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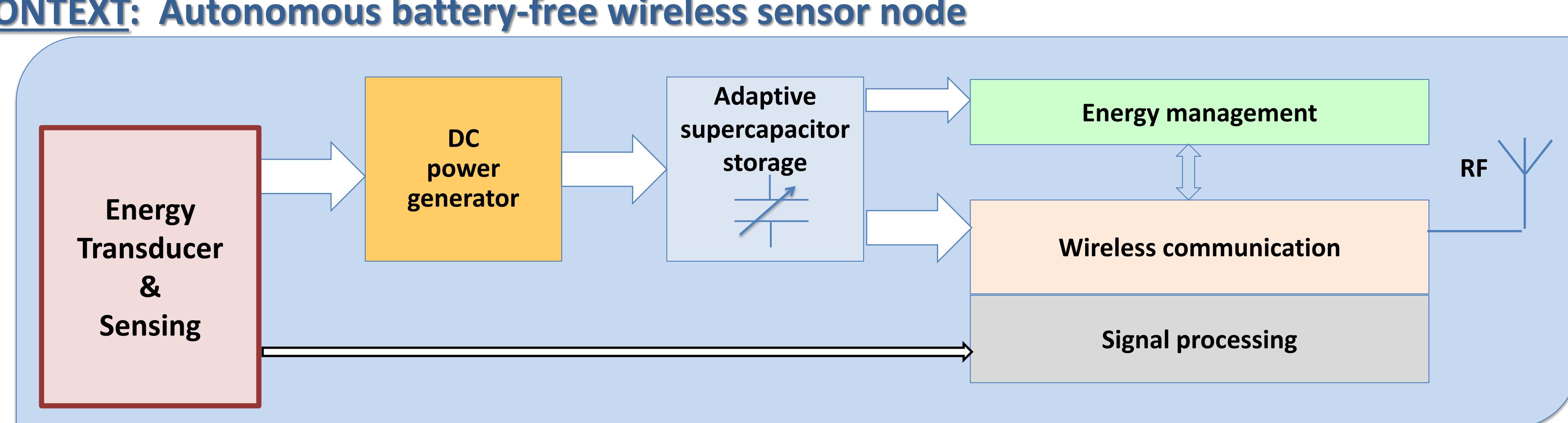
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Self-Powered Adaptive Switched Architecture Storage for Ultra-Capacitors

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CONTEXT: Autonomous battery-free wireless sensor node

