1cm^3 Fuel-Cell, Li-Ion Powered, Wireless Sensor Instrumentation Chip

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Outline

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  - Antenna
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- System Integration
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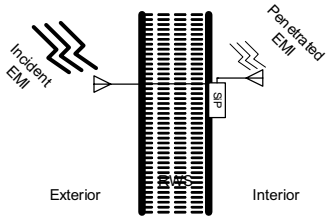
Motivation & Requirements

Motivation:

- EMI[1] Shielding of the SICPS RWS[2]
- The shielding is degraded once exposed to the field.
- "Back to Depot" Test → Not efficient
- Need to verify "How & Why" performance degradation happens

SICPS RWS mounted to an Army HMMWV[3].

System Implemented on the RWS



Requirements:

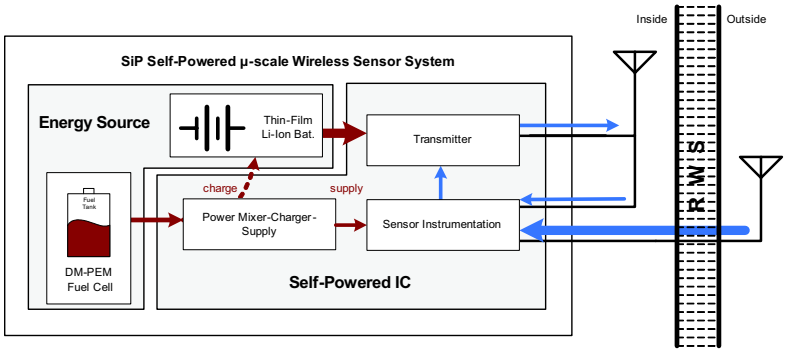
- *In-Situ* Test
- Non-Intrusive: Self-Powered, Long Lasting, and Compact

[1]Electro Magnetic Interference
[2]High Mobility Multi-Purpose Wheeled Vehicle
[2]Standardized Integrated Command Post system Rigid Wall Shelter

Overall System Description

Overall System: System in Package (SiP)

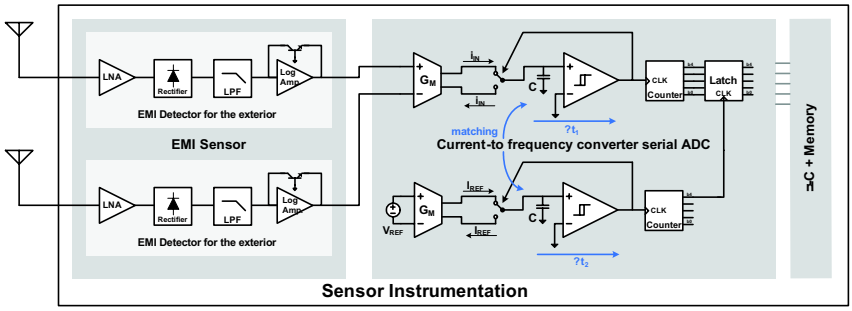
- Self-Powered IC:
  - Sensor instrumentation
  - Wireless telemetry
  - Power mixer-charger supply
- Hybrid energy source:
  - DM-PEM[1] Fuel Cell
  - Li-Ion Battery
- Antennae



[1]Direct-methanol proton-exchange-membrane

Sensor Instrumentation

- EMI Sensor: RMS Detection and Preprocessing
- Analog-Digital Converter (ADC)
- µ-C + Memory



$$T_{IN} = 2\frac{V_H C}{I_{IN}} \qquad NT_{IN} = 2^n T_{REF} \Rightarrow N = 2^n \frac{2\frac{V_H C}{i_{IN}} + \Delta t_1}{2\frac{V_H C}{I_{REF}} + \Delta t_2} \approx 2^n \frac{i_{IN}}{I_{REF}}$$

Wireless Telemetry – Transceiver IC

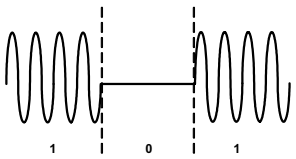
Design Approach:

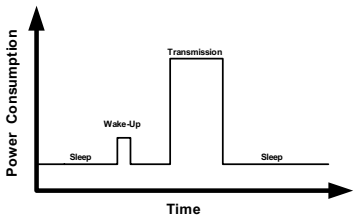
- Trade-Off in design parameters
- Duty cycled operation

$$P_{Bat} = \frac{\left(\frac{4\pi df}{c}\right)^2 kT(BW)_R (SNR)_R}{\eta_{PA}\eta_{Ant}^2\left(1-|\Gamma|^2\right)}$$

Modulation: OOK

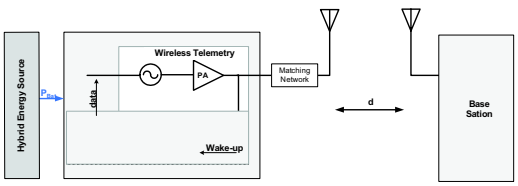
- Simple signal processing.
- Saves energy ≈50% of transmitting period.





