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Innovative Plug-and-Play Battery Charging System to Maximize Overall Electrical Power System Efficiency in 1U and 2U CubeSats

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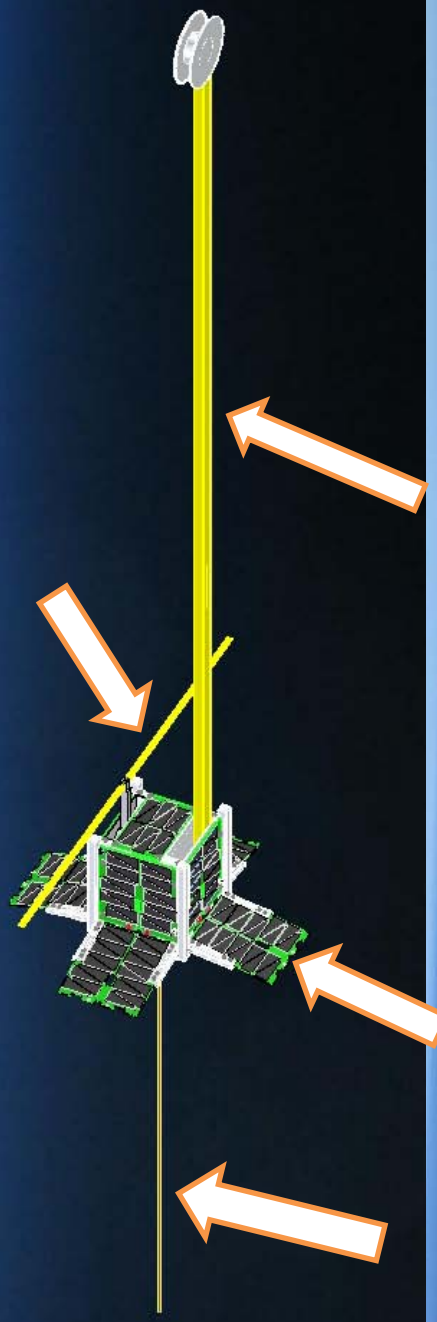
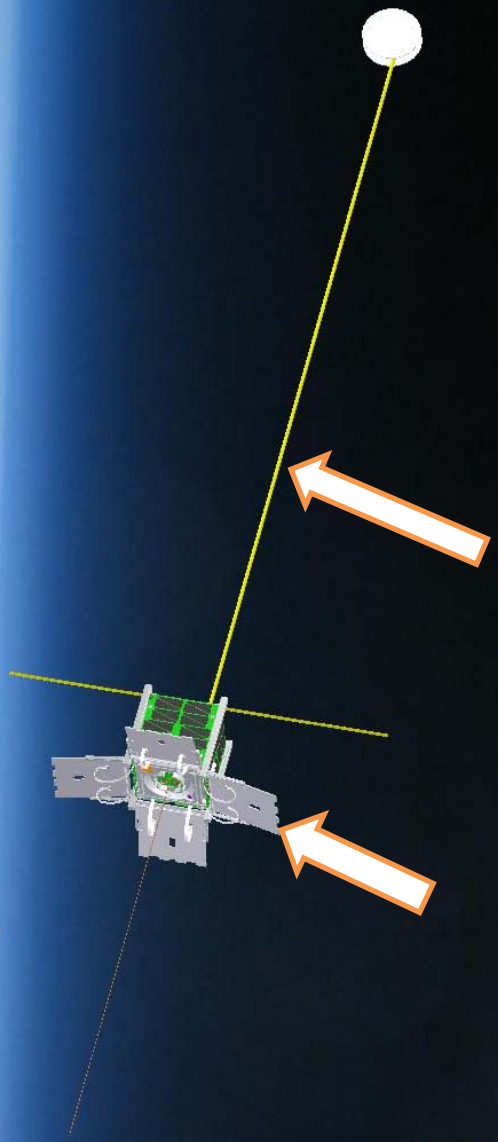
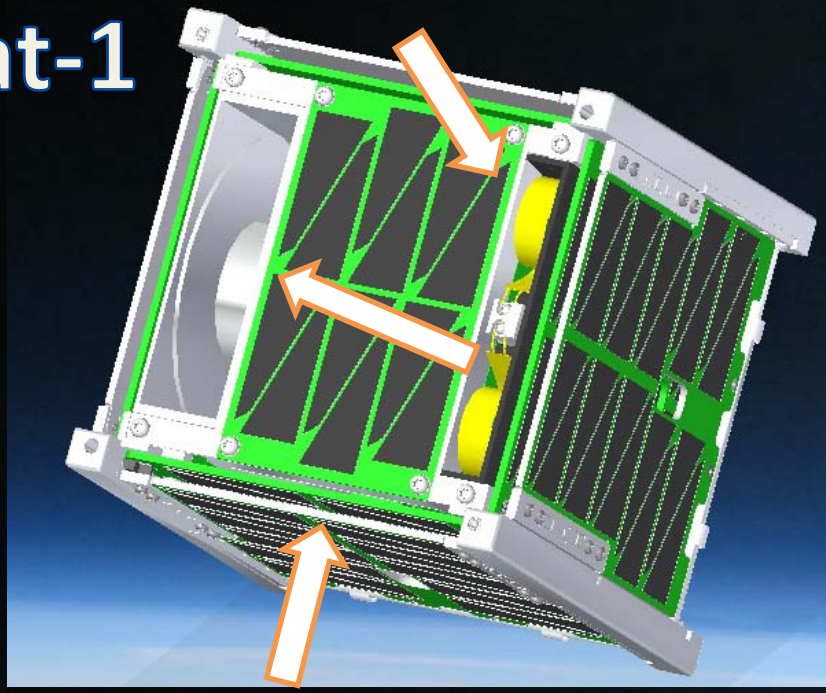
ChargerSat-1

