HIGH EFFICIENCY DESIGNS FOR ENERGY CONVERSION, ENERGY STORAGE AND POWER MANAGEMENT

Applied Power Electronics Conference and Exposition 2013

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Long Beach, March 19, 2013
HIGH EFFICIENCY DESIGNS FOR ENERGY CONVERSION, ENERGY STORAGE AND POWER MANAGEMENT

1. Introduction
2. Circuit design
3. Software and regulation loop
4. Summary
High efficiency designs for energy conversion, energy storage and power management

Introduction

Energy Harvester
- Photovoltaic
- Electro-Mechanical
- Thermo-Electric
- Radio Frequency

Energy Management
- Energy Conversion
- Manage Energy Storage
- Powers Application

Energy Storage
- Thin Film Battery
- Capacitor
- Traditional Battery
- Etc.

Application
- Wireless Sensor
- Powered Card
- Implantable Medical
- Many, many more…

Ambient Energy Harvester

Power Management
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**Introduction**

![Energy Harvesting Sweet Spot Diagram](image)

- **Peak Power**
  - 100W: Power Tools
  - 10W: Laptop Computer
  - 1W: GPS
  - 10mW: Bluetooth Transceiver
  - 1mW: Hearing Aid/Wireless Sensor
  - 100µW: Sensor/Remotes
  - 10µW: RFID Tag
  - 1µW: Watch/Calculator
  - 10nW: µP Standby

**Texas Instruments MSP430 RF2500**

*Wireless Sensor Demo (~60mW Peak)*
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**Introduction**

- **High efficiency designs**
  - Minimize **losses** (on-resistance, coil resistance, ESR, leakage, ...)
  - Minimize **standby power**
  - Maximize **harvested power**
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Introduction

- What is the Maximum Mower Point?
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Introduction

- What is Maximum Power Point Tracking?
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Introduction

- MPPT algorithms
  - Incremental conductance ($\Delta P/\Delta V$)
  - P&O
  - Fractional OCV

- Fractional OCV
  - MPP voltage has a **fixed ratio** to open circuit voltage (0.7 – 0.8)
  - But: Ratio **not constant** and **different** for every generator

- P&O
  - **Generic** algorithm
  - **Oscillates** around MPP

Hill climbing algorithms
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Circuit design

- MPPT works for all converter types
- This case study: Boost converter for low voltage sources
- Input
  - Thermogenerator
  - Solar cell
  - Fuel cell
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**Circuit design**

- **Coupled inductor** DC/DC converter
- **20mV** startup voltage
- **Minimal** thermal gradient or illumination
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Circuit design

- **DC/DC converter** controlled by microcontroller
- Start up circuit starts at 70mV
- Digitally controlled maximum power point tracker
- Integrate your own application
- Algorithm is **portable**
- Regulation of **input** or **output** power
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Circuit design

- **Startup** circuitry

- **Synchronous** rectification

- **µC shuts down** self-oscillating circuit when in regulation
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Circuit design

Oscillator startup

Startup of µC and MPPT
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Software and regulation loop

- **MPPT**
  - Simple and *sufficiently precise* tracking
  - Relatively *slow*
  - Requires *more energy* than FOCV

- **FOCV**
  - *Simplifies* measurement
  - *Energy loss* due to sampling of open circuit voltage
  - Choosing the *sampling period*
  - Voltage constant *varies* around 0.7 and 0.8

- µC enables *dynamically* choosing best algorithm
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**Software and regulation loop**

- **Clock source** dependent on **duty cycle**
- Use **hardware** modules
- **PWM** vs. **PFM**
- Complete **shutdown**
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Energy storage

- Higher Drive Current
- Higher Energy Density
- Lowest Leakage
- 50X SuperCap
- 4,000X < SuperCap
- Rechargeable / Long Life
- Superior Lifetime Energy – never replace a battery

SSB = Best of Both

Super Cap

Thin Film Battery - TFB

Battery

Higher Drive Current, Higher Leakage

Higher Energy Density & Lower Leakage
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Summary

- Most power available if load matches source
- **Power management** ensures maximum power output
- **Energy storage** always required
- Transducers can be shrunken due to more efficient power management
- System costs **significantly lower** when transducers are smaller
Thank you for listening!

Any questions.....?

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