



Weather in a Box

Autonomous self-powered energy harvesting interface and power management system for sensor applications and wireless data transmission

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European Analog Design Contest 2011

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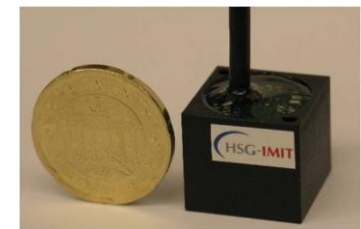
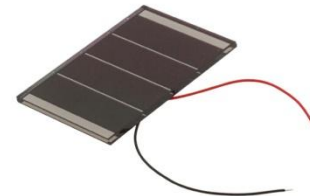
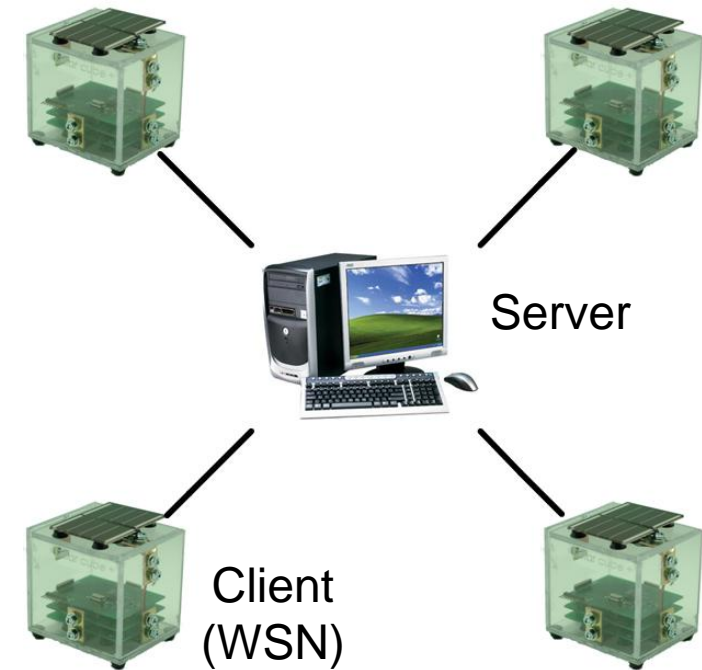
Summary and outlook

Distributed wireless sensor nodes

- Send measurement data to server
- For instance: in- and outdoor weather monitoring

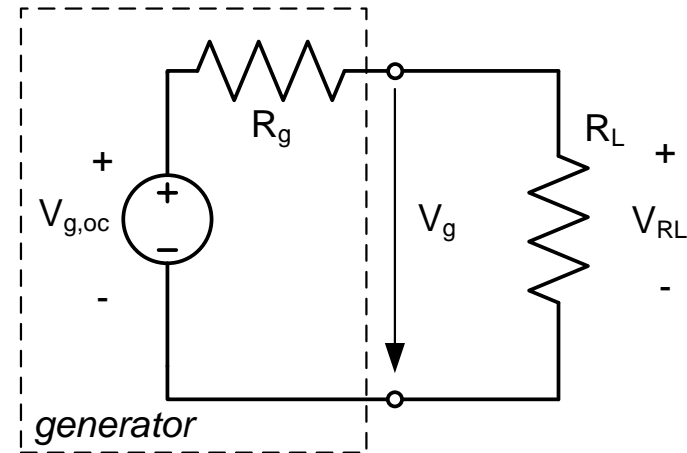
Energy harvesting generators

- Solar cell or vibration driven
- No wiring or batteries needed
- Low fluctuant output power
- Smart power management necessary



Generator

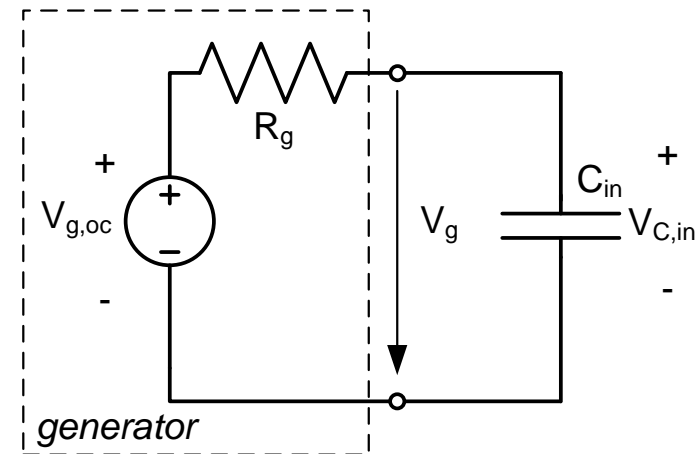
- Output power depends on load
- Matching with internal resistance



