Janus Technologies

School of Engineering Science
Burnaby, BC V5A 1S6
ensc440-darm@sfu.ca

March 2, 2009

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

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

Dear Mr. Leung:

The attached document outlines the design 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.

These design specifications provide details on the implementation of the Wireless Gateway Device. The design specifications are arranged into three tiers of product development that correspond to the production phases we intend to follow. Future designs and development activities are also discussed.

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

Adam Ciapponi
President and CEO
Janus Technologies

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

Janus Technologies

Design Specifications for the SolarMax Wireless Gateway Device

Project Team: Adam Ciapponi
Matthew Giassa
Daniel Hilbich
Rob Szolomicki

Contact Person: Adam Ciapponi
ensc440-darm@sfu.ca

Submitted To: Patrick Leung – ENSC440
Steve Whitmore – ENSC305
School of Engineering Science
Simon Fraser University

Date Issued: March 3, 2009

Revision: 1.2

School of Engineering Science
Burnaby, BC V5A 1S6
ensc440-darm@sfu.ca

Executive Summary

The design specifications in this document provide the design and implementation details for the Wireless Gateway Device (WGD). These design specifications are separated into three distinct tiers of production. The functional requirements corresponding to the design specifications, along with a description of the three productions tiers, can be found in the *Functional Specifications for the SolarMax Wireless Gateway Device* [1].

The design specifications provide a detailed overview of the various components of our WGD as well as integration details and testing plans. The Tier 1 design phase is dominated by hardware design, and mimics the same functionality as the current SolarMax implementation with several optimizations; the component designs in this phase include a 5 button keypad connected to a PIC processor, updated SolarMax firmware for optimized packet transfer, an RS232 UART interface used for communication with a PC and/or the SolarMax device, and a wireless transceiver module which completes the connection between the user and the SolarMax device. Other feedback components include an LCD display and LED indicators. Tier 2 requires the design of a web-based interface for communicating with the control board, as well as the integration of an SD card interface for data logging purposes. Tier 3 finally sees design modifications made to make the entire system as RoHS compliant as possible.

The design details are multifaceted and include material/component considerations as well as testing plans and environmental considerations. Our goal is to provide through this document a thorough and comprehensive overview of our system.

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Glossary

BFSK	Binary Frequency Shift Keying
BPSK	Binary Phase Shift Keying
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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ensc440-darm@sfu.ca

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 provide the functionality to manually retrieve status data through a pushbutton interface and display the data on an LCD screen. In further tiers of development, the WGD will be autonomously acquiring status data over a wireless link then dumping that information to an SD card, where 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, in addition to our overall circuit schematics, as shown in Figure 1 and Figure 2 below.

