

# **ELECTRONIC POWER SUBSYSTEM ANALYSIS, RESEARCH, AND FUTURE PLANS**

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## **ABSTRACT**

The mission of the Kumu A'ō Cubesat project is to develop, test, launch and operate Hawaii's first successfully launched Cubesat. Our primary objective is to develop a fully functioning Cubesat bus to serve as a prototype for future UH Cubesat missions. The Cubesat project provides a way for the students to learn the various steps involved with mission design without being overly ambitious so that student group cannot complete it within 12 month period. To ensure the success of the project, the Kumu A'ō Cubesat team will employ the standardization of commercial off the shelf parts and the knowledge attain over the past 5 years from the previous Cubesat teams. One of the team's main goals is to simplify the fabrication of the bus which will minimize the assembly time and will allow for opportunities to incorporate various payloads. In the beginning of July, our project manager gave a presentation to Dr. Tep Dobry and Josh Ka'akua, advisors of the Native Hawaiian Science and Engineering Mentoring Program, requesting funds to carry out the Kumu a`o Cubesat mission. Then on July 30, the Kumu A'ō Cubesat project was granted \$15,000 from the College of Engineering for travel and material cost. The Kumu a`o team was then assembled from those students whom wished to continue on, from the LEONIDAS Student Research Team, and additional underclassmen engineering students , whom would help facilitate Cubesat activities once the senior team members graduate. I currently serve as the Lead Electronic Power System Engineer for the Kumu A'ō Cubesat.

The Kumu A'ō Cubesat team has been working for two semesters, trying to accomplish the goal of creating a 1U Cubesat. Due to the size of the Cubesat, requirements were set upon each subsystem to fit within the 10 X 10 X 10 cm structure and the mass must be less than 1 kg. The electronic power subsystem (EPS) will supply a continuous source of power, at different voltages needed by each subsystem. The team decided to use solar technology as the primary source of electrical power, backed up by a lithium ion secondary battery.

## **OBJECTIVE**

The goal for 2<sup>nd</sup> semester is to complete the Printed Circuit Board (PCB) design, and testing of each component individually and as a system. Currently, the EPS team is mapping the PCB board manually. PCBArtist (program for designing PCBs) was unable to connect all the chips automatically. The auto function required more space on the board in order to connect everything. Being limited by requirements set in the 1<sup>st</sup> semester, more space couldn't be allocated to the EPS subsystem. Doing the design manually, may create the required space to map each chip together. The level of experience needed is beyond the EPS team's knowledge.

Time has been spent to acquire the knowledge using PCBArtist. Now the task of placing each chip on the board and mapping each pin together, will take another week to finish. If the design will not fit on a single PCB board, there is a “last resort” option to place some chips on the thermo PCB board. Our system engineer expressed that there will be room there, but EPS should not count on it. The EPS team has also concentrated on prototyping the individual chips and integration of multiple components.

## ANALYSIS

The analysis and configuration of each chip, and how they worked together in the system will now be explained. Several problems occurred when implementing each chip individually. Our team was not able to get the exact values needed, but learned several things while testing.

### MAX 1771

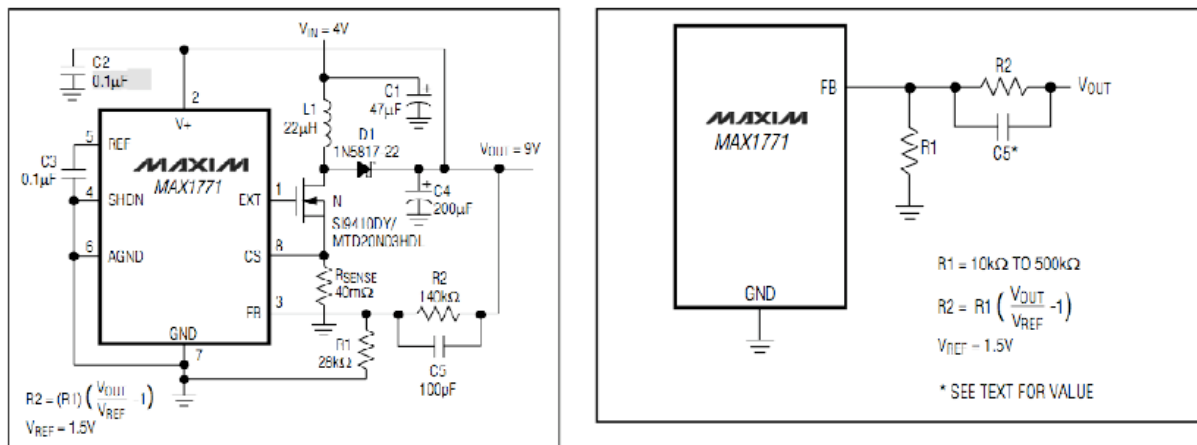


Figure 1: Schematic of MAX 1771/ Adjustable Output

The MAX 1771 was used due to its high efficiency and adjustable output as seen in Figure 1. Using the equations given, the EPS team was able to find accurate resistor values, to receive an output of 6V:  $R1 = 10\text{ K}$  &  $R2 = 30\text{ K}$ . Three MAX 1771 chips were configured the same way and tested to simulate three solar cells getting hit by the sun. A constant 3.3 V was given to the input of each chip via a function generator. A diode was added after each chip to protect current