Fundamentals and idea

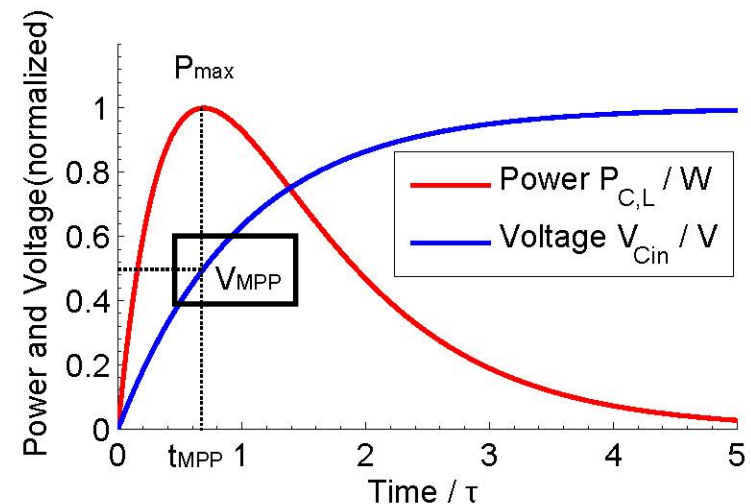
Generator

- Output power depends on load
- Matching with internal resistance



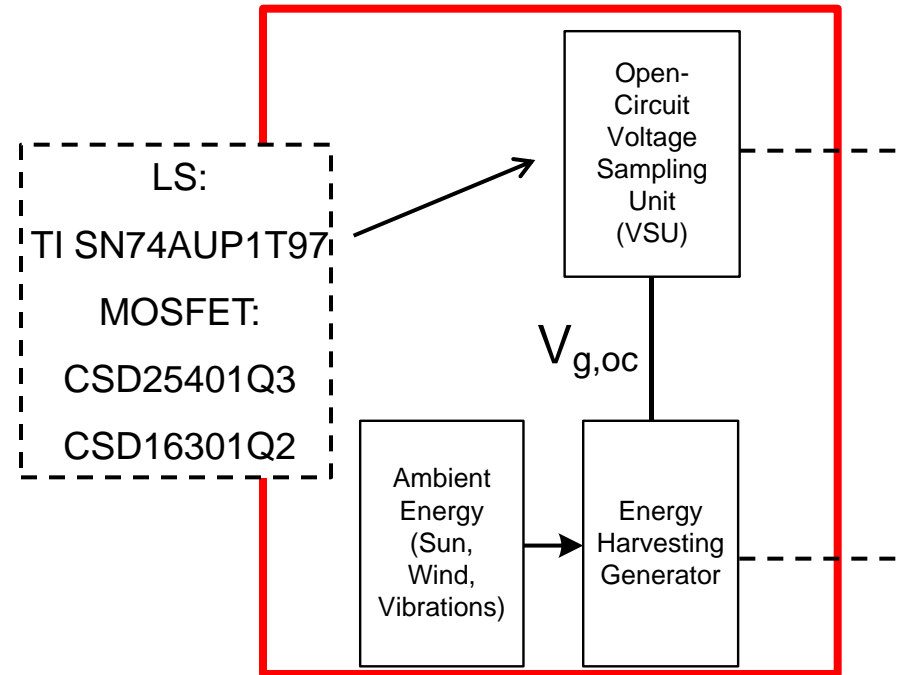
Maximum power point

- Voltage on capacitor is controlled
- $V_{MPP} = k_{ratio} V_{g,oc}$
- k_{ratio} depends on generator type
 - Vibration-driven generator
 $k_{ratio} = 0.5$
 - Solar cell $k_{ratio} \approx 0.7$



