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Wireless Battery Management System

Minkyu Lee, Jaesik Lee, Inseop Lee, Joonghui Lee, and Andrew Chon
Navitas Solutions Inc., 120 Old Camplain Road, Hillsborough NJ 08844, USA
minkyu.lee@navitasone.com

Abstract

In this paper, we present an innovative wireless battery management system (WBMS[TM]) that addresses the issues of the conventional BMS architecture. The WBMS[TM] adopts wireless communication technologies based on a proprietary Wireless Battery Area Network (WiBaAN[TM]) protocol [1]. The WBMS[TM] consists of a multitude of energy-autonomous micro-sensors mounted on each battery cell, and a master module that collects and processes the data from the micro-sensors. The WiBaAN[TM] protocol defines the syntax, semantics and synchronization of the messages between the sensors and the master module.

The WBMS[TM] will enable a battery pack that is simple, light, reliable, and most importantly, inexpensive. The new wireless architecture can completely eliminate the sensing wire-harness and connectors. The WBMS[TM] is designed in such a way that a single master module can communicate with up to a few thousands of sensors. Its star topology makes it possible to eliminate the intermediate slave modules between the master module and the sensors. No isolators are needed due to the wireless nature of the communication. Reduced number of components and connections means less failure points, especially in a harshly vibratory environment.

Keywords: Wireless Sensor Network, Battery Management System, BMS

1 Introduction

In conventional battery management systems (BMS), there is a complex wire-harness between battery cells and battery sensing modules or slave BMSs. Each slave BMS can typically collect sensory data from eight to fourteen battery cells. In order to accommodate a large number of battery cells, a group of the slave BMSs are connected to a master BMS, where the collected data from the battery cells is stored for further processing. Although the hierarchical BMS architecture is widely accepted and used, it has some major disadvantages. The wire-harness can cause various issues such as physical connection failure under vibratory environment, communication error under EMI, complexity of battery pack design, and difficulty in automated manufacturing. These problems often result in low productivity and low reliability. More importantly, the cost of wire-harness, connectors, protective cases, isolators, and manual labor is a significant portion of the overall battery pack cost. For a typical automobile or stationary application, the number of battery cells ranges from a few hundred to a few thousand, and the increased number of battery cells exacerbates the problems mentioned above.

In this paper, we present a new wireless battery management system, or WBMS[TM], which is based on wireless sensor network technologies. The new BMS architecture completely eliminates the sensing wire-harness between sensors and the BMS modules. We expect that the WBMS™ will enable battery packs that are smaller, lighter, more reliable, easier to automate the manufacturing process, and most importantly, low-cost.

2 Wireless BMS Architecture

The Wireless Battery Management System (WBMS™) uses a distributed star topology, where a master BMS wirelessly communicates with each slave BMS module on a battery cell.

Figure 1 shows an example of the wireless BMS with a single master module and a multiple of slave modules that are mounted on battery cells. The slave module has imbedded sensors that measure various physical characteristics such as voltage, current, and temperature of the battery cell. The control commands and responses are delivered wirelessly between the master and slave BMS modules. No wire-harness is involved.

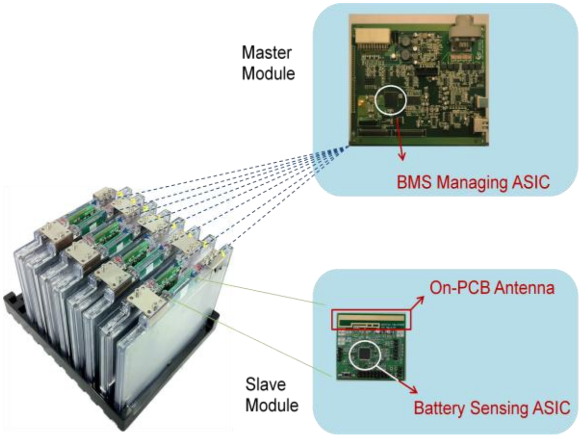

Figure1: Wireless BMS architecture

The master BMS module can broadcast a single command to measure the cell voltage, the slave BMS modules then report the simultaneously measured data back to the master BMS module. More detail communication protocol between the master and slave BMS modules is defined based on a proprietary Wireless Battery Area Network platform.

