

Ultra-Low Voltage Power Management Circuit and Computation Methodology for Energy Harvesting Applications

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Proposed Energy Harvesting System

- Applications which utilize the energy harvested from the environment are emerging.

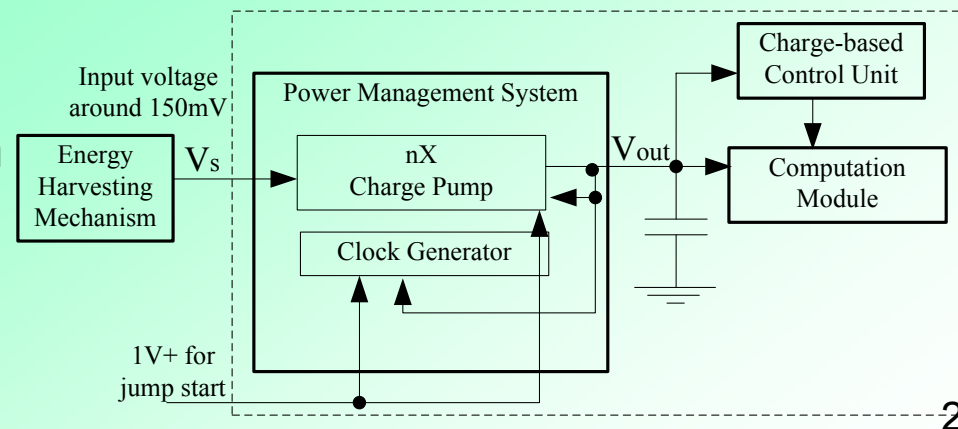
- ❖ Micro-sensor Networks
- ❖ Biomedical Applications
- ❖ Environmental Management
- ❖



solar vibration heat

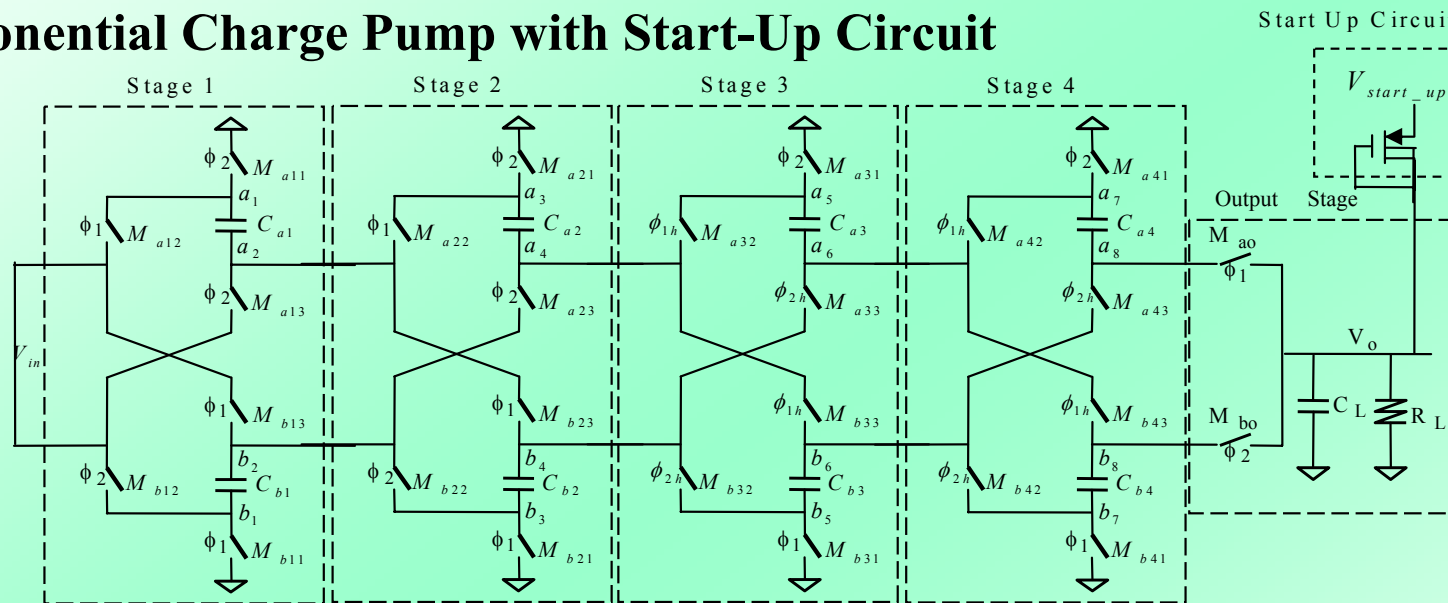
- ✓ **Small harvested voltage** challenges the design of these applications.
 - **Ultra-low voltage power management circuit should be proposed.**
- ✓ Voltage regulator is avoided to reduce the cost of application and **unstable voltage power source** poses robust operation problems.
 - **New computation strategy to control the correct operation is required.**