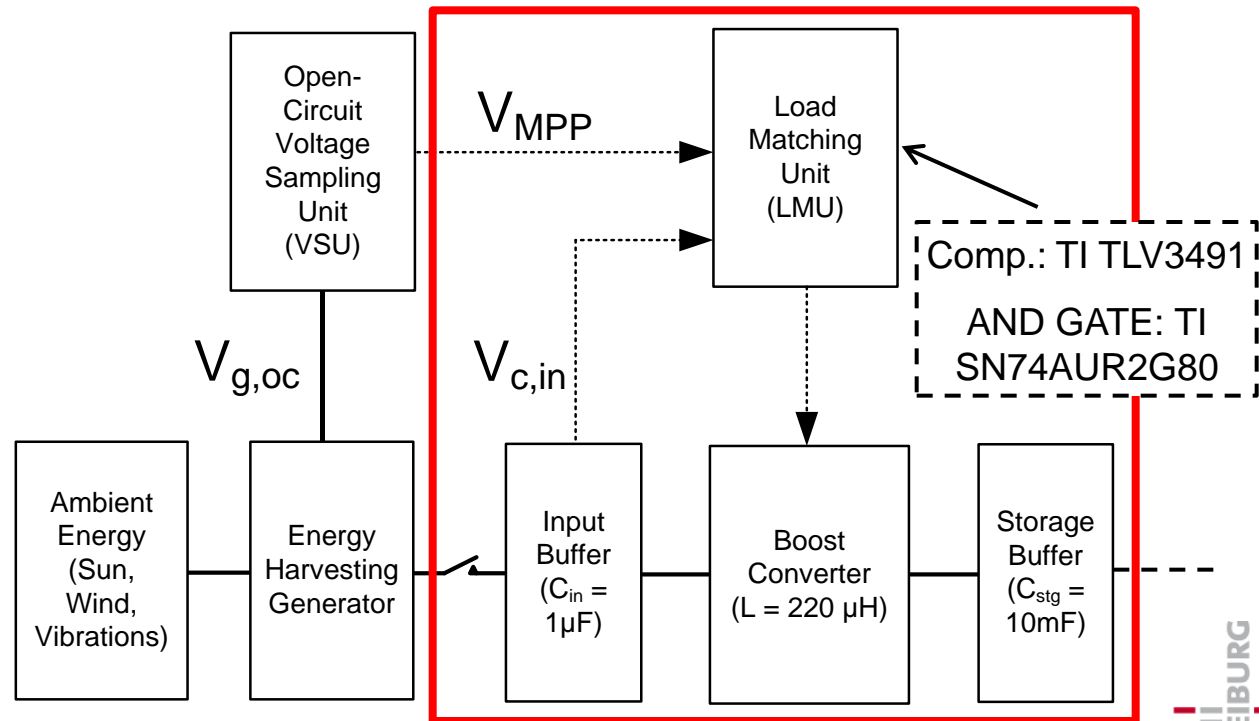
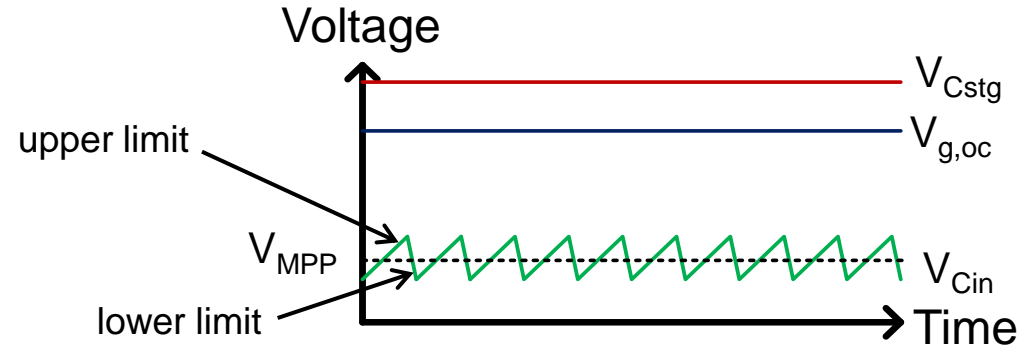
Open circuit voltage sampling unit (VSU)

- Samples $V_{g,oc}$
- Periodically connected to the generator
 - Fast sampling
 - Low energy loss
 - Interface circuit is decoupled during the sampling
- Sampling capacitor and voltage divider to set k_{ratio}
- Provides reference voltage:
$$V_{MPP} = k_{ratio} V_{g,oc}$$