2.1 Wireless Battery Area Network

Wireless Battery Area Network (WiBaAN™) is a wireless communication platform that is optimized for a low-power, highly-secure, high-data-rate wireless network around battery modules or pack. The WiBaAN™ can define several functions, including

- Low power data sensing and communication algorithm
- Sensory data update rate and sequence
- Control physical RF/sensor parameters based on sensing environment
- Processing the raw data to extract characteristic features of interest
- Diagnosis data for battery cells
- Timing control for communication and measurement
- Passive balancing control
- Communication link recovery algorithms

It can use 900MHz unlicensed band (ISM) for wireless communication and can extend the operation to dual band. The WiBaAN can manage up to 780 battery cells under the condition of a 100 ms data update rate. Scalability can be achieved by deploying a hierarchical WiBaAN architecture. Variable on-air-data-rate is provided and a nominal data rate is 1 Mbps. A proprietary data security protocol is adopted for secure data communication.

2.2 Design of WiBaAN Chipset

The WiBaAN™ is implemented in a chipset. The design objectives for WiBaAN™ physical devices were to

- keep the combined power consumption of active and sleep mode within a milliwatt range
- keep the high power supply rejection ratio to endure the environmental noise
- use a relatively cheap and stable CMOS process with automotive qualification
- minimize both the cost and the number of external components
- guarantee the secure and reliable wireless communication link
- use maintenance-free calibration loops to compensate for the performance degradation due to process variation, device aging, and temperature, etc.

The WiBaAN™ chipset consists of a Battery Managing ASIC (NSBM_MA), and a Battery Sensing ASIC (NSBM_SL).

2.2.1 NSBM_MA

The NSBM_MA is a single chip battery management controller that incorporates a RF transceiver with a baseband protocol engine, a micro-controller (optional), and various I/O interfaces. It is designed for operation in ISM frequency band at 810MHz ~ 990MHz. The transceiver uses ASK or FSK modulation. The transceiver deploys an efficient RF architecture that achieves higher dynamic range and low power operation at the same time. It has user configurable parameters like frequency channel, output power, dynamic range and air data rate. The air data rate supported by the NSBM_MA is configurable up to 1Mbps.

The integrated voltage regulators, PLL, and driver amplifier keep the external component count low. An MCU, optional PA and very few external passive components are needed to design a sensor network with the NSBM_MA. To support user-defined applications, on-chip peripherals include SPI, I2C, and CAN. Integrated voltage regulators ensure a high power supply rejection ratio (PSRR) and a wide power supply range.

2.2.2 NSBM_SL

The NSBM_SL is a single package with two ICs that includes a RF transceiver with imbedded baseband protocol engine, as well as imbedded analogue sensors, designed for low power wireless sensor network. The sensors in a NSBM_SL provide cost effective and self-calibration analogue sensors of voltage, temperature, and current of the environment, incorporated with an imbedded 12-bit SAR ADC. The NSBM_SL is designed for operation in ISM frequency band at 810MHz ~ 990MHz. The transceiver uses ASK or FSK modulation. The transceiver deploys an efficient RF architecture that achieves higher dynamic range and low power operation at the same time. It has user configurable parameters like frequency channel, output power, dynamic range and air data rate. The air data rate supported by the NSBM_SL is configurable up to 1Mbps.

The broadcasting remote power-up receiver is imbedded with local power-up sequence to achieve ultra-low power-down standby current, less than 1uA, and extended power-up coverage [2]. The integrated voltage regulators, PLL, and driver amplifier keep the external component count low. A 16MHz crystal and very few external passive components are needed to design a sensor network with the NSBM_SL. To support user-defined applications, NSBM_MA is well suitable for base-band controller. Only a single 3.3V power is supplied, and integrated voltage regulators ensure a high power supply rejection ratio (PSRR) and a wide power supply range.

