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| Battery Charge Regulator |
| The Redesign of the BLUEsat Battery Charge Regulator Subsystem |
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# Introduction

The Battery Charge Regulator (BCR) system is an essential subsystem of the BLUEsat microsatellite. It takes power directly from the solar cells and regulates the amount of current that is supplied to the batteries and the rest of the satellite.

To date there has been no successful implementation of a Battery Charge system that would be suitable for use on the satellite in Low Earth Orbit. Previous implementations of the BCR have either lacked consideration for the performance of the Solar Panel array in Low Earth Orbit (LEO) or failed performance under testing with battery cells and the load that the electrical systems on the satellite would provide.

Poor documentation has required that the current generation of BLUEsat (as of November 2011) rely on word-of-mouth to piece together the machinations behind the designs of previous prototypes of the BCR and therefore to properly analyse why they failed. This document is an attempt to consolidate all previous information about the Battery Charge Regulators and put forward a new design for scrutiny.

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# Specifications

The specifications required for the performance of the BCR, correct as of the publishing of this document, are as follows.

The Battery Charge Regulator must

* Properly charge a single bank of Nickel Metal Hydride (NiMH) 16.8V batteries arranged in 1.2V cells.
* Have the ability to adjust the Maximum Power Point (MPP) individually for each solar panel or, alternatively each pair of opposite panels.
* Cope with a 35V - 0V Voltage range
* Be able to measure voltage and current output from the solar panels independent of the main satellite Telemetry System.
* Is able to provide power in the event of chip failure.
* Can monitor and recognise its own error state
* Has minimal ripple current (no more than 50 mV)
* Can ensure a controlled Satellite start-up from a state of nil charge.

# Previous Designs

There are two well-known previous implementations of the Battery Charge Regulator. The first was designed in 2005 with charging control logic implemented on a QL3060 FPGA chip and charge regulation implemented on the Texas Instruments BQ2004E charge regulator chip. The second was implemented using the Linear Technology LT3652C ‘Power Tracking 2A Battery Charger for Solar Power” chip.

Both these designs have been problematic to the point of requiring a redesign of the Battery Charge Regulation system. These problems have arisen due to poor documentation and maintenance of design-checking infrastructure.

## The QL3060 FPGA and BQ2004E Charge Regulator

Little formal documentation exists for the implantation of this particular system. Current known details about this charge relation come from a hard copy of the “BLUEsat Power System Architecture Drawing” (available on request) and anecdotal evidence on the results of the testing of the sub-blocks of this system.

The drawing, dated 25/01/2005 by M. Hassan, D. Fenton and V. Thiruvarudchelvan illustrates a system where the both charging and power control logic was centralised onto a large QL3060 FPGA. The redesign of the control architecture (see *BLUE2011.2.0 – Design History*) made the need for such a large FPGA obsolete. It is not clear what, if any method was considered for Maximum Power Point tracking from the solar panels.

Furthermore, the Texas Instruments BQ2004E Charge Regulator was never successfully proven. Qualitative analysis shows that the BQ2004E is only capable of charging a maximum of 5.5 volts – far below the 16.8v battery packs of satellite. For this reason, previous testing with prototypes of the NiMh battery banks that would go on the satellite yielded poor results, not able to charge the batteries to a full or sufficient charge.

For this reason, this design was superseded in 2007 with the redesign of the control architecture of the satellite.

## The LT3652 Power Tracker and Battery Charger

The design of the Battery Charge Regulator was attempted as a fourth year honours thesis by William Du. This design centred on the use of the Linear Technology LT3652 battery charging chip. This design was chosen because it combined Maximum Power Point Tracking and Charge Regulation onto a single chip.

However, there are two main problems with this design. Firstly, that Maximum Power Point Tracking (MPPT) is not possible across multiple solar panels. The design originally considered that the solar panels would be tied to a common bus. This is not the case with a Low-Earth-Orbit, cube-based satellite.

The other issue is that the design requires multiple batteries that need to be charged separately. This will add unnecessary complexity to the design of the power supply system for the rest of the satellite. The nature of power distribution in the satellite is such that a single power supply bus is required in order to design a sufficiently simple system.

More information on this design can be found in William Du’s 2011 Honours Thesis (available on request).