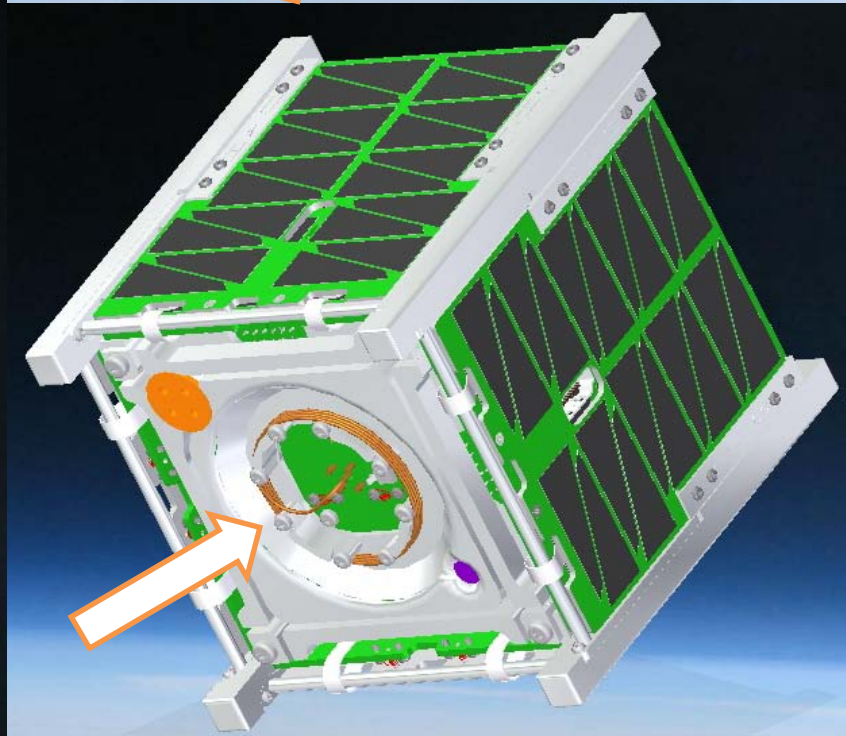
University of Alabama Huntsville

ChargerSat-1









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