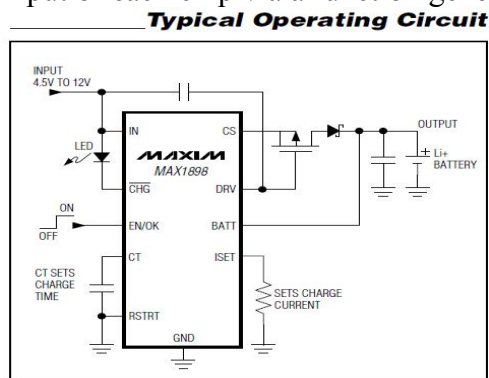


Figure 2: Schematic of MAX 1898

from coming back through the chips, which would (in space) degrade the solar panels. To keep the output of each chip from oscillating, a resistor was put in parallel with the capacitor at the output seen in Figure 1.

The EPS battery charger needed to be safe for lithium-ion technology. Due to lithium-ion being a new technology, not much testing has been done in the space application field. The MAX 1898 was chosen because of the testing background history done on single lithium ion batteries. Being a simple chip to implement, the only thing needed to be configured was the amount of current

SAFT to keep the budget down. So to test out the MAX 1898, an old PDA lithium-ion battery was used to make sure the SAFT batteries would not be ruined. The capacity of the old PDA battery is smaller than that of the SAFT batteries. This will be taken into account in the results.

Not all components required a step-up converter. To provide power to components requiring 3.3 volts, the MAX 1921 was selected. Figure 3 shows the schematic of how the MAX 1921 was setup. In Table 1, shows the unknown values for the schematic shown in figure 3. Theoretically using these values, an output voltage of 3.3 volts should be given by the MAX 1921. Taking a second look at Table 1, for the 1.8 volt output, the same unknown component values are used. This proved to be a problem in the results.

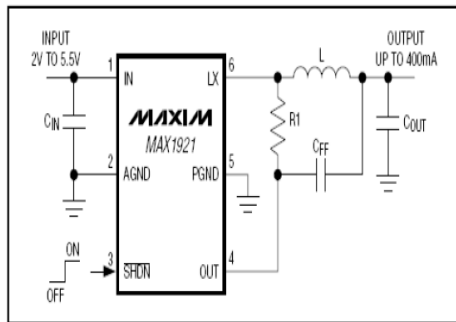


Figure 3: Schematic of MAX 1921

OUTPUT	INPUT SOURCE		
	5V	3.3V, 1 Li+, 3 x AA	2.5V, 2 x AA
3.3V 3.0V	L = 10 $\mu$ H, C <sub>OUT</sub> = 10 $\mu$ F, R1 = 8.25k $\Omega$ , C <sub>FF</sub> = 3300pF		N/A
2.5V	L = 6.8 $\mu$ H, C <sub>OUT</sub> = 6.8 $\mu$ F, R1 = 5.62k $\Omega$ , C <sub>FF</sub> = 4700pF		N/A
1.8V 1.5V	L = 10 $\mu$ H, C <sub>OUT</sub> = 10 $\mu$ F, R1 = 8.25k $\Omega$ , C <sub>FF</sub> = 3300pF	L = 4.7 $\mu$ H, C <sub>OUT</sub> = 4.7 $\mu$ F, R1 = 4.75k $\Omega$ , C <sub>FF</sub> = 5600pF	N/A

Table 1: Unknown Values for MAX 1921

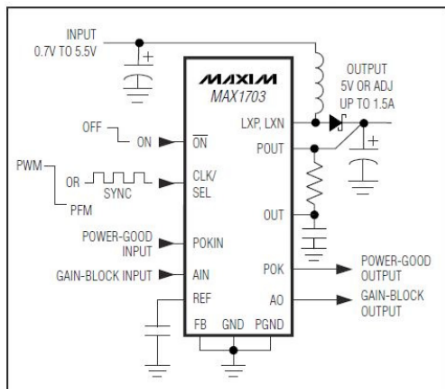


Figure 4: Schematic of MAX 1703

The last voltage required is 5 volts. To meet this need, the MAX 1703 was procured as shown in Figure 4. Test procedures were to be done exactly like the MAX 1771, except only one chip was needed. Fabrication time was thought to be cut down by using this method.

