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Power system design and in orbit performance of Algeria's first micro satellite Alsat-1

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Abstract

On the 28th November 2002, Algeria's first enhanced micro satellite was launched into a 686 km low earth orbit onboard a Cosmos 3M rocket from Plesetsk. The spacecraft was designed, manufactured and launched as a technology transfer programme between the National Centre of Space Techniques (CNTS) Algeria and Surrey Satellite Technology Limited (SSTL) United Kingdom in the timescale of 18 months.

This paper will describe the design and in orbit performance of the mission power system, stressing the decisions taken in order to meet the mission requirements within the 18 months, concept to launch programme.

Most of the design and construction techniques used in the production of the Alsat-1 power system were based on SSTL heritage over the years. It will be shown how off the shelf components either for the generation or storage of the onboard energy can be applied successfully to such missions.
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Keywords: Alsat-1; Power system; Power conditioning; Power distribution; Battery charge regulation; Orbit performance; Solar arrays

1. Introduction

The investment required to put a satellite into orbit means that every precaution is taken into account to make sure it will not fail once in space. The overriding issue of satellite design is redundancy within certain limits of course. Once in orbit you cannot repair, this is why onboard systems are duplicated at the design stage to provide some safety. This applies especially to the power system which has to deliver the required longevity to the satellite.

Satellite power systems generally rely on a combination of solar panels and batteries. The solar panels energize the satellite while it is in sunlight, while the latter take over when it is in eclipse. Recharging the batteries must withstand a large number of charge/discharge cycles. At the time of writing this article, Alsat-1 has completed 2 years and a half in orbit and the batteries have withstood more than 14,000 discharge cycles [11,12].

2. Spacecraft description

Although this paper focuses primarily on the power system, it is interesting to note the complexity of the spacecraft by briefly introducing its payload and platform subsystems [11,12].

2.1. Payload

Payload data remains stored onboard until the spacecraft is commanded to return the data once in contact with the control and command ground station situated in Arzew. The payload comprises two banks of cameras, a set of solid-state data recorders, and two high-speed downlinks.

The imager comprises six lens and sensor pairs, configured in two banks as part of an overall optical bench assembly. The banks are mounted angled away from nadir by approximately 12°, to double the swath width, but with a small overlap of approximately 5% to aid image stitching. The field of view from each bank is 26.6°.

Each imager includes a linear CCD sensor with 10,200 pixels measuring 7 μm × 7 μm each, providing 32 m ground sampling distance at nadir. The lens provides a wide focal plane. The

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complete instrument provides near 20,000 pixels in the standard bands 2, 3 and 4 (green: 0.52–0.62 μm, red: 0.63–0.69 μm and near infra-red: 0.76–0.9 μm).

The two main solid-state data recorders are configured to provide a 2 × 512 MB of solid-state storage. Software windowing functions are employed allowing the whole or only sections of the full swath to be stored. Each instrument bank is cross-connected to two data recorders. A third functionally redundant 128 MB data recorder based on the SA 1100 is also available. Each half of the instrument can be powered separately, which allows flexible management of the onboard power resources.

A high-speed S-band downlink is employed for data retrieval, with 4 W RF power, and operating at 8 Mbps. QPSK modulation is used, with half rate convolutional coding. A quadrifilar helix antenna is employed, providing a circularly polarised, shaped omni-directional pattern, with equal power flux density across the entire footprint [11].

2.2. Spacecraft platform

The platform design for the spacecraft is an enhanced micro satellite measuring 640 mm × 640 mm × 680 mm. The spacecraft weighs 90 kg, of which 19 kg is the payload. The spacecraft has four body mounted aluminium honeycomb panels, with the remaining sides including the spacecraft launch adaptor, sensors, payload apertures and antennas. The structure has been designed to be compatible with a wide range of launchers. The stack of trays carries an optical platform, and between the stack and the panels the battery, wheels and propulsion system are carried. The spacecraft employs a fully passive thermal control system.

