Advanced Materials Research
ISSN: 1662-8985, Vols. 1008-1009, pp 567-570
doi:10.4028/www.scientific.net/AMR.1008-1009.567

Submitted: 2014-05-16
Accepted: 2014-06-06
Online: 2014-08-13

Analysis and Application of Power Balance in Self-powered Sensor

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Keywords: energy harvest; sensor; energy saving

Abstract: wireless sensor network(WSN) nodes based on self-powered function have distinct advantages of battery free and no needing line power, used successfully in lighting control system of modern building. Energy balance and power balance are considered in design of battery-free sensor module. Average current in self-powered wireless sensor module was evaluated based on viewpoint of power balance. Energy balance was discussed in building lighting control system based on special energy storage of super-capacitor. Self-powered wireless sensor module is based on energy harvesting from ambient circumstance. In lighting control system of modern building automation battery-free sensor module has been successfully applied for maintenance and energy saving. The application of battery-free sensor module was analyzed.

INTRODUCTION

Development of new green energy resource, saving energy resource, protecting mankind living circumstances from heavy metal pollution of battery production and treatment of wasted batteries has become a hot concern in industry and academic field. Sensor network, the bottom layer and the key section in Internet of Things, uses commonly RFID technology currently. RFID has obvious drawbacks: needing battery as power supply, or needing alternative electric power line for scanning tags to get the information on objects (cargoes, for instance), though it can also collect information rapidly. Performance of sensor network, as the "neuro-terminals" of Internet of Things, is the key section in the whole network system, impacting on the performance of the whole Internet of Things. Some literatures[1]-[3] discussed the path of self-powered wireless sensor and application in building automation. Yoash Levron et al[4] proposed efficiency control method to reduce capacity of energy storage component. Tan Y.K., Hoe K.Y. and Panda S.K. discussed property of sensor self-powered relying on piezo-electric effect principle. R Torah, P Glynne-Jones, M Tudor[6] investigated power supply harvesting from vibration energy in ambient circumstances, providing concrete design project. D. Han, J. Zhang, Y. Zhang and W. Gu[7] described convergence of Sensor at Aggregation Layer for Internet of Things.

The objective of this work is to discuss the operation principles and application of sensor network with characteristics of self energy harvesting(batter-free),wireless and smart control, analyzing its function protecting living circumstances from heavy metal pollution caused by battery manufacturing and tackling wasted batteries. Application of green source energy wireless sensor network offers a better resolution to reduce large amount of energy consumption in modern buildings, and saving high cost maintaining normal function of modern buildings, which, in turn, reach remarkably the goal saving energy resource, lowering consumption of energy and material resource, protecting circumstances from pollution.

MODULE STRUCTURE OF BATTER-FREE SENSOR

Various kinds of self-energy harvesting sensor module, after a decade efforts of researchers and engineers, have been developed and applied in different fields. A basic block diagram self-powered sensor is shown in Fig.1.There are multifunction sub-blocks in the module. In the first sub-block is the function of self energy harvesting. Green energy from ambient, solar energy, for instance, vibration energy, thermo-electric energy, electromagnetic energy, and the like, can be collected and transferred to electric energy as the power source of control circuits and CPU. In the second sub-block green energy source needs to be transferred to electricity