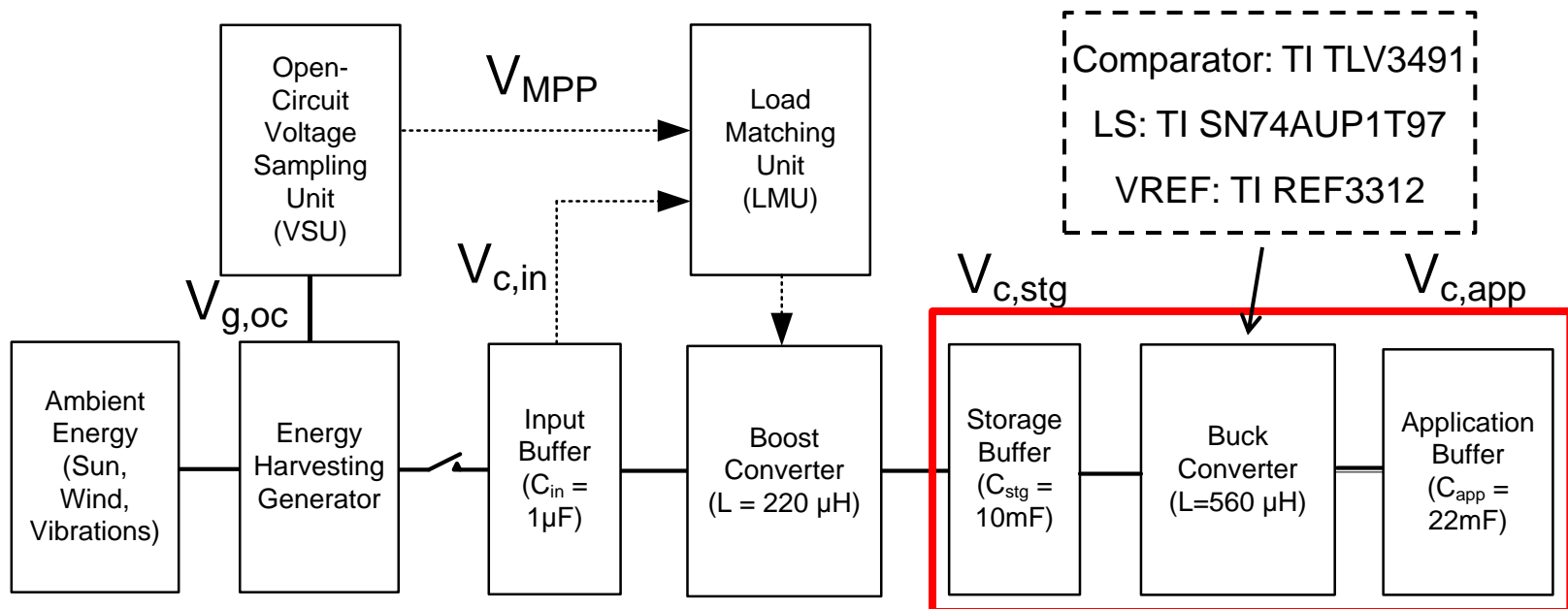
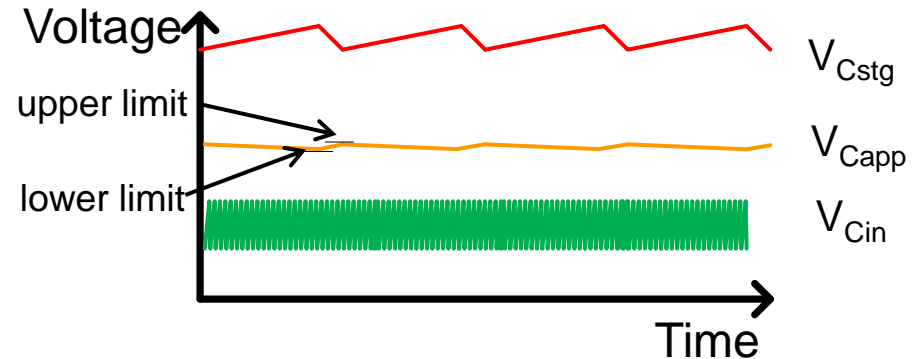
Boost converter

- Controlled by load matching unit (LMU)
 - Compares V_{MPP} with V_{cin}
 - Single-step approach
- Input buffer C_{in} is charged/discharged between upper/lower limit
- Storage buffer C_{stg} is charged



