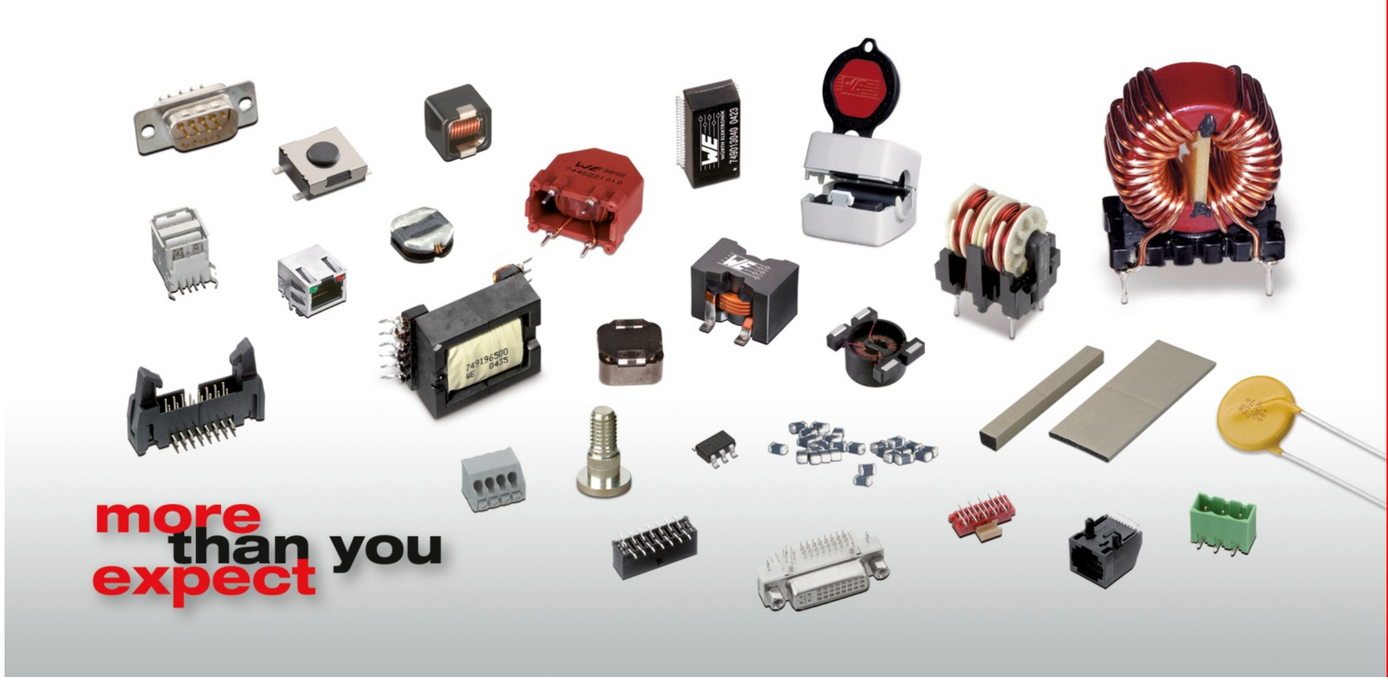
WÜRTH ELEKTRONIK

Wireless Power Charging & Energy Harvesting



Sébastien CHADAL
Enova 2012

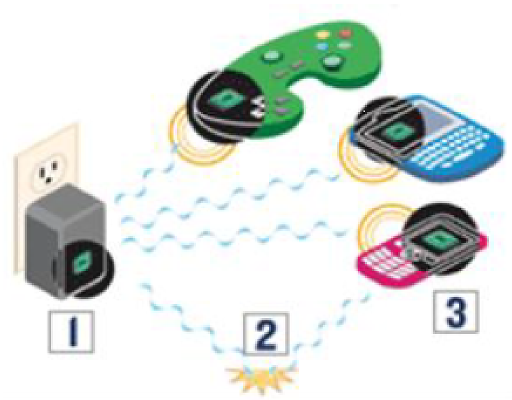
Coils for Wireless Power Charging

Energy Harvesting

- WPC
- ENERGY HARVESTING

Wireless Power Technologie

Conductive Charging
(Wildcharge, Duracell)



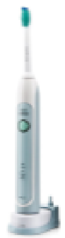
RF Wireless Power *(Powercast)*

TI, Philips, Fulton, Convenient Power, Sanyo and more

Wireless Power Consortium

Palm, Powermat

Toothbrush, Witricity



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Wireless Power Consortium (WPC)

WÜRTH ELEKTRONIK

Proprietary Solutions

Interoperability key to adoption

WPC

- Industry wide standard for delivering wireless power up to 5W
- Aimed to enable interoperability between various charging pads and portable devices
- Standard continues to gain traction with increasing list of members (105+)
- Compatible devices will be marked with a Qi logo

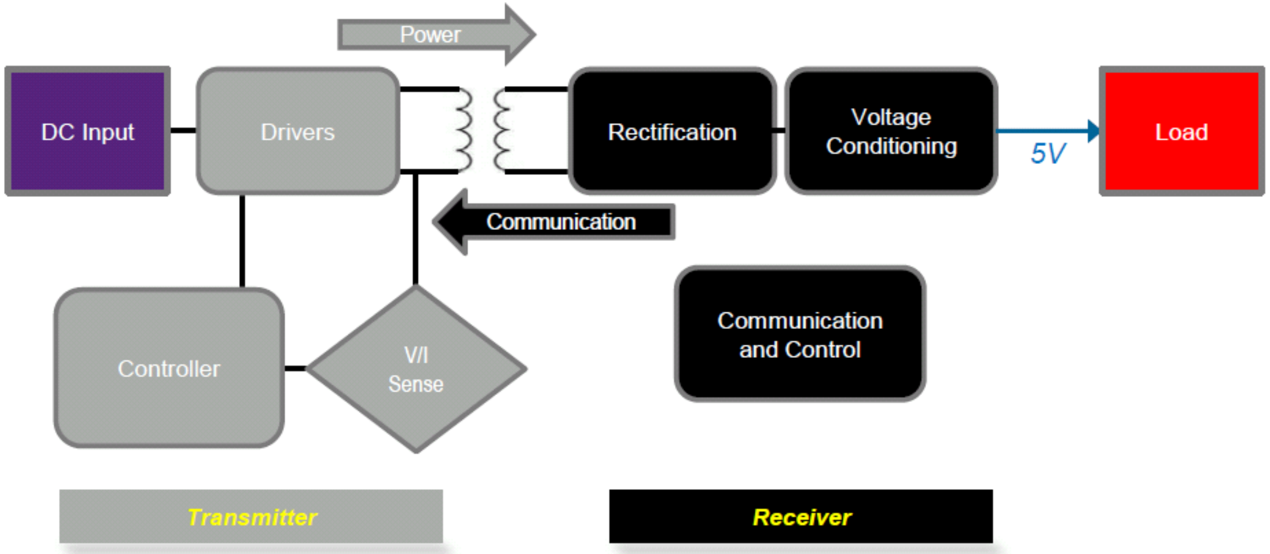
Broad Industry Support

BEST BUY, BELKIN, COMPAL, Continental, DENSO, Energizer, Ever Win International Corp., Haier, Johnson Controls, LG, MOTOROLA, NEC, NOKIA Connecting People, orange, Panasonic, PHILIPS, PRIMAX, RRC, SAMSUNG, SoftBank, Sony Ericsson, Stanley Black&Decker, WÜRTH ELEKTRONIK, Texas Instruments, verizon wireless

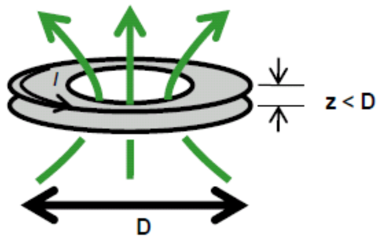
and more...

Doc Texas Instruments

Inductive Power Systeme Overview



- **Power transmitted through shared magnetic field**
  - Transmit coil creates magnetic field
  - Receive coil in proximity converts field into voltage
  - Shielding material on each side directs field
- **Power transferred only when needed**
  - Transmitter waits until its field has been perturbed
  - Transmitter sends seek energy and waits for a digital response
  - If response is valid, power transfer begins
- **Power transferred only at level needed**
  - Receiver constantly monitors power received and delivered
  - Transmitter adjusts power sent based on receiver feedback
  - If feedback is lost, power transfer stops



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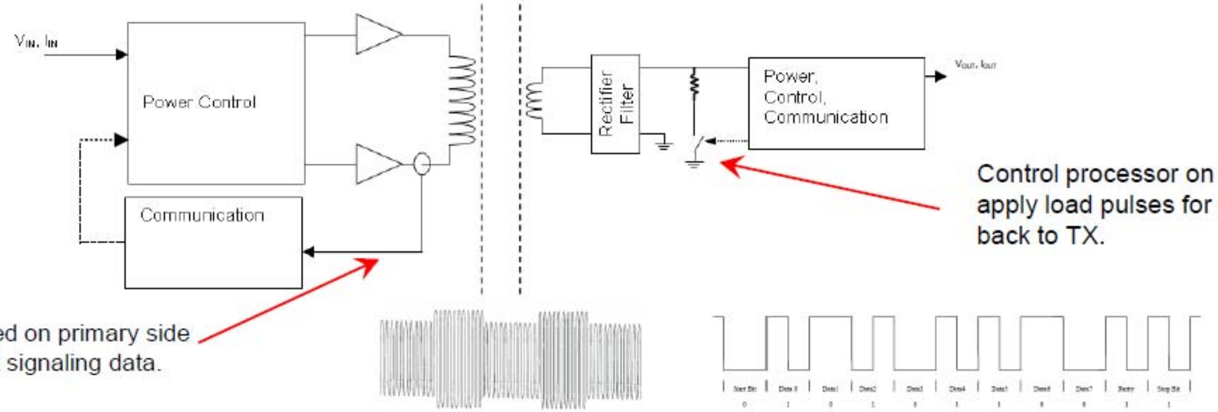
Communication - Basics

- **Primary side controller must detect that an object is placed on the charging pad.**
  - When a load is placed on the pad, the primary coil effective impedance changes.
  - "Analog ping" occurs to detect the device.
- **After an object is detected, must validate that it is WPC-compatible receiver device.**
  - "Digital Ping" – transmitter sends a longer packet which powers up the RX side controller.
  - RX side controller responds with signal strength indicator packet.
  - TX controller will send multiple digital pings corresponding to each possible primary coil to identify best positioning of the RX device.
- **After object is detected and validated, Power Transfer phase begins.**
  - RX will send Control Error Packets to increase or decrease power level
- **WPC Compliant protocol ensures interoperability.**



Control processor on RX side will apply load pulses for signaling back to TX.

Load current is sensed on primary side – demodulated to get signaling data.

