Janus Technologies

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February 15, 2009

Mr. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Functional Specifications for the SolarMax Wireless Gateway Device

Dear Mr. Leung:

The attached document outlines the functional specifications for our SolarMax Wireless Gateway Device. We are designing and implementing a programmable unit that will allow for wireless control and monitoring of solar panels as well as provide data logging and a web-based interface.

Our functional specifications provide a list of high-level requirements that our final product must adhere to. Our specifications are arranged into three tiers of product development that correspond to the production phases we intend to follow. We will use these specifications as a basis for future design and development activities.

Janus Technologies consists of four motivated, innovative, and talented fifth-year engineering students: Adam Ciapponi, Matthew Giassa, Daniel Hilbich, and Robert Szolomicki. If you have any questions or concerns about our proposal, please feel free to contact me by phone at (604) 345-4664 or by e-mail at ensc440-darm@sfu.ca.

Sincerely,

Adam Ciapponi
President and CEO
Janus Technologies

Enclosure: *Functional Specifications for the SolarMax Wireless Gateway Device*

Janus Technologies

Functional Specifications for the SolarMax Wireless Gateway Device

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Executive Summary

We have reached a turning point in today's society where environmental concerns and energy efficiency are at the top of a long list of design considerations, rather than at the bottom. For decades, technologies have been developed to transform natural forms of energy in our environment into forms that we can harness and store; finally, the science behind these technologies has reached the point where they can now be used as feasible sources of energy. The only step remaining is to develop the systems surrounding these technologies to allow them to achieve their full potential.

The Wireless Gateway Device (WGD) is one such system, developed to streamline the operation of the SolarMax solar power conversion system provided by Analytic Systems. This will be achieved by providing data analysis capabilities currently unavailable in the device, and by converting the system to act as a wireless link while providing the groundwork to allow for upcoming sophisticated charge algorithms that could further improve its efficiency. This design will be accomplished as a set of three tiers, each outlining the development of several system requirements of varying importance.

Tier 1 will see the initial conversion of the conventional RS232 system to wireless while keeping the remote control interface intact. The design will utilize easy to use pushbuttons, LED feedback indicators, and an LCD screen to communicate with the user. RoHS compliant PIC microcontrollers will be used along with a predefined data packet structure.

Tier 2 will follow as the system converted to an integrated network allowing users to control the device from any area with appropriate Internet access. The system will then ultimately communicate though a USB interface, and will incorporate the SD interface for data logging. The prototype boards will be upgraded to printed circuit boards when appropriate to reduce material fees and energy consumption.

Tier 3 then sees the completion of the system as the user can communicate via the internet (i.e. a WAP) or directly through a USB connection, and possibly CANbus. The controller capabilities will also be increased to allow communication and arbitration with an array of SolarMax controllers. A battery pack power connection will also be integrated so that the entire system can operate standalone in remote areas.

Throughout its development, the system will be required to adhere to IEEE standards and protocols, such as USB, RS232, and the TCP/IP networking protocol; the design will also keep usability requirements and environmental considerations as top priorities.

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Glossary

AWG	American Wire Gauge
BFSK	Binary Frequency Shift Keying
BPSK	Binary Phase Shift Keying
CAN-bus	Controller-Area Network Bus
CRC	Cyclic Redundancy Check
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DPST	Double-Pole Single-Throw
ECC	Error Correction Code
FAT	File Allocation Table
FCC	Federal Communications Commission (US)
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
LCD	Liquid Crystal Display
PCB	Printed Circuit Board

PIC	Programmable Intelligent Computer
RC	Resistor-Capacitor
RoHS	Restriction of Hazardous Substances Directive
USB	Universal Serial Bus
TCP/IP	Transmission Control Protocol / Internet Protocol
WAP	Wireless Access Point
WGD	Wireless Gateway Device
Wireless Device	An electronic device capable of communicating with a similar such device through a wireless medium, such as through the use of modulated radio waves.

