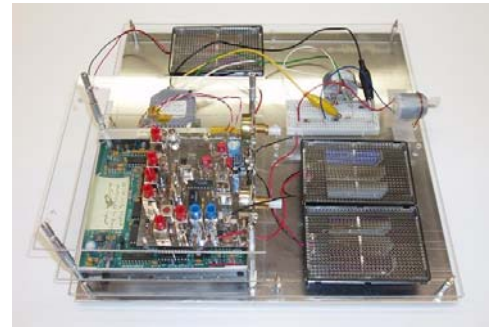


Solar Power System Design: Your objective is to design an electrical Power System for your LABsat. There are at least 8 different solar panel assemblies of various voltages and currents which you may use. You will be scored on how closely you are able to meet the mission objectives. You will have to design, select, and engineer your components to not only provide the required power budget, but also to fit the FLATsat layout for your LABsat as shown to the right. Your LABsat will have to operate with the loads as follows.



✓ Receiver	7v	40 mA	continuous
✓ Transmitter	7v	400 mA	but only a 1 sec telemetry packet every 10 seconds
✓ Telemetry TNC	7v	15 mA	continuous
✓ Momentum wheel	7v	35 mA	continuous
✓ Battery Charging	7v	___ mA	35/65 m eclipse/Sun & 90% charge efficiency

Design Power Budget: First, calculate the *average current* for your transmitter above. _____. Then add up all the load currents to find your average design load current _____. This total would be the solar power requirement if your mission was always in full sun. But your orbit is in a 35 minute dark, 65 minute sun orbit which requires additional current while in Sun to account for the time in eclipse. So, how many mA-minutes do you need in Eclipse? _____. Assume that charging and discharging the battery is only 90% efficient, so then how many mA-minutes are needed? _____. How many mA do you then need to charge during the 65 minutes in the Sun to accumulate that much energy? _____. Now, add that charge current requirement to your previous total and the result is the total required average solar current while you are in the Sun_____.

Your spacecraft’s ability to operate (as evidenced by continuous telemetry for 1 minute) with a positive power budget while also scoring high on its mission objectives is your measure of success. Your excess voltage above the minimum will give a good indication of your design margin. The following paragraphs give you some basic design basis for each of the components of your design:

System Battery: Batteries are used for power in eclipse and to provide peak power for intermittent loads. To simplify this exercise, your spacecraft is assumed to have constant average loads so no eclipse battery system is required. It would take hours and multiple eclipse cycles to see the long term net gain or loss of your power budget if a battery was included.

Charge and Bus regulators: The TNC has an internal series voltage regulator to provide 5.0 volts for the electronics but must have at least 6+ volts on the input to regulate properly. The other loads will all run on the unregulated solar array bus which you are designing to stay above 7 volts. You are adding a resistor to simulate the charge current requirement.

Heater: For this exercise, we do not need spacecraft heaters, but your spacecraft temperature limit is 60 deg C. You must not allow your solar panel to get above that temperature (too close to the lamp). Use the IR heat gun to monitor your panel temperature.

Receiver/Transmitter: You will use the transceiver system used in the Telemetry Lab. To avoid the high peak transmitter currents that require a spacecraft battery, the transceiver will use its own internal battery for its peak currents but you must connect the receiver and transmitter simulator resistors that are equivalent to their average load current.

TNC Telemetry System: The TNC requires 15 mA at 7 to 18 volts, but 7 Volts is sufficient for this test.

Momentum Wheels: We have two motors available. The ones installed in your LABsat are the MC-0507 motors. Your wheel must run throughout the test flight for success. Motor characteristics are as shown in the following table: (Use the existing MC-05/07 momentum wheel on your labsat.)

Motor	Volts	Current	Starting Current	RPM	Mass
MC-05/07	6	35 mA	80 mA	300	
MRE-260	3	80 mA	100 mA	300	

Telemetry System: Your LABsat will transmit its telemetry using the same 5 channel TNC system you used in the telemetry lab. It will be connected to show your solar bus voltage on Channel1 in tenths of a volt, and the system Current in mA on channel 2. Telemetry will be transmitted to the central ground station for observation.

Solar panels: The surface area available for solar panels for this mission is three 6” square panel areas as shown above on the FLATsat models. There are eight different solar panel modules from Solarworld.com that come in multiple sizes, voltages and currents and price: (<http://www.solarworld.com/SolarMini-Panels&Motors.htm>) For advertising purposes commercial panels are often listed with their open circuit voltage and short circuit current specs instead of the more meaningful peak-power specifications. Your peak power will be less than the given open circuit voltage and short circuit current shown in the table below. You must look at the peak-power curve (shown in the box lid) for each panel to determine their optimum voltage and current for your design. Observe the plot and estimate the peak power and optimum power density and add to the chart below. Also note the optimum useable voltage and currents that you might be able to use to series or parallel to meet your requirements.

Number	1-3.0-20	1-1.5-50	3-500	3-1.5-100	4-1.5-200	4-4.0-100	4-6.0-50	Pcsat
Size	1 x 1.75	1 x 1.75	1.75 x 3	1.75 x 3	2.5 x 3.75	2.5 x 3.75	2.5 x 3.75	5.3 x 4.5
Current	20 mA	50 mA	500 mA	100 mA	200 mA	100 mA	50 mA	60 mA
Voltage	3 Volts	1.5 Volts	0.5 Volts	1.5 Volts	1.5 Volts	4.0 Volts	6 Volts	18 Volts
Cost \$	\$11	\$9	\$8	\$10	\$13.50	\$17	\$18	\$32
Mass	5g	5g	13g	13g	24g	24g	24g	76g
Quantity	12	24	18	24	22	32	24	12
Peak Pwr								
W/sq-in								

Design Solar Panel System: First assemble your LABsat as shown below. It will consist of the usual R1/R2 voltage divider for Channel 1 voltage, and the current sensor chip for Channel 2. Compute the three equivalent load resistors to represent the average power needed by the Receiver, Transmitter and battery charging. _____, _____, and _____ Ohms. Add them and the motor to the circuit as shown. Now design your solar panel system to power all these circuits at a minimum of 7 volts and with your design current. Connect your solar panels to Vin as shown.

