Small Student Satellite Power Distribution Module

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***Abstract*— Space technology is one of the most developing fields these days. This paper basically discusses the design of power distribution system of a Pakistani small student satellite. Power Distribution system acts as a backbone for the whole satellite system. PDU receives 28V unregulated form the Power Control Unit (PCU) and then supplies regulated 5V, 12V and unregulated 28V to the loads. The PDU performs current sensing, current limiting, switching and protection of load. The results of this paper shows that the PDU is able to is able to perform all the operations within the requirements of the satellite and as well as provide protection from fault currents. This paper includes the implications for developing a power distiribution module for satellite based on off the shelf components that is cost effective. Therefore this paper is helpful for building satellites that are low cost but highly efficient.**

***Index Terms*—Power Distribution Module, Small Satellite, Current Sensing, Current Limiter, Space Technology.**

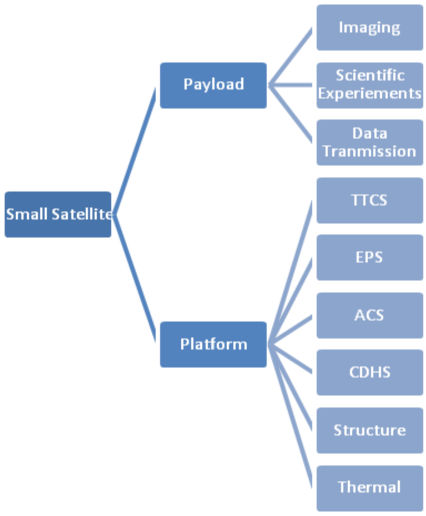

Figure 1 Basic system structure of Small Satellite.[2]

I. Introduction

With the advancements in science, space technology has become an eminent part of research and development. In Pakistan, we see in the past years there has been an increasing trend of progress in this field. However there is much room for improvement and study in this area.

Two years ago, Institute of Space Technology (IST) located in Islamabad launched the very first student satellite of Pakistan by the name of CubeSAT-1[1]. It was launched in November, 2013. Unfortunately the mission couldn't be a successful one and the satellite was lost in space.

Recently, a new project has been initiated of building a small student satellite. The purpose of this project is to attract and invite all the competent students and engineers who can contribute towards this National Space Program. This program aims to develop a space awareness in Pakistan and give easy access of space to the ordinary students and researchers. This satellite is basically categorized as a micro satellite with dimensions 50cmx50cmx50cm and will weigh almost 50 kg. The mission life of this satellite will be 1 year.

The payload of the satellite includes imaging through camera, communication and other scientific payloads. On the platform we also have Electrical Power Sub system (EPS).[2]

II. Electrical power system

Electrical Power system of the satellite can be termed as the backbone because all of the functions are dependent upon it. The electrical system of satellite consists of two sources; The primary source is the solar energy. This solar energy is taken by the solar panels installed on all the four sides of cube shaped satellites. The secondary energy source is the battery which stores excess energy coming from the solar panel. This energy is utilized during eclipse, when there is no sunlight. This power in the form of voltages coming from the panel is then basically regulated and distributed to the loads according to the requirements.

This system is divided into following modules[2]:

- Solar Panel
- Power Conditioning Unit (PCU)
- Battery
- Power Distribution unit (PDU)

This research paper focuses on the power distribution system of the satellite.

III. POWER REGULATION

Power regulation is an important part of Power distribution module. There are two main techniques used for this[3]. Either we use distributed power regulation system or centralized power system. Both have their own advantages and disadvantages which are listed in the table. According to our requirements and keeping in view the pros and cons of each system, we have used centralized power regulation since it is economics and also less space is required. The main disadvantage of distributed distribution system is the amount of time and space required to build it. Also distributed systems are not very economic for small satellites.[3][4]

S.no	parameter	Centralized system	Distributed system
1	Complexity	Low for small satellites	High for small satellites
2	Weight	low	high
3	isolation	Not possible or very difficult to achieve	Yes, the experiments can be isolated on the satellite.
4	No of DC-DC converters used	less	more
5	Economic	Yes as less number of components are used in small satellite	No as larger number of components are used in small satellite

Table 1 Comparison between centralized and distributed power systems.[5]

IV. POWER DISTRIBUTION MODULE

The power distribution module shall receive 28 ± 6 V from the solar panel. This module shall covert these voltages into 5V and 12V regulated voltages and then distribute them according to the load requirements.

The power distribution will also be able to:

- Power regulation
- EMI filtration
- Switching ON/OFF of loads that are switchable
- Current sensing
- Over current protection
- Receive telemetric commands
- Thermal sensing

The main design of the module is shown in the figure 2. There are specified current ratings on each line coming out of the DC-DC converters. The current ratings for each line are also shown in the table. From the table we see that for the same voltage we need different currents depending on the loads. And also we see that there are two types of loads, switchable and non switchable. The non switchable load need continuous power and doesn't require to be switched off.

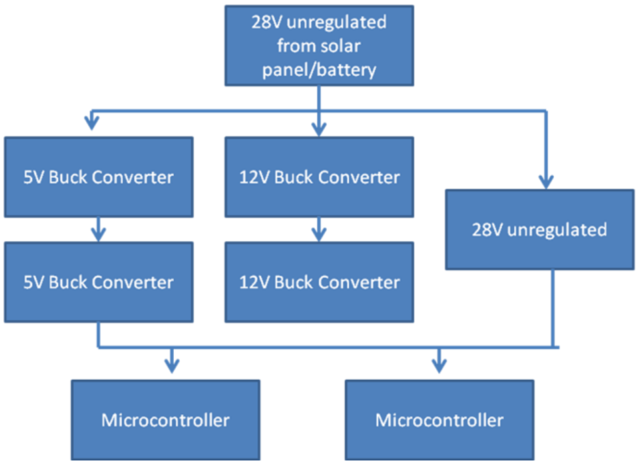

Figure 2 PDU Block Diagram

Sr. #	Voltage Level	Number of Lines@ Current Rating	Switchable/Non-Switchable
1	28V	5 Lines @ 400mA each	Switchable
2	12V	11 Lines @ 300mA each	Switchable
3	5V	8 Lines @ 800mA each	Switchable
4	5V	6 Lines @ 200mA each	Switchable
5	5V	1 Lines @ 600mA each	Non-switchable
6	12V	2 Lines @ 300mA each	Non-switchable

Table 2 Load line requirements.[6]

A. Types of Power Distribution Systems

There are mainly three ways in which the power distribution system can be implemented

- Hard wired
- Fuses
- Power switches

The hard wired systems mean that all the subsystems are connected to the power unit in the form of wires. The main disadvantage of this system is that there is no safety in this type of system. However it can be used in the parts where high currents are required for few seconds. But overall it is not recommended as it is not very flexible.

The second type is fuse based systems in which all the systems are connected to the main power system by means of fuses. This system provides a better reliability and safety methods than the previous hard wired systems. The fuses act as a switch and provide the control to turn on or off a system when the current exceeds a certain limit. However the main problem with this system is that the system is needed to be restarted every time a fuse is blown.

The third and the most efficient and flexible type of system which we have used in our satellite, is implemented by the help of power switches. These switches are connected to the telemetry of the satellites. They switch ON/OFF any power subsystem through a telemetric command. This can be used to conserve power by switching OFF the unwanted modules for the time being. In addition to the this power saving mode, They are also able to provide safety by switching off the modules in case of over current or short circuit. Therefore it is the most reliable and latest method to implement the power distribution system.[7]

In our satellite, we shall implement the last type , which is the power switches. The main type of power switches that we are going to utilize are MOSFETs with high switching frequency. The details of these switches shall be described later in the paper.

V. Power Distribution Electrical Architecture

The Power distribution unit basically comprise of

- DC-DC converters
- Current Sensing circuit
- Microprocessor
- Load switches

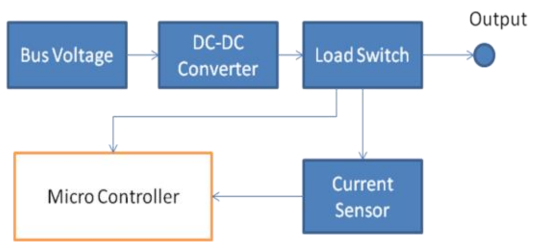

Figure 3 Power distribution architecture of a single load line[8]

A. Switch Mode Power Supplies

In satellites it is obvious to know that power loss cannot be tolerated, so it is needed to keep this to the minimum level. SMPS (DC-DC converters) are highly efficient with minimum power loss as compared to the Linear Regulators. Linear regulators are less efficient as the input and output voltage values and load current differ, results in the heat loss[9].This is because Linear Regulators use some components like zener diodes and transistors that become the cause for the heat dissipation. SMPS vary their power conversion, hence solving the issue of voltage difference that arises in Linear Regulators[10] Another edge switch mode power supplies have over Linear Power Supplies is that they can step up as well as step down the voltage, where as linear regulators can only be regulated at lower voltages[9].Given below is the detailed comparison of Switch Mode Power Supplies and Linear Regulators:

SWITCH MODE POWER SUPPLIES	LINEAR REGULATORS
1-Highly efficient	1-Less efficient
2-No heat dissipation	2-heat dissipation
3 Provide both step up and step down voltage conversion.	3- Only perform step down DC-DC conversion.
4-No input and output voltage difference arises.	4-There is a difference in input and output voltage
5- Noise issues like EMI.	5- Lower noise issues.
7-Less economical	7-More economical

Table 3 Comparison b/w DC Regulators and Linear Regulators[9][10][11]

This is the very reason to use switch mode power supply in PNSS-1. There are two types of DC-DC converters which can be used in SMPS:

- Buck Converters.
- Boost converters.

Boost converters are used to step up the provided voltage and Buck converters are used to step down the voltages. As the power distribution unit shall receive 28 ± 6 V from the solar panel and convert these voltages into 5V and 12V regulated voltages and then distribute them according to the requirement. Currently soft switching technique can be used for Buck, Boost or Buck-Boost converters, because when switching frequency increases switching losses also increase. In soft switching techniques either voltage or current is set to zero in switching transitions, this helps in minimizing switching losses. [11]

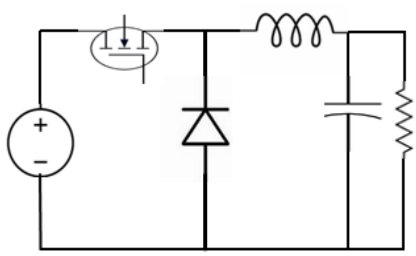

Figure 4 Buck Converter Circuit

B. Current Sensing Circuit:

Current sensing is essential part of the power distribution module as it is required to ensure that all the currents through the lines are within their prescribed limits. If the currents exceed the limit then it may damage the load and as well as affect the voltage supplies.

It is more complicated than voltage sensing because voltage can be sensed at any point. However for current measurement we need to incorporate some kind of sensor inside the module in such a way that it does not affect the system in any way

There are many techniques for current sensing. Since we are working on satellites therefore we need to consider the factors of redundancy, reliability, cost and accuracy into account before we choose any technique. There are magnetic current sensors, hall sensors, current mirror configuration sensor circuits and simple resistive sensing circuits.[12]

Keeping in view the pros and cons of every technique we have selected INA 226 current sensing IC mainly due to the following reasons

- Simpler
- Lesser no of components hence greater reliability
- Less space occupied
- More economic
- Readily available components
- Can handle high current for small time

This current sensing IC can sense current on a line with voltage from 0 to 36V. This IC provides 16 programmable addresses through I^2C Interface.

C. Load Switch

Due to high capacitive loads and chances for short circuit where heavy current could flow, just like the case we have in our power distribution module, power distribution switch needs to be added. Power distribution switch consists of N-type MOSFETs. The device is responsible for switching the load off in case of a short current. [16]

We have selected SIP32429 as a load switch[17]. The over current protection circuit monitors the current passing through the switch, if the current exceeds the limit, the switch turns off and the load is disconnected and hence saved from damage. This switch also implements thermal protection and gets disables if the temperature exceeds the operating temperature range of the IC.

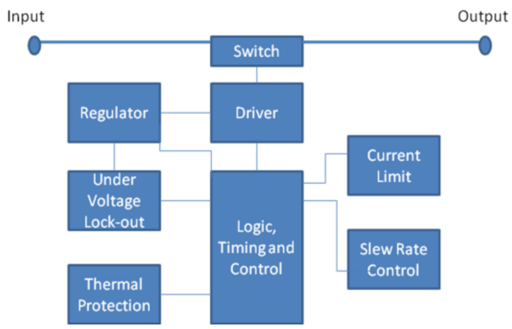

Figure 5 SIP32429 Functional Block Diagram

D. Micro controller:

. A micro controller will also be incorporated in the module.

The main purpose of the micro controller will be switching OFF/ON of the switchable loads

Also will be able current limit the Non-switchable lines in such a way that these shall never be permanently disconnected from the load while still protecting the primary source against load faults and over-current. This will be done by current sensing and voltage sensing function of the load lines. The micro controller will also receive telemetric commands from the Data Handling Unit and will also send the telemetry signals of current, voltage at each line, also the primary voltage and current at the input of dc-dc converters. The telemetries and telecommands will be transmitted through the CAN bus. We have selected PIC18F8585 for this module. It also has inbuilt CAN facility.