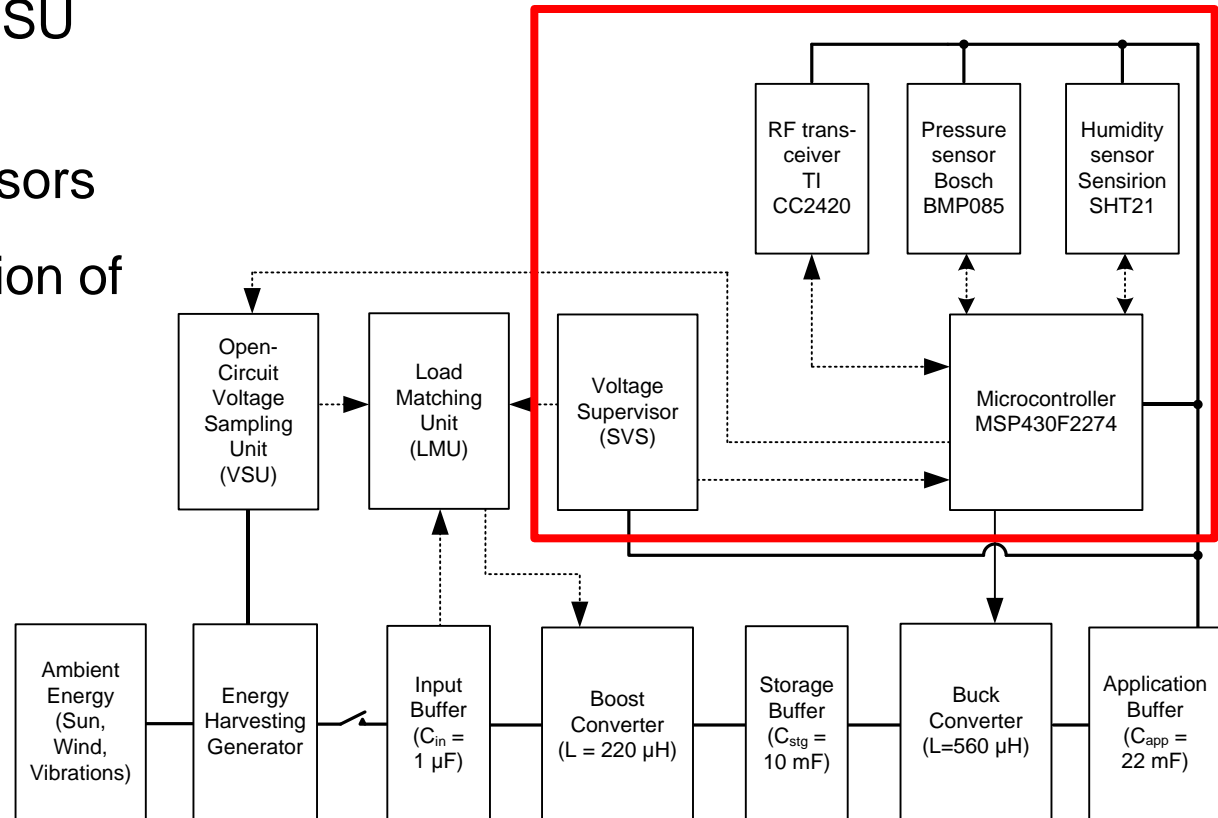
Buck Converter

- V_{Cstg} is not regulated
- V_{Cstg} converted to regulated V_{Capp}
- Schmitt-Trigger is used to realize PFM control



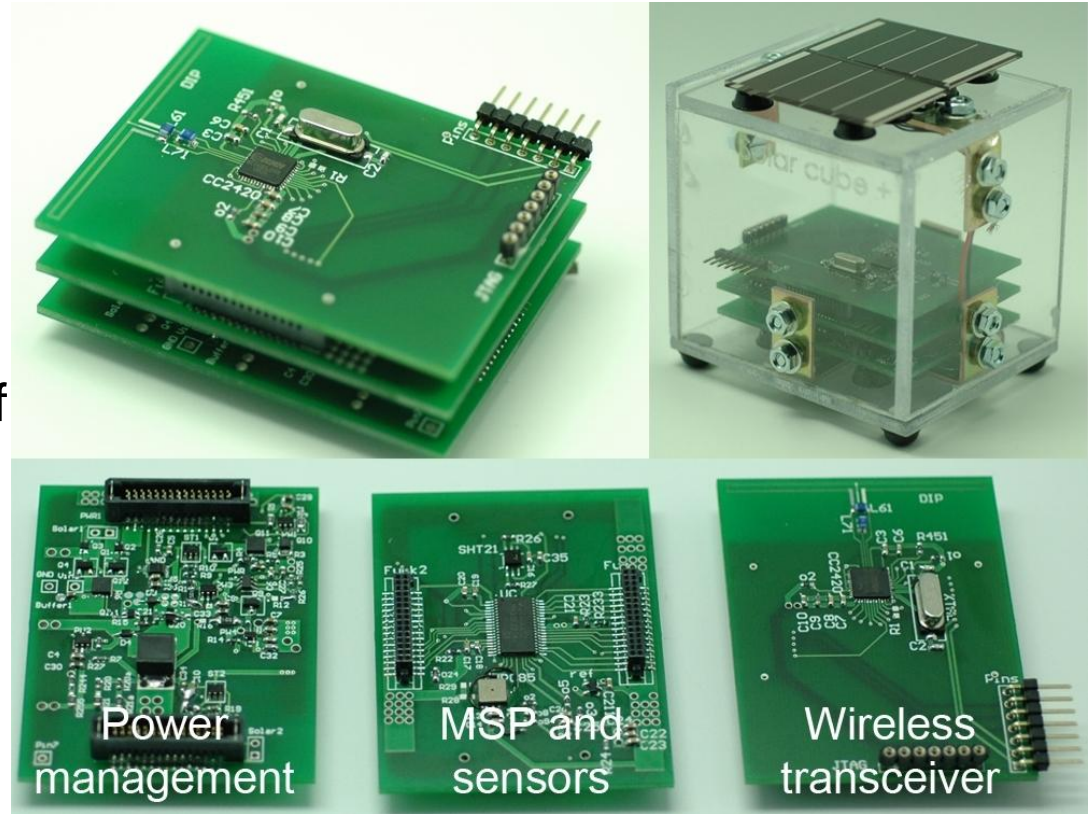
Complete System

- MSP430 controls VSU and buck converter
- I²C interface to sensors
- Wireless transmission of sensor data
- Voltage supervisor controls startup



