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
  ❖ ......

✓ 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.
Without the regulator, the power supply becomes unsteady and timing problems may 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 implement for the computation module

Energy source may not be sufficient for the computation during some time interval and robustness problem emerges when carry 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
- 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.