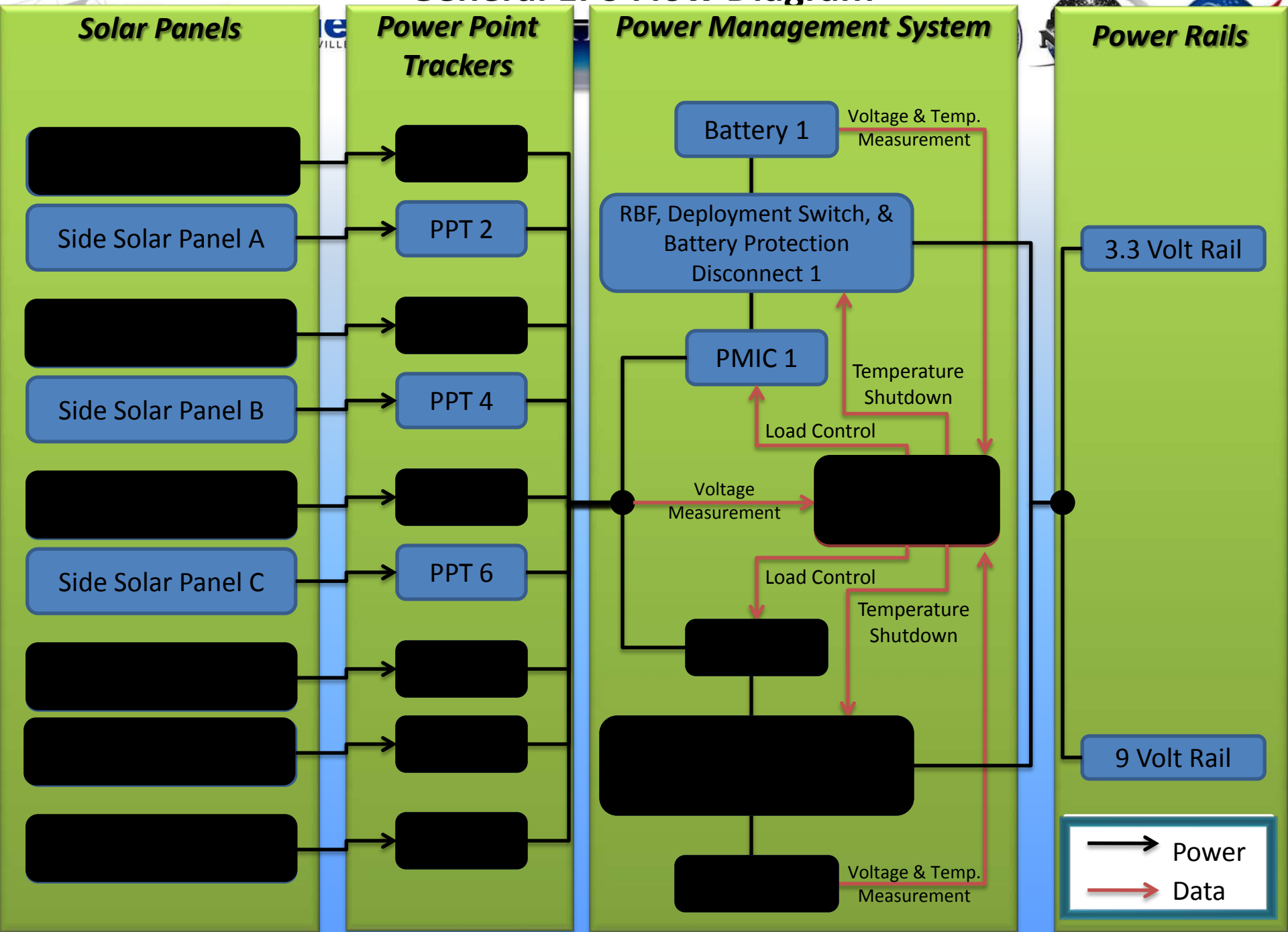
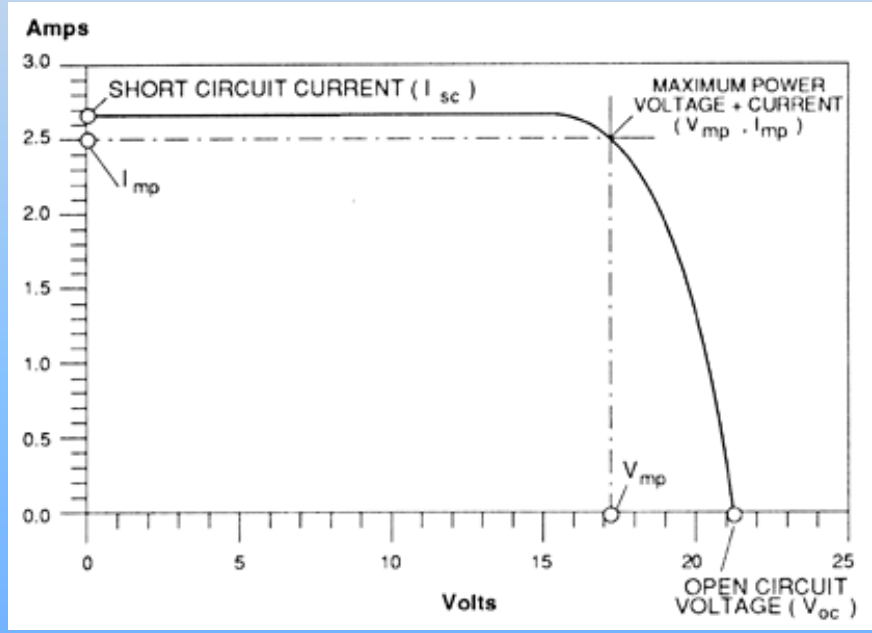
Electrical Power System

