Intelligent Power Management System for a Nanosatellite

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***Executive Summary* – In order to successfully complete its mission, the New Mexico Tech Satellite (NMTSat) requires a power system that will generate, condition, monitor, manage, and distribute power amongst the individual subsystems. After determining a set of subsystems that could successfully meet these requirements, the subsystems were to be designed, constructed, and tested to verify functionality. After much consideration, an electrical power system was purchased in order to distribute the power generated from the hand assembled solar panels and a custom power control and monitoring board was designed to ensure the safety of all subsystems onboard NMTSat. The specifications of off-the-shelf electrical power systems were compared along with the benefits and drawbacks of many different solar panel designs. The electrical needs of NMTSat were also assessed along with many designs to help mitigate the risk of a system failure. Afterwards, the solar panels were constructed and tested to find they operated correctly and sufficiently. The electrical power system was purchased although never received due to the long lead time of the product and other design choices. Finally, the power control and monitoring board was constructed and tested to verify that it functioned as expected. The final, flight-ready models of each system must still be constructed, as well as fully integrated into the satellite frame.**

I. PROJECT DESCRIPTION

The purpose of this project is to design, construct, and test a power management system for the New Mexico Tech CubeSat project (NMTSat). The power management system will consist of three primary subsystems, an electrical power system, solar panels, and a power control and monitoring board. Combined, the three power subsystems will provide power to all other critical and noncritical systems on NMTSat as well as monitor and manage the power usage of each.

The primary function of the solar panels is to collect solar energy to be utilized by the electrical power system for charging of batteries and powering of subsystems.

The power control and monitoring board will be implemented to distribute power amongst the noncritical systems and ensure the safety of all subsystems. The power control and monitoring board will do so by limiting current to the noncritical systems as well as measure the currents from each of the subsystems, and act as an electrical health monitoring system.

The electrical power system will act as the interface between the solar panels, power control and monitoring board, and all other critical and noncritical subsystems on NMTSat. The electrical power system will harness the power generated by the solar panels and regulate it to power all other critical and noncritical subsystems. Power generated above the required operational values will be used to charge the batteries.

II. BACKGROUND

A. Purpose of NMTSat

NMTSat is New Mexico Tech's first nanosatellite constructed fully in house, almost entirely by students. NMTSat is a 3U CubeSat that will be orbiting in a low Earth orbit. NMTSat serves three main purposes. Its primary purpose is educational, providing undergraduate and graduate students with the chance to work on a real world problem. The secondary goals are scientific and experimental. The scientific mission is to research space weather by using onboard instruments such as the Langmuir plasma probe and structural and electrical health monitoring systems. NMTSat will only be in orbit for approximately a month in order to obtain all necessary data for correlation, although any time longer than this is beneficial and could allow for the collection of more interesting data.

B. Critical & Noncritical Subsystems

All instrumentation on NMTSat is broken up into two different types of subsystems, critical and noncritical subsystems. Critical subsystems are defined as those that are required for NMTSat to function. These include command & data handling, communication, electrical power system, and power control & monitoring subsystems. The noncritical subsystems are all other onboard systems such as the space weather instruments and the health monitoring systems.

C. Command & Data Handling (C&DH)

The C&DH system acts as the "brain" of the satellite. It is responsible for communicating with the power control and monitoring board in order to issue instructions and obtain data on the status of the subsystems. The C&DH is also responsible for storing all collected data and transmitting it to the ground station via the communications antenna when requested from the ground station.

D. Electrical Health Monitoring (EHM) System

The EHM system is a subsystem of the power control and monitoring board. The primary purpose of the electrical health monitoring system is to monitor the noise of all systems that may be incurred by the space weather conditions. The EHM system will do so by monitoring the noise on each power line as well as the noise after the current limiting and measurement systems.

E. Structural Health Monitoring (SHM) System

The structural health monitoring system is an array of piezoelectric sensors that are used to monitor variations in the satellite's physical structure. The data collected will then be correlated with the space weather data in order to find any interesting anomalies.

The SHM system influences the design of the solar panels. The piezoelectric sensors will be placed on the solar panels in order to obtain SHM data. The data lines from the sensors will also have to be routed on the solar panels.

F. Triangular Advanced Solar Cells (TASCs)

The triangular advanced solar cells from Spectrolabs are low cost yet efficient solar cells designed for use in applications when space is limited.The TASCs have also been used successfully on previous nanosatellites such as Boston University Satellite, and the Brown University Satellite as an alternative to preassembled panels due to the high costs of preassembled panels.

G. Pumpkin CubeSat Frame

The CubeSat company, Pumpkin, offers fully constructed CubeSat frames along with electronic development boards known as CubeSat kit flight modules. These kits are designed to help test the functionality of systems such as C&DH as well as provide a flight ready frame for the satellite. A 3U CubeSat kit was selected for NMTSat and all printed circuit board dimensions must meet the physical requirements of the Pumpkin CubeSat kit frame.

H. Langmuir Plasma Probe (LPP)

The Langmuir Plasma Probe is a deployable noncritical subsystem that is attached to the frame of the satellite. The LPP is used to measure plasma density in order to be correlated with other space weather data. The placement of solar panels had to be adjusted due to the placement of the LPP on the frame of the satellite.

III. DESIGN CONSTRAINTS

A. Solar Panels

In order to successfully provide power to the satellite, the following constraints must be met.

