Max Power Point Tracking System for Cubesats

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Overview

The environment in which a photovoltaic (PV) cells are operated can vary greatly. Other than the amount of sunlight a PV array receives, the temperature, internal resistance, and efficiency can affect the amount of power it will output. Due to the variability of temperature, and amount of sunlight in orbit around Earth, a Maximum Power Point Tracking (MPPT) system would improve the amount of power supplied to the batteries of a cubesat and reduce the probability of pulling too much power from the PV array thus causing the solar cells to brown-out and provide no power.

A cubesat is a small satellite used for short-term space research and is usually placed in Low Earth Orbit (LEO). Many cubesats, including QB-50 Challenger, do not carry a MPPT system onboard. A MPPT system is used to sense the voltage and current outputted by the PV array and regulate the power delivered to the load. This insures that the load does not pull more power than what the PV array can provide and can improve overall system performance.

Using an Arduino, a voltage/current monitor, and a buck converter, we have built a system based on the constant voltage MPPT algorithm as it is the simplest and easiest method to implement. Currently, it is in the prototype phase. The system reads voltage and current using a triple channel voltage/current monitor. The voltage/current monitor transmits data over the Inter-Integrated Circuit (I2C) communication protocol to the Arduino microcontroller. The buck converter controls the amount of power being supplied to the load. Both the voltage/current monitor and buck converter are controlled by the Arduino. Once finalized, it will be used on future cubesats. An overview of the project, details of the current design and initial test results will be presented.

Cubesats are miniature satellites that house different scientific instruments for space research. They are usually deployed into Earth's orbit and operate for months. QB-50 is a fifty cubesat constellation project lead by he Von Karman Institute of Fluid Dynamics. Each cubesat carries a different science instrument. QB-50 Challenger (Fig. 1), built by the University of Colorado Boulder, is a cubesat that carries an Ion-Neutral Mass Spectrometer (INMS) and will be launched later this year. This cubesat will measure the abundance of Oxygen, Nitrogen, and Nitric Oxide in Earth's lower-thermosphere.

All cubesats are powered using a photovoltaic (PV) array. The power output of a solar cell can vary depending on the conditions it is in. Solar cell efficiency, internal resistance, temperature, and amount of sunlight contribute to the amount of power a solar cell will output. A Maximum Power Point Tracking (MPPT) system takes voltage/current measurements of the power coming from the PV array and optimizes, using a boost/buck converter and an MPPT algorithm, the amount of power being supplied to the load. Many cubesats do not implement a MPPT system even though it can be very beneficial. A MPPT system will optimize the power being delivered to the load, and prevent any brown-outs in which too much power is being pulled than the PV array can supply.