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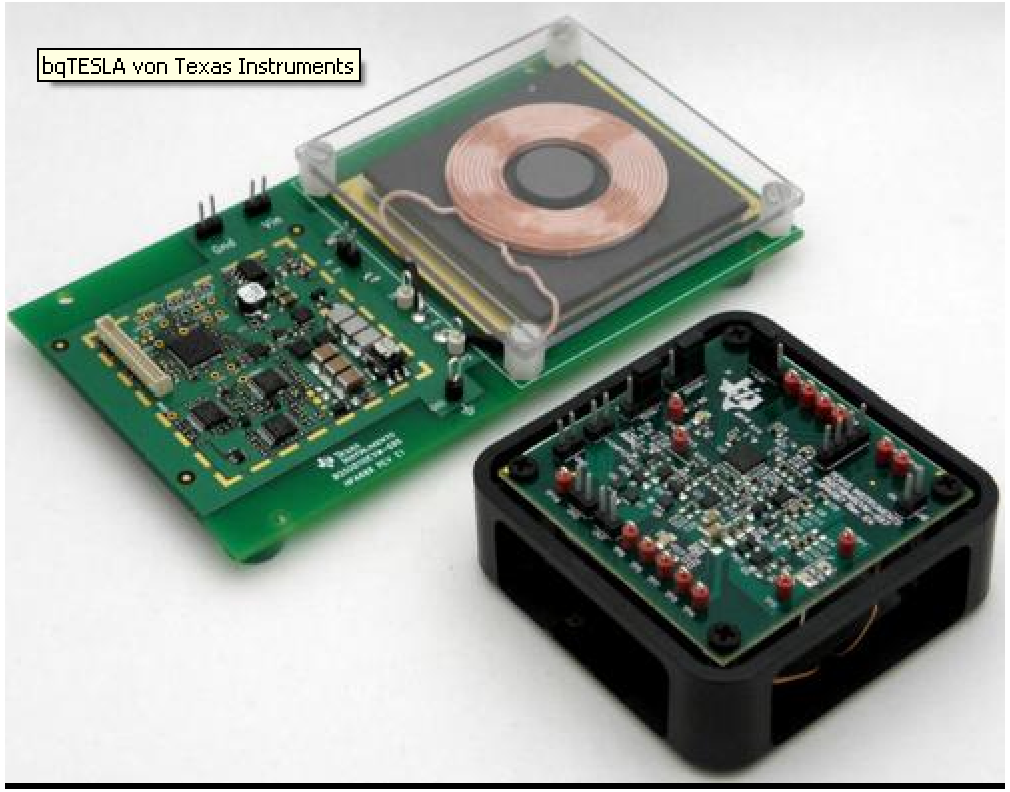
Evaluation Kit

A1-Standard: WE 760308101 with TI BQ500210



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http://www.ti.com/lit/ug/sluu911/sluu911.pdf
http://www.ti.com/lit/ug/slvu447a/slvu447a.pdf

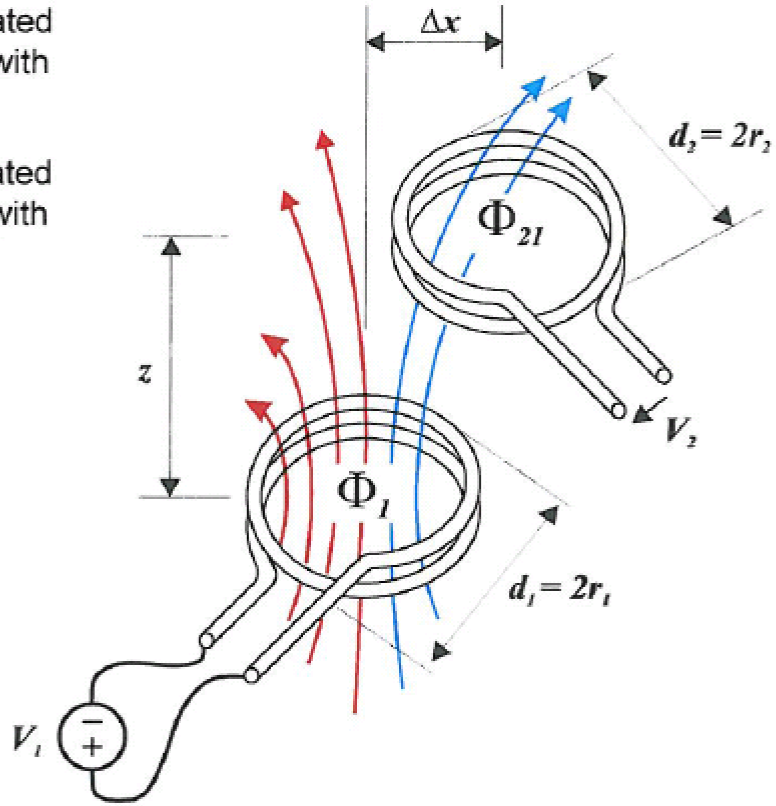
Magnetic coupling

Φ_{21} Magnetic flux generated by coil 1 and linked with coil 2

Φ_{12} Magnetic flux generated by coil 2 and linked with coil 1

$$\kappa_{21} = \frac{\Phi_{21}}{\Phi_1}$$

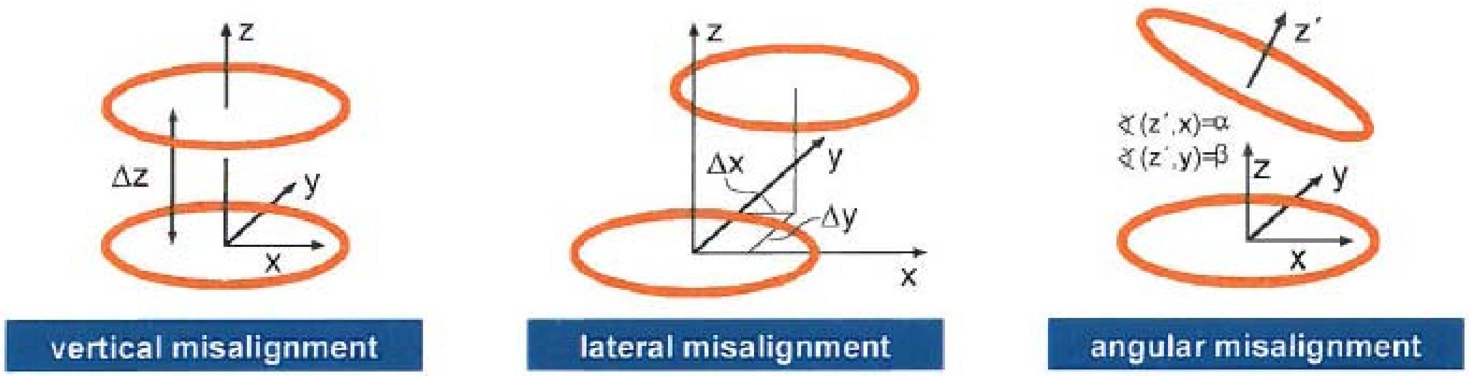
$$\kappa_{12} = \frac{\Phi_{12}}{\Phi_2}$$

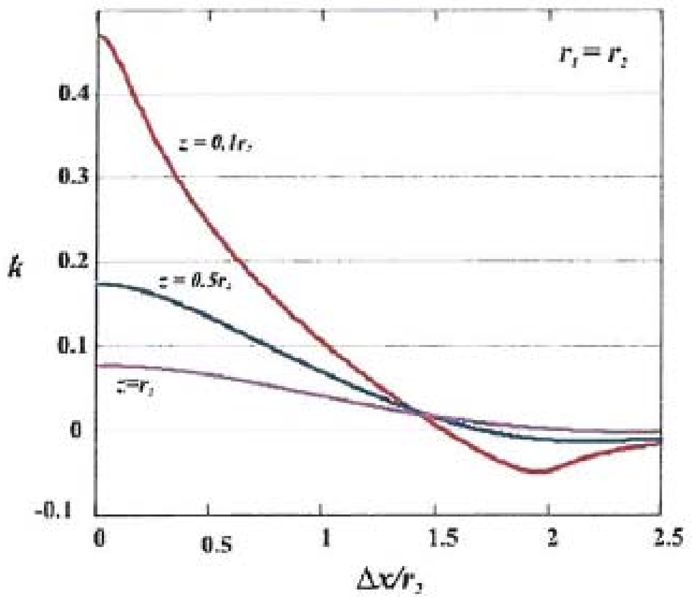


- **Transmission depends on the position of the coils**
  → will determine efficiency