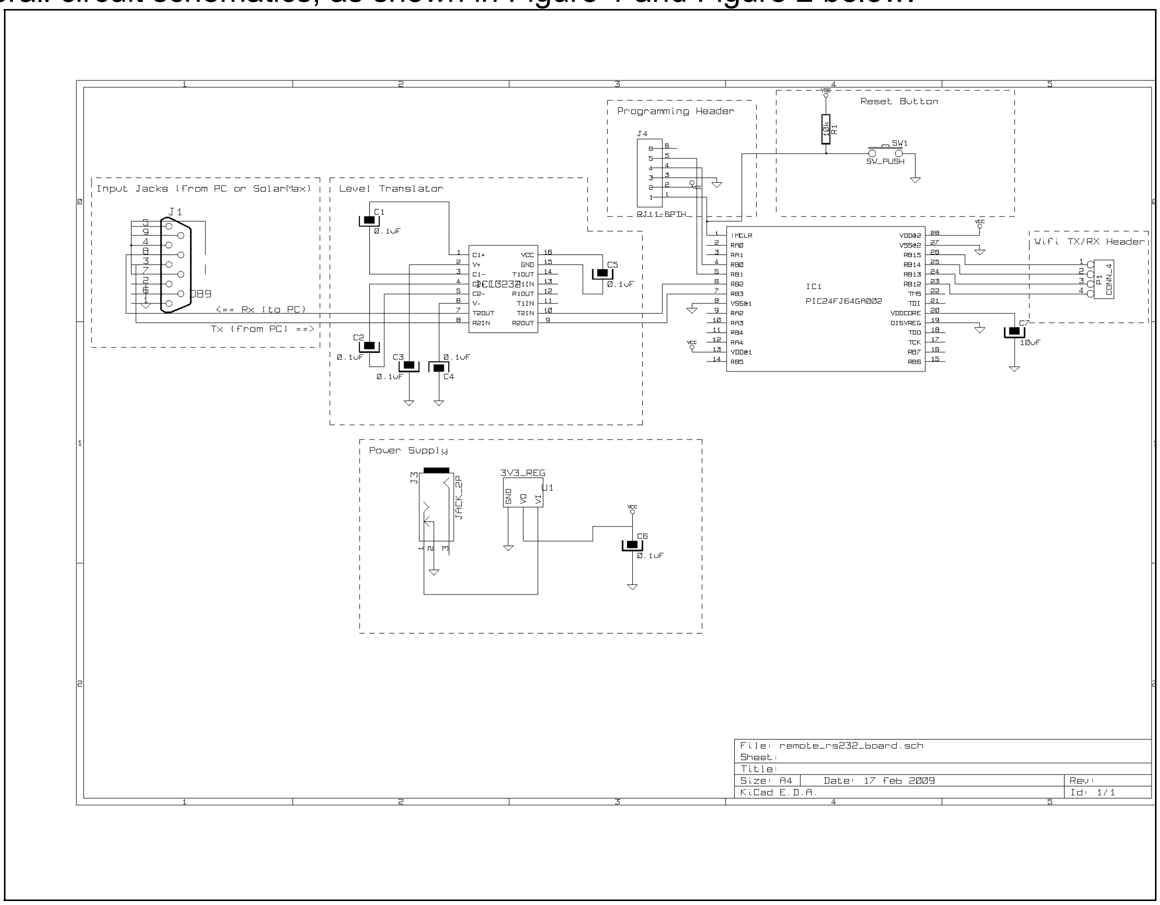

Figure 1 - "Remote" RS-232 Board for Wireless Gateway Device

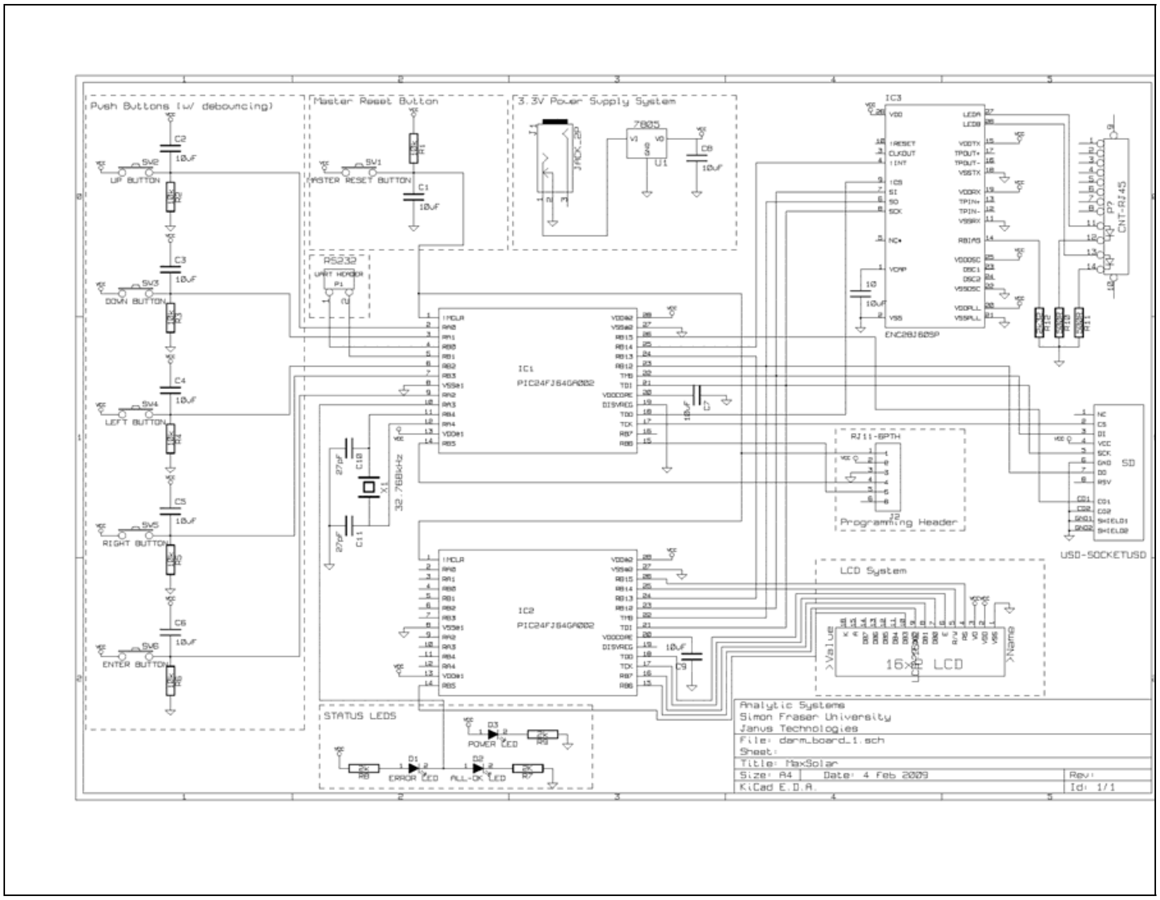

Figure 2 - "Main" Board for Wireless Gateway Device

1.2 Scope

This document specifies the comprehensive design requirements Janus Technologies intends to fulfill by the end of Tier 1 to Tier 3. The functionality of this design is outlined in the *Functional Specifications for the SolarMax Wireless Gateway Device [1]*. Although we are focusing on creating Tier 1 functionality, proof-of-concept design outlines are provided for Tier 2 and Tier 3. The document will include work-in-progress schematics to date that will represent how we currently expect the design will follow. However, these may change once the system is complete. Various visual aids such as flow charts will be used to facilitate the understanding of the logic used in design decisions.