General EPS Flow Diagram



What is a Power Point Tracker?

- Power Point Trackers moderate the amount of current that is drawn from the solar panels
- The Maximum Power Point (MPP) shifts with temperature and cell degradation
- There are many ways to implement power point tracking



Fun Facts About Power Point Tracking

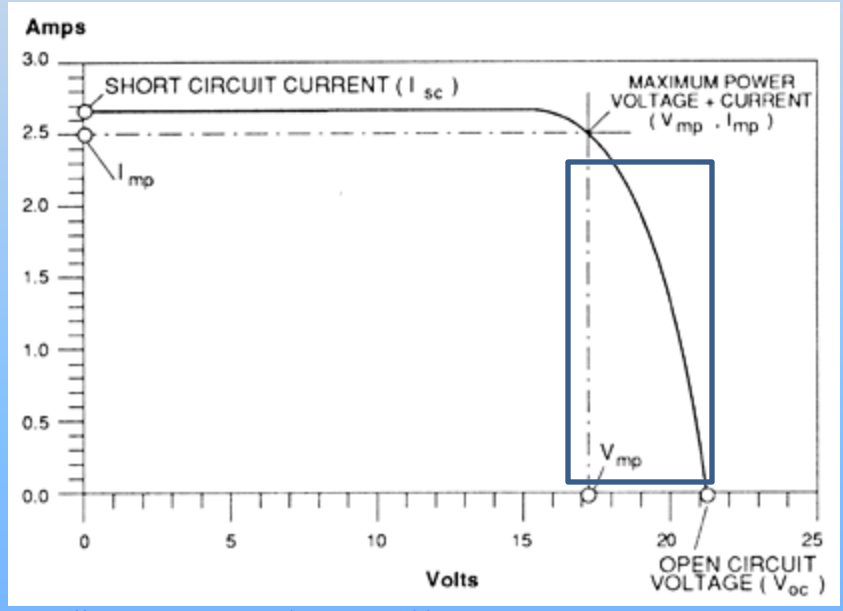
- Power

IF: Draw > Available

THEN: Bus Voltage Drops

IF: Draw < Available

THEN: Power Point Trackers not active



http://www.daviddarling.info/encyclopedia/I/AE_I-V_curve.html

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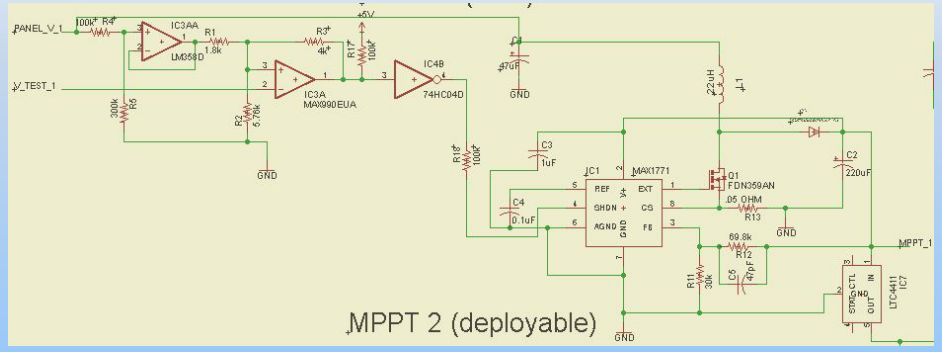
ChargerSat-1 Power Point Trackers

Power Point Tracker



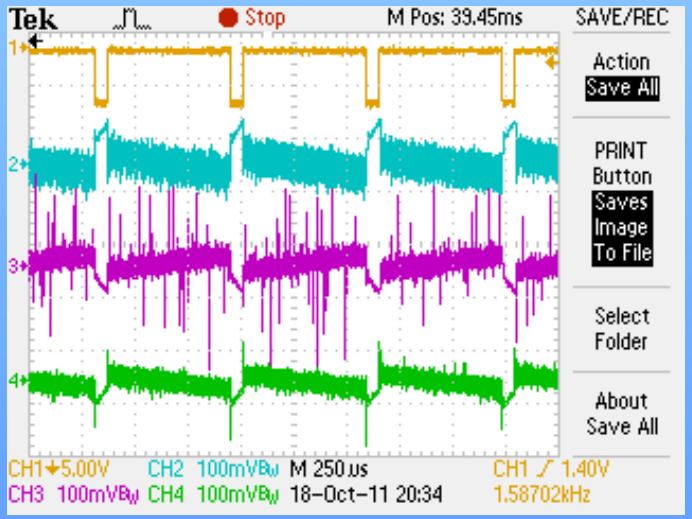
