ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

LASSI POWER BOARD

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1 Introduction

1.1 Objective

Our Sponsor, the Laboratory for Advanced Space Systems at Illinois run by Professor Lembeck, is currently designing the, Illini-Sat 3, their next generation model of cube satellites. We have been tasked with designing the power board for this satellite design. This power board must provide regulated voltages from solar panels and the battery and ensure the battery is in operational parameters. The power board needs to be able to measure the power system parameters for telemetry purposes. Additionally, it must provide control measures to energize or secure loads as required through the interface. The system will interface to the rest of the satellite over a controller area network (CAN-bus).

1.2 Background

The current power board used by the Illini-Sat 2 was developed over a 2.5 year period and carries and impressive array of features. Professor Lembeck wants the next generation board to have a more streamline design such that it is easily integrable with future systems. As a result, this new power board will be designed to be reliable as possible. Since the rest of the satellite is still being developed this design of the power board will serve as a baseline for future iterations. As this is the first design, we are aiming for a single channel design which can easily be scaled to meet the future requirements of the satellite, so additional modules can be added. Our board will serve as a test channel for the design and development of other modules.

1.3 High-level Requirements

1. Provide means for on-board battery charging, monitoring and temperature control.

2. Provide regulated dc bus power rails to support on-board instrumentation and control equipment, along with hot swaps.

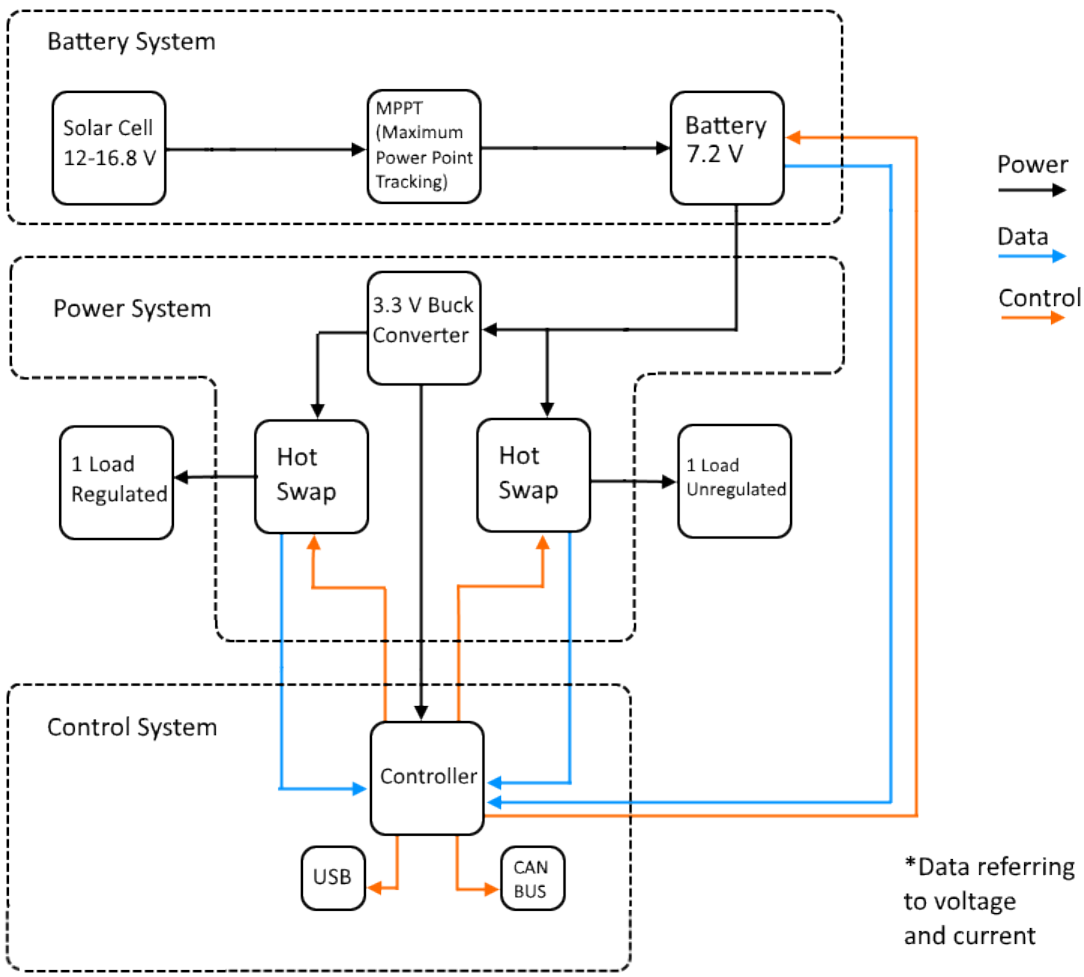
3. Provide protective features for the system to maximize resiliency of the power supply in case of fault conditions. This will include a watchdog timer which can reset the controller in the event of a fault.

4. Read voltage and current readings from the hot swaps on the power board.

5. Implement CAN-bus protocol for communication between the control system and the rest of the satellite.

2 Design

2.1 Block Diagram



2.2 Physical Design

Ultimately, the final iteration of the Illini-Sat3 power board will need to fit on PCB with dimensions of less than 10 by 10 cm and a height of less than 1.5 cm from the top of the board. This will be a multi-semester project as the previous iteration of this board took 2.5 years to develop. Our design will be the first iteration in this process, we have communicated with our sponsor who has requested that we design our model on two PCB's one of which will have the analog power components, and the other will hold the control components to include the micro-controller. In this way it will allow greater modularity for the purposes of building and demoing. This will also allow future groups to more easily build off our design. Also, this will allow LASSI to more easily use our board as a test channel to design and development other modules in the satellite. We will also ensure our design is easily scalable so as the Illini-Sat 3 is developed this power board can easily be adapted by future groups.

2.3 Functional Overview and Block Requirements

2.3.1 External Components

Battery and monitoring system

The design of these components is outside of the scope of this project; however, our system must be designed such that it will interface properly with these components. Due to the nature of this project our design must be flexible enough in nature to function properly with any configuration of these devices. The Batteries will additionally be assumed to be configured 2s2p utilizing INR18650 MJ1 3500mAh Li-ion cells. The following requirements are functions of the battery and monitoring system assumed in the design of the power board. These features are based on the current iteration of the Illini-sat2 bus architecture.

Requirements:

1. Means for monitoring SOC (state of charge) a crucial parameter for the proper operation of the solar power converter.

2. Means provided for battery temperature regulation to include

   a. Heaters

   b. Sensors (negative temperature coefficient thermistor desired)

c. Interface for control signals.

3. Means provided for battery balancing and protection

Solar Panels

The panels serve as the energy source of the satellite. The design of the panels is outside the scope of this project. The following requirements are functions of the solar panel system assumed in the design of the power board. These features are based on the current iteration of the Illini-sat2 bus architecture.

Requirement:

1. Cells will be properly arranged and appropriately configured to be consistent with previously obtained flight data.

2.3.2 Power Components

Solar power converter

Interface between energy source and the power board. Will be implemented with a buck converter with advanced regulation schemes. Due to the low power efficiency of solar cells, will operate in a maximum power point tracking mode of operation during high power demand. Due to basic power balance restrictions this converter must additionally operate in non-MPPT modes of operation based on the power demand of the system. Requires external control signals to determine the proper mode of operation. The implementation of the MPPT scheme will be an extremely simple strategy to serve as an experimental tool for developing an optimum scheme that is mission dependent. The MPPT scheme used here will be a “set it and forget it” strategy as opposed to the more optimal and complicated hill-climbing type algorithms attempted in previous missions. The biasing network for the input voltage regulation sensing pin will be outfitted with a variable resistor for the purpose of testing with PV panels and loads.

Requirements:

1. Must be capable of converting energy from PV panels and charging the Li-ion.

2. Efficiency is most important figure of merit.

3. Must be capable of operating in MPPT mode via input voltage regulation method. (for battery charging operations.)

4. Must be capable of operating in constant output voltage mode. (For battery float/trickle operations.)

5. Must enter standby mode in periods of low illumination. (i.e. low quiescent power consumption mode of operation.

Battery to 3.3V DC/DC converter

This regulator serves the purpose of providing a 3.3V regulated supply to service both payloads as well as the on-board micro-controller. It is appropriately sized to facilitate both load types and should serve to minimize redundant 3.3V converters elsewhere in the satellite. This serves as a design trade off between efficiency and space. As is such this converter must as efficient as practical understanding that at low load efficiency will suffer. As these are the design goals the proper topology for this regulator will be a synchronous buck converter.