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1. Introduction

The wireless gateway device (WGD) is a system capable of acquiring status information from a solar panel charge controller using either onboard physical button inputs in real-time, or by viewing a log file generated by the device. Initially, in Tier 1, the WGD will be autonomously acquiring status data over a wireless link then dumping that information to an SD card. In further tiers of development, a user will be able to access the log data via TCP/IP over the internet. Below is an account of every required system specification.

2. System Requirements

In the following sections of this document, all of the requirements that the WGD must satisfy are documented according to category, with particular emphasis on the overall importance of the respective component or feature.

2.1. System Overview

The WGD system is intended to serve as a bridge between the SolarMax system and an individual user. Multiple input-output interfaces will be provided for the user to interact with in order to acquire device status information from the SolarMax device, along with providing a simple and elegant means to issuing commands to the SolarMax device as well. A summary of the overall system is demonstrated in Figure 1 below.

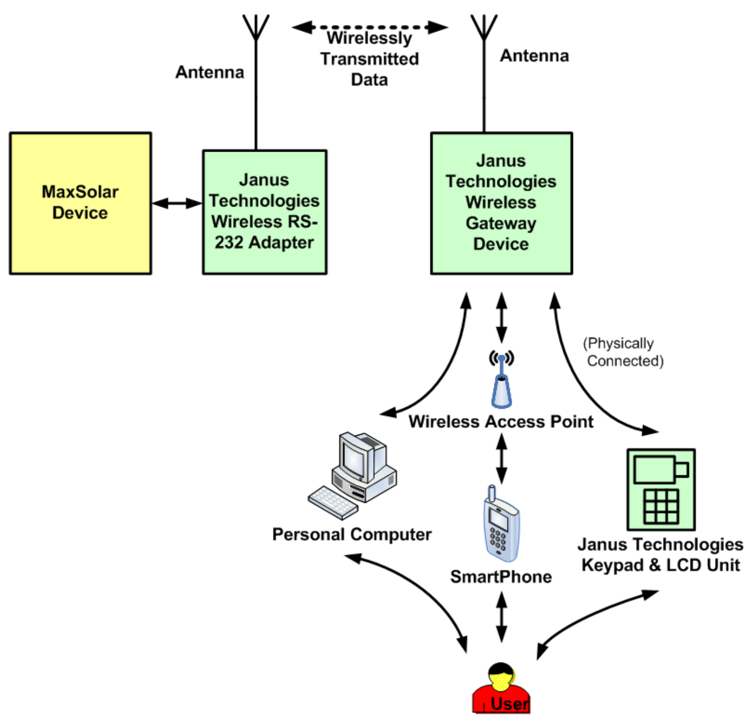

Figure 1 - System Overview

2.2. General Requirements

2.2.1. Tier 1: Required Features

[R-01] A push button interface is required for the user to control the unit manually.
[R-02] An LCD will be included to complement the push button interface and provide a complete input-output system.
[R-03] The entire system will communicate with a SolarMax device as a wireless device.
[R-04] A set of LEDs will be constructed to provide additional system feedback to the user.

2.2.2. Tier 2: Recommended Features

[R-05] A networking system will be implemented so that the user can control the device through the use of a personal computer or smart phone connected to a wireless access point (WAP) following the typical TCP/IP protocol.
[R-06] An SD card interface will be included for data logging purposes.

2.2.3. Tier 3: Optional Features

[R-07] The device will feature a USB and RS-232 interface as an additional means of communication with a personal computer as convenience to the user.
[R-08] The device will conform to RoHS standards, using only RoHS compliant hardware and lead-free solder.

2.3. Physical Requirements

2.3.1. Tier 1: Required Features

[R-09] The device will operate at temperatures between 10 degrees Celsius and 70 degrees Celsius.
[R-10] The device will operate between 0% to 70% relative humidity (non-condensing)
[R-11] The device shall not exceed 2lbs in weight, not including the power supply cable.
[R-12] The transceiver devices will operate properly at distances up to ten (10) feet.

