The Reality about Energy Harvesting

Speaker:
Lorandt Fölkel M.Eng
Field Application Engineer & Business Development Manager
lorandt.foelkel@we-online.de
Energy Harvesting = Energy for free?

- Energy harvesting has recently become a topic of much discussion with its potential to self-power autonomous devices for wearables, medical devices and for IoT (the Internet of Things)

- Examples of real life use cases demonstrating that Energy Harvesting has already progressed from the laboratory to commercial applications

- We need devices that are:
  - Wireless (avoid power and communications cables)
  - Totally autonomous
  - Highly reliable with backup battery lifetime up to 15~20 years
Energy Harvesting = Energy for free?

- We have to consider that the laws of physics are still valid.
- But wasted energy are everywhere
- We just need to:
  - find them
  - convert them (harvest)
  - transform them into electrical energy
  - to store it for the time when not used
  - recall it when needed

Source: Tyndall National Institute

Source: Linear Technology
Basic consideration for Energy Harvesting

First step:
- calculate the total energy demand for your system
- watch out for your peak energy demand

\[ E_{\text{total}} = \int V \cdot I \cdot dt \]
\[ E_{\text{total}} = V_s \cdot (I_c \cdot t_{\text{on}} + \sum_{i} I_{i,p} \cdot t_{i,p}) \]
\[ P_{\text{AVG}} = \frac{E}{\Delta t} = \frac{E_{\text{total}} \cdot DC_{\text{AVG}}}{\Delta t} \]

Vs: Supply Voltage
Ic: continuous current
Ip: pulsed current
tp,i: pulse duration
ton: system on time
DC: sequence Duty Cycle
Basic consideration for Energy Harvesting

Second step:
- consider the source capabilities
- check multiple source availability (solar, thermo, motion, chemical… etc.)
- watch out for the stability over the time (use a data logger)

Third step:
- choose the right harvester (transducer)
- build the right voltage converter (source impedance matching)
- consider an energy storage for back up
  - capacity bank
  - supercaps
  - ultracaps (Supercap/Lithium-Ion)
  - Li-Pol rechargeable
Where to find „free energy“

- **Typical energy harvester output power**
  - RF: 0.1µW/cm²
  - Vibration: 1mW/cm²
  - Thermal: 10mW/cm²
  - Photovoltaic: 100mW/cm²

- **Typical energy harvester voltages**
  - RF: 0.01mV
  - Vibration: 0.1 ~ 0.4 V
  - Thermal: 0.02 ~ 1.0 V
  - Photovoltaic: 0.5 ~ 0.7 V typ./cell

Energy Harvesters becomes more capable

Electronic devices becomes less power hungry
Energy Harvesting Kit “Gleanergy” with Battery lifetime extender

- Environment energy captured and converted into electricity for small autonomous devices making them self-sufficient.

- Thermo Electric Generator (heat)
- Piezo Electric (vibration/strain)
- Photovoltaic (light)
- Induction (motion)
- Battery (Lithium)
Energy Harvesting Kit – Power Demoboard DC2344A

Featuring:

**LTC3106** - Solar Harvesting
  - Battery Lithium
  - Li-Ion Rechargeable

**LTC3107** - TEG Harvesting
  - Battery Lithium

**LTC3330** - Piezo Harvesting
  - Solar Harvesting
  - Battery Lithium
  - Supercap Balancer

**LTC3331** - Piezo Harvesting
  - Solar Harvesting
  - Li-Ion Rechargeable
  - Supercap Balancer
Energy Harvesting Kit – µPC/RF Module Demoboard DC2321A

Featuring:

- TP5901 Dust assembly including ARM Cortex-M3 processor embedded with SmartMesh IP networking software (RF Module)
- E-Ink display for user feedback
- Two coulomb counters for battery data measurement
- Shield board headers and programming headers for development
- Optionally, use DC2510A shield board to connect extra components to the ADCs, GPIOs, and serial ports of the mote
LTC3330 Energy Harvesting Solar