Figure 2 is the actual photos of the managing ASIC and sensing ASIC. There are two different versions of managing ASICs: GX version with a ARM 9 MPU imbedded and LX version without an MPU.

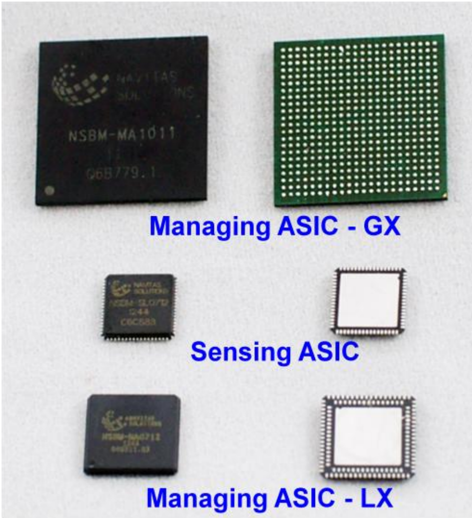

Figure2: Managing ASIC and sensing ASIC

2.2.3 Integration of Slave BMS on battery cells

As shown in Figure 1 above, the slave module includes a sensing ASIC and an on-board PCB antenna. The size of the slave module is very compact so that it can be easily mounted or imbedded on the cell supporter. Figure 3 is the actual photos of a battery pack to illustrate how the slave modules can be mounted on a battery cell supporter.

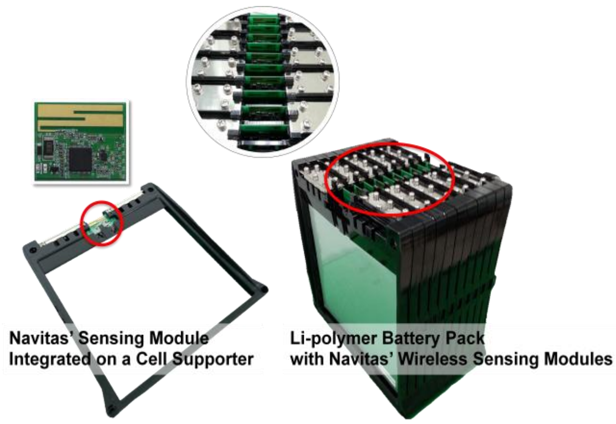

Figure3: Integration of Slave BMS module

A more desirable method is to imbed the slave BMS module into the battery cell during the process of the battery cell production. This requires a slight modification of the cell manufacturing process but it can further reduce the manufacturing cost while improving the reliability.

2.3 Performance of WBMS™

Using the prototype WiBaAN™ chipset, various performance tests have been performed. Table 1 shows a summary of the measured performance and their target specifications of future products.

2.4 Key Advantages of WBMS™

WBMS™ architecture provides the following advantages.

Cost: Significant reduction of a battery pack cost can be achieved due to the reduced number of components such as wire-harness, connectors, protective cases for BMS boards, isolators, and others. In addition, the cost of CMOS technology is coming down fast following the Moore's law.

Productivity: The process of imbedding the slave BMS modules into the battery cells can be fully automated. This will eliminate the manual process of pack manufacturing and maintenance, further reducing the manufacturing cost. A smaller and lighter battery pack is possible. More importantly, wireless communication provides flexibility in modularization of the battery pack design.

Reliability: Highly robust wireless data communication combined with reduced number of failure points can improve the overall system reliability. In addition, perfect isolation of high voltage provided by wireless communication ensures the maximum stability in transient and abnormal operation condition.

Diagnosis: A built-in current sensor on each battery cell allows early detection of internal short circuit on battery cells connected in parallel.