# Proposed Design

The new proposed BCR design focuses on modularity in the implementation of separate Battery Charge Regulators and Maximum Power Point Trackers for the solar panels.

## System Level Layout

In order to achieve MPP tracking for individual solar panels there are two possible configurations for the BCRs.

1. One BCR for each solar panel (6 BCRs, as illustrated in Figure 5.1)
2. One BCR for each opposing pair of solar panels (3 BCRs)

The second option will be very nearly as efficient as the first as only one of each opposing pair of solar cells will be highly illuminated at any given time, and this will simplify the design. The first option is however more robust, as the failure of one BCR will result in the loss of one solar panel, rather than two as would be the case with the second option.

These two options vary from the previous design in the thesis, in which all solar panels are connected to a common bus. This would be much less efficient as at a given instant each panel will have a different MPP as they could be at slightly different temperatures and receiving varying amounts of sunlight.

All BCRs will be connected to a common battery, and will need to be isolated from the battery by diodes or FETs. The use of FETs has an advantage over the use of diodes as they have a much lower voltage drop, reducing the power loss due to heat.

Maximum Power Point Tracking (MPPT) involves the measurement of the solar panel voltage and input currents to the BCR (performed using telemetry hardware) and periodically adjusting the MPP according to an MPPT algorithm such as the Perturb and Observe method (P&O).



Figure 5.1 - Block Diagram showing possible configurations of the BCR subsystem

## Battery Charger Circuit

The new battery charger is based around the LT1513 battery charger IC produced by Linear Technologies. This has many advantages for use in this configuration, such as the following:

* It outputs a constant voltage, allowing multiple BCRs to charge a single battery.
* It works as both a step-down and step-up converter, so it can charge batteries from inputs above and below battery voltage.
* The maximum charge current can be controlled externally. This is useful for adjusting the MPP.

The LT1513 IC allows the maximum charge current to be programmed by a control voltage. By changing this control voltage, the MPP can be adjusted.

## Maximum Power Point Tracker (MPPT)

Control of maximum charge current provided by the LT1513 integrated circuit is to be used for the implementation of a Maximum Power Point Tracker. Realisation of an MPPT algorithm can be provided in the form an analogue control signal to each individual Battery Charger unit. This algorithm would require feedback from voltage and current sensing telemetry data from the solar panels.

This control algorithm needs to be implemented on a central controller of some form. Initial investigations would indicate that the Critical Systems Compute would be unsuitable in this role. The BCR controller would need to be able to power on before the Battery Charging circuitry powers on, in order to monitor all current telemetry, determine error states and therefore control the BCR as necessary. Such a controller would therefore need to be implemented such that it can operate off pure solar panel power in the event of completely discharged batteries (as is the case just after launch).

Due to the power requirements of the LPC2468 microcontroller, or indeed any other microcontroller capable of controlling the critical systems of the satellite, it cannot be reliably powered simply using a source as temperamental as the 6-panel solar array of a rotating microsatellite in Low Earth Orbit.

Currently, it is being debated whether or not to have a default state for the Battery Charge System in the absence of a control signal or to implement a controller entirely separate from the CSC. Having a default state when the other satellite sub-systems are unavailable risks catastrophic failure if the state of the Battery Charging Circuitry is in a state of error. However introducing another microcontroller, however lightweight, introduces a significant design cost. This document will be used to tender what control design would work best.

## Current Progress

As of the 29th of November, 2011, prototype PCBs have been designed and ordered for a new BCR test board based on the LT1513 battery charger IC. These will be used to test the charging of the current batteries and to experiment with different configurations of the overall BCR subsystem.

Chip selection and control design for the MPPT will be debated with the publishing of this document.

# Conclusion

Previous designs for this critical subsystem have proven to be inadequate for the requirements of the satellite. This has occurred due to poor design and testing documentation and lack of proper infrastructure for design testing and verification. This document attempts to consolidate all previous knowledge on the battery charge regulators, put forward proper specifications for the system and a design that meets these specifications for tender.

The battery charging sub-unit has been designed and verified and awaits proper testing. Documentation on this testing will follow.

The control required for the implementation of a Maximum Power Point Tracker is still being debated. Currently the choice lies between having the control on the Critical Systems Computer, which presents error handling issues, and having separate control for the entire Battery Charging system, which presents extra design cost.

Future documentation and finalisation of the BCR design will follow.