1.3 Intended Audience

The intended audience is all of the members of Janus Technologies to ensure all of the design requirements are met according to their specifications. The Engineering department at Analytic Systems involved with development of the SolarMax will refer to this document as reference for modifications once the command hub ownership is transferred to Analytic Systems.

2. System Requirements

In the following sections of this document, all of the design 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 unit and an individual user. Multiple input-output interfaces will be provided for the user to interact with in order to acquire status information from the SolarMax device, along with providing a simple and elegant means of issuing commands to the SolarMax device.

The majority of the data processing is handled by two PICs on the WGD mainboard. The “primary PIC”, which shall be referred to as PIC1, handles pushbuttons, the wireless RS-232 interface, the network interface system, the SD card system, and controls the “secondary PIC” (PIC2). The “secondary PIC” controls just the LCD interface.

A summary of the overall system is demonstrated in Figure 3 below, while Figure 4 and Figure 5 outline the major components on the Janus Technologies Wireless RS-232 Adapter and Wireless Gateway Device shown in Figure 3. Please note that Figure 4 and Figure 5 do not include any “support” circuitry, such as bypass capacitors, pull-up resistors, etc, as shown in Figure 1and Figure 2.

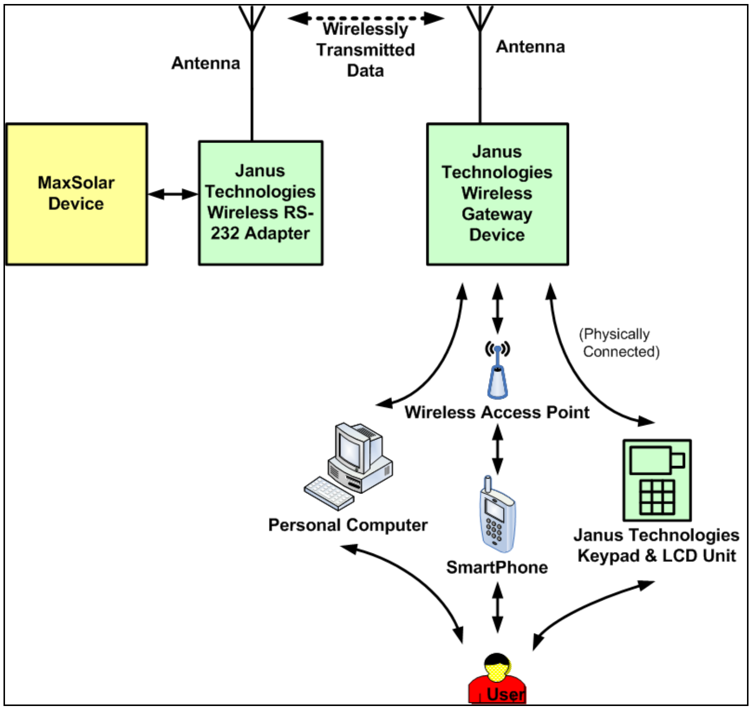

Figure 3 - System Overview

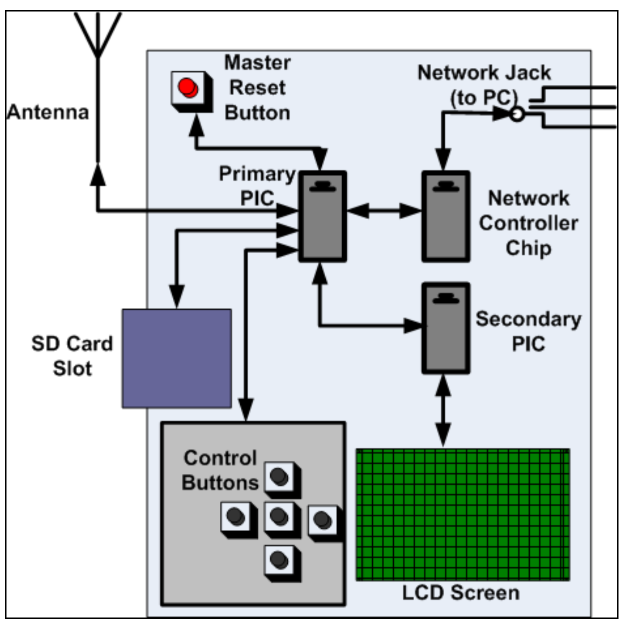

Figure 4 - Wireless Gateway Device Mainboard