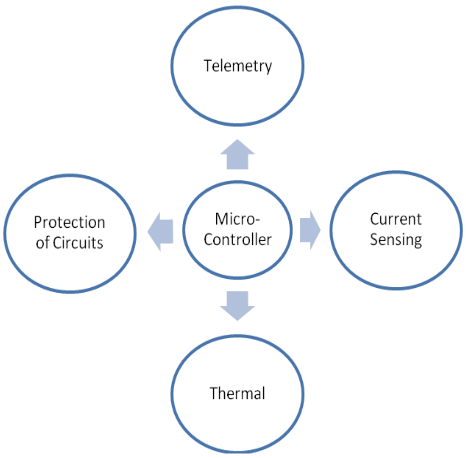

Figure 6 Functions of Microcontroller

VI. Space Related Challenges

There are a lot of challenges while designing a module for small satellite. Some of them are as follows[9]

A. Redundancy:

This factor is to be kept in mind while from component level to the whole level as redundancy increases reliability which is an important parameter for space design. But the main issue with dealing redundancy in small satellites is that lesser space is available and the components are larger due to the redundancy factor. So while selecting the components we had to consider those with high efficiency and lesser space occupied.

B. Space Radiations:

There are a lot of radiations from the stars in the outer space. These radiations can affect the performance of the components. Hence special type of components are used in designing that are immune to these radiations. These components are known as rad hard components. However this is supposed to be a low cost satellite therefore we have employed COTS components instead.

C. Cost:

Since it is an experimental satellite that is to be designed by students, therefore it is low cost. Hence in selection of components we had to select components with high efficiency but low cost.

D. Thermal control:

Temperature of the components need to be monitored and controlled to maintain the temperature. Some of the components might generate too much heat and hence they need to get rid of this heat by the process of thermal conduction to other parts of the satellites. Also some of the components may get too cold due to the cold temperature environment of space. Hence a heater is also employed in the module which will turn on when the temperature falls below the lower limit. This will also be heat transfer through radiations. Or we may insulate them to avoid any heat loss

.

VII. Conclusion

Power system is the only independent module working in the satellite. It needs to be fast, reliable and efficient. It can be considered as a knowledge based artificial intelligence system that has to take decision based on the scenario at the moment. In future, we can take up this concept to larger space crafts as well and make it autonomous.

In this paper, the main design of the power distribution module of a small student satellite has been discussed. We have seen that this module is able to supply regulated voltages and currents according to the requirements of the satellite.

In the follow up , we will try to optimize the performance of these components and will focus on the thermal control and Electromagnetic Interference (EMI) encountered during switching of loads.

The final design will be based on the space graded components and will go through vigorous testing so that it can survive in the harsh space conditions.

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IX. References

[1] "http://www.ist.edu.pk/news/2013/icube-1-launch." .

[2] A. Sabih Zaidi, Z. Arshad, and K. Sarwar, "Pakistan National Student Satellite-1 System Concept Design," SUPARCO, Islamabad, Pakistan.

[3] H. S. Wong and M. J. Blewett, "The UoSAT-2 spacecraft power system," *J. Inst. Electron. Radio Eng.*, vol. 57, no. 5S, pp. S116–S122, 1987.

[4] R. Burt, "DISTRIBUTED ELECTRICAL POWER SYSTEMS IN CUBESAT APPLICATIONS," UTAH STATE UNIVERSITY.

[5] K. Fowler, "http://www.kepcopower.com/fowler.htm." .

[6] U. Iftikhar, M. A. Sibtain, and M. T. Hussain, "Pakistan National Student Satellite-1 Power Distribution Unit Requirement Document," SUPARCO.

[7] Z. Wu, Z. You, and J. Salviqnol, "Tsinghua-1 Micro-satellite power system architecture and design," *Tsinghua Sci. Technol.*, vol. 6, no. 4, pp. 289–293, 2001.

[8] C. C. Huang, C. K. Tseng, and J. J. Yeh, "FORMOSAT-5 satellite Power Distribution circuitry development," in *Signal and Power Integrity (SPI), 2012 IEEE 16th Workshop on*, 2012, pp. 129–132.

[9] Knut Olav and Skyttemyr, "Design and Implementation of the Electrical Power System for the CubeSTAR Satellite," University of Oslo, 2013.

[10] "http://www.engineersgarage.com/articles/smps-switched-mode-power-supply." .

[11] "AN140fa.pdf." .

[12] B. Mamanno, "Current Sensing Solutions for Power Supply designer."

[13] "http://electronicdesign.com/power/eliminate-latching-current-limit-power-supplies." .

[14] C. Cockrill, "Understanding Schmitt Trigger," Texas Instruments.

[15] N. Storey, *Electronics A systems approach*. .

[16] "NCP382-D.PDF." .

[17] "slvs182.pdf." .

[18] R. Oliveira de Magalhaes, "POWER CONDITIONING AND DISTRIBUTION UNIT OF CHINA-BRAZIL SATELLITE CBERS3.