$$k = \pm\sqrt{\kappa_{12}\kappa_{21}}$$

Coupling factor / alignment tolerances

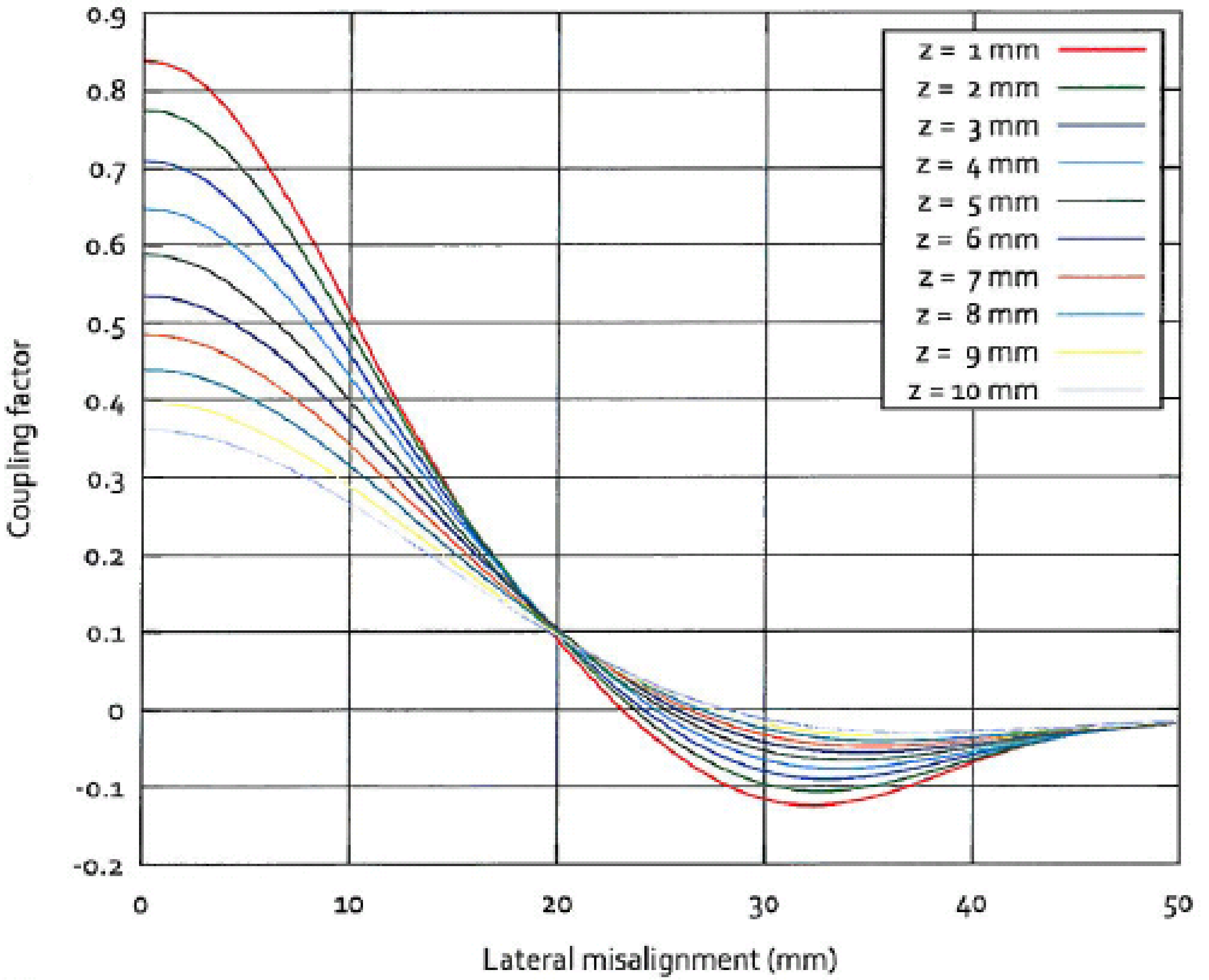




Ways to improve coupling factor k

1)reduction of vertical distance z
2)reduction of coil misalignment x & y

Coupling factor / alignment tolerances

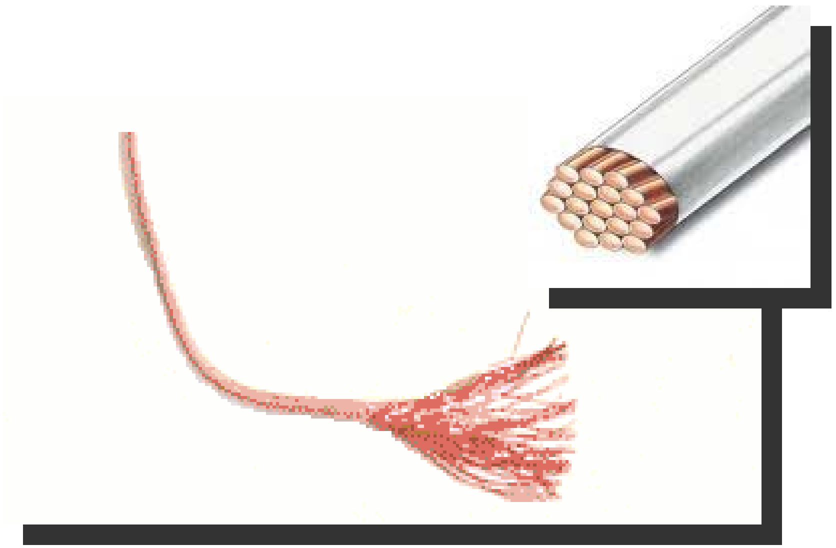


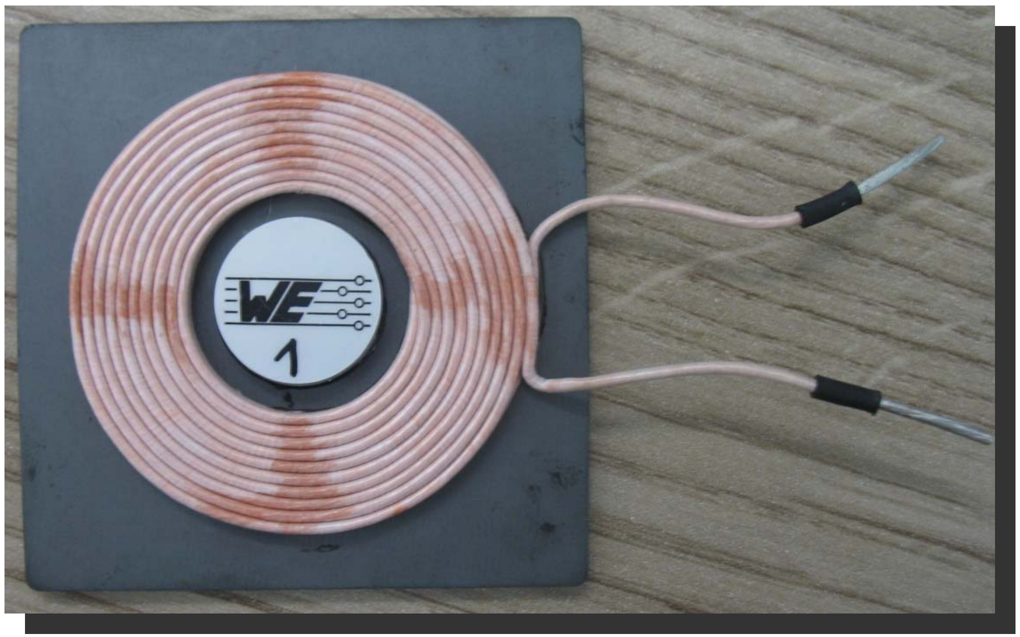
Improvement for coupling factor k

1)reduction of vertical distance z
2)reduction of coil misalignment x & y

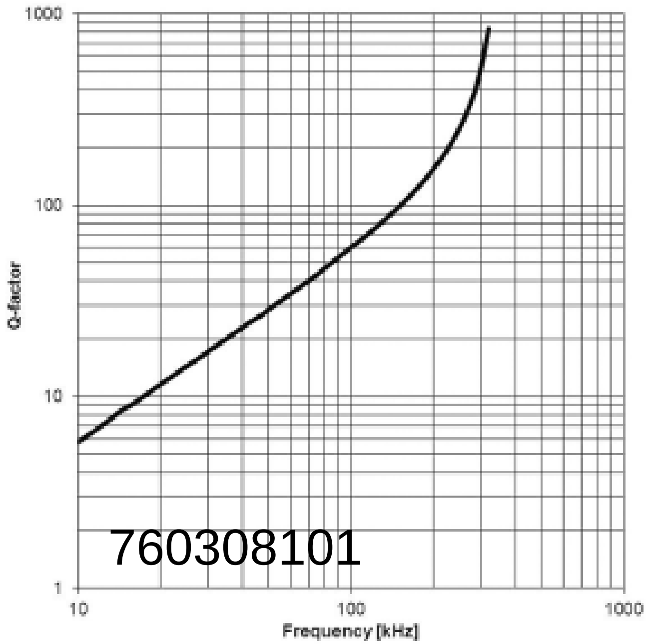
Coil construction

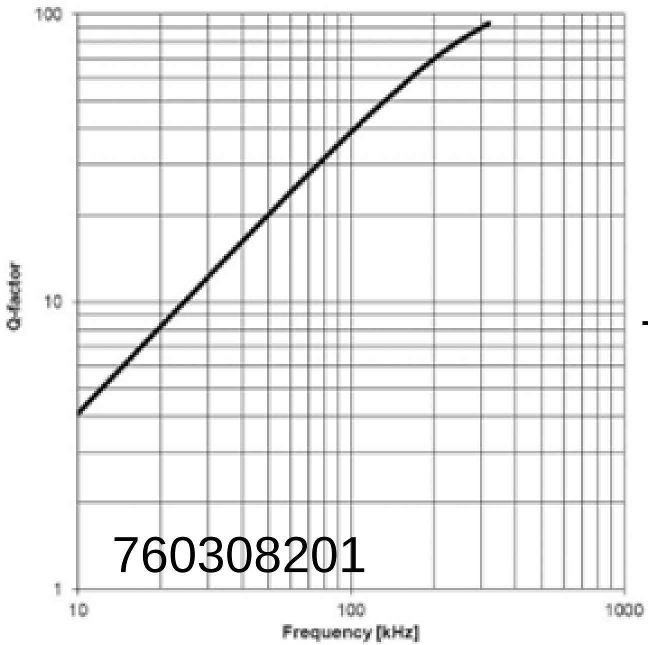
- low DC resistance of the coils
- low frequency dependent resistance (Skin-/Proximity effect)
- high Q-factor
- efficiency up to 90% in first testings

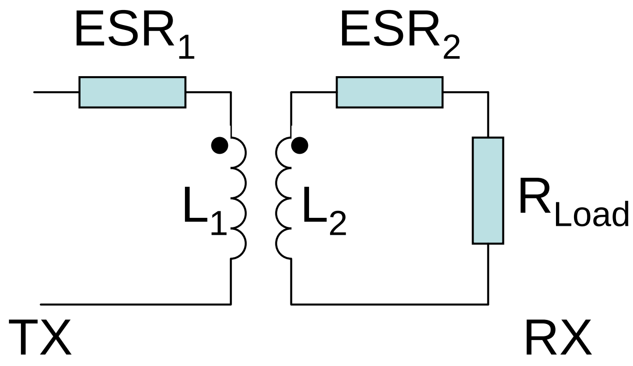




Quality factor – definition







$$Q = \frac{\omega L}{ESR}$$

Equivalent series resistant ESR
-DC resistance
-AC resistance caused by Skin-/proximity

$$\eta = \frac{k^2 Q_{10} Q_{20}}{2 + k^2 Q_{10} Q_{20} + 2\sqrt{1 + k^2 Q_{10} Q_{20} + Q_2{}^2}}$$

Coil quality factors

$Q_{10} = \frac{\omega L_1}{ESR_1}$ = Tx-Side

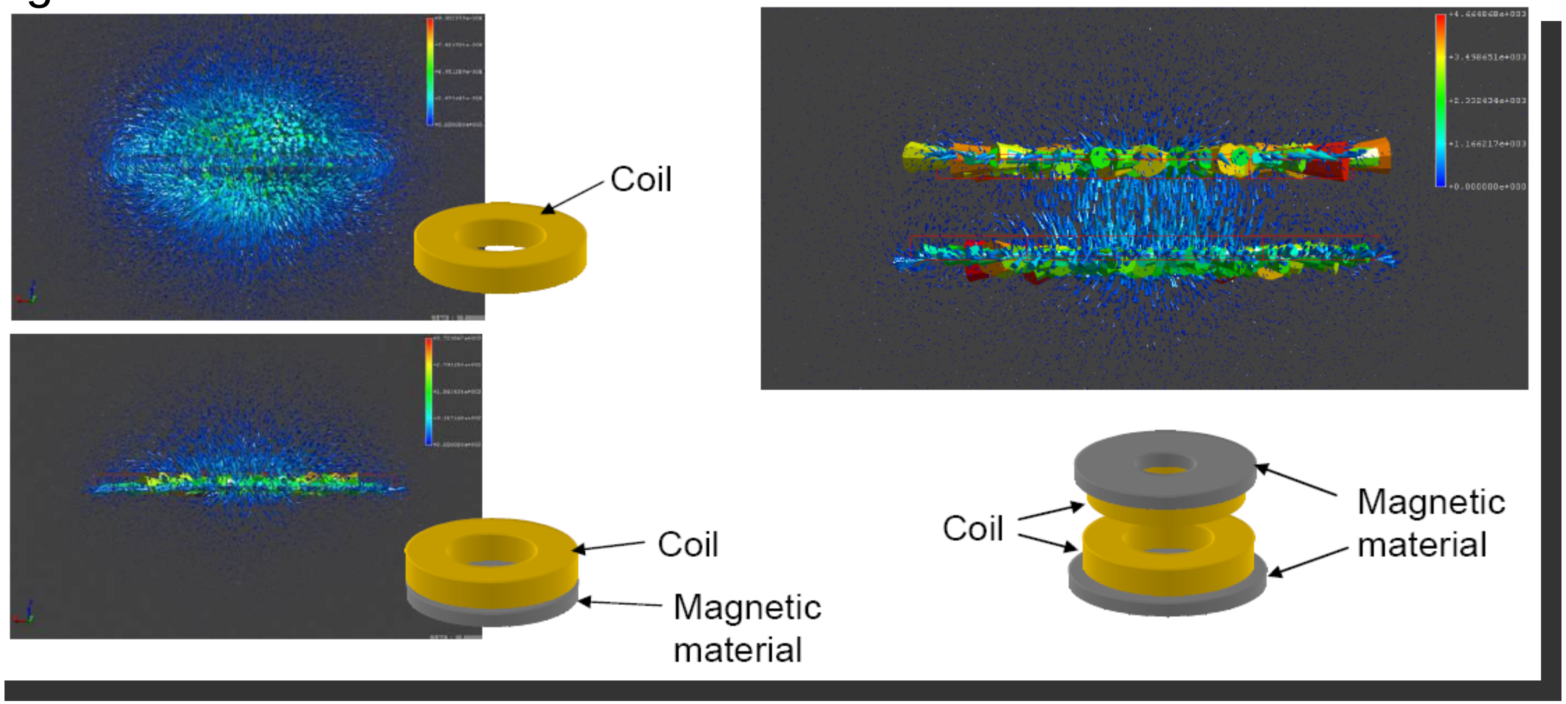
$Q_{20} = \frac{\omega L_2}{ESR_2}$ = Rx-Side

Receiver quality factor

$Q_2 = \frac{\omega L_2}{ESR_2 + R_{Load}}$

Improvement using ferromagnetic shielding

Reasons
→better coupling
→shielding



<u>magnetic field in center of the coil</u>
-WPC A1 and A5 will be replaced by A10 and A11
-center magnet for alignment influences Q-factor significantly