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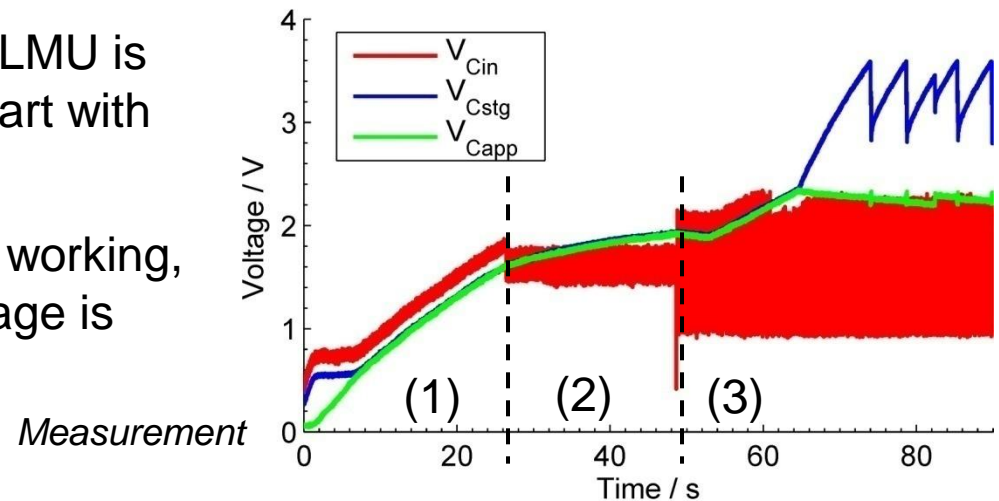
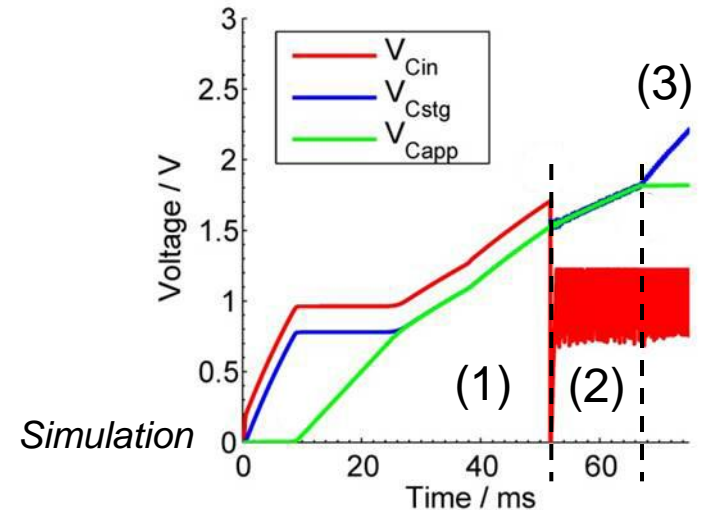