You are constrained by available surface area for your body mounted panels, and by cost and mass. Also, you must series modules to get sufficient bus voltage (*even under high temperature*) to meet the minimum requirements of all loads on the spacecraft (in this case, 6 to 8 volts). *Remember you can only series*

panels with the same current rating. Further you must parallel modules to get enough current (*You can only parallel panels with the same voltage*). Your design must balance all of these constraints. Each box of solar modules has its own I-V and power plot.

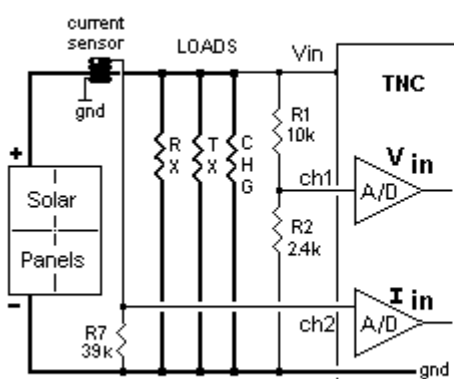
Be sure to do a quick acceptance test of any panel to verify that it works before you try to use it for flight!

Configure your LABsat A/D inputs to read the following parameters:

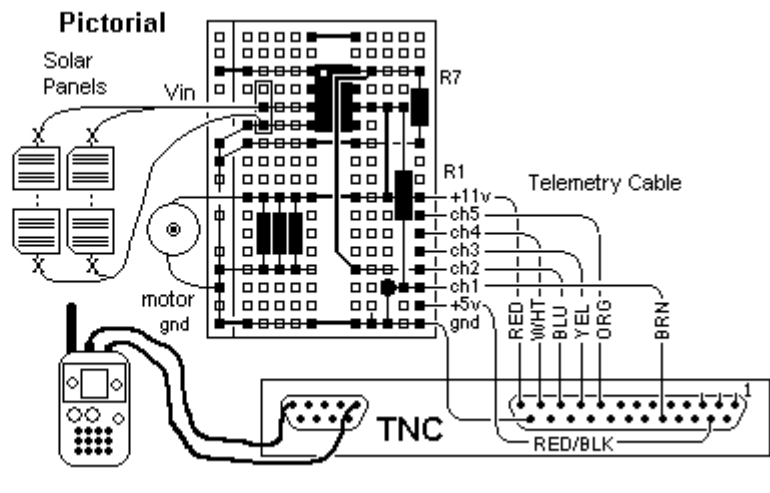
- Channel 1 – Solar array bus voltage in tenths of a volt
- Channel 2 -- Motor current as measured by the current sensor chip in mA.
- Channel 3 – (not used) Temperature (R2 selected as 10k for a half scale count of 128 at room temperature)
- Channel 4 – (not used) Volt Bus

Once you have selected your solar panel design and laid it out on your FLATsat model with all loads, you will then set it in the Sun spot to evaluate its performance. If the motor runs AND the TNC transmits telemetry to the ground station for 1 minute, you have mission success. Otherwise, your spacecraft is dead on orbit.

Schematic



Pictorial



WARNING!!! You must not keep your satellite in the SUN spot for more than 1 minute or you will MELT it! You will be penalized if you melt your solar panels.

SCORING: Unfortunately, this simple spacecraft design laboratory cannot give you all the range of options nor often conflicting requirements to fully simulate all of the design drivers in a real spacecraft, but at least you get the idea of the challenges involved. Teams will be ranked on these quantities::

- Open-circuit voltage, short circuit current, peak design power, and peak measured power.
- Array arrangement efficiency (packing density. Array areas divided by 100 sq inches)
- Array electrical efficiency assuming 100W per square foot illumination
- Solar Bus voltage (motors are almost constant current (no load). Voltage will tell available power)
- Mass of solar panels used

FLIGHT TEST: When your system design is finished, including solid mechanical design to survive the rigors of launch, place your FLATsat model and solar array in the SUN spot to fully illuminate your panel to one-Sun illumination. Go to the ground station and see if you are able to log 1 minute of telemetry to demonstrate your success. Measure each of the electrical and mechanical parameters of your array for your report. Also sketch your solar panel layout.

Post Lab:

Sketch your solar array design and give its overall specifications. Compare actual measured values with design values and comment. Discuss your results under the simulated full sun. Many Government contracts are scored by complex weighting formula to award bonuses for best work. Your project will be scored according to these scoring rules:

- Operating voltage (Ch1 in volts) times system current (Ch2 in mA)
- Divide by solar module total area in square inches. Multiply by 100
- Divide by mass in grams. Multiply by 100
- Divide by temperature in degrees C. Multiply by 100
- Divide by solar module cost in dollars
- The result is your score. Highest score wins.

Laboratory Report:

Prepare a team laboratory report with your partner. Tabulate the key parameters in your design such as:

- Transmitter average current (from page 1) _____
- Average load current (less battery charge) _____
- Battery charge current _____
- Total average current _____
- Solar panel choice _____
- Number of modules in each string _____
- Total solar panel area _____
- Actual operating voltage _____
- Design Operating voltage _____
- Number of strings _____
- Solar Panel mass _____
- Total solar module cost _____

Combine the results of this EPS design project with your earlier two EPS lab exercises into one report. Showing what you have learned about solar power systems, battery charging and discharging and regulator systems.