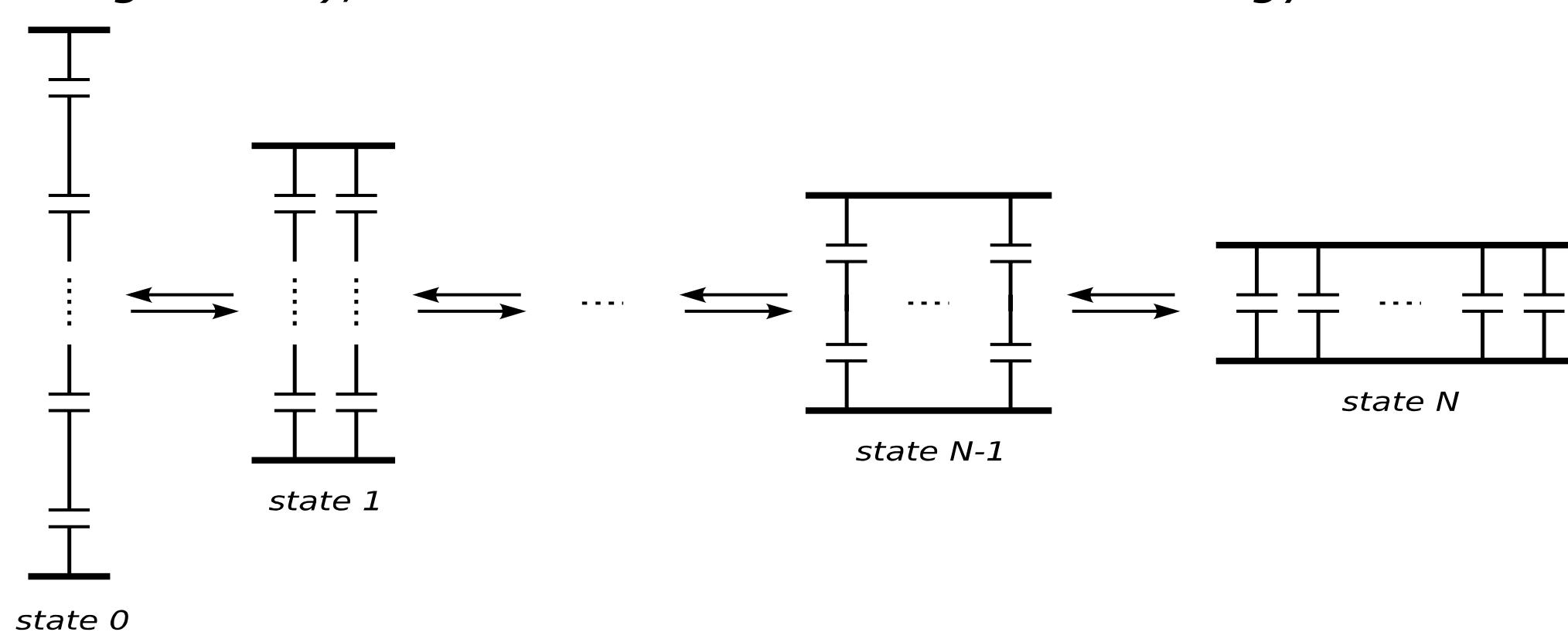


Objectives

- Coupling energy harvesting & storage on supercapacitor (SC)
- Adaptive storage for early startup at charging (low capacitance value) and maximization of stored energy (high capacitance),
- Autonomy of the system and maximum energy usage rate.

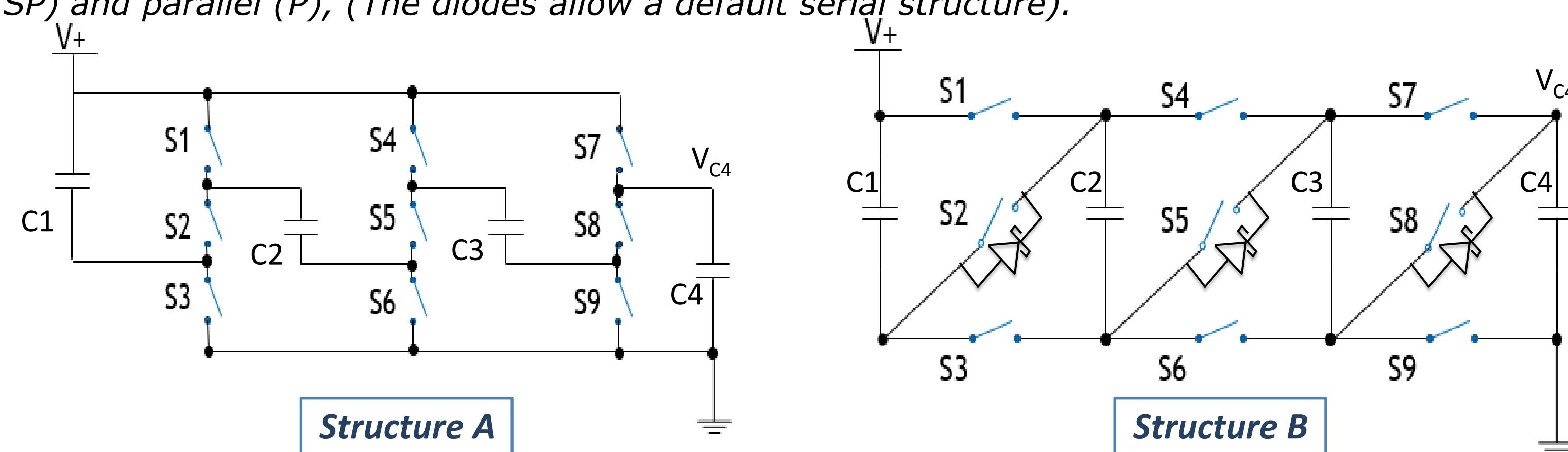
Self-adaptive Architecture

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).