- Must produce 1.2 Watts on orbit with a 0.5 Watt margin (minimum)
- Photovoltaic outputs cannot overstep EPS thresholds

As well as the power specifications, the solar panels must also be configured such that they:

- Route structural health monitoring data lines with reduced interference
- Reduce excess wires
- Meet physical dimension requirements

B. Power Control and Monitoring (PCM)

In order for the power control and monitoring board to ensure the safety of the satellite it must interact with the critical and noncritical systems in various ways. The interactions between the PCM and each system are outlined below.

Noncritical Subsystems

- Power cycling upon instruction from C&DH processor
- Measure current consumption
- Hardware and software current limiting
- Monitor noise on power lines

Critical Subsystems

- Measure current consumption
- Monitor noise on power lines

Solar Panels

- Monitor current from photovoltaic outputs

In order to prevent interfering with the functionality of the critical subsystems the current measurement system must act as if it is transparent, such that if it fails the operation of each critical subsystem remains unaffected. Due to the power constraints and the EHM system, it is required that all components selected be low power and low noise.

C. Electrical Power System (EPS)

The following specifications outline the requirements and functions of an off-the-shelf EPS suitable for this power management system.

- Capable of supplying > 3 Watts
- Photovoltaic inputs
- Onboard microprocessor that communicates via I2C
- PC104/CubeSat kit compatible (a standardized form factor)
- Monitor battery voltages
- 5V, 3.3V conditioned power outputs

IV. DESIGN APPROACH & SOLUTIONS

A. *Solar Panels*

1) *Solar Cell Selection*

The first and most important decision to be made for the solar panels was the selection of the solar cells that were to be used. The Triangular Advanced Solar Cells (TASCs) were cheap and the benefit of using them over traditional silicon cells is that they provide over four times the voltage (see Appendix A). The flight heritage was also a very large determining factor. The TASCs have been flown on other CubeSat projects successfully at universities such as Boston University and Brown University. The cells were $150 per bundle of 50 (approximately $3 per cell) which fit well within the budget allotted for purchasing the solar cells. Unfortunately, these cells do not have a conformal coating on them to prevent them from degrading due to the harsh environment of space. This was disregarded because the overall mission life of NMTSat is short.

2) *Solar Panel Size Constraint:*

After the selection of the TASCs was made the panel sizes were contemplated. The pumpkin frame has 3mm railings on each corner in order to slide into the P-POD for launch. This left 84mm of usable space between the rails on each face of the satellite. By arranging the TASCs as shown in Fig. 1, it was found that 12 pairs, or 24 cells, could fit on the face of one panel. In order to account for the bolts for mounting and the piezoelectric sensors for SHM, the number of cells was reduced to 20 per 1U panel (10 pairs).

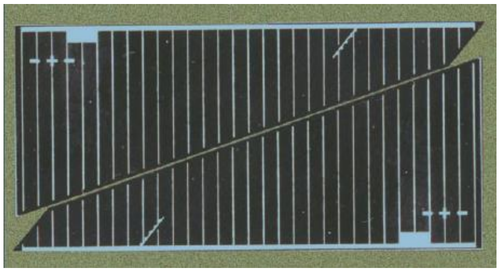

Figure 1: Triangular Advanced Solar Cells (TASCs)

3) *Solar Cell Configuration*

Once the number of cells was determined, the configuration in which they would be electrically connected was decided. The photovoltaic inputs of the Gomspace P31u allowed for 5.5V at 2A (see Appendix B). The highest potential reached by one of the cells is represented by the open circuit voltage (V_{oc}). V_{oc} across one TASC was 2.19V (see Appendix A). This allowed for two TASCs to be configured in series producing a highest possible potential of $V_{oc} \approx 5.4V$ as seen in Fig. 2.

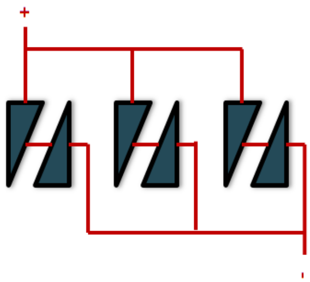

Figure 2: TASC Configuration

This configuration would create 10 pairs of cells on a 1U panel. The maximum current provided by a TASC cell is then represented by I_{sc} = 31mA. With 10 pairs of cells on a 1U panel, the maximum current produced is 310mA. This is then tripled because NMTSat is a 3U CubeSat and the maximum current produced by one face of the satellite in direct sunlight is 930mA. This is well below the 2A input defined on the P31u datasheet.

After determining the cell configuration, the panels also had to be configured in such a way that the panels did not overstep the photovoltaic thresholds on the EPS. The standard for configuring panels in a solar array on a CubeSat is such that only one of the faces on the pair is exposed to sunlight at any particular moment. This is done by configuring the panels as seen in Fig. 3, where the +X, -X is one photovoltaic input, +Y,-Y is the second, and +Z,-Z is the third.

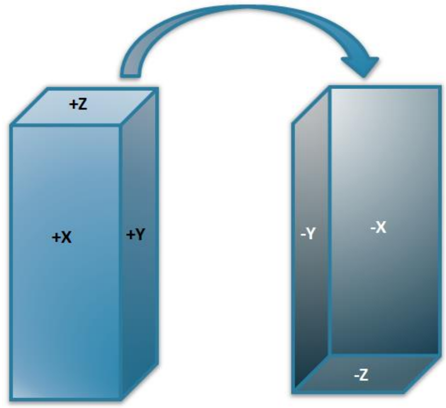

Figure 3: Solar Panel Pairs

4) Power Calculations

After the number of cells that could fit on each 1U panel was determined as well as the configuration for providing maximum voltage in a pair, the full power calculations could be performed. The following equations are all obtained from the Space Mission Analysis and Design (SMAD) book [1].