Efficiency

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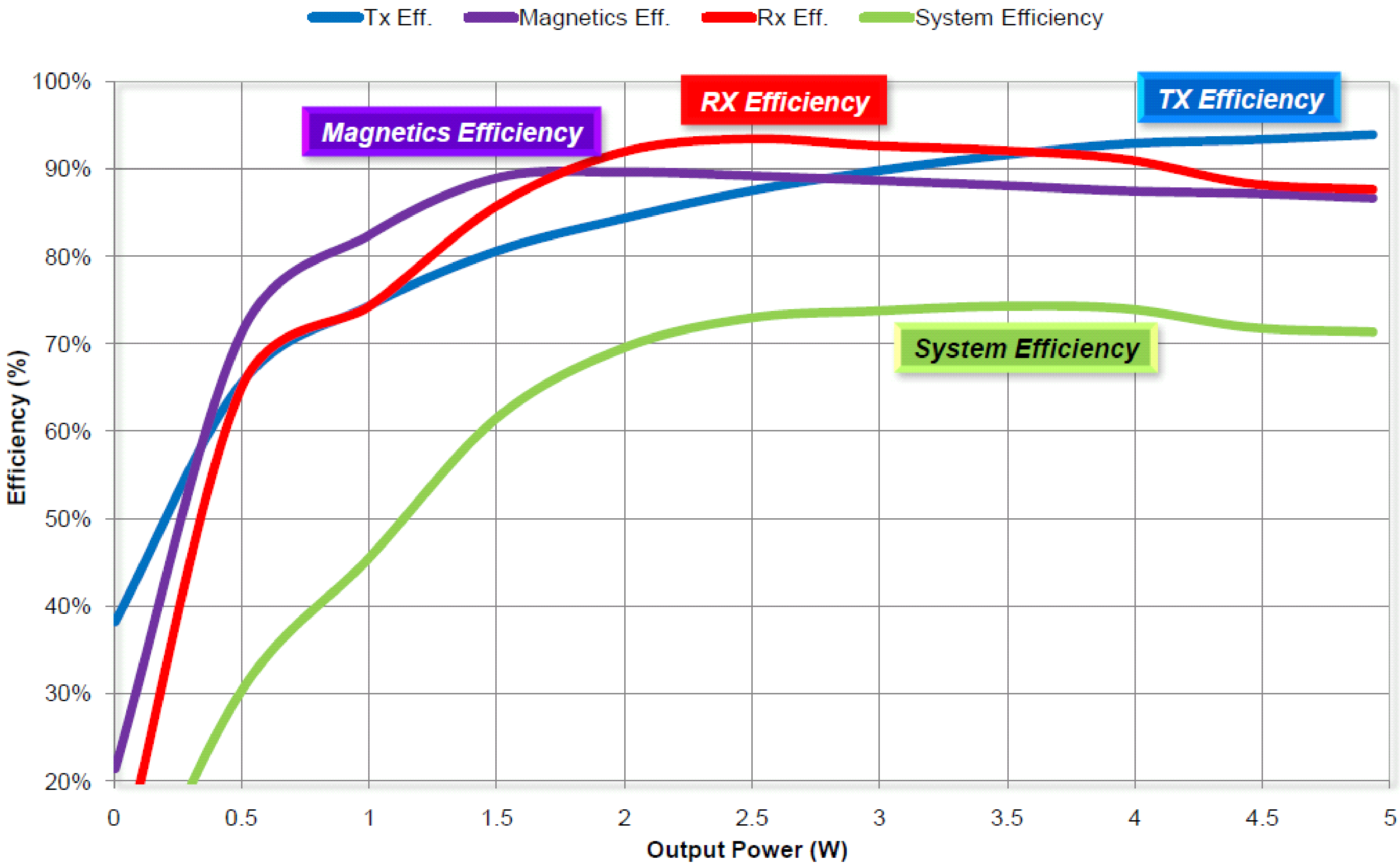
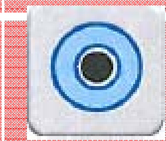
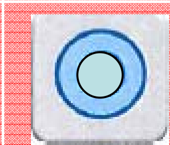
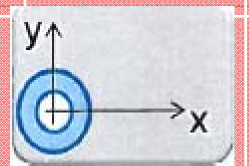
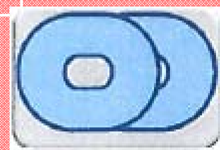
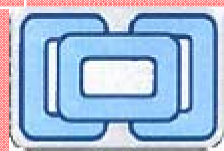
Measured from DC input of Transmitter to DC output of Receiver



Würth Elektronik WPC coils – WE-WPCC

WE-part	Rx/Tx	Qi-compliance	Dimensions	Inductance (at 125kHz)	Q-factor (at 125kHz)
760308101	Transmitter	A1	53.3x53.3x6,5	24µH +-10%	90 min.
760308105	Transmitter (in development)	A5	53.3x53.3x6,5	6,3µH+-10%	TBD
760308106	Transmitter (in development)	A6		11.5/12.5µH	TBD
760308110	Transmitter (in development)	A10	53.3x53.3x6,5	24µH	210
760308111	Transmitter (in development)	A11	53.3x53.3x6,5	6,3µH	TBD
760308201	Receiver		37x37x1,8	10µH +-10%	50

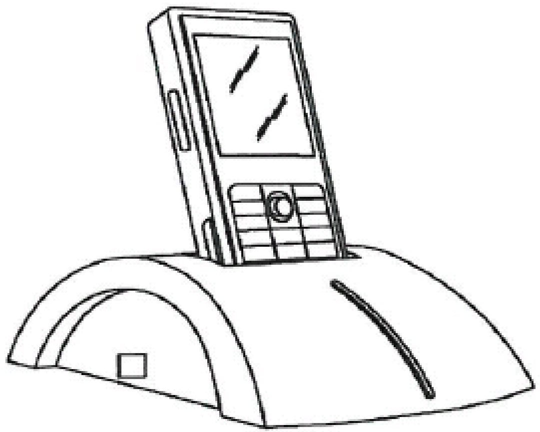
Basic power transmitter designs – Typ A transmitters

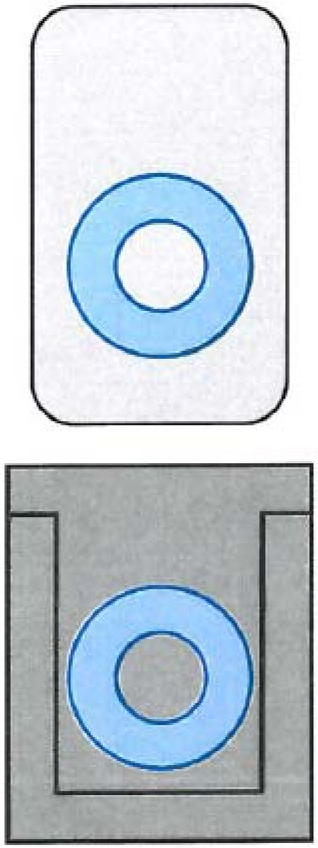
Type	Position		description		WE partnumber
A1, A5	guided (magnet)	single coil	coil dimensions: 43 x 2,1mm variable frequency (105…205kHz) A1: half-bridge, input voltage 19V A5: full-bridge, input voltage 5V		A1 = 760308101 A5 = 760308105
A10, A11	not guided (no magnet)	single coil	coil dimensions: 43 x 2,1mm variable frequency (105…205kHz) A10: half-bridge, input voltage 19V A11: full-bridge, input voltage 5V		A10 = 760308110 A11 = 760308111
A2, A3	free	moving coil	coil dimensions: A2: 40 x 2mm, A3: 33 x 1,8mm full-bridge inverter, input voltage 3…12V A2: fixed frequency (140kHz) A3_ variable frequency (105…140kHz)		
A4	free	two coils	coil dimensions: 70 x 59 x 1,15mm full-bridge inverter, input voltage 5…11V variable frequency (110…180kHz)		
A6	free	three coils	coil dimensions: 53,2 x 45,2 x 1,5mm half-bridge inverter, input voltage 12V variable frequency (115…205kHz)		760308106

Coil typed and positioning

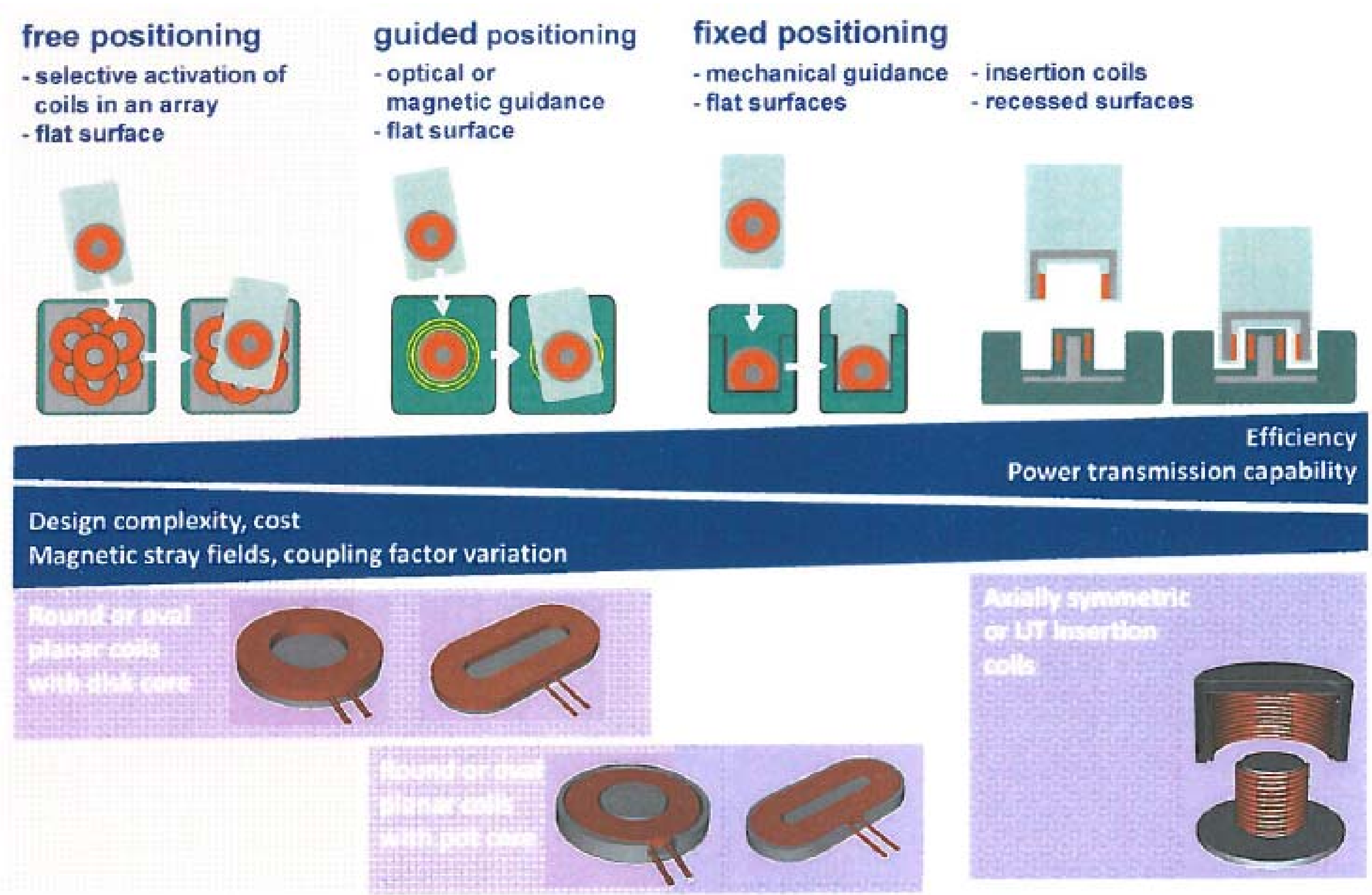
Fixed positioining

- **Mechanical alignment**
- **Very easy positioning**
- **Constant high coupling coefficient**
- **High power transfer capability**





Coil typed and positioning



WPC design KIT

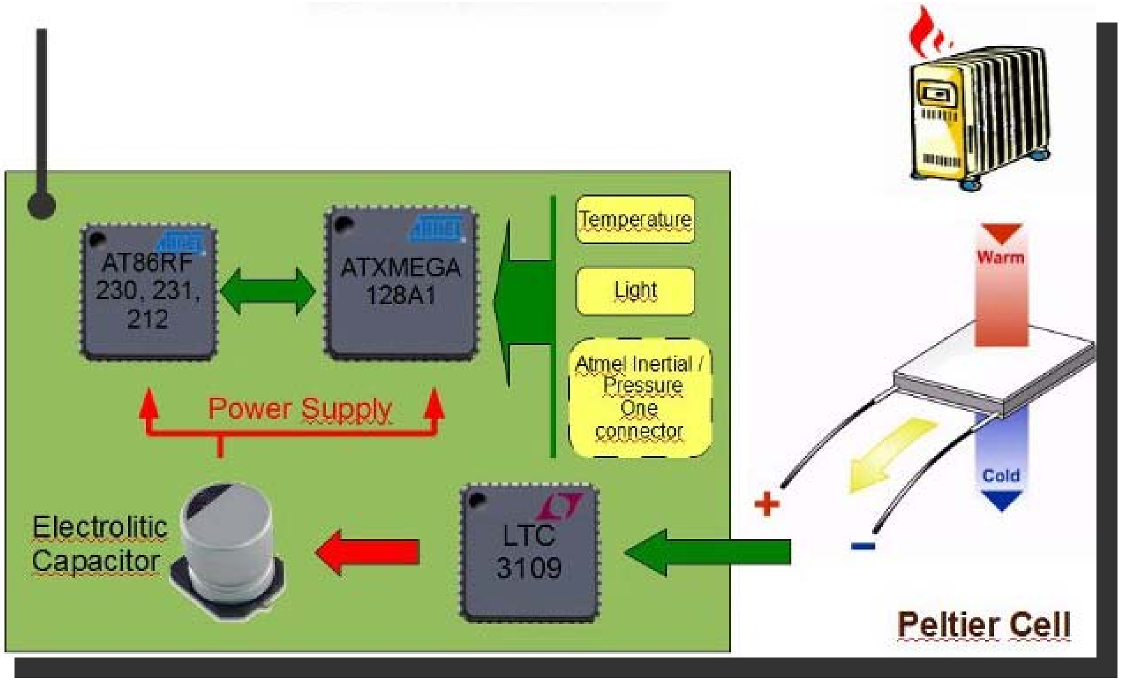
The kit offers the capability to use the receiver outside of the box by transferring the power from the inner located transmitter.

ENERGY HARVESTING

What is Energy Harvesting

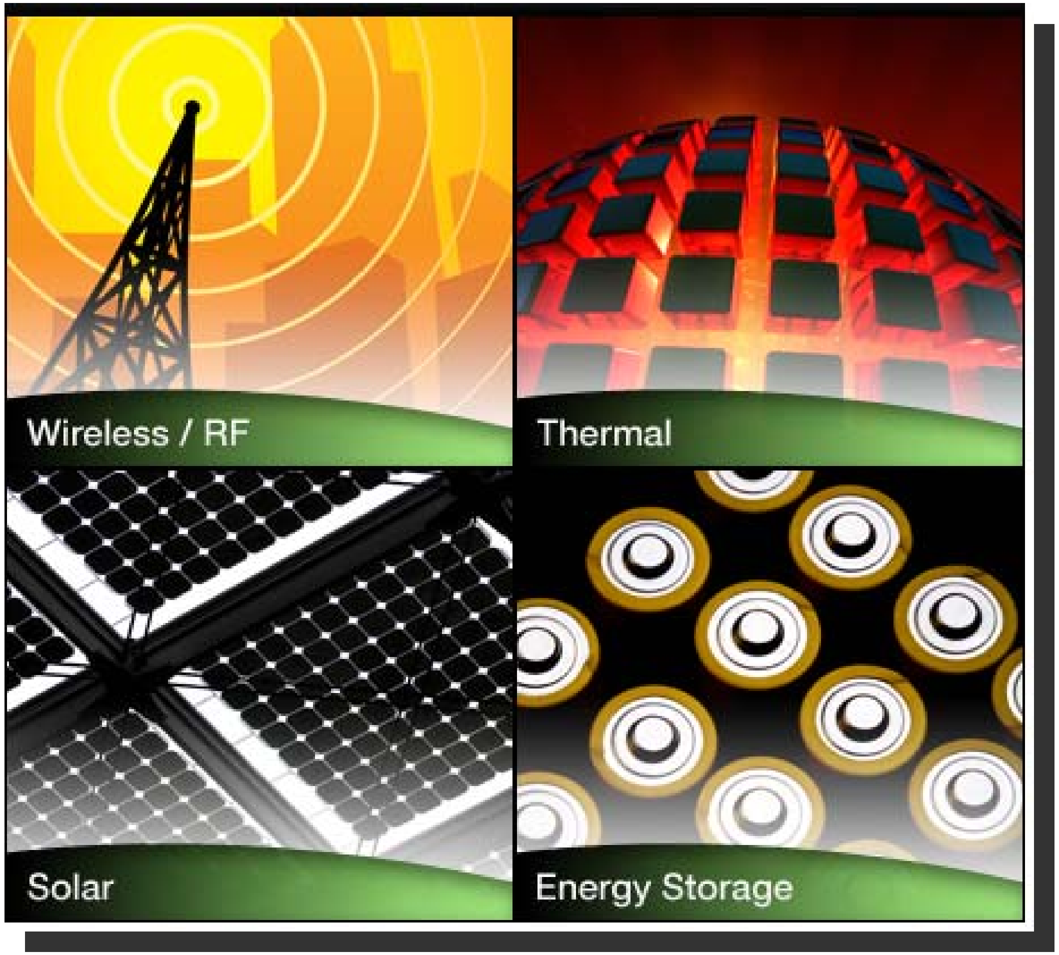
- The process by which energy is derived from external sources, captured and stored for use in electronic systems

- Energy harvesting is the process by which ambient energy is captured and converted into electricity for small autonomous devices, such as satellites, laptops and nodes in sensor networks making them self-sufficient.



What is Energy Harvesting

- sources as lighting, temperature differentials, vibrations, and radio waves (RF energy) → can be re-used to operate low-power electronic devices.



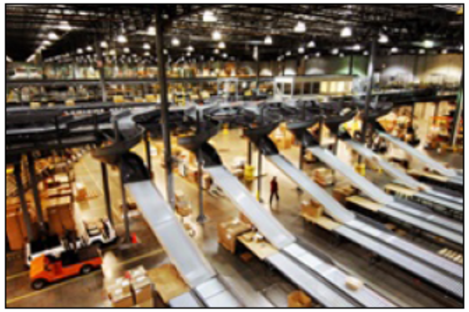
Where is it useful?

- 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

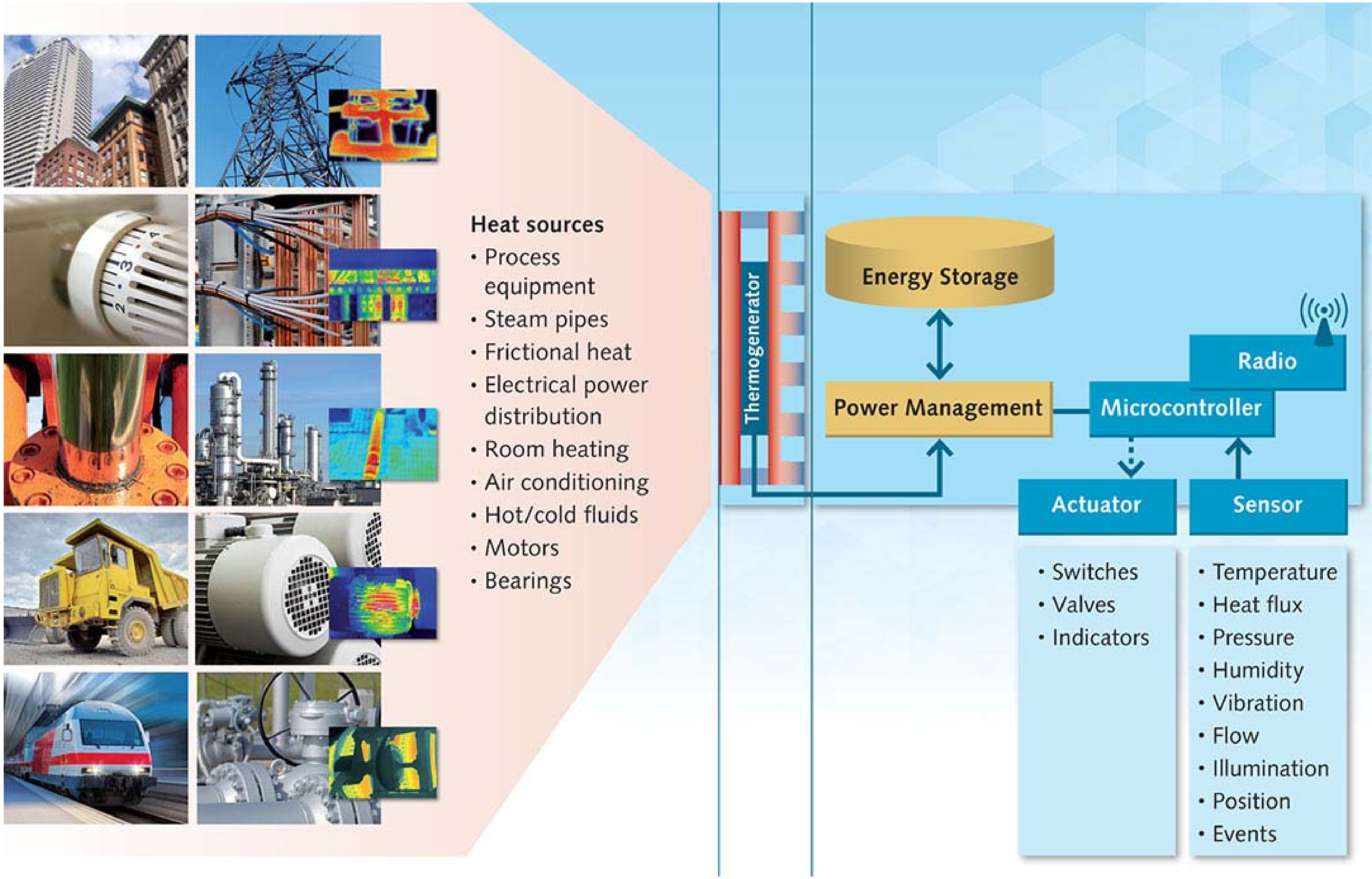


Remote Monitoring

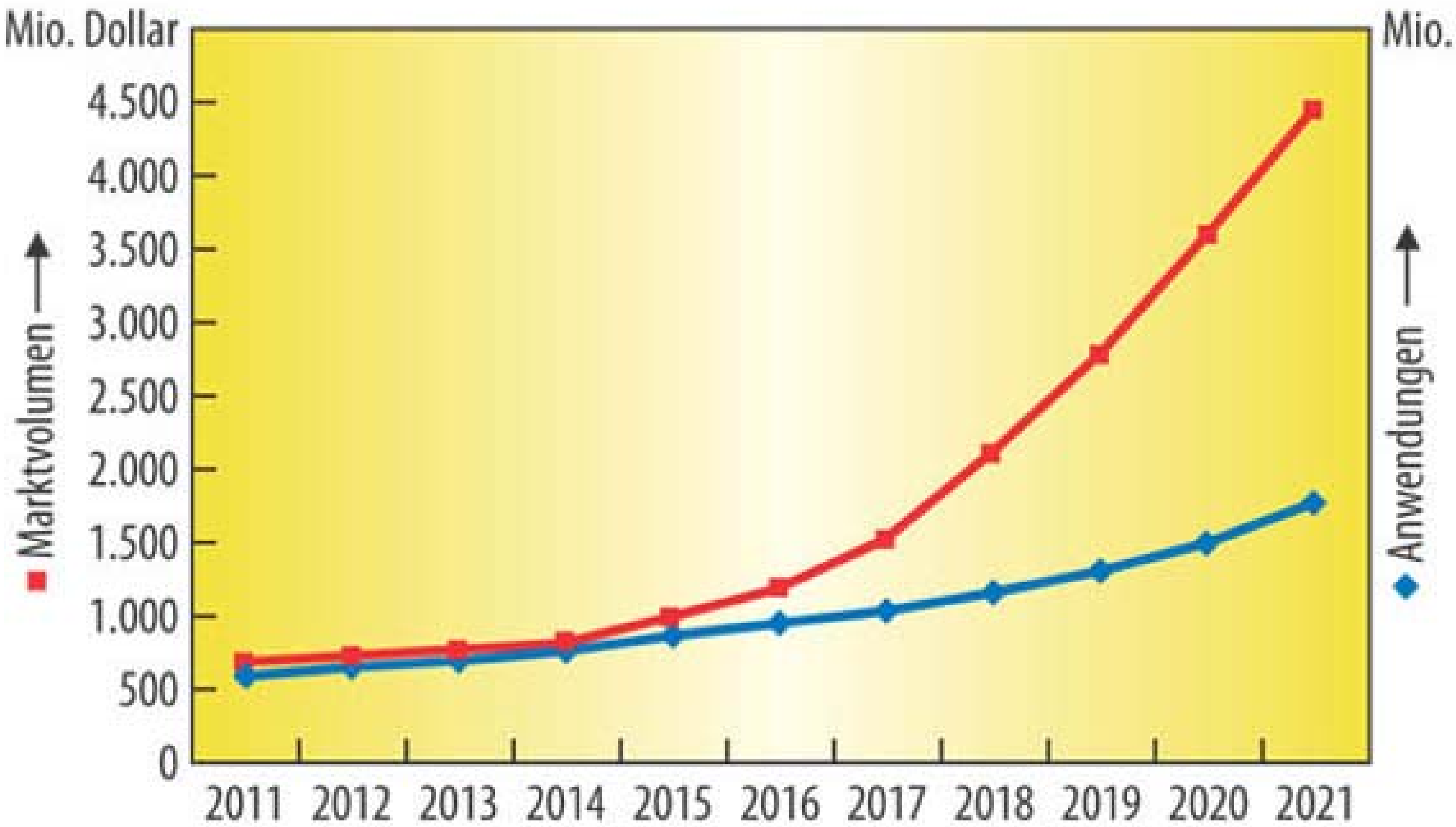
e.g. TPMS

Source: LTC - Sam Nork – Energy Harvesting Presentation

Where is it useful?



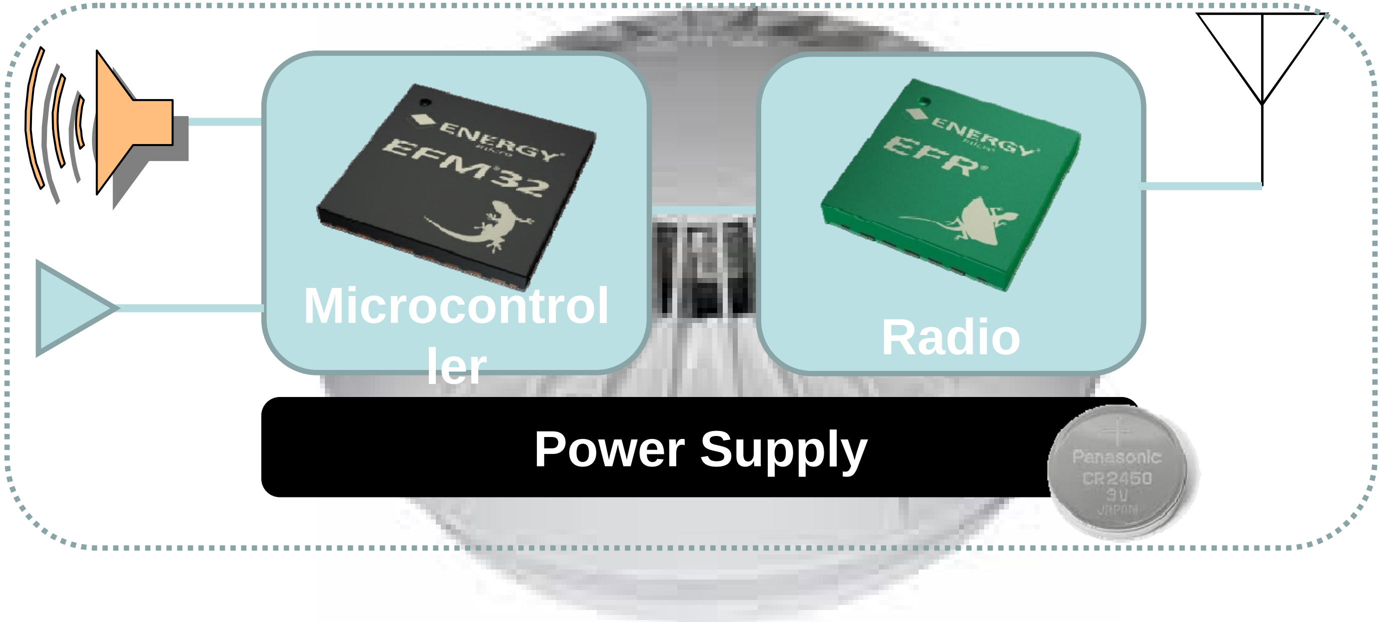
Market demand



- **growth in the 2-digit range will increase the market volume by 4 within the next 5 years after 2015**

Typical applications

Typical applications



- **Wireless Fire Detector**
  - **Using batteries up to 4x longer = less maintenance costs**
  - **Downsizing product using less or smaller batteries**
  - **High performing microcontroller offering more features (sound, multi-sensor detector, etc.) at less energy consumption**
  - **Less heat dissipation of active components providing higher accuracy of the analog measurement system**

Collecting Energy

- **Music club**

--> *A dance club in Rotterdam creates energy to power the LED lighting each visitor creates 20W of power by dancing on the flexible floor*

- **Pedestrian Walk**

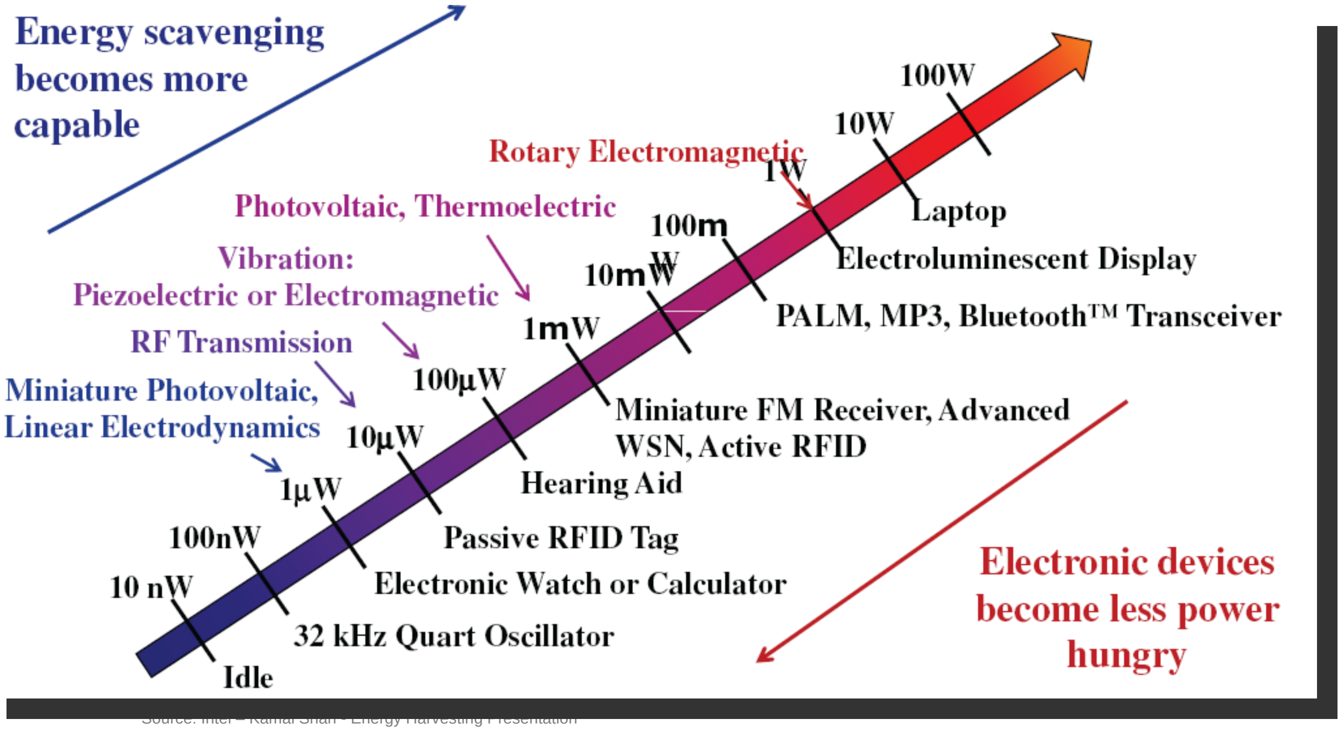
--> *use of piezoelectric materials to harvest electrical energy from pedestrians walking over it*

- **Footbridge**

--> *Piezoelectric materials can harvest energy from vibrations, such as the slight movement of a footbridge as pedestrians walk across it.*

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 Vtyp/per_cell



Source: Intel – Kamal Shah - Energy Harvesting Presentation

3-axis accelerometer…

Würth Elektronik components

Energy Harvesting Transformer WE-EHP 5838

Surface Mount - SMT

VERY LOW SECONDARY DCR

COMPLIANT RoHS&REACh HALOGENFREE

Characteristics

- low profile – less than 4mm
- small dimensions 5.9x5.9mm
- very low secondary R_{DC}
- different turns ratios
- separated welding/soldering pad for a high reliable component

Applications

- Remote Sensors and Radio Power
- Surplus Heat Energy Harvesting
- HVAC Systems
- Industrial Wireless Sensing
- Automatic Metering
- Building Automation
- Predictive Maintenance

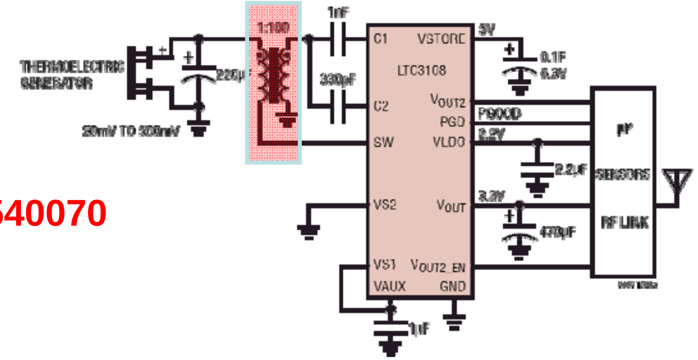
Order Code	Turns ratio N1 : N2	Inductance (1) L_1 ±20% [µH]	Inductance (1) L_2 ±20% [mH]	R_{DC1} typ. [Ω]	R_{DC2} typ. [Ω]	I_{SAT1} (2) [A]	I_{R1} (3) [A]
74488540250	1:20	25.0	10	0.200	42	0.80	1.50
74488540120	1:50	12.0	30	0.082	135	1.00	2.00
74488540070	1:100	7.00	70	0.080	205	1.40	2.05

Transformer designed on EP7 core available on request – Order Code: 760370096 ; 760370097 ; 760370098

Linear Technology - Applications

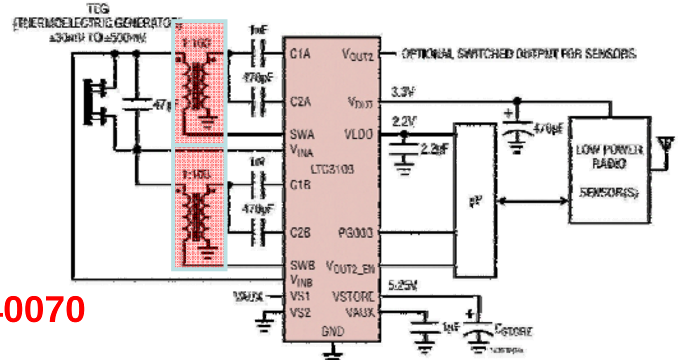
WÜRTH ELEKTRONIK

Wireless Remote Sensor Application Powered from a Peltier Cell



74488540070

Energy Harvesting Operates from Small Differentials of Either Polarity



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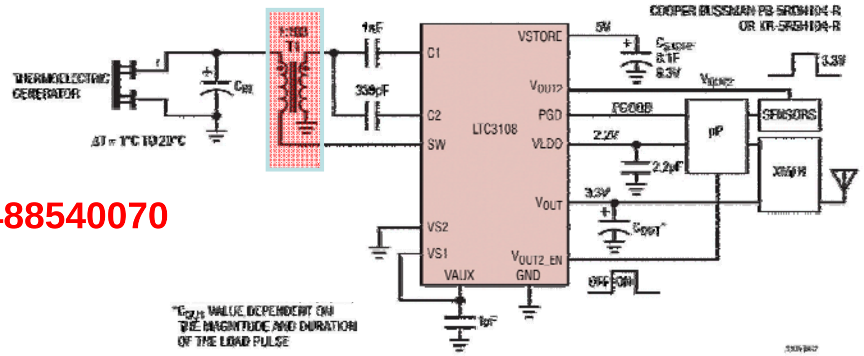
Peltier-Powered Energy Harvester for Remote Sensor Applications



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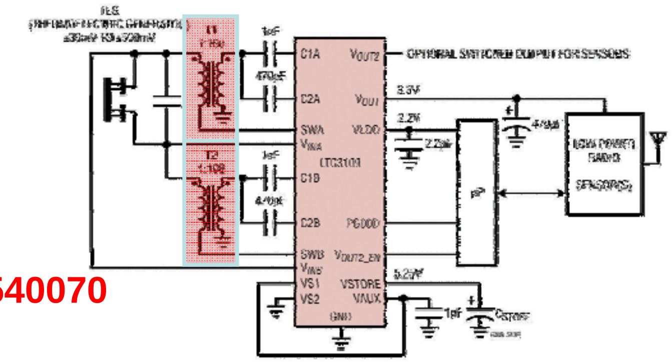
Energy Harvesting Operates from Small Temperature Differentials of Either Polarity



