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To cite this version:

HAL Id: hal-01754705
https://hal.laas.fr/hal-01754705
Submitted on 11 Apr 2018

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Self-Powered Adaptive Switched Architecture Storage for Ultra-Capacitors
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CONTEXT: Autonomous battery-free wireless sensor node

Self-adaptive Architecture
The principle of this structure is to change the value of the total storage capacity according to the state of charge/discharge, to satisfy the objectives: fast charging time with a low capacitance $C_{eq}=C/N$ (series configuration), maximization of stored energy with $C_{eq}=C/N$ (parallel configuration).

Self-adaptive architectures under study
Each of the two types of adaptive structures consists of 4 identical supercapacitors (SC) + 9 switches + 3 Schottky diodes for structure B, allowing three possible configurations: Series (S), series-parallel (SP) and parallel (P). (The diodes allow a default serial structure).

Analysis of the two self-adaptives architectures
Both structures are identical, they have the same number of SCs, switches and configurations (S, SP, P), however, they differ in the SP configuration.

- Impact of the dispersion in capacitance values on losses (worst case)

<table>
<thead>
<tr>
<th>Input</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>$E_{MAX}$ loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tolerance range</td>
<td>C=100mF±20%</td>
<td>0.12</td>
<td>0.08</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>Structure A</td>
<td>0.12</td>
<td>0.08</td>
<td>0.08</td>
<td>0.12</td>
<td>2.08%</td>
</tr>
<tr>
<td>Structure B</td>
<td>0.08</td>
<td>0.08</td>
<td>0.12</td>
<td>0.12</td>
<td>2.16%</td>
</tr>
</tbody>
</table>

Emax loss expressed in % of the stored energy

- Balancing currents, simulation result of the worst case, High current in second switching SP→P (low current in first switching S→SP)

For these simulations, we model each switch by a resistor, and the ultra-capacitor by a capacitor in series with a resistor (C=100mF±20%, $R_{MIN}=0.80Ω$, $R_{MAX}=0.4Ω$).

- Charge profile:
  - The S configuration allows for a fast charging and startup (low Ceq).
  - The P configuration allows for the storage of a large amount of energy (High Ceq).

- Discharge profile:
  - The S configuration allows a maximum energy usage rate in the case of a system powered by an energy harvesting source.

Measurement and calculation of losses
Source and load modeled by a constant current source

Perspectives
Silicon integration of the self-powered and adaptive storage.

Acknowledgments
This work is carried out within the framework of the European project SMARTER funded by the CHIST-ERA program, "Green ICT, towards Zero Power ICT".

Self-powered and adaptive storage system

- Experimental results
  - Energy harvester simulated by a Thévenin generator $E_0=5V$, $R_0=1kΩ$, $R_{LOAD}=1kΩ$, $C=100mF$, $C_{eq}=400mF$, $V_{LOAD}=2V$, $V_{DD}=1V$

- Charge profile:
  - The S configuration allows for a fast charging and startup (low Ceq).
  - The P configuration allows for the storage of a large amount of energy (High Ceq).

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  - The S configuration allows a maximum energy usage rate in the case of a system powered by an energy harvesting source.

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La voie la plus courte vers l'avenir doit être choisie...