AMSAT CubeSatSim – Battery Activity

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Group: _____Date: _____

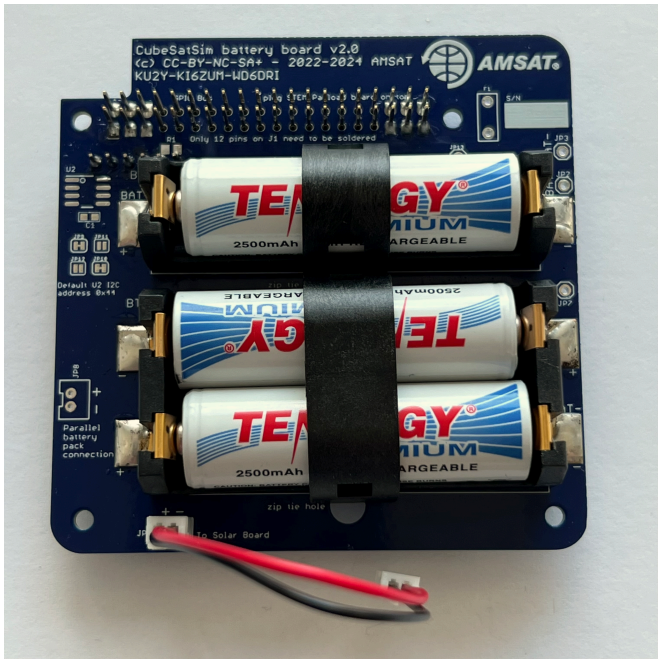
Introduction:

In this activity, you will learn about the Battery in the CubeSatSim and do experiments with charging and discharging.

This online Glossary can help with any terms or acronyms you may not know.

A. Battery Readings

Here is the CubeSatSim battery board:



The word “battery” refers to the fact that most batteries are made up of several cells working together.

How many cells make up the CubeSatSim battery? _____

Batteries are devices that use chemical reactions to produce electrical energy. The type of battery is determined by the chemistry in use.

If your CubeSatSim battery is enclosed in the frame, refer to the Wiki instructions to see the battery board: https://github.com/alanbjohnston/CubeSatSim/wiki/5.-Battery-Board

Can you find the type of battery used in the CubeSatSim? _____

The two main categories of batteries are primary (single use) or secondary (rechargeable).

Do you think the battery in the CubeSatSim is a primary or secondary? _____

Battery readings are voltage in Volts (V) and current in milliAmps (mA).

The battery voltage will always read positive (unless the battery cells were installed backwards!). The battery current will read either positive or negative depending on the direction of electrical current flow.

Individual battery cells are usually labeled with a positive (+) and negative (-) side.

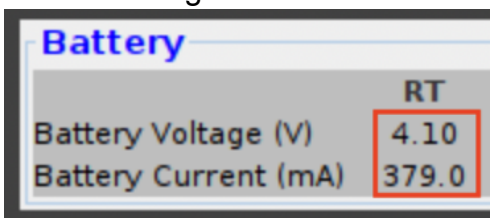
Can you see the positive and negative markings on the CubeSatSim battery?

The CubeSatSim Battery board has a built-in INA219 Voltage and Current sensor. It is either the tiny integrated circuit (IC) on the top left U2, or it is the blue square board on the bottom of the PCB.