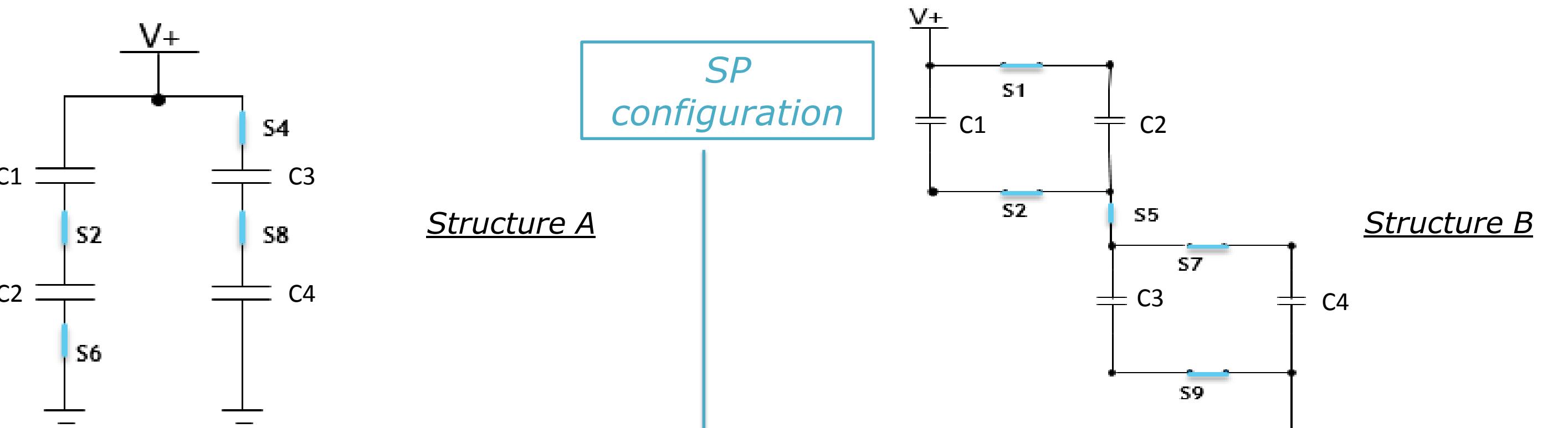
Self-adaptive architectures under study

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

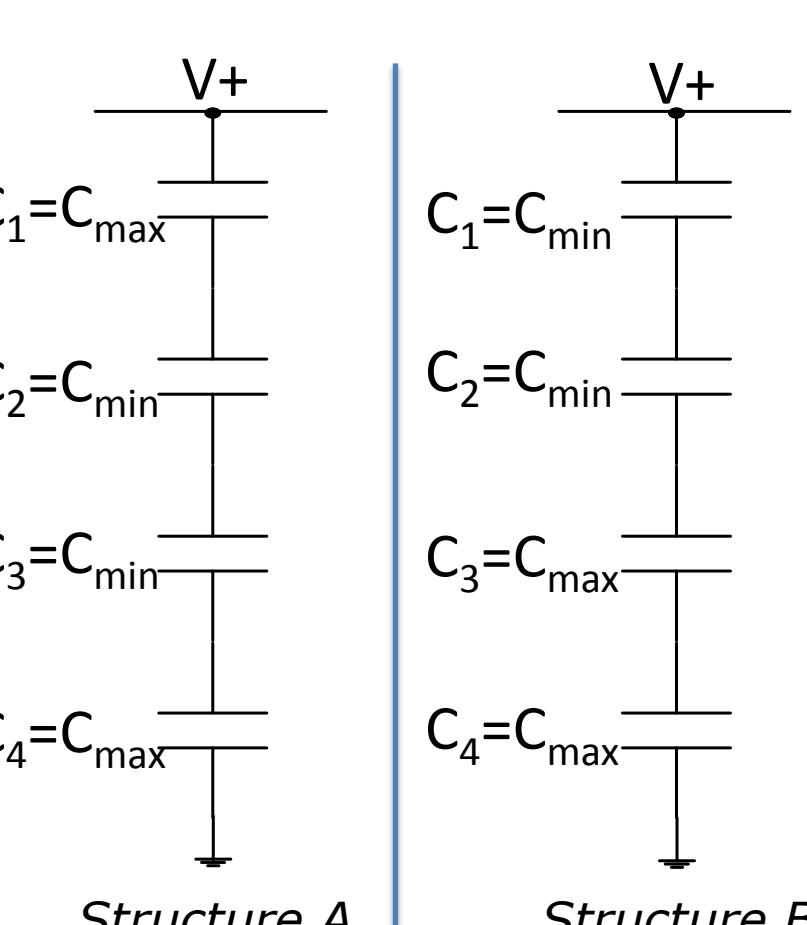
Both structures are identical, they have the same number of SCs, switches and configurations (S, SP, P). However, they differ in the SP configuration.