In order to begin, the number of cells illuminated at once is calculated. An average case was selected in which only 5 panels were exposed to sunlight. 5 panels will expose 20 cells, or a total surface area (SA_{TOT}) of 227.7cm^2. Due to the short mission life of the satellite, it is assumed that the end of life power (P_{EOL}) is equal to the beginning of life power (P_{BOL}). With this in mind and the power of an individual solar cell P_o = 270W/m^2, the life power can be calculated by:

$$P_{EOL} = P_{BOL} = P_O I_D \cos(\theta) \tag{1}$$

Where $I_D = 0.77$, the typical value for inherent degradation and $\theta = 23°$, the worst case angle of incidence. This gives:

$$P_{EOL} = P_{BOL} = 191.37W/m^2 \tag{2}$$

Once P_{EOL} is known, the power produced by the array, P_{SA}, can be calculated.

$$P_{SA} = SA_{TOT} P_{EOL} \tag{3}$$

In this case, $P_{SA} = 4.358W$. These values are then used to calculate the average power delivered to the satellite. For this, the orbit time must be known. In this case it is Low Earth Orbit so $T_d = 90\ min$ and $T_e = 20\ min$. For a maximum power point tracking scheme the following values are determined, $X_e = 0.6$ and $X_d = 0.8$. The average power delivered to the satellite is then found by solving the following equation for P_d:

$$P_{SA} = \frac{\left(\frac{P_d T_e}{X_e} + \frac{P_d T_d}{X_d}\right)}{T_d} \tag{4}$$

Evaluating P_d, we obtain $P_d = 2.6895W$ average power delivered per orbit.

This met the requirement of 1.7 W with excess power to charge batteries in order to power other instrumentation in the eclipse.

5) Circuit Protection

After determining the amount of power that would be produced and deciding it was sufficient, another concern arose. This was the issue of the batteries discharging into the darkened solar panels when they are at a lower potential than that of the battery. For this, blocking diodes were used.

The concern with using blocking diodes was the loss of power. The power loss in a Schottky diode is less than other diodes, thus the Schottky diodes was selected.

After the selection of the diode type, the placement in the circuit had to be considered. One Schottky diode placed at the end of each solar panel would prevent the battery from discharging into the panels but not prevent the cells from discharging into one another. Potential differences between cells might be caused when the Langmuir Plasma Probe casts a shadow upon the illuminated face. For this reason, the diode was placed at the end of every string of TASCs to prevent the loss of power due to shadow discharging. The potential power loss due to shadowing of the cells was much greater than the power loss created by the increased number of diodes. The selected diode configuration is shown below in Fig. 4.

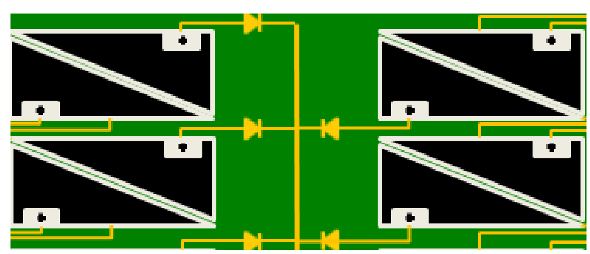

Figure 4: Diode Configuration

6) Structural Health Monitoring

The SHM system required a small area for the placement of piezoelectric sensors on the solar panel as well as a way of routing the data lines from each of these sensors to the SHM board.

The piezoelectric sensors were to be placed on the solar panel circuit board in order to monitor any changes that might occur in the frame structure. The data and ground lines from each of these sensors had to then be routed back to a header on each panel in order to be connected to the SHM board elsewhere in the satellite frame.

7) Connectivity

Another concern when designing the solar panels was ensuring that the trace sizes on the printed circuit board were all large enough to carry the amount of current produced by the solar panels. Routing the data and power lines to the SHM board and EPS was also an issue to be addressed.

The largest concern was the minimum trace size to be used for power. In order to determine this value, the following set of equations was used from [3]:

$$Area(mils) = \left(\frac{Current(amps)}{(k*Temp\ Rise(°C))^b}\right)^{1/c} \tag{5}$$

$$Width(mils) = \frac{Area(mils)^2}{Thickness\ (oz)*1.378(mils/oz)} \tag{6}$$

The values for k, b, and c vary based upon whether the traces are internally or externally placed on the circuit board. The values for both cases are as follows:

Internal traces: k = 0.024, b = 0.44, c = 0.725

External traces: k = 0.048, b = 0.44, c = 0.725

These calculations can easily be performed by PCB trace width calculators found online. The only issue is that these calculations do not characterize the behavior in space. Since this was a large concern, the calculations were performed very generously. The max current was selected to be 2A although the input current from the photovoltaics was only 1A in the worst case. The printed circuit board was selected to have a 2oz copper layer and the traces were selected to have a temperature rise of only $5°C$. This produced a trace width of 23.4mils on external layers in air and a trace width of 60.9 mils on internal layers [3]. It was then assumed that the vacuum of space would perform more as the internal layers of the printed circuit board would, thus the trace size was chosen to be 60 mils for power lines.