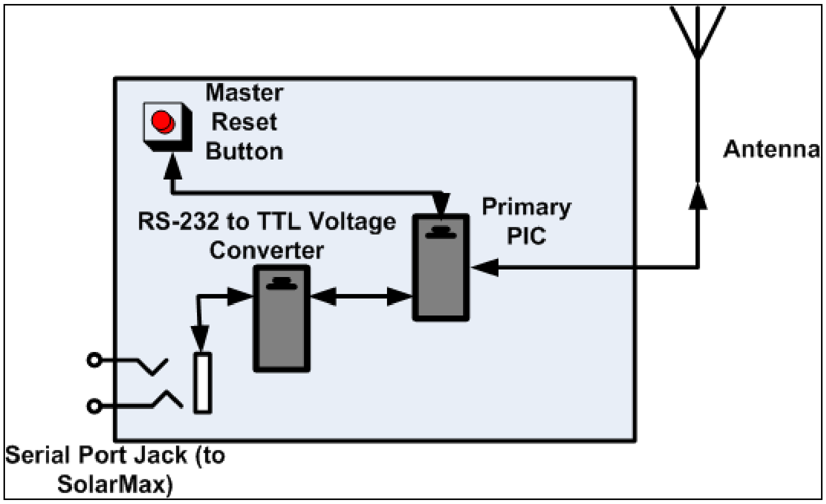

Figure 5 - Wireless RS-232 Adapter Board

2.1.1 Hardware Flow

There are multiple paths that the signals in our system may follow, depending on the Tiers of production as well as the intended purpose of the user.

In Tier 1, the user initiates communication with the SolarMax through the pushbutton interface which interrupts the processing in PIC1. The PIC then processes the interrupt and, through the RS232 interface, communicates with the SolarMax. The SolarMax returns the appropriate data back through the RS232 interface to PIC 1. This flow is represented by the red line in Figure 6.

In Tier 2, the user can now initiate communication through the web based interface. This interface then communicates through an internet connection to the ENC28J60 chip, which controls the low-level implementation details to facilitate the communication. The signal then flows into PIC1 as before, through to the SolarMax and back to PIC1. In Tier 2 however, the signal which carries the data packet information is now passed back to the user through the ENC28J60 web interface, as well as data logged in the SD interface. This flow is represented by the blue line in Figure 6.

In both Tiers, after the data packet has reached PIC1 from the SolarMax it will pass through to PIC2 to facilitate the information appearing on the LCD display. This common flow is represented by the purple line in Figure 6.

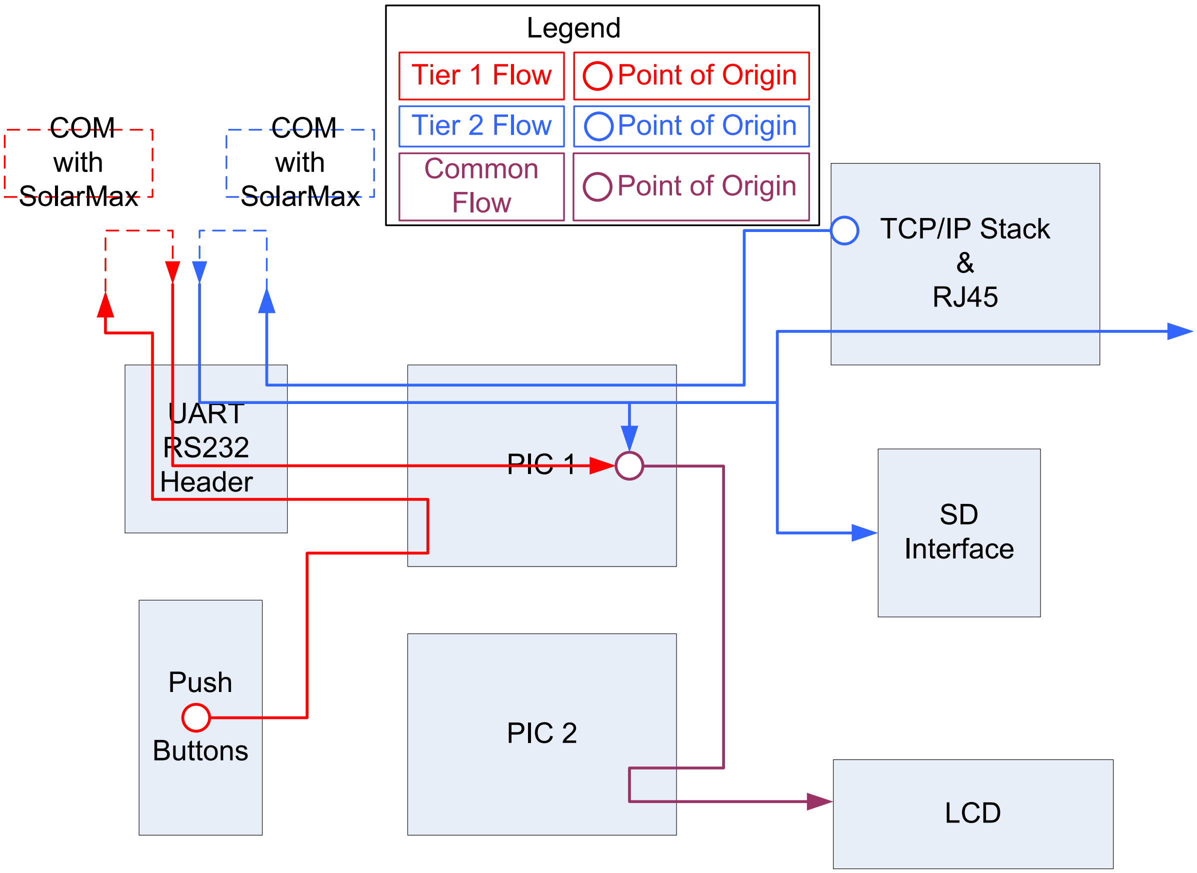

Figure 6 - Hardware (signal) Flow

The hardware flow for communication with the SolarMax is relatively straight forward and can be easily inferred from the wireless adapter board of Figure 5.