Input and Output waveforms of PPT

SHDN (OFF = LOW)

DC-DC Input

DC-DC Output

Comparator In



- Consists of a MAX1771 DC-DC convertor and a MAX990 comparator.
- The MAX990 compares input voltage to the DC-DC to the voltage of a test cell on the solar panel
- Based on the principle that the maximum power point of a solar panel is some percentage of its open circuit voltage.
- Test cell allows for analog tracking of thermal drift and radiation degradation
- PPTs are on the back of Side Panels
- **Status**
  - Prototype Designed and Tested
  - Awaiting Full System Integration and environmental testing

Battery Charging

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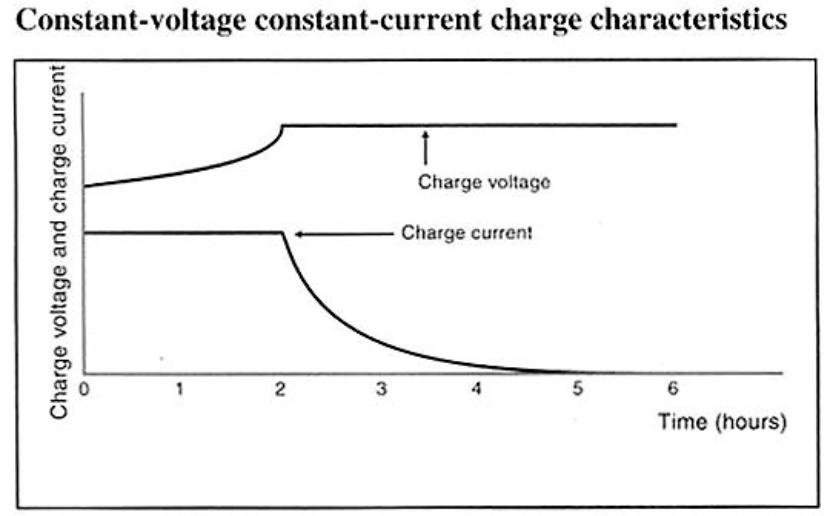
Bi-state Battery Charging