Table1: Measured Performance of WBMS™

Parameter	Measurements	Notes
Operating frequency	868MHz, 902-928MHz	ISM bands
Coverage range	< 10m indoors	< 1km outdoors
Data rate	Up to 1Mbps in ASK/FSK	Variable rate up to 1Mbps
Power consumption in power-down mode	~ 1uW	Standby current < 400nA
Power consumption in power-up active mode	< 1.6 mW	Duty cycle of < 1% Target < 1.5mW
Power-up time	< 1 msec	for sensor node
Supply voltage	12V for Master 2.7~ 5.5V (battery power) for Slave	Internal regulated voltage supply of 1.8V
Measured cell voltage range and accuracy	Range of 2.5V ~ 4.5V Accuracy of 10mV (~0.25%)	Target range of 2.0V ~ 4.7V Target accuracy of 10mV
Measured temperature range and accuracy	Range of -30 ~ +100°C Accuracy of 1.0°C	Target range of -40 ~ 125°C Target accuracy of 1.0°C
Measured cell current range and accuracy	Range of 1A ~ 200A Accuracy of < 1.2 %	Target range of up to 200A Target accuracy of < 1 %
Diagnosis	Over-voltage/under-voltage Short-circuit protection Open-circuit flag Over temperature flag	Suitable for the secondary protection
Technology	TSMC 0.18μm RF CMOS	65nm CMOS for the next

Redundancy or fault-tolerance: A secondary communication channel can be easily added for fault tolerant design. For example, by adding another Managing ASIC on the master BMS, a secondary communication channel can be constructed. For comparison, in conventional wired BMS one would need a separate set of wire-harness to achieve the same level of redundancy. It is also possible to use the wireless channel as a secondary to the conventional wired channel for redundancy purpose. It provides many flexible design options to battery pack manufacturers.

Intelligibility: Each individual battery cell has a build-in flash memory on the slave BMS module. Cell ID and its usage history along with other useful information can be stored. The cell history information can be useful for future applications such as battery secondary-use.

3 Conclusion

In this paper, we presented the concept of WBMS™ architecture and a chipset implementation of the WiBaAN™ protocol. The new architecture addresses a variety of issues brought up by the conventional wired BMS architecture. The WBMS™ architecture is designed to provide battery pack manufacturers with scalable, flexible, reliable, and cost-effective options.

Using the prototype chipset produced, we have built lithium ion battery packs for both automotive and stationary applications. The preliminary performance tests demonstrate the feasibility of WBMS™ on a large-scale battery pack with reliable and secure wireless communication. It also shows that the accuracy of cell sensors is adequate and achievable. The chipset has ultra-low standby/active power consumption current.

References

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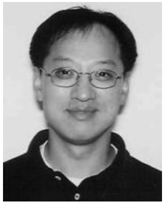
Authors

Dr. Minkyu Lee is the Chief Technology Officer. He received a B.S. degree in Electrical Engineering from Seoul National University, an M.S. degree from the Korea Advanced Institute of Science and Technology, and a Ph.D. degree in Electrical Engineering from the University of Florida.



Dr. Jaesik Lee is a Vice President of Technology. He received a B.S. degree from Yonsei University, an M.S. degree from the Korea Advanced Institute of Science and Technology, and a Ph.D. degree from the University of Illinois at Urbana-Champaign in Electrical and Computer Engineering. He is responsible for development of RF/analog IC design.

Dr. Inseop Lee is the Chief R&D Officer. He is responsible for digital system and ASIC design. He received his B. S. and M. S. degrees in Electronics Engineering from Seoul National University, and earned his Ph.D. degree in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign.

Dr. Joonghui Lee is the head of Navitas Korea. He has expertise in developing battery management systems for lithium ion batteries. He also has experience with new energy systems including photovoltaics and fuel cells. He received a B.S. degree from Seoul National University and a Ph.D. degree from Korea Advanced Institute of Science and Technology.

Mr. Andrew M. Chon is the Chairman and CEO. Andrew Chon received a B.A. in Economics from UMBC and earned an Executive M.B.A. from The Kellogg Graduate School of Management of Northwestern University. He held various senior executive positions with Samsung Electronics, Lucent Technologies, AT&T, and NCR Corporation. He is an elected member of The National Academy of Engineering of Korea.