

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

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DECLARATION

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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 1, 2023

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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.

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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.

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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 protects 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

Component Selection and Design

5.1 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 $1353 \text{ W}/m^2$. 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.

5.2 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-

els. As each solar panel has different temperatures and incident radiance angles, the Maximum Power Point (MPP) is also different. So each solar panel has a MPPT converter to assure that the maximum power available at the solar panels is transferred independently from their working power points. Since the peak power point cannot be accurately predicted, many different algorithms exist for finding the best approximation. The MPPT can be implemented in the EPS using one of three algorithms: **Perturb and Observe, Incremental Conductance, Constant Voltage**

The SPV1040 was chosen as the MPPT IC. It is a boost converter with duty ratio controlled by Perturb and Observe MPPT algorithm. The perturb and observe algorithm is based on monitoring either the voltage or the current supplied by the DC power source unit so that the PWM signal duty cycle is increased or decreased step-by-step according to the input power trend. This chip has inbuilt over-current protection and a cutoff mechanism if the solar panel connection is reverse-inserted to prevent damage to the IC and the external circuit.

Specifications of SPV1040:

- Input Voltage: 0.3 - 5.5V
- Output Voltage: 5V
- Switching Frequency: 100kHz
- Efficiency: 95%

5.3 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%

5.4 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

5.5 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.

Specifications and Operating Conditions of LTC3426:

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

All convertors operate in continuous conduction mode.

5.6 Protection Circuits

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 6

Working

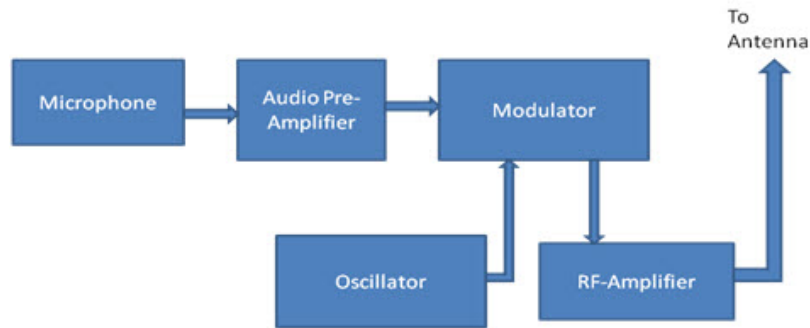


Figure 6.1: FM transmitter circuit block diagram

6.1 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.

6.2 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 7

Result

The circuit was setup as per the circuit diagram & found to be working in good condition without any problem.

Chapter 8

Conclusion

So, far the test result of this project which is the outcome of construction procedures has revealed the successful achievement of the primary objective; the design and construction of the FM transmitter is now ready for either constructional or entrepreneur purposes. The successful completion of this study has indicated that practical FM transmitter can be designed and constructed.

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

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