How to Charge a Li-Po Battery

1. Hold the charge current constant and let the Battery voltage climb
2. Once the battery voltage has reached ~4.25V, hold it constant and let the current drop off

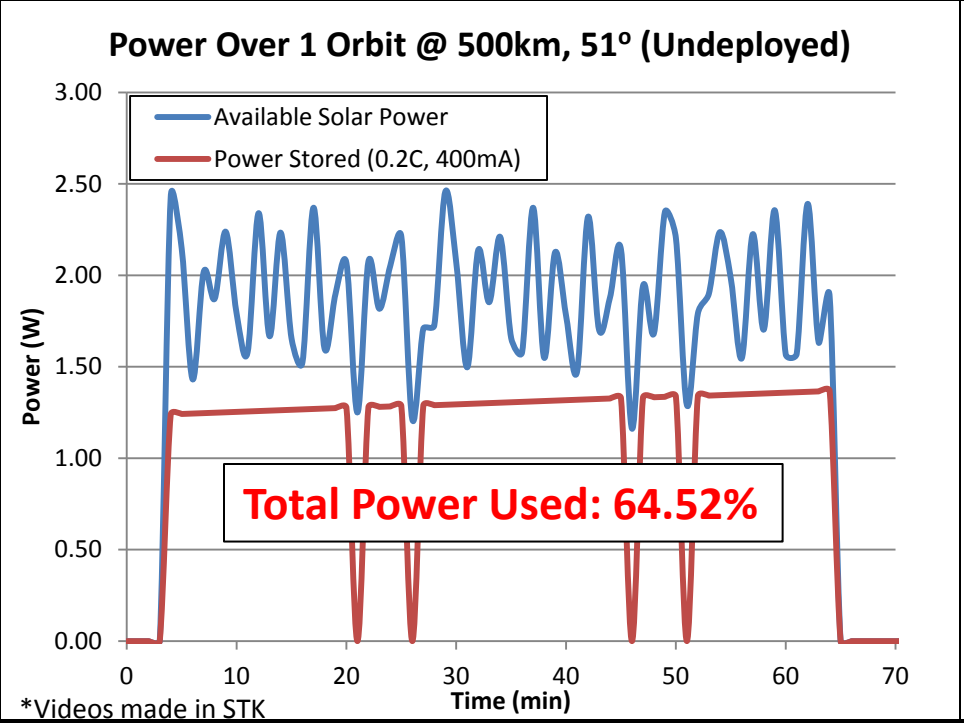


http://www.batterywholesale.com/charging_c.html

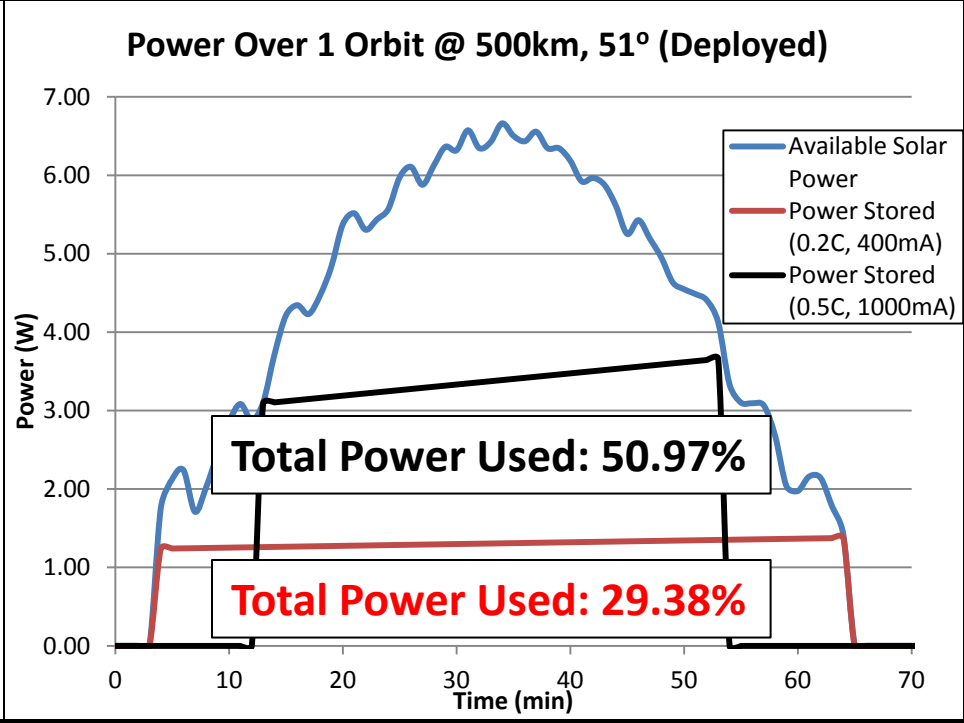
Advantages

1. Easily implemented with COTS solution
2. Maximizes battery lifetime
3. Reliable
4. Minimal chance of violent battery failure

