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Research Article

Battery and Solar Panels Temperature Compensation for Small Satellites Applications

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Abstract

The electrical power system EPS of a small satellite provides electrical energy to all the systems onboard and the payload and it is the most critical system of a satellite. The EPS, in general, consists of solar cells, rechargeable batteries, a power conditioning and distribution units.

The solar cells are the primary source of energy. These photovoltaic cells convert light into electrical energy. The batteries provide power during eclipse as well as during peak load times.

The power conditioning and distribution units provide a stable power bus and distribution of power through power switches to all satellite subsystems. The satellite can only operate normally as long as it has power. A failure of the EPS without any doubt will result in the end of the satellite's mission.

The purpose of this paper is to give a deep insight on how to design circuits for battery and solar panels temperature compensation over a wide range of temperatures (-40°C to +40°C). Both temperature circuits will be based on thermi-linear network of the type YSI 44203. The thermo couple will be located on each of the four solar panels and in the battery pack. Data from these networks will be routed to the BCR for temperature compensation. The design will be based on off the shelf components COTS.

Keywords: Small Satellites; Temperature Compensation; Solar Cells; Batteries; Power Conditioning; Power Distribution; Off the Shelf Components

Introduction

Before testing begins on the BCRs, the BCR End of Charge EoC Voltage and the BCR Solar Array Maximum Power Point Tracking Voltage must first be set up on both BCR1 and BCR2. Both of these voltages vary with temperature; so, in order to optimise efficiency, this must be considered.

This is achieved in the form of temperature compensation thermi-linear networks YSI 44203 that are located on each of the four solar panels and in the battery pack. The pulse width modulation PWM chip (UA 494A) has two error op-amps providing a means to adjust the output pulse width. One of these op-amps is used for battery temperature compensation and the other for solar panel temperature compensation. The inputs of each error op-amp are connected to the battery or solar panel voltage via a voltage divider and to the battery or solar panel compensation thermi-linear network also via a voltage divider network, see figures 1 to 4.

Battery temperature compensation

To set up the End of Charge Voltage for the BCR, the resistor values of the voltage dividers must be set. The resistors for selecting the End of Charge Voltage were chosen using 1% tolerance resistance decade boxes. Both resistors R110 and R188 were set to 47KΩ.

For BCR1, a 23.2KΩ resistor was used for R105, the resistor parallel to this R106, being left unpopulated, was chosen to be 480KΩ giving an End of Charge Voltage of 14.22 Volts at 23.5°C, figure 1.

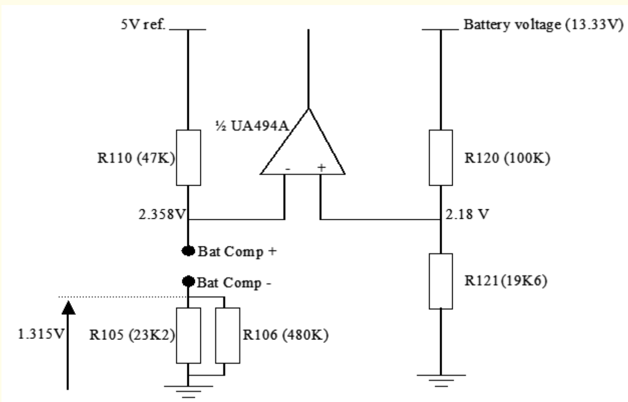

Figure 1: Battery temperature compensation for BCR1.

For BCR2, a 23.2KΩ resistor was used for R182, and the resistor parallel to this R184 was chosen to be 49.9KΩ giving an End of Charge Voltage of 14.31Volts at 23.5°C, figure 2. The resistor values of the divider, which sense the battery voltage, had been calculated at the design stage giving values for R121 and R190 of 19.6KΩ. For these calculations the battery temperature coefficient was assumed to be -40mV/°C per ten cells in series. This can be considered to be – 705 mV for the whole pack. The thermi-linear network resistance deviation with temperature is indicated in the YSI 44203 datasheets.

Solar panel temperature compensation

Once again, the procedure for calculating the resistor values of the voltage dividers used to track the Maximum Power Point (MPP) of the solar panels was followed. The resistors setting the Maximum Power Point Voltage were chosen using 1% decade resistance decade boxes. R108 and R186 were calculated over several iterations giving rise to a value of 10K for both resistors. R115 and R193 were set to 24K.

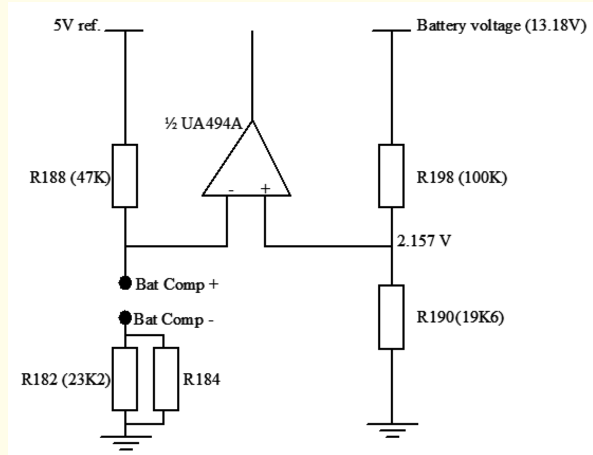

Figure 2: Battery temperature compensation for BCR2.