2.3.2. Tier 2: Recommended Features

[R-13] The transceiver devices will operate properly at distances up to one-hundred (100) feet.

2.3.3. Tier 3: Optional Features

[R-14] The transceiver devices will operate properly at distances up to one-thousand (1000) feet.

2.4. Electrical Requirements

2.4.1. Tier 1: Required Features

[R-15] The device will operate from a single 12V power supply capable of providing at least 750mA of current.

[R-16] The device will utilize a 3.3V voltage regulator to provide stable power regulation to the PIC and other onboard components.

[R-17] The power regulation components of the device will use a filter to keep the power supply rails relatively free of noise.

2.4.2. Tier 2: Recommended Features

[R-18] Additional bypass capacitors will be used to connect unused power pins on the PIC to ground as a precaution.

[R-19] Unused data pins on the PIC will be connected to a signal ground.

2.4.3. Tier 3: Optional Features

[R-20] The device will have an optional battery pack connection allowing for the device to operate from a 3V battery.

[R-21] Voltage regulators with lower power requirements will be used to improve the energy efficiency of the device. Switch-mode power supply regulators will be investigated and implemented to improve efficiency.

2.5. Mechanical Requirements

2.5.1. Tier 1: Required Features

[R-22] The push button interface will be a simple matrix of double-pole single-throw (DPST) switches that require less than 10N of force to operate.

2.5.2. Tier 2: Recommended Features

[R-23] IC socket holders will be soldered directly to the circuit board, allowing chips such as the PIC to be replaced with relative ease, removing the need to de-solder components in the event that a single chip is damaged.

2.5.3. Tier 3: Optional Features

[R-24] Pin headers will be connected to the board allowing for the addition and removal of modular components such as the push button matrix, allowing for the matrix to be connected to the main device through a ribbon cable.

[R-25] A joystick style input control will be used to replace the 5 separate button setup.

2.6. Environmental Requirements

2.6.1. Tier 1: Required Features

[R-26] All ICs and other major components on the device will be RoHS compliant.

[R-27] Any un-needed components or waste from the production of the device will be disposed of in an environmentally sound manner.

2.6.2. Tier 2: Recommended Features

[R-28] The entire device should be constructed on a PCB to reduce the use of aluminum wires and solder, along with reducing the total energy used in the production of our device.

2.6.3. Tier 3: Optional Features

[R-29] All components will be connected to the main device with the use of silver solder as opposed to the traditional tin/lead type of solder.

2.7. Standards

2.7.1. Tier 1: Required Features

[R-30] The integrity of all wireless transmissions will be verified through the use of the CRC-32-IEEE 802.3 checksum algorithm.

[R-31] The SolarMax device itself will send data to one of our wireless transceiver devices through an RS-232 interface.

[R-32] The network interface component will communicate with an external computer using the TCP/IP networking protocol, version 4.

2.7.2. Tier 2: Recommended Features

[R-33] The device will allow an external system to communicate with it through a USB interface.

2.7.3. Tier 3: Optional Features

[R-34] The device will allow an external system to communicate with it through a CAN-bus interface.

2.8. Reliability and Durability

2.8.1. Tier 1: Required Features

[R-35] A predefined packet structure will be utilized for wireless data transmission, incorporating CRC algorithms to provide a reliable means of data transfer.

2.8.2. Tier 2: Recommended Features

[R-36] A strong plastic casing will house the device to prevent damage due to shock.

2.8.3. Tier 3: Optional Features

[R-37] A self-test routine will examine the status of all chips and verify the integrity of program code stored in the PIC.

2.9. Safety Requirements

2.9.1. Tier 1: Required Features

[R-38] At a minimum, AWG 20-gauge wire will be used for connecting power supply voltages throughout the circuit, such as those labeled "V_{CC}", "V_{DD}", "V_{SS}", and so on.

[R-39] Wires no smaller than AWG 24-gauge wire will be used for data connections.

[R-40] A toggle-switch will be connected to the input power connector so that a user can cut the power to the device without needing to disconnect the power supply itself.