2.1.2 Software Flow

The software flow for the system is based on interrupts from the user which initiate communication with the SolarMax unit, as well as the manipulation and display of information contained in the data packet. This flow is represented in Figure 7.

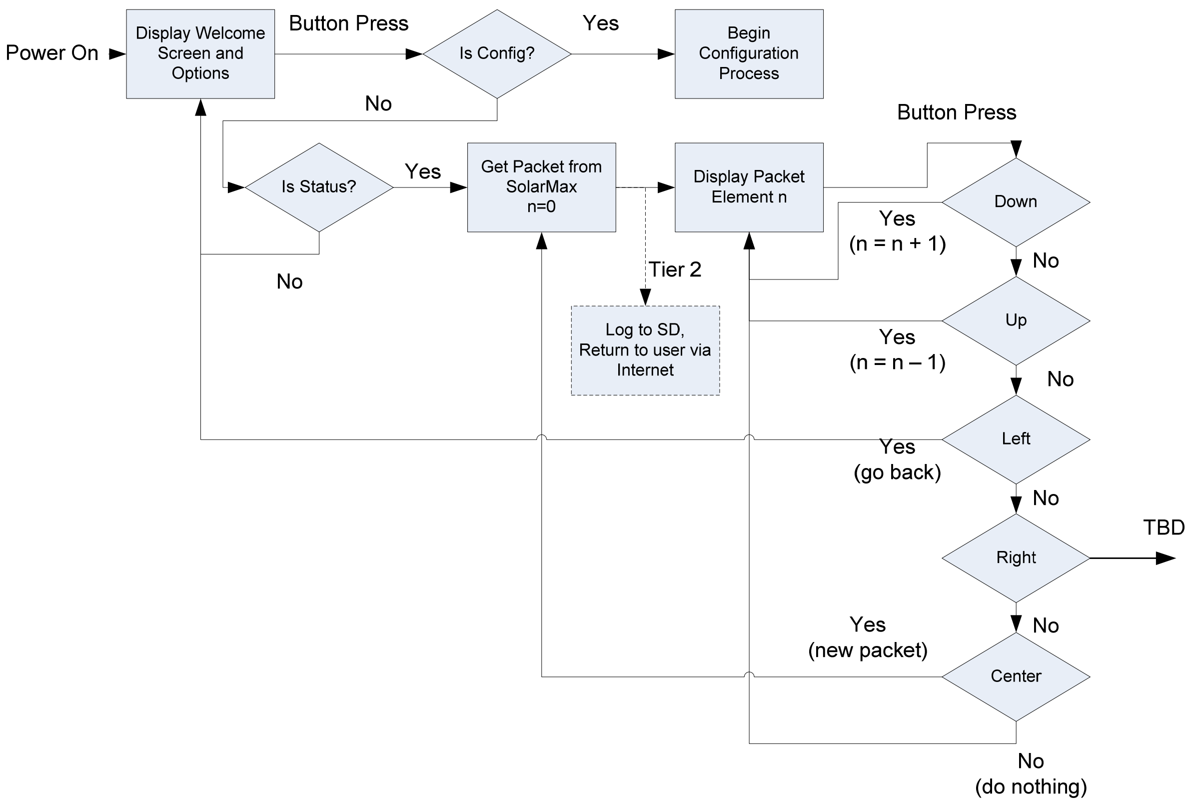

Figure 7 - Software Flow Diagram

Note that the flow diagram includes button presses as the user interrupt, but the user can initiate these interrupts through the web based interface in Tier 2 which will mimic the same button presses. Also, in Tier 2 the data packet information is written to the SD interfaced and returned to the user via the internet connection, and not just displayed on the LCD. Finally, while navigating using the buttons once a packet has been received, we have not yet decided on an appropriate action for the right button that is distinct from the center button.

3. Tier 1 Specifications

3.1 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 use of double pole single throw (DPST) pushbuttons will also increase design redundancy, as they are less likely to fail if a single connection point is damaged. The pushbuttons will all be connected to the "primary PIC" (Figure 4), which acts as the central processing unit in the Wireless Gateway Device.

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 8 below. Its layout should be very intuitive and simple for all users to understand.

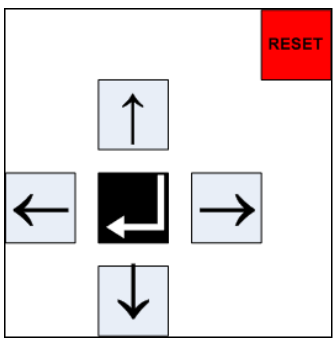

Figure 8 - Push Button Interface Layout

The push buttons are implemented using switches and a simple RC circuit for debouncing. The schematic for one of the pushbuttons is shown below in Figure 9, where the remaining buttons follow the same pattern. The master reset button is different only in the fact that it connects to the PIC MCLR pin whereas the other buttons are connected to regular inputs.