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

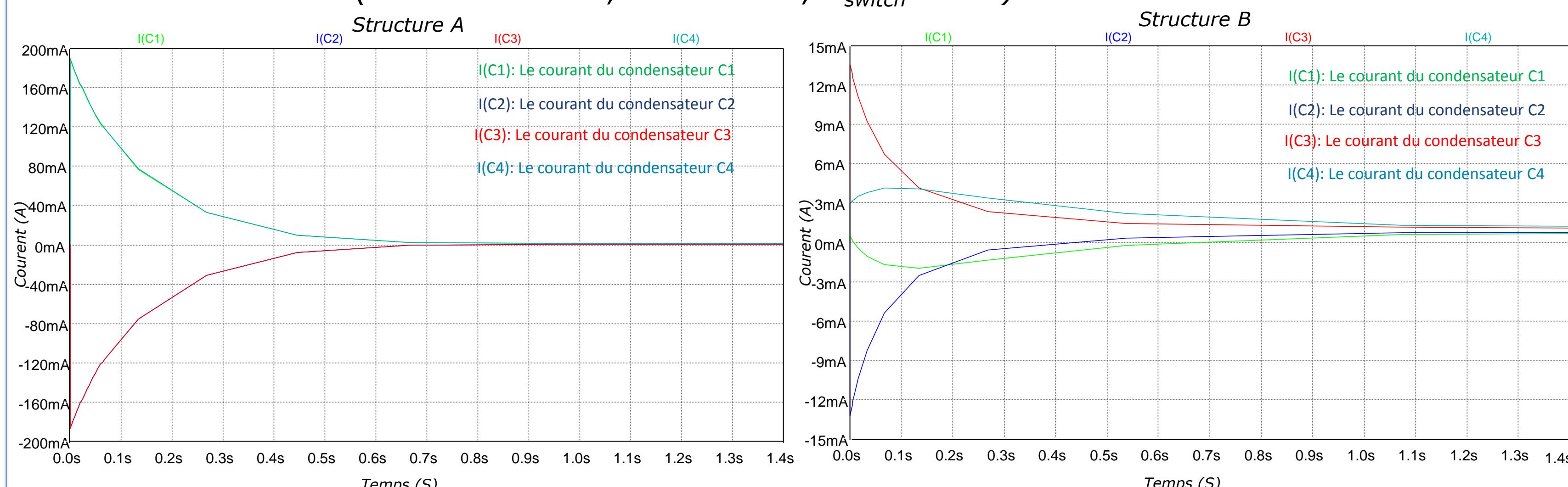
Input	Output				
Tolerance range $C=100mF\pm20\%$	C_1 (F)	C_2 (F)	C_3 (F)	C_4 (F)	E_{MAX} loss
Structure A	0.12	0.08	0.08	0.12	2.08%
Structure B	0.08	0.08	0.12	0.12	2.16%

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)