Architecture

- Does not require a conventional mixer.
- The receiver can be absorbed by the sensor instrumentation.



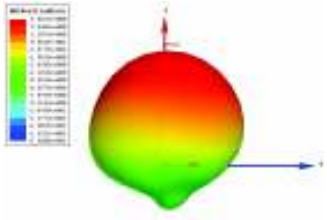
Wireless Telemetry – Antenna

Major Challenge:

- The antenna should be mounted on conducting surfaces.
- The dimension should be minimized.
- High sensitivity for weak signals.

Novel Compact Antenna*:

- Comprised of a series of metal plates arranged vertically.
- Works efficiently when mounted on a metal wall



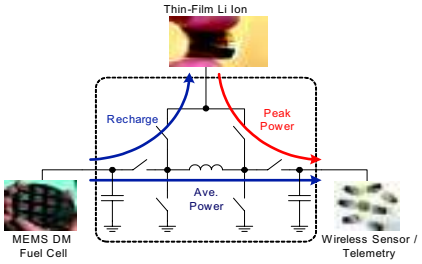
Radiation pattern with antenna mounted on metal wall (920MHz).

*Patent Pending

Energy & Power – Power Mixer-charger-Supply IC

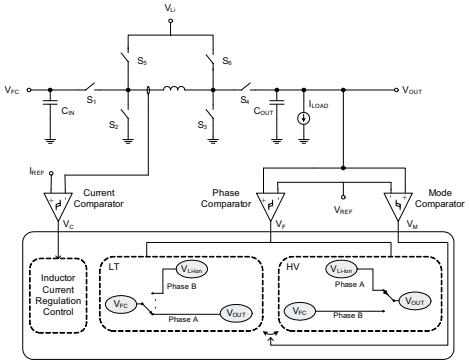
Design Approach:

- Multiple input energy source.
- Multiple output (supply loads, recharge Li-Ion)
- High efficiency with limited space



Modes of operation:

- LT Mode[1] : Boost (FC[2] → Load)
- LT Mode : Boost (FC → Li Ion)
- HV Mode[3] : Buck (Li Ion → Load)
- HV Mode : Boost (FC → Load)

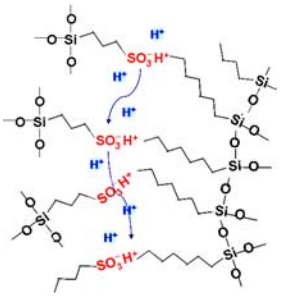


[1]Light Mode
[2]Fuel Cell
[3]Heavy Mode

Energy & Power – Fuel Cell (DM-PEM)

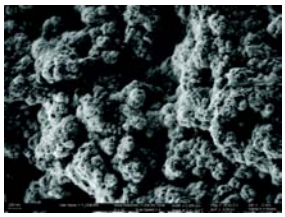
Glass-Based Proton Exchange Membranes

- High Conductivity : 10^{-3} S/cm
- Low Methanol Permeability : 10^{-10} mol-cm/cm2-day-Pa
- Binary Silicate Glass Electrolyte
  - Oxidized 3-mercaptopropyl methoxysilane (3MPS)
  - 3-Glycidoxypropyl trimethoxysilane (GPTMS)

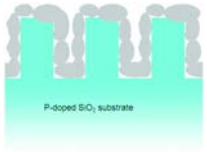


SiO_2-Pt/C Composite Electrodes:

- Good Adhesion
- Chemical Stability
- High Porosity
- Large electrochemically active area



Proton conductivity pathway for 3MPS-GPTMS films.



Energy & Power – Li-Ion

Critical Parameters:

- Self Discharge
- Discharge Current
- Charge/Discharge Efficiency

Button Type Li-ion Cells:

- Many Options
- Acceptable lower cost alternative ($2/cell), though performance is lower than the thin film.

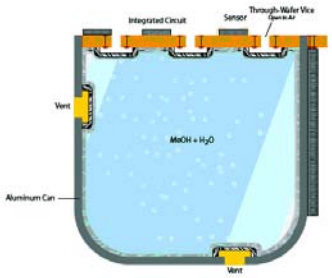
Front-Edge Thin-Film Li-ion Cells:

- Reasonable Performance:
- However…

  New Technology

  Expensive

System Integration



Conceptual Illustration

- Common substrate
- Sensor and integrated circuit are located on the exterior of the device.
- Oxygen and CO_2 vents
- Wicking material: Orientation Independent

Conclusion

- Micro-scale System Integration
- Hybrid Energy Source
- Low power Integrated Circuit

→ Non-Intrusive T&E Solution for the better design cycle