[R-41] Aluminum heat sinks will be connected to all voltage regulators to prevent the regulators from overheating and failing.

2.9.2. Tier 2: Recommended Features

[R-42] Solder connections which directly connect to a power supply rail will be encased in either hot-glue or a resin so that a user can not directly touch such a point directly.

[R-43] Pin headers, provided with jumpers to protect them, will be used as "taps" should an engineer need to test the voltage at the supply rails.

2.9.3. Tier 3: Optional Features

[R-44] All remaining power connections will be sealed with a conformal coating to prevent short circuits in the event of environmental interference due to moisture.

2.10. Performance Requirements

2.10.1. Tier 1: Required Features

[R-45] The serial data sent via the wireless transceiver devices will be sent at a rate of at least 1000 baud.

[R-46] The data logging system will be able to store at least 256MB of log files.

[R-47] The log files will be stored in a FAT partition, allowing the log files to be read with relative ease directly from the SD card using a standard personal computer.

2.10.2. Tier 2: Recommended Features

[R-48] The serial data sent via the wireless transceiver devices will be sent at a rate of at least 4000 baud.

[R-49] The display of commands on the LCD from push button input should be provided to the user within 0.1 seconds.

[R-50] The LCD should provide at least two rows of alphanumeric output.

2.10.3. Tier 3: Optional Features

[R-51] An RJ12 connection will be provided for users to debug or reprogram the PIC without having to connect additional wires.

2.11. Usability Requirements

2.11.1. Tier 1: Required Features

[R-52] A user must be able to operate the system with no documentation other than the manual for the WGD system.

[R-53] The installation and use of the WGD system will require no additional tools or hardware.

[R-54] Any and all error codes the device may produce must be documented and made available for the user in the product manual.

2.11.2. Tier 2: Recommended Features

[R-55] Any input devices will be ergonomic in design to allow for comfortable use of the WGD system.

2.11.3. Tier 3: Optional Features

[R-56] All output devices, such as an LCD screen, will display output at a minimum size of 4mm x 7mm per character to allow for enhanced readability by a user.

[R-57] Manuals and documentation will be provided in multiple languages to allow the device to be used by people not fluent in English.

3. Wireless Transceiver Devices

Easily the most important aspect to our WGD system, the wireless transceiver devices are the components which will allow the WGD system to communicate with an external device or peripheral, in this case, the SolarMax device, through a wireless medium. This will be accomplished by using wireless transceiver devices that will connect to an external antenna to transmit or receive data wirelessly. The transceivers will also handle all the low-level details, including the digital modulation of the original signal by means of binary phase shift keying (BPSK) or binary frequency shift keying (BFSK).

This will allow us to transmit serial data back and forth between the WGD system and the SolarMax device without having to concern ourselves with the implementation details specifically. The inclusion of error-checking code in our packet headers will also rule out data integrity and data correctness issues, resulting in a reliable, modular, and robust wireless interface. An example of such a configuration is shown in Figure 2 below.

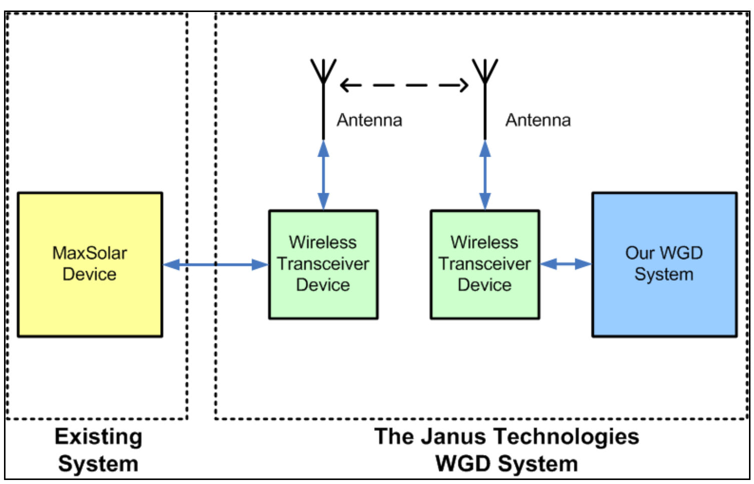

Figure 2 - Wireless Transceiver Overview

3.1. General Requirements

[R-58] The wireless transceiver devices must be capable of transmitting serial data between the SolarMax device and the WGD system in a consistent and reliable manner, emulating a wired connection between the two devices.