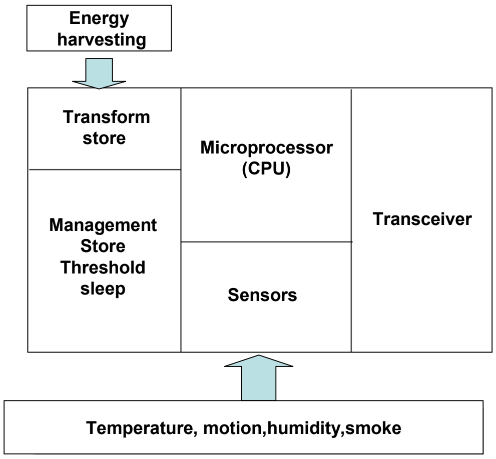

Fig.1 Block diagram of self-powered sensor module

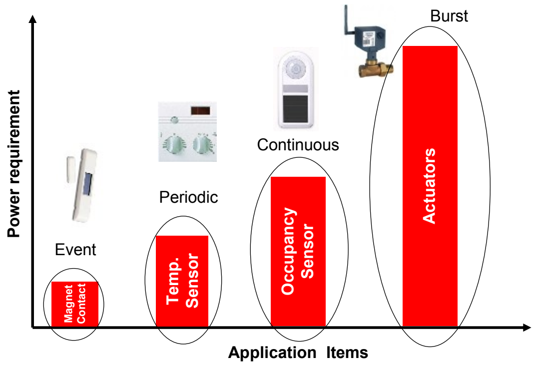

Fig.2 Typical power requirement of different items in control process

energy and stored in cluster capacitor (supper capacitor). As to the next sub-block, management of harvested energy can be realized. Energy collected from green sources, such as, motion displacement, has minimum value about 200μJ, which can not drive any circuit usually. But in successful design of the self-powered sensor module 3 telegrams packages on location and state of the ambient surroundings picked up by the sensor can be emitted with so minimum energy. The function is implemented with excellent design of energy level and energy balance through special electronic technology.

Green energy collector (harvester) have the features of mini size, mini power consumption, and low threshold values of wakening up, abundant energy, and needing no time for connection with other section in the module. Unit of energy transferring and storing needs to self-driven at voltage (10-20)mV, and can lift the voltage of (10~20) mV up to 3V to meet the requirement of CPU operation. Management unit can implement energy assignment, fast wakening up circuits, no energy waste. CUP in the module needs to have extremely low power consumption, extremely low sleep current (even lowered to the level of nA), periodical and hardware wakening up and driving. Sensor unit of the module requires low power supply, no pre-warm time, much short response time. Transceiver unit needs to have efficient emitting power(3-5telegram packages can be emitted with power of 200μW), much low maintaining current, fast setting up variable emitting power, effective radio communication protocol and operation channels.

In the module of self-energy harvesting sensor almost all circuits are in sleep state in more than 90% time, which just is wakened up at appropriate moment. The minimum sleep current of CPU in the self-powered sensor module can be lowered to 20nA, an extremely low value in electric circuit design. Various level power used to wake up different sections need to be designed in detail for other electric circuits in the module.

Balance Analysis of Power and Energy

Sleep current in self-powered sensor module must be much less due to much low green energy collected in ambience. Various power levels of items in control process with sensor module are shown in Fig.2. Door-Window magnetic sensor is trigged with event mode, needing quite small driving power. Temperature-humidity sensor needs to periodically be wakened up and needing higher power than that used in event driving mode. As to occupancy sensor more power ought to be supplied for continuous detection of ambient occupant state, which needs to supply certain power successively. In practical application of self-powered

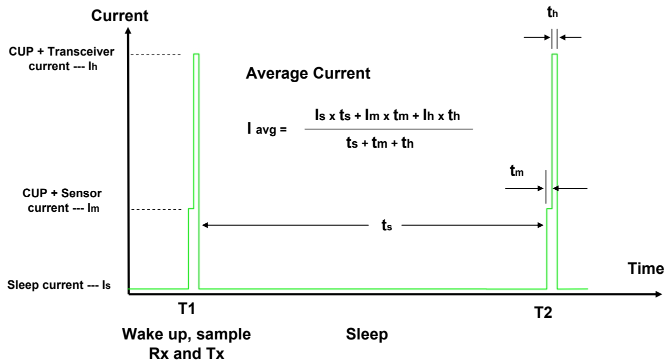

Fig3 Control current evaluation in sensor module

sensor, driving actuators need comparatively the largest power in the whole control process,. which has the burst work mode in building automation control process. Another sensor work periodically, and detects ambient temperature and humidity per two minutes.