http://www.rcgroups.com/forums/showthread.php?t=151687



*Videos made in STK



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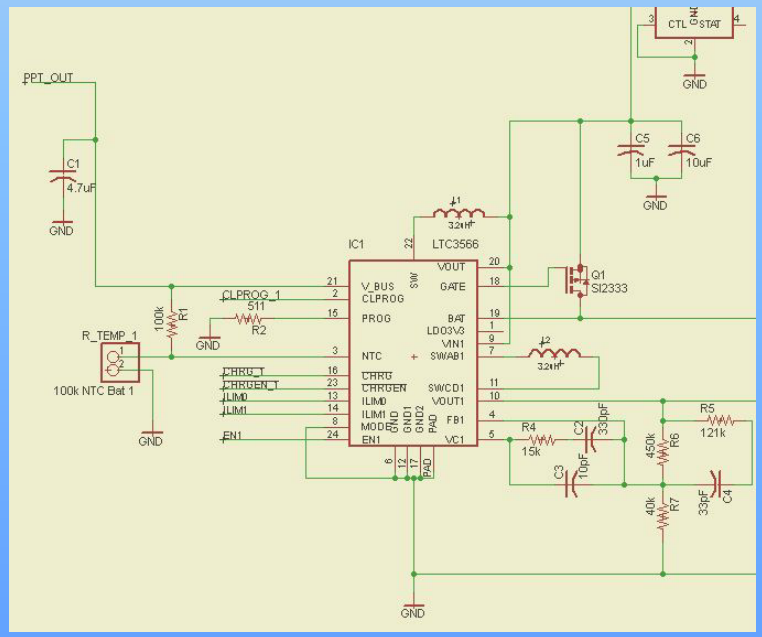
Power Management System (PMIC)

- Based on USB PMIC
- Automatically connects the battery to output of PMIC when input voltage drops below threshold
  - Entering eclipse
- Battery charging efficiency of over 90% (~92% measured)

Status

- Prototype Designed and Tested
- Awaiting Full System Integration and Environmental Testing



