Signal Acquisition and Conditioning Test Results

Testing of the power acquisition and conditioning circuit will involve five phases as shown in Table 1. Phase 1, early testing, will involve varying the length of the windbelt to maximize AC current production and minimize length. Subsequent tests of the early stage involve varying fan speed and the angle at which wind is applied.

(***Warning: All Lithium-Ion battery testing MUST be accomplished with the battery in plain site prior to remotely testing. Li-Ion batteries can become highly unstable if charging conditions are less than nominal.***)

Table 6 - Signal Acquisition Test Descriptors

Test ID	**Phase -Component**	**Description**	**Pass Condition**	**Outcome**
P.1	Early - Windbelt Component	Vary length of the belt and measure AC voltage peak-peak using an oscilloscope.	AC current production is at a maximum, size of windbelt is at a minimum.	The size of the windbelt was larger than expected, but $2V_{AC}$ was generated consistently.
P.2	Early - Windbelt Component	Vary fan speed and measure AC voltage using oscilloscope.	AC current production is maximized.	Lowering fan speed surprisingly did not have a large effect on voltage generated. Outdoor testing saw the same numbers as indoor.
P.3	Early - Windbelt Component	Vary the angle at which the optimal wind speed is applied and measure AC voltage.	AC current production is maximized.	Angle has a large effect on voltage generated. When outdoors, the randomness of the angle serves

				to normalize output.
P.4	Intermediate I - AC/DC Rectification Component	Connect optimal design from early testing phase to half-wave rectifier circuit. *(Requires completion of windbelt.)*	Smoothing levels are adequate, and levels are held at 80% or higher of 3.3V with minimum fall time.	Although 3.3 V was not achieved, 1.2 V_{DC} proved to be adequate voltage for the boost converter to operate.
P.5	Intermediate I - AC/DC Rectification Component	Connect optimal design from early testing phase to full-wave rectifier circuit. *(Requires completion of windbelt.)*	Smoothing levels are adequate, and levels are held at 85% or higher of 3.3V with minimum fall time.	A full-wave rectifier was decided against, due to a larger voltage drop and higher cost and complexity.
P.6	Intermediate II - Primary Boost Converter Component	Connect output of rectifier to boost converter at VIN_DC port (pin 2). Measure output of boost controller at VSTOR (pin 15) using an oscilloscope (*Requires completion of custom PCB power management module.*) When running without MPPT, reference Figure 4 in the bq25504 technical document for the proper port configuration.	Measure voltage levels at output over elongated periods of time. Levels should not exceed those allowable by the battery (4.2V). Observe and track the DC output signal as it fluctuates over time to determine whether MPPT is necessary. Verify that the boost controller remains on during harvesting periods.	The boost converter was not tested for a configuration where MPPT was not enabled. This was considered a waste of time, since MPPT is a very powerful feature of the device. With MPPT enabled, the boost converter provided levels that were safe for the battery, never exceeding 4.2 V or dropping below 3.1 V.
P.7	Intermediate	Manually charge the	Measure voltage	The battery was

	II - Lithium Ion Battery Component	Li-Ion battery at the specified voltage for a nominal charge period. Measure the output voltage with a multimeter. *(May be done in an automated fashion as well.)*	levels of the battery periodically until it is determined that the battery has fully discharged. Record the time it took for the battery to discharge.	attached to the boost converter and allowed to discharge to the undervoltage level. At this point, the boost converter automatically cut power, and the battery was disconnected.
P.8	Intermediate II - Voltage Regulation Component	Connect fully charged Li-Ion battery to voltage regulator on custom PCB. Test DC output with multimeter at both outputs. *(Should be completed after battery testing)*	Measure voltage levels at both ports to ensure that 3.3 V is being provided to the XBee and 3.7 V is being provided to the second boost converter (5 V out).	The battery reads 4.2 V when fully charged, and about 3.5 V when discharged to the point that the boost converter shuts down. During operating periods, the buck converter reads 3.3 V and the secondary boost reads 5 V.
P.9	Intermediate II - Secondary Boost Converter Component	Connect 3.7 V pin to secondary boost converter and measure voltage at the output using a multimeter. Do not configure MPPT yet. *(Not sure which boost converter will be used yet)*	Measure voltage levels at the output of the boost converter. Output should be 5V to adequately supply the Cortex processors. Observe the output over time to determine whether MPPT is required at the secondary boost converter level.	MPPT is required to operate the circuit more efficiently. 5 V was supplied to the camera module, regardless of input voltage from the battery management solution.