- **Proposed System:**
 - ❖ Energy Harvesting Mechanism
 - ❖ Power Management System
 - ❖ Computation Module
 - ❖ Charge-based Control Unit



Ultra-Low Voltage Power Management

16X Exponential Charge Pump with Start-Up Circuit



- Pump the voltage from around **150mv** to more than **1V**.
- A **start-up circuit** is needed which only functions at the beginning of the circuit running.
- This charge pump has a **cross-coupled structure** which has 2 symmetrical branches.
- The cap voltages on one branch are pushed by caps on the other and **exponential voltage gain** is achieved.

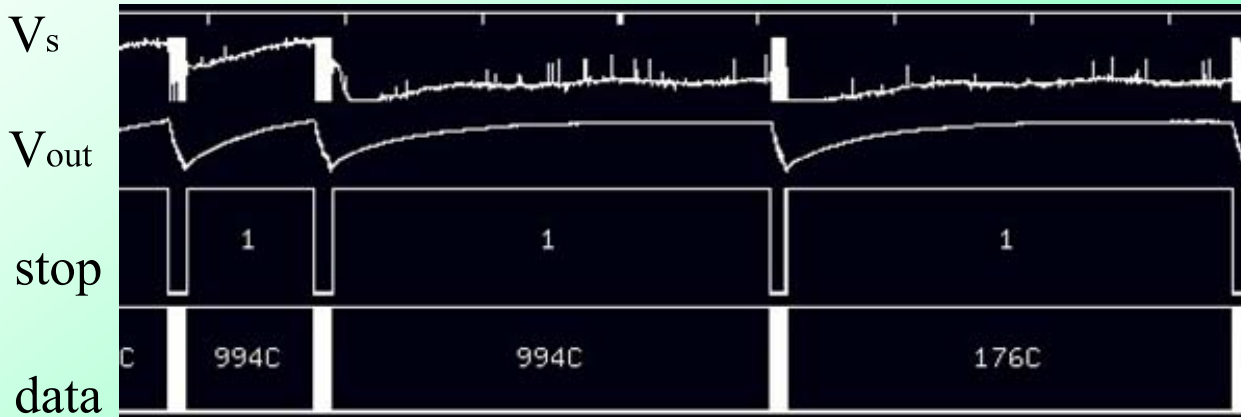
Charge Based Computation Methodology

- ✓ Without the regulator, the power supply becomes unsteady and timing problems may be encountered.
 - **Self-timed asynchronous pipeline design** is proposed to implement the computation module to track the supply fluctuations and adjust the circuit performance.
 - ❖ **A 4-Tap FIR filter is implemented for the computation module**
- ✓ Energy source may not be sufficient for the computation during some time interval and robustness problem emerges when carrying the computation out.
 - **Charge Based Computation methodology** is presented where the atomic computation is only carried out when there's enough charge on the capacitor at the supply side for the operation.
 - ❖ **Simple start-stop control: a hysteretic comparator is used to monitor the capacitor charge status at the supply side and generate the control signal for correct operation.**