The time constant is set to be 0.1 seconds which is experimentally effective, as demonstrated in [2], using a 10kΩ resistor and a 10μF capacitor.

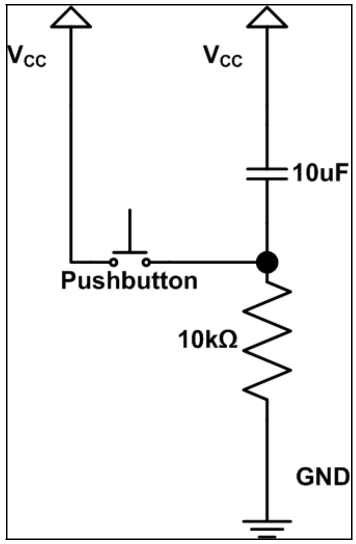

Figure 9 - Push Button Component Schematic

There is also a software component to the debouncing which ensures that the button input signal remains pressed for a definable period of time to prevent erroneous signals. The complete push button process is demonstrated in Figure 10.

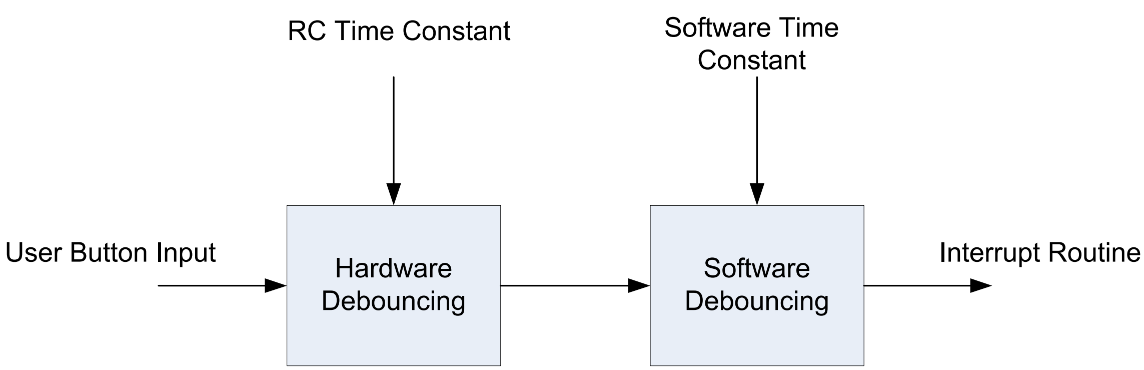

Figure 10 - Complete Push Button Flow

An example of the transient response of a pushbutton can be seen in Figure 11 below.

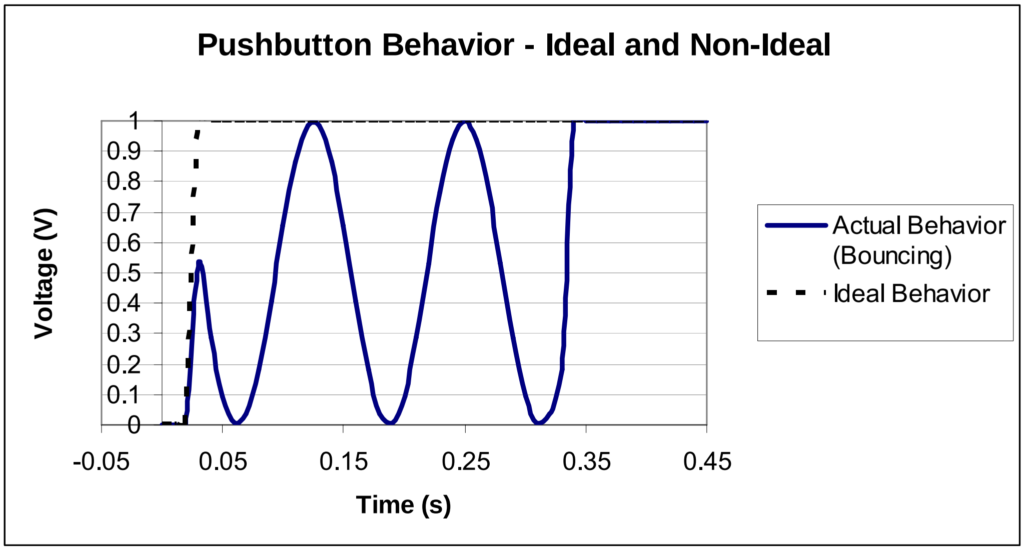

Figure 11 - Pushbutton Behavior - Ideal and Non-Ideal

As can be seen above, a simple push of a pushbutton can register several rising or falling edge triggers for the device it is connected to. This is undesirable, and the inclusion of a debouncing circuit for all pushbuttons. Assuming an input is normally "low" (i.e.: 0V) and a "high" value (i.e.: V_{cc}, or 3.3V) is generated when the pushbutton is depressed, then the inclusion of a pull-down resistor and a capacitor to the supply voltage introduces an RC time constant which prevents the voltage from decreasing rapidly [3].

