POWER BOARD FOR ILLINISAT-3

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1 Introduction

1.1 Objective

CubeSats are a class of nanosatellites that use a standard size and form factor. The standard CubeSat size uses a “one unit” or “1U” measuring 10x10x10 cms and is extendable to larger sizes [1]. The development of CubeSats grew so much over the past few years that it had advanced into industry with government and academia for increasing capabilities. They now provide a low cost, effective platform for science investigators, new technology demonstrations and advanced mission concepts using constellations, swarms disaggregated systems [1]. With a rapid increase in number of CubeSats launched, there are problems associated with it. During the years of 2010-2015, there has been 187 CubeSat mission launched into orbit, from which only ~50% were successful [2]. Around 15% experienced early loss and around 23% of them were dead on arrival (DOA). The goal of the project is to develop a power board that is very reliable. Instead of introducing more complexity into the system, the system should be as simple as absolutely possible, minimizing the points of failure.

1.2 Background

The CubeSat program at UIUC is responsible for designing an IlliniSat-2, a generic picosatellite bus system. A system that is used for five CubeSat mission that UIUC is currently developing. IlliniSat-2 is a scalable CubeSat platform that handles all communication, power, command and data handling, and attitude determination and control needs for the satellite [3]. The problem with IlliniSat-2 is that it is “too centralized”. This results in longer development time for each mission due to over complicated software. Also, certain parts of the system are too fragile and too slow and the whole bus is more expensive than previously anticipated.

With the launch of Laboratory for Advanced Space Systems at Illinois’ (LASSI) it is now time to develop a better bus system, IlliniSat-3. LASSI mission is to support students, faculty, and other customers utilizing small satellite resources designed, developed and tested at the University of Illinois at Urbana-Champaign. We propose to redesign the power board, which will be responsible for battery charging, voltage regulation and output channel control. For the microcontroller choice, we plan on using the ATSAMS70, but this might change for a less powerful microcontroller. The board will have an RS-422 connection for an extra interface for debugging. There will be a CAN transceiver chip included on the board.

1.3 High-Level Requirements

- The power board must be able to charge two 2-cell Lithium Ion battery packs, as well as read battery voltage and current.
- The power board must have two outputs that provide short circuit protection and programmable over-current limit.
- The power board must maintain healthy battery temperature by controlling Kapton battery heaters based on temperature sensors.

2 Design

The power board requires a battery pack for successful operation. The power from the battery pack is essential to the entire system, and power board ensures that it is distributed safely. The following diagram illustrates the top-level structure of the power board and how it interacts with other parts.

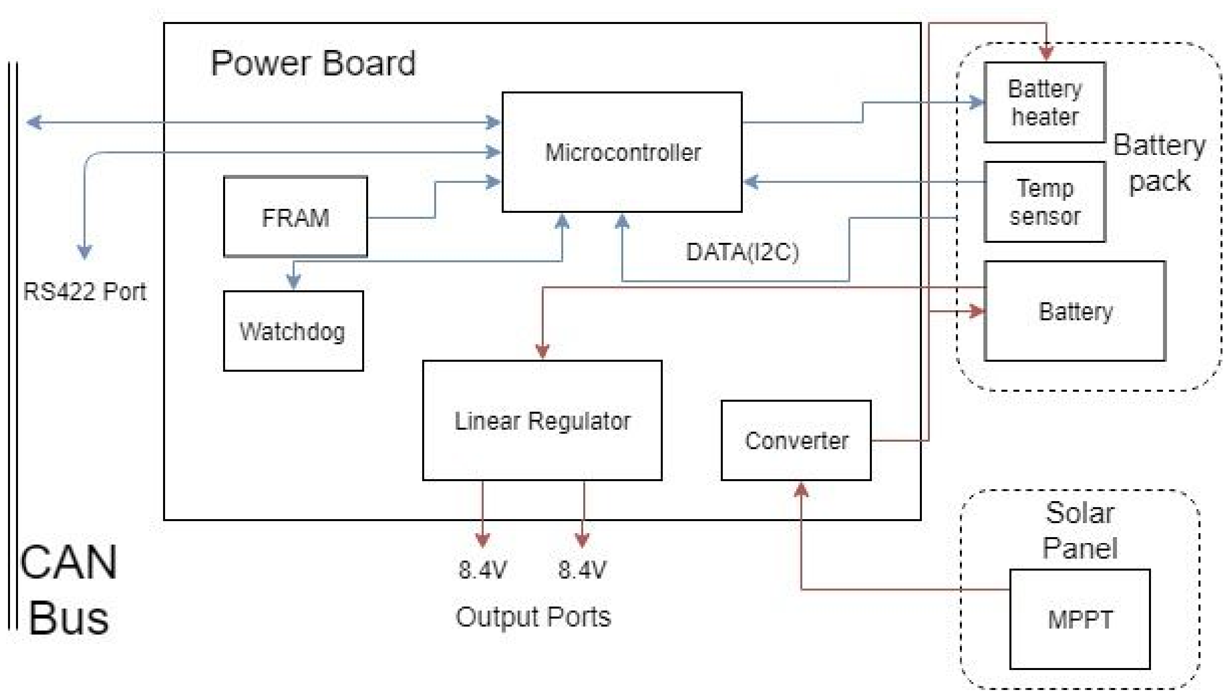

Figure 1. Block Diagram

2.1 Power Board

The power board is responsible for managing the generation, storage and distribution of the electrical power. The raw power from the battery will be regulated and then distributed through hot-swap switches controlled by a microcontroller.

Requirement 1: The power board shall consist of two output ports, 8.4V each.
Requirement 2: The power board should disconnect the power from the system when Remove Before Flight (RBF) connector is inserted, but has to be able to charge the battery pack.
Requirement 3: The power board shall communicate with the rest of the system thought CAN bus.
Requirement 4: The power board shall incorporate a low power microcontroller for communication, power delivery and monitoring.

2.1.1 Microcontroller

A control unit manages the power board. It communicates through the CAN bus with the rest of the system, as well as RS 422 for an extra interface for debugging. The FRAM will hold the powerboard code and load it into the microcontroller on the power on. Microcontroller will also receive telemetry data from the battery pack through I2C port.

Requirement 1: Must be low power, since the power board has to be on at all times over the duration of the mission.
Requirement 2: Microcontroller must have I2C capability.

2.1.2 FRAM

FRAM should store the microcontroller configuration. This block might be removed if we choose a microcontroller with adequate amount of FRAM memory.

Requirement: Adequate amount of memory.

2.1.3 Converter

The power from outside (the solar panel) has to be converted for safe delivery to the battery pack. Correct voltage and current levels have to match the specifications of the battery pack.

Requirement: Must provide the correct voltage and current levels to match the specifications of the battery pack, in order to charge the batteries.

2.1.4 Watchdog

The design needs an external hardware watchdog for reliability despite that the microcontroller might have it's internal watchdog.

Requirement: Must be an external, hardware watchdog.

2.2 Battery Pack

Battery pack contains over and under charge protection and I2C communication lines to send telemetry data. The battery pack is outside the scope of this project, but it is very important aspect of the power system. We will have the battery pack present to test our power board.

2.3 Solar Panel

Solar panel is outside the scope of this project. The solar panel provides power to the converter that resides on the power board, from which the power charges the battery pack.

3 Safety and Ethics

3.1 Safety

Our design will interact with lithium ion battery pack. Although the battery pack has a safety preventing mechanism such as over and under voltage protection and over current protection, we still need to be concerned with several lithium ion battery related safety issues. While storing the lithium ion battery packs, we need to assure the battery packet is away from combustible materials and within the environment with temperature between 5℃ to 20℃. These actions would prevent fire hazard relevant to the battery. We also should ensure a minimum of 50% capacity for the battery before long time storage. While using the charging or discharging the battery, we should prevent overcharge and over discharge, limiting the voltage within 4.2 V when charging, and minimum of 3V when discharging [4].

In our design, we plan on utilizing the DC-DC converter which will effectively regulate voltage passing from the battery pack through the power board to other integrated boards. It is important to provide adequate isolation/space for the DC-DC converter such that other parts of the system have minimum interference. Adequate isolation could protect the converter from high energy transient which most likely will damage the converter [5].

3.2 Ethics

Our design is the redesign and improvement on the old power board used in previous version of IlliniSat bus. In the new design, several integrated parts such as battery packs and battery heaters will remain unchanged. In our report and design process, we need to clearly identify the unchanged parts and give credits to their designer/author, following the ACM Code of Ethics 1.5 and IEEE Code of Ethics #7, “Respect the work required to produce new ideas…...” [7] and “......to credit properly the contributions of others” [6].

Our work involves understanding and building upon many engineers’ work before us. It is important that we do not share their work publicly and use their work to obtain benefits without the approve from the original author. IEEE Code of Ethics #2 clearly stated, “to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties …...” [6].

While working on this projects, we will receive advice from professors and graduate students. It is crucial to acknowledge their advice and criticism. This practice would help our team to recognize and correct errors and mistakes quickly and effectively. According to IEEE Code of Ethics #7, “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors…...” [6].

References

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