Calculation method of average control current in self-powered sensor module is given in Fig.3 .Different level currents are supplied to corresponding sections in self-powered sensor module. The lowest current I_s (20nA) needs to supply CPU successively. The second higher current level I_m means sum of sensor current and CPU sleep current. The highest current I_h refer to sum of CPU sleep current and current for driving transceiver in self-powered sensor module. Time durations corresponding the processes are t_s for CPU sleep, t_m for CPU sleep plus sensor operation, and t_h for CUP sleep and transceiver operation.

So the average current supplied self-powered sensor module can be calculated with the formula below:

$$I_{av} = \frac{I_s \times t_s + I_m \times t_m + I_h \times t_h}{t_s + t_m + t_h} \tag{1}$$

Here given an example of calculation of average current in self-powered sensor module EnOcean STM110C, which has parameters as the following: *CPU 24μA for 42.6ms; Transmit current 8.6 mA for × 1.2 ms x 3; Sleep current 80nA (20nA timer); Wake up interval 100 sec; Transmit(per time of wake up) 100 sec*

Each package with identical content will be emitted three times to ensure the reliability of wireless communication. The average operation current, hence, can be calculated as below:

$$I_{av} = \frac{I_s \times t_s + I_m \times t_m + I_h \times t_h}{t_s + t_m + t_h} = \frac{80nA \times 100s + 24\mu A \times 42.6ms + 8.6mA \times 1.2ms \times 3}{100s + 42.6ms + 3 \times 1.2ms} = 0.39\mu A \tag{2}$$

Energy storage and maintenance have important effect in many places on application of self-energy harvesting sensor. Capacitor value for energy store in self-powered sensor module is much large, even reach to 1 Faraday, forming so-called “super capacitor”.

Much long time need to charge the “super capacitor” before reaching the final high voltage, which implies that all circuits in sensor module do not work during charging “super-capacitor”. The resolution of this problem is to use another capacitor with smaller capacitance of several hundred μF, which can be rapidly charged in short time and supply CUP in the module with enough voltage. “Super capacitor” will be continuously charged as the small capacitor has been charged to the high limit value. Once “super capacitor” is charged to reach the highest voltage it can provide all circuits in the self-powered module with enough energy for much long time, 60hours, for instance, from Friday through Monday, the weekends assuming no light incident into office room in weekends(see Fig.4).

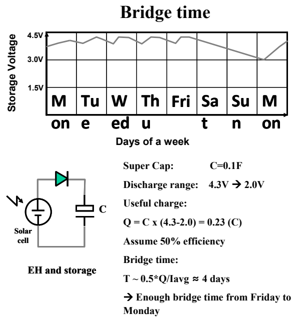

Fig.4 Calculation of bridge time for super capacitor

CONCLUSION

Problems on power balance in short time and energy balance in long time need to be solved in elf-energy harvesting sensor module for different function sections. The resolution approaches include control of sleep time and triggering power, reasonable design process on combination of supper capacitor with regular capacitor for energy storage. Aspects of efficiency, communication channel, protocol ought to be taken into account for making resolution of energy budget in the control system with self-powered sensor module. Variety of battery-free wireless smart sensors can be employed in building automation to realize outstanding energy source conservation and protection our mankind living circumstances from heavy metal pollution. Self-powered, wireless, smart sensors have much great promising and broad application fields in the future.

ACKNOWLEDGEMENTS

This work was supported by National Nature Science Foundation of China (No. 60971078), by Guizhou Provincial Foundation for International Collaborative Science and Technology Research(No. G [2012]7019), by Nature Science & Technology Foundation of Guizhou Province (No. J [2011]2028), by Ph D research foundation of Guizhou Normal University, and by Guizhou province special found for outstanding scholar research conditions(TZJF-2011-57)

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