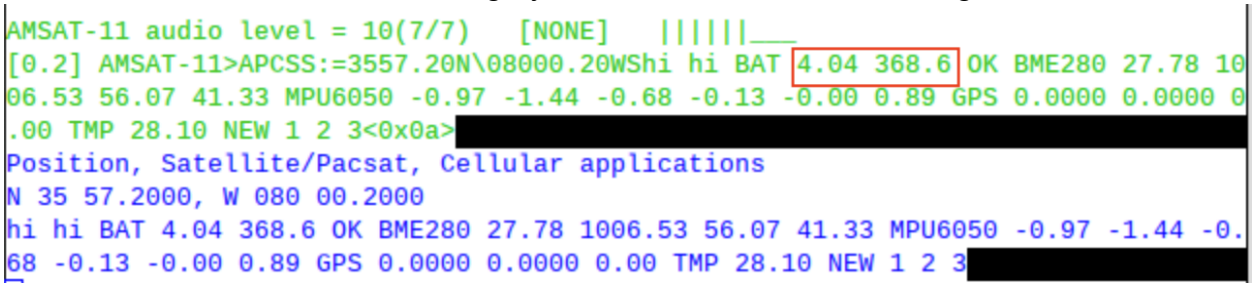
We will now read this sensor.

You can read the CubeSatSim battery in several ways:

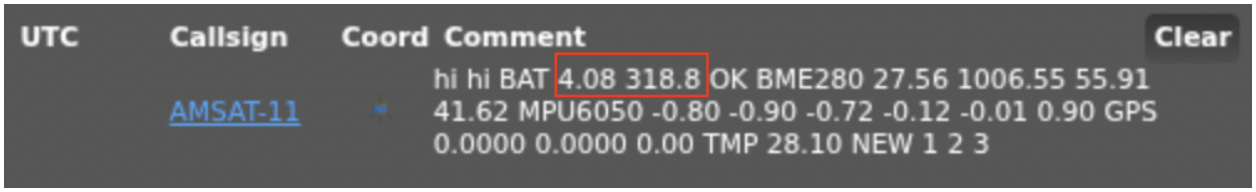
- Mode 2 or 3 with FoxTelem decoding. The values are in the Battery or Battery2 rectangles



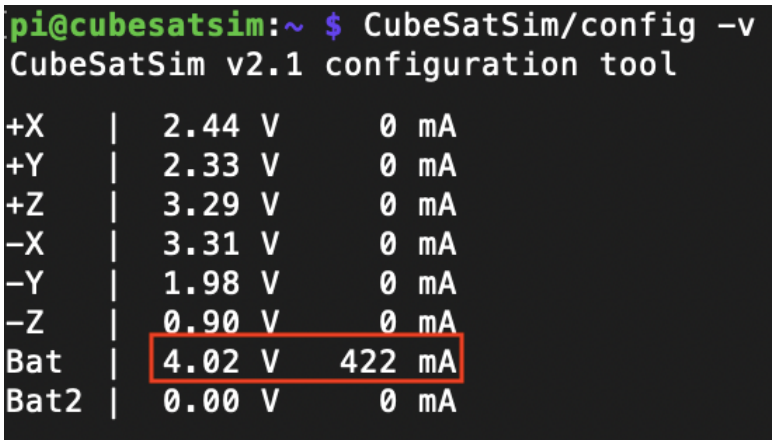
- Mode 1 with APRS decoding by Direwolf after the “BAT” string



- Mode 1 with APRS decoding by WebSDR in DIG Packet mode after the “BAT” string in the same order as previously described:



- You can also read them in any mode by logging into the Raspberry Pi Zero 2 and typing the **CubeSatSim/config -v** command:



- In SSTV mode, camera images will have the battery information at the top of the image

- A Voltmeter can measure the Battery voltage on the board stack. It could be measured on the Battery or Solar PCB

Power up the CubeSatSim and record the battery readings:

Battery Voltage _____ Volts (V)

Battery Current _____ milliAmps (mA)

Notice that the Battery Current varies quite a bit. Take 5 readings and average them to get an Average Battery Current:

_____ (mA) _____ (mA) _____(mA) _____ (mA) _____ (mA)

Average Battery Current _____ milliAmps (mA)

Now, plug in the USB-C cable and verify that the red charging LED illuminates. Record the battery voltage and current again:

Battery Voltage _____ Volts (V)

Battery Current _____ milliAmps (mA)

How does the battery voltage change? _____

How does the current change? _____

B. Battery Charging and Discharging

To observe the battery charging and discharging, voltage and current measurements need to be taken over a period of time. You could do this with a timer and periodically record the readings, but the best way is to use the graphic capabilities of FoxTelem.