The final connectivity issue was the routing of data lines from the piezoelectric sensors to the SHM board and power lines from the solar panel to the EPS. A ribbon cable system was designed, with the understanding that special connectors would need to be selected. The headers needed to be ruggedized, locking headers that passed rigorous vibration testing. Most locking headers are larger than necessary for this application and break the 6mm constraint provided for the solar panels to fit within the P-POD. For this reason, the idea was proposed that the connectors be attached to the back plane of the printed circuit board and a hole cut into the frame of the CubeSat in order to accommodate the height. This is depicted in Fig. 5.

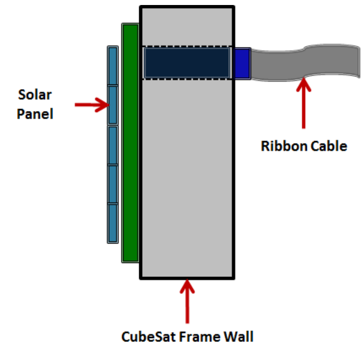

Figure 5: Solar Panel Mounting and Cable Routing

8) *Manufacturing Process:*

The final step in creating the solar panels was to find an effective and efficient way to manufacture the panels once the components were selected and ordered.

One concern was the process in which the cells adhere to the printed circuit board itself. Other CubeSat projects have used a conductive silver epoxy that is resistant to outgassing. This was considered but the cost was beyond the budget of NMTSat once again (approximately $1000 for the necessary amount of epoxy). For this reason, lead free solder was chosen. The pads were constructed in order to provide thermal relief as seen in Fig. 6. This allows the solder to flow between pads without heating up the board excessively and provides a solid connection.

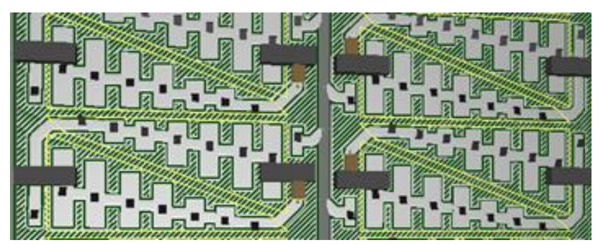

Figure 6: Solar Cell Thermal Relief

The process by which the solder can be melted is still under consideration. A reflow oven is the process of choice but currently one is not available. For this reason, the cells will be heated with a hot air rework station. The rest of the components such as the diodes and connectors will be surface mount components soldered by hand.

B. Power Control and Monitoring (PCM)

1) PCM Physical & Electrical Requirements

In order to meet the physical and electrical requirements of the satellite, the power control and monitoring board must meet three main constraints. The printed circuit board layout must be CubeSat kit compatible, meaning that it adheres to the PC/104 mechanical standard. The onboard microprocessor that controls all other subsystems on the PCM board must also be a variation of the Texas Instruments MSP430 Microprocessor and communicate with the command & data handling. It was decided for NMTSat that all subsystems must comply to the PC/104 standard and if they contain a microprocessor it must be a variant of the MSP430.

2) Current Limiting System

Power to the noncritical subsystems has to be controlled and limited by the PCM. Power distribution switches with adjustable current limits were selected, as the current drawn by each noncritical subsystem varies. The TPS2553 power distribution switches have adjustable current ranges between 75mA and 1.3A which satisfies the requirements of all subsystems. The current limit is set by using an external resistor, and can also be controlled by an output pin on the microprocessor. This allows the system to have a hard set current limit that it will never breach, as well as allowing the PCM processor to turn the subsystem off and on upon instruction. Also on these switches is a fault pin. When the fault pin is set low a flag is sent to the PCM processor informing it that a noncritical subsystem has malfunctioned. All of this data is then sent to the C&DH system to be stored in memory.

3) Current Measurement System

The current measurement system is implemented in order to measure the current to each subsystem, both critical and noncritical, as well as monitor the current produced from each of the 5 solar panels. For this subsystem the MAX4072 chip was chosen, as it fits all the needs of the system. The chip obtains the voltage drop across a small current sense resistor and amplifies this voltage by a gain of 50. The output potential of the chip is then located between a selectable reference value and 3.3V (the maximum output). For this case the reference voltage was used as 1.5V as it was approximately half the maximum output. The size of the sense resistor then varies depending on the current range one is looking at. The calculations for a 40mA current are shown here.

$$I_{max} * R_{sense} = \frac{V_{out\,max} - V_{ref}}{Gain} \quad (7)$$

From here, a 30% margin was used to ensure the sense resistor was large enough as seen in Eq. 8 and the value to be used for the sense resistor is shown in Eq. 9.

$$I_{max} = 0.3 * 40mA + 40mA = 52mA = 0.052A \quad (8)$$

$$R_{sense} = \frac{3.3V - 1.5V}{50 * 0.052} \quad (9)$$

4) Electrical Health Monitoring System

The EHM system is designed to measure the noise on all 3.3V and 5V power lines located throughout the satellite. In order to do so, a small system was devised that would filter out the DC component of the signal and amplify the remaining components of the signal. The block diagram for this system can be seen below.

Figure 7: EHM Functional Diagram

The first issue addressed was amplifying the noise. After filtering the DC component the remaining noise would be extremely small (on the order of microvolts) but could vary greatly. For this reason programmable gain amplifiers were chosen so the gain could easily be adjusted to accommodate the varying noise levels.