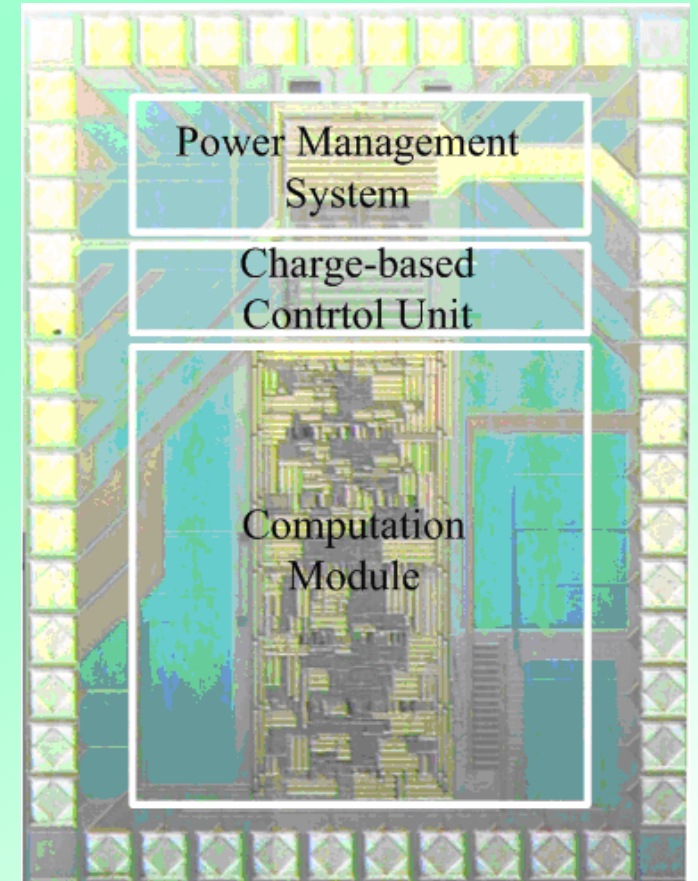
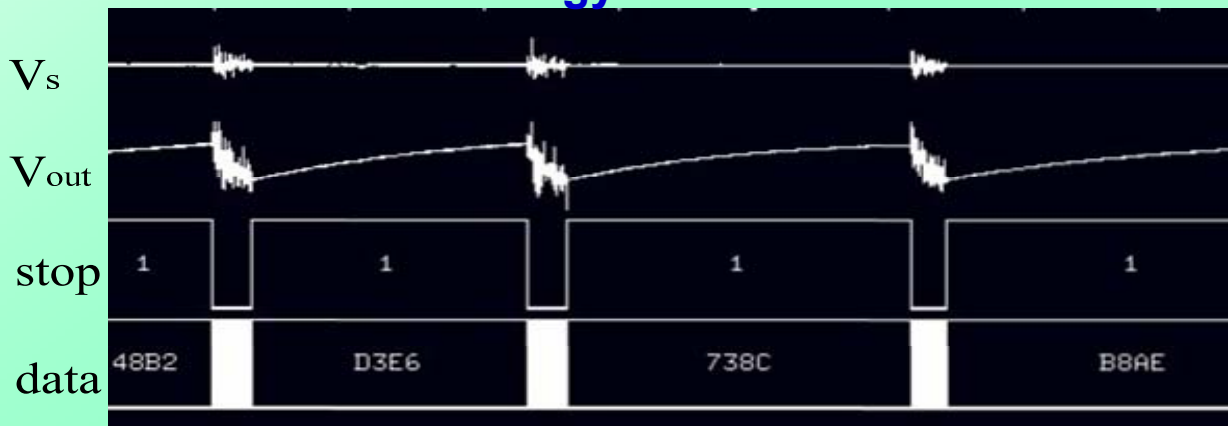


Experimental Results

- Harvested energy source fluctuation between 169mV and 190mV



- Solar cell as the energy source



Die Photo of the Tested Chip

- In order to measure the robustness of the proposed system, 10^{12} output samples were collected and **no error** was found when comparing with the correct samples