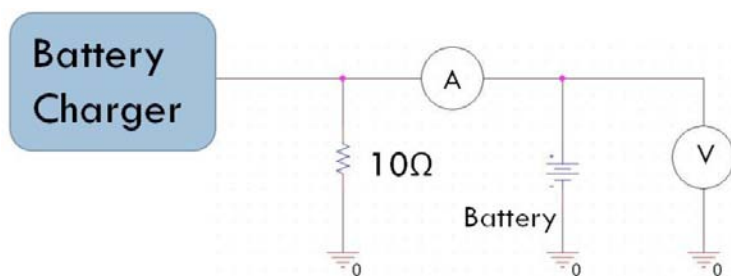
## RESULTS

**MAX 1771** - Results from tests earlier came up neither good nor bad. During testing, each chip was giving a different voltage as seen in Table 2. As stated earlier, three MAX 1771 chips were configured the same way, and given the same input. Theoretical voltage for this chip is 6V. From Table 2, Chip 1 and Chip 2 were very similar, but somehow Chip 3 was not even close. The setup of each individual chip was checked numerous times and found that every chip was set up the same. The EPS team figured that maybe one of the passive elements could have been faulty. So using the set up of Chip 1, Chip 2 & 3 replaced Chip 1 separately, hoping to get the same output of Chip 1. This would prove that the chips were fine and that the passive elements were faulty. Results show the setup of Chip 3 to be faulty and that each chip is working correctly.

Input	Theoretical	Chip1	Chip 2	Chip 3	Placement
3 V	6 V	6.254 V	6.306 V	2.844 V	B4 diode
3 V	6 V	6.741 V	6.504 V	3.271 V	Aft Diode
3.30 V	6 V	6.254 V	6.316 V	3.013 V	B4 Diode
3.30 V	6 V	6.67 V	6.467 V	2.994 V	Aft Diode

**Table 2: Test Results for MAX 1771**

**MAX 1898** – The current output of the chip was set to 1.4 amps, by making  $R_{set}$  equal to 1 kilo-ohm (low current is used to keep the lithium ion battery from leaking). Setting up the circuit as in Figure 2, the output voltage should be 4.1 volts. To test the charger, variable input voltages ( $V_{in}$ ) were supplied to the charger. Every single test with variable  $V_{in}$ , 4.1 volts was found at the output. Having confidence the charger was wired and working correctly, the SAFT lithium-ion batteries were connected to the MAX 1898.



**Figure 5: MAX 1898 Test Setup**

The gauge not being wired up yet, the MAX 1898 was tested by connecting an ammeter between the charger and the battery. A multimeter was also connected after the SAFT battery to test for voltage. Results showed that the battery was receiving the 4.1 volts. Further tests will be done to gain a desired current that help prolong the life of the battery.

**MAX 1921** – To solve the problem of having similar unknown values for the MAX 1921, the data sheet was looked at. The data sheet showed that the resistor was the difference in getting a certain output voltage. By using the method of guessing and checking, the resistor at the output was found to be 360 kilo-ohms. Table 3 shows the results of testing. During testing the output

Input	Theoretical	Output	Shunt 6.4Ω	Output Current
4.0 V	3.3 V	3.28 V	3.001 V	469mA
4.70 V		3.338 V	2.83 V	442mA
5.0 V		3.337 V	3.269 V (10Ω)	327mA

**Table 3: Test Results for MAX 1921**

was shunted with a 6.4 ohm resistor. This process was used to calculate the output voltage and simulate how the circuit reacted with a load connected.

**MAX 1703** – This chip turned out to be a “problem chip”. 5 volts was never achieved at the output. Several factors could have accounted for the failure of the testing. The MAX 1703 needed to be soldered to another board in order for it to be used on a protoboard because of its size. Many attempts were recorded, but still, 5 volts was not achieved. Experts were called in to assess the failure in the circuit, but nothing was found. To solve the mystery, an evaluation kit was purchased to help keep the project moving forward. Also, bigger MAX 1703 chips were ordered, to eliminate the need for the chip to be soldered onto an adapter.

## **FUTURE PLANS**

The EPS team is looking to procure the rest of the missing components on their list. To correct the MAX 1703 problem, an evaluation kit was ordered, and upon arrival, much testing will be done. The solar cells from Spectrolab still need to be purchased and tested to further the integration of the EPS system. This is due to an administrative setback and will be sorted out this summer. Eric Miller with Hawaii Natural Energy Institute, offered to test the solar cells under his solar simulator. This will help the EPS team immensely when configuring final modes and failure modes.

## **CONCLUSION**

In conclusion, the EPS team was able to learn several things about the system. The design and layout of all the components works to a certain extent. The selected converters meet the requirements set by the team last semester. The battery charger safely and effectively charges the SAFT lithium-ion battery. Many things are needed to be done before the system is flight ready. Prototyping and testing helps the EPS team move forward every day.

The Kumu a’o project has helped me grow individually. The chance to work on such a project has helped me socially and in the class room. My GPA went up a point and a half from last semester. I recommend working on this project to anyone who looks for challenging, fun, and new problems every day. Not many projects at school allow undergraduates to receive such work and experience.

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