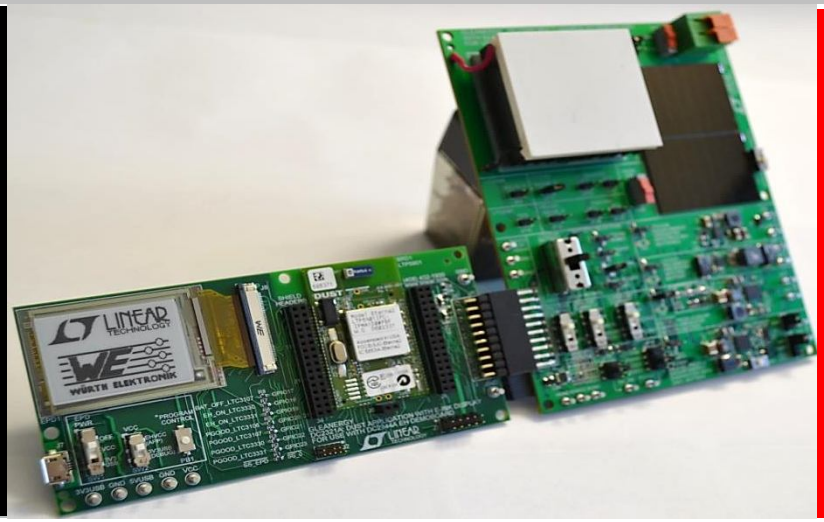
The Reality about Energy Harvesting



Speaker:

Lorandt Fölkel M.Eng
Field Application Engineer &
Business Development Manager
lorandt.foelkel@we-online.de

Power Sources Manufacturers Association
The Multinational Power Electronics Association

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**

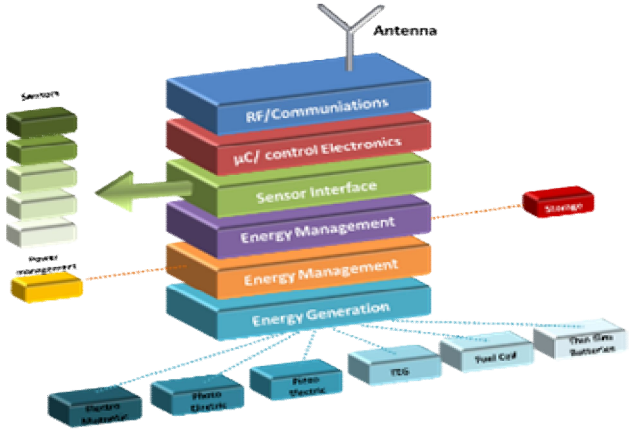
Energy Harvesting = Energy for free?

- 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

Mechanical Age

Source: Linear Technology

Digital Age



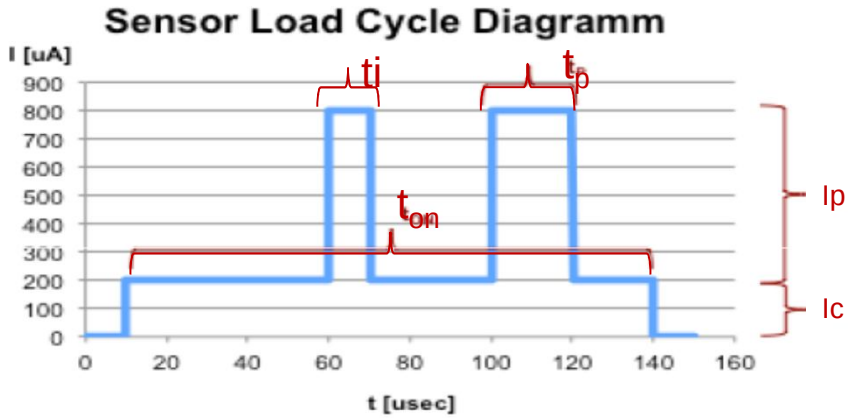
Source: Tyndall National Institute

Wireless IoT devices

Basic consideration for Energy Harvesting

First step:

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



$$E_{total} = \int V * I * dt$$

$$E_{total} = V_S * (I_c * t_{on} + \sum_i I_{i,p} * t_{i,p})$$

$$P_{AVG} = \frac{E}{\Delta t} = \frac{E_{total} * DC_{AVG}}{\Delta t}$$

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)