The first stage of the EHM system is the removal of the DC component. For this a simple RC high pass filter with a cutoff frequency of 7Hz was used. Instead of selecting a resistor and capacitor to create a time constant (7Hz), the natural impedance of the programmable gain amplifiers was used in place of the resistor.

After the signal is filtered and the remaining noise is amplified, the signal then goes into the analog to digital converter (ADC) on the MSP430 microprocessor. The final point of concern was the sampling rate of the ADC. The sampling rate of the ADC was 10kHz and the frequency of the amplified noise was unknown. For this reason, another simple lowpass filter was created with a 5kHz cutoff to prevent aliasing of the signal. This also helps to ensure that all the data collected from the EHM system is usable.

5) Microprocessor Functions

The 16-bit variation of the MSP430 was selected for the PCM processor because it met all of the needs for the PCM and was requested by the customer. The MSP430 communicates with the C&DH processor via I2C, in order to send the data collected from the current measurement and EHM systems. Whenever a current limit is reached, an interrupt is triggered to inform the MSP430 that a system has been shut down. Another General Purpose Input Output (GPIO) pin is used to inform the C&DH system has drawn too much current and has been turned off. All the data collected by the current measurement and EHM systems are stored separately in onboard memory (up to 120KB). Before the data is stored, the ADC value is read and a running average is computed of the sample. This average value is then converted to its equivalent RMS value, when it is then stored in memory. The data is kept until the C&DH processor requests it. Upon instruction, the data is retrieved from memory and sent to the C&DH processor.

The MSP430 on the PCM is in control of turning on and off subsystems upon instruction from the C&DH. Another GPIO on the MSP430 is used to enable the 3.3V & 5V lines to all of the subsystems as well as the current measuring systems for each instrument. The microprocessor is also in charge of selecting the multiplexer line of the current measurement system in order to retrieve data about the desired subsystem. For this reason only one subsystem can be measured at a time. Finally, the MSP430 is used to select the gain for the programmable gain amplifiers on the EHM board.

C. Electrical Power System (EPS)

There are two manufacturers of suitable electrical power systems, Gomspace and ClydeSpace. One EPS system from each manufacturer that met the specifications outlined previously was selected. A comparison of the two can be seen below in table 1. The standard system was the set of requirements outlined by the customer. The ‘s’ represents a category that is satisfactory, meaning that the requirement is adequately met. The ‘+’ represents any category in which the EPS more than met the requirements while on the other hand, the ‘-‘ represents any category which did not meet the requirements outlined.

Table 1: EPS Comparison

	Standard	Gomspace P31u	Clyde Space EPS2-10
Price	$4,200	s	-
MPPT	Included	s	s
Battery	Included	s	s
PV inputs	3	s	s
Battery V	7.4V	s	+
Interface	I2C	s	s
Battery Capacity	2600mAh	s	-
3.3V I Out	5A	s	-
5V I Out	4A	s	s
PV Power Conversion	30W	s	-
Documentation	---	+	-

The comparison of the specifications and features of the two electrical power systems revealed the Gomspace P31u would more effectively meet the needs of NMTSat. The documentation of the Gomspace unit was also much better, as it had a step-by-step process on how to set up the EPS and verify that it functioned, as well as a manual on how to configure it to the needs of NMTSat. The full system diagram of the EPS system is shown in Appendix B.

IV. TESTING & FUTURE WORK

A. Electrical Power System (EPS)

The Gomspace P31u EPS was selected and ordered but has not been received due to a change in plans. NMTSat was contacted by another university CubeSat project and offered a trade collaboration. An EPS of our choice would be purchased and sent in exchange for a functioning LPP. The projected costs of the LPP were lower than that of the EPS so the decision was made to accept the exchange due to the low budget constraints.

Testing on the EPS will commence upon arrival. Once the EPS has been received it must be characterized individually as well as characterized while functioning in conjunction with the solar panels and PCM.

B. Solar Panels

The preliminary design of the solar panels has been completed and the printed circuit board has been made. The panels have also been constructed with a hot air rework station instead of the reflow oven (as the working status of the reflow oven is still unknown at this time). The full 3U panel was tested using this process. A picture of one of the solar panels used for testing can be seen in Fig. 8.

Figure 8: Solar Panel Testing

The heating of the board was not a concern, as originally expected. The board was expected to warp due to thermal expansion but the thermal relief on the cells and printed circuit board prevented this damage. The solar panels were then taken out into the sunlight to verify that they worked properly. The open circuit voltage and short circuit current were then compared to the expected values from the TASC datasheet. The open circuit voltage produced was 4.84V which was below the 5.5V maximum of the EPS input. The expected short circuit current for the pairs of cells was 992mA and the measured current was 800mA. This 3U panel produced 3.9W which was less than expected but the manufacturing process for the panels is not extremely efficient.

The locking Molex connecters were assembled in order to verify that they worked properly and locked sufficiently. The configured connecter can be seen below in Fig. 9.