For the spacecraft to be able to carry out initial launch injection corrections, a propulsion system is included. A butane based monopropellant system was selected, as it provides a high density Isp, allowing lower volume tanks to be used when compared with a conventional Nitrogen system. A further advantage is that the storage pressure is much lower, reducing shipping and safety concerns.

The propulsion system delivers approximately 20 m/s deltaV, and comprises 2 cylindrical tanks holding 2.5 kg of propellant, and a single low-thrust thruster augmented by a small resistojet to boost its efficiency. The system is designed as "V" shape onto the spacecraft base plate, alongside the propulsion-controller electronics.

A GPS receiver is carried to aid navigation during the critical phases and also provides an accurate spacecraft clock [11].

The power system comprises four body mounted GaAs solar panels and a 4 Ah NiCd battery. A raw 28 V bus is distributed alongside a regulated 5 V bus. Lines are electronically switched and over-current protected with electronic switches. The system delivers over 30 W orbit average power with 12 W for the platform and 20 W for payload operations [1,5].

The telemetry and telecommand system employs S-band with a dual redundant CPFSK 9.6 kbps uplink, and a single 38.4 kbps QPSK downlink, with redundancy provided by the two payload downlinks. The uplink employs patch antennas, whereas the downlink employs a simple monopole antenna. The data handling system employs a dual redundant control area network (CAN) bus for distribution of telemetry and telecommand, as well as small file transfers and boot loading. Two functionally redundant onboard processors are carried. The OBC186 is used for housekeeping, and an OBC386 for attitude control.

3. Power system description

The primary power to the satellite is supplied via 4 solar panels. The power from each of the four solar panels is fed into a dedicated battery charge regulator (BCR), i.e. one BCR per solar panel. The output of the BCRs is connected to a 22 cell, 4 Ah NiCd battery, the power distribution module (PDM) input and the power conditioning module (PCM) input. The solar arrays and BCR outputs are isolated from each other using one blocking diode per BCR. See Fig. 1 for the power system block diagram. By isolating the solar arrays from the bus using a BCR per panel suits the low earth orbit environment and the nature of the Alsat-1 design for several reasons [3–5]:

1. The maximum power point (MPP of an individual panel can be tracked over the changing thermal conditions while in sunlight.
2. The battery is charged for the majority of the sunlight period efficiency of the power system.
3. The direct connection between the battery and the bus ensures maximum efficiency.

Although, a failure of a BCR can result in a graceful degradation of orbit average solar array power, a failure in the PCM, the PDM or the battery will result in the loss of the spacecraft mission.

As mission lifetime and reliability were considered as key parameters, a momentum biased attitude control system was selected, augmented by a gravity gradient boom. This provides natural platform stability, as well as providing an inherently safe spacecraft attitude configuration [1].

3.1. Solar panels

The solar cells used on Alsat-1 were ENE (Belgium) type single junction GaAs/Ge cells, mounted on aluminium face sheet

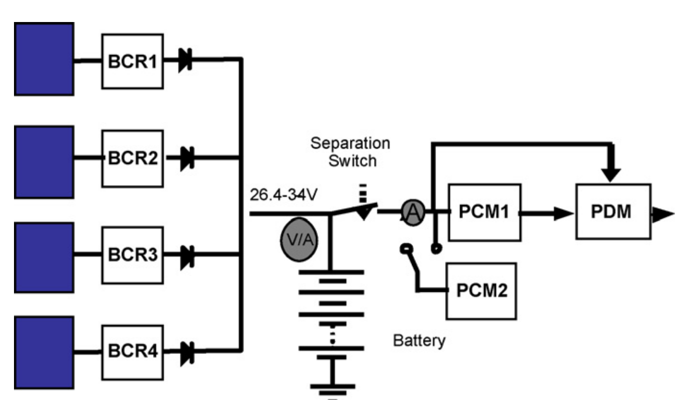

Fig. 1. Alsat-1 power system block diagram.

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