[R-59] The devices must allow for some manner of addressing, allowing multiple such devices to transmit data at the same frequency.

[R-60] The devices must communicate using a pre-specified data packet structure, which will enforce the appropriate use of error correction codes (ECC).

3.2. Electrical Requirements

[R-61] The wireless transceiver components must be able to operate from a single 3.3V power supply.

[R-62] The wireless transceiver components must be able to directly handle RS-232 data signals from the SolarMax device without sustaining any damage due to electrical overload.

3.3. Physical Requirements

[R-63] The wireless transceiver and antenna must be able to fit onto a 6” x 4” printed circuit board or perforated breadboard.

[R-64] The wireless signal transmitted must have enough power to provide some resilience to external noise.

[R-65] The wireless signal must not occupy a bandwidth reserved for specific purposes, as per FCC regulations.

3.4. Usability Requirements

[R-66] The antenna must be resilient to some degree of mechanical stress, and must be fixed to the WGD system securely.

[R-67] The device must operate correctly at a certain minimum distance, as specified in requirement **[R-12]**.

4. Push Button Interface

The push button interface provides a basic user input interface. The user is able to press a single button at a time, while simultaneous button presses from multiple buttons are ignored altogether. Push button input is edge-triggered; holding down a single button for an extended period of time has the same effect as pressing it and releasing it very quickly.

The six (6) push buttons that are included in our device are as follows:

- “Up”, “Left”, “Down”, and “Right” buttons, for navigating through menus shown on the LCD.
- “Enter” button, for executing an action through the menus shown on the LCD.
- “Reset” button, which resets the entire system (This button needs to be held for a specified period of time before the software acts upon it).

The button layout can be seen in Figure 3 below. Its layout should be very intuitive and simple for all users to understand.

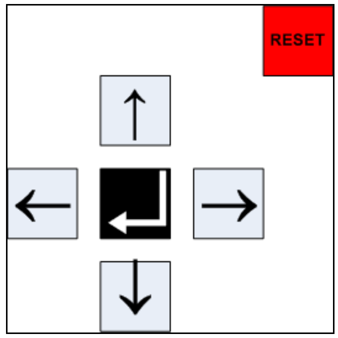

Figure 3 - Push Button Interface Layout

4.1. General Requirements

[R-68] Six (6) push buttons will be required in total.

4.2. Electrical Requirements

[R-69] An RC de-bouncing circuit will be implemented to prevent erratic electrical waveforms from being generated at the input of the PIC due to imperfections in the push buttons.

[R-70] The push buttons must be able to conduct at least 2mA of current.

4.3. Physical Requirements

[R-71] The push buttons must be 4-pin DPST for stability so that they do not snap off of the main board of the device.

[R-72] The physical dimensions of the visible cross-sectional area of the push buttons must be at least 5mm by 5mm.

4.4. Usability Requirements

[R-73] The buttons themselves should be arranged in a very intuitive and non-arbitrary layout for convenience of the user.

[R-74] All buttons must be normally open switches and must automatically return to the “open” position when the user is no longer holding down a button.

5. LCD Output System

The LCD component of our system provides a basic output device for the user. The LCD, in conjunction with the push button interface, will provide the user with the ability to interact with our system in a rapid and reliable manner. An example of the type of LCD device we are using is shown in Figure 4 below. Although the device will require additional power to run, such a component is an important feature to our system [1], and can be disabled automatically based on specific criteria, such as a lack of user input for a certain period of time.