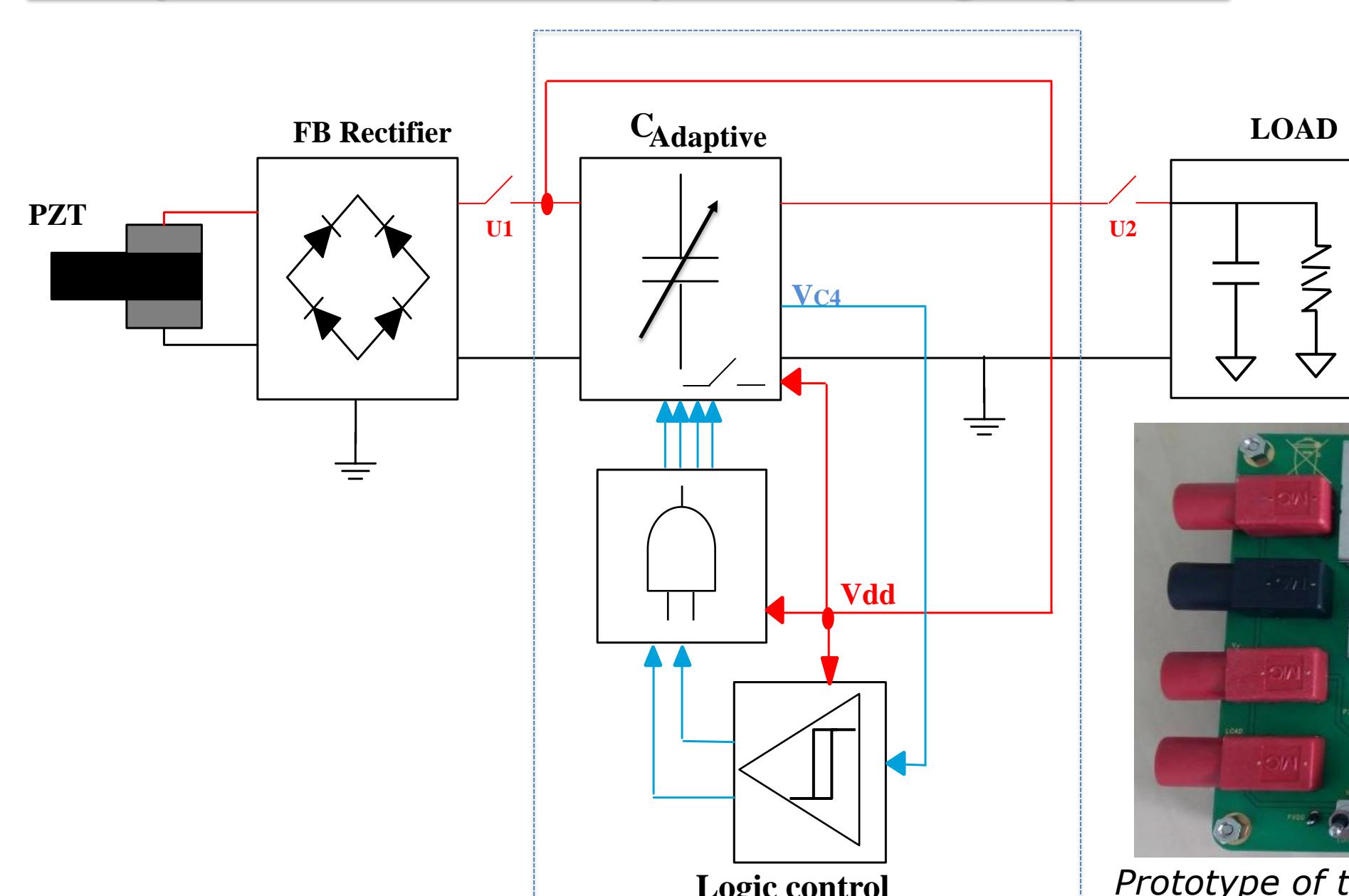
For these simulation, we model each switch by a resistor, and the ultra-capacitor by a capacitor in series with a resistor ($C=100mF\pm20\%$, $ESR=0.08\Omega$, $R_{switch}=0.4\Omega$).



Conclusion

- Low losses \Rightarrow balancing circuit not necessary
- Structure B exhibits lower balancing currents

