ENERGY PROCESSORS FOR EH DESIGNS
High Efficiency Energy Harvesting-based Power

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Energy Harvesting Overview

- Energy can be harvested from almost any environment:
  - Light, vibration, flow, motion, pressure, magnetic fields, RF, etc.

- Energy Harvesting applications include:
  - Permanently powered wireless sensors,
  - Hybrid & Active RFID, data logging and access control

- Self-Powered Systems need reliable energy storage:
  - Must have energy storage because EH Transducer energy source is not always available
  - Self-Powered devices enable inaccessible remote placement and lower installation costs
  - High battery cycle life enables extended operation – no more service calls

- Ideal storage solution is a highly-efficient, eco-friendly, energy storage device that lasts the life of the product
Energy Processing for Wireless Sensors

Transducer
- Photovoltaic
- Thermoelectric
- Piezoelectric
- Inductive
- RF

Processor and Radio Link
- Microcontroller
- RF Wireless
- Optimized Protocol
- MCU + Radio

Energy Processing
- Power Conversion
- Energy Storage
- Power Management
- EnerChip™ CC
  or EnerChip EP

Sensor
(e.g., temperature, pressure, occupancy)
## Energy Harvesting Transducers

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Challenge</th>
<th>Typical Electrical Impedance</th>
<th>Typical Voltage</th>
<th>Typical Power Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light</strong></td>
<td>Conform to small surface area; wide input voltage range</td>
<td>Varies with light input</td>
<td>DC: 0.5V to 5V [Depends on number of cells in array]</td>
<td>10μW-15mW (Outdoors: 0.15mW-15mW) (Indoors: &lt;500μW)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low kΩ to 10s of kΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>AC:</strong> 10s of volts</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td><strong>DC:</strong> 0.5V to 5V</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Wide range</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vibrational</strong></td>
<td>Variability of vibrational frequency</td>
<td>Constant impedance</td>
<td>AC: 10s of volts</td>
<td>1μW-20mW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10s of kΩ to 100kΩ</td>
<td></td>
<td></td>
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<tr>
<td><strong>Thermal</strong></td>
<td>Small thermal gradients; efficient heat sinking</td>
<td>Constant impedance</td>
<td>DC: 10s of mV to 10V</td>
<td>0.5mW-10mW (20°C gradient)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1Ω to 100s of Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RF &amp; Inductive</strong></td>
<td>Coupling &amp; rectification</td>
<td>Constant impedance</td>
<td>AC: Varies with distance and power</td>
<td>Wide range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low kΩs</td>
<td>0.5V to 5V</td>
<td></td>
</tr>
</tbody>
</table>
EH Transducer – Variable Impedance

Example: Photovoltaic Cell

Current-Voltage Curve

$V_{OC}$: Open-circuit voltage
$I_{SC}$: Short-circuit current
$V_{OP}$: Optimum operating voltage
$I_{OP}$: Optimum operating current
$P_{MAX}$: Maximum operating power
EH Transducer – Constant Impedance

Examples: Thermoelectric Generators, Piezoelectric Materials, Electromagnetic

Current-Voltage Curve

- Voc: Open-circuit voltage
- Isc: Short-circuit current
- Vop: Optimum operating voltage
- Iop: Optimum operating current
- Pmax: Maximum operating power
Matching Impedance is Critical

Reach $P_{\text{MAX}}$ when $R_T = R_L$

Impedance mismatch means significant lost power

EP stage matches transducer impedance for high efficiency power conversion and optimal power management to load
EnerChip CC Energy Harvester and Battery

- Solid State Battery with Integrated Charge Control
  - Reflow tolerant, surface mount technology and assembly process
  - 3.3V compatibility, power-fail detect and automatic back-up
  - Drop-in solution, small footprint and minimal external component count
  - Thousands of recharge cycles, low self-discharge, flat $V_{OUT}$
  - Single-Chip Energy Harvesting Solution

![Diagram of EnerChip CC block diagram]

EnerChip CC 20-pin DFN Package
CBC915 Energy Processor - Universal Energy Harvesting Device:

- Supports Multi-Modes of EH: Electromagnetic, Photo Voltaic, Thermo-Electric & Piezoelectric
- Enables system to be “Energy Aware” provides harvester status to system
- Achieves high-efficiency conversion – 70%-90%
Cymbet CBC915 Energy Processor

» High-Efficiency, Universal Energy Harvesting Device

» Supports Maximum Power Point Tracking (MPPT):
  » Dynamically matches output impedance of EH Source device to load

• Provides Energy Awareness to host:
  – Conveys harvester status to host system via I²C interface
  – Monitors & reports whether EH system is running from harvested or stored energy
  – Input power measurement and status reporting
  – Enables “Coulomb counting” by host system
EVAL-09 Universal Energy Harvesting Kit

Thermoelectric Generator (TEG) or RF Induction or Photovoltaic Cell or Electromagnetic or Piezoelectric Generator

Various Transducer Interface Electronics

Energy Processor CBC915 EnerChip Energy Storage

CC2500 Radio MSP430 with Temperature Sensor

Available at www.avnetexpress.avnet.com keyword Eval-09