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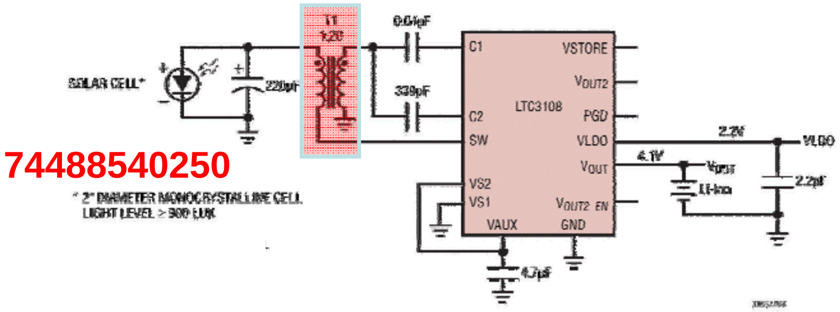
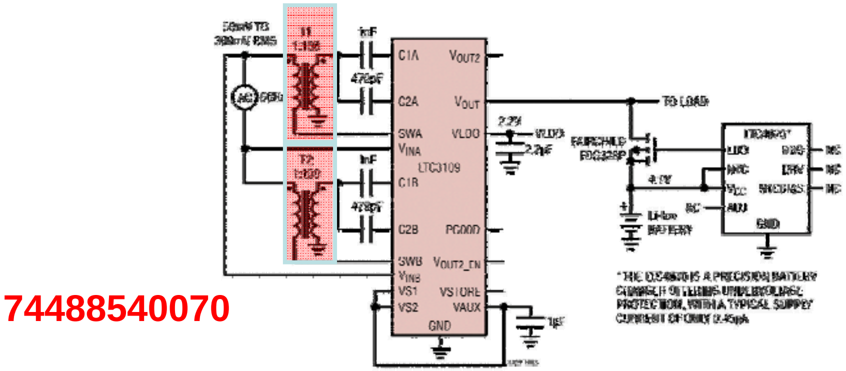
Linear Technology - Applications

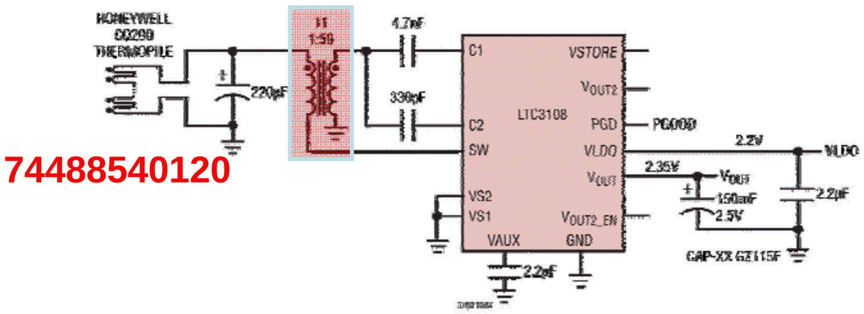
Li-Ion Battery Charger and LDO Powered by a Solar Cell



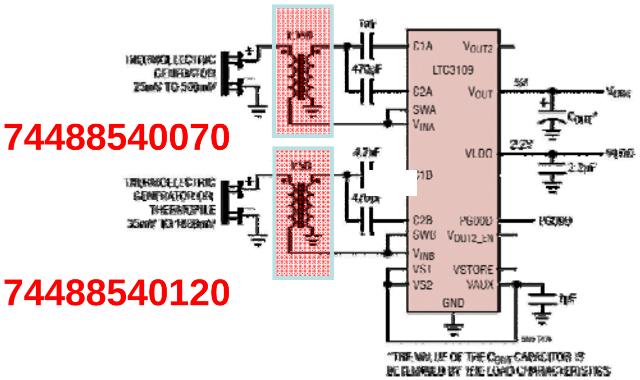
Li-Ion Battery Charger and LDO Operates from a Low Level AC Input



Supercapacitor Charger and LDO Powered by a Thermopile Generator

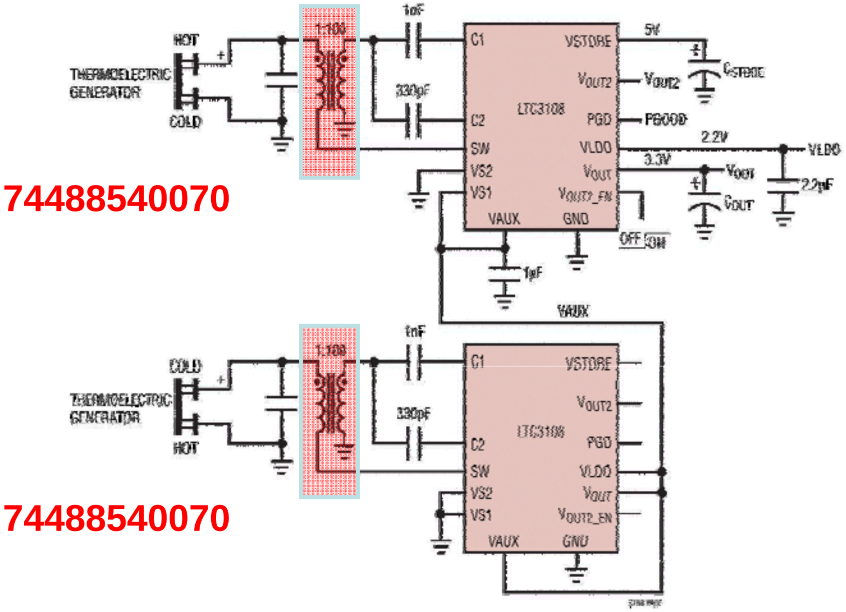


Dual-Input Energy Harvester Generates 5V and 2.2V from Either or Both TEGs, Operating at Different Temperatures of Fixed Polarity

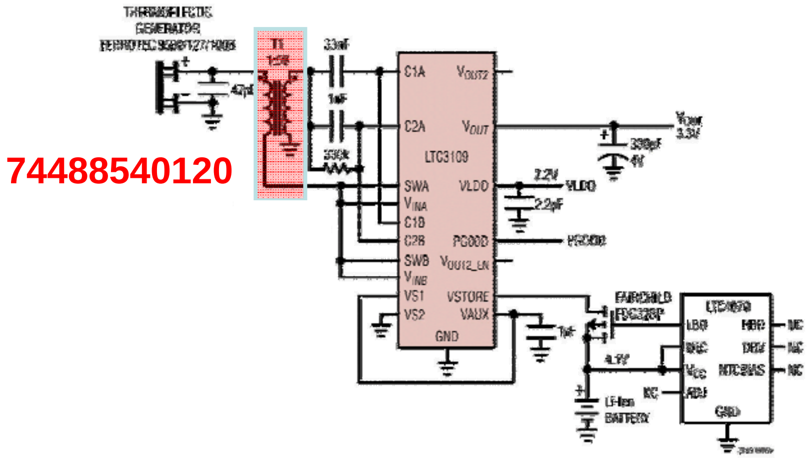


Linear Technology - Applications

Dual TEG Energy Harvester Operates from Temperature Differentials of Either Polarity



Unipolar Energy Harvester Charges Battery Backup



- **Linear Tech Preferred Partner for Magnetics**

http://cds.linear.com/docs/Product%20Info/EnergyHarvestingPartners.pdf

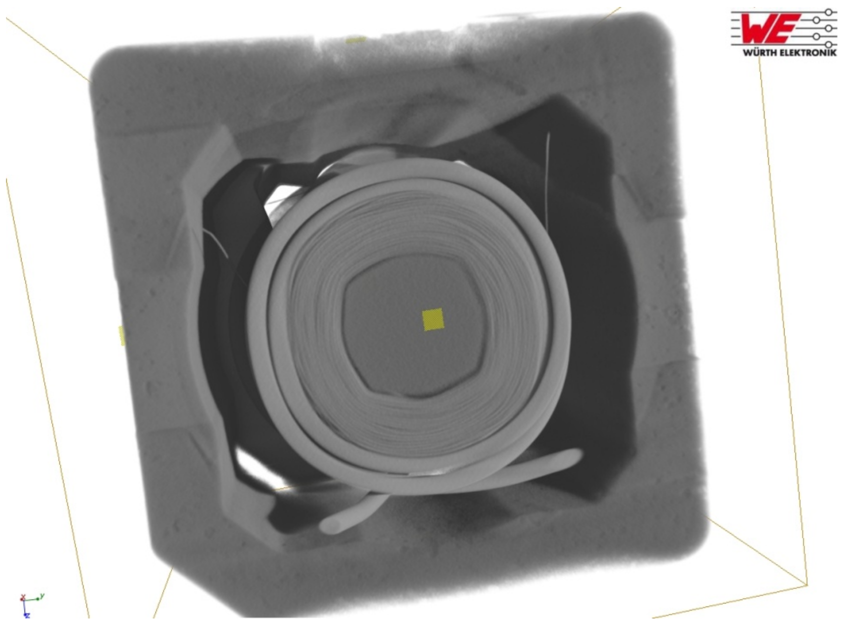
Design specifics

- **thicker wire for primary winding**
- **very thin wire for secondary winding**

- 1 : 20 turns ratio
  → N1: 24 turns
  → N2: 480 turns

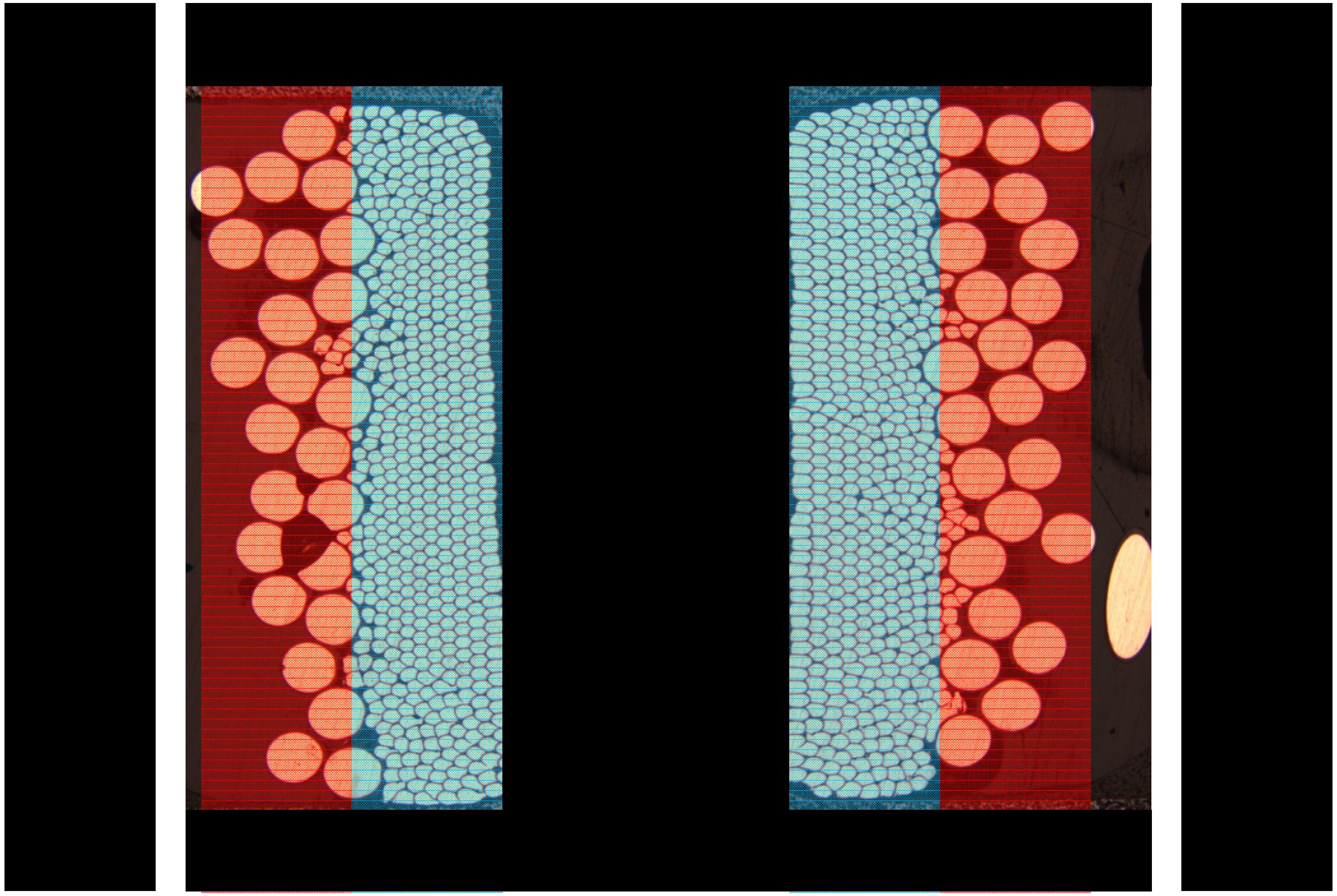
- 1 : 50 turns ratio
  → N1: 17 turns
  → N2: 850 turns

