2004 Fall GTAC Review:

A Monolithic, Self-Powered System-On-Chip (SOC) with Fully Integrated Micro-Fuel Cell Hybrids

Min Chen
Advisor: Prof. Gabriel A. Rincón-Mora
Georgia Tech Analog and Power IC Design Laboratory
School of Electrical and Computer Engineering
Georgia Institute of Technology

Abstract

Trend

- Micro-power applications in consumer electronics, biomedicine, military, and space exploration arenas

Motivation

- Technology unbalance between IC fabrication and conventional battery technology (e.g., Li-ion, NiCd, NiMH)
- Market demands, such as lightness, miniature size, pennyworth, longevity, and multi-function

Concept

- Battery integration in a single chip

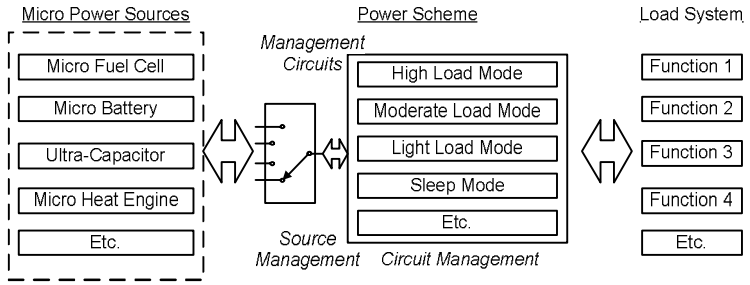
Goal

- Implementation of a monolithic, self-powered SOC, where batteries, power management circuits, and application circuits are all integrated into a single chip.

GEDC Industry Advisory Board, October 2004.
© 2004 Georgia Electronic Design Center. All Rights Reserved.
Redistribution for profit prohibited.

System Requirement

- Micro-power sources
- Power scheme (source and circuit management)
- Power management circuits
- Application circuits



Micro-Power Sources

	Li-ion or Li-polymer	Thin-Film Li-ion Battery	Micro-Fuel Cell	Ultra-Capacitor
Integrability	No	Yes	Yes	No
Energy Density	Moderate	Moderate	Potentially Highest	Low
Power Density	Moderate	High	Low	Highest
Transient Response	Moderate	Moderate	Slow	Fast
Temperature Range	-40 to 65ºC	-25 to 120ºC	50 to 130ºC	-40 to 70ºC
Cycle Life	>1,000	>10,000	Unlimited	>100,000
Self-Discharge Rate	Moderate	Low	Zero	High
Cost	Low	Moderate	High	Moderate

Modeling of Power Sources

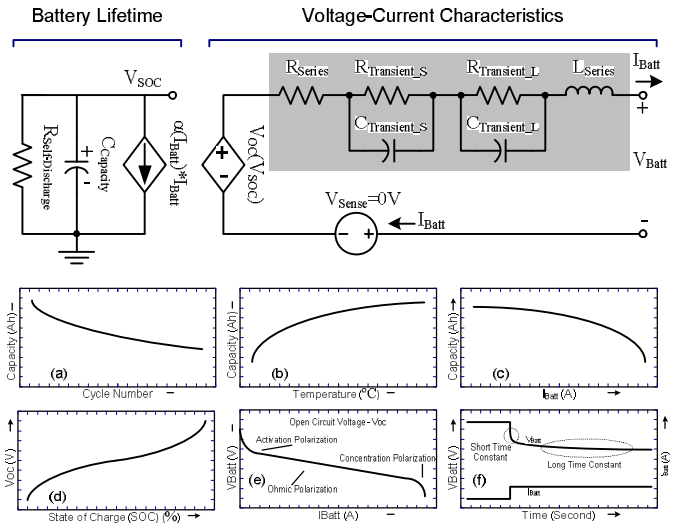
Electrochemical models or mathematical models

- Using deductive method (fundamental mechanism)
- Providing macroscopic and microscopic information
- Involving a system of coupled, time-variant, spatial, partial differential equations (numerical technique)

Electrical models or circuit models

- Using inductive method (empirical equation)
- Providing macroscopic information
- Involving curve fitting of a bundle of measurement

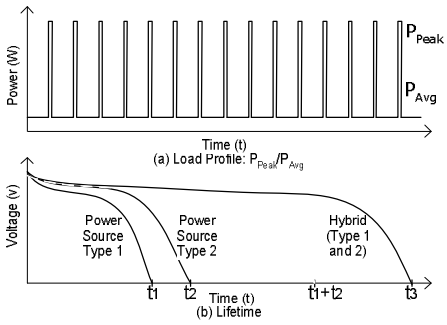
A Unified Battery Model

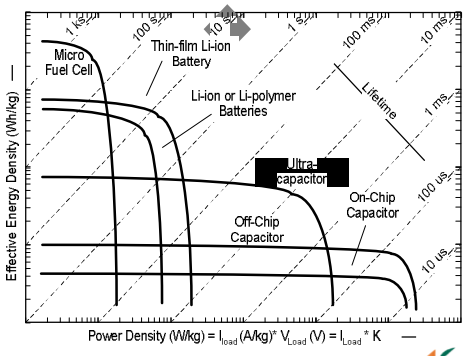


Power Scheme

Source Management (High PAPR Application)

- Single configuration: micro-fuel cell (t_1); thin film Li-ion battery (t_2)
- Hybrid configuration: hybrids (t_3)





Power Scheme

Circuit Management

- Mode hopping, soft switching, dynamic voltage scaling, etc.

Management circuits

- Charging circuits, power supplies circuits, references, protection circuits, monitoring circuits, and interface circuits

Proposed SOC Solution

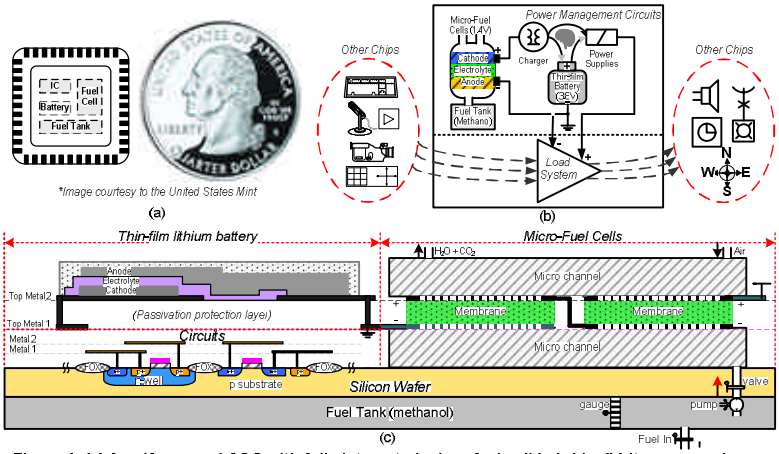


Figure 1. (a) A self-powered SOC with fully integrated micro-fuel cell hybrids, (b) its power scheme and management circuits, and (c) its physical profile view.

Summary

Research Progress

- 2004 Spring GTAC Review
  - Project definition
  - Literature survey
- 2004 Fall GTAC Review
  - System analysis and investigation
  - Comparison of micro-power sources
  - Modeling of power sources (ongoing)
- Future Work
  - Power scheme
  - Management circuits design and simulation
  - Layout and tape-out
  - Prototype and test plan
  - Experimental evaluation