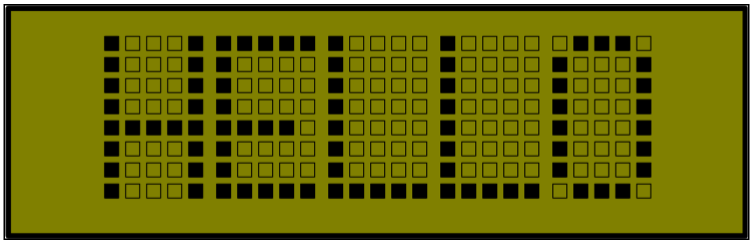

Figure 4 - Sample LCD Screen Output

5.1. General Requirements

[R-75] The LCD must be able to display at least two “rows” and ten “columns” of characters.

[R-76] The minimum resolution per character must be at least five pixels wide by eight pixels tall.

[R-77] The LCD must be durable enough so as not to be damaged by a user accidentally touching it.

5.2. Electrical Requirements

[R-78] The LCD must be able to run off of a 3.3V power supply.

5.3. Physical Requirements

[R-79] The LCD must not be larger in size than 2” x 5” x 0.5”.

5.4. Usability Requirements

[R-80] The LCD must be able to display all basic alphanumeric and punctuation symbols from the Latin alphabet.

[R-81] The LCD must provide its own backlight to improve readability in poorly lit environments.

[R-82] The LCD will only update its display according to user input, allowing the user time to read any output displayed.

6. Network Interface System

The network interface system will provide a means for the WGD system to connect directly to a local area network or the Internet itself. This will allow for the device to be monitored or even controlled remotely. This could prove to be among the most valuable feature to the WGD system as it allows a user to control it from virtually any location worldwide, provided that an Internet connection is available to both the remote user and the WGD system.

This system will handle all of the implementation details involved in all layers of the Open Systems Interconnection (OSI) model [2]. It will be divided into two major subsystems. One will handle both the physical and data link layers, and will be managed by a single chip [3], while the network, transport, session, and presentation layers are handled by firmware freely provided by Microchip Technology [4]. Finally, the application layer itself is handled by software that will be developed by Janus Technologies. The software will run on a PIC manufactured by Microchip Technology.

6.1. General Requirements

[R-83] The networking system will provide a means for a user to monitor the device through the use of a computer or similar device capable of communicating via the Internet (eg: a SmartPhone, laptop, etc).

[R-84] The networking system will allow a user to issue commands to the SolarMax device.

6.2. Electrical Requirements

[R-85] The entire networking system must be able to operate from a 3.3V power supply.

[R-86] The networking system must be able to directly interface with any standard networking equipment, such as a personal computer or a router, without any components failing due to the additional load.

6.3. Physical Requirements

[R-87] The networking system must connect to other network devices by means of an 8P8C connector, often referred to as an RJ45 jack.

6.4. Usability Requirements

[R-88] The networking system must be able to be automatically assigned an IP address by a DHCP server, and must support DNS resolution.

[R-89] The device must be able to service at least one user request per second.

7. SD Card Data Logging System

The SD card data logging system stores data for logging and debugging purposes. The software stored in the PIC determine which data is to be stored to a file on the SD card. This data will include readings from the SolarMax device, in addition to error messages that may aid developers and engineers in the debugging of the system.

Provided that our device is powered off, the SD card may be removed or reinserted without the use of any tools, and can be interfacing rapidly and easily with a standard personal computer, allowing backups of the data stored on the SD card. A standard SD card is shown below in Figure 5, courtesy of Sandisk.com [5].

Figure 5 - An SD Card (Approximate Size)

7.1. General Requirements

[R-90] The card holder must be capable of holding a standard SD card without user assistance.

7.2. Electrical Requirements

[R-91] The card itself must be able to operate from a 3.3V power supply.

7.3. Physical Requirements

[R-92] The cardholder will need to be able to hold the SD card in place securely, regardless of the physical orientation of the device.