- PMIC prototype circuit

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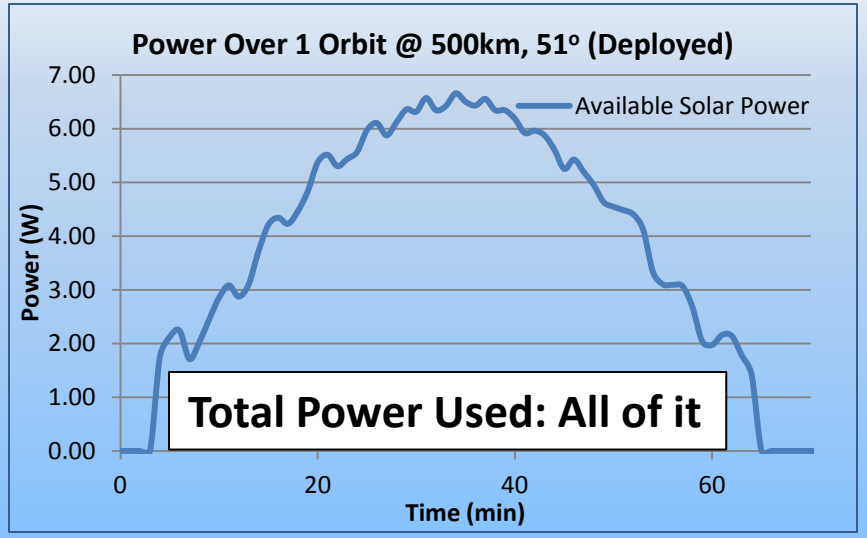
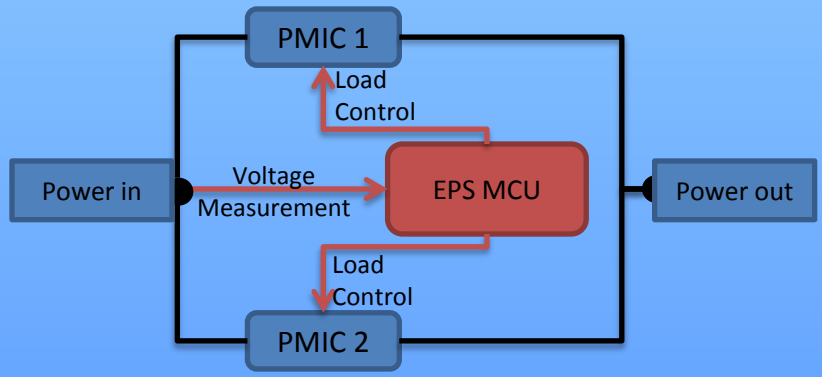
Load Matching & Battery Charging

- To fully utilized the power point trackers one must use all of the power available from the solar panels at any given time
- PMICs charge the batteries with unused power on the output based on an externally set input current limit
- The load matching circuit adjusts the input current limit of the PMICs till the input voltage drops below a certain voltage
  - Signifies PPT activation
- Once the load matching circuit locks onto the MPP, it tracks dV/dt, adjusting the input current limit accordingly to maintain PPT lock

Status:

- Working Prototype
- Control system under development
  - Allows Parallel Programming and Electrical Development





Pros and Cons

Advantages

- All available power used (minus charging losses)
- Automatically optimized
- Extremely tolerant to solar panel fatigue and failure
- Modular
  - Can be supplied by any 5V input
  - Can charge many Li-Pos on the market
- Wide charge current range
  - 0.01mA to 2A per PMIC
  - ChargerSat-1 EPS capable of fully utilizing combined 20W solar array
- System failure behaves like bi-state charger

Disadvantages

- Effects on battery lifetime unknown
  - Only gone through 15-20 charge cycles
- Battery failure rate unknown
  - Although 0% failure rate so far

EPS comparison

ChargerSat-1 EPS

- EPS: 85.6-80%
  - PPT: 93-87% efficient
  - PMIC: ~92% efficient
- Compensates for solar cell degradation and thermal gradients
  - No limit on mission lifetime
- Modular and easy to implement
- Extremely Robust
  - Can still function with over 50% of EPS failure

Direct Energy Transfer

- ~80% efficient
  - Not taking in to account thermal gradients
- After 25% solar cell degradation, batteries can not be fully charged
  - Limits mission lifetime
- After 30% solar cell degradation, $V_{mp} < V_{Batt}$

  (numbers from Spectrolab paper using UTJ)

Special thanks to

- University of Alabama in Huntsville
- Alabama Space Grant Consortium
- National Space Science and Technology Center (NSSTC)

Without them, none of this would be possible