P.10	Advanced I - Primary Boost Converter Component	Connect the battery to the boost converter as shown in Figure 4 of the bq25504 technical document. Measure duration and level of charge without MPPT enabled across the terminals of the battery and at pin 15. *(Should be completed after battery testing. Do not leave the battery unattended!)*	Battery duration, charge level and output should be within 20% of the measured discharge period of the battery when measured separately. Compare discharge rate with those of the battery without the sustainable energy source.	It was determined that running the boost converter without MPPT was inefficient and impractical for use with a battery management application. This test was not performed.
P.11	Advanced I - Primary Boost Converter Component	Configure the boost converter as shown in Figure 2 of the bq25504 technical document. Measure duration and level of charge with MPPT enabled for a solar energy application with the Li-Ion battery attached. *(Should be completed after battery testing. Do not leave the battery unattended!)*	Battery duration, charge level and output should be within 20% as above for elongated periods. Compare discharge rates with those of the battery without the sustainable energy source, and with the source but without MPPT.	This test was completed for a windbelt application. The intermediate step was not necessary. Discharge rates were determined acceptable for the application. Adding the sustainable source elongated the battery life by about 2 hours over a 24 hour period.
P.12	Advanced I - Secondary Boost Converter Component	Configure the boost converter for use with MPPT and measure the output of the converter using a multimeter. *(Should be completed after non-MPPT testing if*	Measure voltage at the output over elongated periods to ensure that the signal provided is 5 V, and that adding MPPT further stabilizes	The signal was measured at 5 V regardless of the input voltage to the boost converter when MPPT is enabled.

		required)	the signal for use with the MCU.	
P.13	Advanced II - Secondary Boost Converter Component	Configure the boost converter for use with MPPT and connect the M0 and M4 processors. Measure voltage at the output using a multimeter. *(Should be completed after MPPT testing without load.)*	Measure voltage at the output over elongated periods to ensure that the signal provided is 5 V.	Although voltage level drops at the output of the boost converter when the camera module is connected by about 0.35 V, the secondary boost converter still reads 5 V at the output.
P.14	Advanced II - Integration with Focus on Signal Acquisition	Deploy a single node in a controlled environment and monitor power conditions closely. *(Should be completed after all other component testing.)*	Measure voltage levels, battery duration and charge throughout the elongated period, and confirm that CV algorithms, networking, and all power dependent subsystems are fully-functional.	This was not completed since CV was not functional on the embedded camera. Bursts of 1000 packets were sent to test the radio functionality, and the ability of the buck converter to provide current ot the radio. This was successful during a 4 hour testing period.
P.15	Advanced II - Integration with Focus on Signal Acquisition	Deploy a single node in an outdoor environment. Allow node to operate without intervention and monitor conditions remotely. *(Should be completed after controlled*	Measure voltage levels, battery duration and charge throughout the elongated period, and confirm that CV algorithms, networking, and	With both the camera module and radio connected to the power module, the node stayed powered on for approximately 24 hours. CV was not functioning at the

		integration testing.)	all power dependent subsystems are fully-functional.	time, but TX tests were run.
P.16	Advanced III - Acceptance with Focus on Power Management Requirements	Deploy multiple (3-4) nodes in an outdoor environment. Allow node to operate without intervention and monitor conditions remotely. *(Should be completed after controlled and single-node integration testing.)*	Measure voltage levels, battery duration and charge throughout the elongated period, and confirm that CV algorithms, networking, and all power dependent subsystems are fully-functional.	This was not completed, as CV was not fully functional on the cameras that the power module was characterized for.

Intermediate testing focused on continuing testing with the optimized design chosen from phase 1. The rectifier circuit was connected to the windbelt, and smoothing and fall time were optimized. For the second intermediate phase, the focus was on providing safe levels at the output of the boost converter with the MCU connected to a non-battery power source.

Advanced testing allowed for connection of the battery and MCU to the boost converter and deployment in an outdoor environment. Battery voltage levels, duration, and charge levels will be measured for as long as the battery maintains its charge. Once components are proven fully functional, the signal acquisition system will be tested as a whole in a controlled testing environment. Acceptance testing was performed in the field, with less distance between nodes for easy maintenance and monitoring prior to actual deployment on the Lehigh Valley Trail. Tests were run to ensure that all power-dependent requirements were satisfied after integration level testing was completed.