3.2 LCD Output System

The LCD component of our system will provide users with a simple feedback mechanism to determine the current state of our system. In addition to providing error messages, the LCD system will provide a series of basic menus which will allow a user to view the status of all device parameters pertaining to the SolarMax device. The LCD system will employ a basic monochrome display, which uses 5 by 8 pixels per character (Figure 12, which shows the number '8') and displays up to 2 by 20 characters (Figure 13).

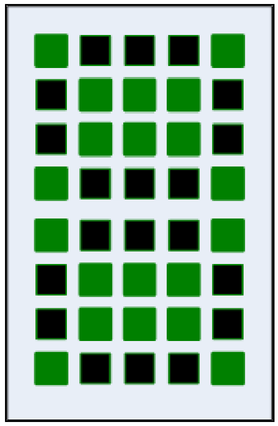

Figure 12 - A Single LCD "Cell", Showing the Number '8'

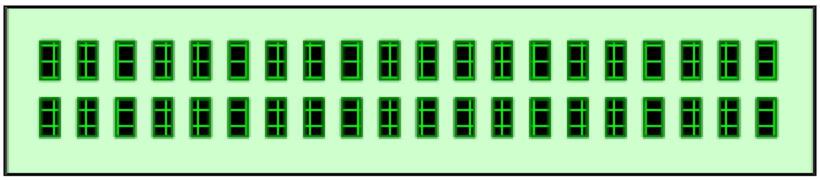

Figure 13 - A 2 by 20 Character LCD Screen

The LCD system itself will be handled by the “secondary PIC” ()

3.3 LED Feedback

A set of LEDs will be implemented to provide additional feedback to the user, each of which will have its own particular function:

- Power LED: Is active only when power is provided to the Wireless Gateway Device, letting the user know that the device is powered on.
- Error LED: Is active only when an error condition is encountered. This is used primarily for development and debugging purposes.
- All-OK LED: Is active when no error conditions are encountered, and the device is operating properly.
- Ethernet Connected LED: Is built into the RJ45 jack for Ethernet connectivity, and is active only when an Ethernet/CAT5E cable is connected to the Wireless Gateway Device.
- Ethernet Busy LED: Is built into the RJ45 jack for Ethernet connectivity, and is active only data is being transferred between the Wireless Gateway Device and an external network device.

3.4 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), and will comply with FCC standards so that they do not operate at illegal frequencies.

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 14 below.

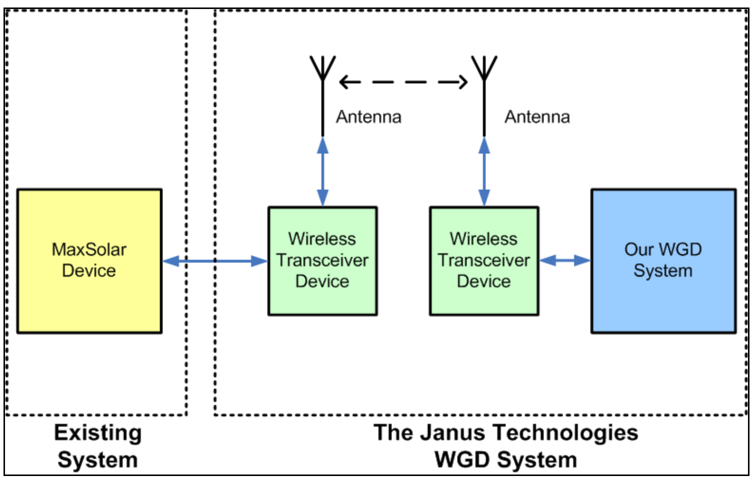

Figure 14 - Wireless Transceiver Overview

The data itself will be transmitted using hardware-based UART controllers in the PICs on both the Wireless Gateway Device (Figure 4) and the Wireless RS-232 Adapter Board (Figure 5). Effectively, all wireless communications are simply standard UART/RS-232 data transfers, using a wireless medium instead of cables. The wireless data transfer will be accomplished through the use of wireless transmitter/receiver devices, coupled with antennas. The wireless transmitter/receiver devices will be provided by Linx Technologies [4].

4. Tier 2 Specifications

4.1 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 is achieved by means of connecting the Wireless Gateway Device to a router or another PC directly using CAT5 cable and the Ethernet/RJ45 jack which will be incorporated into the Wireless Gateway Device.

Between the use of a specific chip [5], along with sample code provided free of charge and royalties by Microchip Technology [6], all of the OSI model layers are addressed [7], allowing for the Wireless Gateway Device to rapidly integrate with any network, and being compatible with TCP/IP, DNS, and DHCP protocols. The network system will also allow any wireless device to connect to it as well, such as a SmartPhone, iPhone, etc.

The network interface system will be controlled by SPI through the “primary PIC” (Figure 4). The networking interface has particularly strict timing requirements, so it will be prioritized above any other devices connected by SPI, such as the LCD system, or the SD card system.

4.2 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. The card itself will employ the use of a FAT partition, which will make the card itself compatible with virtually any operating system, should it be removed from the Wireless Gateway Device.