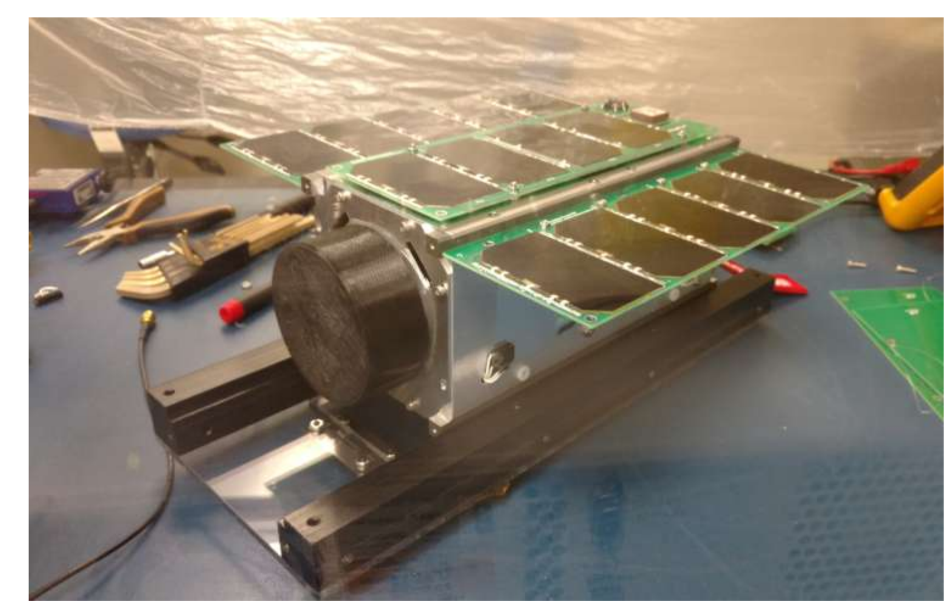

Figure 1. QB-50 Challenger

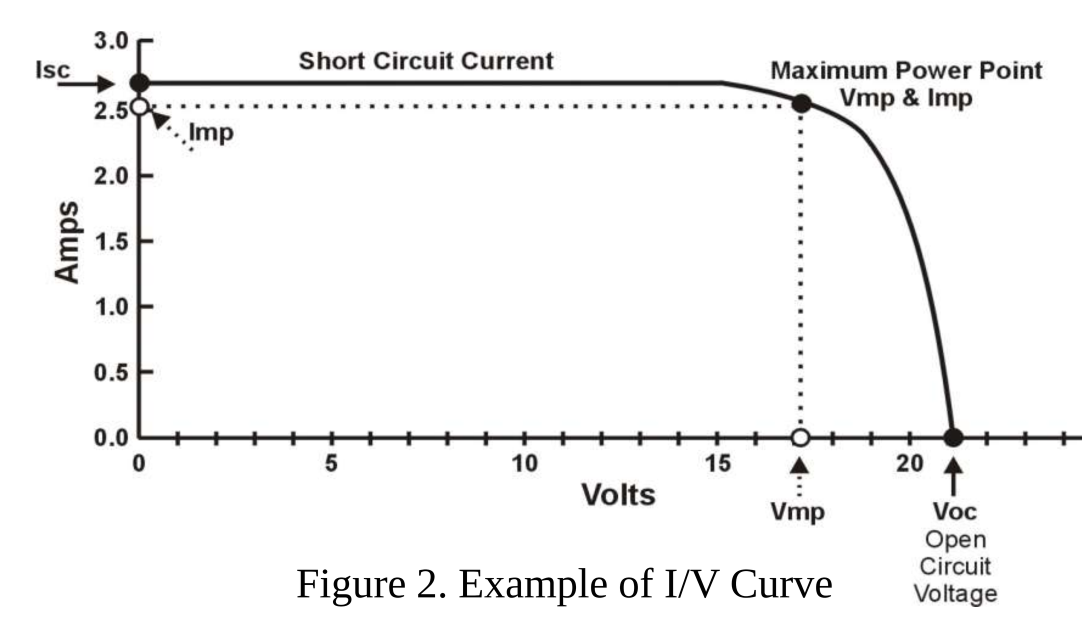

Figure 2. Example of I/V Curve

The concept of MPPT is to maximize the amount of power a PV array can output and supply the load without browning-out the solar cells. To do this, a microcontroller, MPPT algorithm, voltage/current sensor, and boost/buck converter are needed.

Components of the system:

- PV Array
- Arduino Uno (Atmel ATmega328P)
- Triple Channel Voltage/Current Monitor (TI INA3221)
- Buck Converter (TI TPS5420)
- Li-Ion Batteries

