DESIGN AND DEVELOPMENT OF A POWER CONDITIONING UNIT FOR AN EARTH OBSERVATION MICROSATELLITE

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ABSTRACT

The microsatellite project of the Universities of Naples (SMART) is aimed for the design and development of a small size and mass satellite, but with all functionality foreseen for larger ones. This led to the design of a 28V, fully-regulated bus. Voltage control logic is based on a shunt regulator, which requires a minimum power consumption of 2W. In order to attain 28V for the whole orbit a DC/DC converter is used as battery discharge regulator. On the other hand, battery charge is carried out at constant current.

1. INTRODUCTION

Microsatellites have been firstly aimed at radio amateur communications [1] and technology demonstrations [2]. Successively, a large variety of science applications has been identified, including Earth remote sensing [3, 4, 5, 6].

In this framework, a project was started at the two University of Naples to design and develop a multi-mission microsatellite bus (SMART), with the additional capability to fly high resolution (<10m) electro-optical sensors [7]. Such a mission sets challenging requirements on configuration (sensor allocation and field of view), mass, and power. As for the latter, besides payload consumption, it is worth noting that high resolution requires good attitude performance, which can be obtained by reaction wheels and star tracker. This hardware has an additional impact on the power budget [8]. In order to fulfil the power requirement, a fully regulated electrical power subsystem is envisaged for the SMART microsat [9]. It is based on GaAs deployable solar panels [8], while Li-Ion technology is under consideration to replace the NiCd battery.

In the following, the authors present the design of a power conditioning unit capable of managing this level of power (~110W peak; ~50W average) within microsatellite constraints. In particular, the voltage control technique is outlined as well as the hardware implementation. Battery charge and discharge is also described. As for the other subsections (power distribution, data management, and panel status monitoring), only functional features are described, since they are still under design.

Hardware is selected on the grounds of cost and delivery time. Whenever possible space qualified components are envisaged, but existing off-the-shelf components are also used, provided that operational pressure and temperature ranges are compatible with space application. In the latter case, tests are to be performed at the University laboratory facility (thermal vacuum chamber, shaker) to verify design choices.

2. POWER CONDITIONING UNIT SECTIONS AND FUNCTIONS

The power conditioning unit is divided into different sections which manage different functions.

- ***Solar panel management*** mainly consists in the parallel connection of the five solar panels, whose currents are measured. ON/OFF switches on each solar panel line are under consideration in order to limit the power dissipated through the shunt regulator and/or to force battery discharge.
- ***Voltage regulation*** keeps bus voltage at 28V in sunlight. The section consists in a shunt regulator (§3).
- ***Battery management*** consists in a battery discharge regulator (BDR) and a battery charge regulator (BCR). The former is a DC/DC converter which regulates the bus voltage at 28V, while the latter is a current regulator (§4).
- ***Power source management*** switches BDR whenever the solar array is not able, partially or totally, to supply loads. It also enables the supply line to BCR whenever possible.
- ***Power distribution*** manages and switches the supply power according to the power needs and switching functionality of the different kind of loads. It is divided into three sub-sections:
    1. Switchable, current-limited loads. These lines are also protected against load failures by a blocking unit (capacitive/inductive loads).
    2. Unswitchable, current-limited loads (receiver and the computer). These lines are also protected.
    3. Switchable (pyroshock mechanisms). These lines are unprotected and without limit on current.
- ***Data management*** is the logical interface with computer. It manages and formats status, commands, and measurements. Besides voltage and current, temperature measurements are to be envisaged for critical components.

3. VOLTAGE REGULATOR

Voltage regulation in sunlight is based on a shunt-logic (Fig. 1). In particular, a Zener diode (Z) gives the voltage reference signal, while a voltage divider gives a signal proportional to the actual bus voltage. The operational amplifier (OA) generates an error signal, which is the command for the bipolar junction transistor (BJT). The latter regulates the shunt current (proportional to the power dissipated through the regulator). It is worth noting that the OA acts as a sensor and control logic, while the BJT as an actuator. The configuration, in terms of transistor type (npn or pnp) and OA input connections, has been selected so that the system is stable.

An increase in the output voltage causes an increase of the currents through the

Zener and the voltage divider. Thanks to Zener properties, the error signal becomes larger. Consequently, the current in the shunt row increases and the current to the loads is reduced. As a consequence, bus voltage is stabilised to the nominal value. Of course, the overall functionality is assured by the OA virtual short behaviour.

In order to limit the number of DC/DC converters, the OA is supplied on the ground and on the bus voltage. Due to this supply configuration and considering the constraints of OA's output, a minimum current always flows through the shunt branch. Considering also currents through the Zener and the voltage divider, a power dissipation of ~2W is foreseen.