Spice Simulation

- Verify functionality and dimensioning
- Using TI Spice models

System Startup

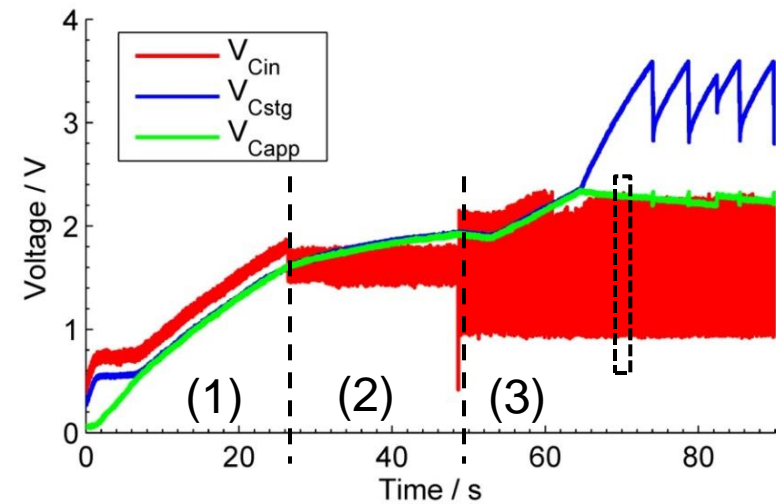
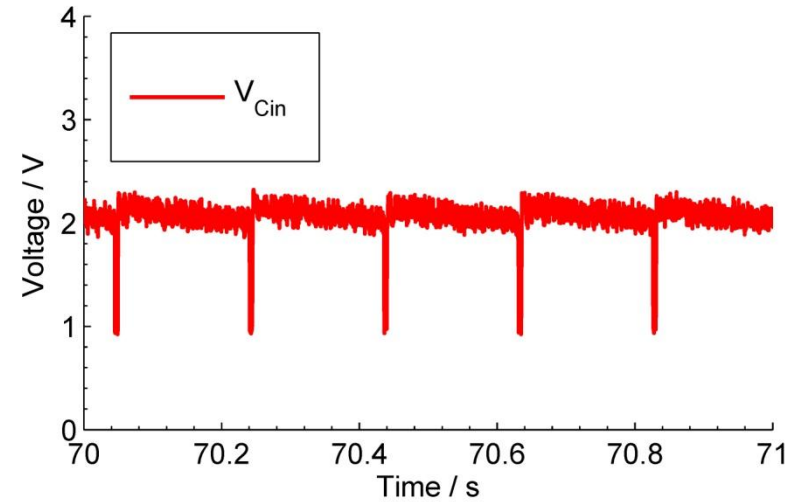
- *Phase 1:* All active devices turned off
- *Phase 2:* Boost converter and LMU is working to enable system to start with low $V_{g,oc}$
- *Phase 3:* MSP430 and VSU is working, $V_{g,oc}$ is sampled and input voltage is adapted