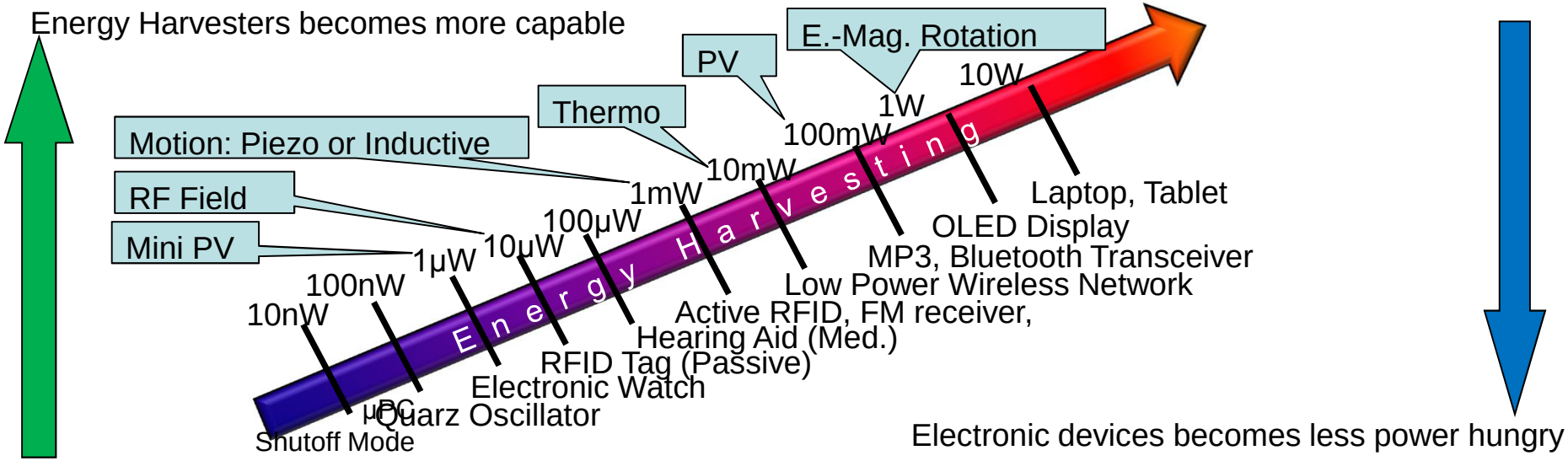
Third step:

- 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“

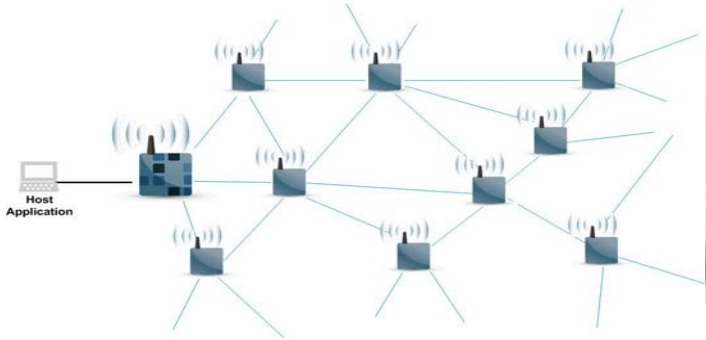
- **Typical energy harvester output power**
  - RF: 0.1µW/cm²
  - Vibration: 1mW/cm²
  - Thermal: 10mW/cm²
  - Photovoltaic: 100mW/cm²

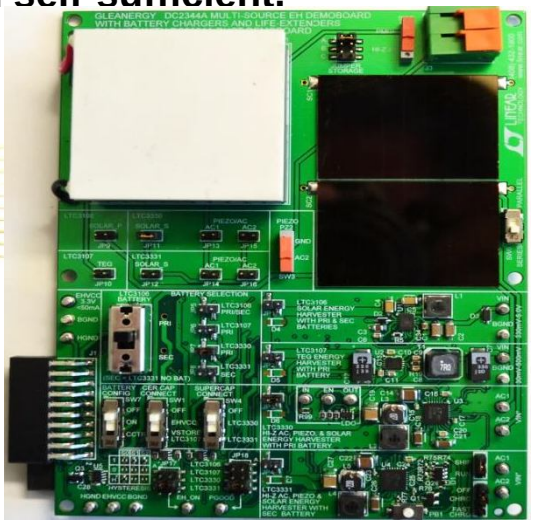
- **Typical energy harvester voltages**
  - RF: 0.01mV
  - Vibration: 0.1 ~ 0.4 V
  - Thermal: 0.02 ~ 1.0 V
  - Photovoltaic: 0.5 ~ 0.7 V typ./cell



Energy 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)

Regulated Voltage
Power Good
EH_ON or Batt. Information

Energy Harvesting Kit – Power Demoboard DC2344A

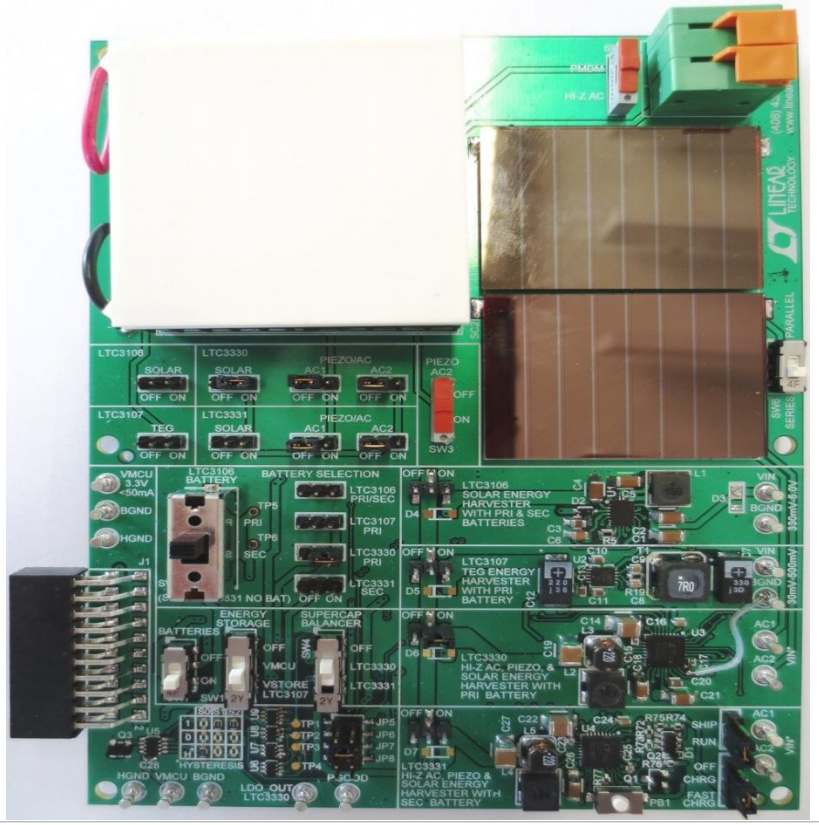
Featuring:

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

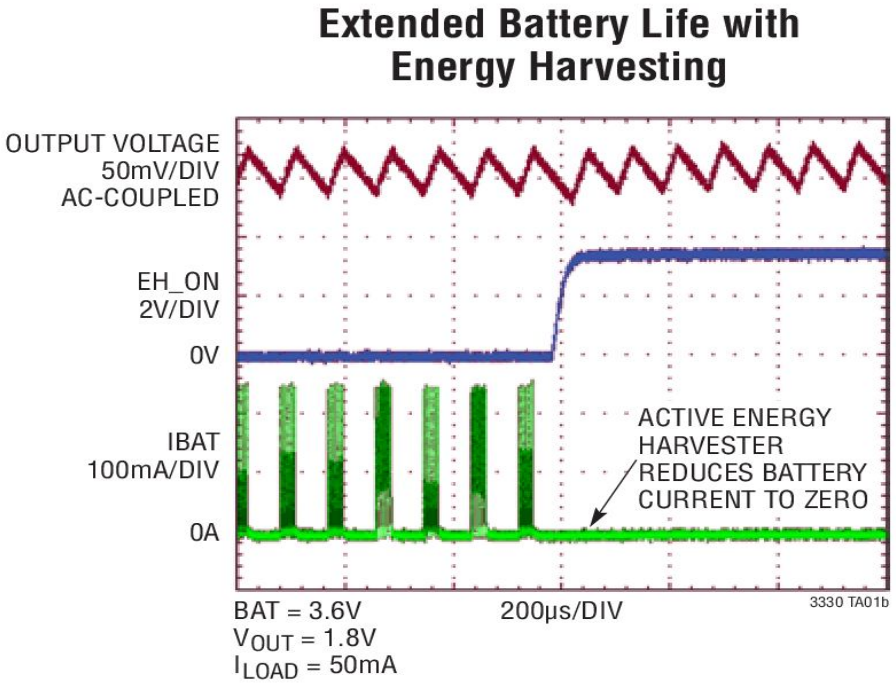


Energy Harvesting Kit – µPC/RF Module Demoboard DC2321A

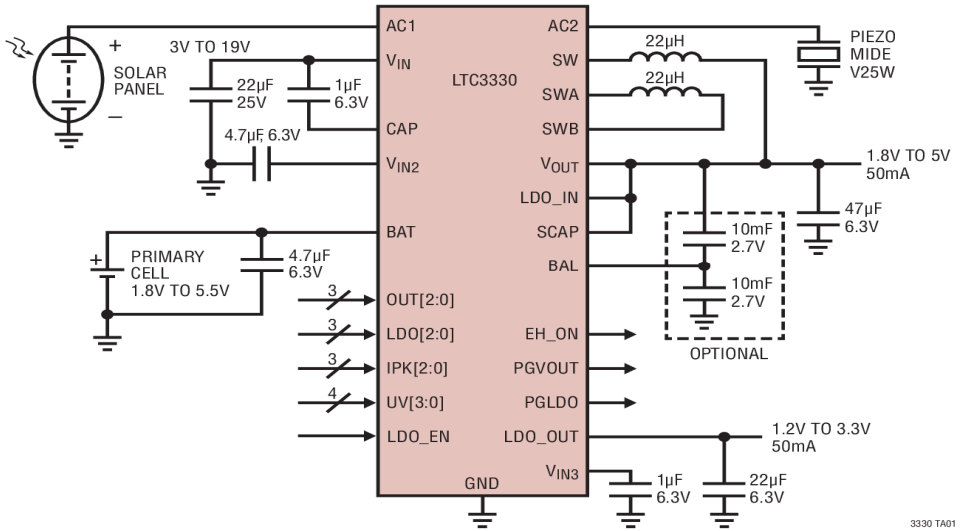
Featuring:

- 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



L = 2 pcs.
744773122



Source: Linear Technology Corporation

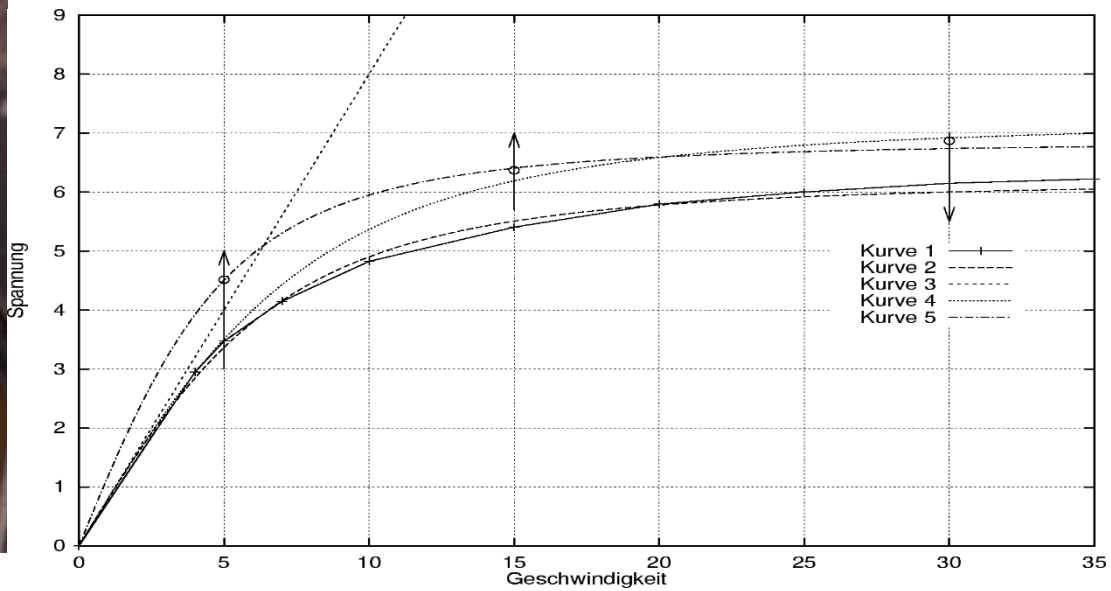
Typical Inductive Transducers

Average Power: 3W

Downhill Peak Power: 4W

Output Voltage: 6V @ 12Ω Load

Felt Efficiency: <10%



Typical Inductive Transducers

EM-1D-09 — Vibration Generator

Generator Data		
Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm^3
Mass	42	g
Inner Resistant	430	Ω
Resonant Frequency	14.2	Hz
Power Output (0.5*g continous*)	3.6	mW
Power Density	0.11	mW/cm^3
Specific Power	85.7	mW/kg
Frequency Range of 50% Power	12.4 - 16	Hz

Generator Code: 151001200019

EM-1D-10 — Vibration and Push-Button Generator

Generator Data		
Dimensions (L x W x H)	60x24x22	mm
Volume	32	cm^3
Mass	46.5	g
Inner Resistant	430	Ω
Resonant Frequency	47	Hz
Power Output (0.5*g continous*)	30	mW
Power Density	0.96	mW/cm^3
Specific Power	660	mW/kg
Frequency Range of 50% Power	42 - 48	Hz
Energy Output (1x Push Button)	1.5	mJ

Generator Code: 151001200018

Source: www.pmdm.de

EnOcean

Per Click 30µC
6.38V @ 4.7µF

Source: www.enocean-alliance.org

Other Development Kits: EnOcean

Source: 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**

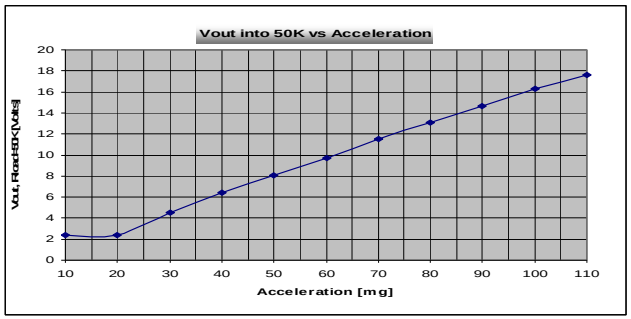
- 1x Energy Harvesting Generator P/N: AFIK-1002
- 1x Wireless Snap Switch
- 1x Wireless Rocker Switch
- 1x Receiver
- 1x USB Cable
- 1x Antenna bushing

Source: ZF Cherry

Typical Inductive Transducers

Ferro Solutions

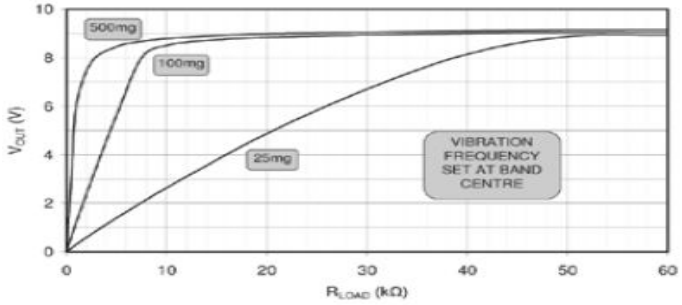
Size: DxH = 6cm x 6.75cm



POWER OUTPUT @ 60 HZ (Rectified DC Power)		
Acceleration	25 milli-*g*	0.3 mW
	50 milli-*g*	1.3 mW
	100 milli-*g*	5.2 mW
BANDWIDTH (Δf = 3 Hz)		
Peak frequency		60 Hz
50% power delivered		+/-1.5 Hz
Q @ 100 milli-*g*		18

Perpetuum

Size: DxH = 6.85cm x 6.85cm



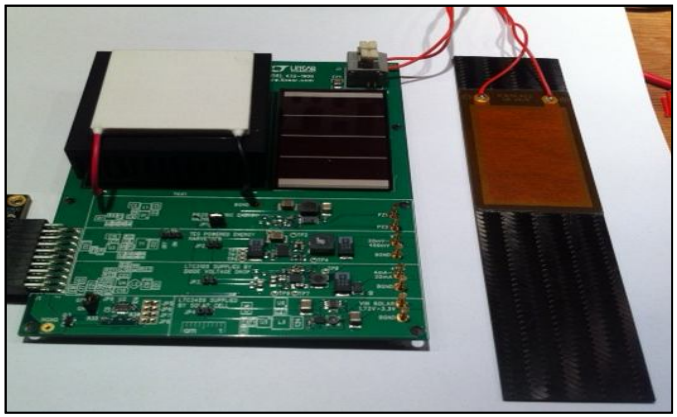
Operates from prevalent 100Hz/ and 120Hz vibration bands found on electrical machines

1mW peak power at 0.025G with >2Hz half-power bandwidth

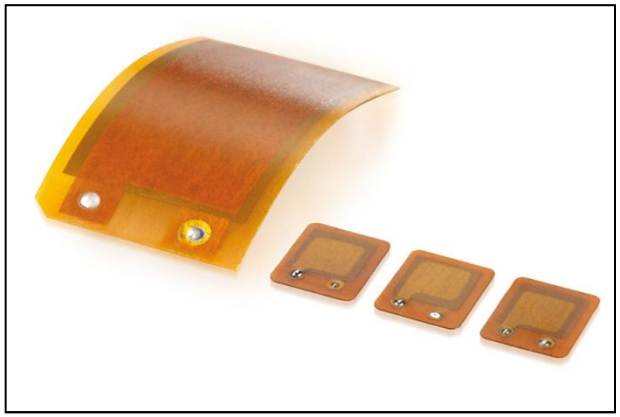
Typically >0.3mW output on 95% of machines

Examples for Piezo Transducers

PI Ceramic



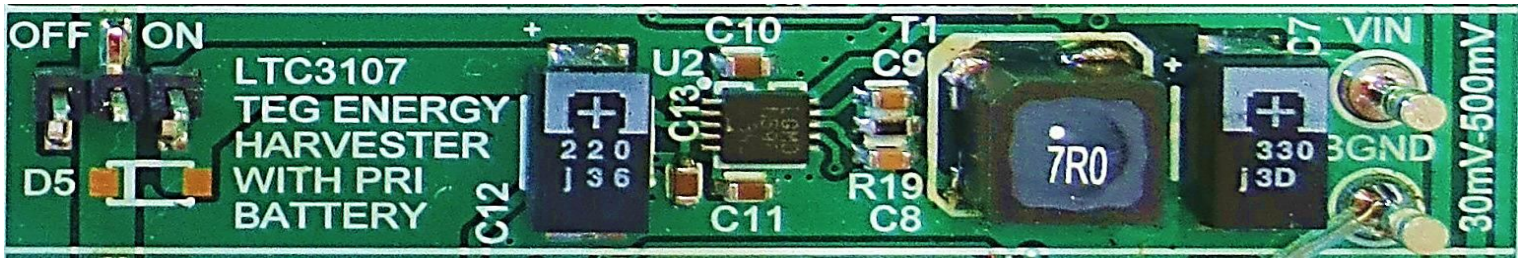
The “Piezo Ruler” Size: 150 x 35 x 2,5 mm³

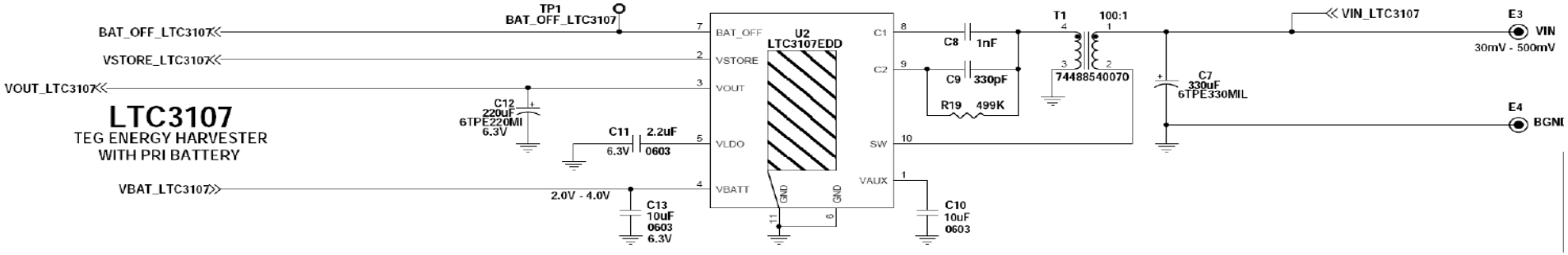


Made from DuraAct Transducers

Source: Linear Technology Corporation

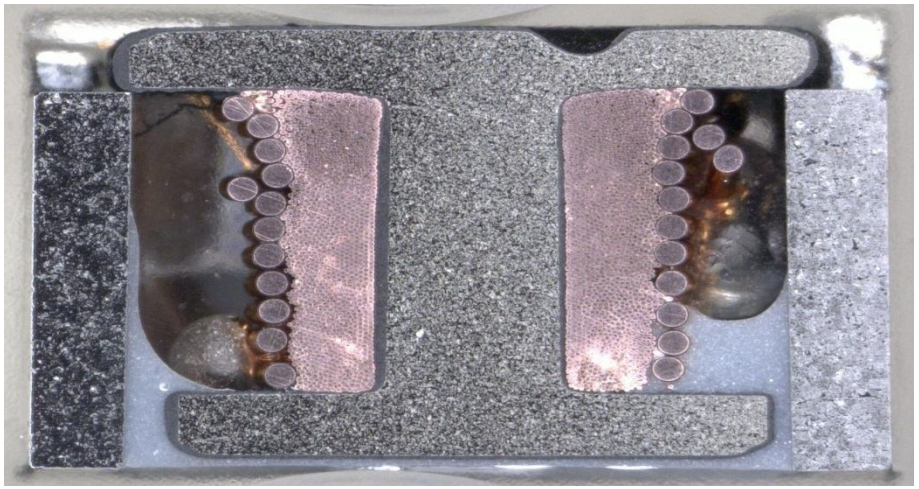
EH-Kit: LTC3107 - TEG

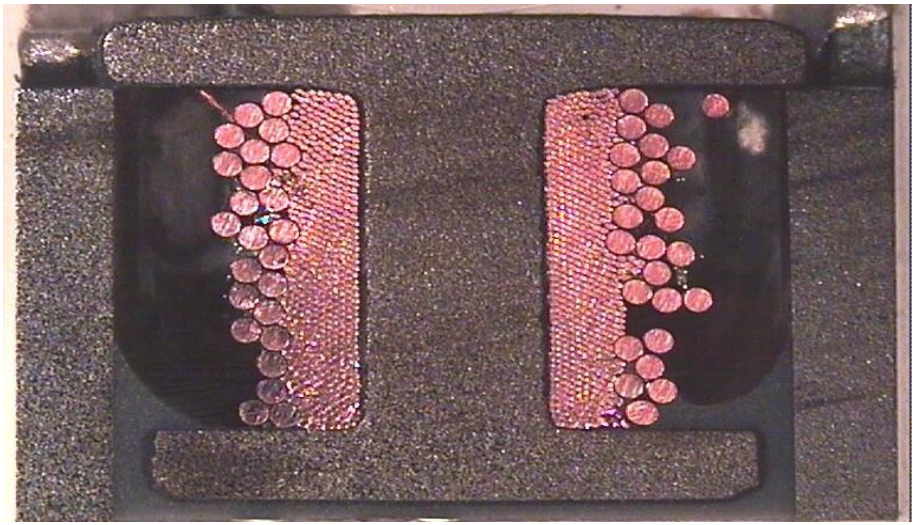




What is behind the WE-EHPI transformer?

- **winding style**





Würth Elektronik eiSos components

WE-EHPI
Energy Harvesting Power Inductor

Characteristics

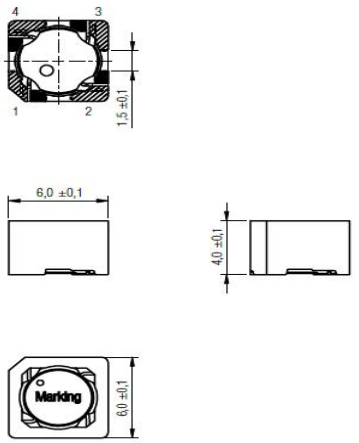
- Low profile: 4 mm
- Small footprint 6 x 6 mm
- Very low secondary R_{DC}
- Different turn ratios available
- Separated welding/soldering pad for a high reliable component
- Optimized, high reliable winding style

Applications

- Wireless fire, alarm, gas and metering remote sensors driven by environmental energies based on energy harvesting voltage transformers like LTC3108/LTC3109
- Sensors with predictive battery replacements in applications which are difficult to access
- Energy self-sufficient supply using subsequent installed sensors for energy harvesting

QR-Code

Dimensions (in mm)

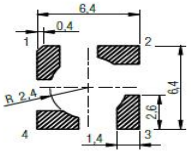


Electrical properties

Order Code	L_1 ±20% (µH)	L_2 ±20% (µH)	n	I_{R1} (A)	I_{sat1} (A)	R_{DC1} (Ω)	R_{DC2} (Ω)
744 885 400 70	7.5	75000	1:100	1.9	1.3	0.085	205
744 885 401 20	13.0	33000	1:50	1.7	1.0	0.090	135
744 885 402 50	25.0	10000	1:20	1.5	0.7	0.200	42

Schematic

Land pattern (in mm)



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

Asset Tracking/Monitoring

Building Security, Lighting & Climate Control

Plant Automation

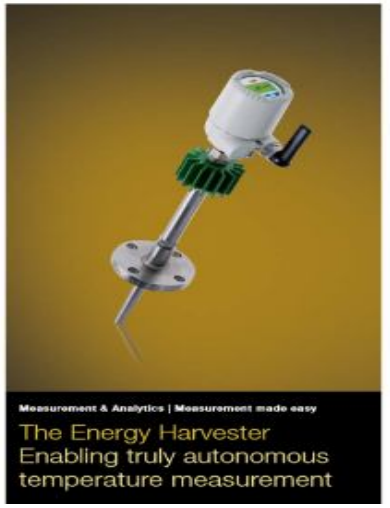
Remote Monitoring

TPMS

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 measu wireless devices

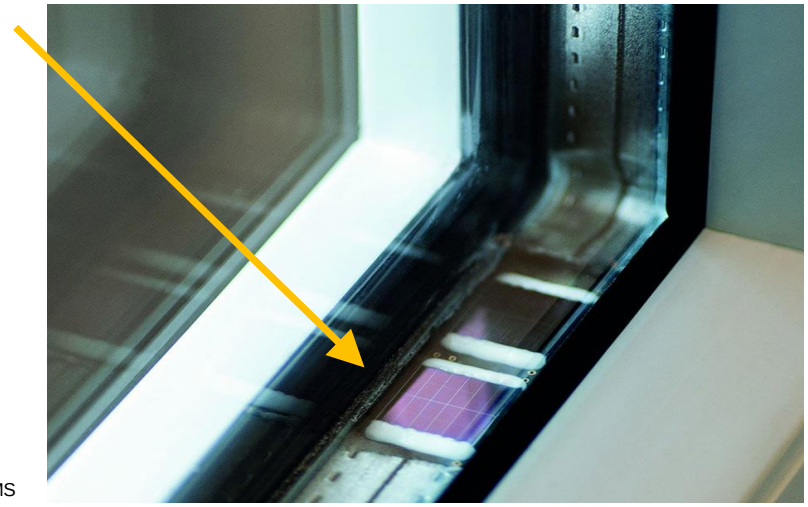


Energy Harvested Application

- **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:

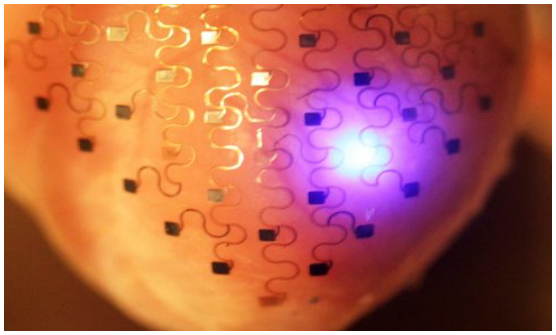
- **Aftermarket solutions for Portable Navigators & Mobile Phones (Solar)**
- **GSM/GPS module (5W Solar)**
- **Window status monitoring for Hotels and Homes (Solar)**
- **Chainsaw electronic at engine (TEG)**
- **High Voltage cable status (Magnetic field)**
- **Water purification plant PH measuring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

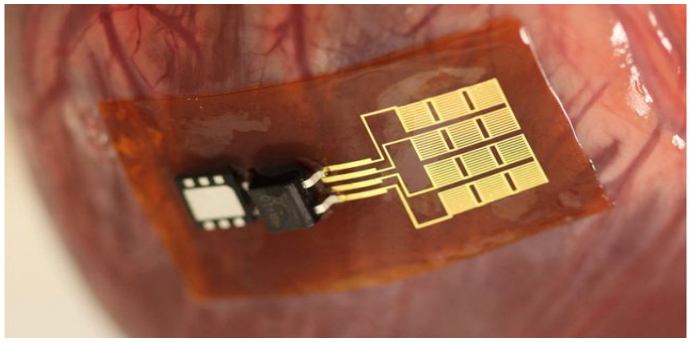


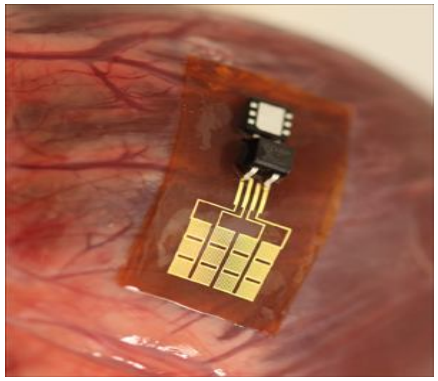
© Fraunhofer IMS

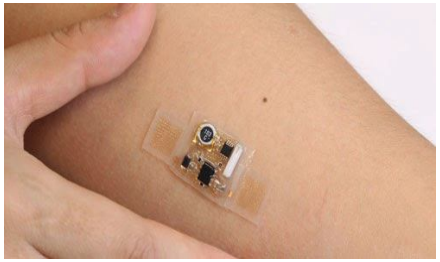
Energy Harvesting Healthcare Application

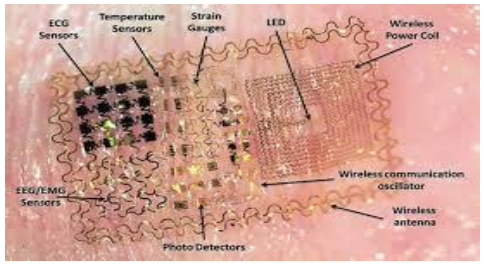
- **Pacemaker**

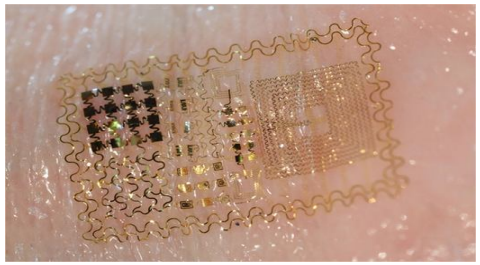












Source: Prof John A. Rogers University of Illinois

Another application for Harvesting?

Source: http://www.joaolammoglia.com/concept/1/aire-concept/

We are Power Sources Manufacturers Association – The Multinational Power Electronics Association member

WÜRTH ELEKTRONIK

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: LINEAR TECHNOLOGY, dust networks®, SILICON LABS