT to optimize power generation.
- Control the Simple Beacon (which contains only the call sign of the satellite) before the TTC gets switched on.
- Implement a watchdog timer to keep a check on the operation of the OBC.
- Take action on the basis of OCPC triggers.
- Deployment of antenna at the time of satellite initialisation.
- Turn on the battery heater when temperature goes below critical level

Chapter 5

Methodology

5.1 Identifying Power Requirements

Before designing the EPS, the power requirements of the various subsystems of the cubesat has to be identified. A power budget has to be prepared accounting all the energy, voltage and current requirements of the subsystems. The orbital parameters at which the cubesat might be operating should also be considered. The orbital altitude, period and eclipse time and the daylight time has to be identified and documented. After this, the peak power budget has to be calculated and total energy and power demands are to be found out.

5.2 Literature Review

In order to select the suitable architecture and topologies, literature study has to be conducted. Various articles regarding the implementation of cubesats and EPS were studied and the findings were recorded.

5.3 Architecture Design and Topology selection

The design of EPS starts with the selection of appropriate EPS architecture based on the comparison of overall efficiency, battery size, and reliability. The EPS design is critical for CubeSat mission success, therefore selection of proper EPS architecture is one of the important steps. Different standard EPS architectures are classified on the basis of various topologies like dc-bus voltage regulation, interface of

PV panels, location of power converters, and number of conversion stages. The necessary topology has to be selected based on the demands and constraints.

5.4 Forming Specifications

After deciding upon a suitable architecture, the specifications of various components of the EPS has to be finalised. This includes deciding the number of required power converters and their input and output parameters, deciding the number, size and type of battery for energy storage and the characteristics of the solar panels and specifications of the MPPT device.

5.5 Design and simulation

Suitable ICs able to perform the various functions of different components in an EPS have to be identified. The ICs must be suitable for operation in outer space. After selecting the ICs, the design of them are to be completed and necessary schematics and PCB design has to be completed. Also, the circuits obtained have to be verified with the help of simulation results.

5.6 Procurement of components

The components which were finalised has to be procured. Surface Mount components are preferred due to the space constraints, also the selected components must be applicable in outer space applications.

5.7 Fabrication and Testing

The components have to be soldered into the PCB and the results are to be observed. Initially, each component maybe developed individually and tested before optimizing the entire circuit into a single, centralized form.

Chapter 6

Component Selection and Design

6.1 Solar Panels

TJ Solar Cell 3G30C - Advanced is selected. This cell is a GaInP/GaAs/Ge on Ge substrate triple junction solar cell. The end-of-life version of the 3G30C solar cell offers best EOL-performance values. Connected to the EPS via an external bypass diode protection.

Specifications:

- Average Open Circuit Voltage: 2.7V
- Maximum Power Point Voltage: 2.41V
- Average Short Circuit Current: 520.2 mA
- Maximum Power Point Current: 504.4mA

It has an average efficiency of 29.8% at $1353 \text{ W}/\text{m}^2$. This solar cell is excellent for space applications.

Solar panels are connected in such a way that each side has two cells connected in series. The maximum voltage developed per side is 4.4V and the maximum current that can be generated per side at peak power point is 0.5A. Panels on opposite sides are connected in parallel.

6.2 Maximum Power Point Tracking Circuit

The MPPT converter connected to the solar panels increases the efficiency as the maximum power is transferred from the radiated energy that is on the solar pan-

6.3 Battery

The most popular types of batteries use the following materials: Nickel Cadmium (NiCd), Nickel Metal Hydride (NiMH), Nickel Hydrogen (NiH₂), Lithium Ion (Li-Ion) and Lithium Polymer (Li-Po). The Li-Po and Li-Ion became the standard use in space technology due to their high energy density (Upto 200 Wh / kg on Li-Po and upto 250 Wh / kg on Li-Ion) and also due to the number of charging cycles being as high as the NiMH, whilst presenting higher operating temperatures. The Panasonic NCR 18650 GA Li-Ion cell was selected based on the calculation of EOL power, EOL efficiency and due to it's high energy density. Specifications of Panasonic NCR 18650 GA:

- Voltage: 3.7V - 4.2V
- Capacity: 3500mAh
- 1800 cycles till capacity reduces to 60%

6.4 Battery Charger

The battery also needs a charger to regulate its current and voltage while charging. BQ25302, a synchronous Buck Battery Charger IC was selected and connected in external power path mode.