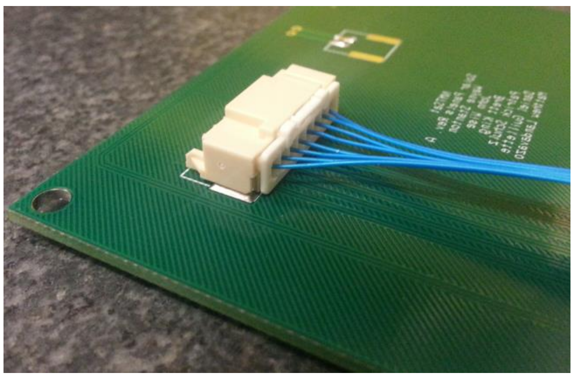

Figure 9: Molex Connector

The functionality tests of the solar panels have been completed but the best method for adhering the cells to the printed circuit board has not yet been determined so testing will continue on this. The piezoelectric sensors must also be soldered to the board and the data lines tested to verify they work properly. Finally, once the solar panels are complete and the EPS has been received a system test between the two can be conducted to make sure they function together as expected.

C. Power Control and Monitoring (PCM)

The design of the PCM and all of its individual subsystems has been completed as well as the printed circuit board design The current measurement, current limiting, and EHM system were all prototyped individually before the printed circuit board was designed. The results from the electrical health monitoring system can be seen below in Fig 10. This shows the input from a 9V battery (in order to avoid the 60Hz noise introduced by the function generator) that is then filtered and amplified by the programmable gain amplifier. The FFT of the output of the electrical health monitoring system is shown in Fig. 11 to verify that noise was amplified.

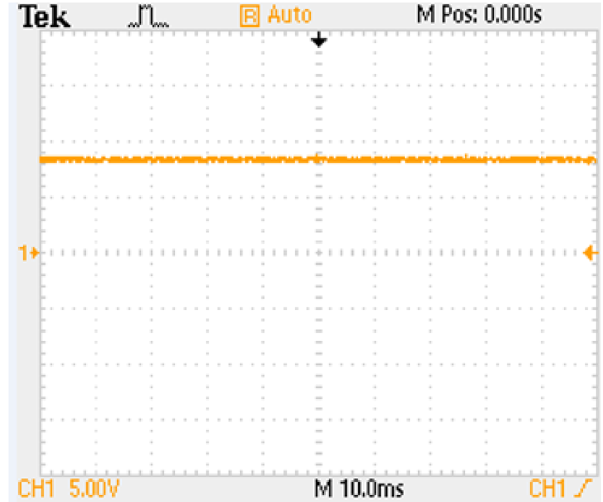

Figure 10: DC Power

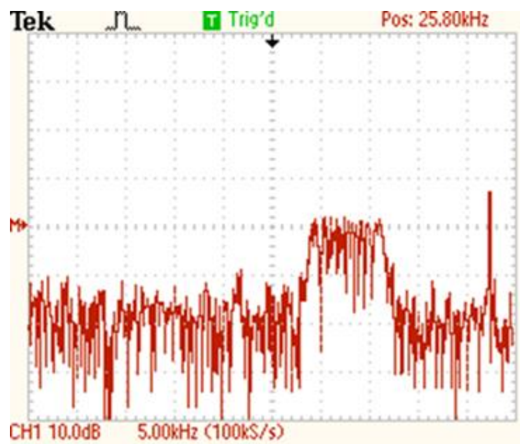

Figure 11: FFT of EHM Output

The final testing and population of the printed circuit board is currently in progress. The current measuring and current limiting systems have both been tested successfully. A picture of the test board can be seen in Fig. 12.

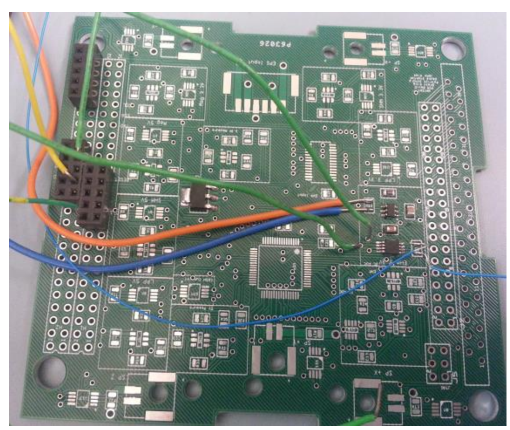

Figure 12: PCM Testing

The testing must continue with multiplexers, EHM system, and the microprocessor. The values for the current limiting resistors can be selected (see Appendix A) based on the needs of each subsystem once they are completed.

The final testing will include the functions of the microprocessor. The entire functionality of the microprocessor needs to be verified. This was pushed back by the customer due to the concern that the other subsystems would not be completed in time. Afterwards, the PCM, EPS, and solar panels can be tested as a full unit. Upon verifying that these work properly together, they can then be fully installed into the satellite frame.

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APPENDIX

A. TASC Datasheet

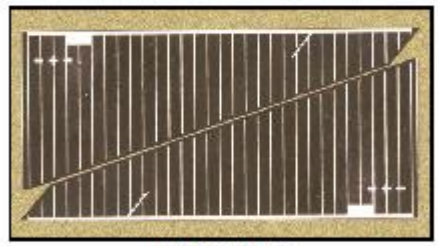
Spectrolab

Photovoltaic Products www.spectrolab.com

Triangular Advanced Solar Cells (TASC)

Product Description & Applications

- Designed for high power terrestrial applications, where space is at a premium.
- Two solar cells can be arranged within an approximate rectangular area of 0.611 x 1.254 inches (1.55 x 3.18 cm) with a cell gap of 0.018 inches (0.46 mm). See picture.
- Each solar cell is ideally matched to charge a single 1.2 V battery cell (eg. Ni-MH, NiCad, etc.). Cells can be wired in parallel for increased current. Two solar cells in series can charge one 3.6V Li-ion battery cell.
- A major advantage using these solar cells compared to silicon cells is that they deliver greater than 4 times higher voltage. Therefore, only one of Spectrolab's multi-junction solar cells is required to generate the same voltage as 5 Si solar cells connected in series
- Compared to typical silicon cells, these solar cells are ***over twice as efficient*** and thus will deliver more than twice the power for the same area.
- Uses and applications: A variety of power-consuming electronic equipment can benefit from these cells, especially if the area available is small or the time required for charging is limited. For example, these cells help power devices used during business trips, emergency situations or for the outdoor activities.