Provided that our device is powered off, the SD card may be removed or reinserted without the use of any tools, and can interface 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 15, courtesy of Sandisk.com [8].

The SD card interface will be handled directly by the “primary PIC” (Figure 4) through SPI. No particular timing constraints have been put in place, as the SD card is a simple storage device that stores log data, and nothing else.

Figure 15 - An SD Card (Approximate Size)

5. Tier 3 Specifications

5.1 USB RS232 Interface

The USB and RS232 connectivity is by request from Analytic Systems to provide enough breadth in the communication capabilities of our command hub for their purposes. The USB interface, when connected, would directly replace the LCD and button-push functionality. This would require a simple Visual Basic program that can be used to interface with our device and send it equivalent commands. In order for this to occur naturally when the USB connection is made to the wireless gateway device, our device will display a notice of disability regarding the typical input buttons, i.e.,

" USB CONNECTED
BUTTONS DISABLED"

When the USB connection is broken, the command hub will continue functioning as normal. When the RS232 is connected, the connection can be detected by the PIC interfacing with it. Once this is done, the buttons will be disabled akin to when the USB is detected and the LCD will display the following:

" RS232 CONNECTED
BUTTONS DISABLED"

This will interface with a computer running the same Visual Basic application to send commands to our device. The only real difference is that the default COM port the computer will use is the default COM1 port. Once the RS232 connection is broken, the standard operation of the command hub will continue. If the USB or RS232 is connected while there is a system restart, the command hub will check which one is connected at startup and react accordingly. If both USB and RS232 are connected, our system will default to accept commands by USB only until the USB is unplugged, at which time our system will cross over to accept input from the RS232. The Visual Basic application isn't necessarily going to be designed by Janus Technologies but rather is a theoretical application of these two communications technologies. Janus Technologies will be merely providing the means to allow for future Windows application development.

5.2 RoHS

Silver solder will be used as opposed to lead based solder to minimize hazardous materials present in the device, and only RoHS compliant components will be used in the final design of our system. In addition to this, the prototyping boards used to connect components will be replaced with professional printed circuit boards (PCBs). The etchant used to fabricate these boards will be disposed of through the appropriate chemical disposal system at Simon Fraser University. The implementation of small, high quality PCBs will allow for us to reduce solder and wire usage, and will reduce energyrelated costs involved in the production of an equivalent system using perforated bread boards, as less soldering and circuit testing will be required.

6. System Test Plan

The majority of the subsystems in the Wireless Gateway Device will be assessed on a pass/fail basis, including:

- The pushbutton interface
- The LCD system
- The SD card interface
- The status LEDs

The only two systems which will be assessed in a subjective manner are the network interface system, and the wireless data transfer system.

The network interface system will be evaluated by connecting the wireless gateway device to a simple network router or access point, and status requests will be issued from several machines, each with different internet browsers, operating systems, and so on. The minimum requirements are that the network interface system is able to provide a single machine with a single status update at least once per second. Based on the processing capabilities of the PICs employed in our design, the ideal scenario is that the Wireless Gateway Device is able to service at least three times as many requests in ideal circumstances. Since the Wireless Gateway Device is not expected to serve as a “high traffic” device, its ability to service a limited number of network requests is not a reason for concern.

The wireless data transfer system will have even more stringent requirements. It must be able to transmit at least 75% of all data packets successfully, as well as reject corrupted packets at least 99% of the time. This is to ensure that accurate data is being transmitted. Fortunately, the design of a very specific packet structure, in addition to the inclusion of CRC-based error correcting codes (ECC) at both the hardware and the software level, reduces the chance of incorrect data being parsed by the Wireless Gateway Device to a negligible level.

Furthermore, the wireless gateway device will be connected to a portable power supply (i.e.: battery cells), and will be moved away from the Wireless RS-232 Adapter Board (which shall remain stationary) in 10 foot increments. The average number of successfully received packets will be calculated, and statistics pertaining to data transfer success rate versus the distance between the two devices will be calculated. This will allow for formal operating specifications with respect to wireless transceiver range to be calculated.

Finally, both boards will be tested at temperature ranges between 30 and 70 degrees Celsius to demonstrate their tolerance to changes in temperature. Although the majority of individual components are rated over a larger temperature range, Janus Technologies would prefer not to risk damaging the only prototype device. Future testing will included testing over wider temperature ranges.

7. 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 provided in the design specifications of this document 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.

8. References

[1] Ciapponi, A., M. Giassa, D. Hilbich, and R. Szolomicki, *Functional Specifications for the SolarMax Wireless Gateway Device*, 2009

[2] A Guide to Debouncing. 2009. *The Ganssle Group*. 4 Mar 2009. <http://www.ganssle.com/debouncing.pdf>

[3] Patrick Leung, Informal discussion about hardware pusbutton debouncing solutions, 3 Feb 2009.

[4] LT Series – Long Range RF Transceiver Modules. 2009. *Linx Technologies Product Catalog.* 20 Feb 2009. <http://www.linxtechnologies.com/Products/RF-Modules/LT-Series-RF-Transceiver-Module/>

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

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

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

[8] 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>