- 1 : 100 turns ratio
  → N1: 12 turns
  → N2: 1200 turns



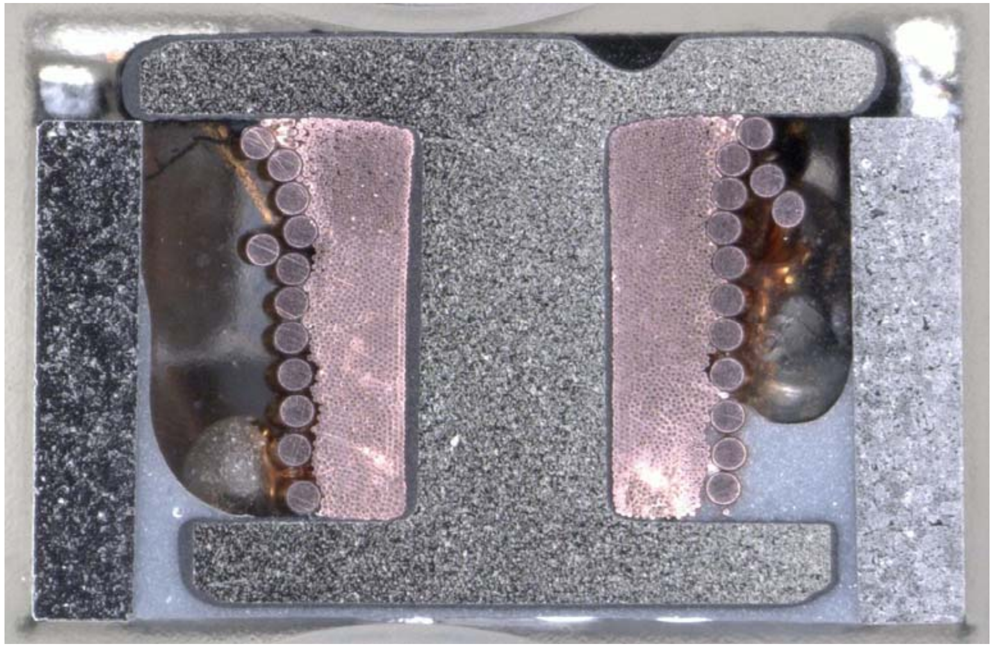
Design specifics

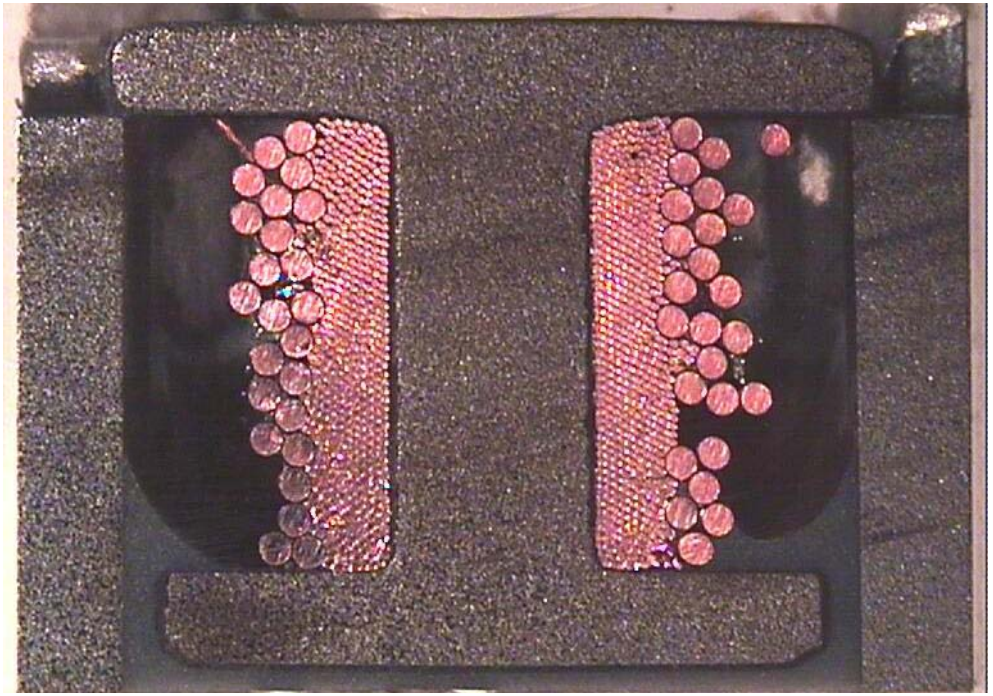
- **winding style**



Design specifics

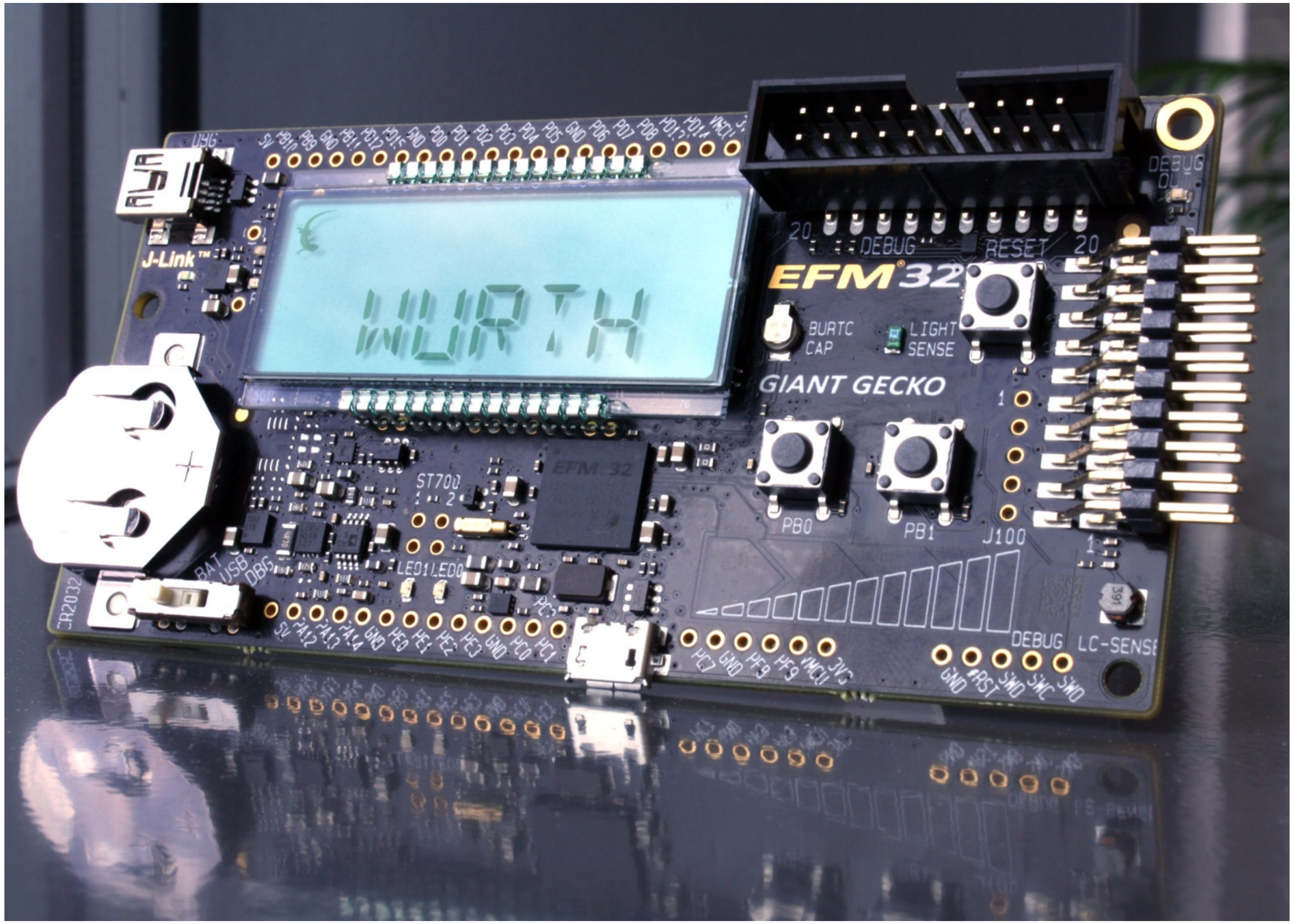
- **winding style**





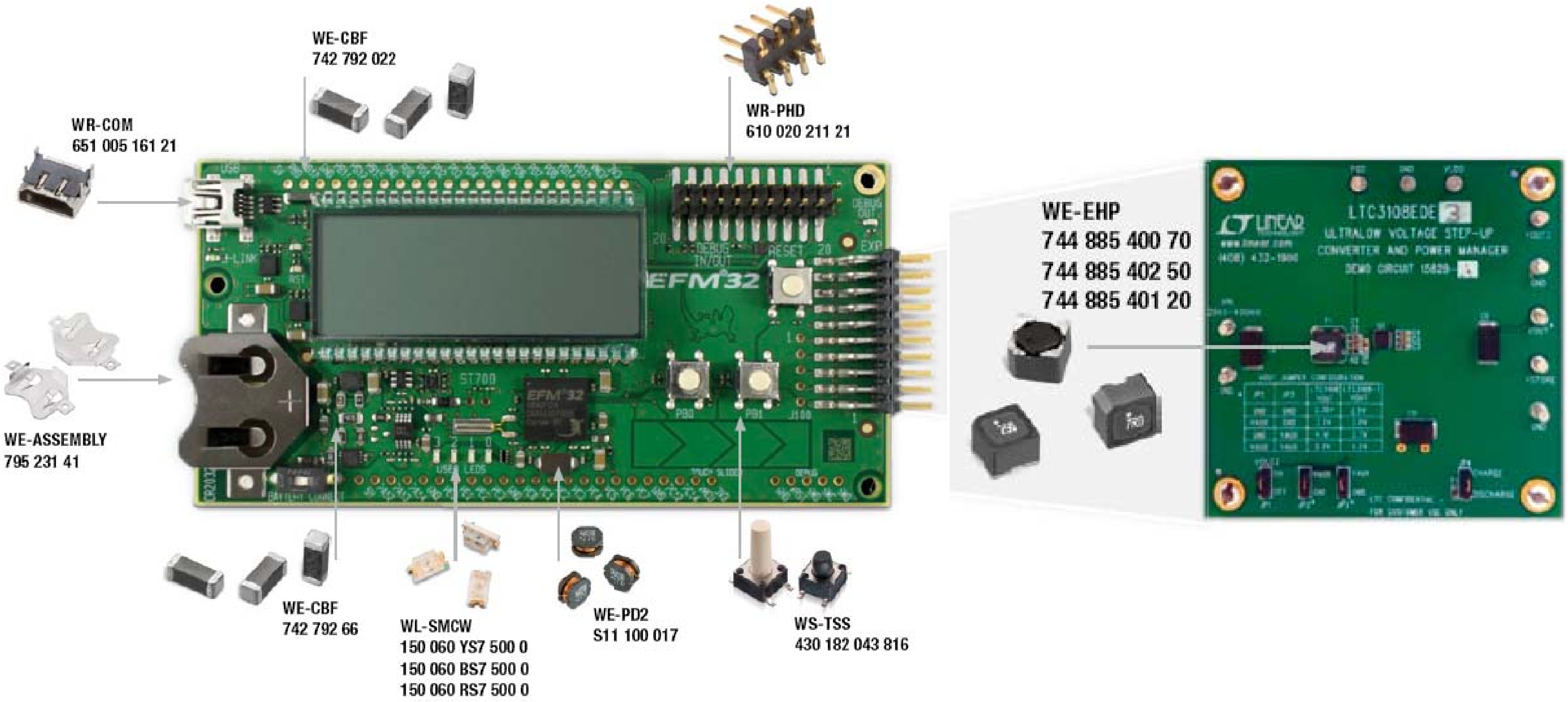
Energy Micro Systems - Applications

- **Low Energy Consumption MicroController Board**



Energy Harvesting Sample Kit

- **R E A D Y T O G O**



Energy Harvesting Trends

- Energy Harvesting applications are potentially everywhere
- Power needs of typical applications continue to drop
- Energy source characteristics determine transducer choice
- Reliable, regulated power achieveable with properly designed systems