Measurement results

Load matching

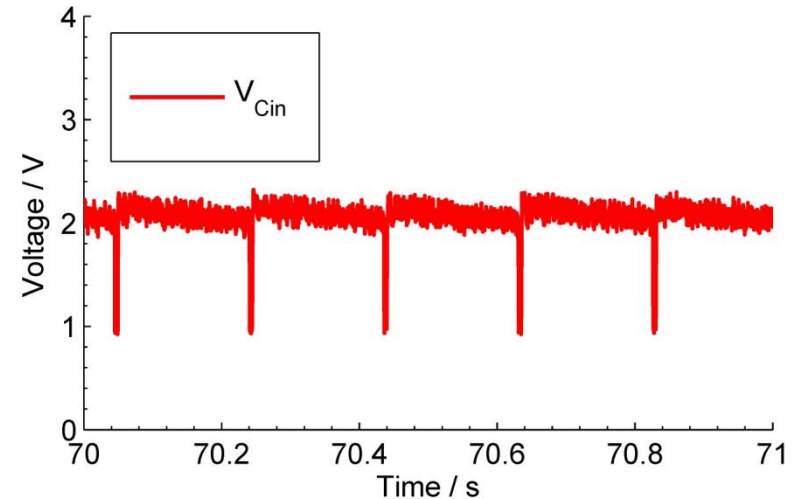
- $V_{g,oc}$ is sampled every 200 ms



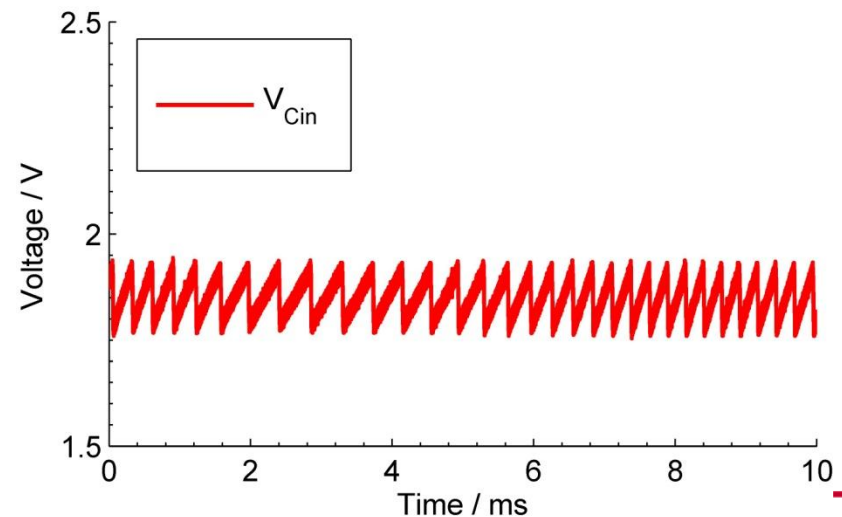
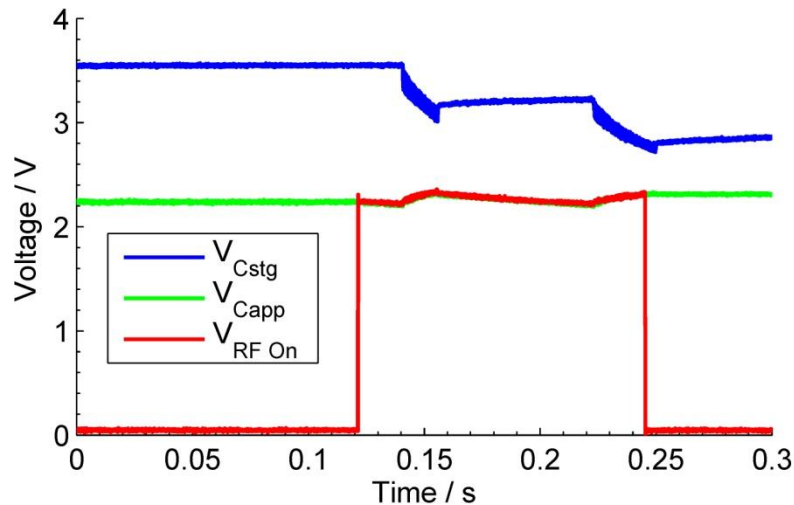
Measurement results

Load matching

- $V_{g,oc}$ is sampled every 200 ms
- V_{Cin} is adapted to $0.7 V_{g,oc}$
- $V_{g,oc} = 2.65 \text{ V} \rightarrow V_{Cin} = 1.85 \text{ V}$



Supply RF transceiver



WSN for weather monitoring powered by energy harvesting generators

- Efficient self-startup
- Maximum power point tracking
- Reliable power management for sensors and RF transceiver

Outlook

- Measurements with different generator types
- Integrating complete RF protocol
- Long-term field test
- Integrated circuit (ASIC)

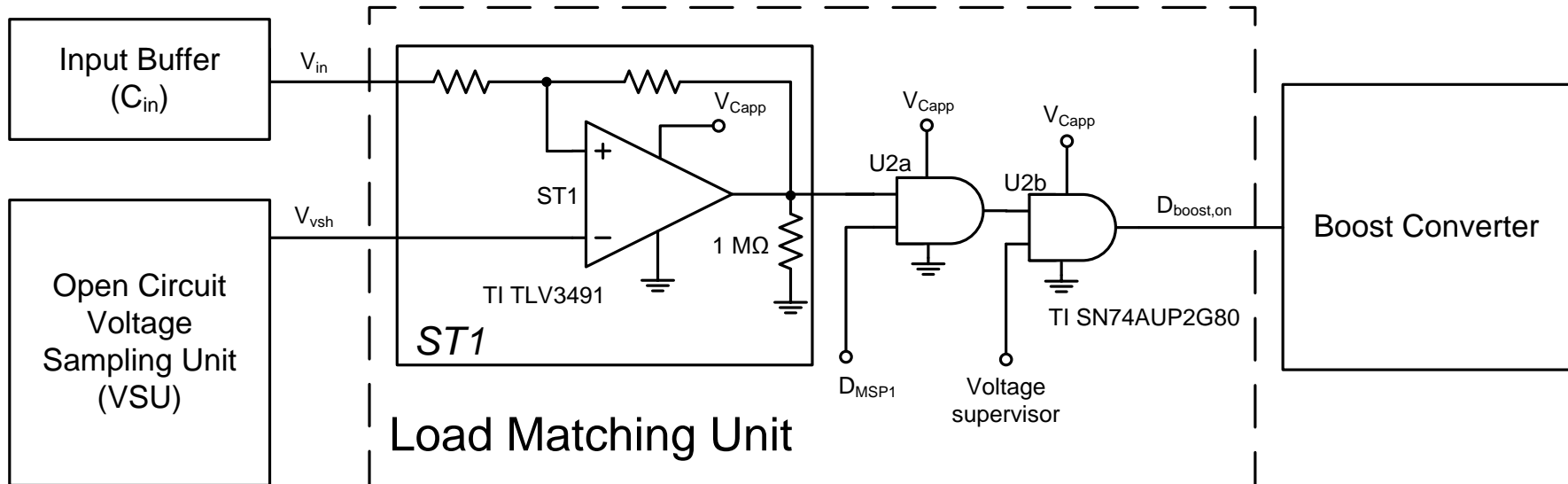
Acknowledgment



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Thank you for your attention!



Weather in a Box - Circuit

