Chapter 7
Conclusions

Abstract

This chapter concludes on the electronic scheme, which has been implemented for the power supply subsystem, in the CubeSat satellite. The scheme is evaluated, in respect with the demands of the application stated in Chapter 1 and conclusion are drawn.

7.1. Conclusion

Solar cells

It was supposed to receive triple junction solar cells fabricated by EMCORE company. But still we have not got any more accurate data about them. As can be seen from equation used in SABER simulation, the behavior of solar cell is dependent on a lot of parameters. So far as simulation has been performed, majority of parameters were guess. Due to this statement, results obtained from simulation can be taken only for general conception. There is not any problem, after receiving real data, to run simulation again and profit proper results.

The final scheme of the power supply is presented in figure 3.4 in chapter 3.

Input power

In section 3.3, the input power from the solar arrays is computed.

- Average input power, per one side: $P_{av} = 2.07$ [W]
- Albedo radiation power, for one side: $P^{*}_{ALB} = 0.554$ [W]
- Infrared radiation power, for one side: $P^{*}_{IR} = 0.324$ [W]

It is shown that the most favorable situation is when three sides of the satellite are illuminated by Sun. From characteristic of the solar cells, it is deducted that a certain amount of power can be delivered considering the infrared and albedo energy radiated by Earth. This quantity is calculated and it has been proposed as a mission statement to verify it through housekeeping data which will be sent back to Earth.

A theoretical background about photovoltaic and batteries is presented, as well as an overview of different possibilities of implementation, existent on the market.

Concerning the application and the specifications for the system, batteries are chosen to be four Li-Ion type.

Thermal model

First of all was computed the temperature equilibrium for the satellite, considering no internal heat sources. If all equilibrium temperatures are compared than can be seen that the worst case for Cubesat is in eclipse when only side with camera is pointed to the Earth. Temperature range according to the temperature equilibrium is:

$T_{\max} = 55$ [˚C]

$T_{\min} = -124$ [˚C]

Model of the board in Saber

Highest obtained temperature for switch of step-down converter is 40.9˚C, which is far away from maximum for industrial standard. Of course this temperatures will add up with the temperatures of surroundings and they are not final.

From thermal control shielding for batteries is suggested (as the most temperature sensitive part of power subsystem). MLI can be easily used for this. Also heat pipes seem to be relevant for the current application.

Some basic considerations about electromagnetic compatibility problems are presented in section 5.5. Potential sources of noise are analyzed and a comparison between them is made.

There were a few reasons for not performing all the necessary tests at the time of delivering the report. One of the strongest reasons has been lack of components, due to long delivery time from the manufacturers. Due to constrains about mass and dimensions of the power supply board, all the electronic components have been chosen in respect with reliability (brand-name, well-known manufacturers), small outline packages and high-efficiency. This led to some delays in practical implementation of the designed board. One result is that it has been decided to realize separate PCBs for each module of the power supply and to test them independently, further connections between modules being easy to be done later.

Analog part of the PSU

Test boards have been made for different circuits, which are included in the analog part of the PSU. Until now have been completed tests for battery protection circuit, the step-up converter and battery charger. These circuits are working properly. It has been observed bigger voltage ripple than it was expected at the output of the step-up converter. This was due to the output filtering capacitor used, being general purpose with a large ESR.

MCU

For MCU and it's additional circuits were selected proper components and then final design scheme was created (Appendix C). Also software for supervising power supply unit were designed and written. Program guards protection circuits for each user and in case of failure turn-off user. With measured signals from whole unit MCU can provide OBC with precise information about situation in the PSU. Also from these signals digital MPPT control signal is calculated, furthermore selecting which signal should drive the MPPT converter. As a last function, MCU provide external watchdog and bootpin selector for the OBC. Source code for the software is included on the enclosed CD.

After the development all possible tests, available at the time, were performed on microcontroller and the results obtained are satisfying the demands for the software and hardware, which was described in chapter 2.

Only tests of the communication with OBC must be performed later after testing facility will be prepared. Also tests on the real solar cells must be done to test the digital version of MPPT control signal.

Batteries

The tests performed over the battery protection circuit shown that this device is working properly, implementing an efficient overcharging and overdischarging protection, as expected from the analysis performed in section 4.3. Charging and discharging characteristic for a string of two batteries are depicted in section 6.3.

7.2. Future work

System engineering

It will be necessary to cooperate with other groups next semester and keep track on interfaces. It is still a lot of work to implicate PSU subsystem to the entire design.

Thermal analysis

- Verify 2D model by measurement in vacuum chamber at low temperatures.

2D model:

- It is necessary to find exact values for R_{thjc} for specification of model.
- Make 2D model according to the final PCB, which respecting geometrical position of device.
- Models for other boards if parameters will be delivered.
- Try to include radiation.

3D model:

- Define more sophisticated geometry.
- Connect models for conduction and also for radiation in ANSYS, run them simultaneously.
- Make transient thermal analysis.

Thermal control:

- Consult with MK9 group about using of heat pipes and find hardware
- Design thermal shield for batteries in cooperation with MK9

EMC

- Measurement by using spectrum analyzer on our board must be done

MCU

- Tests of the communication with OBC must be performed later after testing facility will be prepared.
- Tests on the real solar cells must be done to test the digital version of MPPT control signal.

Analog part of the PSU

In order to verify well-functioning of all the modules and to prove the accuracy of the design, further separate experimental tests for each circuit must be performed. After that a general test must be made for proving expected behaviour. In respect with the design work done so far, it is necessary to finish the final board for the power supply. Because of the small outline components selected for the application, this will imply cooperation with some specialized companies in mounting SMD components. A prototype of the entire board is programmed to be finished in the near future.