See the "CubeSatSim Telemetry Activities Instructors Guide BPSK V1" for information on how to generate real-time graphs in FoxTelem.

Observe the battery voltage and current over 30 minutes of running on battery (USB-C cable not plugged in).

Also generate a graph of Power vs time. You can do this by exporting the graph data and the formula power = voltage x current

What happens to battery voltage over time? _____

Why? _____

What happens to battery power over time? _____

What happens to battery current over time? _____

Why? (Hint: it relates to what happens to power) _____

Now plug in the USB-C cable and verify that the red charging LED illuminates.

Observe the battery voltage and current over 5 minutes of charging the battery (USB-C cable plugged in).

Also generate a graph of Power vs time. You can do this by exporting the graph data and the formula power = voltage x current

What happens to battery voltage over time? _____

Why? _____

What happens to battery power over time? _____

What happens to battery current over time? _____

Why? (Hint: it relates to what happens to power) _____

Add the BME Temperature reading to the graph.

What happens to the temperature over time? _____

C. Battery Safe Mode

Satellites have battery management techniques to try to avoid a fully discharged battery.

Why? _____

In AMSAT's Fox-1 series of CubeSats, this is known as "Safe Mode". The CubeSatSim implements a simple version of Safe Mode when the battery voltage gets too low.

Run the CubeSatSim in BPSK Mode 3 without the USB-C cable plugged in. In FoxTelem, setup a graph of battery voltage and add Safe Mode to the graph. Run until Safe Mode is activated.

At what voltage is Safe Mode activated? _____

Now, plug in the USB-C cable and observe what happens to Safe Mode.

What happens to Safe Mode when the USB-C cable is plugged in?:
_____

Unplug the USB-C cable and keep running the CubeSatSim and observe what happens after running in Safe Mode for a while.

What happens eventually? _____

Can you see any LEDs illuminated inside the CubeSatSim? _____

Plug in the RBF plug. Now can you see any LEDs illuminated? _____

What does this mean? _____

D. Battery Trickle Charging

The CubeSatSim battery charging circuit implements something called trickle charging.

Start with a partially or fully discharged CubeSatSim battery. Plug in the USB-C charging cable, and do a graph of battery voltage and current. Observe over several hours.

Does the battery ever stop charging? _____

What is the value of the charging current after a long time? _____

E. Solar Panel Charging

The CubeSatSim can be charged by either the USB-C cable or by the solar panels.

Place the CubeSatSim sunlight (or halogen lamp - be careful of over heating!) Record the non-zero solar panel currents (you might see three sides supplying current):

Solar Panel Currents _____ (mA) _____ (mA) _____ (mA)

Sum these three currents to give the total Solar Panel charging current: _____ (mA)

Record the Battery current: _____ (mA)

Copy the Battery current you measured in Part A _____ (mA)

How did the solar panel current affect the battery current? _____

Add the Total Solar Panel current and the Battery Current: _____ (mA)

How does this compare this current to the Battery current from Part A?
_____

If you have a turntable, place the CubeSatSim on the turntable in the sun in the Low setting (L) and look at how the Battery Current changes.

F. Battery Self-Discharge

The batteries in the CubeSatSim will self-discharge over a period of several days.

The best way to measure this is to use a digital voltmeter that reads the voltage to a precision of 0.001 Volts.

Start with a CubeSatSim with a fully charged or partially charged battery and the RBF plug inserted. Record the battery voltage to three decimal points over a week at one day intervals at approximately the same time each day and record in the table.

Day	Battery Voltage in Volts (V)
Day 0	
Day 1	
Day 2	
Day 3	
Day 4	
Day 5	
Day 6	

Day 7	

How much does the battery voltage drop over a week? _____