For BCR1, a 63.4KΩ resistor was used for R102, and the resistor parallel to R103 was chosen to be 21.6KΩ, giving an equivalent resistor for R102//R103 of 16.11KΩ, and giving a MPP voltage of 35.2V at 23.5 °C, figure 3.

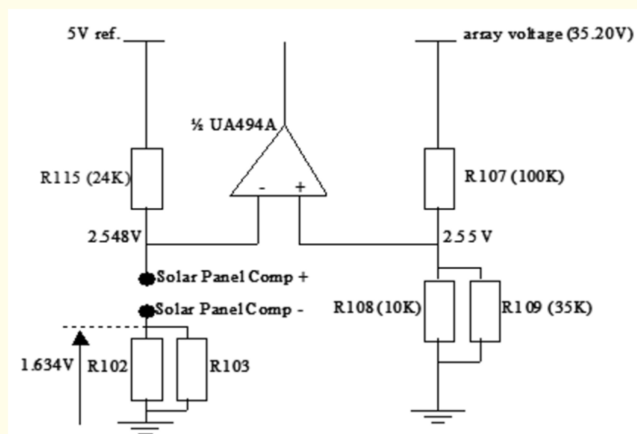

Figure 3: Solar array temperature compensation for BCR1.

For BCR2 a 22.6KΩ resistor was used for R180, and the resistor parallel to R181 was chosen to be 49.9KΩ, giving an equivalent resistor for R180//R181 of 15.56KΩ, and giving a MPP voltage of 36.5V at 23.5 °C, figure 4.

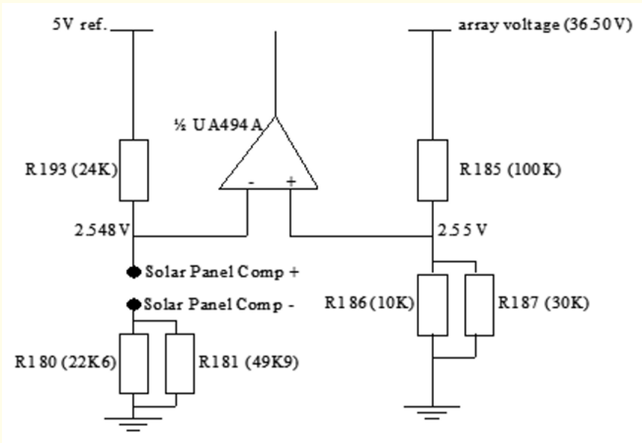

Figure 4: Solar array temperature compensation for BCR2.

BCR1 has a safety margin in its tracking point of 3V and BCR2 has a safety margin of 2V. The safety margin accounts for degradation of the MPP of the panels over their lifetime and also helps counter-act incorrect MPP tracking at zero yaw.

For these calculations and from the manufacturer's data sheet, the temperature compensation coefficient of the solar cells was assumed to be -6.41 mV/°C per solar cell for the GaAs/Ge.

Design anomaly

Due to the under-voltage lockout function, as the PWM could not fully turn itself ON as initially the IC power comes from an IC via an 27V Zener diode. The MPP circuitry, which sets the array voltage, is referenced to the 5V reference of the IC, which, due to the under-voltage lock out, was no higher than 4V. This in turn set the array voltage too low to turn on the IC.

To overcome this problem the following linear regulator circuit was used to replace the 27V Zener diode, allowing the IC supply voltage to be independent of the array voltage, solving the problem.

Parts list

- 100nF - CAP/100N/5021
- 6.2V - DIO/BZV85/*
- 1uF - CAP/1000N/6021

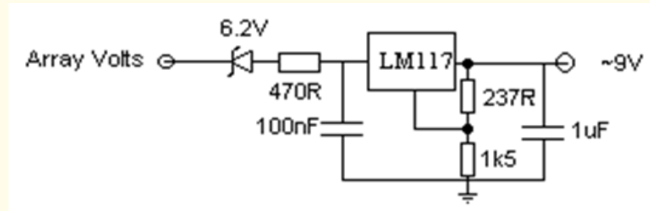

Figure 5: UC 494A start-up circuit.

- 1.5KΩ - RES/1.5KΩ/R
- 237Ω - RES/237Ω/R
- 470Ω - RES/470Ω/W21 - Wire wound resistor
- LM117 - ICD/LM117/0010

Battery temperature compensation calculations

Figure 6: Battery temperature compensation calculations.

Conclusions

The following paper is a research review regarding solar panels and battery temperature compensation and the effects of warm and cold temperatures on battery charging setpoints.

When space batteries are exposed to warm or cold temperatures, it is important that the battery charge regulator BCR has temperature compensation in order to maximize the life of the batteries by assuring that they are receiving the proper recharge setpoints in all temperatures ranges and conditions.

The present paper details the design for the battery and the solar arrays temperature compensation circuitry for a low earth orbit spacecraft. Both temperature circuits will be based on thermi-linear network of the type YSI 44203. The thermo couple will be located on each of the four solar panels and in the battery pack (aluminium core). Data from these networks will be routed to the BCR for temperature compensation. The design will be based on off the shelf components COTS.

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