Extended Battery Life with Energy Harvesting

OUTPUT VOLTAGE
50mV/DIV
AC-COUPLED

EH_ON
2V/DIV
0V

IBAT
100mA/DIV
0A

BAT = 3.6V
V_OUT = 1.8V
I_LOAD = 50mA

ACTIVE ENERGY HARVESTER
REDUCES BATTERY CURRENT TO ZERO

Source: Linear Technology Corporation
Typical Inductive Transducers

Average Power: 3W
Downhill Peak Power: 4W
Output Voltage: 6V @ 12Ω Load
Felt Efficiency: <10%
Typical Inductive Transducers

**EM-1D-09**

**Generator Data**

- **Dimensions (L x W x H):** 60x24x22 mm
- **Volume:** 32 cm³
- **Mass:** 42 g
- **Inner Resistant:** 430 Ω
- **Resonant Frequency:** 14.2 Hz
- **Power Output (0.5g continuous):** 3.6 mW
- **Power Density:** 0.11 mW/cm³
- **Specific Power:** 85.7 mW/kg
- **Frequency Range of 50% Power:** 12.4 - 16 Hz

Source: [www.pmdm.de](http://www.pmdm.de)

**EM-1D-10**

**Generator Data**

- **Dimensions (L x W x H):** 60x24x22 mm
- **Volume:** 32 cm³
- **Mass:** 46.5 g
- **Inner Resistant:** 430 Ω
- **Resonant Frequency:** 47 Hz
- **Power Output (0.5g continuous):** 30 mW
- **Power Density:** 0.96 mW/cm³
- **Specific Power:** 680 mW/kg
- **Frequency Range of 50% Power:** 42 - 48 Hz
- **Energy Output (1x Push Button):** 1.5 mJ

Source: [www.pmdm.de](http://www.pmdm.de)

**EnOcean**

**Per Click 30µC**

6.38V @ 4.7µF

Source: [www.enocean-alliance.org](http://www.enocean-alliance.org)
Other Development Kits: EnOcean

Product name: EDK 350
Frequency: 868 MHz
Ordering Code: S3004-X350
Description:
The EnOcean Developer Kit EDK 350 gives the designer a fast and full overview of the powerful Dolphin platform. OEMs can develop their own energy-autonomous applications for building automation and other purposes, and assure themselves a competitive edge. The kit covers the entire product range, from energy harvesting and wireless modules to ready-made product solutions.
Other Development Kits: ZF Cherry

- CHERRY’s Energy Harvesting Evaluation Kit

  - 1x Energy Harvesting Generator P/N: AFIK-1002
  - 1x Wireless Snap Switch
  - 1x Wireless Rocker Switch
  - 1x Receiver
  - 1x USB Cable
  - 1x Antenna bushing

Source: ZF Cherry
Typical Inductive Transducers

Ferro Solutions

Size: DxH = 6cm x 6.75cm

Perpetuum

Size: DxH = 6.85cm x 6.85cm

POWER OUTPUT @ 60 Hz (Rectified DC Power)

<table>
<thead>
<tr>
<th>Acceleration</th>
<th>Power Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 milli-g</td>
<td>0.3 mW</td>
</tr>
<tr>
<td>50 milli-g</td>
<td>1.3 mW</td>
</tr>
<tr>
<td>100 milli-g</td>
<td>5.2 mW</td>
</tr>
</tbody>
</table>

BANDWIDTH (Δf = 3 Hz)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak frequency</td>
<td>60 Hz</td>
</tr>
<tr>
<td>50% power delivered</td>
<td>+/-1.5 Hz</td>
</tr>
<tr>
<td>Q @ 100 milli-g</td>
<td>18</td>
</tr>
</tbody>
</table>

Operates from prevalent 100Hz/ and 120Hz vibration bands found on electrical machines
1mW peak power at 0.025G with >2Hz half-power bandwidth
Typically >0.3mW output on 95% of machines
Examples for Piezo Transducers

**PI Ceramic**

The “Piezo Ruler” Size: 150 x 35 x 2.5 mm³

Made from DuraAct Transducers

Source: Linear Technology Corporation
EH-Kit: LTC3107 - TEG

LTC3107
TEG ENERGY HARVESTER WITH PRI BATTERY

VT0RE_LTC3107
VOUT_LTC3107
VBAT_LTC3107

LTC3107 TEG ENERGY HARVESTER WITH PRI BATTERY
What is behind the WE-EHPI transformer?