Requirements:

1. Must be very efficient at high loads.

2. At max current condition for the regulator must be within the ripple specification for the micro-controller.

3. Must operate in CCM (continuous conduction mode) for all loads and have acceptable ripple performance.

4. Must be capable of delivering maximum anticipated load. (value will be assumed based on previous flight data.)

Hot Swaps

The Hot swaps simply provide a means for the CDH section to energize or secure loads as necessary. These also have OC and UV protection features for system reliability. For this project two hot-swaps will be provided, this will be scaled based on mission needs in the future. The first serve as the supply for unregulated loads this will be at battery voltage with an assumed maximum load current of 3A. The second hot swap will provide regulated 3.3Vdc with an assumed maximum load current of 2A.

Requirements:

1. Hot swaps will provide the power delivery system with over-current protection in the event of a faulty payload.

2. Hot swaps will be provided with a means to automatically re-attempt energization to see if the fault condition has cleared.

3. Hot-swaps will be capable of to energizing and securing power to loads on a routine basis that reflect the system energy requirements.

2.3.3 Control Components

Micro-Controller

The control system on the power board will be run by a micro-controller. The controller must be able to interact with the sensor data from the battery and power components as well as send the proper control signals within I2C standards. The processor must also interface with the rest of the satellite within CAN-bus standards. We have coordinated with our Sponsor and have agreed that the STMicroelectronics STM32F072RBT6TR[1] micro-controller is the best fit, as it fulfills all of our requirements and the STMicroelectronics controllers have a good track record at a reasonable cost.

Requirements:

1. I2C compatible for communication with hot-swaps and battery pack.

2. CAN-bus compatible to interface with rest of satellite

3. USB-compatible for easy programming and debugging

4. Can run on a 3.3V power source provided by our Buck Converter.

5. A/D sensors capable of measuring voltage between 0-7.4 V

6. Watchdog Timer to reset system in case of a fault.

Multiplexor

Given this is the first iteration of the power board, our design will serve as a solid prototype for the power and control methods which will be incorporated into future designs. With this in mind, scalability is of the highest importance as the Illini-Sat 3 is still in the design phase and additional requirements may need to be added in future semesters. A MUX will be used to channel the sensor signals into the required processor pins, this way an arbitrary number of additional power components can be added without significantly changing the control system.

Decoder

The decoder will ensure scalability of control signals output by the microprocessor in the same way as the MUX will do for sensor signals.

2.4 Risk Analysis

Due to the mission objectives of the LASSI program, we must adhere to the rigorous standards of safety for objects transported to the International Space Station. Given the high cost of building and launching a satellite it is critical that the power board is reliable and sufficiently redundant to ensure mission success. The final design of the power board will feature multiple redundant channels to ensure there is no single point of failure in the board. At this point in the development process we must ensure acceptable performance of a single channel that can easily incorporate additional channels. Fault protection will be incorporated into each of the hot swap units to ensure overall system reliability in the case of a single payload failure. We will also provides a means to secure power to unnecessary loads during eclipse periods in order to precluded unnecessary draining of stored energy.

3 Safety and Ethics

The greatest safety risk in our project is the battery pack that the Illini-Sat 3 will used as its power source. Lithium Ion batteries can catch fire if they are not kept within operating parameters. One of the high-level requirements of our power board is to ensure the battery is kept within proper temperature and operating conditions. We will adhere to the lab safety precautions when testing our system and will not implement the battery pack into our system until we can ensure the appropriate sensors are working within design parameters.

As engineers we will make sure to follow the ACM Codes of Ethical and Professional Conduct [2]. According to code 2.9 we must “Design and implement systems that are robustly and usably secure.” This essentially is the purpose of our project, to design a power board which is more reliable to ensure a better success rate with this new generation of satellites.

References

[1] "STM32F072RBT6TR Datasheet," STMicroelectronics. [Online]. Available: https://www.mouser.com/datasheet/2/389/stm32f072c8-956183.pdf [Accessed: 02-Feb-2019]

[2] "ACM Code of Ethics and Professional Conduct," Association of Computing Machinery. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 02-Feb-2019].

[3] Wang, Zipeng. "DESIGN OF A SCALABLE NANO UNIVERSITY SATELLITE BUS," Senoir Thesis. University of Illinois at Urbana-Champaign, 2018.