Specifications and Operating Conditions of BQ25302:

- Input Voltage: Upto 5V
- Output Voltage: Upto 4.2V
- Switching Frequency: 1.2MHz
- Output Current: Limited to 1.2A
- Efficiency: 94.3% at 1A from 5V input
- Thermistor: Semitec 103AT-2 (10k Ω)
- Charging Temperature: Limited between 0 - 45 °C

The Battery Charger circuit schematic is shown below:

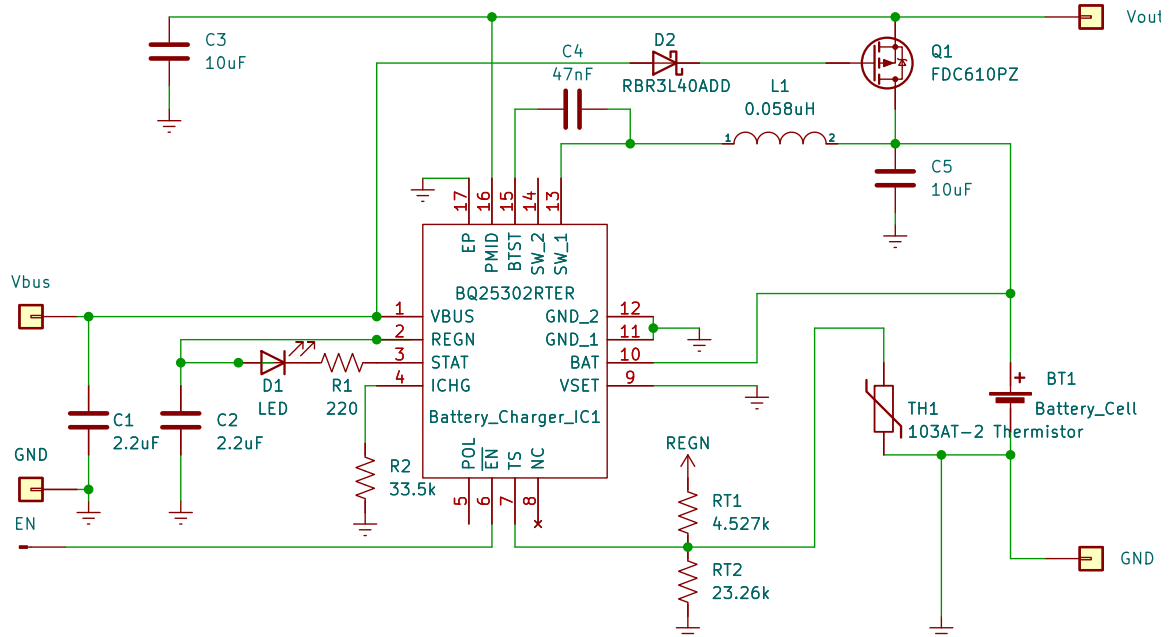


Figure 6.2: Battery Charger circuit with BQ25302

6.5 Buck and Boost Converters

The power conditioning is associated with regulating the voltage to accommodate for the charging voltage and the voltages of the satellite's subsystems. In most subsystems, the need for a specific voltage requires a regulation of either a step-up or a step-down of the supplied voltage. It can be done by buck convertor(step-down) and boost converter(step-up). TPS62203 was selected as the buck converter to provide step down voltage of the DC bus to supply the 3.3V loads.

Specifications and Operating Conditions of TPS62203:

- Input Voltage: 3.6 - 5V
- Output Voltage: 3.3V
- Switching Frequency: 1MHz
- Output Current: 300mA (max.)

LTC3426 was selected as the boost converter to provide step up voltage of the DC bus to supply the 5V loads.

- Input Voltage: 3.6 - 5V
- Output Voltage: 5V
- Switching Frequency: 1.2MHz
- Output Current: 500mA (max.)

The Buck and Boost Converter circuit schematic is shown below:

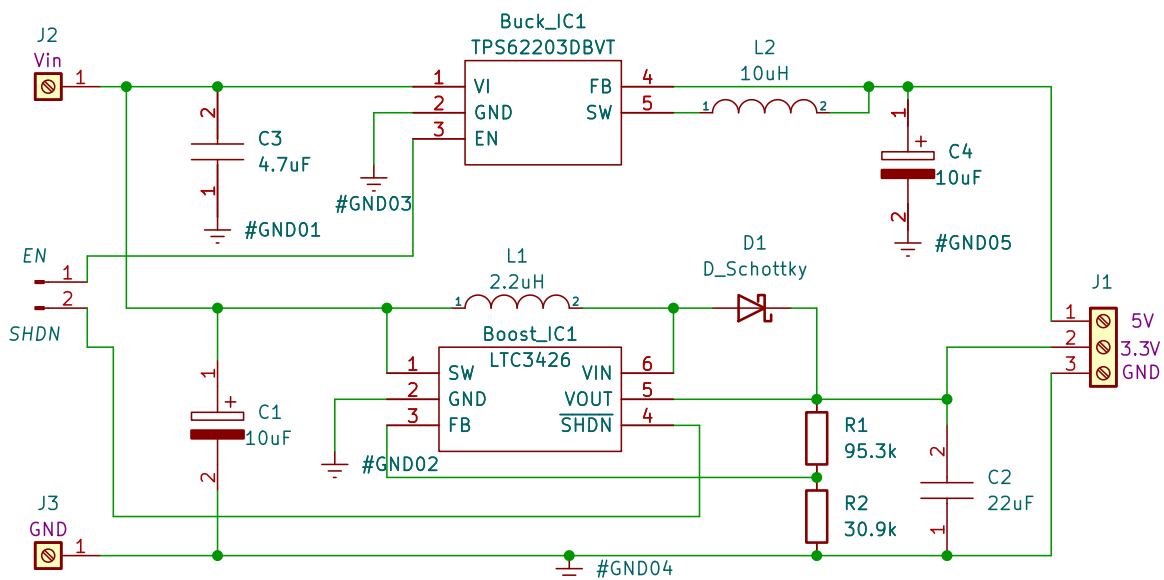


Figure 6.3: LTC3426 as boost IC and TPS62203 as buck IC

The circuit used for the protection purpose is the current limiting circuit. Unlike a fuse that breaks a circuit connection, a current limiter only limits the current at a predetermined level. The current limiting circuit can be as simple as a single resistor (a passive current limiter), with the voltage drop across the resistor being dependant on the consumed current by the load. Higher the current drawn by the

load, higher the voltage drop on that resistor. In many cases, this is not preferable. An active current limiting circuits does not drop the voltage if the current drawn by the load is below the allowable range. With this mechanism, all power is delivered to the load in the normal condition. If the load tries to draw a current that is more than allowed then the current limiting circuit will act as a resistor, controlling its resistant value to limit the current to a predetermined level.

Chapter 7

Working

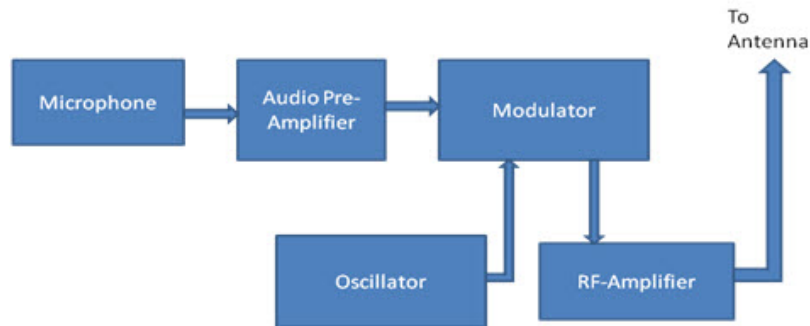


Figure 7.1: FM transmitter circuit block diagram

7.1 Pre-amplification stage

- The first stage of the circuit is a preamplifier stage based on transistor Q1 which can be any low noise npn transistor.
- This is a collector to base biased amplifier stage where resistor R2 sets the collector current and R1 provided the necessary collector to base bias.
- C1 is the input DC decoupling capacitor which couples the input audio signal to the Q1 base.
- C8 is the power supply bypass capacitor.
- If you are going with a battery eliminator, then it must be well filtered and regulated. C3 and C4 are for suppressing the ripple if any.

- C3 prevents any noise disturbance to pass into the input of transistor
- Q2 and C4 suppresses voltage spikes and noise disturbance in the power supply.

7.2 Modulator & Oscillator stage

- Next stage is the oscillator cum modulator stage.
- Modulation stage is served by transistor Q2. Q2 can be 2N2369, 2N2219, 2N1711.
- Electrolytic capacitor C2 couples the output of the first stage to the second stage.
- R3 and R4 are the biasing resistors of Q2.
- R5 is the emitter resistor of Q2.
- Inductor L1 and trimmer capacitor C5 form the tank circuit which is necessary for creating oscillations.
- The modulated FM signal is available at the collector of Q2 and it is coupled to the antenna using capacitor C9.
- L1 can be constructed by making 4 turns of 1mm enamelled copper wire on a 10mm diameter plastic former.
- Trimmer C5 can be used for adjusting the transmission frequency.
- Trimmer capacitor C6 can be adjusted for obtaining the maximum range.
- The antenna can be a 1m copper wire.

Chapter 8

Workplan

Activites	Timeline
Identifying Power Requirements	Completed
Literature Review	Completed
Architecture Design and Topology selection	Completed
Forming Specifications	Completed
Design and simulation	Partly Completed
Procurement of components	February
Fabrication	March
Testing	April
Final Project Report	As per KTU Schedule

Chapter 9

Applications

- Non-commercial broadcasting and commercial broadcasting
- Simple to build and use
- Most of the components required for this circuit can be procured from your junk box.
- The circuit can be powered from anything between 6 to 12V DC.
- Useful during natural disasters to broadcast warnings or other messages when other communication techniques fail
- Range of antenna and frequency can be extended by choosing the wanted components
- Can also be used as an FM bugger circuit by taking advantage of Capture effect in FM waves.

REFERENCES

-

Power Distribution System for a CubeSat

Project report for degree of

of

Bachelor of Technology in Electrical and Electronics Engineering

by

Mary Angel Gomez | Mayoogha SL
TRV19EE036 | TRV19EE037

Naveen AB | Navya S
TRV19EE038 | TRV19EE039



ELECTRICAL AND ELECTRONICS ENGINEERING
GOVERNMENT ENGINEERING COLLEGE, BARTON HILL

JANUARY 2, 2023