A SELF-POWERED, SELF-SUSTAINING SYSTEM-ON-CHIP (SOC) SOLUTION POWERED FROM HYBRID MICRO-FUEL CELLS

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ABSTRACT

Lightness and integration are crucial features of Object Force Warrior (OFW), where the weight and size of reconnaissance and surveillance electronics become disabling factors for a soldier in the field. This paper proposes a self-powered, self-sustaining system-on-ship (SOC) solution with fully integrated micro-fuel cell/thin-film lithium-ion battery hybrids. A power scheme is proposed whereby micro-fuel cells charge an in-package thin-film lithium-ion battery, which in turn handles fast load dump events. The power management circuits constitute the "brain" of what amounts to a single chip solution.

1. INTRODUCTION

Key to the success of army intelligence is swiftness. With this in mind, the Objective Force (i.e., U.S. Army's future full spectrum force) must be equipped with lightweight and fully integrated combat systems (Plichta et al., 2000). However, a large portion of a soldier's equipment is electronic equipment, whose solution is currently discrete and distributed with bulky batteries (e.g., Li-ion, NiMH, NiCd, etc.). Therefore, integrating the battery with a power efficient system in a single chip would not only reduce weight and size, but also prolong battery life and increase mobility.

2. BACKGROUND

A general power management system is comprised of three parts: an energy supporting source, a power scheme, and power management circuits (e.g., charging circuits, power supply circuits, references, protection circuits, monitoring circuits, interface circuits, and so forth). For portable electronics, the energy source is typically a battery whose chemistry usually requires it to be bulky and discrete.

3. PROPOSED SOLUTION

Figure 1 illustrates a proposed self-powered, self-sustaining system-on-chip (SOC) solution. The single chip is comprised of integrated energy sources, highly efficient power management circuits, and any load system (e.g., sensors, meters, GPS, etc.). The chip meets the light and integrated requirements of Object Force Warrior (OFW) and other similarly restricted portable electronics.

3.1 Integrated Energy Sources

The proposed solution requires in-package energy sources with ambient operating temperatures (e.g., 0-85ºC) and only emergent micro-fuel cells (Kohl, 2004) and thin-film lithium-ion batteries (Bates et al., 2000) are capable of this integration. These technologies, however, are at their infancy, still requiring work in modeling, integration, and management. This paper discusses the strategies and state-of-the-art of all these issues.

3.2 Power Scheme

In considering a scheme, power efficiency and battery life are paramount. Micro-fuel cells have potentially high energy density but low peak currents and slow response rates while thin-film lithium-ion batteries have

high peak currents and fast response rates yet relatively low energy density. Thus, for high peak-to-average power ratio applications (i.e., asynchronous and time-variant events), as is the case in portable military electronics, a hybrid power scheme that complements the advantages of micro-fuel cells and thin-film lithium-ion batteries promises to overcome the SOC paradigm, resulting in high efficiency, long battery life, light weight, and miniature size (Jarvis et al., 200). Figure 1(b) shows the proposed hybrid scheme. The micro-fuel cells mostly charge the fast responding thin-film lithium-ion battery, which in turn supplies power to time-variant loads. A mode manager (i.e., the "brain") determines the operating mode of the circuits and power sources, optimally prolonging battery life.

3.3 Power Management Circuits

The proposed SOC solution requires a custom charging circuit that differs from conventional charging methods, such as constant-current and -voltage charging schemes. Special protection circuits must sense and process temperature and load information among other things for the safe regulation of the hybrid energy sources. Power supply circuits, references, protection circuits, monitoring circuits, and interface circuits must all operate under the special circumstances of the integrated battery.

REFERENCES

Bates, J.B. et al., 2000: Thin-Film Lithium and Lithium-ion Batteries, *Solid State Ionics*, v 135, 33-45.

Jarvis, L.P. et al., 2002: Fuel cell/lithium-ion battery hybrid for manportable applications, *Proceedings of Seventeenth Annual Battery Conference on Applications and Advances*, 69-72.

Plichta, E.J. et al., 2002: Mobile Power Challenges for the Army's Objective Force, *Proceedings of Seventeenth Annual Battery Conference on Applications and Advances*, 109-111.

CONCLUSION

A self-powered, self-sustaining SOC solution with fully integrated micro-fuel cell hybrids is proposed. This solution promises to integrate systems into a single chip, overcoming the SOC paradigm and consequently pushing portable electronics into the next decade.

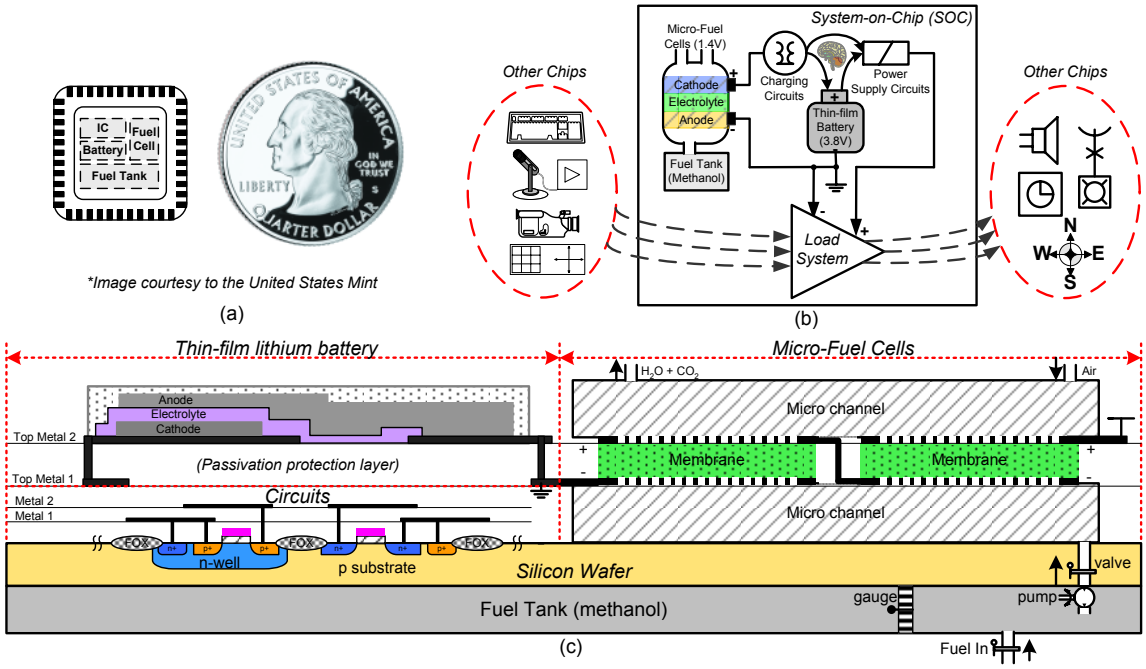

Figure 1. (a) A self-powered, self-sustaining SOC, (b) its power scheme, and (c) its physical profile view.