- winding style
Würth Elektronik eiSos components

WE-EHPI
Energy Harvesting Power Inductor

NEW!

Characteristics
- Low profile: 4 mm
- Small footprint 6 x 6 mm
- Very low secondary R_{sec}
- Different turn ratios available
- Separated welding/soldering pad for a high reliable component
- Optimized, high reliable winding style

Applications
- Wireless fire, alarm, gas and metering remote sensors driven by environmental energies based on energy harvesting voltage transformers like LTC3100/LTC3102
- Sensors with predictive battery replacements in applications which are difficult to access
- Energy self-sufficient supply using subsequent installed sensors for energy harvesting

Optimized for LTC3100/LTC3102
and more

Electrical properties

<table>
<thead>
<tr>
<th>Order Code</th>
<th>I_{1} ±20% (µH)</th>
<th>I_{2} ±20% (µH)</th>
<th>n</th>
<th>I_{st} (A)</th>
<th>I_{max} (A)</th>
<th>R_{DC1} (Ω)</th>
<th>R_{DC2} (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>744 886 400 70</td>
<td>7.5</td>
<td>75000</td>
<td>1:100</td>
<td>1.9</td>
<td>1.3</td>
<td>0.085</td>
<td>205</td>
</tr>
<tr>
<td>744 885 401 20</td>
<td>13.0</td>
<td>33000</td>
<td>1:50</td>
<td>1.7</td>
<td>1.0</td>
<td>0.090</td>
<td>135</td>
</tr>
<tr>
<td>744 885 402 50</td>
<td>25.0</td>
<td>10000</td>
<td>1:20</td>
<td>1.5</td>
<td>0.7</td>
<td>0.200</td>
<td>42</td>
</tr>
</tbody>
</table>

Transformer designed on EP7 cores are available on request – Order code: 760370096, 760370097, 760370098

During design stage of this series, we used S11100032, S11100033 & S11100034.
With our standard series we have replaced these order codes.
Where is it useful?

- Where line power is unavailable or costly
- Where batteries are costly or difficult to replace
- Where energy is needed only when ambient energy is present

Source: LTC - Sam Nork – Energy Harvesting Presentation
Industrial Application

- TSP300-W with Energy Harvester – the first autonomous Wireless temperature sensor.

- Enables the easy addition of temperature measuring points throughout operations.

- Shorten installation times by eliminating complex wired infrastructure and lower overall implementation costs of process measurement with ABB’s wireless devices.
Energy Harvested Application

- Customer feedback for EH projects:
  - Total amount of harvested energy: min 50µW up to 200mW
  - The highest harvested energy was 5W using Solar cells

Devices are:
- Aftermarket solutions for Portable Navigators & Mobile Phones (Solar)
- GSM/GPS module (5W Solar)
- Window status monitoring for Hotels and Homes (Solar)
- Chainsaw electronic at engine (TEG)
- High Voltage cable status (Magnetic field)
- Water purification plant PH measuring (chemical)
- Temperature measurement for engines (TEG)
- Object tracking at airport (Piezo & RF-ID)

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Energy Harvesting Healthcare Application

- Pacemaker

Source: Prof John A. Rogers University of Illinois
Another application for Harvesting?

Source: http://www.joaolammoglia.com/concept/1/aire-concept/
Energy Harvesting Evaluation Boards:
“Gleanergy” p/n: IC-744 888
“To Go” Kit   p/n: IC-744 885

More information at:
Booth #811

or visit:
www.we-online.com/gleanergy

and at our local distributor:
www.digikey.com

In collaboration with: