Watt Smart

School of Engineering Science • Burnaby, BC • V5A 1S6

October 19, 2009

Dr. John Bird
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Dear: Dr. Bird and Mr. Whitmore,

The attached document presents the functional specification for the wireless single phase power monitoring system, which is being implemented in the ENSC 440 course. The product that is being designed is a home power monitoring system which will assist the user in measuring the power consumption of various appliances in their home. Moreover, this device will be able to simultaneously transmit the measured data through a wireless connection to a computer and plot a graph of energy and power consumption for the appliances under test.

The functional specification document is intended to provide a set of requirements for system functionality for the prototype as well as the commercial version of the product. This report includes the overall system requirements and also the requirements for specific component such as the analog circuit, MCU, wireless module and PC interface.

Watt Smart Inc. consists of five enthusiastic, dedicated upper-year engineering students: Glen Nogayev, Kamyar Ghomi Osgoei, Wenqi Sun, Babak Sobhani, and Titus Cheung. If you have any questions or concerns about our proposal, please feel free to contact Titus at tcc11@sfu.ca.

Sincerely,

Watt Smart Inc.

Enclosure: Functional Specification for Wireless Single Phase Power Monitoring System

Watt Smart

School of Engineering Science • Burnaby, BC • V5A 1S6

Functional Specification for Wireless Single Phase Power Monitoring System

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Executive Summary

An average household in present times contains many appliances and electronic devices such as plasma and LCD televisions, state of the art sound systems, various home heating and cooling elements. Together, all of these appliances consume a large amount of energy if they are plugged in for an extended period of time. According to BC Hydro, the average household power consumption in British Columbia is 11,000 kWh/year [1]. Even though BC has some of the lowest electricity rates in North America, it still costs the consumers hundreds of dollars every year. Moreover, there are only a few affordable devices on the market which are capable of monitoring the power consumption of various household appliances and providing the user with a clear picture of their electricity usage. The solution that has been proposed and is being developed is the Wireless Single Phase Power Monitoring System (WPMS).

The design and implementation of WMPS will be broken down into two stages. After the completion of the first stage, the device will perform the following tasks:

- Accept two simulated sinusoidal voltage and current wave signals as inputs and perform ADC
- Transfer the digital data to a PC using an RS-232 connection
- Perform basic power and energy calculations on a PC and display the results on the screen

At the end of the second stage of development, WPMS will also incorporate the following additions:

- Measure the voltage in the wall outlet and the current draw of an appliance under test
- Send the measure data to a PC over a wireless connection
- Plot the real-time power and energy consumption as well as provide instantaneous readings for voltage, current and the power factor

With all of these features included, the WPMS prototype will be fully operational. The completion deadline for the working prototype is set for December 3rd, 2009.

Table of Contents

Glossary

AC	Alternating Current
ADC	Analog to Digital Converter
DC	Direct Current
DMM	Digital Multi Meter
GUI	Graphical User Interface
I/O	Input/Output
MCU	Microcontroller Unit
PCB	Printer Circuit Board
RS-232	Recommended Standard 232 (computer serial port)
SPI	Serial Peripheral Interface Bus
UART/USART	Universal (Synchronous) Asynchronous Receiver Transmitter
WPMS	Wireless Power Monitoring System

1. Introduction

The ability to measure the power consumption accurately with minimum error is very challenging. WPMS, a product being developed by Watt Smart is a device that calculates the power consumption of different home appliances with highest accuracy possible. It has the ability to measure input/output voltage, current drawn, power facture, energy and more importantly power consumption. It also has the capability to transmit the data to a PC through wireless connection, which will provide users with understandable graph and data.

1.1. Scope

This document outlines the functional requirements that must be met by a Wireless Power Monitoring System (WPMS). The set of requirements outlined in the document describes the functionalities of the proof-of-concept version of the system as well as the commercial version. The listed requirements will drive the design of WPMS and will be traceable in future design documents.

1.2.Intended Audience

This document is intended for all Watt Smart Inc. members. Project managers and development team can consult this document as a reference for functional specification. Investors can also use this document to get detailed information for their marketing purposes. Finally, test engineers will be using this document to perform a detailed check of all functionalities to make sure all the requirements are met and no failure are observed.

1.3.Classification

The following notation is used in this document to illustrate function requirements:

[Rn-p] A functional requirement

N The requirement number

P Priority of the functional requirement

- I Proof of concept Prototype
- II Proof of concept Prototype and Commercial Product
- III Commercial Product Only

2. System Overview

This system is designed to measure the voltage and current values for each appliance in the sensor unit and then send them to the main unit (PC) to calculate the power and energy consumption as well as display the instantaneous voltage and current readings and the power factor of the appliance under test. Figure 1 below illustrates the overall system functionality:

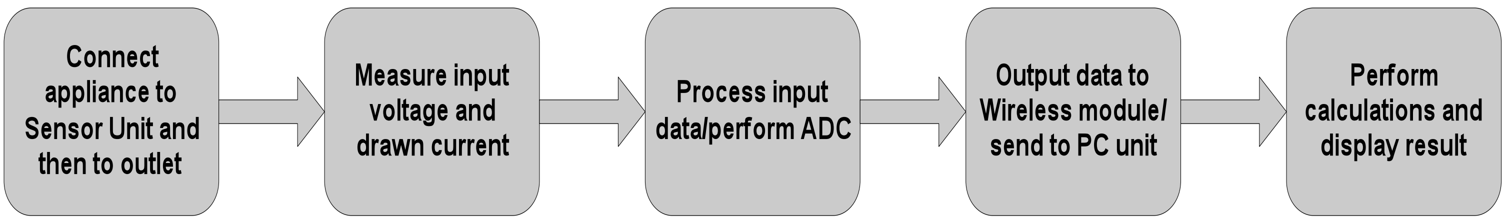

Figure 1: Overall System Block Diagram

The two main system inputs are the voltage and current. The MCU will sample these analog inputs, perform ADC and generate required outputs which will then be sent to the PC unit through the wireless module.

In order to setup the system, the user must plug the WPMS sensor unit into a power outlet and then plug the desired appliance into the socket on the sensor unit. The sensor unit will automatically turn on and start measuring the values. It will take 4800 voltage and current samples every second. On the PC side, the user will have to launch the application, which will process the received data and display various real-time graphs and instantaneous readings for power and energy consumption. The user will be able to toggle the graphs and choose specific values that they want to be displayed.

3. Overall System Requirements

3.1. General Requirements

[R1 - III] WPMS should be easy to use, not difficult to install and have a user friendly computer interface.

[R2 - II] WPMS should accurately measure the power consumption of the appliance under test

[R3 - III] WPMS should be able to support multiple power consumption sensors

[R4 - III] Start-up kit should consist of one sensor unit, one USB dongle and the PC application software with a cost of $100 (additional sensor units should have a cost of $30)

3.2. Physical Requirements

[R5 - I] The sensor unit should have a maximum dimension of 13cm x 3.5cm x 6cm (L x H x W) and the USB dongle should measure 6cm x 1cm x 3cm (L x H x W).

[R6 - I] The sensor unit should weight approximately 400g and the USB dongle should weight 40g.

[R7 - II] Analog circuit, MCU and wireless module should be integrated into a single sensor unit.

[R8 - II] Sensor unit should be placed in a hard plastic enclosure.

[R9 - II] USB dongle should be able to be plugged into a USB port on a computer.

[R10 - II] WPMS should have a 3-pronged plug that is compatible with Canadian wall outlets.

3.3. Electrical Requirements

[R11 - II] WPMS sensor should accept a 120VAC/60Hz input from a Canadian wall outlet.

[R12 - II] The input voltage should not exceed 125VAC and the input current should not be higher than 40A.

[R13 - II] The sensor unit should be powered by a 120VAC to 5VDC internal adapter, eliminating the need of an external power supply.

[R14 - II] The USB dongle should be powered by the USB Vbus line.

3.4. Communication Requirements

[R15 - II] Zigbee wireless module is required for the communication with the computer.

[R16 - I] The wireless protocol for communication should be Zigbee 2004

3.5. Mechanical Requirements

[R17 - I] There should be a 5mm clearance between the PCB and the plastic enclosure of the sensor unit.

[R18 - II] The socket in the sensor unit should be compatible with 2 and 3-pronged appliance plugs.

3.6. Environmental Requirements

[R19 - II] The final product should be intended for indoor use only.

[R20 - II] WPMS should have an operational temperature range from -15 to +60 degrees Celsius.

[R21 - III] WPMS should not emit any signals that will interfere with other electronic devices.

[R22 - III] WPMS should not be affected by interference from other electronic devices.

3.7. Performance Requirements

[R23 - I] The sensor unit should be able to measure the input voltage and current values with an accuracy of ±2%.

[R24 - I] WPMS should be able to provide power and energy readings accurate to within ±5%.

[R25 - I] The transmission range for the Zigbee module should be between 10 and 75 meters [2].

[R26 - II] The over-the-air transfer rate should be at least 20 kbits/s [2].

3.8. Reliability and Durability Requirements

[R27 - III] WPMS should be able to withstand daily usage and frequent physical operations.

3.9. Safety Requirements

[R28 - II] The appliance under test should not draw more than 40A of current.

[R29 - III] WPMS should not emit any harmful electromagnetic waves.

[R30 - II] The sensor unit should be properly insulated to prevent a short circuit or electric shock.

3.10. Luxury Requirements

[R31 - III] The ability to remotely turn on and off the appliance connected to WPMS.

[R32 - III] The ability to view the real-time power consumption graphs over the Internet.

4. Standards and Regulation Requirements

[R33 - III] IEC 61000 Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test [3].

[R34 - III] IEC 61000 Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test

[R35 - III] IEC 61000 Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test

[R36 - III] Title 47 of the Code of Federal Regulations - Part 15: Testing and measurement techniques concerning unlicensed broadcasts and spurious emissions [4].

[R37 - III] Applicable UL standards as defined by UL project engineers upon submission of our product sample [5].

5. Analog Circuit

The front-end analog circuit is responsible for measuring line voltage and current drawn by the appliance and conditioning these signals for MCU input. The requirements for this component are divided into general and electrical.

5.1. General Requirements

[R38 - II] Probes should be used measure AC voltage and current signals from the wall outlet.

[R39 - II] Processed waveforms should be suitable for MCU analog input.

[R40 - II] Circuit should use the outlet voltage to provide a continuous supply of power for the rest of the sensor unit.

5.2. Electrical Requirements

[R41 - II] The CT should provide voltage readings for current draw in the range between 0 to 40A.

[R42 - II] Voltage divider should step the voltage down from 120VAC to 2.5VAC.

[R43 - III] A varistor should be placed at the input between the live and neutral pins to ensure the circuit will not get damaged in the case of a voltage spike.

[R44 - III] Filter capacitors should be used to clean up the input signal.

[R45 - II] A 5VDC power supply should be provided for the rest of the sensor unit.

6. MCU

The main function of the microcontroller unit is to sample the voltage and current waveforms from the analog circuit and perform ADC with very high precision timing. This section is broken down into general and electrical requirements.

6.1. General Requirements

[R46 - II] MCU should be able to capture 80 samples per cycle of power electricity (60HZ), which is equal to 80 samples for every 1/60th of a second.

[R47 - II] MCU should store waveform samples in a table for both voltage and current and transfer them to the wireless module.

[R48 - II] The timing and delay between voltage and current captures should be very accurate and constant up to micro seconds.

[R49 - II] Support communication protocols to be able to communicate with the wireless module.

6.2. Electrical Requirements

[R50 - II] MCU should be 8 or 16 bits.

[R51 - II] MCU should have at least two 10-bit ADC channels.

[R52 - II] SPI interface for communication with the wireless module should be supported.

[R53 - II] MCU should support UART/USART for RS232 protocol [6].

[R54 - II] The supply voltage should be 5VDC.

[R55 - II] MCU should contain at least 8 I/O ports.

6.3. Software Requirements

[R56 - II] The MCU should support C compiler and debugger.

[R57 - II] The EEPROM memory should be at least 1024 bytes.

7. Wireless Module

The main function of the wireless module is to transfer the data collected by the analog circuit/MCU to the PC for further processing. This section is broken down into general and electrical requirements.

7.1. General Requirements

[R58 - II] The wireless sensor (transmitter) must have an SPI interface for connecting to the MCU.

[R59 - III] The wireless range between the wireless sensor and the receiver should have the ability to be extended via additional intermediate sensors or relay nodes.

[R60 - III] Data sent from multiple sensors should be received properly at the receiver with no errors.

7.2. Electrical Requirements

[R61 - II] The wireless sensor (transmitter) should be powered by the AC line via an internal AC/DC transformer.