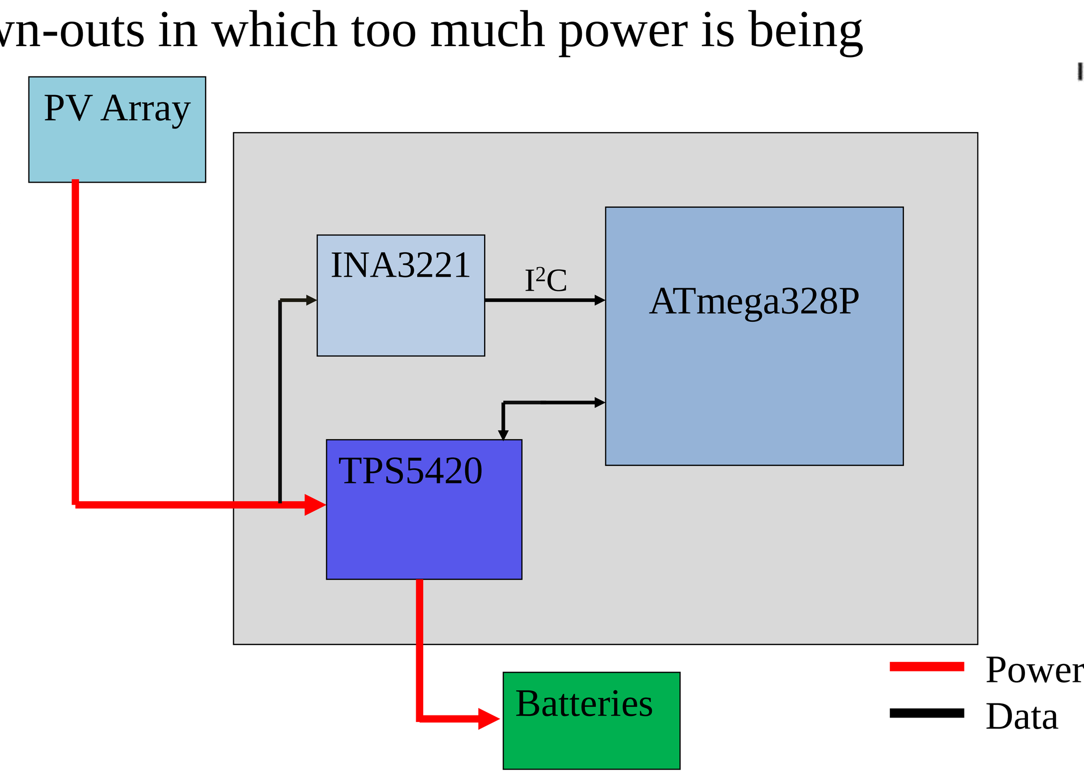

Figure 3. MPPT Device Block Diagram

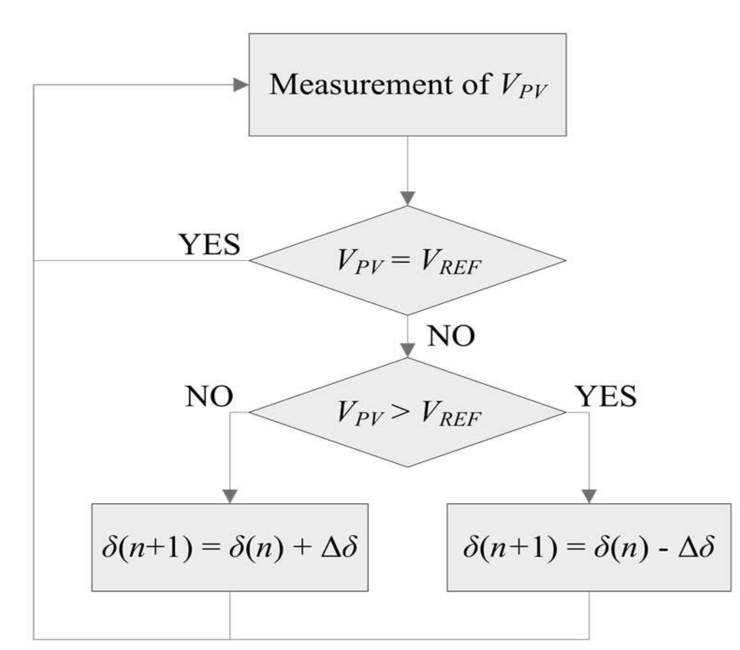

Figure 4. Constant Voltage Algorithm Flowchart (Dolara et al. 2009)

The Arduino Uno interfaces with the INA3221 over the I²C communication protocol and the buck converter which controls the power supplied to the batteries (Fig. 3). A MPPT algorithm optimizes the power output of the PV array by find the max power point of the I/V curve and setting the voltage to be at that point (Fig. 2). There are three major MPPT algorithms exist: perturb and observe, incremental conductance, and constant voltage. This system employs the constant voltage method as it is the simplest, computationally. With this method, power is interrupted, Voc with zero current is measured and operation is resumed with the output voltage at 76% of the measured Voc (Fig. 4). Generally, the ratio of the max power point voltage over the open circuit voltage is about 0.76 (Yu et al. 2009).

Results and Future Work

A prototype of the device was built using spare components of QB-50 Challenger including the Electrical Power System (EPS) board, backplane, and I²C breakout board (Fig. 5). The EPS board contains both the INA3221 and TPS5420. Both these components work well with the Arduino. The INA3221 and TPS5420 can read voltage values up to 26 V and 36 V, respectively. The PV array of QB-50 Challenger averages 16.5 V and 466 mA of output in full sunlight on Earth. The device will have no problem handling the incoming power. The device is currently powered by an external power supply. It will need further testing and development to know how much physical space it requires on a cubesat or if it can be placed on a current cubesat circuit board. Testing for the device's effectiveness will be done using the external power supply and possibly, a solar panel simulator. When the device is out of its prototype phase, it will be finalized and implemented on future cubesat missions.

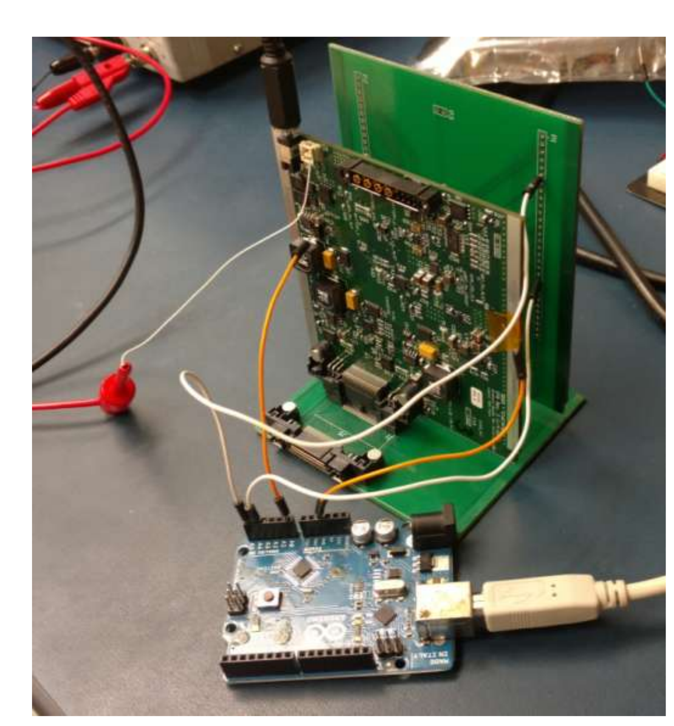

Figure 5. Prototype of device

References

Dolara, A., Faranda, R., Leva S., 2009, Journal of Electromagnetic Analysis and Applications, Vol. 1 No. 3

Yu, Z., Ogboenyira K., 2009, *Renewable Energy Through Micro-Inverters*

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