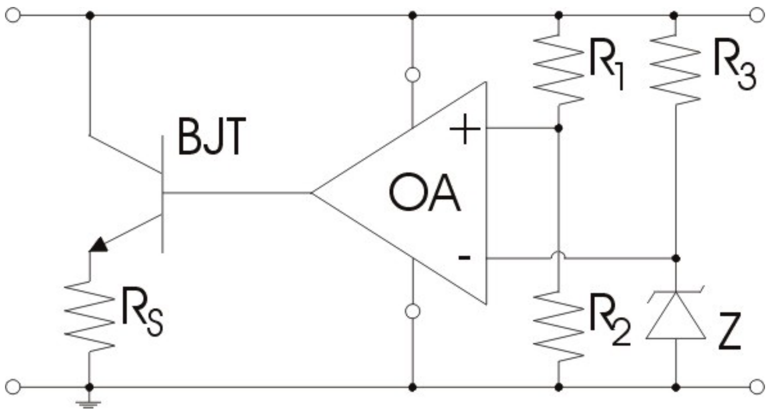

Figure 1. Voltage regulation section

4. BATTERY MANAGEMENT

NiCd battery was firstly selected for the SMART satellite, while Li-Ion are presently under analysis, thanks to its great performance in terms of power density. In particular, Li-Ion technology is currently under qualification for large satellites, while programmes to qualify small capacity Li-Ion cell could be started next year.

Battery management consists in two main functions: charge and discharge. As far as the former is concerned, constant current charge is a requirement which both NiCd and Li-Ion technology share. Therefore, BCR is basically a current regulator [10], which senses battery voltage (to get the end-of-charge signal).

Problems can arise when current is available for charge, but it is smaller than required. Therefore, charge management logic is based on the assumption that battery charge is enabled by the Power Source Management Section whenever the proper current is available. This implies the need for shunt current sensing, which is to be implemented within the voltage regulator.

As for discharge, since the number of series-connected cell is dimensioned on the basis of bus voltage and battery cell charge voltage, bus voltage during eclipse tends to be well below the nominal bus value. Therefore, battery discharge is performed by means of a DC/DC converter whose output is the nominal bus voltage. Such a design implies that battery package works at a lower voltage level but with a current larger than the one flowing through the loads. Therefore, battery capacity must be properly selected, considering the actual current to be supplied by each cell string.

5. CONCLUSION

The authors presented the status of the SMART microsatellite power conditioning unit design. In particular, the authors described its functionality and subsections. The voltage regulation and the battery management sections, which are in a more advanced status, are treated in more details.

The main design driver was to have a unit which could bear as many resemblances as possible to the corresponding unit of a bigger satellite. The objective of the SMART project is indeed the realisation of a microsatellite where “micro” applies only to size and mass, while functionality is preserved. This approach was selected because, besides research aims, SMART programme was started in order to involve students in design and development activities.

The voltage regulation technique has been identified and its hardware implementation is currently under realisation. The shunt logic allows to use a control technique simpler than the one required by peak power tracking. It gives a 2W continuous power consumption which must be included in the power budget.

With reference to battery management, charge is performed at constant current, while discharge is carried out at constant voltage by means of a DC/DC converter. Shunt-current sensing is also required in order to enable battery.

6. REFERENCES

1. Jansson D., 1987. Spacecraft Technology Trends in the Amateur Satellite Service, *Proceedings of the 1st Annual AIAA/USU Conference on Small Satellites*, October 7-9, Utah State University, Logan, Utah.
2. N.P. Bean, J.M. Radbone, M.N. Sweeting, and J.W. Ward, 1988. The UOSAT-C, D & E Technology Demonstrations Satellites, *Proceedings of the 2nd Annual AIAA/USU Conference on Small Satellites*, September, Utah State University, Logan, Utah.
3. Kilgus C.C., E.J. Hoffman, W.E. Frain, 1989. Monitoring the Ocean with NAVY Radar Altimeter Lightsats, *Proceedings of the 3rd Annual AIAA/USU Conference on Small Satellites*, September 26-28, Utah State University, Logan, Utah.
4. Redd F.J. and T.A. Olsen, 1990. Microspacecraft and Earth Observation: the Electrical Field (ELF) Measurement Project., *Proceedings of the 4th Annual AIAA/USU Conference on Small Satellites*, August 27-30, Utah State University, Logan, Utah.
5. Mostert, S., and J.A. Koekemoer, 1997. The Science and Engineering Payloads and Experiments on SUNSAT, *48th Congress of the International Astronautical Federation*, October 6-10, Turin, Italy (paper IAF-97-IAA.11.1.04).
6. Sungdong Park *et al.*, KITSAT-3 Launch and Initial Operations, *5th International Symposium on Small Satellites Systems and Services*, June 19-23, La Baule, France.
7. D’Errico, M., and S. Vetrella, 1997. Mission Analysis of an Earth Observation Microsatellite, *48th Congress of the International Astronautical Federation*, October 6-10, Turin, Italy (paper IAF-97-B.3.01).
8. D’Errico M. and M. Pastena, 1998. Solar Array Design and Performance Evaluation for the SMART Microsatellite, *49th Congress of the International Astronautical Federation*, Sept. 28- Oct. 2, Melbourne, Australia (paper IAF-98-R.1.06).
9. D’Errico M. and M. Pastena, 2000. Design of the SMART Microsatellite Electrical Power Subsystem. *Proceedings of the 5th International Symposium on Small Satellites Systems and Services*, June 19-23, La Baule, France, pp. 12.
10. Pastena M.and M. Grassi, 1999. Design and Performance Analysis of the Electronic Power Subsystem of a Multi-Mission microsatellite. *Acta Astronautica*, Vol. 44, No. 1, pp. 31-40.