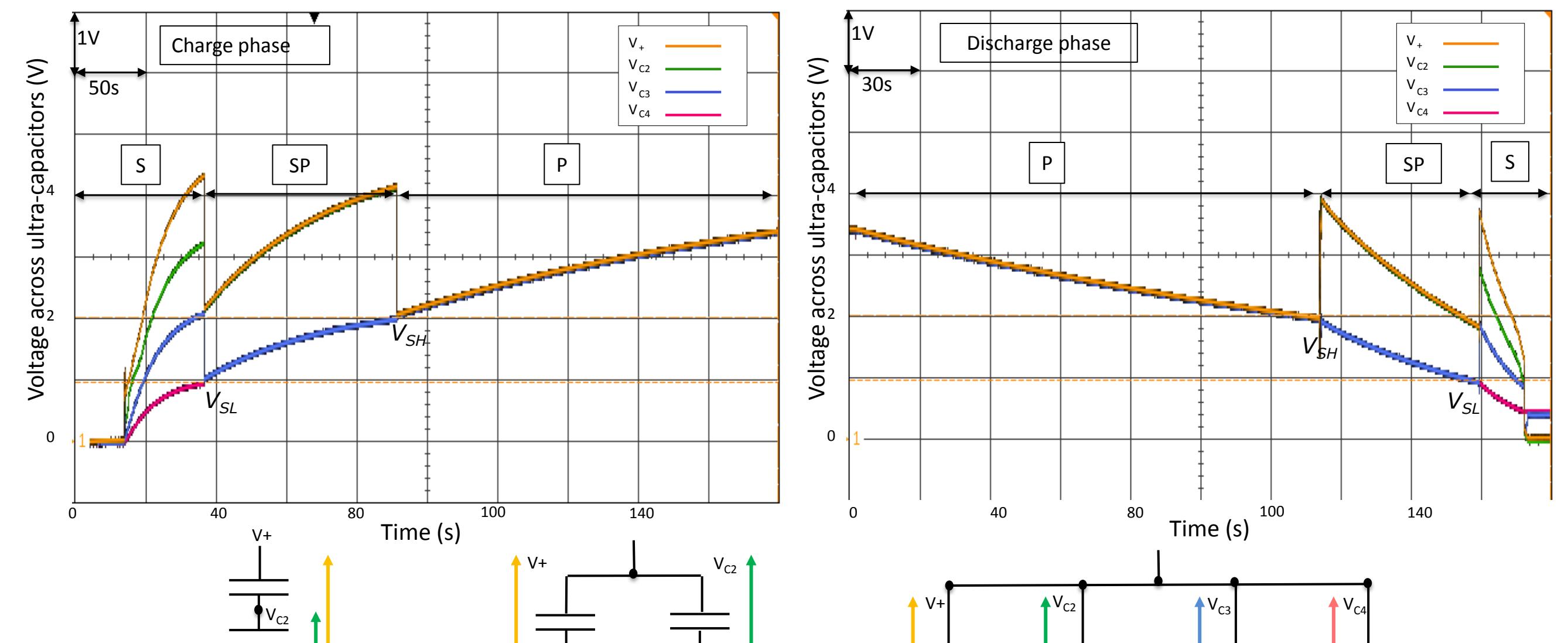
Self-powered and adaptive storage system



Prototype of the autonomous adaptive storage system

Experimental results

Energy harvester simulated by a Thévenin generator
 $E_{th}=5V$, $R_{th}=1k\Omega$, $R_{LOAD}=1k\Omega$, $C=100mF$, $C_{fix}=400mF$, $V_{SH}=2V$, $V_{SL}=1V$



Charge profile:

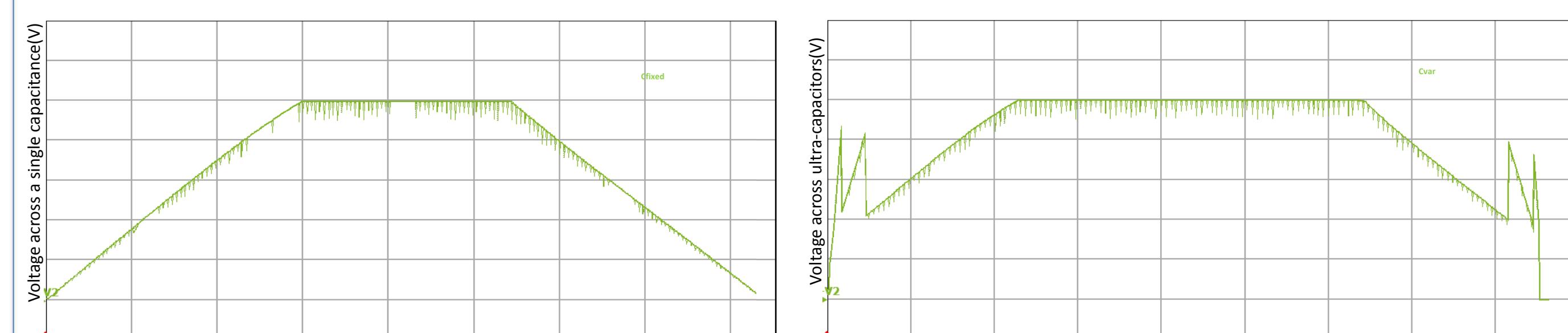
- The S configuration allows for a fast charging and startup (low C_{eq}).
- The P configuration allows for the storage of a large amount of energy (high C_{eq}).

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



	Charge		Discharge	
	$\Delta E/C_{fixed}$ (J/F)	$\Delta E/C_{variable}$ (J/F)	$\Delta E/C_{fixed}$ (J/F)	$\Delta E/C_{variable}$ (J/F)
Theoretical calculation	12.25	12.25	11.05	12.18
Measurement	12.46	12.89	11.01	12.23
Losses		Delivered energy rate		
1.7%		5.2%		10%

Perspectives

Silicon integration of the self-powered and adaptive storage.

Acknowledgments

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