Not Actual Size

Typical Cell Electrical Parameters

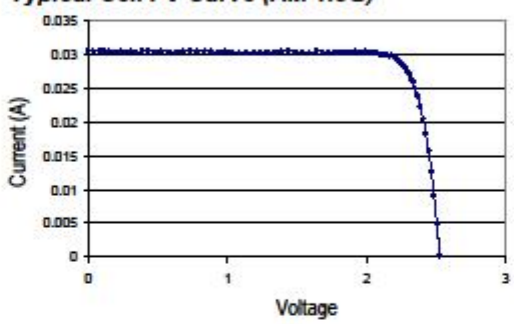
1 Sun, AM1.5G (100.0 mW/cm²) 25°C

I_{sc}= 31 mA	I_{mp}= 28 mA
V_{oc}= 2.52 V	V_{mp}= 2.19 V
P_{mp}= 0.027 W/cm²	Cff= 80 %
Efficiency= 27 ± 3% Absolute	Temp. Coeff. V_{mp} = -6.2 mV/°C

Product Description

Cell Type	Improved triple-junction gallium arsenide
Method of Cell Growth	Metal Organic Vapor Phase Epitaxy
Polarity	n/p
Thickness	190 µm (0.0075 in.)
Area	2.277 cm² (0.353 sq. in.)
Mass	0.234 g
Assembly Methods	Soldering, welding, metallized epoxy
Device Design	Monolithic, two terminal triple junction. n/p $GaInP_2$, GaAs, and Ge solar cells interconnected with two tunnel junctions.
Antireflective Coating	Multi-layer providing low reflectance over wavelength range 0.3 to 1.8µm.

Typical Cell I-V Curve (AM 1.5G)



ISO9001:2000 REGISTERED

SPECTROLAB

A BOEING COMPANY

The information contained on this sheet is for reference only. Actual specifications for delivered products may vary. 4/10/02

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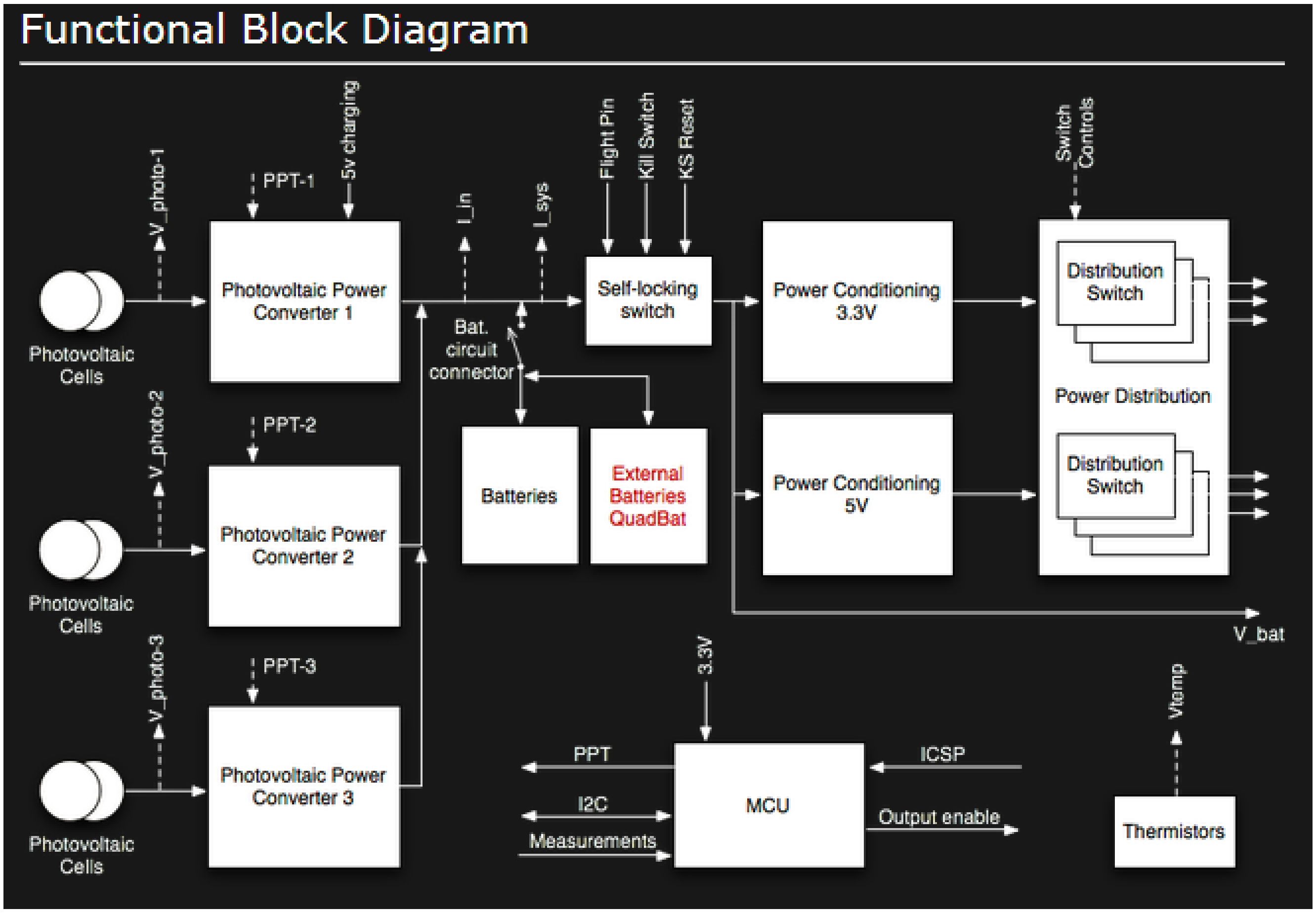
B. EPS datasheet (Relevant Data)