[R62 - II] The wireless sensor (transmitter) should be in sleep/standby mode when not transmitting in order to reduce power consumption.

[R63 - II] The wireless receiver should be powered by the USB VBUS +5V line.

8. PC Interface

The PC interface consists of the USB dongle which will receive the data from the wireless module and the PC application which will use this data to perform the calculations and graph the real-time power and energy consumption. This section consists of general, operating system and interface requirements.

8.1. General Requirements

[R64 - II] The USB dongle should be able to receive data and transfer it to the PC database.

[R65 - II] The PC application should perform appropriate calculations and provide real-time power and energy consumption graphs.

[R66 - II] The PC application should display the instantaneous voltage and current values as well as the power factor of the appliance under test.

8.2. Operating System Requirements

[R67 - I] The operating system for the prototype device should be Windows XP.

[R68 - III] The commercial product should be compatible with any Windows or Mac system.

8.3. Interface Requirements

[R69 - II] Appropriate drivers for USB dongle should be installed on the computer

[R70 - II] The PC application must be simple to use and should contain a user friendly GUI.

[R71 - III] The PC application should contain a help tab in the program menu to provide the user with additional help.

9. Documentation Requirements

This section outlines the requirements for the documentation that will be included with the commercial product.

[R72 - III] A detailed user manual should be provided with the product.

[R73 - III] Technical documents for the components of the product should be accessible.

[R74 - III] The company should have a website which contains an FAQ section and online technical support for this product.

10. Proposed Test Plan

The test plan for the prototype product is outlined below. It will involve testing individual components first and then doing the integrated system testing.

10.1. Component Testing

Analog Circuit Test

The analog circuit will be tested by plugging it into the outlet and using the DMM and the oscilloscope to measure and display the resulting voltage and current waveforms. The expected result will be a sinusoidal scaled down version of the original signals. The circuit will also be tested to ensure that it provides a 5VDC power supply for the MCU and the wireless module.

MCU Test

To insure accuracy and the functionality of the MCU, it will be tested before it is connected to the wireless module. A sinusoidal signal from a function generator will be applied to the analog inputs of the microcontroller. The MCU should be able to convert the input analog waveform to digital samples proportional to the magnitude of the input signal. The output signals will be checked using an oscilloscope. Moreover, an LCD display has been incorporated into the first level prototype design so that MCU readings and calculations can be viewed directly on the LCD without the need to send them to the PC. This will ensure that the MCU is fully tested and it is working properly before it is added to the rest of the system. Finally, before connecting the MCU to the wireless module, it will first be connected to the PC directly to validate the MCU/wireless module communication signals.

Wireless Module Test

The wireless module is developed and tested separately from the analog, MCU, and PC sections. It functions as a drop-in replacement for the wired connection between the MCU and the PC. The wireless transmitter will be connected to another MCU. A known data packet will be assembled and sent out. The receiver must be able to receive the data packet. An error correction in the protocol will be used to identify whether or not there is an error.

PC Application Test

The PC module testing is done without connectivity to the wireless module or the MCU first. The PC application will simulate a received data packet by reading in data of same byte length from a file. The application will calculate the power factor and subsequently the energy consumed. Since the data used is fictitious, the expected power factor and the energy usage are known. The calculated values are tested against these known values.

10.2. Integrated System Testing

RS-232 System Test

This integration test will involve connecting the analog circuit and the MCU directly to the PC using the RS-232 port. The test will determine whether or not the analog circuit and the MCU are functioning correctly by analyzing the MCU output on the computer. This will be done by applying different voltage and current waveforms to the circuit input and checking the calculated values on the PC.

Wireless System Test

In this integration test, the wireless module will be added to the system. This test will involve combine the elements of the RS-232 system test and the wireless module test and ensure that the whole system is functioning correctly. After the signal is passed through the analog circuit and the MCU, it will be transmitted to the PC through the wireless module. On the PC, the acquired data will be analyzed for validity by comparing the expected and measured results.

11. Conclusion

The functional specifications presented in this document outline the requirements for both the prototype device and the commercial product. The development for the prototype device will be taking place over two stages during which various product features will be implemented. These two stages are expected to be completed by December 3rd, 2009. By that time, the prototype will be completely functional and it will include all of the priority I requirements. Following that, additional requirements will be added to the product until it becomes fully commercialized.

12. References

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