[R-93] The cardholder will only release the card when the user manually attempts to remove it.

[R-94] The cardholder will be located near one of the edges of the main device, allowing for easy access to it.

7.4. Usability Requirements

[R-95] A user must be able to remove the card from its onboard holder without the use of tools.

8. Documentation and Manuals

Thorough documentation on all aspects of both the design and use of our wireless gateway device (WGD) system will be maintained and catalogued. This will allow for the preparation and production of extensive documentation on the WGD, and will lend itself well to the creation of an exhaustive and comprehensive user manual. This manual will provide users with little to no background knowledge of the device to be able to configure and use the WGD with relative ease.

The manual itself will be of professional quality, and will include images to guide users through each section in the manual. It will be structured in a linear manner, guiding users through the following key stages in the configuration and use of the WGD system:

- Safety precautions
- Device requirements (physical, electrical, environmental)
- Device installation and configuration
- Device use and initialization

- Debugging the device and interpreting error codes
- Warranty and repair details
- Contact information in order to reach Janus Technologies

The aforementioned documentation will also be included as part of a technical documentation package which will be kept confidential, and will not be provided to customers. This will serve as a basis for a series of design specifications that may be used to repair the device in the event of component failure or damage the device may sustain as a result of misuse by the user, or from unexpected environmental damage. This documentation, along with the device manual, will form an all-encompassing technical description of the WGD system, and could be used to both maintain and improve on the design of our existing WGD system.

9. System Test Plan

9.1. Individual Component Testing

Prior to including any components in our design, each component is individually tested to ensure that it is not faulty or damaged. In the case of individual discrete components such as resistors, diodes, and capacitors, simple tests involving the use of a digital multi-meter or impedance analyzer is sufficient.

In the case of integrated circuits, the circuit in question will be connected to a solder-less breadboard and its performance will be evaluated by our design engineers to ensure that the circuit operates as per its specifications as documented by the component's manufacturer. This will reduce system testing early on in the design of the WGD system, and prevent unneeded system testing as a result of a single unreliable component.

9.2. Integration Testing

In addition to the testing of each individual component, a recursive integration testing methodology will be employed. Although this will require that several subsystems be re-tested frequently, it will reduce the possibilities of a single addition to the WGD system causing existing subsystems to fail. This will also allow for the final revision of the WGD system to take place very rapidly, as opposed to the chaos that typically ensues when all integration testing occurs at the end of project development.

Throughout the design of the WGD system, test plans will be prepared for each of the major systems outlined in sections 3 through 7 this document. Each test plan will be very basic, indicating the expected behavior of a single subsystem, along with a summary of the observed behavior. This will allow multiple test plans to be executed in parallel, reducing the amount of time required to test the entire system, and distributing the workload evenly amongst all design engineers.

10. Conclusion

The WGD controller will improve the usability and performance of the current SolarMax system, allowing previously impossible power outputs to be achieved through an accessible and intuitive user interface. This will be accomplished through the completion of the requirements in this functional specifications document over a course of three design tiers. Tier 1 requirements are already being satisfied and the project is well underway; promising progress is already being made in both the functionality of the device and integration of the various components and protocols that are required.

11. References

[1] Eugen Trandafir, General meeting to discuss project work with Analytic Systems, 16 Jan 2009

[2] Internetworking Basics. 2009. *Cisco Internetworking Technology Handbook*. 9 Feb 2009. <http://www.cisco.com/en/US/docs/internetworking/technology/handbook/Intro-to-Internet.html>

[3] ENC28J60. 2009. *Microchip Product Catalog*. 20 Jan 2009. <http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en022889>

[4] Ethernet Solutions Design Center. 2009. *Microchip Design Resources*. 6 Jan 2009. <www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1489 >

[5] Standard SD Cards. 2009. *Sandisk Products Catalog.* 9 Feb 2009. <http://www.sandisk.com/Products/Item(2363)-SDSDB-8192-A11-SanDisk_Standard_SDHC_Card_8GB.aspx>