Development of a Low-Cost Energy Storage Solution for CubeSats

Mission for Education and Multimedia Engagement Satellite (MEMESat-1)
The University of Georgia Small Satellite Research Laboratory

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Introduction

The Board of Batteries (BoBa) is the battery management and energy storage board for MEMESat-1. BoBa captures the energy generated by solar panels during periods of illumination and provides power to the satellite during eclipse. This research focuses on the development of a simple and effective electrical subsystem that uses a low-cost Lithium-Ion battery pack to store and supply power to the satellite. Heating and battery management circuits keep the batteries within desired temperature and voltage ranges. BoBa's objective is a simple and low-cost satellite energy storage system; consequently, these designs are implemented with affordable consumer parts. BoBa challenges the necessity of expensive and complicated power systems by providing an accessible, inexpensive, and straightforward solution for CubeSats.

Battery Management

BoBa contains a Ricoh battery management system integrated circuit (IC) to protect the batteries against extreme fault conditions. This IC monitors the state of the batteries to determine if there is an over-charge or over-discharge condition. If either situation occurs, the batteries are disconnected from ground and reconnected once the batteries return to a safe voltage.

Design Overview

BoBa is comprised of 4 Lithium-Ion cells arranged in a 2S-2P (2 in series, 2 in parallel) configuration to increase both the battery capacity and voltage supplied. A single battery cell is rated for 3,400 mAh at a nominal voltage of 3.60V; BoBa's capacity will be 6,800 mAh with a nominal voltage of 7.20V. This battery pack is connected to a Printed Circuit Board which contains peripheral circuits to ensure essential functionality. These circuits include a battery management system, a heating regulation component, and pre-flight inhibits. BoBa is validated through charge cycle testing which ensures the system obtains the rated depth-of-discharge, disconnects batteries in over-charge or over-discharge conditions, and re-charges when integrated with a solar panel system.

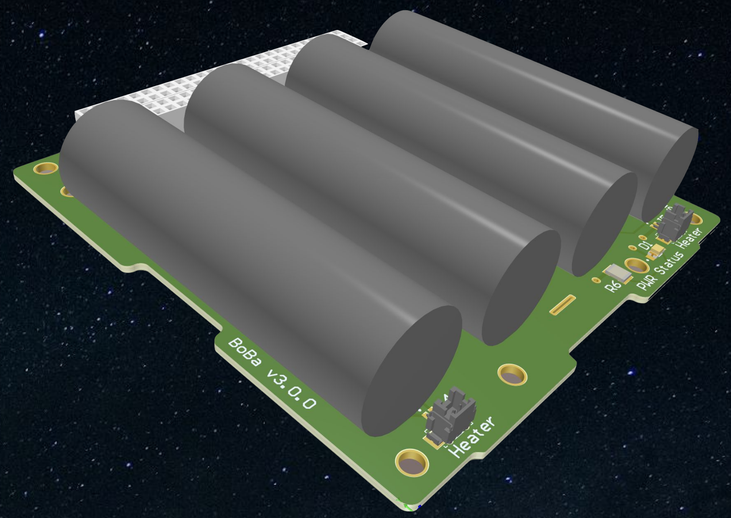

Figure 1. BoBa CAD Model

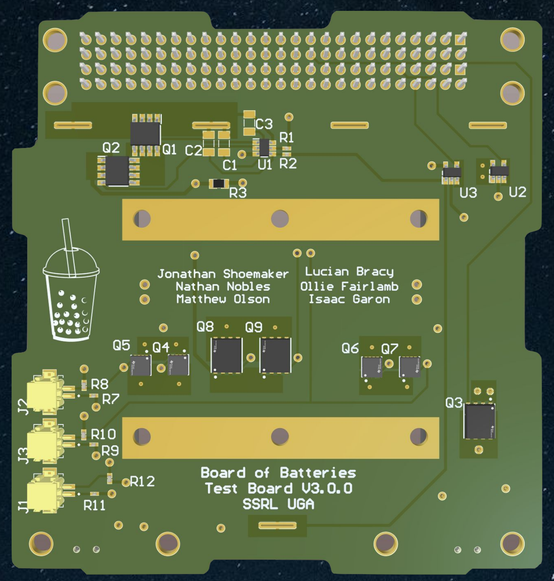

Figure 2. CAD of BoBa Circuitry

Heat Regulation

The Samsung 35E batteries used onboard BoBa have an operating temperature of [0,45] ˚C. To ensure nominal operation and extend battery lifetime, a heating subsystem regulates the system temperature. Two Kapton heaters are attached to the batteries and operated by a low-side MOSFET. Additionally, two thermistors monitor the temperature of the batteries. A microcontroller can utilize this subsystem by observing the temperature of the batteries and operating the heaters to adjust the temperature as needed.

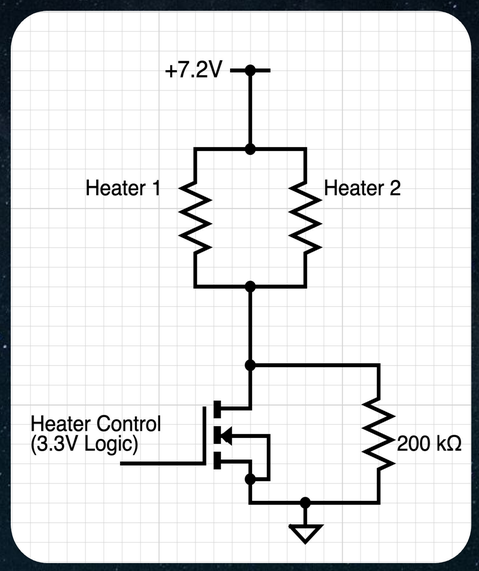

Figure 3. Heater Control Circuit Schematic

Pre-Flight Inhibits

BoBa features 3 pre-flight inhibits: a ground inhibit, a charging inhibit, and a load inhibit. Both the charging inhibit and the load inhibit utilize p-mos MOSFETs while the ground inihbit uses n-mos MOSFETs. The gate voltage of the MOSFETs are controlled by a roller switch connected to the frame of the satellite. When the switches are closed before deployment, the MOSFETs inhibit the satellite. When the switches are opened after deployment, the MOSFETs un-inhibit and reconnect BoBa to the EPS.

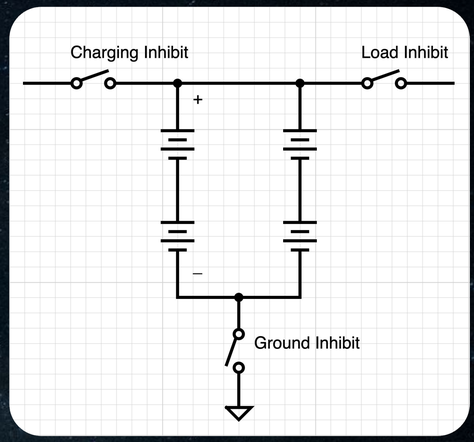

Figure 4. Inhibit Placement Schematic

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