**This datasheet is for the newest version of the Gomspace P31u. The version ordered is an older version and the datasheet will have to be obtained from Gomspace before testing is done. The only difference is the PV input voltages. For the test system we will be receiving the marked value is 5.5V.

Specifications

Parameter	Condition	Min	Typ	Max	Unit
Battery - Voltage - Current, charge - Current, discharge *(*Only on Pxx-S)*	Battery connection (depends on battery configuration) (depends on battery configuration)	6.0 (*12.0)	7.40 (*14.9)	8.40 (*16.80) 6.00 12.00	V V A A
PV inputs - Voltage - Current, charge *(*Only on Pxx-S)*	Photo-voltaic inputs (Customer selectable)	0 (*0) 0.00	4.2 (*8.4)	5.5** ~~6.5~~ (*17) 2.00	V V A
5V_in - Voltage - Current, cont.	Battery charge input (beware of inrush) 5V => 0.9A charge, 4V => 0A charge @5V	4.10	5.00 0.9	5.00 1.1	V A
OUT-1,2,3,4,5,6 - Voltage - Current limit	Latch-up protected outputs Configurable Current cut-off limit (Cust. select)	0.5	3.3/4.98 Select	3.0	V A
+5V - Voltage - Current, cont.	5V regulated output (always on) Total current including output channels !!!		4.98	4.00	V A
+3.3V - Voltage - Current, cont.	3.3V regulated output (always on) Total current including output channels !!!	3.28	3.3	3.32 5.00	V A
V_BAT - Voltage - Current out *(*Only on Pxx-S)*	Raw battery voltage (depends on battery configuration)	6.0 (*12.15)	12	8.40 (*16.80)	V A



Functional Block Diagram
V_photo-1
PPT-1
5v charging
I_in
I_sys
Flight Pin
Kill Switch
KS Reset
Switch Controls
Photovoltaic Cells
Photovoltaic Power Converter 1
Bat. circuit connector
Self-locking switch
Power Conditioning 3.3V
Distribution Switch
Power Distribution
V_photo-2
PPT-2
Photovoltaic Cells
Photovoltaic Power Converter 2
Batteries
External Batteries QuadBat
Power Conditioning 5V
Distribution Switch
V_bat
V_photo-3
PPT-3
3.3V
Vtemp
Photovoltaic Cells
Photovoltaic Power Converter 3
PPT
I2C
Measurements
MCU
ICSP
Output enable
Thermistors

C. Current limiting datasheet (Relevant Information)

Table 1. Common R_{ILIM} Resistor Selections

Desired Nominal Current Limit (mA)		Ideal Resistor (kΩ)	Closest 1% Resistor (kΩ)	Resistor Tolerance			Actual Limits		
				1% low (kΩ)	1% high (kΩ)		IOS MIN (mA)	IOS Nom (mA)	IOS MAX (mA)
75		SHORT ILIM to IN					50.0	75.0	100.0
120		226.1	226	223.7	228.3		101.3	120.0	142.1
200		134.0	133	131.7	134.3		173.7	201.5	233.9
300		88.5	88.7	87.8	89.6		262.1	299.4	342.3
400		65.9	66.5	65.8	67.2		351.2	396.7	448.7
500		52.5	52.3	51.8	52.8		448.3	501.6	562.4
600		43.5	43.2	42.8	43.6		544.3	604.6	673.1
700		37.2	37.4	37.0	37.8		630.2	696.0	770.8
800		32.4	32.4	32.1	32.7		729.1	800.8	882.1
900		28.7	28.7	28.4	29.0		824.7	901.5	988.7
1000		25.8	26.1	25.8	26.4		908.3	989.1	1081.0
1100		23.4	23.2	23.0	23.4		1023.7	1109.7	1207.5
1200		21.4	21.5	21.3	21.7		1106.0	1195.4	1297.1
1300		19.7	19.6	19.4	19.8		1215.1	1308.5	1414.9
1400		18.3	18.2	18.0	18.4		1310.1	1406.7	1517.0
1500		17.0	16.9	16.7	17.1		1412.5	1512.4	1626.4
1600		16.0	15.8	15.6	16.0		1512.5	1615.2	1732.7
1700		15.0	15.0	14.9	15.2		1594.5	1699.3	1819.4